JUNE 11, 2015

CORRECTIVE MEASURES STUDY

RAYTHEON COMPANY

(FORMER HUGHES AIRCRAFT COMPANY)

1901 WEST MALVERN AVENUE

FULLERTON, CALIFORNIA

PREPARED FOR:
RAYTHEON COMPANY

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

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June 11, 2015

VIA FEDERAL EXPRESS – STANDARD

Mr. William F. Jeffers, PE
Hazardous Substances Engineer
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
DEPARTMENT OF TOXIC SUBSTANCES CONTROL
9211 Oakdale Avenue
Chatsworth, CA 91311-6505

Re: Transmittal of Corrective Measures Study, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California

Dear Mr. Jeffers:

Enclosed is one hard copy with a compact disc that contains a copy of the above-referenced report. We would like to schedule a meeting with the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) and other stakeholders in the next month to discuss the Corrective Measures Study Report.

If you have any questions or require further information, please contact us at 858-455-6500.

Sincerely,

HARGIS + ASSOCIATES, INC.

PROFESSIONAL GEOLOGIST
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Enclosure: 1 copy w-CD

Other Offices:
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cc w/encl: (1 copy w-CD)
Mr. Paul Pongetti, Department of Toxic Substances Control, Cypress
Mr. Paul E. Brewer, Raytheon Company
Mr. Carl Bernhardt, California RWQCB, Santa Ana Region
Mr. Dave Mark, Orange County Water District
Mr. Eric Silvers, Regency Centers
Mr. Jeffrey Lochner, Athena Property Management

(2 copies w-CDs)
Mr. Dave Schickling, City of Fullerton

(via CD only) (*Hard Copies Provided Upon Request*)
Mr. Van Xayarath, City of Fullerton
Mr. Robert Logan, RG, Kennedy/Jenks Consultants
Mr. James A. Biery, PE, TE, City of Buena Park
Ms. Jennifer Schaefer, The Morgan Group, Inc.
Rosalind McLeroy, Esq., The Morgan Group, Inc.
Mr. William Yowell, Prudential Real Estate Investors
Ms. Tizita Bekele, PE, Department of Toxic Substances Control, Cypress
Mr. Mike McGee, City of Buena Park
Ms. Carol Owens, The Morgan Group, Inc.

(via Email) *(via CD if document too large)*
Mr. Duc Nguyen, Orange County Public Works (County Property Permit CPP # 2013-00184)

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HARGIS + ASSOCIATES, INC.

CORRECTIVE MEASURES STUDY

RAYTHEON COMPANY
(FORMER HUGHES AIRCRAFT COMPANY)
1901 WEST MALVERN AVENUE
FULLERTON, CALIFORNIA

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APPENDICES

Appendix

ACRONYMS AND ABBREVIATIONS

AOC	Areas of Concern
AOP	Advanced Oxidation Process
bls	Below land surface
CACA	Corrective Action Consent Agreement
CFFD	City of Fullerton Fire Department
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
COCs	Compounds of concern
CSM	Conceptual Site Model
1,1-DCE	1,1-Dichloroethylene
DCHDPE	Double-contained, high-density polyethylene
DPE	Dual phase extraction
DTSC	California Environmental Protection Agency, Department of Toxic Substances Control
DWR	California Department of Water Resources
EPA	U.S. Environmental Protection Agency
G&M	Geraghty & Miller, Inc.
GETs	Groundwater extraction and treatment system
GHG	Greenhouse gas
gpm	Gallons per minute
H+A	Hargis + Associates, Inc.
HAC	Hughes Aircraft Company
HDPE	High-density polyethylene
HHRAs	Human Health Risk Assessments
$HiPO_x$™	Hydrogen peroxide and ozone
Kroll	Kroll Environmental Enterprises, Inc.
LAS	Lower Aquifer System
LPGAC	Liquid phase granular activated carbon
MAS	Middle Aquifer System
MCLs	Maximum Contaminant Levels
MNA	Monitored Natural Attenuation
msl	Mean sea level
NPV	Net present value
O&M	Operation and maintenance
OCGB	Orange County Groundwater Basin
OCWD	Orange County Water District
OCSD	Orange County Sanitation District
OMB	United States Office of Management and Budget
OSHA	Occupational Safety and Health Administration
P&T	Pump-and-treat
POCs	Points of compliance
RAOs	Remedial Action Objectives
Raytheon	Raytheon Company
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment

ACRONYMS AND ABBREVIATIONS (continued)

RFI	RCRA Facility Investigation
RWQCB-SA	California Regional Water Quality Control Board, Santa Ana Region
the Site	1901 West Malvern Avenue, northeast of the intersection of Malvern Avenue and Gilbert Street, Fullerton, California
SPDP	Special Purpose Discharge Permit
SVE	Soil vapor extraction
SWMUs	Solid Waste Management Units
SWRCB DDW	State Water Resources Control Board Division of Drinking Water
TCE	Trichloroethylene
UAS	Upper Aquifer System
USTs	Underground storage tanks
UV/chem-ox	Ultraviolet light with hydrogen peroxide chemical oxidation
VOCs	Volatile organic compounds
WDR	Waste Discharge Requirements
Well 9	City of Fullerton production well No. 9

CORRECTIVE MEASURES STUDY

RAYTHEON COMPANY
(FORMER HUGHES AIRCRAFT COMPANY)
1901 WEST MALVERN AVENUE
FULLERTON, CALIFORNIA

EXECUTIVE SUMMARY

This Corrective Measures Study (CMS) has been prepared by Hargis + Associates, Inc. on behalf of Raytheon Company (Raytheon) (formerly Hughes Aircraft Company [HAC]) for the site located at 1901 West Malvern Avenue which is northeast of the intersection of Malvern Avenue and Gilbert Street in Fullerton, California (the Site) (Figures ES-1 and ES-2). This CMS report was prepared in accordance with the CMS Work Plan Update for the Site which was approved by the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC). Additionally, this CMS report was prepared in accordance with the Corrective Action Consent Agreement (CACA) with the DTSC.

A CMS is being conducted to determine appropriate groundwater corrective actions associated with operations at two former areas of the Site (former Building 609 area and former Building 601 area, Figure ES-2) in accordance with the CACA with the DTSC. The purpose of the CMS is to identify and evaluate a corrective measure alternative(s) that will address groundwater in the regional aquifer system containing volatile organic compounds (VOCs) and 1,4-dioxane at and downgradient of the Site.

ES-1.1 SITE DESCRIPTION AND REGULATORY HISTORY

The Site is located entirely within the City of Fullerton in Orange County, California. The Site and its vicinity were used primarily for light agricultural purposes prior to development in the late 1950's. Following purchase of the Site by HAC in 1957, and prior to the closing of most of the facility in 2000, a total of approximately 100 buildings and/or temporary structures were constructed. Manufacturing operations at the Site started in 1959. HAC's operations included machining/fabrication, assembly, plating, laboratory, testing, warehouse, facility operations, and maintenance, transportation, and offices. The HAC facility was involved in the manufacture of radar systems and associated components, undersea weapons systems, surface ship systems, anti-submarine warfare systems, surveillance and sensor systems, communications systems, and command and control systems. Raytheon, the successor to HAC in ownership of the Site, sold the former property to SunCal Development. All structures at the Site, with the exception of those retained by Raytheon for current operations, were demolished between mid-2000 and late 2001.

Environmental investigations have been ongoing at the Site since 1995. Since that time, two primary California state agencies have provided oversight, the California Regional Water Quality Control Board, Santa Ana Region (RWQCB-SA) and DTSC. The City of Fullerton Fire Department also provided limited oversight during this time period.

Work completed under the oversight of DTSC started in 1995, with the preparation of the Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA). The RFA was submitted to DTSC and included an overview of 24 Solid Waste Management Units (SWMUs) and 4 Areas of Concern (AOC). In 1995, the RCRA Facility Investigation (RFI) Work Plan provided recommendations for assessment of 19 of the 24 SWMUs and the 4 AOC. The RFI included assessment of soil, perched groundwater, and the regional aquifer system conducted between 1996 and 2005. There were several Human Health Risk Assessments (HHRAs) prepared between 1997 and 2002 which were reviewed and approved by DTSC. As of the beginning of 2003, which was when the CACA was finalized, the focus of additional assessment and remediation was the regional aquifer system as the HHRAs indicated that soil conditions were protective of human health. CMS activities started in 2003 and have included additional groundwater assessment, bench and pilot testing, groundwater monitoring, and groundwater modeling. In 2014, a revised and updated CMS Work Plan was submitted to DTSC and was subsequently approved in January 2015.

ES-1.2 PREVIOUS INVESTIGATIONS

In 1996, the initial phase of the RFI focused on completion of soil assessment pursuant to the RFI Work Plan. In 1996 and 1997, additional RFI work focused on deeper soil assessment, perched zone water assessment, and assessment of the uppermost portion of the regional aquifer system. In 1997 and 1998, the initial draft RFI Report and HHRA were submitted to DTSC. The 1998 HHRA concluded that soil conditions were protective of human health and cleanup of soil was not required. DTSC approved the HHRA in 1998, but required additional groundwater assessment. In 1999 and 2000, there was additional groundwater assessment and assessment of 1,4-dioxane in soil and groundwater. In 2001 and 2002, additional groundwater assessment was conducted, several iterations of a perched zone vapor intrusion HHRA were prepared, and DTSC approved the perched zone risk assessment which allowed property development to proceed in 2002. Between 2003 and 2005, additional groundwater assessment was conducted in accordance with the CACA. In April 2005, DTSC provided approval on RFI completion. Additional groundwater assessment continued through 2014 as part of the CMS activities.

The specific areas subject to the CACA have been identified based on the extensive RFI, subsequent groundwater assessment activities, and also takes into consideration voluntary remediation conducted by Raytheon.

ES-1.3 PREVIOUS REMEDIATION

Voluntary soil vapor extraction and dual phase extraction remediation programs were initiated in 1997 and 1998, respectively, and completed by mid-2000. This voluntary remediation reduced the mass and concentration of VOCs in soil and a perched zone overlying regional groundwater in the vicinity and to the south of former Building 609. This remediation significantly reduced, but did not eliminate, VOCs and 1,4-dioxane which were dissolved in perched zone water that flows at low rates into the regional aquifer system.

CMS bench and pilot testing activities were initiated in 2004. A pilot groundwater extraction and treatment system started operation in 2008 and has been modified and upgraded several times. The pilot groundwater extraction and treatment system has reduced the mass of VOCs and 1,4-dioxane in the regional aquifer and has substantially reduced mass flux along the western portion of the Site. As of the end of February 2015, approximately 95,600,000 gallons of groundwater has been extracted and approximately 130 pounds of VOCs and 26 pounds of 1,4-dioxane have been treated. The pilot system will continue operations concurrent with CMS Report review and Corrective Measures Implementation (CMI) design.

ES-1.4 SUBSURFACE CONDITIONS AND GROUNDWATER USE

Two localized perched zones overlying the regional aquifer system were identified at depths ranging from approximately 80 to 120 feet below land surface under portions of the Site during the course of the RFI. The perched zones do not represent a usable source of groundwater due to the limited area over which they occur and the small quantities of water flowing through these zones.

The regional aquifer system in the southern portion of the Site is heterogeneous and is interpreted to include a structural fold based on regional subsurface studies and on an evaluation of Site lithology, geophysical, water level, and water quality trends. The Site hydrostratigraphic units within the regional aquifer system have been named using arbitrary naming conventions. The relatively thick coarse zones that appeared to be relatively continuous across the southern portion of the Site were named Unit A, Unit B, and Unit C (Figure ES-3). The regional groundwater system is used for municipal supply purposes with the closest downgradient production well located approximately 4,000 feet to the west southwest of the southwestern boundary of the Site (Figure ES-4).

The primary transport zone for compounds of concern (COCs) within the regional groundwater system is within Unit B. In general, the COCs enter Unit B where it is relatively shallow, about 120 to 140 feet below land surface (bls), and are transported westward near the Site, shifting to a southwest flow direction with increasing distance downgradient from the Site (Figure ES-5). In addition to understanding the direction of groundwater flow within Unit B, it is important to understand the geometry of Unit B. Unit B dips to the south, such that COCs starting out at about 120 to 140 feet bls can be transported to depths of approximately 1,000 feet bls at the southwestern boundary of the Site along Malvern Avenue (Figure ES-3). Unit B flattens out to the south of Malvern Avenue and is roughly 1,100 feet bls to the south of the Site.

The nearest potential receptor is the City of Fullerton production well No. 9 (Well 9) (also sometimes referred to as F-AIRP) located at the Fullerton Municipal Airport approximately 4,000 feet downgradient of the Site boundary (Figure ES-5). Unit B is within the deepest screen interval of this well. 1,1-Dichloroethylene (1,1-DCE) has been detected in the deepest screened zone in Well 9; however, the concentration of 1,1-DCE detected in water extracted from this production well is and has historically been below the drinking water maximum contamination level (MCL), and meets standards of protection of human health established by the Federal and State agencies for drinking water.

ES-1.5 REMEDIAL ACTION OBJECTIVES AND CORRECTIVE MEASURES ALTERNATIVES

General remedial action objectives (RAOs) for groundwater at the Site are to protect human health and the environment. The following are the specific RAOs for groundwater as outlined in the DTSC approved CMS Work Plan Update:

- Prevent unacceptable exposure to groundwater containing COCs;
- Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas; and
- Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at point(s) of compliance and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical.

Retained corrective measure technologies have been assembled into several corrective measures alternatives (Table ES-1). All of the alternatives, with the exception of the No Action Alternative, incorporate Institutional Controls. All of the alternatives have some degree of natural attenuation, including, but not limited to, the Monitored Natural Attenuation (MNA) Alternative. Some of the alternatives incorporate groundwater extraction and treatment with different methods of managing treated water end use. For these alternatives, there were varying combinations of three different extraction wellfield configurations that were evaluated: on-site extraction wells; off-site extraction wells aligned along Brea Creek Channel; and off-site extraction wells to the south of Brea Creek. There are multiple end uses of treated groundwater that are evaluated that include use of reinjection only or a combination of focused reinjection and non-potable reuse. The different groundwater extraction and end use configurations were evaluated to assess similarities and differences in performance of the different alternatives to facilitate selection of a preferred alternative as well as acceptable alternate configurations should access limitations prevent implementation of the preferred alternative.

ES-1.6 CORRECTIVE MEASURE ALTERNATIVE CONTINGENCIES

Contingencies for groundwater corrective measures alternatives may be implemented in order to address specific concerns or may be implemented to modify the scope of the respective program in response to changes in field conditions or observations during CMI, thus increasing the flexibility of the respective corrective measure alternative based on an ongoing evaluation of the results of the associated monitoring programs. Specific contingencies for groundwater corrective measures alternatives along with associated triggers have been developed as part of the CMS.

ES-1.7 PREFERRED CORRECTIVE MEASURE

The preferred corrective measure for the Site has been developed using the retained groundwater corrective measures alternatives and incorporates respective contingency actions to ensure that proposed groundwater RAOs are met.

The preferred groundwater corrective measure alternative is On-Site and Brea Creek Alignment Extraction with On- and Off-Site Unit B Injection (could include non-potable reuse) (Alternatives GW5A/5B) (Figures ES-6 to ES-9). It is understood that there is some uncertainty as to: 1) the ability to obtain access for extraction wells and/or associated pipeline along the Brea Creek Alignment; and/or 2) the ability to obtain access/install injection pipelines in the residential neighborhood to the west of the Site; as such the preferred alternative may be modified during the CMI design.

The Institutional Controls for the preferred groundwater corrective measure alternative consist of the following: submittal of system performance reports to nearby water users (Cities of Fullerton and Buena Park); annual review of water production and water quality data from Well 9 and Buena Park BP-SM1; annual review of well permits issued in areas from near the Site to within 0.5-mile of point of compliance wells to determine if new groundwater extraction wells have been installed in the area; annual review of water production from Orange County Water District for the wells identified on Figure ES-4 and any other new production wells that may installed in this vicinity.

Alternatives GW5A/B would extract groundwater using five existing wells, EW-01, EW-02, MW-21, MW-29, MW-31, and four proposed extraction wells EW-03, EW-04, EW-06, and EW-07, at a total design flowrate of 490 gallons per minute (Figure ES-6). The five existing wells and proposed extraction well EW-07 are located onSite. Proposed extraction wells EW-03, EW-04, and EW-06 are located offsite.

There are two potential locations for groundwater treatment systems. The groundwater corrective measure alternative allows for use of one or both of these treatment system locations. The treatment processes would include filtration of groundwater containing 1,4-dioxane and VOCs before treatment, followed by use of an Advanced Oxidation Process (AOP) to treat 1,4-dioxane and some of the VOCs; followed by liquid phase granular activated carbon to serve as a final polish for VOC treatment and for reduction of residual hydrogen peroxide from the AOP (Figure ES-7). The AOP that will be used in the treatment system employs ultraviolet light and hydrogen peroxide. This configuration is currently being used as part of the pilot groundwater extraction and treatment system.

The end use of treated groundwater for the preferred alternative includes reinjection of the entire volume of groundwater that is extracted and treated or a combination of reinjection and non-potable reuse. The location and target zone for injection wells is relatively flexible; however, the preferred alternative incorporates reinjection into Unit B in the residential neighborhood to the west of the Site. As such, if non-potable reuse of treated groundwater is incorporated into the remedy, reinjection of a portion of the treated groundwater into Unit B is maintained in this area (Figure ES-8 and ES-9).

If non-potable reuse is incorporated into the remedy, the extracted groundwater would be treated to standards required as part of the Waste Discharge Requirements (WDR) permit for groundwater reinjection issued by the RWQCB-SA. This treated water would be provided to the purveyor of non-potable water who is responsible for the construction, permitting, and operation of the non-potable distribution system. In addition, any tertiary treatment exceeding WDR standards that may be required for non-potable reuse will be the responsibility of the water purveyor. The determination of whether non-potable water reuse will be incorporated into the remedy will be made by Raytheon and the purveyor of non-potable water during CMI design. This determination could also be made at some time in the future after CMI design is complete as long as the initial CMI design incorporated an injection wellfield with sufficient capacity to accept the entire volume of groundwater extracted and treated.

ES-1.8 OPTIONAL RECONFIGURATION OF WELL 9

A packer testing program is currently being conducted at Well 9. This program is being conducted and funded by Raytheon and coordinated with the City of Fullerton and is expected to be complete in late 2015/early 2016 during off peak water demand. Well 9 is a municipal water supply well located on the north boundary of the Fullerton Airport (Figure ES-2). Well 9 is approximately 1,060 feet deep and was constructed with 7 separate screen intervals. The concentration of 1,1-DCE detected in water extracted from Well 9 is and has historically been below the drinking water MCL, and as such meets standards of protection of human health established by the Federal and State agencies for drinking water. The City of Fullerton is considering sealing off the lower screen interval if it can be demonstrated that doing so will reduce the concentration of 1,1-DCE in the water produced from the well without unduly impacting the well's ability to maintain its current pumping rate or causing other unintended / unacceptable degradation in the quality of the water produced.

