Attachment 1

DRAFT REPORT | JULY 2021

Freeway Well Feasibility Study Report

PREPARED FOR

City of Santa Rosa

City of Santa Rosa

PREPARED BY

WEST YOST

Water. Engineered.

Freeway Well Feasibility Study Report

Prepared for

City of Santa Rosa

Project No. 405-12-18-69

Project Manager: Jim Connell, PE	Date
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Table of Contents

Table of Contents

LIST OF TABLES

LIST OF FIGURES

Table of Contents

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms Per Liter
AACE	Association for the Advancement of Cost Engineering
AF	Acre-foot
BAAQMD	Bay Area Air Quality Management District
C	Celsius
CGA	California Groundwater Association
City	City of Santa Rosa
CR	Continuous Regeneration
DCA	Dichloroethane
DCE	Dichloroethylene
DDW	Division of Drinking Water
DNAPL	Dense Nonaqueous Phase Liquid
EBCT	Empty Bed Contact Time
EPI	Estimation Program Interface
ft	Feet
GAC	Granular Activated Carbon
gpm	Gallons Per Minute
H	Horsepower
IR	Intermittent Regeneration
lbs	Pounds
MCL	Maximum Contaminant Level
mg/L	Milligram Per Liter
OPPC	Opinion of Probable Project Cost
PAC	Powdered Activated Carbon
Sonoma Water	Sonoma County Water Agency
TCA	Trichloroethane
TCE	Trichloroethylene
TDS	Total Dissolved Solids
USEPA	U.S. Environmental Protection Agency
UV	Ultraviolet
VOCs	Volatile Organic Compounds

Executive Summary

The City of Santa Rosa (City) has a currently inactive municipal water supply well known as the Freeway Well. This well was installed in 1957 and is 16-inch in diameter and 817 feet deep. The well is capable of producing up to 2,000 gallons per minute (gpm) of water and was historically operated at 800 gpm on a continuous basis. In 1987, volatile organic compounds (VOCs) were detected in the routine sampling of groundwater from the well. The level of trichloroethylene (TCE) in the groundwater exceeded the maximum contaminant level (MCL) allowed in drinking water of 5 micrograms per liter (µg/L) and use of the well for potable water production was discontinued.

The City is interested in evaluating the feasibility of modifying the existing Freeway Well, constructing a new replacement well, or treating the groundwater to restore the lost potable water production capacity. The City retained West Yost to provide hydrogeologic and engineering services to characterize the geology and vertical distribution of contaminants in the aquifer and to develop and evaluate alternatives to restore or replace potable water production from the well.

The City applied for and received a grant from the State Water Resources Control Board Proposition 1 Grant Program to examine the area around the Freeway Well to more fully characterize the groundwater contamination problem, better understand the lithology and deep aquifer hydrology, and provide additional groundwater sampling and data analysis to develop alternatives for groundwater cleanup and/or groundwater protection.

To better inform how the City might achieve its goals for the Freeway Well site, a Feasibility Study was completed, including the following four overarching tasks:

1. Identification, description and evaluation of treatment technologies and alternatives for VOC removal from the Freeway Well, if feasible;
2. A cost-benefit analysis of the economic feasibility of project alternatives. Costs will include conceptual cost estimates of capital costs (design, construction, start-up) and annual operation, monitoring, residuals management, and maintenance costs, including materials and operating consumables (e.g., electricity). Benefits will include estimates of financial and economic benefits because of the ability to bring the Freeway Well back on-line;
3. Ranking of project alternatives based on defined project objectives, including the cost-benefit analysis; and
4. Recommended alternative and rationale for selection, if feasible.

Additional detail is provided in Chapter 1 of this report.

FREEWAY WELL BACKGROUND

The Freeway Well is on the eastern margin of the Santa Rosa Plain in alluvium derived from the Mayacamas Mountains. The well is constructed in alternating layers of fine-grained materials including clay and sandy clay; and coarse-grained aquifer materials, including clayey sand and sand. A lithologic log of a boring completed at the Freeway Well site in 2020 shows three zones of coarse-grained aquifer materials in the screened interval of the Freeway Well at 150 to 180, 270 to 300, and 480 to 510 feet below ground surface.

Pump testing shows that the estimated aquifer hydraulic parameters of the Freeway Well are consistent with the hydrogeology of the area and indicative of a relatively low permeability aquifer with semiconfined to confined storage characteristics. During pump testing of Freeway well, 20 feet of drawdown was recorded in the Santa Rosa High School observation well located 1,600 feet northeast of the Freeway Well and 14 feet of drawdown was recorded in the Tesconi observation well located 2,400 feet to the west of the Freeway Well. The estimated radial extent of drawdown was approximately 7,300 feet. Pumping in the Freeway Well reverses the gradient and the direction of groundwater flow west of the site and steepened the gradient to the east.

In October 2013, the City conducted sampling of the groundwater at discrete depths within the Freeway Well to determine the vertical distribution of the groundwater contamination. Water samples were collected at depths ranging between 100 and 600 feet. For some of the constituents present in the groundwater, the concentrations are slightly lower at the upper and lower depths, but for all constituents, the concentrations do not appear to vary significantly over the varying depths.

Groundwater samples were collected in September and October 2020 from monitoring wells installed at different depths near the Freeway Well and from the Freeway Well for water quality analysis. Table 2-3 summarizes the recent results for the VOC analysis. The VOC concentrations in shallow and deep regions tended to be lower than in the middle region of the aquifer. Based on the 2020 sampling, the TCE concentration in the groundwater in the Freeway Well is still above the MCL.

Additional background on the Freeway Well is provided in Chapter 2 of this report.

REMEDIAL ACTION ALTERNATIVES

The remedial action alternatives included:

- Abandonment of the Freeway Well
- Well retrofit and/or replacement
- Groundwater treatment alternatives

Abandonment of the Freeway Well would include blocking off contaminated zones to prevent migration of contaminants. Modifying the existing well is not considered feasible as the existing well has a gravel pack that extends almost the full depth of the well. It is not possible to block off the contaminated zones as water can flow vertically through the gravel pack. Replacing the well, while feasible, would not be expected to significantly improve the water quality, and groundwater treatment would still be needed. Additionally, it is likely to be less productive than the existing well due to observed lower yield of the deeper water-bearing zones.

Groundwater treatment alternatives included oxidation/manganese oxide-coated media filtration for manganese removal, followed by air stripping or granular activated carbon (GAC) for TCE removal. Several other treatment alternatives to remove organic constituents were briefly examined and discarded from further evaluation after a literature review indicated air stripping and GAC were considered Best Available Technologies for TCE removal.

Both the air stripping and GAC alternatives were evaluated to estimate capital and operational costs and possible treatment system footprint on the existing Freeway Well property. The estimated project cost for the two treatment alternatives range between $4 million and $5 million. However, due to the size and configuration of the existing well site, it would be infeasible to construct all the needed treatment facilities and equipment on the existing well site property.

The well retrofit and treatment alternatives are described in more detail in Chapter 3.

SUMMARY AND RECOMMENDATIONS

A new well, constructed on the Freeway Well site and screened to avoid the higher levels of contamination in the existing Freeway Well, would likely still require wellhead treatment for VOCs and manganese removal and be less productive than the existing well. The treatment facilities needed to remove TCE and manganese to meet regulatory levels for drinking water cannot feasibly fit within the existing Freeway Well parcel. Furthermore, it would be more cost effective to construct a new well at a different site that would not require treatment for contaminant removal.

Utilizing the existing Freeway Well would require wellhead treatment for VOCs and manganese removal, which cannot feasibly fit within the site. Furthermore, due to the time needed to disinfect and verify adequate disinfection of the well and treatment facilities after a long-term shut down, Freeway well could not effectively serve as an emergency well. Instead, the well would need to construct be utilized as a production well, but it would first need to undergo an extensive State permitting process to shift from standby status to production status. While permitting is not an insurmountable obstacle, operating the existing Freeway Well could cause further migration of contaminants from the upper zone into the lower zone of the aquifer. Therefore, the recommended project is to properly abandon the Freeway Well to prevent further migration of contaminants from upper aquifer zones into lower aquifer zones.

After permitting and financing are obtained, abandonment of the Freeway Well can be accomplished fairly quickly, likely in less than 12 months. This takes into account the time needed for preparation of bid documents, bid solicitation, bid selection, award negotiation and execution, and project execution.

CHAPTER 1
Introduction

1.1 BACKGROUND

The City of Santa Rosa (City) has a currently inactive municipal water supply well known as the Freeway Well. The location of the well is shown in Figure 1-1. This well was installed in 1957 and is 16-inch in diameter and 817 feet deep. The well is capable of producing up to 2,000 gallons per minute (gpm) of water and was historically operated at 800 gpm on a continuous basis. In 1987, volatile organic compounds (VOCs) were detected in the routine sampling of groundwater from the well. The level of trichloroethylene (TCE) in the groundwater exceeded the maximum contaminant level (MCL) allowed in drinking water of 5 micrograms per liter (µg/L) and use of the well for potable water production was discontinued.

The City pursued an evaluation of the feasibility of modifying the existing Freeway Well, constructing a new replacement well, or treating the groundwater to restore the lost potable water production capacity. The City retained West Yost to provide hydrogeologic and engineering services to characterize the geology and vertical distribution of contaminants in the aquifer and to develop and evaluate alternatives to restore or replace potable water production from the well.

The City applied for and received a grant from the State Water Resources Control Board Proposition 1 Grant Program to examine the area around the Freeway Well to more fully characterize the groundwater contamination problem, better understand the lithology and deep aquifer hydrology, and provide additional groundwater sampling and data analysis to develop alternatives for groundwater cleanup and/or groundwater protection.

The City's Scope of Work in the grant agreement includes the following tasks:

Task 1. Project Management

Task 2. General Compliance Requirements/Project Effectiveness and Performance

Task 3. Permitting and Environmental Compliance

Task 4. Technical Advisory Committee

Task 5. Stakeholder Advisory Group

Task 6. Remedial Investigation Workplan

Task 7. Remedial Investigation Report

Task 8. Feasibility Study Report

Task 9. Public Outreach

The Freeway Well Remedial Investigation was completed in February 2021, in accordance with the grant requirements. The findings documented in the Remedial Investigation Report are summarized in Section 1.2 below.

This Feasibility Study Report fulfills the grant requirements for Task 8 Feasibility Study Report.

Attachment 1

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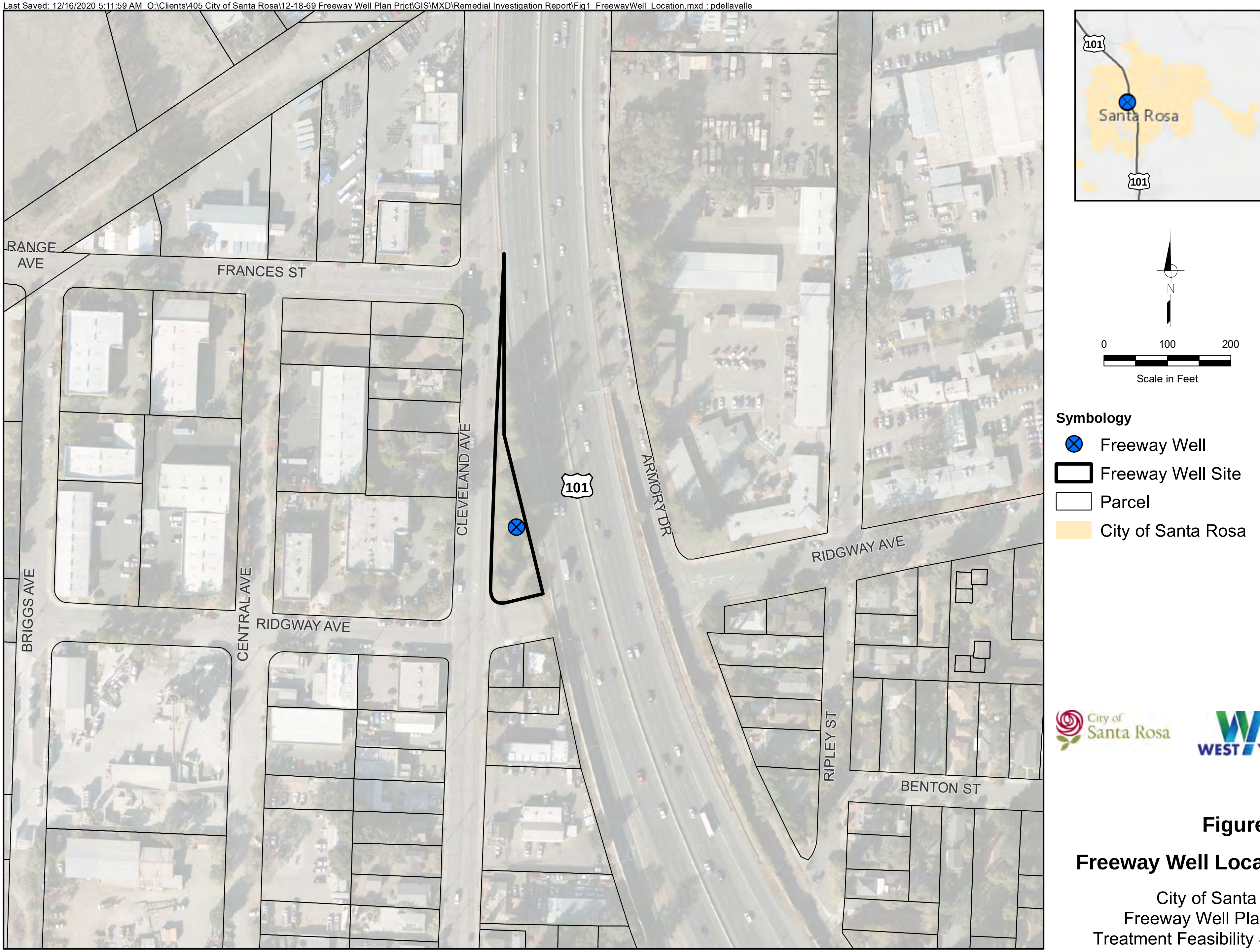

Figure 1-1

Freeway Well Location

City of Santa Rosa
Freeway Well Planning
Treatment Feasibility Study

1.2 REMEDIAL INVESTIGATION REPORT

In February 2021, the City completed the Freeway Well Remedial Investigation Report (West Yost, February 2021). To complete the Remedial Investigation Report, records research, site investigations, monitoring well construction, and aquifer testing were completed. The data obtained through the extensive research and investigations were analyzed and the following conclusions were stated in the Remedial Investigation Report:

1. The records research did not uncover any releases or potentially responsible parties to the contamination of Freeway Well that had not been previously identified.
2. The records research and aquifer testing indicated that a replacement well drilled near the Freeway Well would be expected to have lower concentrations of VOCs as are found in the Freeway Well, if the replacement well were screened at different levels as the Freeway Well.
3. The monitoring well construction and aquifer testing confirmed that the Freeway Well remains contaminated at the same approximate concentrations as had been noted during previous sampling events in prior years.
4. The construction of the Freeway Well, with a gravel pack extending through several of the semi-confined aquifers, is almost certainly contributing to cross-contamination of the deeper aquifers.
5. Modifying the Freeway Well to block off contaminated zones is not considered feasible.
6. Wellhead treatment could be feasible and would be explored and discussed in a Feasibility Study report that would be completed after the Remedial investigation Report had been approved by the State.

Based on the findings indicated above, the Remedial Investigation Report documented the following recommended actions for the City's consideration:

1. Explore less contaminated areas as potential sites to construct a replacement well.
2. Properly abandon and seal the Freeway Well to prevent it from remaining as a conduit between the upper and lower aquifers to protect groundwater quality, even if it is determined that wellhead treatment is feasible.
3. Explore the option of constructing a new well on the Freeway Well site that would be screened only at the lower aquifer with the upper aquifer sealed off.

1.3 FEASIBILITY STUDY OBJECTIVES

As indicated above, the Freeway Well had historically produced approximately 800 gpm of municipal water supply for the residents of the City. Assuming this well could be returned to active status as a municipal well, and operated 50 percent of the time, the Freeway Well would produce approximately 645 acre-feet of water per year.

The loss of the Freeway Well impacted the City's potable water supply portfolio. For many years the City has been interested in the possibility of restoring production of potable water at the site and protecting the aquifer from further degradation. To accomplish these goals, the City needed to develop and evaluate technical information. Therefore, the objective of this Feasibility Study is to characterize the geology and aquifer conditions and understand the likely sources and vertical distribution of contaminants. This information will be used to evaluate the feasibility of alternative water production and treatment options.

To better inform how the City might achieve its goals for the Freeway Well site, a Feasibility Study was completed, including the following four overarching tasks:

1. Identification, description and evaluation of treatment technologies and alternatives for VOC removal from the Freeway Well, if feasible;
2. A cost-benefit analysis of the economic feasibility of project alternatives. Costs will include conceptual cost estimates of capital costs (design, construction, start-up) and annual operation, monitoring, residuals management, and maintenance costs, including materials and operating consumables (e.g., electricity). Benefits will include estimates of financial and economic benefits because of the ability to bring the Freeway Well back on-line;
3. Evaluation of project alternatives based on defined project objectives, including the cost-benefit analysis; and
4. Recommended alternative and rationale for selection, if feasible.

1.4 GRANT TASK CROSS-REFERENCE

Table 1-1 summarizes the grant requirements stipulated in the grant agreement and provides a reference to the relevant chapters and sections in this report.

Table 1-1. Grant Requirements and Cross-Reference to Report Chapters and Sections

Grant Requirement	Relevant Report Chapters and Sections
8.1.1 Summary of the Project Area's history, geology, hydrogeology, surface water, local land use, previous investigations, and remedial actions	Chapter 2 Section 2.1
8.1.2 Summary of the nature and extent of constituents of concern in the impacted media (e.g., soils, groundwater, surface water, etc.) including types of contaminants, concentrations detected, and vertical and lateral extent of the contamination	Chapter 2 Section 2.2
8.1.3 Summary of the contaminant properties and transport based on soil and aquifer properties	Chapter 2 Section 2.3
8.1.4 Proposed remedial action objectives that the future proposed implementation project will achieve	Chapter 3 Section 3.2.1
8.1.5 Proposed remedial action alternatives that will be evaluated	Chapter 3 Section 3.2.2
8.1.6 Evaluation of the remedial action alternatives and options	Chapter 3 Section 3.2.3
8.1.7 Estimated total life cycle costs, cost benefit analysis, and estimated schedule for each cleanup alternative evaluated	Chapter 3 Sections 3.3 to 3.5
8.1.8 Description of rationale for selecting the preferred alternative	Chapter 4

CHAPTER 2
Groundwater Contamination

2.1 PROJECT AREA DESCRIPTION

The City previously had an active, municipal water supply well, known as the Freeway Well. The well is located on a northerly elongated triangular parcel wedged between Cleveland Avenue and Highway 101, north of College Avenue at Ridgway Avenue. The parcel includes a stand of redwood trees, the well building, a storage building (which formerly housed the emergency backup generator for the well), below grade utility vaults, and a small parking area. The property is fenced with a vehicle access gate along the southern property boundary on Ridgway Avenue. Land use in the vicinity includes a mix of light industrial use centered around existing and former railroads and surrounding residential properties.

The Freeway Well, drilled and constructed in 1957, is a 16-inch diameter, 817-foot deep well reportedly capable of producing up to 2,000 gpm.

In March of 1987, the City conducted routine sampling of the Freeway Well and the analytical results revealed the presence of TCE at a concentration above the allowable MCL. TCE is a known carcinogen, and one of several compounds known as volatile chlorinated hydrocarbons or organic compounds, also called VOCs.

The State of California, Division of Drinking Water (DDW) ordered the City to discontinue use of the Freeway Well for potable supply, and to physically disconnect the well from the City's distribution system.

The Freeway Well is on the eastern margin of the Santa Rosa Plain in alluvium derived from the Mayacamas Mountains. The well is constructed in alternating layers of fine-grained materials including clay and sandy clay; and coarse-grained aquifer materials, including clayey sand and sand. A lithologic log of a boring completed at the Freeway Well site in 2020 shows three zones of coarse-grained aquifer materials in the screened interval of the Freeway Well at 150 to 180, 270 to 300, and 480 to 510 feet below ground surface.

Pump testing shows that the estimated aquifer hydraulic parameters of the Freeway Well are consistent with the hydrogeology of the area and indicative of a relatively low permeability aquifer with semiconfined to confined storage characteristics. Pumping in the Freeway Well caused 20 feet of drawdown in the Santa Rosa High School observation well located 1,600 feet northeast of the Freeway Well and 14 feet of drawdown in Tesconi observation well located 2,400 feet to the west of the Freeway Well. The estimated radial extent of drawdown was approximately 7,300 feet. Pumping in the Freeway Well reverses the gradient and the direction of groundwater flow west of the site and steepened the gradient to the east.

2.2 NATURE AND EXTENT OF CONSTITUENTS OF CONCERN

In March 1987, TCE at a concentration above the MCL for drinking water was found in the groundwater from the Freeway Well during routine groundwater sampling. Confirmation sampling of the groundwater and analyses for VOCs were conducted over the years since the detection of VOCs in the Freeway Well. Table 2-1 below summarizes the concentrations of the constituents with levels above their associated detection limits for reporting. The California drinking water MCLs for these constituents are also listed in Table 2-1. As shown, the TCE concentrations in the Freeway Well continued to be above the associated MCL.