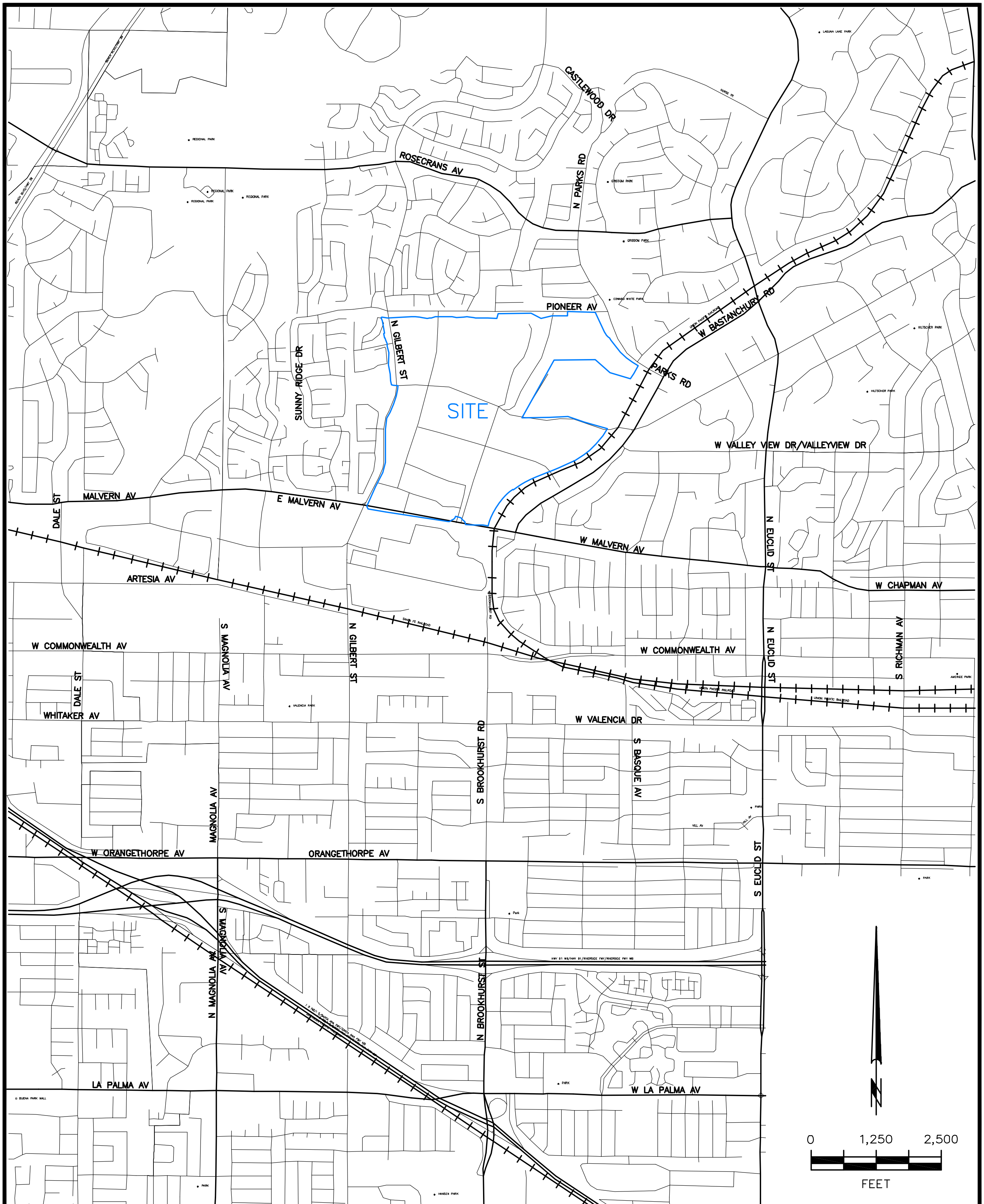
Sealing off the lower most screen interval would reduce the quantity of groundwater extracted from Unit B and minimize hydraulic influences that operation of Well 9 has on the selected groundwater corrective measures alternative. Several groundwater model simulations were performed to assess the approximate extent of the capture zone of the on- and off-site groundwater extraction systems with and without the lower screen of Well 9 isolated. The results of the modeling indicate that the capture zone would be larger if the lower screen of Well 9 could be isolated (Figure ES-10). The increased capture zone with Well 9 lower screen isolated would improve the hydraulic capture of the preferred corrective measure alternative; however, the vast majority of the mass is contained by the preferred corrective measure alternative with Well 9 operating in its current configuration (Figure ES-10). This indicates that reconfiguration of Well 9 is an optional task and as such would not be a requirement incorporated into the preferred corrective measure alternative and would be subject to separate agreements between Raytheon and the City of Fullerton.

TABLE ES-1
CORRECTIVE MEASURES EVALUATION SUMMARY

ALTERNATIVE	ALTERNATIVE DESCRIPTION	OVERALL PROTECTION OF HUMAN HEALTH AND ENVIRONMENT	ABILITY TO ATTAIN REMEDIAL ACTION OBJECTIVES			SHORT TERM EFFECTIVENESS[2]	LONG TERM EFFECTIVENESS	REDUCTION OF TOXICITY, MOBILITY AND VOLUME	IMPLEMENTABILITY	NET PRESENT VALUE (@1.4%)	GREEN AND SUSTAINABLE
			PREVENT EXPOSURE TO GROUNDWATER WITH COCS[1]	CONTAINMENT OF FORMER SOURCE AREA	CONTAIN COCS IN GROUNDWATER AND MEET MCLs						
GW1	No Action	Low	Low	Low	Low	High	Low	Low	High	There is no cost associated with this alternative	Not Applicable
GW2	Monitored Natural Attenuation (MNA)	Low	Low	Low	Low	High	Low	Low	High	$ 9,500,000 (30 yr)	Low
GW3	On-Site Extraction with Injection, Off-Site MNA	Moderate	Moderate	High	Moderate	High	Moderate	Moderate	High	$ 13,400,000 (20 yr)	High
GW4	On-Site and Brea Creek Alignment Extraction with On-Site and Shallow Off-Site Injection	High	High	High	High	High	Moderate	High	Moderate	$ 17,800,000 (20 yr)	High
GW5A	On-Site and Brea Creek Alignment Extraction with On-and Off-Site Unit B Injection	High	High	High	High	High	High	High	Moderate	$ 20,600,000 (20 yr)	High
GW5B	On-Site and Brea Creek Alignment Extraction with Off-Site Unit B Injection and Non-Potable Reuse	High	High	High	High	High	High	High	Moderate	$ 20,600,000 (20 yr)	High
GW6A	On-Site and South of Brea Creek Extraction with On- and Off-Site Distributed Injection	High	High	High	High	High	High	High	Moderate	$ 23,800,000 (20 yr)	Moderate
GW6B	On-Site and South of Brea Creek Extraction with Off-Site Unit B Injection and Non-Potable Reuse	High	High	High	High	High	High	High	Moderate	$ 23,800,000 (20 yr)	Moderate

[1] Exposure to groundwater with COCs likely met for all alternatives due to existing non-site specific institutional controls; however, rating incorporates protection of production wells.
[2] Short-term effectiveness for all off-site groundwater extraction and treatment is rated high because short-term impacts during construction would be minimized by abatement plans.

COCs Compounds of Concern
MCLs Drinking water maximum contaminant levels.
yr Years



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Hydrogeology/Engineering

FIGURE ES-1. SITE LOCATION

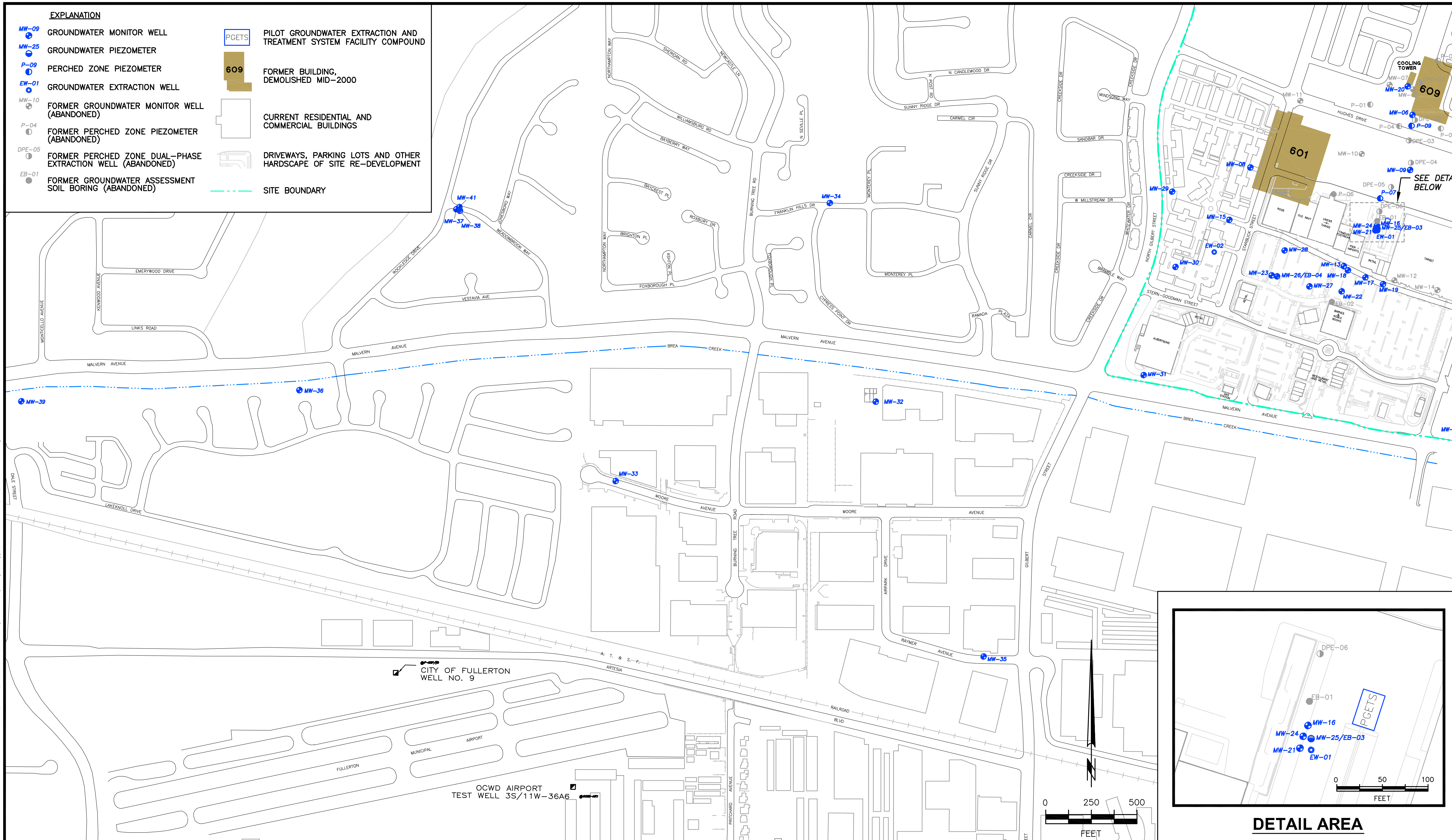

FIGURE ES-2.
WELL AND PIEZOMETER LOCATIONS

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05/15 | RPT NO. 532.52 | 410-9458 | A

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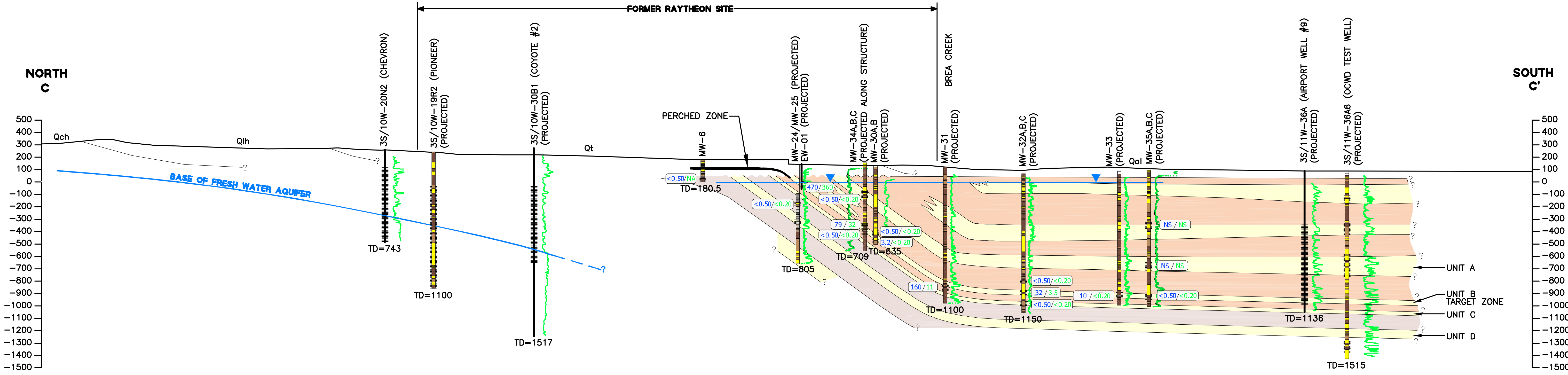


EXPLANATION

(yellow)	RELATIVELY COARSE ZONE, PREDOMINANTLY SANDS WITH LITTLE TO NO SILT OR CLAY
(light brown)	MIXED ZONE, MIXTURES OF SANDS, CLAYS, AND SILTS
(dark brown)	RELATIVELY FINE ZONE, PREDOMINANTLY SILTS OR CLAYS WITH LITTLE TO NO SAND
(pale yellow)	PREDOMINANTLY COARSE ZONE
(peach)	MIXED ZONE
(pink-gray)	RELATIVELY FINE ZONE
	SCREENED INTERVAL OF MONITOR WELL

LGRD
0 (OHM–M) 100 500

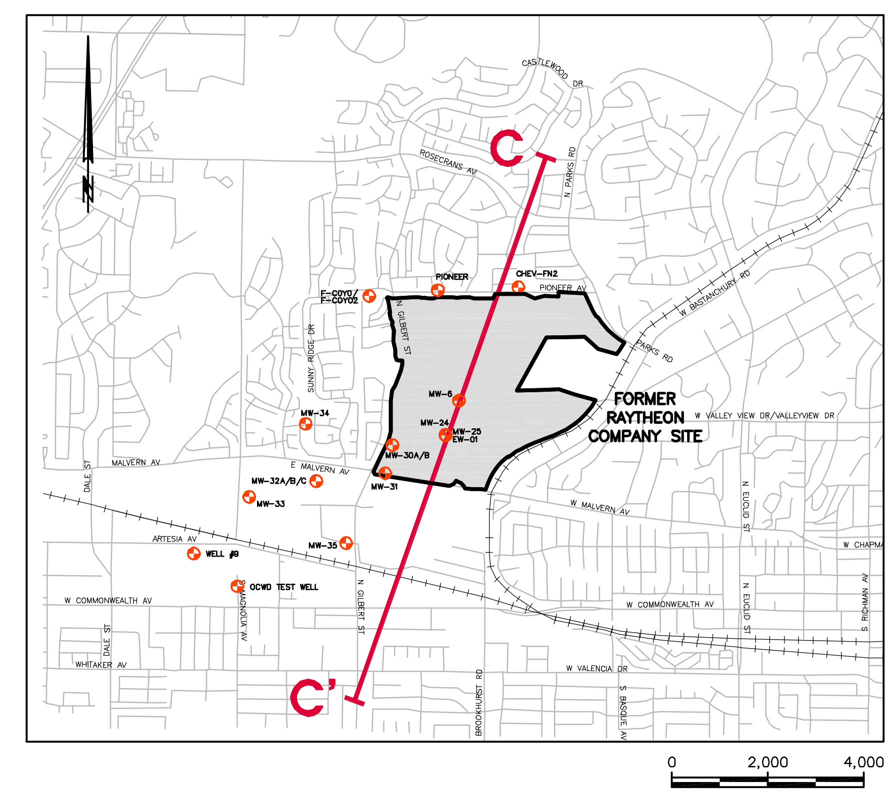
RESISTIVITY LOG (ohm–m) (LATERAL OR SHORT–NORMAL) OF WELL BOREHOLE. RIGHT EDGE OF THE LITHOLOGIC LOG COLUMN IS THE ZERO ohm–m LINE.

VERTICAL SCALE: 0, 800, 1,600 FEET

HORIZONTAL SCALE: 0, 400, 800 FEET

Qal	ALLUVIUM, HOLOCENE: UNCONSOLIDATED AND POORLY CONSOLIDATED GRAVEL, SAND AND SILT.
Qt/ Qoa	TERRACE DEPOSITS/OLDER ALLUVIUM, UPPER PLEISTOCENE TO HOLOCENE: POORLY CONSOLIDATED GRAVEL, SAND AND SILT, COMMONLY REDDISH–BROWN; LOCALLY RED–BROWN SILT.
Qlh	LA HABRA FORMATION, UPPER PLEISTOCENE: OLIVE–GRAY TO RED–BROWN SILTSTONE; PALE YELLOW–BROWN TO RED–BROWN THICK–BEDDED FRIABLE SANDSTONE; PALE–YELLOW–GRAY POORLY BEDDED PEBBLY SANDSTONE; AND PALE–YELLOW–BROWN UNSORTED PEBBLE–COBBLE CONGLOMERATE; BASAL PART FILLS IRREGULAR CHANNELS CUT INTO UNDERLYING STRATA.
Qch	COYOTE HILLS FORMATION, UPPER PLEISTOCENE: MODERATE YELLOW–BROWN TO MODERATE BROWN THICK–BEDDED TO MASSIVE FRIABLE PEBBLY SANDSTONE; OLIVE–GRAY TO GRAY–BROWN MASSIVE SILTSTONE; AND YELLOW–BROWN MASSIVE SANDSTONE AND PEBBLE CONGLOMERATE.
470	1,1–DICHLOROETHYLENE CONCENTRATION, MICROGRAMS PER LITER, FEBRUARY 2015 UNLESS OTHERWISE INDICATED
NA	NOT ANALYZED FOR (SPECIFIC ANALYTE) IN FEBRUARY 2015
NS	NOT SAMPLED IN FEBRUARY 2015
360	1,4–DIOXANE CONCENTRATION, MICROGRAMS PER LITER, FEBRUARY 2015 UNLESS OTHERWISE INDICATED
	NOTE: SURFACE DISTRIBUTION OF STRATIGRAPHIC UNITS AND DESCRIPTIONS OF STRATIGRAPHIC UNITS EXCERPTED FROM YERKES, 1972.
▼	APPROXIMATE UNIT B GROUNDWATER LEVEL, FEBRUARY 2015
?	QUERIED WHERE INFERRED
NOTE:	NOT ALL ON–SITE WELLS ARE DEPICTED ON CROSS SECTION