Table 2-1. Historical Freeway Well Water Quality, 1987-1995

Constituents	Units	Concentration	Sample Date	MCL[(a)] (Effective Date)
Initial Sampling				
Trichloroethylene (TCE)	µg/L	8.0	3/24/1987	5 (5/1989)
Confirmation Sampling				
TCE	µg/L	8.3	6/11/1987	5 (5/1989)
		25.0	10/13/1987	
		2.2	8/11/1989	
		9.1	5/24/1995	
1,1-Dichloroethane (1,1-DCA)	µg/L	1.2	5/25/1989	5 (6/24/1990)
1,1-Dichloroethene (1,1-DCE)	µg/L	1.1	6/11/1987	6 (2/25/1989)
		2.6	10/13/1987	
		1.2	8/11/1989	
		4.3	5/24/1995	
1,1,1-Trichloroethane (1,1,1-TCA)	µg/L	1.6	6/11/1987	200 (2/25/1989)
		5.0	10/13/1987	
		2.0	8/11/1989	
		0.69	5/24/1995	
1,1,2-Trichloro-2,2,1-Trifluoro ethane (Freon 113)	µg/L	7.3	6/11/1987	1,200 (6/24/1990)
Trichlorofluoromethane (Freon 11)	µg/L	14.0	5/25/1989	150 (6/24/1990)

(a) Maximum contaminant levels and effective dates for drinking water in the State of California.

In October 2013, the City conducted sampling of the groundwater at discrete depths within the Freeway Well to determine the vertical distribution of the groundwater contamination. Water samples were collected at depths ranging between 100 and 600 feet. Table 2-2 lists the sampling depths and associated water quality data. For some of the constituents present in the groundwater, the concentrations are slightly lower at the upper and lower depths, but for all constituents, the concentrations do not appear to vary significantly over the varying depths.

Table 2-2. Freeway Well Discrete Depth Sampling Water Quality[a], 2013

Depth, feet	VOCs, µg/L				Chloride, mg/L	Total Dissolved Solids, mg/L
	TCE[b]	1,1-DCE	Freon 113	Toluene		
118	18	3.1	12	ND[b]	14.4	290
178	17	3.0	12	ND[b]	13.9	260
278	22	4.1	16	0.67	13.8	280
343	22	3.9	16	0.79	13.9	280
414	24	4.2	17	0.81	13.6	280
458	24	4.2	16	0.90	13.6	290
498	20	3.6	13	0.87	14.2	280
590	19	3.4	11	1.0	13.7	280

(a) Sampling conducted on October 4, 2013.
(b) Not detected. For toluene, the detection limit for reporting is ≥0.50 µg/L.
mg/L = Milligrams per Liter

Groundwater samples were collected in September and October 2020 from monitoring wells installed at different depths near the Freeway Well and from the Freeway Well for water quality analysis. Table 2-3 summarizes the recent results for the VOC analysis. The VOC concentrations in shallow and deep regions tended to be lower than in the middle region of the aquifer. As shown, based on the 2020 sampling, the TCE concentration in the groundwater in the Freeway Well is still above the MCL.

Table 2-3. VOCs in Groundwater, 2020

Depth	Monitoring Wells				Freeway Well	
	Shallow, µg/L	Middle, µg/L	Deep, µg/L	Sample Date	Concentration, µg/L	Sample Date
t-Butyl Alcohol (TBA)	ND[a]	ND[a]	7.7	9/4/2020	ND[a]	9/24/2020
	ND[a]	ND[a]	ND[a]	10/8/2020		
Chloroform	0.53	1.1	0.52	9/4/2020	ND[a]	
	ND[a]	ND[a]	ND[a]	10/8/2020		
1,1-Dichloroethylene (DCE)	1.1	1.2	ND[a]	9/4/2020	3.4	
	1.1	2.9	0.71	10/8/2020		
Freon 113	4.1	3.4	0.86	9/4/2020	7.2	
	3.4	9.4	2.1	10/8/2020		
4-Isopropyl Toluene	ND[a]	ND[a]	0.69	9/4/2020	ND[a]	
	ND[a]	ND[a]	ND[a]	10/8/2020		
TCE	4.3	9.4	ND[a]	9/4/2020	21	
	4.6	14	ND[a]	10/8/2020		

(a) Not detected. For TBA, the detection limit for reporting is ≥5.0 µg/L. For chloroform, 1,1-DCE, 4-Isopropyl Toluene, and TCE, the detection limit for reporting is ≥0.50 µg/L.

2.3 CONTAMINANT PROPERTIES AND TRANSPORT

2.3.1 Contaminants

As of September 24, 2021, the groundwater in the Freeway Well is contaminated with three VOCs: TCE, dichloroethylene (DCE), and Freon 113. TCE and Freon 113 are both common cleaning and degreasing solvents and DCE is a breakdown product of TCE. TCE is present at concentrations greater than the MCL of 5 µg/L. Both DCE and Freon 113 are present in concentrations much less than their respective MCLs.

TCE is one of the most widely made and used chlorinated solvents. It has been manufactured in the United States since the 1920s primarily for use as a solvent for metal degreasing, but also as a refrigerant and as a dry-cleaning fluid. TCE is a VOC that poses a human health hazard to the central nervous system, kidney, liver, immune system, reproductive system, and to the developing fetus. TCE is also characterized by U.S. Environmental Protection Agency (USEPA) as carcinogenic to humans by all routes of exposure (i.e., by inhalation, ingestion, and dermal exposure).

Freon 113 is a chlorofluorocarbon used as a solvent for cleaning metal parts and electronics. It is a solvent for oils, grease, and soldering flux. It has high chemical stability, low toxicity, and no flammability which makes it desirable for cleaning by hand.

2.3.2 Properties and Transport of TCE

TCE is denser than water and has a low absolute solubility in groundwater (see Table 2-4). Therefore, when free phase TCE is spilled, it will move downward through an aquifer as a dense nonaqueous phase liquid (DNAPL) until it accumulates in pools on top of low permeability layers. DNAPL pools can act as long-lasting source areas of TCE contamination. TCE is moderately soluble in water (1000 mg/L at 20˚ Celsius (C)) but the solubility is orders of magnitude greater than the 5 µg/L MCL. As groundwater moves through these source areas, TCE partitions into an aqueous phase and is spread through the aquifer by advection and dispersion (Russell, Matthews, and Sewell, 1992).

TCE can destroy the structure of clayey minerals, making them more permeable to dissolved contaminants. TCE is not readily degraded in groundwater, although some TCE may naturally degrade under anaerobic conditions. However, TCE may degrade into compounds that are toxic and more difficult to degrade than TCE, such as DCE and vinyl chloride (SWRCB, 2009).

The Henry's Law constant for TCE is 0.00892 atm-m^3/mo at 20˚C which is high enough, when combined with its low solubility in water and high vapor pressure, for efficient transfer of TCE to the atmosphere. The evaporation half-life of TCE in water is on the order of 20 minutes at room temperature in both static and stirred vessels (Dilling, 1975; Dilling et al., 1975).

Table 2-4. Physical Properties of Organic Contaminants in the Freeway Well

Chemical	Specific Gravity, g/cc	Aqueous Solubility, mg/L	Vapor Pressure, mm Hg	Henry's Constant, atm-m3 mol	Vapor Density, g/L	Water Diffusion Coefficient, sq.cm/sec	Est. Half-Life in Groundwater, days
1,1-DCE	1.22[a]	400[a]	495[a]	2.1E-02[a]	3.96[a]	9.5E-06[b]	56-132[c]
TCE	1.46[a]	1,100[a]	57.8[a]	0.00892	5.37[a]	8.3E-06[d]	321-1,653[d]
Freon 113	1.57[e]	170[e]	285[e]	0.526[f]	6.5[e]	-	-

(a) Montgomery, J.H., and Welkom, L.M., 1990, Groundwater Chemicals Desk Reference, Lewis Publ., Chelsea, MI, 650p.
(b) Tetra Tech, Inc., 1988, Chemical Data for Predicting the Fate of Organic Chemicals in Water, Vol.2, Database EPRI EA-5818, Vol.2, Elec. Power Res. Inst., Palo Alto, CA, 411p.
(c) Howard, P.H., et. al., 1991, Handbook of Environmental Degradation Rates, Lewis Publ., Chelsea, MI, 725p.
(d) Lucius, J.E., et. al., 1990, Properties and Hazards of 108 Selected Substances, USGS Open File Report, 90-408, 559p.
(e) Hansch, C., Leo, A., D. Hoekman. Exploring QSAR - Hydrophobic, Electronic, and Steric Constants. Washington, DC: American Chemical Society., 1995., p. 3
(f) USEPA; Estimation Program Interface (EPI) Suite. Ver. 4.1. Jan, 2011.

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Russell, H.H., Matthews, J.E., and Sewell, G.W. 1992. *TCE Removal from Contaminated Soil and Groundwater*. EPA Groundwater Issue 540/S-92/002.

State Water Resources Control Board. 2009. *Groundwater Information Sheet TCE*.

CHAPTER 3
Remedial Action Alternatives

The purpose of this chapter is to describe the evaluation of remedial action alternatives to protect groundwater and to allow for the Freeway Well to be returned service. A retrofit of the existing Freeway Well and a replacement of the Freeway Well are briefly discussed; however, due to the construction of the Freeway Well, a retrofit of the existing well is not considered feasible. Furthermore, a replacement of the well at the existing site is considered likely to result in a well with similar issues to the existing Freeway Well. Therefore, this chapter focuses on groundwater treatment alternatives to potentially allow for the Freeway Well to be returned to service.

3.1 REMEDIAL ACTION OBJECTIVES

Before the City became a customer of the Sonoma County Water Agency (Sonoma Water) in 1959, groundwater production from the aquifers beneath the City served as the City's primary water supply. Even with the current Sonoma Water supply, the City regularly uses groundwater to help meet peak summer demands. The City also needs emergency supply for public health and safety if the Sonoma Water supply were to be interrupted. Under current normal operations, groundwater makes up approximately 5 to 10 percent of the City's annual supply. If production of potable water from the Freeway Well can be reestablished without inducing the spread of contamination currently present in the upper water bearing zones, access to an aquifer that has served as an important and unusually productive source of drinking water can be reestablished.

The purpose of the proposed remedial actions discussed in this report is to protect and/or determine the feasibility of reestablishing the Freeway Well as a source of potable water supply serving the City. In reviewing remedial action alternatives, the City has evaluated the feasibility of the following:

- Abandoning and properly destroying the existing Freeway Well to protect groundwater resources for future use;
- Installing a new well which only taps into the lower water bearing zones; and
- Pumping and treating contaminated groundwater from the Freeway Well to potable water standards.

3.2 FREEWAY WELL RETROFIT/REPLACEMENT ALTERNATIVES

The Freeway Well Remedial Investigation Report concluded that modifying the existing Freeway Well to block off contaminated zones is not considered feasible. The Freeway Well is constructed with nearly continuous perforations and a gravel pack extending from 38 feet below surface to the bottom of the well at 800 feet. As such, water can flow vertically through the gravel pack around any seal or packer that could be placed in the well.

Furthermore, VOCs detected in the deepest of the newly installed on-site monitoring wells at 510 feet below the surface indicate that contaminants have penetrated deep into the aquifer. Therefore, the screened sections above this level would have to be excluded, including the most productive zone in the well. As described in the Remedial Investigation Report, flow velocity testing conducted in 2020 demonstrated that 99 percent of the water produced from the well enters between 107 and 280 feet below ground surface; no measurable flow was detected below 300 feet. Therefore, placing a pump deep in the well below a packer set at 580 feet below surface (in the first blank section below the VOC detection at 510 feet) would significantly reduce the efficiency and yield of the well.

Proper abandonment of the well was recommended in the Remedial Investigation Report to eliminate the conduit for transport of contaminants from the upper zones into the lower zones. The recommended approach is to fill the well from bottom to top with a sand cement slurry[1] and blast perforate the blank casing from 107 to 400 feet below surface. The work should be done under permit from the Sonoma County Department of Health Services and in accordance to Section 25B-7 of the Sonoma County Municipal Code and Article 299 of the California Groundwater Association (CGA) Standard Practices.

While it may be feasible to construct a new well at the existing site that taps into the lower water bearing zones and does not create a conduit between the upper water bearing zones and the lower water bearing zones, the yield of the lower water bearing zones is unknown. As indicated in the Remedial Investigation Report, very little flow was documented from the lower zones during the aquifer test, and the new well can be expected to be less productive than the existing well. Additionally, given the likely presence of a long-term secondary source of TCE in the aquifer and the depth within the aquifer to which VOCs are present, the new well can be expected eventually produce TCE at concentrations exceeding the MCL and require treatment.

3.3 GROUNDWATER TREATMENT ALTERNATIVES

The treatment objectives, technologies, and alternatives evaluated are discussed below.

3.3.1 Treatment Objectives

For the development of the treatment alternatives and associated costs, the objectives of the treatment process are to:

- Reduce TCE concentrations in the groundwater from 25 µg/L to below the MCL of 5 µg/L
- Reduce manganese concentrations from 600 µg/L to below the secondary MCL of 50 µg/L
- Provide continuous treatment of groundwater for potable use at a flow rate of 700 to 1,000 gpm

It should be noted that the groundwater quality constituents listed in Chapter 2 were measured in the existing Freeway Well during the aquifer test and likely represents a higher degree of contamination than would be found in the lower water bearing zones.

3.3.2 Treatment Technologies

The USEPA maintains a Drinking Water Treatability Database that identifies treatment processes, based on literature review, that have been tested for reducing concentrations of common contaminants in source waters.

[1] A sand cement slurry such as an "11 sack mix", which is made up of 94 lbs. of Portland Type I/II or II/V cement to a maximum of 188 lbs sand, and maximum 7 gallons of water.

The treatment processes identified from the USEPA literature review as effective in removing or reducing TCE in water, along with removal rates from the cited studies, are listed below:

- Air stripping with packed tower (60 to 100 percent removal)
- Adsorption with activated carbon (75 to 99 percent removal)
- Membrane separation (81 to 98 percent removal)
- Advanced oxidation with ozone and hydrogen peroxide (> 90 percent reduction)
- Advanced oxidation with ultraviolet (UV) light and titanium dioxide (90 percent reduction)

Packed tower air stripping and activated carbon adsorption were noted by USEPA as the best available technologies for TCE removal (USEPA, 2009). The cited studies that tested membranes for TCE removal showed widely differing results – one study showed 81 to 98 percent removal while another study showed 0 to 3 percent removal. Although the advanced oxidation processes were found to be effective in TCE reduction, the required dosages and/or contact times were higher and longer than the typical ranges for drinking water treatment.

Manganese oxide-coated media filtration is commonly used for manganese removal in drinking water treatment.

3.3.3 Treatment Alternatives

Based on the literature review discussed above regarding available treatment technologies, West Yost evaluated both packed tower air stripping and activated carbon adsorption contactors as viable treatment alternatives for TCE removal. Both alternatives assume use of manganese dioxide-coated media filtration for manganese removal upstream of the TCE removal treatment process so that the manganese does not precipitate and foul the media used in the TCE removal system.

3.3.3.1 Manganese Oxide-Coated Media Filtration - Manganese Removal

The process description, design and operational considerations, design criteria, and conceptual site layout for manganese removal treatment are discussed below.

3.3.3.1.1 Process Description

Filtration using a manganese oxide-coated media, such as manganese greensand, has historically been use for manganese removal. The media is chemically treated to form a manganese oxide coating on the media. When water with manganese passes through the media bed, the soluble manganese is adsorbed onto the media's oxide surface. An oxidant can be added to oxidize the soluble manganese to manganese oxide continuously prior to filtration or intermittently after filtration and adsorption of the soluble manganese onto the media. The manganese oxide is then removed by backwashing the filter. The oxidant is also used to regenerate the media's adsorption/oxidation capacity.

3.3.3.1.2 Design and Operational Considerations

Design and operational considerations include media, media regeneration, and backwashing, as discussed below.

3.3.3.1.2.1 Manganese Oxide-Coated Media

There are a number of proprietary manganese oxide-coated media on market. The different proprietary media have different removal efficiencies, loading rates, and backwashing requirements (AWWA, 2015). Along with design considerations, the availability and cost should be considered when selecting the media.

3.3.3.1.2.2 Continuous or Intermittent Regeneration

Operational options for manganese removal with manganese oxide-coated media filter include continuous regeneration (CR) and intermittent regeneration (IR).

In the CR process, an oxidant or combination of oxidants is applied continuously to the raw water ahead of the filter. The manganese will precipitate to manganese oxide and be removed by the media. If the oxidant is underfed, the oxidizing capacity of the media will complete the oxidation of the manganese. If the oxidant is underfed for an extended period, the oxidative capacity of the media will be exhausted, and manganese could pass into the treated water. Therefore, it is important for the media to be regenerated at all times. As long as adequate oxidant is applied, the media will remain continually regenerated. The media will require periodic backwash to remove the precipitates.

In the IR process, the raw water is applied to the filter and oxidation of the manganese occurs directly on the media using the oxidative capacity of the media. After treating a certain volume of water (with a certain concentration of manganese), the oxidative capacity of the media will be consumed, and media will require regeneration. Before regeneration, the media should be backwashed to remove the precipitates. Then a dilute oxidant solution should be applied downflow to the media bed. The filter will require rinsing until the excess oxidant is gone. The excess oxidant can be recycled and used for the next regeneration.

The CR process is used when iron removal is also needed and is predominant. The IR process is normally used when manganese removal is required with lesser quantities of iron present in the raw water. Based on the most recent Freeway Well water quality data (from November 2020), the iron concentration is below the iron MCL and iron removal is not required. Therefore, the IR process is recommended. A dilute potassium permanganate solution can be used to regenerate the filter media.

3.3.3.1.2.3 Backwashing

The filter will require periodic backwashing to remove the manganese precipitate that accumulates in the filter over time. The filter should be backwashed before media regeneration (after the filter has treated a certain volume of water) or when the differential pressure across the filter exceeds a setpoint level. The backwash will include a surface wash step using raw water, and a surface wash pump will be needed to boost the pressure of the raw water for delivery through the filter surface wash system.

It is assumed that the filter will be a multi-cell filter, and that one cell will be backwashed at a time with the filtered water produced from the other cells in the filter. A backwash tank is often needed to store the spent washwater for metered discharge into the sewer; however, with the facility's proximity to a major sewer trunk line, it is assumed that the spent backwash water can be discharged directly into the sewer and no backwash storage tank is needed.

3.3.3.1.3 Conceptual Design

The manganese treatment system would include the following equipment and facilities:

- Pressure filter with manganese greensand
- Surface wash pump
- Potassium permanganate batching and feed system

Table 3-1 summarizes the design criteria for the manganese treatment system.

Table 3-1. Manganese Treatment System Preliminary Design Criteria

Parameter	Units	Value
Pressure Filter		
Number of Units	number	1
Capacity	gpm	1,000
Configuration	-	Horizontal
Filter Diameter	feet	8
Filter Shell Length	feet	24
Number of Filter Cells	number	3
Total Filtration Area	square feet	200
Filtration Rate	gpm/square feet	5.0
Surface Wash Pump		
Surface Wash Supply	-	Raw Water
No. of Pumps	number	1
Pump Type	-	Centrifugal
Pump Capacity	gpm	135
Total Dynamic Head	feet	70
Drive	-	Constant Speed
Motor Size	Horsepower	5
Oxidant		
Chemical	-	Potassium Permanganate
Chemical Use per Regeneration	pounds	37.5

Photo 1 shows an example of a horizontal, multi-cell pressure filter and piping. The manganese treatment system will be upstream of the TCE treatment process, and the process flow diagram and conceptual layout of the manganese treatment system are incorporated into the process flow diagram and layouts for the air stripping and GAC contactor alternatives on Figures 3-1 through 3-4.

The site layouts on Figures 3-2 and 3-4 show the equipment footprint and the approximate space needed for process piping and access. As shown on the figures, the site does not have adequate space to accommodate the needed treatment facilities with adequate access within the boundaries of the existing well site.

Photo 1
Example Multi-cell Filter (from http://www.loprest.com)

3.3.3.2 Packed Tower Air Stripping – TCE Removal

The process description, design and operational considerations, design criteria, and conceptual site layout for packed tower air stripping treatment are discussed below.

3.3.3.2.1 Process Description

Air stripping is a process that uses air to strip volatile compounds from water. This process applies Henry's Law, which states that the equilibrium partial pressure of a constituent above a liquid is proportional to the concentration of the constituent in the liquid. When air that does not contain the target constituent is introduced to water with the target constituent, a portion of the constituent will leave the liquid phase and enter the gas phase in the air stream to achieve equilibrium. The proportional constant in Henry's Law is known as Henry's constant, and constituents with higher Henry's constants are more susceptible to removal from a liquid by air stripping. Air stripping is generally effective for removal of contaminants with a Henry's constant of 0.01 or higher. TCE has a Henry's constant of 0.5 (at 25°C).

There are a wide variety of gas transfer systems used in water treatment. One of the more efficient methods for removal of volatile contaminants from water is packed tower air stripping. Packed tower air stripping involves pumping the contaminated water to the top of a tower containing packed material. The water is evenly distributed over the packed material and flows down through the material. Air is blown up through the tower, contacting the water and stripping the volatile contaminant from the water. The packing material is designed to provide increased surface area for mass transfer to occur. The treated water collects in a sump at the bottom of the tower. The air with the stripped contaminant exits into the atmosphere through the top of the tower.

3.3.3.2.2 Design and Operational Considerations

Design and operational considerations include liquid loading rate, air-to-water ratio, packing material type and depth, water temperature, discharge air quality, pump replacement and addition, and packing media cleaning and replacement, as discussed below.

3.3.3.2.2.1 Liquid Loading Rate

The liquid loading rate is the flow rate over a unit area of the packing bed. For a fixed operating flow rate, the liquid loading rate is set by varying the diameter of the packed tower. The liquid loading rate affects the removal efficiency. For a given compound, applying a lower liquid loading rate increases the removal efficiency of that compound, but it requires reducing the tower capacity or increasing the tower diameter. The selection of the liquid loading rate should consider the volatility of the compound. For more volatile compounds, higher liquid loading rates can be used. For TCE, which is relatively volatile, loading rates of 20 to 30 gpm per square foot (gpm/sf) have been used to achieve greater than 90 percent removal.