CROSS SECTION LOCATION



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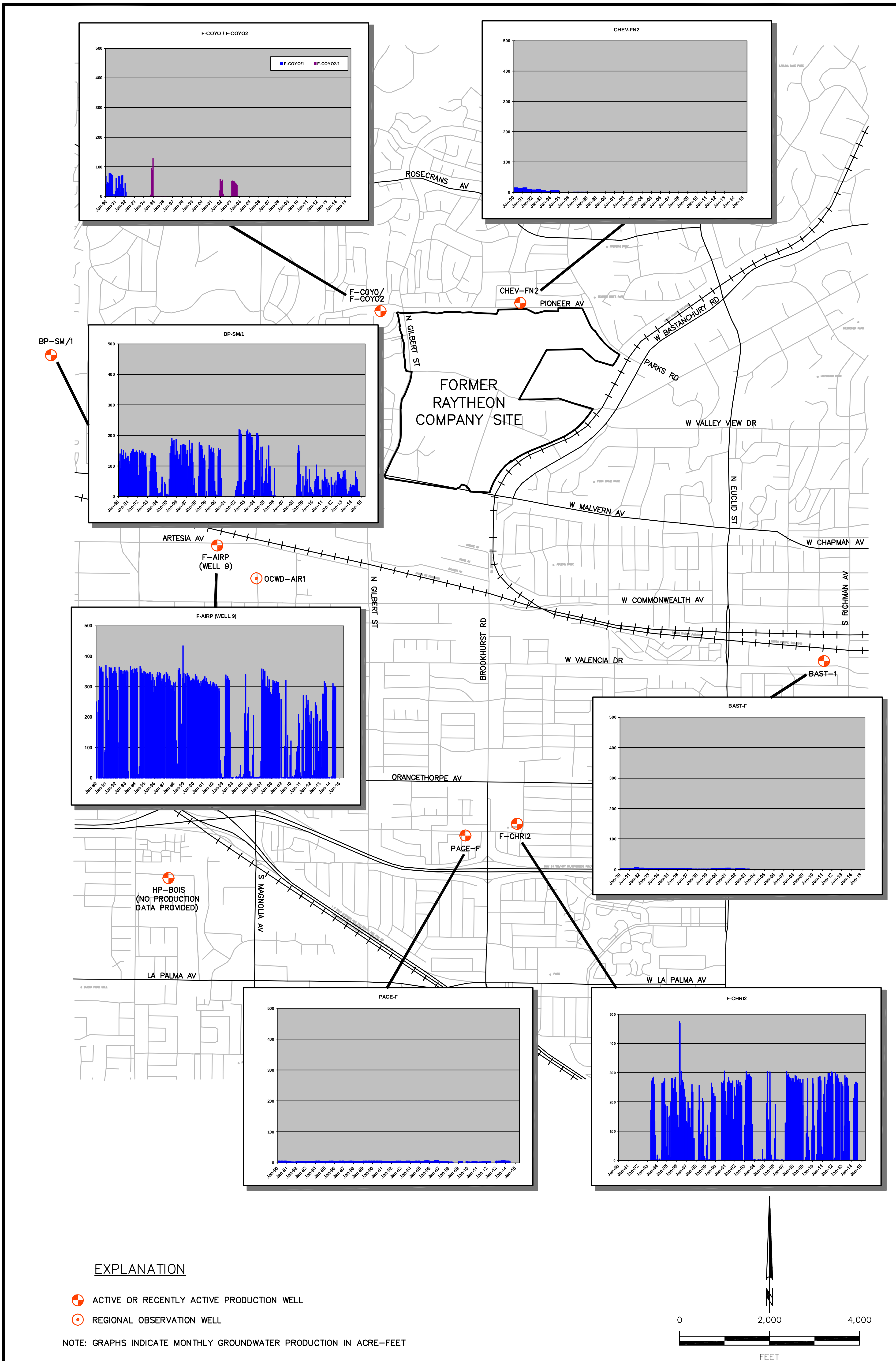
Hydrogeology/Engineering

05/15 | RPT NO. 532.52 | 310-1315 | A

FIGURE ES-3.
REGIONAL CONCEPTUAL GROUNDWATER MODEL HYDROGEOLOGIC CROSS-SECTION C-C'



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05/15	RPT NO. 532.52	410-9459	B

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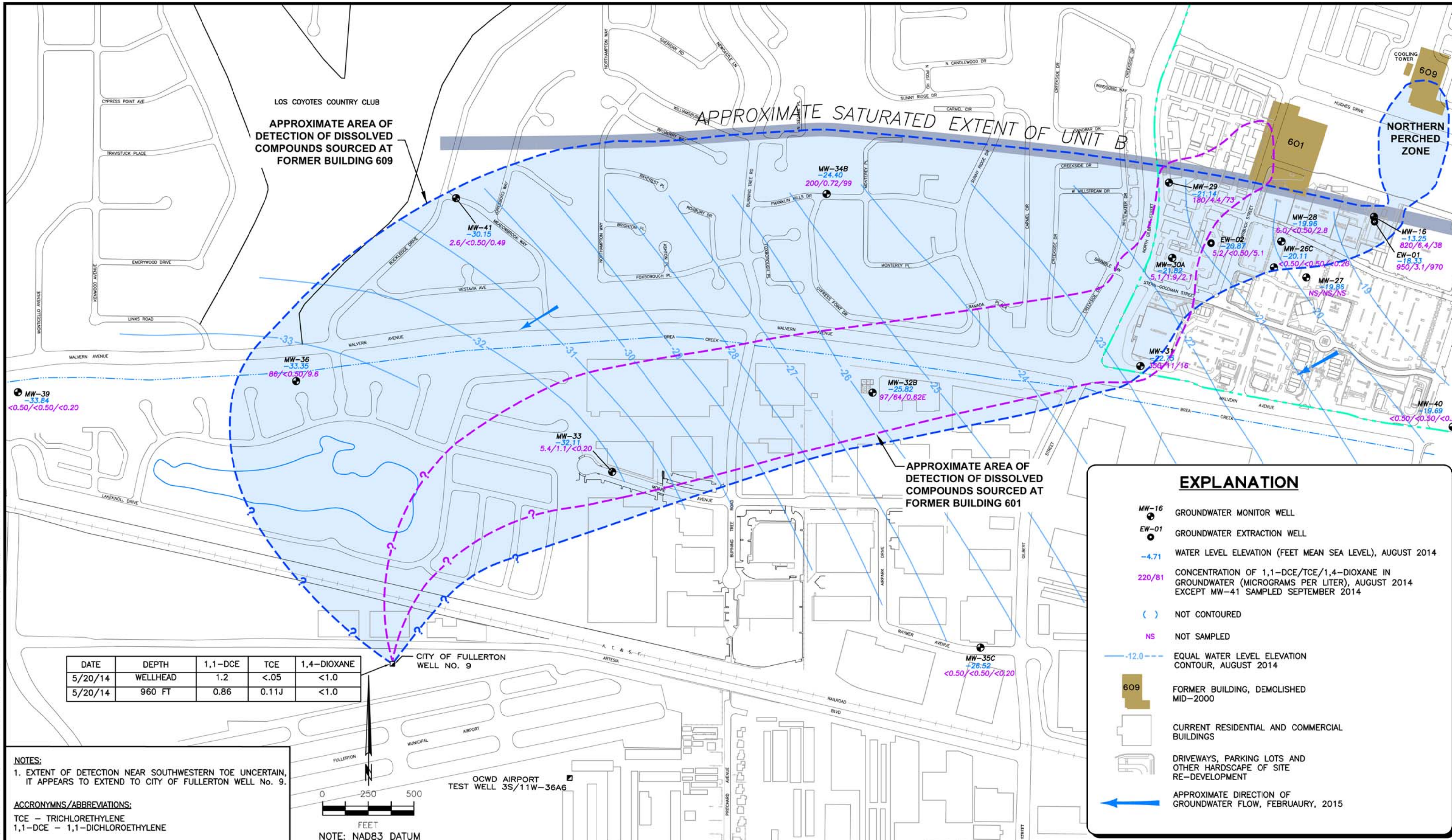
FIGURE ES-4.
REGIONAL PRODUCTION WELLS



DATE	DEPTH	1,1-DCE	TCE	1,4-DIOXANE
5/20/14	WELLHEAD	1.2	<.05	<1.0
5/20/14	960 FT	0.86	0.11J	<1.0

05/15 RPT NO. 532.52 220-2293 A

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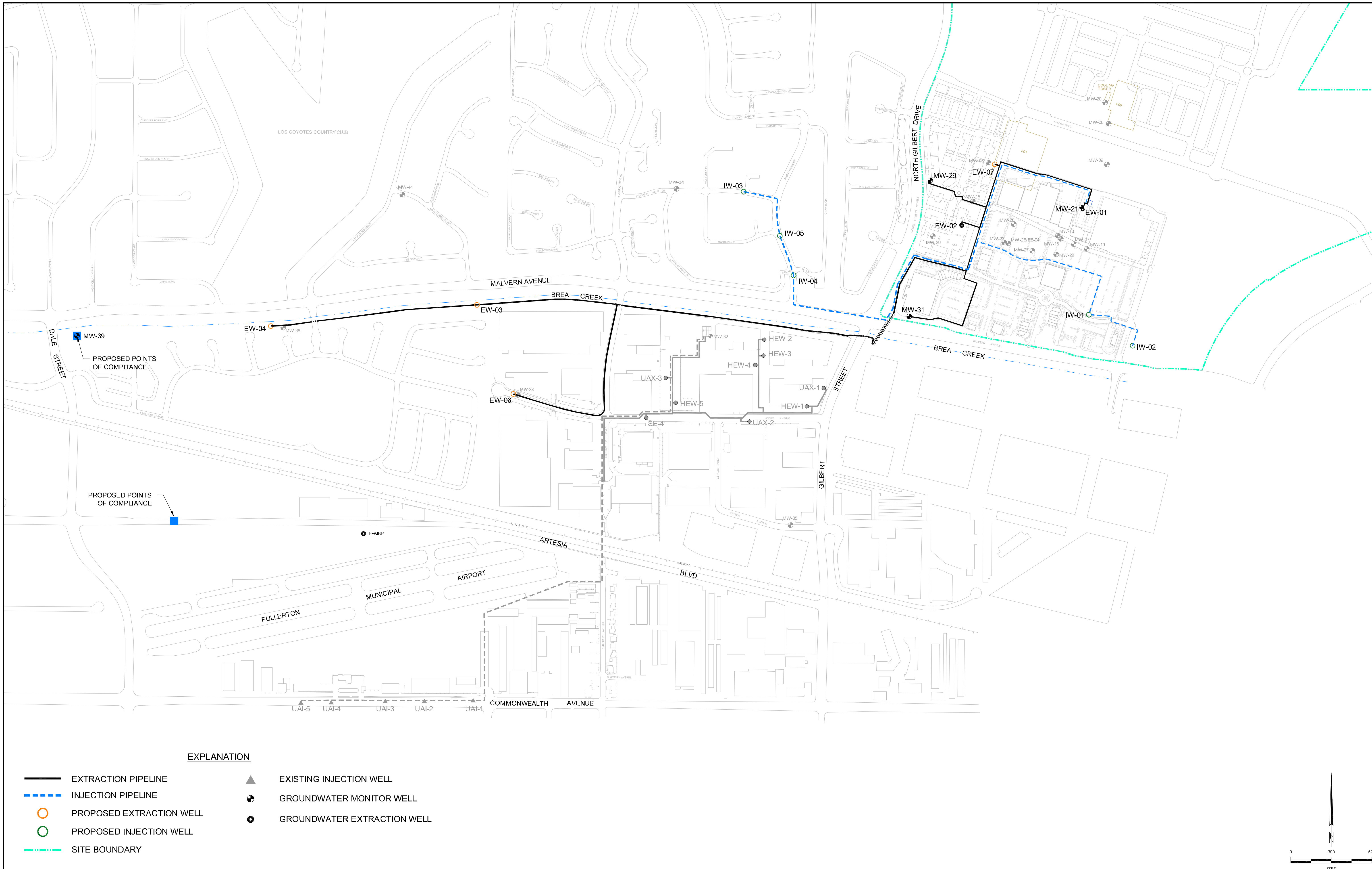
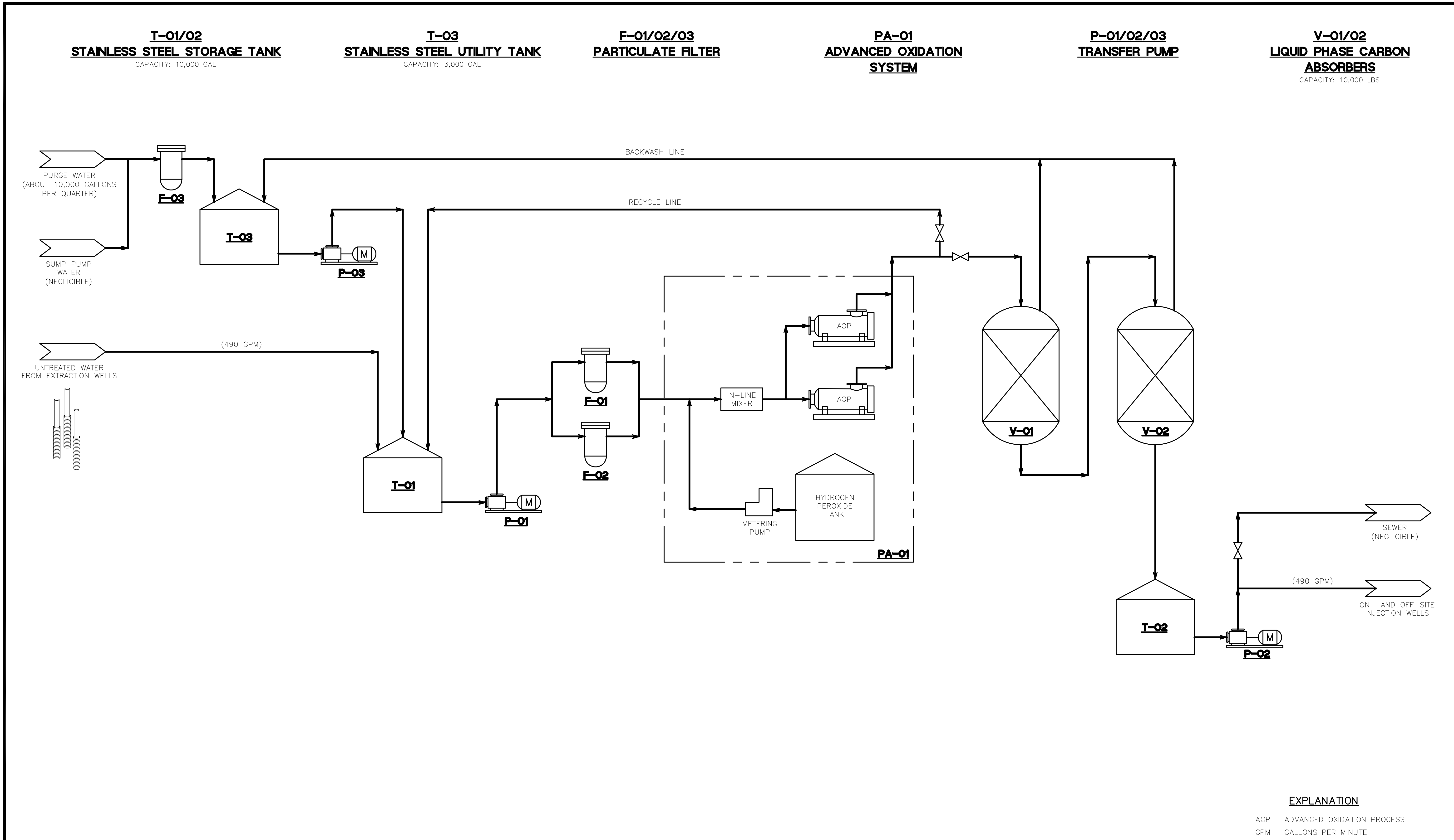
FIGURE ES-5.
CONCEPTUAL SITE MODEL OVERVIEW, UNIT B/TARGET ZONE



06/15 | RPT NO. 532.52 | 410–9462 | A

FIGURE ES–6. ALTERNATIVE GW5A: ON–SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON– AND OFF–SITE UNIT B INJECTION



May 15, 2015 – 1:14pm ADH – T:\2015\500-599\532 Raytheon\Engineering\P&IDs\560-0354.dwg

05/15	RPT NO. 532.15	560-0354	A

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FIGURE ES-7.
ALTERNATIVE GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND OFF-SITE UNIT B INJECTION
SIMPLIFIED PROCESS FLOW DIAGRAM

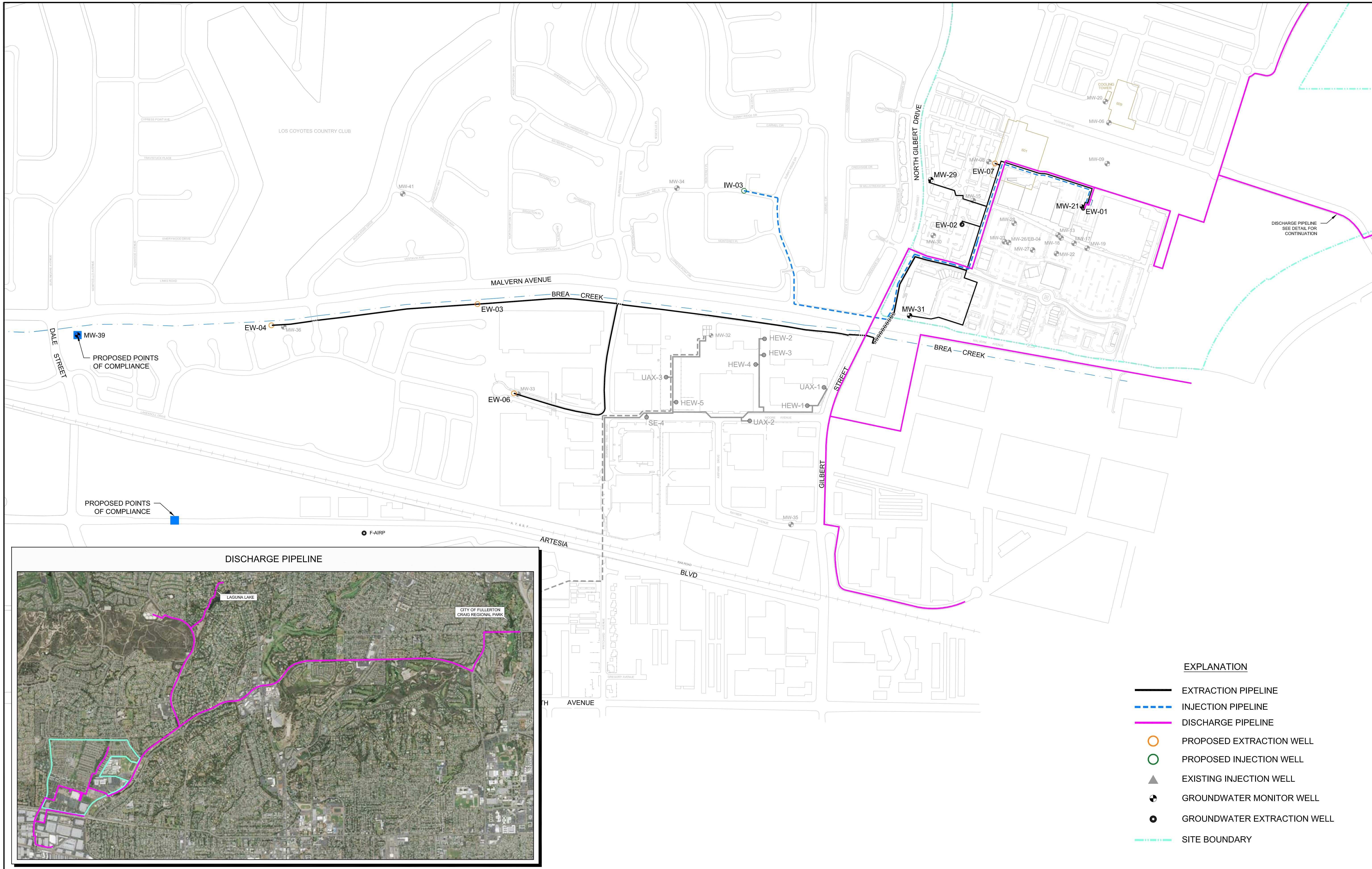
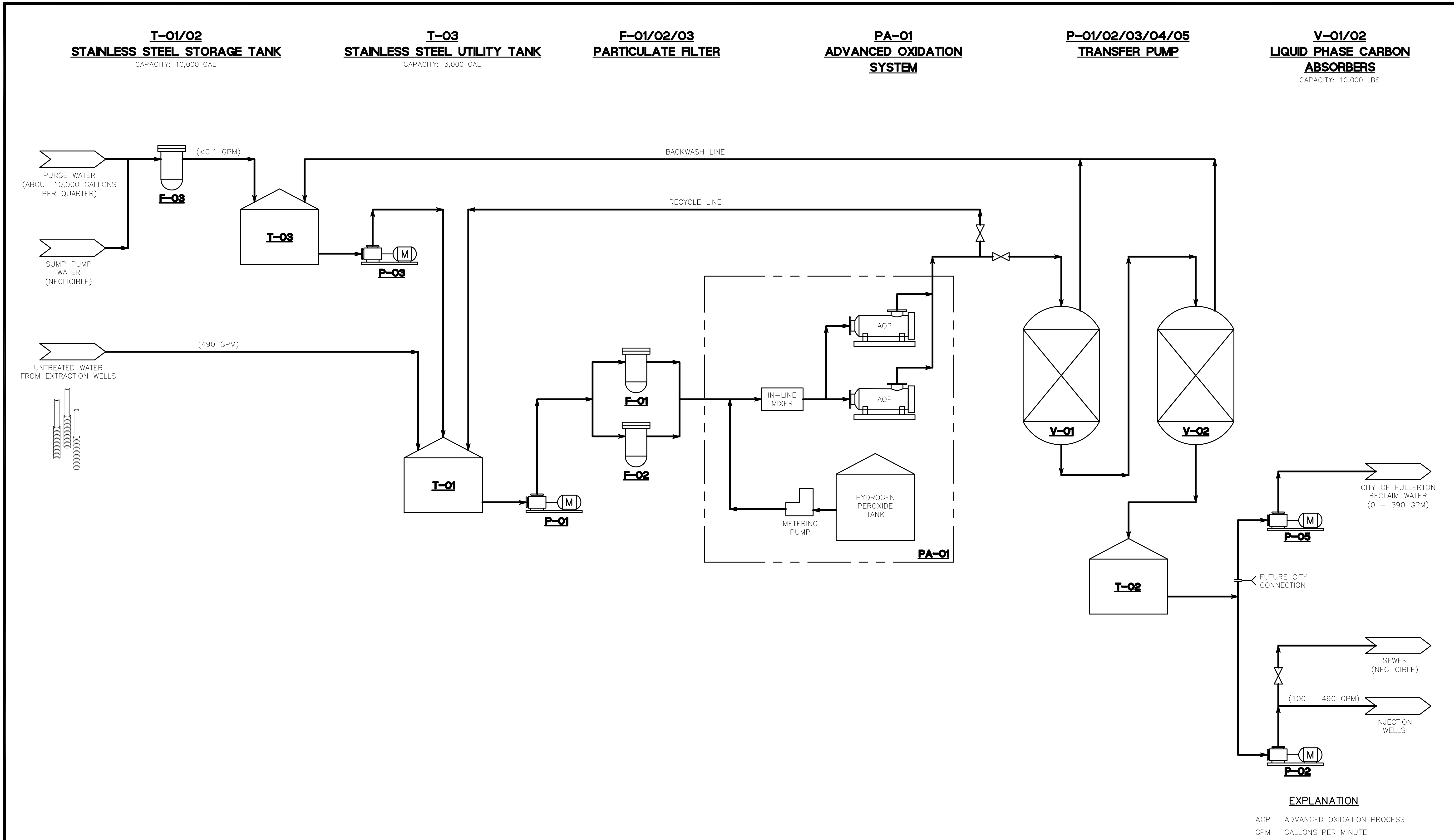