3.3.3.2.2.2 Air-to-Water Ratio

The air-to-water ratio affects the removal efficiency of the packed tower system. Increasing the ratio of air to water increases the removal efficiency of the system, but it also increases the size of the blower needed for a given tower capacity, as well as the operating cost to run the blower. As with the liquid loading rate, the volatility of the compound should be considered when setting the air-to-water ratio. Less volatile compounds are more difficult to strip and require high air-to-water ratios to achieve high removal efficiencies. For TCE, air-to-water ratios ranging between 20 to 1 and 30 to 1 have been used to achieve greater than 90 percent removal.

3.3.3.2.2.3 Packing Material Type and Depth

Packing material is available in different shapes, sizes, and materials of construction. The size and shape of the packing material affect the packing factor, and thereby the headloss across the system, as well as the overall rate of mass transfer. Larger packing has a lower packing factor and lower rate of mass transfer per unit volume; but it costs less on a unit volume basis and results in lower headloss, which allows for higher application rates and smaller tower diameter for a given flow rate. Conversely, smaller packing has a higher packing factor and higher mass transfer rate, thereby requiring shorter depths of packing to achieve a target removal efficiency at a given flow rate. The required removal efficiency will impact the packing size and shape selection. The ratio of the tower diameter to the packing size must also be considered to avoid poor water distribution from wall effects.

The cost, weight, and durability of the material under operating conditions will influence the selection of the material of construction. For most water treatment applications, plastic packing is desirable due to its low cost, lightness, and durability.

The depth of the packing material affects the removal efficiency of the system. Increasing the packing depth increases the contact time between the water and air, and therefore, increases the removal efficiency. Increasing the packing depth also increases the height of the packed tower and the capital cost of the system. As noted above, the packing material size and shape will also impact the packing depth. For TCE removal, packing depths between 15 and 25 feet have been used to achieve greater than 90 percent removal.

3.3.3.2.2.4 Water Temperature

Although water temperature will not be a controlled parameter, the water temperature impacts the efficiency of the packed tower air stripping system and should be considered in the design of the system. Temperature affects the volatility of a compound; compounds are less volatile and more difficult to remove by air stripping at lower temperatures. The system should be designed for the coldest water temperature under normal conditions.

3.3.3.2.2.5 Air Discharge

The contaminant removed by the air stripping process will be present in the air discharged from the system and will enter the atmosphere. The VOC concentrations in the groundwater are relatively low, and it is expected that treatment of the discharged air will not be needed. If the air stripping alternative proceeds into design, the concentrations of the organic compounds in the air exiting the tower should be estimated and compared with the Bay Area Air Quality Management District's (BAAQMD) air emission limits to confirm that air treatment is not needed.

3.3.3.2.2.6 Pump Replacement and Addition

The air stripping process operates at atmospheric pressure. The water is pumped to the top of the tower, gravity flows down through the packing material, and is collected in the sump at the base of the tower. The packed tower air stripping system will require replacement of the Freeway Well pump with a pump that is sized for the lower head to pump to the top of the air stripping tower. A second set of pumps would be needed to deliver the treated water from the sump into the water distribution system.

3.3.3.2.2.7 Packing Media Cleaning and Replacement

The packing material will require periodic chemical cleaning to remove fouling. The cleaning frequency will depend on the water quality. High hardness, iron, and manganese will expedite fouling. The blower discharge pressure is monitored for indication of packing fouling. When fouling is identified, it can be cleaned in place by isolating the tower and recirculating an acid solution in a closed loop for several hours. The spent cleaning solution will require neutralization, typically with caustic soda, prior to disposal. If packing material is not regularly cleaned, it may become too fouled to clean and would require replacement. If the packing material is properly maintained, it should last at least 10 to 15 years.

3.3.3.2.3 Conceptual Design

A packed tower air stripping system to treat the groundwater from the Freeway Well would include the following equipment and facilities:

- Packed aeration tower
- Blower
- Treated water pumps

Table 3-2 summarizes the preliminary design criteria for the packed tower air stripping system.

Table 3-2. Packed Tower Air Stripping System Preliminary Design Criteria

Parameter	Units	Value
Packed Tower		
Water Flow Rate	gpm	1,000
Liquid Loading Rate	gpm/square feet	26
Tower Diameter	feet	7
Tower Height	feet	28
Packing Depth	feet	20
Packing Volume	cubic feet	770
Air Flow Rate	cubic feet per minute	5,350
Design Liquid Temperature	Fahrenheit	45
Initial Concentration	µg/L	25
TCE Removal Efficiency	percent	98
Blower		
No. of Blowers	number	2 (1 Duty + 1 Standby)
Blower Type	-	Centrifugal
Blower Capacity	cubic feet per minute	5,350
Pressure	inches W.C.	4
Motor Size	Horsepower	7.5
Treated Water Pumps		
No. of Pumps	number	2 (1 Duty + 1 Standby)
Pump Type	-	Centrifugal, Horizontal Split Case
Pump Capacity	gpm	1,000
Total Dynamic Head	feet	170
Drive	-	Variable Speed
Motor Size	Horsepower	60

Photo 2 shows an example of a packed tower aeration treatment facility. Figure 3-1 and Figure 3-2 show a process flow diagram and a conceptual site layout of a packed tower aeration treatment facility, respectively. The site layout shows the equipment footprint and the approximate space needed for process piping and access. As noted above and shown on the figure, the existing Freeway Well parcel does not have adequate space to accommodate the needed treatment facilities.

Photo 2
Example Packed Tower Aeration Treatment Facility (from https://www.h2ktech.com)

3.3.3.3 Granular Activated Carbon – TCE Removal

The process description, design and operational considerations, design criteria, and conceptual site layout for granular activated carbon contactor treatment are discussed below.

3.3.3.3.1 Process Description

Adsorption is the mass transport of substances (adsorbate) in a fluid onto the surface of a solid (adsorbent) that the fluid comes in contact with. The adsorbate becomes bound to the surface of the adsorbent, primarily through physical forces.

A commonly used adsorbent in water treatment is activated carbon, which is carbon material heated at high temperatures to increase its surface area for adsorption. Carbonaceous material typically used to manufacture activated carbon include coal, coconut husk, wood, and peat. The type of raw material and the activation temperature influence the surface area, average pore size, abrasion resistance, and other physical properties of the activated carbon product.

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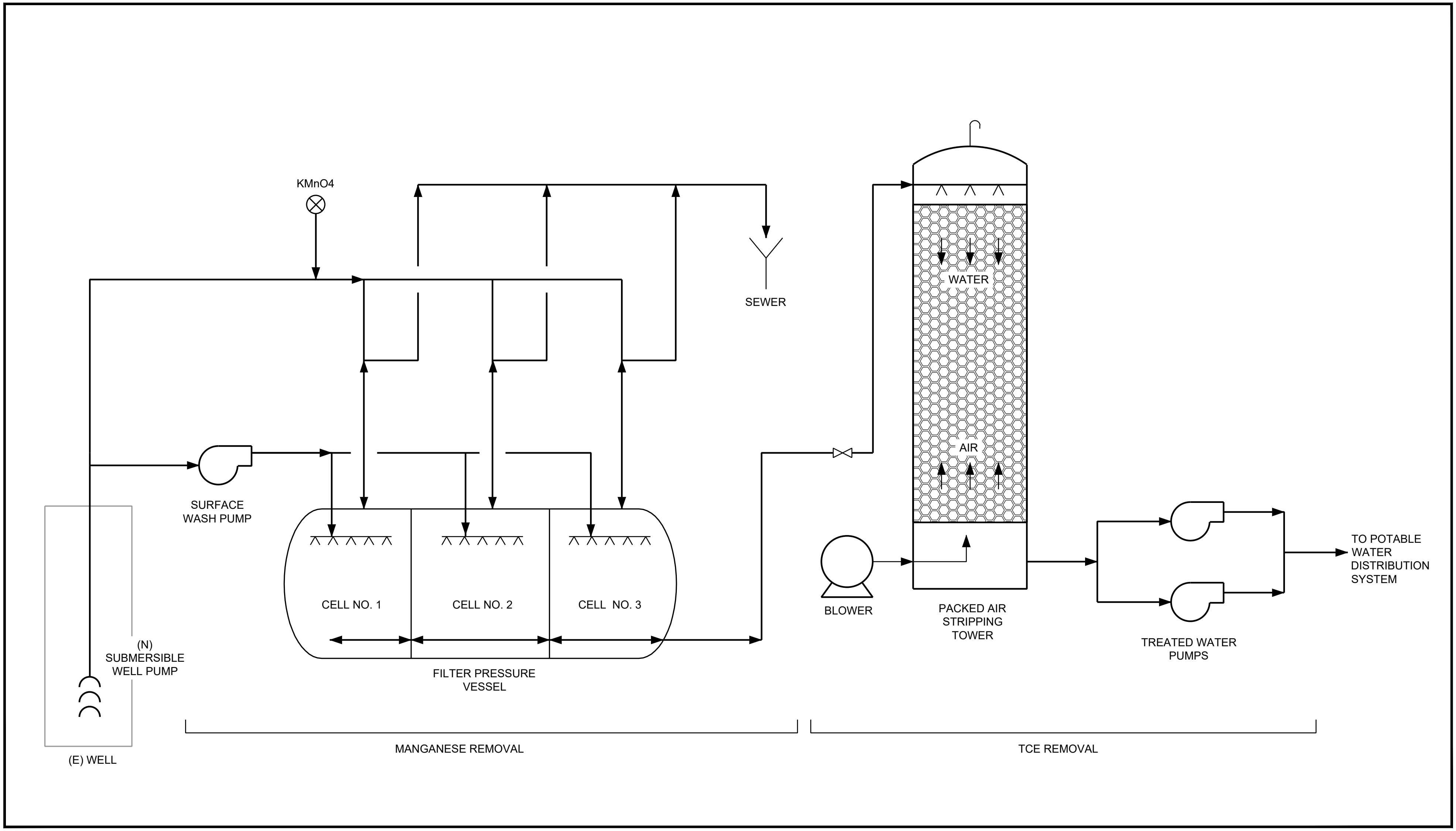