FIGURE ES-8. ALTERNATIVE GW5B: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH OFF-SITE UNIT B INJECTION AND NON-POTABLE REUSE

06/15 | RPT NO. 532.52 | 410-9463 | A



May 15, 2015 – 1:18pm ADH – T:\2015\500-599\532 Raytheon\Engineering\P&IDs\560-0354.dwg

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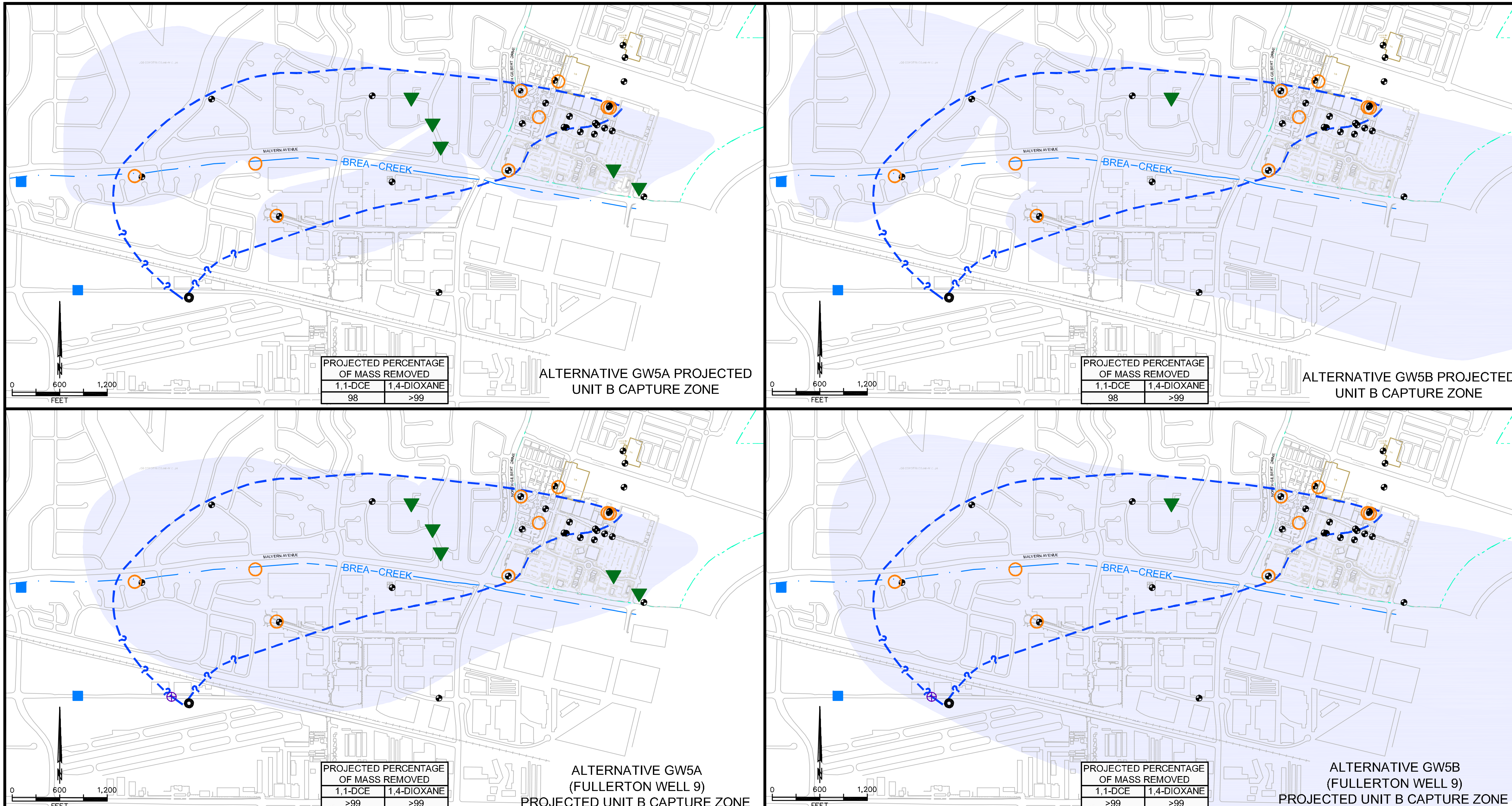
Hydrogeology/Engineering

05/15	RPT NO. 532.15	560-0354	A

FIGURE ES-9.
ALTERNATIVE GW5B: ON-SITE AND BREA CREEK EXTRACTION WITH OFF-SITE UNIT B INJECTION AND NON-POTABLE REUSE
SIMPLIFIED PROCESS FLOW DIAGRAM



ALTERNATIVE GW5A PROJECTED UNIT B CAPTURE ZONE

PROJECTED PERCENTAGE OF MASS REMOVED	
1,1-DCE	1,4-DIOXANE
98	>99

ALTERNATIVE GW5B PROJECTED UNIT B CAPTURE ZONE

PROJECTED PERCENTAGE OF MASS REMOVED	
1,1-DCE	1,4-DIOXANE
98	>99

ALTERNATIVE GW5A (FULLERTON WELL 9) PROJECTED UNIT B CAPTURE ZONE

PROJECTED PERCENTAGE OF MASS REMOVED	
1,1-DCE	1,4-DIOXANE
>99	>99

ALTERNATIVE GW5B (FULLERTON WELL 9) PROJECTED UNIT B CAPTURE ZONE

PROJECTED PERCENTAGE OF MASS REMOVED	
1,1-DCE	1,4-DIOXANE
>99	>99

EXPLANATION

1,1-DCE = 1,1-DICHLOROETHENE

- EXTRACTION WELL
- INJECTION WELL UNIT B
- INJECTION WELL SHALLOW ZONE
- INJECTION WELL UNIT A
- PROPOSED POINTS OF COMPLIANCE
- FULLERTON WELL 9
- ADDITIONAL PERFORMANCE MONITOR WELL
- EXISTING MONITOR WELL
- SITE BOUNDARY
- CAPTURE ZONE
- APPROXIMATE AREA OF DETECTED DISSOLVED COMPOUNDS IN UNIT B

Jun 05, 2015 - 10:38am ADH - T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9464.dwg

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

06/15 | RPT NO. 532.52 | 410-9464 | A

FIGURE ES-10.
PROJECTED CAPTURE ZONES FOR ON- AND OFF-SITE GROUNDWATER EXTRACTION ALTERNATIVES WITH AND WITHOUT WELL 9 LOWER SCREEN ISOLATION (GW5A AND GW5B)

CORRECTIVE MEAUSURES STUDY

RAYTHEON COMPANY
(FORMER HUGHES AIRCRAFT COMPANY)
1901 WEST MALVERN AVENUE
FULLERTON, CALIFORNIA

1.0 INTRODUCTION

This Corrective Measures Study (CMS) has been prepared by Hargis + Associates, Inc. (H+A) on behalf of Raytheon Company (Raytheon) (formerly Hughes Aircraft Company [HAC]) for the site located at 1901 West Malvern Avenue which is northeast of the intersection of Malvern Avenue and Gilbert Street in Fullerton, California (the Site) (Figures 1 and 2). This CMS report was prepared in accordance with the CMS Work Plan Update for the Site which was approved by the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) (DTSC, 2014; H+A, 2014a). Additionally, this CMS report was prepared in accordance with the Corrective Action Consent Agreement (CACA) with the DTSC (DTSC, 2003).

1.1 PURPOSE AND SCOPE

A CMS is being conducted to determine appropriate groundwater corrective actions associated with operations at two former areas of the Site (former Building 609 area and former Building 601 area) (Figure 2) in accordance with the CACA with the DTSC (DTSC, 2003). The purpose of the CMS is to identify and evaluate a corrective measure alternative(s) that will address volatile organic compounds (VOCs) and 1,4-dioxane detected in groundwater at and downgradient of the Site. For the purposes of this document the term “former property” refers to the approximate 293 acre portion of the former HAC Facility sold by Raytheon in 1998.

In accordance with the CMS Work Plan Update and the CACA CMS requirements, this CMS Report includes the following elements:

- Section 1 provides an introduction, the overall purpose and scope of the CMS Report, a background summary of the Site, and an overview of groundwater production wells in the vicinity of the Site;
- Section 2 describes tasks completed in support of the CMS;
- Section 3 presents remedial action objectives (RAOs) for groundwater;
- Section 4 provides identification and initial screening of corrective measures technologies;
- Section 5 presents and evaluates corrective measures alternatives;
- Section 6 provides contingency plans to modify corrective actions based on monitoring or remedy reviews conducted during Corrective Measures Implementation (CMI);
- Section 7 presents elements of the preferred corrective measure alternative;
- Section 8 lists references cited;
- Appendix A describes groundwater flow modeling conducted in support of the CMS; and
- Appendix B presents detailed cost estimates developed as part of the corrective measures alternatives evaluation.

1.2 SITE BACKGROUND

The following sections present a summary of the background history of the Site. A more comprehensive summary of the Site background is found in the 2003 CMS Work Plan and 2014 CMS Work Plan Update (H+A, 2003a and 2014a).

1.2.1 Location and History of Operations

The Site is located entirely within the City of Fullerton in Orange County, California. The Site and its vicinity were used primarily for light agricultural purposes prior to development in the late 1950's.

Following purchase of the Site by HAC in 1957, and prior to the closing of most of the facility in 2000, a total of approximately 100 buildings and/or temporary structures were constructed.

Manufacturing operations, which started at the Site in 1959, included machining/fabrication, assembly, plating, laboratory testing, warehouse facility operations, and maintenance, transportation, and offices. The HAC facility was involved in the manufacture of radar systems and associated components, undersea weapons systems, surface ship systems, anti-submarine warfare systems, surveillance and sensor systems, communications systems, and command and control systems.

Raytheon, as the successor to the defense business of HAC in ownership of the Site, sold the former property to SunCal Development. All structures at the Site, with the exception of those retained by Raytheon for current operations, were demolished between mid-2000 and late 2001. The development of the southern portion of the Site as a retail complex was complete by mid-2002. The central and northern portions of the Site were subsequently developed for residential purposes.

Off-site areas include adjacent residential properties located west, east, and north of the Site and a mixed commercial and industrial area to the south of Malvern Avenue. There is also a high school located adjacent to the eastern portion of the Site. Several Raytheon office buildings remain south of the high school.

1.2.2 Regulatory History

Environmental investigations have been ongoing at the Site since 1995. Since that time, two primary California state agencies have provided oversight, the California Regional Water Quality Control Board, Santa Ana Region (RWQCB-SA) and DTSC. The City of Fullerton Fire Department (CFFD) also provided limited oversight during this time period.

DTSC has provided oversight with respect to the Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) conducted in 1995, the RCRA Facility Investigation (RFI) conducted from 1996 to 2005, and CMS activities conducted from 2003 to present, which were implemented in accordance with the CACA executed between DTSC and Raytheon on January 15, 2003. The RWQCB-SA and CFFD provided oversight with respect to fuel underground storage tanks (USTs) and associated piping. A summary of the regulatory history of the Site follows, additional details regarding previous investigations prior to 2003 are presented in Appendix A of the 2003 CMS Work Plan (H+A, 2003a) and details of activities conducted in accordance with the CACA between 2003 and 2015 are presented in Section 2.

1.2.2.1 Resource Conservation and Recovery Act Facility Assessment and Investigation

In 1995, the RFA was conducted (Kroll Environmental Enterprises, Inc. [Kroll], 1995a) and was submitted to DTSC which included an overview of 24 Solid Waste Management Units (SWMUs) and 4 Areas of Concern (AOC). Recommendations for assessment were provided for 19 of the 24 SWMUs and the 4 AOCs. A RFI Work Plan was prepared for assessment at 19 SWMUs and 5 AOCs (Kroll, 1995b).

Between 1996 and 2005, the RFI and associated Human Health Risk Assessments (HHRAs) were conducted and documented in multiple reports which were submitted to DTSC. In 1996, Geraghty & Miller, Inc. (G&M) conducted the first phase of the RFI. This phase of the RFI focused on completion of soil assessment pursuant to the RFI Workplan (G&M, 1996). In 1996 and 1997, H+A prepared the Phase 2 RFI Workplan and associated addenda that focused on deeper soil assessment, perched zone water assessment, and assessment of the uppermost portion of the regional aquifer system. In 1997 and 1998, the RFI Report and HHRA and subsequent revisions were submitted to DTSC (H+A, 1998, Foster Wheeler Environmental Corporation, 1998) and DTSC approved the HHRA (DTSC, 1998), but required additional groundwater assessment. In 1999 and 2000, there was additional groundwater assessment; assessment of 1,4-dioxane detected in soil and groundwater; additional soil gas surveys; transmittal of two Fact Sheets; and a Public Participation meeting. In 2001 and 2002, additional groundwater assessment was conducted, several iterations of a perched zone vapor intrusion HHRA was prepared, and DTSC approved the perched zone risk assessment which allowed property development to proceed (Montgomery Watson Harza, 2002; DTSC, 2002b and 2002c). In 2003 to 2005, additional groundwater assessment was conducted in accordance with the CACA. In 2005, DTSC provided approval on RFI completion (DTSC, 2005).

1.2.2.2 Fuel-Related Investigations and Remediation

The status of former USTs and investigations conducted at the respective USTs during the RFI were summarized in the RFI Report (H+A, 1998). Assessment and remediation activities conducted at several areas between 1997 and 2002 are summarized as follows.

Between 1997 and 2002, there was assessment and several phases of remediation conducted under RWQCB-SA and/or DTSC oversight near former Building 602. A final remediation plan was reviewed and approved by DTSC in late 2001, and the current property owner initiated soil remediation and completed the remediation and submitted a closure report in early 2002 (Clayton Group Services, Inc., 2002; H+A, 2001a). The former fuel UST in this area is referred to as SWMU-25 by DTSC. DTSC issued a closure letter for SWMU-25 in June 2002 (DTSC, 2002a).

In 2001, diesel-impacted soil was identified during grading activities in several areas of the Site. Some of the areas were located near former USTs and several areas were near fuel pipelines between former USTs. Soil removal and confirmation sampling was conducted. RWQCB-SA provided no further action at the subject areas at the end of 2001 (H+A, 2001b; RWQCB-SA, 2001).

1.2.2.3 Voluntary Remediation

Voluntary soil vapor extraction (SVE) and dual phase extraction (DPE) remediation programs were initiated in 1997 and 1998, respectively. The scope of this program was presented in the draft RFI Report in 1997. A pilot SVE test was conducted in the former source area at SWMU-3 in mid-1997. The full scale SVE wellfield was constructed, and system operation was started in late 1998. The SVE system was operated until mid-1999, and system construction and operation were summarized in a report prepared later in 1999 (H+A, 1999). A DPE system was constructed along the higher VOC concentration portion of the perched zone and the system operation was started in late 1998. The DPE system was operated until mid-2000. Three reports were prepared detailing the construction, operation, and closure of the SVE/DPE systems and provided to Raytheon and copied to DTSC (H+A, 1999, 2000a, and 2000b).

The SVE and DPE systems significantly reduced the concentration and mass of VOCs, but these systems could not eliminate migration of VOCs and 1,4-dioxane dissolved in perched water.

1.2.3 Geology

The regional geology of the Site area and the local geology of the Site are summarized below based principally on information presented in the 2015 Conceptual Site Model (CSM) Document (H+A, 2015).

1.2.3.1 Regional Geology

The Site is located within the regional Orange County groundwater basin (OCGB), a portion of the Los Angeles basin. The Los Angeles basin is a deep structural depression filled with Tertiary and Quaternary sediments derived from surrounding highlands, and underlain by a basement complex comprised of igneous and metamorphic rock (Yerkes, 1972).

1.2.3.2 Local Geology

The Site is located along the southern flank of the West Coyote Hills, an anticlinal uplift within the Los Angeles basin. The axis of the Coyote Hills anticline generally coincides with the crest of the hills, approximately 1-½ miles north of the Site, and trends approximately east-west. The Coyote Hills have been mapped as being bounded to the south by the east-west trending Norwalk fault, inferred by geomorphology, geophysical data, and subsurface lithology interpreted from oil well logs (Yerkes, 1972). However, more recent subsurface work suggests that what had been called the Norwalk fault does not propagate to the surface in the Site vicinity (Pratt et al., 2002).

Stratigraphic units mapped in the vicinity of the Site include the Lower Pleistocene San Pedro formation, and the Upper Pleistocene Coyote Hills and La Habra formations and Older Alluvium

(Yerkes, 1972). The La Habra formation and Older Alluvium have also been mapped in nearby areas as the Lakewood formation of Late Pleistocene age (California Department of Water Resources [DWR], 1961). Strata comprising the Coyote Hills formation have been previously included within the San Pedro formation or within the La Habra formation (DWR, 1961; Dibblee, 2001).

The primary geologic structural feature at and in the vicinity of the Site is the monoclinal fold exhibited by a local southward dip of approximately 42 degrees in the hydrogeologic units underlying the terrace deposits between exploratory boring EB-1 (near monitor well MW-16) and monitor well MW-31 (H+A, 2010c) (Figure 3). These dipping units become nearly horizontal in the OCGB south of Malvern Avenue.

1.2.4 Hydrogeology

This section presents a brief summary of regional and local hydrogeologic conditions.

1.2.4.1 Regional Hydrogeology

The Site is located within the OCGB. Aquifers in the OCGB have been divided into three separate systems called the upper, middle, and lower regional groundwater systems (DWR, 1967).

The Upper Aquifer System (UAS) is located within the OCGB to the south of Malvern Avenue. The UAS in this area includes stream terrace and older alluvial deposits as well as the La Habra/Lakewood formation (Figure 4). It is believed that coarse-grained facies in the La Habra/Lakewood formation, corresponding to the upper aquifer, pinch out south of the Coyote Hills or are folded and unconformably truncated near the southern boundary of the Site (H+A, 2005c).

The Middle Aquifer System (MAS) underlies the UAS to the south of Malvern Avenue and extends to approximately -1,500 feet mean sea level (msl) in this area. The MAS is believed to include the Coyote Hills formation and the San Pedro formation (Figure 4) and may include portions of the La Habra formation incised as channels into the underlying Coyote Hills formation.

The Lower Aquifer System (LAS) underlies the MAS and extends to the base of the freshwater zone. The LAS is believed to include portions of the Fernando group of Pliocene age. The base of the freshwater zone in the vicinity of the Site is estimated to be approximately -300 feet msl just north of the Site and -3,000 feet msl south of the Site in the OCGB (DWR, 1967).

Groundwater production in the OCGB is primarily from the lower portion of the UAS and the upper portion of the MAS between approximately -250 feet msl and -1,000 feet msl (DWR, 1967).

1.2.4.2 Local Hydrogeology

Site hydrostratigraphic units consist of strata having similar hydraulic properties and lithologic characteristics, which have been correlated across and downgradient of the Site. The soils encountered at the Site are generally interbedded sand, silty to clayey sand, sandy silt, and sandy clay, with local gravel layers (H+A, 1998). Correlation of strata with thicknesses on the order of several feet or less is typically not possible between boreholes. However, some larger scale stratigraphic zones are regionally extensive and can be correlated across the Site and vicinity as described below.

Definition of hydrostratigraphic units in the Site vicinity was refined after completion of additional groundwater assessment activities in 2004, and confirmed and further refined during the 2008 through 2014 well construction activities.

Two localized perched zones were identified under portions of the Site during the course of the RFI (H+A, 1998). Perched zones were identified based on the occurrence and behavior of groundwater, and are not clearly expressed lithologically. The perched zones do not represent a usable source of groundwater due to the limited area over which they occur and the small quantities of water flowing through these zones.

The water table in the regional groundwater system beneath the Site occurs in unconsolidated sediments ranging from sand to silt and clay (H+A, 1998). The hydrogeology in the southern portion of the Site is heterogeneous and is interpreted to include a structural fold based on regional subsurface studies and on an evaluation of Site lithology, geophysical, water level, and water quality trends (H+A, 2010b) (Figure 3). The primary geologic structural feature at and in the vicinity of the Site is the monoclinal fold exhibited by a local southward dip of approximately 42 degrees in the hydrogeologic units underlying the terrace deposits between exploratory boring EB-1 (near monitor well MW-16) and monitor well MW-31 (H+A, 2010b) (Figure 3). These dipping units become nearly horizontal in the OCGB south of the Site.

The Site hydrostratigraphic units have been named using arbitrary naming conventions. The relatively thick coarse zones that appeared to be relatively continuous across the southern portion of the Site were named Unit A, Unit B, and Unit C (Figures 3 and 4).

The primary transport zone for compounds of concern (COCs) has been referred to as the Target Zone or Unit B. The geometry, and thus the hydraulic characteristics of Unit B, are influenced by the south-dipping monoclinal fold beneath the southern portion of the Site (Figure 3). North of the vicinity of extraction well EW-01, where the perched zone merges with the regional groundwater system, Unit B extends above the water table and becomes unsaturated. Due to the locally steeper dip of strata within the monoclinal fold, regional water level fluctuations cause the water table within Unit B to shift to the north or south with rising and falling water levels, respectively. The northern extent of the saturated Unit B is thus relatively well constrained, although seasonally variable due to changes in water levels along this saturated/unsaturated zone transition (Figure 5). To the south, the elevation of south-dipping strata decreases and, therefore, the depth to Unit B increases. The southern limb of the monoclinal fold occurs south of the Site, where the dip of Unit B becomes very shallow (Figure 3). The elevation of the base of Unit B (Target Zone) in the basin is approximately -1,000 feet msl. Based on evaluation of monitor wells and other test wells at and in the vicinity of the Site, the elevation of the base of Unit B has been contoured (Figure 6).

The direction of groundwater flow in Unit B has been evaluated at and downgradient of the Site (H+A, 2015). Water level data from monitor wells located at and downgradient of the Site indicate the average groundwater flow direction from April 2012 through March 2014 is westward near the Site, shifting to a southwest flow direction with increasing distance downgradient from the Site.

1.2.5 Summary of Impacts and Subject Areas of Corrective Action

The specific areas subject to the CACA have been identified based on the extensive RFI, subsequent groundwater assessment activities, and also takes into consideration voluntary remediation conducted by Raytheon.

As outlined in the initial 2003 CMS Work Plan and the updated CMS Work Plan, there are two specific areas that are being addressed in this CMS:

1. Groundwater within a portion of the regional aquifer system where concentrations of 1,1-dichloroethylene (1,1 DCE) and 1,4-dioxane have been detected, and which, for the purposes of this document, will be collectively referred to as the former Building 609 area.

2. Groundwater within a portion of the regional aquifer system where concentrations of trichloroethylene (TCE) and 1,1-DCE have been detected, and which, for the purposes of this document, will be referred to as the former Building 601 area.

1.2.5.1 Building 609 Overview

The Building 609 area included three subsurface features where VOCs and 1,4-dioxane were detected: 1) soil from land surface to approximately 80 feet below former grade (the former source area); 2) a perched zone extending from under the former source area approximately 600 to 800 feet to the south; and 3) regional groundwater from the toe of the perched zone extending to the west of the former property boundary. The former source area, including soil in the vicinity of SWMU 3, and the perched zone were the subject of voluntary remediation conducted by Raytheon.

As outlined in the initial and Updated CMS Work Plans, the former source area remediation was completed prior to 2001 and will not be part of this CMS based on the HHRAs, soil assessment, and data collected during operation of the voluntary source remediation program.

As outlined in the initial and Updated CMS Work Plans, prior remediation and results of HHRAs indicate that the potential exposure pathway associated with the perched zone is related to continued migration of post-remediation residual VOCs and 1,4-dioxane near the toe of the perched zone to the regional groundwater. This potential pathway will be addressed as part of the regional groundwater corrective action and further perched zone remediation is not part of this CMS.

VOCs and 1,4-dioxane have been detected in groundwater samples collected from monitor wells near the toe of the perched zone and in the regional groundwater system to west/southwest of monitor well MW-36, which is located approximately 4,500 feet west of the former property boundary along Malvern Avenue (Figure 5). The results of recently completed groundwater assessment are documented in a well construction report (H+A, 2013d). This potential pathway is being addressed in the CMS remedy selection to protect the regional aquifer system and current or future potential production wells (potential receptors).

1.2.5.2 Building 601 Overview

The Building 601 area included two subsurface areas where VOCs were detected: 1) soil from land surface to approximately 120 feet below former grade (the former source area); and 2) regional groundwater from the former source area extending to the west of the former property boundary. Perched groundwater was not encountered in this area of the Site.

As outlined in the initial and Updated CMS Work Plans, the former source area will not be part of the CMS based on the HHRAs, soil assessment, and prior assessments.

As outlined in the initial and Updated CMS Work Plans, TCE and/or 1,1-DCE have been detected in groundwater samples collected from monitor wells MW-08 (adjacent to the former source area) and MW-15 (downgradient of the former source area). Subsequent samples collected from monitor well MW-08 also contained 1,4-dioxane; however, these detections were associated with a historical high water level and appear to be associated with the former Building 609 area. Subsequent assessment also indicated detection of relatively low concentrations of TCE in monitor wells near the southwest corner of the former property and in monitor wells to the west of the former property. In general, the TCE from the former Building 601 area appears to be commingled with the former Building 609 area 1,1-DCE and 1,4-dioxane to the west of the former property. As such, VOCs from the former Building 601 area will be considered in the CMS concurrent with the former Building 609 area to protect the regional aquifer system at current or future hypothetical receptors.

1.3 PRODUCTION WELLS

The closest currently active production well is operated by the City of Fullerton and for the purposes of this report has been designated Well 9 (also known as F-AIRP), which is located on the north side of Fullerton Municipal Airport (Figures 2 and 7). The deepest screen interval within Well 9 extends from approximately 980 to 1,060 feet below land surface (bls). It appears that Unit B is within this screened interval. This well operates on an as-needed basis and influences water levels in on- and off-Site monitor wells. The City of Buena Park operates a production well further to the west, designated BP-SM-1. Unit B may be unsaturated or erosionally truncated at this well, or, if present, would be closer to the water table given the location of this well with respect to the monoclinal fold. The two production wells located north of the Site are in an area where Unit B does not exist. The remaining three production wells are not located downgradient of the Site.

2.0 CORRECTIVE MEASURES STUDY

The following tasks have been conducted in accordance with CMS and Groundwater Assessment work plans and associated addenda since the initial 2003 CMS Work Plan was prepared:

- Groundwater monitoring and assessment from 2003 to present;
- Bench and pilot testing of groundwater treatment technologies from 2004 to present;
- Conceptual Model Update; and
- Groundwater modeling.

2.1 GROUNDWATER MONITORING AND ASSESSMENT

Routine groundwater monitoring has been conducted at the Site since 2003 and has been documented in periodic monitoring reports and data submittals. The following outlines groundwater assessment activities conducted to support the CMS since 2003.

- Between late 2003 and early 2004, deep exploratory boreholes and monitor wells were installed on the southern portion of the former property to assess regional groundwater conditions, refine the conceptual site model, and improve the monitor well network (H+A, 2003b, 2003c, 2004a, 2004b, 2004d, and 2004e). The results of these investigations were summarized in a report which presented two potential groundwater conceptual model alternatives (H+A, 2005c).

- In December 2007, there was a detection of 1,1-DCE and 1,4-dioxane in monitor well MW-26C (H+A, 2008a). Based on this detection and other data collected at the Site, one of the two conceptual models presented in the 2005 groundwater assessment report was determined to more accurately represent Site conditions (H+A, 2008b). This conceptual model indicated that there was a structural fold that provided a groundwater transport pathway (aka Unit B or target zone) within the regional groundwater system, which became the focus of subsequent investigations.

- Between 2008 and 2013, multiple phases of groundwater assessment have been conducted on and to the west/southwest of the former property as outlined in multiple groundwater work plan addenda (H+A, 2008b, 2008c, 2008d, 2009a, 2009c, 2010b, 2011b, 2011c, 2011d, and 2013a). The results of the multiple groundwater assessment phases indicated that VOCs and 1,4-dioxane were detected primarily within Unit B on the southwestern portion of the former property and to the west/southwest of the property (Figure 5) (H+A, 2009b, 2009d, 2010c, 2011a, 2013c, and 2013d). The presence of a structural fold roughly parallel with Malvern Avenue creates a condition where Unit B slopes to the south from the toe of the perched zone, where the bottom of this zone is approximately 180 feet bls, to Malvern Avenue, where the bottom of this zone is approximately 1,000 feet bls (Figure 3).

- The results of additional groundwater assessment conducted in 2013 indicated monitor wells MW-37 and MW-38 were not screened in Unit B, thus suggesting a relatively small data gap in the vicinity of these monitor wells (H+A, 2013d). A groundwater work plan addendum was submitted to DTSC to address this data gap (H+A, 2013e). Monitor well MW-41 was installed in August 2014 and provided additional lithologic and hydrologic information that was used to delineate the western extent of VOCs and 1,4-dioxane in Target Zone groundwater near monitor wells MW-37 and MW-38 (H+A, 2014c). Monitor well MW-41 provided additional lithologic information that suggested the structural feature identified at and to the immediate west of the Site continues westward along the base of the west Coyote Hills. Both water level and water quality from the temporary and final well installations at monitor well MW-41 provide multiple lines of evidence that monitor well MW-41 is screened within Unit B. Low- to non-detect levels of VOCs and 1,4-dioxane at monitor well MW-41 suggest the western extent of contaminants has been delineated and no further monitor well installations were recommended as part of the groundwater assessment for the Site (H+A, 2014c).

2.2 BENCH AND PILOT TESTING

Multiple groundwater pilot tests have been conducted at the Site starting in 2004. The pilot groundwater extraction and treatment system has reduced the mass of VOCs and 1,4-dioxane in the regional aquifer and has substantially reduced mass flux along the western portion of the former property. As of the end of February 2015, approximately 95,600,000 gallons of groundwater has been extracted and approximately 130 pounds of VOCs and 26 pounds of 1,4-dioxane have been treated. The pilot system will continue operations concurrent with CMS Report review and CMI design. The following outlines the pilot testing activities.

- In 2004, a one-day field pilot test of an advanced oxidation process (AOP) that uses hydrogen peroxide and ozone (HiPOx™) to treat extracted groundwater was completed (H+A, 2004c and 2004f). Between 2005 and 2007, work plan preparation, and design and permitting of an extended pilot test involving extraction and treatment of groundwater from two wells screened within the regional groundwater system near the toe of the perched zone using the HiPOx™ AOP technology was completed (H+A, 2005a, 2005b, 2005d, and 2006). Construction of the pilot test treatment system was completed in 2008 and the treatment system was started in July 2008 (H+A, 2008e). From July 2008 through November 2009, the pilot system was operated with extraction wells EW-01 and MW-21 operating at a combined rate of approximately 20 gallons per minute (gpm) on a nearly continuous basis.

- In 2009, a work plan to expand the pilot treatment system to include a new extraction well, EW-02, located near the western portion of the former property was prepared (H+A, 2009c). Pilot system expansion took place between November 2009 and March 2010 to incorporate extraction well EW-02 into the extraction well network (H+A, 2010a and 2010c). During this time, the pilot test treatment equipment was also modified to increase the treatment system capacity from 20 gpm to 50 gpm, which is the maximum allowable flowrate in accordance with the sewer discharge permit. Beginning in March 2010, the pilot test system was operated near the maximum capacity of approximately 50 gpm on a nearly continuous basis from extraction well EW-02.

- Results of the extended pilot test using the HiPOx™ AOP treatment system indicated this technology could not reliably treat for 1,4-dioxane in Site groundwater without formation of bromate as a treatment byproduct. This was especially true when the pilot system was extracting groundwater with higher concentrations of 1,4-dioxane from wells near the toe of the northern perched zone (extraction wells EW-01 and MW-21), where the perched zone seeps into the regional groundwater system; but there were also occasions when the HiPOx™ AOP system didn't meet the treatment goal for 1,4-dioxane and/or bromate was generated as a by-product at concentrations above drinking water standards while treating lower-concentration groundwater from extraction well EW-02. After numerous efforts to optimize the HiPOx™ AOP treatment system were unsuccessful, alternative treatment technologies were considered for pilot testing.

- In 2011 and 2012, a bench and pilot test work plan was prepared and implemented to evaluate three additional groundwater treatment technologies because the existing HiPOx™ AOP treatment system periodically resulted in formation of bromate above drinking water standards as a by-product of the treatment technology (H+A, 2011b and 2012). The alternative technologies evaluated were an absorptive technology using a proprietary synthetic resin, and two alternative AOP technologies using ultraviolet light with hydrogen peroxide chemical oxidation (UV/chem-ox). To facilitate a pilot test of treating groundwater using a synthetic media as an alternative technology, extraction wells EW-02 and MW-21 were operated at approximately 40 gpm and 10 gpm, respectively. The synthetic media pilot test was completed on March 9, 2012, and operation of the pilot groundwater extraction and treatment system (GETS) was restored to 50 gpm, entirely from extraction well EW-02. Concurrent with the synthetic media pilot test, bench-testing of the UV/chem-ox AOP treatment technologies was conducted using groundwater collected from extraction wells EW-02 and MW-21. The results of the bench and pilot testing indicated that the three technologies evaluated were capable of treating VOCs and 1,4-dioxane without the formation of bromate above drinking water standards.

- In 2013, a pilot test work plan addendum was prepared to replace the existing AOP technology with one of the bench-tested AOP technologies to monitor and confirm treatment system performance. An additional objective was to add an existing well (MW-29) to the extraction wellfield to enhance containment of higher concentration VOCs and 1,4-dioxane along the west side of the former property (H+A, 2013b). Construction and installation of the new pilot treatment system and the connection of existing monitor well MW-29 to the treatment system began in the second quarter 2014 (H+A, 2014d). The existing HiPOx™ AOP treatment system was replaced with a new pilot UV/chem-ox treatment system supplied by Trojan Technologies. Initial startup of the modified pilot GETS with extraction well EW-02 and new extraction well MW-29 operating at 40 gpm and 10 gpm, respectively, was completed during the fourth quarter 2014. Extraction wells EW-01 and MW-21 are on standby for the current phase of pilot testing, but may be used as part of the selected groundwater corrective measure alternative. The results of the pilot test operation and monitoring continue to be documented in quarterly data submittals and annual reports.

2.3 CONCEPTUAL SITE MODEL

In accordance with the CMS Workplan Update, the current understanding of the CSM for the Site was presented under separate cover in a technical memorandum summarizing the CSM and numerical groundwater flow model construction (H+A, 2015). The CSM incorporates early project assessment and remediation activities that were documented in the initial CMS Work Plan prepared in 2003 (H+A, 2003a) and integrates groundwater assessment data that has been collected between 2003 and late-2014 to provide the current understanding of the CSM. An overview of the CSM follows:

The Site is located on the southern portion of the West Coyote Hills in Fullerton, California. The Coyote Hills have formed due to complex folding and faulting in the area.

The CSM includes the following key elements:

1. There are relatively low concentrations of residual COCs at the two former source areas. The primary COCs at the former Building 609 area are 1,1-DCE and 1,4-dioxane. Prior remediation in this former source area significantly reduced both residual concentrations and mass in the soil underlying the former building and the perched zone (Northern Perched Zone). Residual COCs in the soil and the Northern Perched Zone enter a portion of the regional groundwater system near the southern terminus of the Northern Perched Zone (toe of perched zone). The primary COCs at the former Building 601 area are TCE and 1,1-DCE. There is no perched zone in the vicinity of the Building 601 area; therefore, the residual COCs from this former source area enter a portion of the regional groundwater system near the southwest corner of former Building 601. The results of prior health risk assessments at both of these former source areas and the area overlying the Northern Perched Zone coupled with the great depth to regional groundwater (over 100 feet bls) indicate that the only potential pathway for human exposure to COCs is from groundwater extraction from the portions of the regional aquifer system containing COCs. No groundwater extraction, other than for sole purposes of treatment, is allowed on the Site.

2. Residual COCs enter portions of the regional groundwater in two general areas: a) at the toe of the perched zone south of former Building 609 and b) in the vicinity of the southwest corner of former Building 601. The hydrostratigraphic units within the regional groundwater system slope (dip) to the south in the area north of Malvern Avenue (Figure 3) due to deep faulting in this area. The primary transport zone within the regional groundwater system for COCs from both of the former source areas is a relatively coarse zone referred to as “Unit B” or the “Target Zone”. Given the dip of the hydrostratigraphic units north of Malvern Avenue and the depth of the regional groundwater table (first groundwater in regional groundwater system), the depth to first groundwater in Unit B near the toe of the perched zone and southwest corner of Building 601 is about 120 feet bls. The depth to Unit B is approximately 1,000 feet bls south of these two areas along Malvern Avenue. North of these two

areas Unit B becomes unsaturated. The approximate location of where Unit B becomes unsaturated is illustrated on Figure 5.

3. Once the COCs have entered respective portions of the regional groundwater system, the COCs appear to be transported to the west at and near the Site and appear to be transported in a more southwesterly direction further downgradient from the Site. The COCs remain in Unit B downgradient from the Site due to the lower water level elevations in Unit B as compared to water level elevations in overlying and underlying hydrostratigraphic units. Given the preferential transport within Unit B, the depth to groundwater containing COCs increases as one approaches Malvern Avenue, such that the COCs are encountered at depths of approximately 1,000 feet bls in groundwater near and to the south of Malvern Avenue.