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Figure 3-1

Mn Filter + Air Stripping Process Flow Diagram

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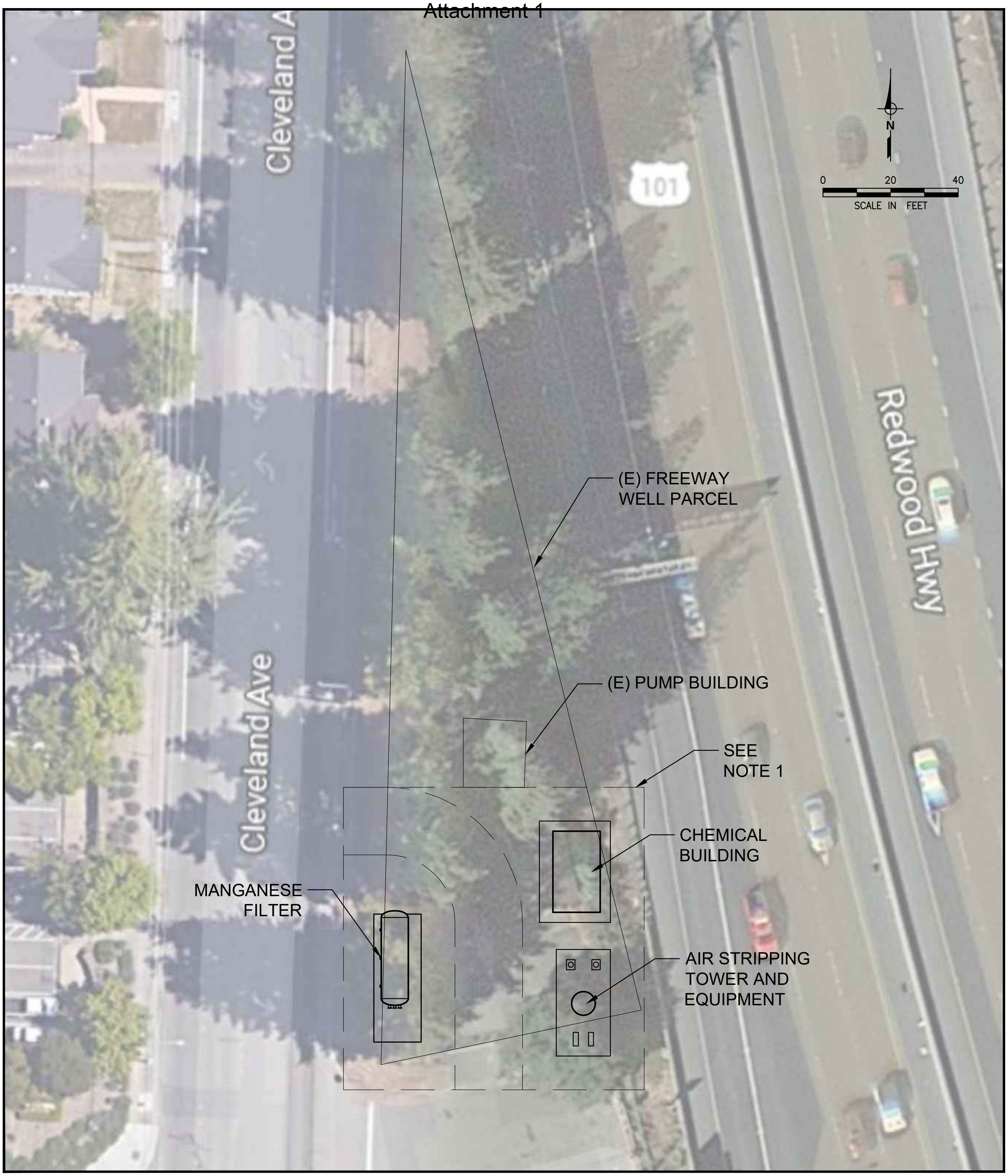
Attachment 1



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Notes:

1. Estimated envelope of space needed for new treatment facilities that includes a driveway and assumed 10-foot setback for access and maintenance. The proposed treatment facilities cannot feasibly fit within the existing Freeway Well parcel.

Figure 3-2

Mn Filter + Air Stripping Site Layout

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Activated carbon is available in granular form (granular activated carbon, GAC) or powdered form (powdered activated carbon, PAC). The granular form is typically used where long-term, continuous treatment is needed. The contaminant is removed by passing the source water through a bed of GAC. The powdered form is commonly used when the need for treatment is intermittent (e.g., seasonal). The PAC is added to the source water and subsequently removed by sedimentation and/or filtration. GAC would be most suitable for providing continuous treatment for TCE reduction at the Freeway Well.

3.3.3.3.2 Design and Operational Considerations

Design and operational considerations for GAC contactor design includes contactor vessel and well pump replacement, GAC media, empty bed contact time, hydraulic loading rate, contactor configuration and carbon change-out, as discussed below.

3.3.3.3.2.1 Contactor Vessel and Well Pump Replacement

The GAC contactor can be configured in pressure vessel or a gravity-flow, open bed. Pressure vessels are recommended for this application to avoid breaking head and requiring re-pumping of the groundwater. Pressure vessels would allow pumping the groundwater through the treatment system, directly into the water distribution system. However, installation of GAC contactors will introduce additional headloss and require replacement of the Freeway Well pump. The replacement pump would be sized to overcome the additional headloss from the GAC contactors to pump the water into the distribution system.

3.3.3.3.2.2 GAC Media

GAC media produced from different raw materials at different activation temperatures will have different properties. Parameters used to characterize GAC include iodine number (indication of pore volume available), molasses number (indication of degree of adsorption of larger molecules), hardness/abrasion number (indication of resistance to wear), ash content (reduces efficiency and overall activity of the activated carbon), and apparent density (indication of the quality of the activated carbon). Other size-related parameters include particle size distribution and mesh size, which affects hydraulic performance and kinetics. Finer mesh sizes may result in higher pressure, but the higher rates of reaction promoted by the finer mesh sizes may enable use of a shallower bed. When selecting and specifying the GAC media for optimal TCE removal and GAC performance, the GAC properties and size parameters will need to be considered.

3.3.3.3.2.3 Empty Bed Contact Time (EBCT)

A certain amount of contact time between the GAC media and source water is needed for the adsorption of the TCE contaminant onto the GAC media. The contact time provided is determined by dividing the GAC bed volume by the flow rate through the volume; this parameter is referred to as the empty bed contact time (EBCT), as it does not account for the space occupied by the carbon media. The optimal EBCT for TCE removal is impacted by the initial TCE concentration in the source water, the adsorption potential of the media, and the presence of competing contaminants in the source water. One study reported an optimal EBCT for TCE removal of 9 minutes from a source water with an initial concentration of 25 µg/L (Ahmed & Hand, 2015). An EBCT of 10 minutes was assumed for sizing the facility and estimating costs.

3.3.3.3.2.4 Hydraulic Loading Rate

The hydraulic loading rate is determined by dividing the filter bed area by the flow rate through the filter. Low hydraulic loading rates can cause channeling. High hydraulic loading rates can result in abrasion of the GAC media in addition to high headloss across the filter. The contactor should be designed to provide a hydraulic loading rate between 4 and 9 gpm/sf at the normal operating flow rate for proper operation.

3.3.3.3.2.5 Contactor Configuration and Carbon Change-Out

To maximize carbon use, the GAC system should be configured with at least two contactors operated in series. The source water would flow into the first or “lead” contactor, and the treated water from the lead contactor would flow into the second or “lag” contactor. The media in the lead contactor would have three zones: exhausted GAC in the top layer; a mass transfer zone in the middle layer; and unspent GAC in the bottom layer. The media in the lag contactor would be unspent. The mass transfer zone in the lead contactor will continue to migrate down the media bed as the volume of exhausted GAC increases until all the GAC media in the lead contactor is expended (as determined by TCE breakthrough). This configuration allows full saturation of the carbon in the lead contactor prior to carbon replacement.

Treatment of water could continue through the lag contactor, while the lead contactor is taken offline for carbon change-out. The lag contactor can then be operated as the lead contactor when the vessel with the fresh carbon is brought back online for operation as the lag contactor. This would require manifold piping and valving to allow switching lead/lag contactor configuration. Sample ports should be provided at the inlet and outlet of each vessel and along the side of each vessel at intermediate bed depths to allow tracking the migration of the mass transfer zone for scheduling carbon replacement.

3.3.3.3.2.6 Backwashing

After new carbon is loaded into a vessel, the carbon should be soaked (for 24 hours) to wet the carbon and then backwashed (for about 60 minutes) prior to placing the contactor in service. Backwash rates will depend on the carbon type but are typically between 5 and 10 gpm/sf.

Maintenance backwashes are typically not needed, but a maintenance wash should be performed if the differential pressure across the contactor increases to more than 50 percent of its clean bed headloss (e.g., from solids accumulation on the carbon bed). Backwashing re-stratifies the carbon media and should be minimized after the initial wash to avoid disrupting the mass transfer zone and reducing the carbon life.

It is assumed that the water for the initial backwash and any maintenance backwash can be supplied from the water distribution system and a washwater supply tank is not needed. A washwater pump station is assumed to be needed to boost the pressure of the washwater supply for backwash. Since the booster pump is needed only periodically for occasional backwashes, it is assumed that only one booster pump will be installed with no inline redundancy. A backwash tank is often needed to store the spent washwater for metered discharge into the sewer; however, with the facility’s proximity to a major sewer trunk line, it is assumed a backwash tank would not be required for this facility.

3.3.3.3.3 Conceptual Design

A GAC system to treat the groundwater from the Freeway Well would include the following equipment and facilities:

- GAC contactor pressure vessels
- Washwater supply booster pumps

Table 3-3 summarizes the design criteria for the GAC system.

Table 3-3. GAC System Preliminary Design Criteria

Parameter	Units	Value
GAC Contactors		
Design Flow Rate	gpm	1,000
Number of Contactors	number	2
Contactor Configuration	-	Vertical, Operated in Series
Vessel Diameter	feet	12
Filtration Area	square feet	113
Hydraulic Loading Rate	gpm/square feet	8.84
Media Depth per Contactor	Inches	71
Total Media Depth	feet	11.8
Total Bed Volume	cubic feet	1,336
Empty Bed Contact Time	minutes	10
Washwater Supply Pump		
Washwater Supply	-	Treated Water (from Distribution System)
No. of Pumps	Number	1
Pump Type	-	Centrifugal
Pump Capacity	Gpm	850
Total Dynamic Head	Feet	40
Drive	-	Constant Speed
Motor Size	Horsepower	15

Photo 3 shows an example of the GAC contactor vessels and piping manifold. Figure 3-3 and Figure 3-4 show a process flow diagram and a conceptual site layout of the GAC contactors, respectively. The site layout shows the equipment footprint and the approximate space needed for process piping and access. Similar to the packed tower aeration alternative, the treatment facilities for the GAC contactor alternative cannot feasibly fit within the existing Freeway Well parcel.