4. The nearest potential receptor is Well 9 (also sometimes referred to as F-AIRP) located at the Fullerton Municipal Airport approximately 4,000 feet downgradient of the Site boundary (Figure 5). Unit B is within the deepest screen interval of this well. 1,1-DCE is present in the deepest screened zone in Well 9; however, the concentration of 1,1-DCE detected in water extracted from this production well is and has historically been below the drinking water Maximum Contaminant Level (MCL), and as such meets standards of protection of human health established by the Federal and State agencies for drinking water. Depth-specific sampling of Well 9 was conducted in April and May 2014 by Raytheon with cooperation and input from the City of Fullerton and the Orange County Water District (OCWD) (H+A, 2014b). The results of depth-specific sampling indicate that 1,1-DCE appears to be entering Well 9 from the lowermost screen interval and not from the uppermost screen interval; however, the results were not conclusive as to the potential contribution of 1,1-DCE from other intermediate screens. The concentration of 1,1-DCE detected from the deepest screen interval was less than the drinking water MCL. TCE was detected from the lowermost screen interval at lower concentrations than 1,1-DCE and was also below the drinking water MCL. TCE was not detected in the wellhead samples collected from Well 9 which represents a composite sample of water

contributed from all screen intervals. 1,4-Dioxane was not detected in groundwater samples collected as part of the depth-specific sampling program.

Operations of the current pilot extraction and treatment system have reduced the COC mass in the regional groundwater and have reduced off-Site migration of COCs.

2.4 GROUNDWATER FLOW MODELING

Construction of the numerical flow model was initiated in 2011 and was completed in late 2012 after the results of groundwater assessment had largely defined the general orientation and configuration of the fold along Malvern Avenue. Calibration of the groundwater flow model was largely completed in 2013. Based on the structural complexities and the highly transient groundwater conditions, solute transport modeling is not planned. The model construction and results of calibration were documented under separate cover in a technical memorandum along with the current understanding of the CSM (H+A, 2015).

The objective of the regional flow model is to simulate a transient flow field that is representative of dynamic groundwater flow conditions at and in the vicinity of the Site to provide a tool that will aid in evaluation of corrective measures alternatives and remedial design. As discussed during the September 25, 2013 meeting with DTSC, the current groundwater flow model is adequate to support evaluation of groundwater corrective measures alternatives using capture zone analysis. The groundwater model simulates groundwater flow and was used to develop CMS groundwater extraction and treatment (aka pump-and-treat [P&T]) wellfields and evaluate the relative effectiveness of the corrective measures alternatives (Section 5.2). Results of groundwater modeling conducted to support development and evaluation of corrective measures alternatives and remedial design is presented in Appendix A.

3.0 REMEDIAL ACTION OBJECTIVES FOR GROUNDWATER

General RAOs for groundwater at the Site are to protect human health and the environment. The following are the specific RAOs for groundwater as outlined in the DTSC-approved CMS Work Plan Update:

- Prevent unacceptable exposure to groundwater containing COCs;
- Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas; and
- Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at point(s) of compliance (POCs) and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical.

Corrective measures for groundwater are evaluated in this CMS Report with respect to the RAOs for groundwater listed above and the following drinking water standards at existing and potential receptors: Federal and California State drinking water MCLs and California Notification Levels.

4.0 GROUNDWATER CORRECTIVE MEASURES TECHNOLOGIES

This section identifies and screens corrective measures technologies and process options applicable to the groundwater corrective action to narrow technologies included in the corrective measures alternatives evaluation. This section also provides a general description of the retained technologies.

4.1 IDENTIFICATION AND SCREENING OF POTENTIAL TECHNOLOGIES

The following treatment technologies and process options were identified to address COCs in groundwater:

- No Action
- Institutional Controls
- Passive In-Situ Treatment Technology
  - Monitored Natural Attenuation (MNA)
- Active In-Situ Treatment Technologies
  - Biological Reduction
  - Chemical Oxidation
  - Chemical Reduction
  - Steam Injection
  - Electrical Resistance Heating
  - Air Sparging
  - Permeable Reactive Barriers
- Groundwater Extraction with Ex-Situ Treatment Technologies
  - Extraction
  - Treatment
  - Treated water discharge or end use process options

As agreed upon with DTSC during a September 25, 2013 meeting and stated in the CMS Work Plan Update, given the area and depth at which VOCs and 1,4-dioxane have been detected at and in the vicinity of the Site, active in-situ treatment technologies were screened due to the technical infeasibility of implementing these technologies over the area and depth of groundwater impacts.

4.2 DESCRIPTION OF RETAINED TECHNOLOGIES

Retained technologies include: no action; Institutional Controls; monitored natural attenuation; and groundwater extraction and treatment. A general description of each of these technologies is provided in this section. Each retained technology is assembled into corrective measures alternatives and further evaluated in Section 5.

4.2.1 No Action

Remediation activities have already taken place at the Site, including previous voluntary remediation of soil and perched water and extended operation of a pilot GETS. For the purposes of this document, the no action alternative would consist of No Further Action. No additional active technologies are associated with this groundwater corrective measure alternative. Some degree of natural attenuation is likely already occurring within the groundwater system and will likely continue to occur under the No Action Alternative. For the purposes of this document natural attenuation as a stand-alone alternative will be evaluated separately as part of a MNA Alternative. The No Action Alternative is a stand-alone alternative that provides a baseline for comparison to other alternatives.

4.2.2 Institutional Controls

Institutional Controls are non-engineering methods by which Federal, State, and local governments or private parties can prevent or limit access to impacted media. Generally, Institutional Controls alone will not achieve RAOs; however, Institutional Controls may be applied in conjunction with other process options. All of the corrective measures alternatives with the exception of the No Action Alternative include Site-specific Institutional Controls.

The primary Institutional Controls for impacted groundwater at the Site are deed restrictions to prohibit future well installation and thereby minimize potential exposure risks.

For off-property groundwater, there are multiple permits, basin management, and monitoring requirements. Groundwater wells must be permitted through the appropriate permitting agency in accordance with county ordinances. The Orange County Health Care Agency is responsible for permitting wells located in Fullerton and the City of Buena Park is responsible for permitting wells located in Buena Park. Groundwater extraction from the OCGB is managed by the OCWD under a special act of the State Legislature. OCWD does not limit groundwater extraction by area or entity, but does monitor and establish fees for parties who extract groundwater from the basin. The primary monitoring and operating requirements applicable to entities that administer public drinking water systems have been established by the State Water Resources Control Board Division of Drinking Water (SWRCB DDW) Programs (formerly California Department of Health Services). The SWRCB DDW requirements ensure that delivered water meets safe drinking water standards.

The primary Institutional Controls that were identified and considered for the groundwater corrective action include coordination with local agencies with jurisdiction over well drilling and groundwater use within the area of the Site. The information provided by these Institutional Controls would protect public health by reducing the possibility that production wells in the vicinity of the Site could contain COCs exceeding safe drinking water standards, and coordinate operation of the wells and selected corrective action in a manner that maintains utilization of the water resource and meets the goals of the selected groundwater corrective measure alternative.

The Institutional Controls for all of the groundwater corrective measures alternatives with the exception of the No Action Alternative consist of the following:

- Submittal of system performance reports to nearby water users (Cities of Fullerton and Buena Park);

- Annual review of water production and water quality data from City of Fullerton Well 9 and Buena Park BP-SM1;

- Annual review of well permits issued in areas from near the Site to within 0.5-mile of POC wells to determine if new groundwater extraction wells have been installed in the area; and

- Annual review of water production from OCWD for the wells identified on Figure 7.

4.2.3 Monitored Natural Attenuation

Natural attenuation refers to a potential reduction in contaminant mass due to naturally occurring processes in the groundwater. Natural attenuation occurs to some degree in all corrective measures alternatives. The corrective measure alternative that relies solely on natural attenuation processes to achieve RAOs is referred to as MNA as this alternative includes a groundwater monitoring component to assess the performance of natural attenuation processes.

MNA includes physical processes such as dispersion, diffusion, dilution, adsorption, and passive volatilization; and chemical processes such as chemical oxidation, reduction, neutralization, precipitation, and reactions resulting from biological processes. Biodegradation and chemical transformation of COCs in groundwater was described in the CSM (H+A, 2015). Given the concentrations of 1,1-DCE, TCE, and 1,4-dioxane detected in groundwater downgradient of the Site, it is expected that biodegradation and chemical transformation of COCs are not dominant processes affecting the COCs at and in the vicinity of the Site. However, it is possible that biodegradation and/or chemical transformation of COCs may be occurring at a slow rate such that, with reduced mass flux from former source areas, one or more of these processes could contribute to a gradual reduction of COC mass over the long term.

A specific protocol for evaluating natural attenuation of chlorinated solvents in groundwater is available from the U.S. Environmental Protection Agency (EPA) (EPA, 1998). MNA requires development of a monitoring program after natural attenuation has been selected as either a portion of, or as the entire groundwater corrective action. The monitoring program is intended to verify the performance of the corrective action and allow for modifications to the approach, as necessary.

4.2.4 Groundwater Extraction and Ex-Situ Treatment

Groundwater extraction and treatment (also referred to as P&T) is a generic term used to describe one of the most well established and widely used remediation technologies for containment and/or removal of dissolved groundwater contaminants. The groundwater extraction and treatment technology is used exclusively at about 65 percent of the Superfund sites where groundwater is contaminated and at many sites where groundwater has been impacted by petroleum hydrocarbons or solvents (EPA, 2004). This technology includes extraction and conveyance of groundwater to a treatment system (extraction); treatment of extracted water to meet end use requirements (treatment); and discharge or use of treated groundwater (discharge/use). The following subsections provide an overview of each of these three components.

4.2.4.1 Groundwater Extraction

Groundwater is extracted from one or more extraction wells located inside and/or at the leading edge of the impacted area to remove COCs from the groundwater system and maintain a capture zone sufficient to reduce the migration of COC-impacted groundwater. Groundwater is extracted from vertical wells using well pumps. The groundwater is typically pumped using submersible pumps and conveyed in above- and/or below-grade pipelines to an equipment compound for treatment.

Access constraints for extraction wells and associated conveyance pipelines have to be considered as part of corrective measure alternative evaluations. The access to off-property areas are generally more difficult and therefore create a larger set of constraints when compared to on-property access. At the time of preparation of this document, there were several exploratory meetings with the Cities of Fullerton and Buena Park regarding access to off-property public rights of way as well as with the Orange County Flood Control District regarding access to areas adjacent to the Brea Creek Channel. There were no fatal flaw access issues identified during these meetings; however, availability of access will remain uncertain until design is initiated which follows selection of the corrective measure alternative. Given these uncertainties, there were several off-site wellfield configurations that were evaluated in different corrective measures alternatives (Section 5). The evaluation of multiple alternatives was intended to allow identification of a preferred corrective measure alternative, but allow for selection of a contingency wellfield configuration in the event access for the preferred alternative is not readily obtainable.

The overall performance of the groundwater extraction wellfield is influenced by the hydraulics and water quality of the groundwater system and constrained by available access for wells and pipelines. In addition to these considerations, the performance of the groundwater corrective action can also be influenced by end use of treated groundwater. For example, reinjection of treated groundwater can also influence overall performance of the corrective action. The relative performance of different extraction well configurations, and in some cases injection well configurations, were evaluated using the calibrated three dimensional groundwater flow model (Section 5; Appendix A).

4.2.4.2 Treatment

Extracted groundwater is conveyed to one or more treatment system locations for treatment. The number and location of treatment systems depends on access constraints and wellfield configuration. The type of treatment process depends on the COCs and end use of treated groundwater.

4.2.4.2.1 Treatment System Location

The treatment system(s) locations may vary based on the selected groundwater corrective measure alternative and access constraints. There are two potential locations for groundwater treatment systems, one in the general area of the existing pilot treatment system and the other is collocated with an existing groundwater treatment system located south of Brea Creek Channel and west of Gilbert Street at a site referenced as the Former Building 684 Site (Figure 8). The Former Building 684 Site is under the oversight of the RWQCB-SA and includes an extraction wellfield in the shallow groundwater system, a treatment system, and an injection wellfield that returns the treated groundwater to the shallow groundwater system on the south side of Fullerton Municipal Airport (Figure 8). For the purposes of this document, the location of the treatment system is assumed to be in the general area of the existing pilot treatment system; however, the location and number of treatment systems will be determined after the corrective measure alternative is selected during CMI design. As such, groundwater corrective measures alternatives will allow for use of one or both of these treatment system locations.

4.2.4.2.2 Treatment System Process Options

The extracted groundwater will contain 1,4-dioxane and VOCs. The treatment requirement for these compounds depends on the end use of the treated groundwater. As is described in the following section, there are two end use options that have been selected as preferred options as they both preserve the water resource. One is reinjection and the other is non-potable use for one or more of the following applications: industrial process water, maintenance of water features, and irrigation use.

The reinjection discharge option would require treatment to standards set in the RWQCB-SA general waste discharge requirements (WDR) permit. This permit requires treatment of VOCs to drinking water MCLs and 1,4-dioxane to the current notification level. In addition, this permit generally requires that the treated groundwater be injected back into: a) the formation from which it was extracted and/or b) an interval(s) with similar or poorer quality than the groundwater zone from which it is extracted. Given these requirements, the treatment processes would include filtration of groundwater before treatment, followed by use of an AOP to treat 1,4-dioxane and some of the VOCs; and followed by liquid phase granular activated carbon (LPGAC) to serve as a final polish for VOC treatment and for reduction of residual hydrogen peroxide from the AOP process. The AOP that will be used in the treatment system employs ultraviolet light and hydrogen peroxide. This configuration is currently being used as part of the pilot GETS.

The treatment system described above for reinjection may also be appropriate for non-potable end uses. For example, it is anticipated that the overall inorganic water quality of the treated groundwater will be similar to the groundwater produced from municipal supply wells in the vicinity of the Site which is currently used for various non-potable as well as potable applications. Specific non-potable applications may have different treatment requirements. For the purposes of this document, it is assumed that the treatment process to meet WDR will also meet non-potable use requirements and to the extent additional treatment is required for non-potable application this would be conducted separately from the corrective measure alternative by the purveyor of the non-potable water.

The above-referenced treatment processes are incorporated for each of the groundwater corrective measures alternatives that include groundwater extraction and treatment. It is anticipated that these technologies will be utilized during initial operation of the respective groundwater corrective measures alternatives. It is also recognized that alternate treatment processes may develop and/or portions of the treatment process may not be required over the duration of the groundwater corrective action. As such, the treatment process can be modified as long as the COCs have been treated to meet end use permit conditions.

4.2.4.3 End Use of Treated Groundwater

End use options for the treated groundwater could include one or more of the following: reinjection; non-potable reuse; disposal to the sanitary sewer; and/or disposal to the storm drain.

The groundwater corrective measures alternatives incorporating groundwater extraction and treatment rely on estimated wellfield extraction rates ranging from roughly 200 to 600 gpm (Section 5) (Table 3). Given these extraction rates, disposal of the entire treated groundwater flow to a sanitary sewer or storm drain is considered to be a waste of the water resource and, as such, both of these options are not retained for further consideration, with the exception of maintaining a sanitary sewer for small intermittent discharges. Sewer discharge will be maintained for periodic short-term, low-flow discharge of treated groundwater. Treated water discharge to the sewer under this scenario would not exceed 50 gpm for short periods of time.

Reinjection of treated groundwater does maintain the water resource and can be used to enhance the performance of the groundwater corrective action. As such, groundwater injection is retained as an option for managing treated groundwater. Reinjection does however require installing and maintaining injection wells which can pose operational challenges over time depending primarily on the performance of the injection wells. There are several injection well configurations that have been incorporated into the corrective measures alternatives. These configurations include one or more of the following: injection into the same formation as groundwater is extracted (Unit B) either on- or off-property; injection into existing shallow zone off-site injection wells that are operated as part of the Former Building 684 Site; and/or on-Site injection into Unit A. As indicated in the prior section, groundwater injection wells would be implemented under a WDR permit, which allows for injection of groundwater into the same unit as it is extracted and injection into other units as long as the treated groundwater quality is similar or better than that of the injection interval. The inorganic water quality of Unit B is similar to Unit A and is better than the off-site shallow zone (Table 1). The differences in injection wellfield configuration will be evaluated further in Section 5 with the goal of allowing a moderate degree of flexibility in future injection of treated groundwater into one or more of the three target zones (shallow groundwater, Unit A, and/or Unit B).

Non-potable reuse is an option for use of the treated groundwater. Non-potable reuse would off-set existing demand on the potable water system, which preserves the overall water resource. In addition, this end use is more energy efficient when compared to reinjection as the energy used to lift the groundwater from the regional aquifer to the treatment system is maintained with delivery of the water to end user. The City of Fullerton has expressed an interest in potentially using the treated groundwater for non-potable uses and has identified several non-potable applications as follows: irrigation; industrial process water; and water make up to fill Laguna Lake. Laguna Lake is a water feature located to the northeast of the Site that requires a nearly continual addition of water to maintain lake level. In this case, treated groundwater could be used as long as the lake did not overflow into surface water drainage, which would create a condition where the water resource is wasted and would also trigger need for a National Pollutant Discharge Elimination System permit. The City of Fullerton has prepared an estimate of the average volume of water required for irrigation, industrial, and lake use based on use over the past 5 years by month (Figure 9). The necessary infrastructure to support this non-potable use is not currently in place, but the City of Fullerton has prepared conceptual pipeline routing necessary to support the non-potable end users (Figures 10 and 11).

Overall reinjection and/or non-potable reuse are maintained and evaluated as part of the groundwater corrective measures alternatives (Section 5). The alternatives that incorporate non-potable use options are anticipated to be cost neutral when compared to the respective alternative that relies solely on reinjection because the purveyor of this non-potable water would fund incremental costs as part of the non-potable use project.

5.0 GROUNDWATER CORRECTIVE MEASURES ALTERNATIVES

Groundwater corrective measures alternatives have been assembled using retained technologies identified in Section 4. The evaluation criteria, assembly of corrective measures alternatives, and evaluation of each of the assembled alternatives are presented in this section.

5.1 CORRECTIVE MEASURES ALTERNATIVES EVALUATION CRITERIA

Each corrective measure alternative was evaluated based on:

- Overall protection of human health and the environment
- Ability to attain RAOs
- Short-term effectiveness
- Long-term reliability and effectiveness
- Reduction of toxicity, mobility, and volume or mass through treatment
- Implementability
- Cost
- Green and Sustainable

5.1.1 Protection of Human Health and the Environment

Each corrective measure alternative was evaluated as to its overall protection of human health and the environment. The corrective measures alternatives were evaluated to determine the degree to which potential human exposure is minimized or eliminated and the degree to which the groundwater resource is protected or improved.

5.1.2 Attain Remedial Action Objectives

Each corrective measure alternative will be evaluated as to its ability to achieve RAOs. In addition, the time frame to achieve the RAOs will be evaluated for each RAO with the exception of the long-term goal of attaining drinking water MCLs in groundwater. This long-term goal will be evaluated on a comparative basis between corrective measures alternatives since the actual time frame to achieve this goal, to the extent it is practical, cannot be reliably estimated using existing predictive tools such as numerical groundwater models.

5.1.3 Short-Term Effectiveness

Short-term effectiveness considers the effect of each remedial alternative on the protection of human health and the environment during the construction and implementation phase. The considerations evaluated during the analysis of each alternative for short-term effectiveness are presented below.

- Protection of the community and workers during implementation of the respective corrective measure alternative:
  - Risks to the community and/or workers that must be addressed
  - How the risks will be addressed and mitigated
  - Remaining risks that cannot be readily controlled

- Environmental impacts:
  - Environmental impacts that are expected with the construction and implementation of the alternative
  - Mitigation measures that are available and their reliability to minimize potential impacts
  - Impacts that cannot be avoided, should the alternative be implemented

5.1.4 Long-Term Reliability and Effectiveness

Long-term effectiveness considers the effect and permanence of maintaining the protection of human health and the environment during the anticipated useful life of the remedy. The primary components of this criterion are the magnitude of residual risk remaining at the Site after completion of the corrective measure alternative, and the extent and effectiveness of controls that may be required to manage the risk posed by treatment residuals and/or untreated COCs.

The considerations evaluated during the analysis of each alternative for long-term effectiveness and reliability are presented below.

- Magnitude of Residual Risks:
  - o Identity of remaining risks (e.g., risks from treatment residuals) as well as risks from untreated residual COCs
  - o Magnitude of the remaining risks

- Adequacy and Reliability of Controls:
  - o Likelihood that the technologies will meet required process efficiencies or performance specifications
  - o Type and degree of long-term management required
  - o Long-term monitoring requirements
  - o Operation and maintenance (O&M) functions that must be performed
  - o Difficulties and uncertainties associated with long-term O&M functions
  - o Potential need for technical components replacement
  - o Magnitude of threats or risks should the remedial action need replacement
  - o Degree of confidence that controls can adequately handle potential problems
  - o Uncertainties associated with land disposal of residuals and untreated wastes

5.1.5 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

Each corrective measure alternative was evaluated as to its reduction of toxicity, mobility, and volume or mass. As described in Section 4, each alternative has some degree of natural attenuation occurring. The relative reduction of toxicity, mobility, and volume or mass was estimated to be relatively low for the alternatives that rely solely on natural attenuation processes (No Action and MNA Alternatives) based on the nature and extent of COCs downgradient of the Site. For corrective measures alternatives incorporating groundwater extraction and treatment, the relative reduction of toxicity, mobility, and volume or mass was assessed based on the estimated percentage of 1,1-DCE and 1,4-dioxane removed using model projected capture zones and measured concentrations within different portions of the groundwater system as described in greater detail in Appendix A.

5.1.6 Implementability

Each corrective measure alternative was evaluated as to its implementability. The implementability evaluation addresses the technical and administrative feasibility of implementing each corrective measure alternative. Technical feasibility will be evaluated based on the ability to construct and operate the corrective measures alternatives given the existing site-specific construction conditions and reliability of the technology. Administrative feasibility will be evaluated based on the ability to coordinate with other agencies, obtain permits, and receive any on-Site and off-site approvals or access required for the corrective measure alternative selected.

5.1.7 Cost

Each corrective measure alternative was evaluated as to its estimated cost. As indicated in Section 5.1.2, it is difficult to project the time frame to achieve the long-term goal of attaining drinking water MCLs in groundwater. It is reasonable to expect that corrective measures alternatives that incorporate active groundwater extraction and treatment would achieve the long-term goals in a shorter time frame than those alternatives that rely solely on natural attenuation processes. In addition, lower concentration areas of the groundwater system that are remote and isolated from former source areas can attain these long-term goals in shorter time frames when compared to higher concentration areas closer to former source areas, such that the number of extraction wells and cumulative extraction rate would decrease over time. The cost estimates do not incorporate a decrease in the number of extraction wells or reduction in extraction rate over time, which is a relatively conservative means of estimating future costs. Given these factors, the duration of corrective measures alternatives that rely solely on natural attenuation are assumed to be active for 30 years and those that incorporate groundwater extraction and treatment are assumed to be active for 20 years. A preliminary cost estimate including both capital and O&M costs has been developed for each corrective measure alternative (Appendix B). The cost estimates include calculations to determine the net present value (NPV) of each corrective measure alternative incorporating the aforementioned durations.

The NPV has been estimated using the United States Office of Management and Budget (OMB) 2015 discount rate guidelines for use in benefit-cost and other types of economic analysis.

5.1.8 Green and Sustainable Screening

Each corrective measure alternative was screened as to its sustainable practices. The green and sustainable screening is based on conservation of the water resource and energy consumption to operate the respective corrective action alternative.

5.2 CORRECTIVE MEASURES ALTERNATIVES

Corrective measure technologies retained from Section 4 have been assembled into several alternatives. As indicated in Section 4, all of the alternatives, with the exception of the No Action Alternative, incorporate Institutional Controls. All of the alternatives have some degree of natural attenuation. Groundwater alternatives 3 to 6 incorporate groundwater extraction and treatment with different methods of managing treated water end use. There are different extraction wellfield configurations that are being evaluated: on-Site extraction wells (GW3 to GW6); off-site extraction wells aligned along Brea Creek Channel (GW4 and GW5); and an off-site extraction well to the south of Brea Creek (GW6). There are multiple end uses of treated groundwater that are evaluated that include use of reinjection only (GW3, GW4, GW5A, and GW6A) or a combination of focused reinjection and non-potable reuse (GW5A and GW6A). These different groundwater extraction and end use configurations were evaluated to assess similarities and differences in performance of different alternatives to facilitate selection of the preferred alternative(s) that also allows flexibility in implementation to account for uncertainties in access and end uses of treated groundwater.

The following corrective measures alternatives have been assembled and evaluated further in this section:

- GW1: No Action;
- GW2: MNA;
- GW3: On-Site Extraction with Injection, Off-Site MNA
- GW4: On-Site and Brea Creek Alignment Extraction with On-Site and Shallow Off-Site Injection
- GW5A: On-Site and Brea Creek Alignment Extraction with On- and Off-Site Unit B Injection
- GW5B: On-Site and Brea Creek Alignment Extraction with Off-Site Unit B Injection and Non-Potable Reuse
- GW6A: On-Site and South of Brea Creek Extraction with On- and Off-Site Distributed Injection
- GW6B: On-Site and South of Brea Creek Extraction with Off-Site Unit B Injection and Non-Potable Reuse

Each of the corrective measures alternatives, with the exception of the No Action Alternative, will also include a description of one or more contingencies that could be implemented to improve the performance of the respective corrective measure alternative based on key monitoring data collected during the CMI phase (Section 6). The corrective measures evaluation has been summarized (Table 2). Flowrates for extraction and end use options for each of the pump and treat alternatives are summarized in Table 3.

As indicated in Section 4.2.4.2.1, there is no definite location for the treatment system or treatment systems. Raytheon currently has two existing treatment facilities that could be utilized for future CMI for the Site, one located off-site at 2357 Moore Avenue, Fullerton, California, and the current pilot test system on-Site located at 1901 West Malvern Avenue, Fullerton, California. The location of the treatment system(s), and decision to utilize one or both existing treatment systems will be determined during the design phase. For the purposes of this document, a single treatment system located at the West Malvern Site has been used for evaluation of corrective measures alternatives incorporating groundwater extraction and treatment.

5.2.1 Groundwater Alternative GW1: No Action

Groundwater Corrective Measure Alternative GW1 does not utilize any corrective measures technologies or Site-specific Institutional Controls (Table 2).

5.2.1.1 Alternative GW1: No Action Description

The No Action Alternative serves as the baseline for comparison of the effectiveness of the other alternatives. Under Alternative GW1, no remedial action would be implemented to address COCs in groundwater at the Site. Also, no additional Institutional Controls would be implemented and groundwater monitoring would not be performed.

5.2.1.2 Overall Protection of Human Health and the Environment

Currently, there are no groundwater production wells within the vicinity of the Site that exceed MCLs for site-related COCs in drinking water and no surface waters are affected as Site COCs are constrained to deep groundwater. As such, the No Action Alternative is currently protective of human health and ecological receptors. The No Action Alternative may be protective of human health in the long-term; however, this alternative does not directly control COC migration in groundwater nor does it include Site-specific Institutional Controls that monitor quality and use of groundwater in the vicinity of the Site. There are pre-existing non-site specific Institutional Controls that prevent exposure; other than these Institutional Controls, Alternative GW1 does not eliminate, reduce or control the potential consumption of groundwater in excess of the SWRCB DDW MCLs for drinking water.

5.2.1.3 Attain Remedial Action Objectives

Prevent unacceptable exposure to groundwater containing COCs. Currently, there are no groundwater production wells within the vicinity of the Site that exceed MCLs for Site-related COCs in drinking water. Alternative GW1 does not include active remediation to reduce, or control COC migration nor does it contain Site-specific Institutional Controls, but does include non-site specific Institutional Controls to monitor and control the pathway by which persons could be exposed to groundwater containing COCs. Alternative GW1 could result in future shut down of groundwater production wells if natural attenuation is not sufficient to control future migration of COCs in groundwater.

Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas. Alternative GW1 will not achieve this RAO.

Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at POCs and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical. Alternative GW1 may meet the short-term goal if future extraction patterns in the groundwater basin in the general vicinity of the Site remain similar to those over the past decade or so. Changes in groundwater extraction patterns could pose a relatively high risk to this alternative meeting the short-term goal. Alternative GW1 would not likely achieve the long-term goal.

5.2.1.4 Short-Term Effectiveness

Alternative GW1 does not include any active measures and would pose no short-term risks to the community or to workers as a result of implementing the alternative. In addition, no environmental impacts from construction activities would occur.

5.2.1.5 Long-Term Reliability and Effectiveness

The No Action Alternative would have minimal effectiveness reducing the impacted groundwater due to continuing mass flux from the former source areas to the groundwater system and low degradation rates.

Risks posed by COCs in the groundwater are expected to gradually decrease as COC concentrations decrease over time through physical dilution, dispersion, and diffusion of COCs. COC concentrations may be reduced to levels near or below drinking water MCLs on the order of 30 years or more depending on the rate of mass flux from the former source areas to the groundwater system, contaminant degradation in groundwater, and other natural attenuation processes.

An evaluation of the adequacy and reliability of controls for the No Action Alternative is not applicable as there are no controls associated with this alternative.

5.2.1.6 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

Alternative GW1 does not provide any reduction in toxicity beyond the natural attenuation of COCs that may occur in the groundwater environment. No reduction of mobility or volume through treatment would occur since no treatment technologies would be implemented. Overall, the relative reduction of toxicity, mobility, and volume or mass was estimated to be relatively low for the alternatives that rely solely on natural attenuation processes.

5.2.1.7 Implementability

Alternative GW1 is implementable both from a technical and administrative feasibility. No permits or off-site access agreements are included in the No Action Alternative.

5.2.1.8 Cost

Alternative GW1 does not include any active measures and would have no capital or O&M costs associated with its implementation.

5.2.1.9 Green and Sustainable Screening

This type of screening does not apply to the No Action Alternative as there is no associated action implemented.

5.2.2 Groundwater Alternative GW2: Monitored Natural Attenuation

Groundwater Corrective Measure Alternative GW2 relies on natural processes to reduce concentrations of COCs in groundwater and includes verification monitoring (Table 2). This alternative also includes: Site-related Institutional Controls and off-site Institutional Controls described in Section 4.2.2.

5.2.2.1 Alternative GW2: Monitored Natural Attenuation Description

Alternative GW2 includes MNA throughout the groundwater containing COCs and would include Institutional Controls to prevent installation of water supply wells on the Site and monitor production wells downgradient of the Site. Alternative GW2 also includes groundwater sampling for MNA parameters from the existing and new monitor wells associated with this alternative (Figure 12). Monitoring would consist of quarterly groundwater sampling at selected key monitor wells and POCs for five years, with other wells being monitored on a less frequent basis. The results of groundwater monitoring and analysis of MNA would be presented in quarterly reports during this time frame. For cost estimating purposes, groundwater monitoring would continue for 30 years with sampling frequency being reduced over time. Reports after year 5 would be prepared annually.

Following DTSC approval of corrective action termination, the monitor wells would be decommissioned in accordance with State and local requirements.

Alternative GW2 would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.2.2 Overall Protection of Human Health and the Environment

Currently, there are no groundwater production wells within the vicinity of the Site that exceed MCLs for site-related COCs in drinking water and no surface waters are affected as Site COCs are constrained to deep groundwater. As such, the MNA Alternative is currently protective of human health and ecological receptors. Alternative GW2 may be protective of human health in the long-term; however, this alternative does not directly control migration of COCs in groundwater.

Alternative GW2 also includes Site Institutional Controls. Deed restrictions would prevent the drilling of new water supply wells on-Site. The existing institutional oversight of public water supply systems should provide adequate protection of public water supplies by verifying MCLs for COCs are not exceeded. The public is informed of the groundwater contamination and its unsuitability for consumption through DTSC's public participation process and periodic fact sheets issued to the community.

5.2.2.3 Attain Remedial Action Objectives

Prevent unacceptable exposure to groundwater containing COCs. Currently, there are no groundwater production wells within the vicinity of the Site that exceed the MCLs for Site-related COCs in drinking water. Alternative GW2 does not include active remediation to reduce, or control COC migration, but does include Institutional Controls to monitor and control the pathway by which persons could be exposed to groundwater containing COCs. Alternative GW2 could result in shut down of groundwater production wells if natural attenuation is not sufficient to control future migration of COCs in groundwater.

Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas. Alternative GW2 will not achieve this RAO.

Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at POCs and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical. Alternative GW2 may meet the short-term goal if future extraction patterns in the groundwater basin in the general vicinity of the Site remain similar to those over the past decade or so. Changes in groundwater extraction patterns could pose a relatively high risk to this alternative meeting the short-term goal. Natural attenuation processes will eventually reduce and/or disperse the concentrations of COCs in the aquifer over time. This reduction of COCs will require a substantial period of time and MCLs might not be attained.

The potential risk during implementation of Alternative GW2 would be managed through OCWD monitoring requirements for water production and the SWRCB DDW Program requirement that ensures delivery of safe drinking water, as well as Site-specific Institutional Controls prohibiting installation of water wells on the Site.

5.2.2.4 Short-Term Effectiveness

Alternative GW2 would have similar short-term effectiveness as Alternative GW1 described in Section 5.2.1.4, as no active remediation facilities would be installed. The performance of Alternative GW2 would be based on naturally occurring processes to reduce the concentration of COCs in groundwater beneath and emanating from the Site. Performance of Alternative GW2 is monitored on a regular occurrence (quarterly for the first 5 years then less frequently thereafter).

<u>Protection of Community and Workers</u>. During implementation of field activities for Alternative GW2, it is anticipated that there will be minor short-term impacts to the community due to sampling and monitor well installation. These impacts could include temporary road/lane closures, traffic detours, noise associated with drilling and well installation equipment,

monitoring, and dust. These impacts would be minimized through the implementation of various abatement plans (e.g., traffic control plans).

Workers would be adequately protected during construction by adhering to Occupational Safety and Health Administration (OSHA) practices. Workers would also be protected while operating and maintaining facilities by adhering to appropriate health and safety procedures. In addition, monitor wells are not planned to be installed in arterial roadways to minimize risks associated with repeated work in high traffic areas over the duration of the project.

Environmental Impacts. There are no adverse long-term environmental impacts anticipated to be associated with Alternative GW2. Given land use at and surrounding the Site, environmental permitting beyond those required to construct and maintain the remedy is not anticipated to be required.

5.2.2.5 Long-Term Reliability and Effectiveness

The MNA Alternative would have minimal effectiveness reducing the impacted groundwater due to continuing mass flux from the former source areas to the groundwater system and low degradation rates. There is no current human exposure to Site COCs exceeding MCLs in groundwater, so that current conditions are protective of human health. Consumption of impacted groundwater exceeding MCLs is not expected to occur given existing and anticipated future groundwater production in the area and associated Institutional Controls. Installation of water supply wells on-Site will be prohibited by deed restriction or land use covenant. In the unlikely event that a water supply well is installed in the vicinity of the Site, consumption would be controlled by existing non-site specific Institutional Controls.

With respect to adequacy and reliability of controls, monitoring facilities proposed for this alternative are proven and reliable. The monitor wells and monitoring equipment are common, well established remedy components that have been implemented elsewhere. The reliability in natural attenuation to control migration of COCs is considered to be relatively low given the nature and extent of COCs in the groundwater system.

Current and proposed Institutional Controls are based on programs currently or anticipated to be implemented and managed by OCWD and SWRCB DDW. In addition well permits are required to install and maintain water supply wells and monitor wells within Orange County. These programs are expected to continue; therefore, the long-term permanence of such measures is considered to be high.

Alternative GW2 would include a contingency to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.2.6 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

Alternative GW2 does not directly reduce toxicity, mobility, volume or mass as there is no active groundwater treatment. However, as stated in the previous section, there will be some limited permanent reduction in VOC mass and volume in the groundwater due to natural processes. Overall, the relative reduction of toxicity, mobility, and volume or mass was estimated to be relatively low for the alternatives that rely solely on natural attenuation processes.

5.2.2.7 Implementability

Alternative GW2 for groundwater is implementable both from a technical and administrative feasibility. All construction and monitoring for Alternative GW2 would occur in areas that are currently developed and would be completed under new and/or existing access agreements with property owners, cities, and/or agencies. Additional monitor wells will need to be constructed that will require well installation permits from Orange County Health Care Agency and/or the City of Buena Park. Access agreements may need to be executed for new well locations. New access agreements and permits for this project, if required, should be readily obtainable.

5.2.2.8 Cost

Estimated present worth remedy lifetime cost for Alternative GW2 is $9,500,000 (30-year NPV discount at 1.4 percent). Detailed cost estimates and a NPV summary are included in Appendix B.

5.2.2.9 Green and Sustainable Screening

The energy requirements for Alternative GW2 are low as there is no operating wellfield. In addition, this alternative does not extract groundwater and therefore does not have issues with treated groundwater end use; however, given the potential for additional migration of COCs in groundwater, this alternative would rate relatively low when evaluated in preserving the existing water resource.

5.2.3 Groundwater Alternative GW3: On-Site Extraction and Injection with Off-Site Monitored Natural Attenuation

Groundwater Corrective Measure Alternative GW3 includes on-site extraction and treatment. The end use of treated groundwater would be on-Site reinjection (Tables 2 and 3).

5.2.3.1 Alternative GW3: On-Site Extraction and Injection with Off-Site Monitored Natural Attenuation Description

Alternative GW3 includes on-Site extraction and treatment to control COC migration in the regional groundwater downgradient of the Site. The objective of Alternative GW3 is to establish hydraulic containment of impacted groundwater located on-Site. Alternative GW3 would extract groundwater using five existing wells, EW-01, EW-02, MW-21, MW-29, and MW-31, and one proposed extraction well, EW-07, at a total design flowrate of 220 gpm. The impacted groundwater would be conveyed below-grade in double-contained, high-density polyethylene (DCHDPE) pipeline to a treatment facility (Figure 13).

The extracted groundwater would be treated using an AOP treatment system with UV/chem-ox to treat 1,4-dioxane and LPGAC to treat VOCs (Figure 14). Multi-bag filters would be used to remove particulates prior to treatment for 1,4-dioxane and VOCs. The treatment system would be located at the existing pilot treatment facility. The treated groundwater would be discharged to two proposed on-Site Unit B injection wells, IW-01 and IW-02, via a below-grade high-density polyethylene (HDPE) pipeline. If for any reason the discharge to the injection wells was temporarily not viable, treated water could be discharged for short periods of time at rates up to 50 gpm to the sanitary sewer under a new Special Purpose Discharge Permit (SPDP) issued by the Orange County Sanitation District (OCSD). Discharge flowrate to the sanitary sewer under the existing SPDP for the pilot system cannot exceed 50 gpm, mainly due to the capacity of the existing connection.

Alternative GW3 includes MNA throughout the off-site area and would include Institutional Controls to prevent installation of water supply wells on the Site and monitor production wells downgradient of the Site. Alternative GW3 also includes groundwater sampling for MNA parameters from the existing and new monitor wells downgradient of the Site. Natural attenuation processes would also occur in on-Site areas where active groundwater extraction and treatment is implemented although MNA parameters would not be monitored in on-Site areas. Groundwater monitoring would also be conducted during operation of the groundwater corrective action to monitor performance of the groundwater extraction and treatment portion of this corrective measure alternative. Initial monitoring would include quarterly sampling of selected key monitor wells and POCs and less frequent sampling of other wells. The initial monitoring would also include quarterly water level measurements at accessible wells. Overall monitoring frequency would decrease with time.

Following DTSC approval of corrective action termination, the treatment system would be demobilized. Demobilization would include teardown of remediation system equipment, abandonment of the extraction and collection systems, and removal of equipment from the Site.