Photo 3
Example GAC Contactor Vessesls and Piping Manifold (from http://www.aqueousvets.com)

Attachment 1

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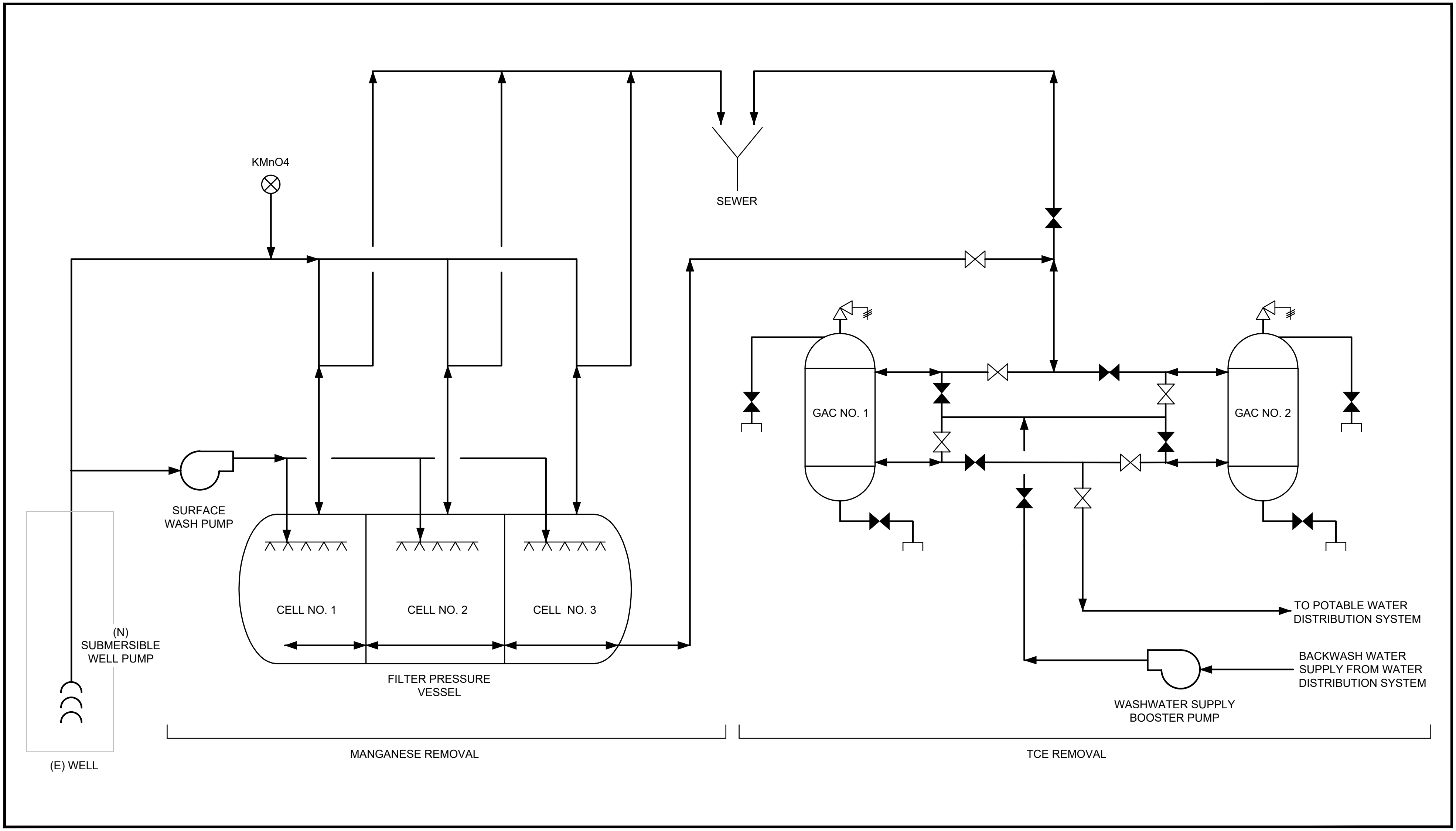

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Figure 3-3

Mn Filter + GAC Process Flow Diagram

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Attachment 1

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Notes:

1. Estimated envelope of space needed for new treatment facilities that includes a driveway and assumed 10-foot setback for access and maintenance. The proposed treatment facilities cannot feasibly fit within the existing Freeway Well parcel.

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Figure 3-4

Mn Filter + GAC Site Layout

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3.3.4 Operation as Emergency Well

With the addition of the treatment facilities, it would not be practical to operate the Freeway Well as an emergency well for potable water supply due to the time needed to bring the well facilities online. After a long shut down period, the treatment facilities would have to be disinfected before they can be brought into service for potable water production.

For the manganese filters, disinfection involves soaking the filter in highly chlorinated water for at least 12 hours, and then running the filter to waste or backwashing process to thoroughly remove the highly chlorinated water. The packed tower for air stripping would undergo a similar process; but rather than soaking, the highly chlorinated water would be recirculated through the packing media in the tower. Chlorine solution cannot be used for disinfection of the GAC filters as it will damage or "use up" the GAC media. Disinfection of the GAC would have to be performed with a high pH solution that is recirculated through the media in the vessels, and then neutralized for disposal.

After completion of the disinfection procedure, bacteriological samples must be collected from the facilities and tested for the presence of total coliform bacteria. The test method requires 22 to 24 hours of incubation. The facilities can be placed in service only if none of the samples show the presence of total coliform bacteria.

The disinfection process could take one to two days. The verification process would require at least another day. The emergency situation could be over in the two to three days that would be needed to prepare the well facilities for service. Therefore, operation of the Freeway Well, if reinstated, would have to be as a production well and not an emergency well.

3.4 ESTIMATED PROJECT COST

To prepare a cost-benefit analysis, life cycle costs were first developed using estimated project cost and annual operation and maintenance costs.

3.4.1 Conceptual Opinion of Probable Project Cost

The Association for the Advancement of Cost Engineering (AACE) International publishes guidelines for classes of cost estimates and their expected accuracy ranges. Based on these guidelines, the preliminary opinion of probable project cost (OPPC) summarized below is a Class 5 Estimate. Class 5 estimates are based on limited information and are generally prepared for strategic planning purposes, assessment of initial viability, evaluation of alternate schemes, and project screening. Typical accuracy ranges for Class 5 estimates are (-)20 to (-)50 percent on the low side and (+)30 to (+)50 percent on the high side.

West Yost estimates the cost to properly abandon a well to be approximately $100,000. This estimate includes well abandonment/demolition, inspection of work, and brief report of the work completed. The estimate does not include project costs, such as administration, engineering, procurement, and management. The total cost of well abandonment could be two to three times higher when project costs are added. Additionally, this cost does not include demolition of other existing facilities at the Freeway Well site, such as the existing buildings.

The OPPCs for the treatment alternatives were developed using budgetary quotes from vendors and cost data from similar projects. The cost estimate summarized in Table 3-4 below applies the following contingencies and markups:

- 9.25 percent sales taxes on materials (applicable in Santa Rosa, California)
- 30 percent indirect project cost (general conditions, contractor overhead and profit, bonds, insurance, mobilization and demobilization)
- 40 percent for conceptual-level estimating contingency
- 10 percent for construction contingency
- 30 percent for project costs (planning, permitting, design, construction management, engineering services during construction, and administrative and legal costs)

Table 3-4. Capital and Project Costs

Element	Mn Filter + Air Stripping Tower	Mn Filter + GAC Contactor
Site Work and Yard Piping	87,500	112,300
Treatment System	1,124,600	1,249,600
Electrical and Instrumentation	316,000	356,000
Subtotal Project Costs	**1,528,100**	**1,717,900**
Taxes on Materials (9.25%)	64,400	73,700
Subtotal	**1,592,500**	**1,791,600**
GC, OH&P, Mob/Demob (30%)	477,800	537,500
Subtotal	**2,070,300**	**2,329,100**
Estimating Contingency (40%)	828,200	931,700
Subtotal	**2,898,500**	**3,260,800**
Construction Contingency (10%)	289,900	326,100
Total Construction Cost	**3,188,400**	**3,586,900**
Project Costs (30%)	956,600	1,076,100
Total Project Cost	**4,145,000**	**4,663,000**

It should be noted that these costs only include construction of the treatment facilities. They do not include land acquisition and associated work that are needed, as the existing well site cannot support the proposed treatment facilities.

3.4.2 Annual O&M Cost

Estimates of annual O&M costs were developed for the treatment alternatives and are summarized in Table 3-5. The annual O&M costs were developed applying the following assumptions:

- Treatment unit operation 50 percent of the year (during higher water demand periods from Spring to Fall)
- 2 hours a day for routine operations and maintenance of the facility

- Energy use is based on additional lift/head introduced by treatment system (it does not include energy use for pumping from groundwater well into the distribution system)
- Annual maintenance materials cost estimated at 3 percent of equipment cost
- Manganese greensand regeneration every two days; chemical use of 37.5 lbs of potassium permanganate per regeneration; 4 labor hours per regeneration
- Monthly chemical cleaning of the packed air stripping tower; 8 labor hours per clean
- Air stripping tower packing media replacement once every ten years
- GAC media usage rate of 0.0953 lbs of GAC per 1,000 gallons treated; 8 labor hours per media changeout

The O&M cost estimates apply the following unit cost assumptions:

- $100/hour for labor (including benefits)
- $0.27/kWh energy rate
- $2.68/lb of potassium permanganate
- $25,000 for packing media replacement
- $40,000 for GAC media changeout of one vessel

The labor, chemical use, and chemical disposal costs are estimated to be greater for the air stripping tower alternative due to the additional labor and chemicals needed for monthly chemical cleaning of the packing material. The energy cost is also higher for the air stripping tower alternative, since it introduces greater head and also requires operation of a blower. The media replacement cost is significantly higher for the GAC contactor alternative. The GAC media requires regular replacement when the media adsorptive capacity is exhausted. The GAC media in the lead vessel will be replaced at a time when there is breakthrough from the lead vessel. The media replacement in one GAC vessel is estimated to be needed two to three times a year.

Table 3-5. Annual Operations and Maintenance Costs

Element	Mn Filter + Air Stripping	Mn Filter + GAC Contactor
Annual Labor	77,600	73,700
Annual Energy Use	31,800	19,600
Annual Chemical Use and Disposal	10,400	9,200
Annual Maintenance Materials	10,600	13,500
Annual Media Replacement	2,500	49,900
Total Annual O&M Cost	**132,900**	**165,900**

3.4.3 Life Cycle Cost

Table 3-6 provides a summary of the life cycle cost of the two treatment alternatives. The life cycle costs are based on a discount rate of 4 percent and a cost period of 20 years.

Table 3-6. Life Cycle Costs

Element	Mn Filter + Air Stripping	Mn Filter + GAC Contactor
Total Project Cost	4,145,000	4,663,000
Present Value of Total Annual O&M Cost	1,806,200	2,254,700
Total Life Cycle Cost	**5,951,200**	**6,917,700**

Based on a discount rate of 4 percent, a cost period of 20 years, and 183 days of operation at 1,000 gpm, the cost per acre-foot (AF) for treatment is $541/AF and $629/AF for the air stripping and GAC contactor alternatives, respectively.

3.4.4 Cost-Benefit Analysis

Groundwater production from a new well at a different site that will not require treatment for contaminant removal would be more cost effective than treating groundwater from the Freeway Well. Based on cost data from a recent well installation project, the cost of installing and equipping a new well (not including land acquisition) could be 25- to 50-percent less than the cost of producing and treating groundwater from the Freeway Well.

Non-cost factors, such as the risk of further contaminating the aquifer, the infeasibility of obtaining decent production yield from a well screened at just the lower levels, and the lack of adequate space on the existing well site for the needed treatment facilities, override the economic factors and make treatment of the Freeway Well infeasible.

3.5 POSSIBLE PROJECT SCHEDULE

Abandonment of the Freeway Well can be accomplished in approximately 12 months after permitting and financing are obtained. This takes into account preparation of bid documents, bid solicitation, bid selection, award negotiation and execution, and project execution.

Both treatment alternatives evaluated above would require approximately the same time to implement. Once financing and permitting are complete, design would be expected to take 9 to 12 months and construction would take approximately 12 months, possibly 18 months considering long lead time items such as the treatment vessels, electrical panels, and control panels. This does not include the time required to solicit bids for design and bids for construction, bid award periods, contract negotiations, and contract execution.

3.6 REFERENCES

Dr. Zeyad Ahmed, PE and Dr. David W. Hand, BCEEM. 2015. *The Effect of Volatile Organic Compounds on GAC Adsorbers*. http://www.sawea.org/pdf/2015/Techincal_Program_19/Zeyad_%20Ahmed.pdf

John Civardi, Mark Tompeck. AWWA. 2015. *Iron and Manganese Removal Handbook, Second Edition*.

United States Environmental Protection Agency (USEPA). 2009. *Drinking Water Treatability Database: Trichloroethylene*. https://iaspub.epa.gov/tdb/pages/contaminant/contaminantOverview.do

CHAPTER 4
Recommended Alternative

4.1 RECOMMENDED ALTERNATIVE

The following remedial action alternatives to protect and/or reestablish the Freeway Well as a source of potable water supply were evaluated and are discussed in the sections below:

- Abandoning and properly destroying the existing Freeway Well to protect groundwater resources for future use;
- Installing a new well which taps only into the lower water bearing zones; and
- Pumping and treating contaminated groundwater from the Freeway Well to potable water standards.

4.1.1 Discussion of Alternatives

Abandonment of the existing Freeway Well would entail filling the well from bottom to top with a sand cement slurry (described in Chapter 3) and blast perforating the blank casing from 107 to 400 feet below surface. Proper abandonment of the well would eliminate the conduit for transport of contaminant between the aquifer zones and is recommended.

A new well could be constructed on the Freeway Well site and screened to avoid the higher levels of contamination in the existing Freeway Well, but would likely still require wellhead treatment for VOCs and manganese, though a lower VOC concentration would be expected. Furthermore, the new well would only draw from the lower aquifer zones, which had low yield during the 2020 aquifer flow tests. The new well would likely be less productive than the existing well. Therefore, the construction of a new well on the Freeway Well site is not considered to be a viable alternative. It would be more cost effective to construct a new production well at a different site that would not require treatment for contaminant removal.

While the groundwater pumped from the Freeway Well could theoretically be treated to potable water quality, the treatment facilities needed to remove TCE and manganese to meet regulatory levels for drinking water cannot feasibly fit within the existing Freeway Well parcel.

Additionally, the Freeway Well could not be operated as an emergency well due to the time needed for the disinfection and verification processes before the well and treatment facilities can be placed into service.

In order to use Freeway Well as a production well with wellhead treatment, it would first need to undergo an extensive State permitting process to shift from standby status to production status. While permitting is not an insurmountable obstacle, operating the existing Freeway Well could cause further migration of contaminants from the upper zone into the lower zone of the aquifer.

It is the City's opinion that the more critical concern is protection of the groundwater resource. Therefore, the recommended project is to properly abandon the Freeway Well to prevent further migration of contaminants from upper aquifer zones into lower aquifer zones.

4.1.2 Possible Project Schedule

Following completion of permitting and financing, bid documents for abandonment of the Freeway well can be prepared within two months. The bid and award period is anticipated to require four months, and project execution is anticipated to require one to two months.

Appendix A

Cost Estimates - AST

WEST YOST
Water. Engineered.

PROJECT: Freeway Well Planning Project
OWNER: City of Santa Rosa
LOCATION: Santa Rosa, CA
WEST YOST PROJECT #: 405-12-18-69
TITLE: Conceptual Level Opinion of Probable Cost
Air Stripping Tower Alternative

CAPITAL AND PROJECT COST

	Description	Quantity	Unit	Unit Cost, $	Cost, $
Sitework					
DIV 2					
	Clearing and Grubbing	1	LS	15,000	15,000
	Grading	1,500	SF	25	37,500
	Yard Piping	1	LS	30,000	30,000
	Tie-in to Water System	1	EA	5,000	5,000
					-
	Subtotal				**87,500**
Concrete					
DIV 3					
	Air Stripping Tower Foundation	1	LS	25,000	25,000
	AST Concrete Pad	16	CY	1,400	22,400
	Chemical Building Concrete Pad	18	CY	1,400	25,200
	Manganese Filter Concrete Pad	20	CY	1,400	28,000
					-
	Subtotal				**100,600**
Masonry					
DIV 4					
	Fiberglass Chemical Building (24' x 14')	1	LS	60,500	60,500
	Subtotal				**60,500**
Metals					
DIV 5					
	Miscellaneous Metals	1	LS	3,000	3,000
	Subtotal				**3,000**
Finishes					
DIV 9					
	Coating & Painting	1	LS	40,500	40,500
					-
	Subtotal				**40,500**
Equipment					
DIV 11					
	Air Stripping Tower	1	LS	140,000	140,000
	Air Stripping Tower Installation	1	LS	25,000	25,000
	Blowers	2	EA	15,000	30,000
	Blower Installation	2	EA	5,000	10,000
	Treated Water Pumps	2	EA	15,000	30,000
	Treated Water Pump Installation	2	EA	5,000	10,000

	Description	Quantity	Unit	Unit Cost, $	Cost, $
	AST Chemical Cleaning System	1	LS	15,000	15,000
	AST Chemical Cleaning System Installation	1	LS	5,000	5,000
	Manganese Filter	1	LS	475,000	475,000
	Manganese Filter Installation	1	LS	25,000	25,000
	KMnO4 Chemical System	1	LS	15,000	15,000
	KMnO4 Chemical System Installation	1	LS	5,000	5,000
					-
	Subtotal				**785,000**
Mechanical					
DIV 15					
	AST Piping, Fittings, and Valves	1	LS	45,000	45,000
	AST Ducting	1	LS	30,000	30,000
	Manganese Filter Piping Fittings, and Valves	1	LS	45,000	45,000
	Chemical Piping, Fittings, and Valves	1	LS	15,000	15,000
					-
	Subtotal				**135,000**
Electrical and Instrumentation					
DIV 16					
	Electrical	1	LS	158,000	158,000
	Instrumentation	1	LS	158,000	158,000
	Subtotal				**316,000**

	Subtotal	**1,528,100**
Taxes on Materials	9.3%	64,400
	Subtotal	**1,592,500**
Indirect Costs (General Conditions, Mob/Demob, Contractor OH&P)	30.0%	477,800
	Subtotal	**2,070,300**
Estimating Contingency	40.0%	828,200
	Subtotal	**2,898,500**
Construction Contingency	10.0%	289,900
	Total Estimated Construction Cost	**3,188,400**
Planning, Permitting, Design, CM, ESDC	30.0%	956,600
	Total Estimated Construction Cost	**4,145,000**

OPERATIONS AND MAINTENACE COSTS

	Description	Quantity	Unit	Unit Cost, $	Cost, $
	Labor	776	HR	100	77,600
	Annual Energy Use	119,241	kWh/yr	0.27	31,829
	Chemical Use - Potassium Permanganate	3,422	lbs	2.68	9,171
	Packing Media Routine Cleaning	6	EA	200	1,200
	Maintenance Materials	1	LS	10,575	10,575
	Packing Media Replacement	1	LS	2,500	2,500
					-
	Subtotal				**132,875**

Appendix B

Cost Estimates - GAC

Attachment 1

PROJECT: Freeway Well Planning Project
OWNER: City of Santa Rosa
LOCATION: Santa Rosa, CA
WEST YOST PROJECT #: 405-12-18-69
TITLE: Conceptual Level Opinion of Probable Cost
GAC Contactor Alternative

CAPITAL AND PROJECT COST

	Description	Quantity	Unit	Unit Cost, $	Cost, $
Sitework					
DIV 2					
	Clearing and Grubbing	1	LS	15,000	15,000
	Grading	1,690	SF	25	42,250
	Yard Piping	1	LS	45,000	45,000
	Tie-in to Water System	2	EA	5,000	10,000
					-
	Subtotal				**112,250**
Concrete					
DIV 3					
	GAC Concrete Pad	21	CY	1,400	29,400
	Chemical Building Concrete Pad	18	CY	1,400	25,200
	Manganese Filter Concrete Pad	20	CY	1,400	28,000
					-
	Subtotal				**82,600**
Masonry					
DIV 4					
	Fiberglass Chemical Building (24' x 14')	1	LS	60,500	60,500
					-
	Subtotal				**60,500**
Metals					
DIV 5					
	Miscellaneous Metals	1	LS	3,000	3,000
					-
	Subtotal				**3,000**
Finishes					
DIV 9					
	Coating & Painting	1	LS	49,000	49,000
					-
	Subtotal				**49,000**
Equipment					
DIV 11					
	GAC Vessels	2	EA	198,000	396,000
	GAC Vessel Installation	2	EA	12,000	24,000
	Washwater Supply Pump	1	EA	12,000	12,000
	Washwater Supply Pump Installation	1	EA	5,000	5,000
	Manganese Filter	1	LS	475,000	475,000
	Manganese Filter Installation	1	LS	25,000	25,000

	Description	Quantity	Unit	Unit Cost, $	Cost, $
	KMnO4 Chemical System	1	LS	15,000	15,000
	KMnO4 Chemical System Installation	1	LS	5,000	5,000
					-
	Subtotal				**957,000**
Mechanical					
DIV 15					
	GAC Piping, Fittings, and Valves	1	LS	45,000	45,000
	Manganese Filter Piping Fitings, and Valves	1	LS	45,000	45,000
	Chemical Piping, Fittings, and Valves	1	LS	7,500	7,500
					-
	Subtotal				**97,500**
Electrical and Instrumentation					
DIV 16					
	Electrical	1	LS	178,000	178,000
	Instrumentation	1	LS	178,000	178,000
					-
	Subtotal				**356,000**

	Subtotal	**1,717,850**
Taxes on Materials	9.3%	73,700
	Subtotal	**1,791,550**
Indirect Costs (General Conditions, Mob/Demob, Contractor OH&P)	30.0%	537,500
	Subtotal	**2,329,050**
Estimating Contingency	40.0%	931,700
	Subtotal	**3,260,750**
Construction Contingency	10.0%	326,100
	Total Estimated Construction Cost	**3,586,850**
Planning, Permitting, Design, CM, ESDC	30.0%	1,076,100
	Total Estimated Construction Cost	**4,662,950**

OPERATIONS AND MAINTENACE COSTS

	Description	Quantity	Unit	Unit Cost, $	Cost, $
	Labor	737	HR	100	73,700
	Annual Energy Use	73,322	kWh/yr	0.27	19,572
	Chemical Use - Poassium Permangante	3,422	lbs	2.68	9,171
	Maintenance Materials	1	LS	13,470	13,470
	Media Replacement	1.25	EA	40,000	49,853
					-
	Subtotal				**165,766**