Alternative GW3 would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.3.2 Overall Protection of Human Health and the Environment

Protection of human health ecological receptors would be achieved under Alternative GW3 through similar mechanisms outlined for the MNA alternative (Section 5.2.2.2). In addition, the remedy reduces COC concentration and mass through the operation of an on-Site GETS.

Alternative GW3 also includes the same Institutional Controls as outlined for the MNA alternative (Section 5.2.2.2).

The treated groundwater discharge option for Alternative GW3 would be managed by meeting discharge requirements as specified under a WDR permit issued by the RWQCB-SA.

As the groundwater extraction and treatment technologies included for the Site under Alternative GW3 is presumptive and based on standard, accepted treatment practices, this alternative does not pose any unacceptable short-term risks or other adverse impacts.

5.2.3.3 Attain Remedial Action Objectives

Prevent unacceptable exposure to groundwater containing COCs. Currently, there are no groundwater production wells within the vicinity of the Site that exceed the MCLs for Site-related COCs in drinking water. Alternative GW3 includes active remediation to reduce, or control COC migration on-Site and also includes Site-specific Institutional Controls to monitor and control the pathway by which persons could be exposed to groundwater containing COCs. Alternative GW3 could result in shut down of groundwater production wells if natural attenuation is not sufficient to control future migration of COCs in groundwater downgradient of the Site.

Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas. Alternative GW3 would provide effective, short- and long-term control of the on-Site COCs in groundwater through extraction and treatment of groundwater using proven technologies. The projected hydraulic capture zone of the on-Site extraction and injection wellfield is based on the groundwater model as shown in

Appendix A. It is anticipated that the capture zone would be established in a relatively short time frame (several months) after the extraction wellfield becomes operational.

Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at POCs and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical. The off-site, lower-concentration areas would naturally attenuate over time. COC concentrations may be reduced to levels near or below drinking water MCLs in one to several decades assuming the on-Site groundwater extraction system is effective in minimizing migration of COCs in groundwater downgradient of the former source area and natural attenuation processes contribute to concentration reduction in off-site groundwater.

The potential risk during implementation of Alternative GW3 would be managed through OCWD monitoring requirements for water production and the SWRCB DDW Program requirement that ensures delivery of safe drinking water, as well as Site-specific Institutional Controls prohibiting installation of water wells on the Site.

5.2.3.4 Short-Term Effectiveness

Alternative GW3 incorporates an on-Site GETS and naturally occurring processes to reduce the concentration of COCs in groundwater beneath and downgradient of the Site. Performance of Alternative GW3 is monitored on a regular basis (quarterly for the first 5 years then less frequently thereafter).

<u>Protection of Community and Workers</u>. During construction of Alternative GW3, it is anticipated that there will be limited short-term impacts to the community. These impacts could include temporary road/lane closures, traffic detours, noise associated with drilling and well installation equipment, pipeline installation, and dust. These impacts would be minimized through the implementation of various abatement plans (e.g., traffic control plans, air permits, and building permits).

Workers would be adequately protected during construction by adhering to OSHA practices. Workers would also be protected while operating and maintaining facilities by adhering to appropriate health and safety procedures. In addition, monitor, extraction, and/or injection wells are not planned to be installed in arterial roadways to minimize risks associated with repeated work in high traffic areas over the duration of the project.

Environmental Impacts. There are no adverse long-term environmental impacts anticipated to be associated with Alternative GW3. However, it is noted that electrical consumption for operation of equipment, submersible pumps, and ancillary equipment will generate greenhouse gas emissions (GHG), but quantities are expected to be minimal. Treated groundwater from Alternative GW3 will be re-injected into the aquifer, maintaining goals of water conservation. Given land use at and surrounding the Site, environmental permitting beyond those required to construct, maintain, and operate the remedy is not anticipated to be required.

5.2.3.5 Long-Term Reliability and Effectiveness

With respect to long-term reliability and effectiveness of controls, the technologies and associated equipment, and monitoring facilities proposed for this alternative are proven and reliable. The monitor wells, monitoring equipment, extraction wells and pumps, conveyance piping, transfer pumping, treatment processes for removal of the COCs, treated water management facilities, and associated instrumentation and control systems are common, well established remedy components that have been implemented elsewhere. In general, injection wells are an established method for changing the rate and direction of the groundwater flow, which can decrease the overall treatment period, and increase removal efficiency of COCs.

Current and proposed Institutional Controls are based on programs currently implemented and managed by the OCWD and SWRCB DDW. In addition, well permits are required to install and maintain water supply wells and monitor wells within Orange County. These programs are expected to continue; therefore, the long-term permanence of such measures is considered to be high.

Alternative GW3 would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.3.6 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

The toxicity of VOCs and 1,4-dioxane in extracted groundwater would be irreversibly reduced or eliminated by the treatment process options currently considered for these COCs (i.e., AOP, and LPGAC). Use of these treatment processes would satisfy the statutory preference for treatment as a principal element of the remedial action. The majority of VOCs and 1,4-dioxane will be destroyed by the AOP. The remaining VOCs will be removed by adsorption onto LPGAC. The VOCs will be thermally destroyed when the LPGAC is reactivated at a permitted off-site facility. The mobility of COCs present in on-Site groundwater will be effectively reduced through hydraulic containment using extraction.

Under Alternative GW3, the extraction and treatment system would actively remove volume and mass from on-Site groundwater. As discussed above, the off-site downgradient lower-COC concentration areas would naturally attenuate. Additional mass would be lost through degradation and other natural attenuation processes. Therefore, overall volume and mass of COCs in the groundwater would be reduced over time.

The relative reduction of toxicity, mobility, and volume or mass was assessed based on the estimated percentage of 1,1-DCE and 1,4-dioxane removed using model projected capture zones and measured concentrations within different portions of the groundwater system as described in greater detail in Appendix A. Overall, the relative reduction of toxicity, mobility, and volume or mass for Alternative GW3 was estimated to be moderate (Appendix A).

5.2.3.7 Implementability

Alternative GW3 is implementable both from a technical and an administrative feasibility.

The groundwater remediation system would require building and/or well permits from the Orange County Health Care Agency, City of Fullerton, City of Buena Park, a SPDP from the

OCSD (if short-term contingency disposal is pursued), and registration of extraction wells/treatment system with OCWD (to the extent the treated groundwater is temporarily disposed of to the sewer), and a WDR permit issued by the RWQCB-SA for reinjection of treated groundwater. The well permits, OCWD registration, and WDR permits are readily attainable and the SPDP to the sanitary sewer is existing, but subject to renewal. All proposed remediation system construction would occur in areas that are currently developed and would be completed under new and/or existing access agreements with property owners and agencies. Additional monitor, extraction and injection wells, pipelines and treatment facilities will need to be installed that will require well installation and building permits from Orange County Flood Control District, the City of Fullerton, and/or the City of Buena Park. Access agreements may need to be executed for new well locations. New access agreement and permits for this project, if required, should be readily obtainable.

Ongoing O&M requirements would involve coordination with property owners and tenants.

5.2.3.8 Cost

Estimated present worth remedy lifetime cost for Alternative GW3 is $13,400,000 (20-year NPV at 1.4 percent). Detailed cost estimates and a NPV summary are included in Appendix B.

5.2.3.9 Green and Sustainable Screening

The energy requirements for Alternative GW3 are moderate as the extraction wellfield and capacity of this groundwater extraction and treatment alternative is smaller than other groundwater extraction and treatment alternatives. This alternative does return treated groundwater to the groundwater basin and therefore preserves the water resource. Discharge of treated groundwater to the sanitary sewer would be temporary in nature and would not exceed 50 gpm. This type of discharge would be minimized to preserve the water resource and a replenishment assessment fee would be paid to OCWD for treated groundwater discharged to the sanitary sewer.

5.2.4 Groundwater Alternative GW4: On-Site and Brea Creek Alignment Extraction with On-Site and Shallow Off-Site Injection

Groundwater Corrective Measure Alternative GW4 includes on-Site and off-site extraction. End use of treated groundwater would be reinjection in on-Site (Unit B) and off-site (shallow groundwater) injection wells (Table 3).

5.2.4.1 Alternative GW4: On-Site and Brea Creek Alignment Extraction with On-Site and Shallow Off-Site Injection Description

Alternative GW4 includes on- and off-site extraction and treatment to control COC migration in the regional groundwater system both on-Site downgradient of former source areas and off-site. The objective of Alternative GW4 is to establish hydraulic containment of impacted groundwater located on-Site and hydraulic containment and treatment of impacted groundwater off-site. Alternative GW4 would extract groundwater using five existing wells, EW-01, EW-02, MW-21, MW-29, MW-31, and 3 proposed new extraction wells, EW-03, EW-04, and EW-07, at a total design flowrate of 420 gpm. The impacted groundwater would be conveyed through a below-grade DCHDPE pipeline to a treatment facility (Figure 15).

The extracted groundwater would be treated using an AOP treatment system with UV/chem-ox to treat 1,4-dioxane and LPGAC to treat VOCs (Figure 16). Multi-bag filters would be used to remove particulates prior to treatment for 1,4-dioxane and VOCs. The treated groundwater would be discharged to five existing off-site Shallow Zone injection wells, UAI-1, UAI-2, UAI-3, UAI-4, and UAI-5, and two proposed on-Site Unit B injection wells, IW-01 and IW-02, via a below-grade HDPE pipeline. If for any reason the discharge to the injection wells was temporarily not viable, treated water could be discharged for short periods of time at rates of up to 50 gpm to the sanitary sewer under a new SPDP issued by the OCSD. Discharge flowrate to the sanitary sewer under the existing SPDP for the pilot system cannot exceed 50 gpm, mainly due to the capacity of the existing connection.

Groundwater monitoring would be conducted during operation of the groundwater corrective action to monitor performance of the corrective measure alternative. Initial monitoring would include quarterly sampling of selected monitor wells and POCs and less frequent sampling of other wells. Natural attenuation processes would also occur in areas where active groundwater extraction and treatment is implemented although MNA parameters would not be monitored as part of this alternative. The initial monitoring would also include quarterly water level measurements. Overall monitoring frequency would decrease with time.

Following DTSC approval of corrective action termination, the treatment system would be demobilized. Demobilization would include teardown of remediation system equipment, abandonment of the extraction and collection systems, and removal of all equipment from the Site.

Alternative GW4 would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.4.2 Overall Protection of Human Health and the Environment

Protection of human health and the environment would likely be achieved under Alternative GW4 as the remedy reduces COCs concentration and mass through the operation of on- and off-site groundwater extraction wellfields.

Alternative GW4 also includes the same Institutional Controls as outlined for the MNA alternative (Section 5.2.2.2).

The treated groundwater discharge option for Alternative GW4 would be managed by meeting discharge requirements specified under a WDR permit issued by RWQCB-SA.

As the groundwater extraction and treatment technologies included for the Site under Alternative GW4 are presumptive and based on standard, accepted treatment practices, this alternative does not pose any unacceptable short-term risks or other adverse impacts.

5.2.4.3 Attain Remedial Action Objectives

Prevent unacceptable exposure to groundwater containing COCs. Currently, there are no groundwater production wells within the vicinity of the Site that exceed the MCLs for site-related COCs in drinking water. Alternative GW4 includes active remediation to reduce, or control COC migration on- and off-site, and also includes Institutional Controls to monitor and control the pathway by which persons could be exposed to groundwater containing COCs. Shut down of groundwater production wells and/or consumption of groundwater containing COCs exceeding MCLs is not and will not likely occur given existing and planned groundwater production in the area and the GETS that provides hydraulic containment both on- and off-site.

Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas. Alternative GW4 would provide effective, long-term control of the COCs in groundwater through extraction and treatment of groundwater using proven technologies. The projected hydraulic capture zone of the extraction and injection wellfield is based on the groundwater model as shown in Appendix A. It is anticipated that the capture zone would be established in a relatively short time frame (several months) after the extraction wellfield becomes operational.

Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at POCs and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical. The off-site extraction wellfield would contain and treat a large proportion of the COCs in off-site groundwater. In addition, COC mass that is potentially outside the off-site extraction wellfield capture zone would naturally attenuate. COC concentrations could be reduced to levels near or below drinking water MCLs within a period one to several decades assuming the on- and off-site groundwater extraction system is effective in minimizing migration of COCs in groundwater and natural attenuation processes further contribute to the concentration reduction.

The potential risk during implementation of Alternative GW4 would be managed through OCWD monitoring requirements for water production and the SWRCB DDW Program requirement that ensures delivery of safe drinking water, as well as Site-specific Institutional Controls prohibiting installation of water wells on the Site.

5.2.4.4 Short-Term Effectiveness

Alternative GW4 incorporates an on- and off-site groundwater extraction and treatment system and naturally occurring processes to reduce the concentration of COCs in groundwater beneath and downgradient of the Site. Performance of Alternative GW4 is monitored on a regular basis (quarterly for the first 5 years then less frequently thereafter).

Protection of Community and Workers. During construction of Alternative GW4, it is anticipated that there will be limited short-term impacts to the community. These impacts could include temporary road/lane closures, traffic detours, noise associated with drilling and well installation equipment, pipeline installation, and dust. These impacts would be minimized through the implementation of various abatement plans (e.g., traffic control plans, air permits, and building permits).

Workers would be adequately protected during construction by adhering to OSHA practices. Workers would also be protected while operating and maintaining facilities by adhering to appropriate health and safety procedures. In addition, monitor, extraction and/or injection wells are not planned to be installed in arterial roadways to minimize risks associated with repeated work in high traffic areas over the duration of the project.

Environmental Impacts. There are no adverse long-term environmental impacts anticipated to be associated with Alternative GW4. However, it is noted that electrical consumption for operation of equipment, submersible pumps, and ancillary equipment will generate GHG emissions, but quantities are expected to be minimal. Treated groundwater from Alternative GW4 will be re-injected into the aquifer, maintaining goals of water conservation. Given land use at and surrounding the Site, environmental permitting beyond those required to construct, maintain, and operate the remedy is not anticipated to be required.

5.2.4.5 Long-Term Reliability and Effectiveness

With respect to long-term reliability and effectiveness of controls, the technologies and associated equipment and monitoring facilities proposed for this alternative are proven and reliable. The monitor wells, monitoring equipment, extraction wells and pumps, conveyance piping, transfer pumping, treatment processes for removal of the COCs, treated water management facilities, and associated instrumentation and control systems are common, well established remedy components that have been implemented elsewhere. In general, injection wells are an established method for changing the rate and direction of the groundwater flow, which can decrease the overall treatment period, and increase removal efficiency of COCs.

COC mass in the downgradient lower-concentration portion of the off-site groundwater that is potentially outside the extraction wellfield capture zone would naturally attenuate. Current and proposed Institutional Controls are based on programs currently implemented and managed by the OCWD and SWRCB DDW. In addition, well permits are required to install and maintain water supply wells and monitor wells within Orange County. These programs are expected to continue; therefore, the long-term permanence of such measures is considered to be high.

Alternative GW4 would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.4.6 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

The toxicity of VOCs and 1,4-dioxane in groundwater throughout the wellfield capture area would be irreversibly reduced or eliminated by the treatment process options currently considered for these COCs (i.e., AOP and LPGAC). Use of these treatment processes would satisfy the statutory preference for treatment as a principal element of the remedial action. The majority of VOCs and 1,4-dioxane will be destroyed by the AOP. The remaining VOCs will be removed by adsorption to LPGAC. The VOCs will be thermally destroyed when the LPGAC is reactivated at a permitted off-site facility. The mobility of COCs present in groundwater will be effectively reduced through hydraulic containment using extraction.

Under Alternative GW4, the extraction and treatment system would actively remove volume and mass from throughout the groundwater wellfield capture area. Additional mass would be lost through degradation and other natural attenuation processes. Therefore, overall volume and mass of COCs in the groundwater would be reduced over time.

The relative reduction of toxicity, mobility, and volume or mass was assessed based on the estimated percentage of 1,1-DCE and 1,4-dioxane removed using model projected capture zones and measured concentrations within different portions of the groundwater system as described in greater detail in Appendix A. Overall, the relative reduction of toxicity, mobility, and volume or mass for Alternative GW4 was estimated to be high (Appendix A).

5.2.4.7 Implementability

Alternative GW4 is implementable both from a technical and an administrative feasibility.

The groundwater remediation system also requires building and/or well construction permits from the Orange County Health Care Agency, City of Fullerton, City of Buena Park, Orange County Flood Control District, a treated water discharge permit from the OCSD (to the extent the treated groundwater is temporarily disposed of to the sewer), registration of extraction wells/treatment system with OCWD, CFFD permits for materials storage, and a WDR permit issued by the RWQCB-SA. The well permits, OCWD registration, and WDR permits are readily attainable and the SPDP to the sanitary sewer is existing, but subject to renewal. All proposed remediation system construction would occur in areas that are currently developed and would be completed under new and/or existing access agreements with property owners and agencies. The Brea Creek pipeline and well alignment will require a new access agreement with Orange County Flood Control District. Additional monitor, extraction, and injection wells, pipelines and treatment facilities will need to be installed that will require well installation and building permits from Orange County Flood Control District, the City of Fullerton and/or the City of Buena Park. Access agreements may need to be executed for new well locations. New access agreement and permits for this project, if required, should be readily obtainable with the potential exception of permits for the pipelines along the Orange County Flood Control District right of way adjacent to the Brea Creek Channel.

Ongoing O&M requirements would involve coordination with property owners and tenants.

5.2.4.8 Cost

Estimated present worth remedy lifetime cost for Alternative GW4 is $17,800,000 (20 year NPV at 1.4 percent). Detailed cost estimates and a NPV summary are included in Appendix B.

5.2.4.9 Green and Sustainable Screening

The energy requirements for Alternative GW4 are moderate to high as there are on-Site and off-site extraction wellfields. This alternative does return treated groundwater to the groundwater basin and therefore preserves the water resource. Discharge of treated groundwater to the sanitary sewer would be temporary in nature and would not exceed 50 gpm. This type of discharge would be minimized to preserve the water resource and a replenishment assessment fee would be paid to OCWD for treated groundwater discharged to the sanitary sewer.

5.2.5 Groundwater Alternative GW5: On-Site and Brea Creek Alignment Extraction, Pump and Treat

Groundwater Corrective Measure Alternative GW5 consists of on- and off-site groundwater extraction, treatment, and different end uses of the treated groundwater (Figures 17 through 20). Off-site extraction wells are aligned along Brea Creek. Two options for treated water end use are:

- Alternative GW5A: Injection Well Discharge; on- and off-site injection into the Unit B; off-site injection provides forced-gradient, enhanced hydraulic flushing of a relatively stagnant area downgradient to the west of the Site as observed in Alternative GW4.
- Alternative GW5B: Injection Well Discharge and City of Fullerton Non-Potable Water Reuse; off-site injection into Unit B provides enhanced flushing to the west of the Site,

City of Fullerton water re-use for non-potable irrigation and industrial water supply as well as make-up water for the Laguna Lake.

5.2.5.1 Groundwater Alternative GW5A: On-Site and Brea Creek Alignment Extraction with On- and Off-Site Unit B Injection

Alternative GW5A includes on-Site and off-site extraction and treatment to control COC migration in regional groundwater both on-Site downgradient of former source areas and off-site. The objective of Alternative GW5A is to establish hydraulic containment of impacted groundwater located on-Site and hydraulic containment and treatment of impacted groundwater off-site. Alternative GW5A would extract groundwater using five existing wells, EW-01, EW-02, MW-21, MW-29, and MW-31, and four proposed extraction wells, EW-03, EW-04, EW-06, and EW-07, at a total design flowrate of 490 gpm. The impacted groundwater would be conveyed through a below-grade DCHDPE pipeline to a treatment facility located on-Site (Figure 17).

The extracted groundwater would be treated using an AOP treatment system with UV/chem-ox to treat 1,4-dioxane and LPGAC to treat VOCs (Figure 18). Multi-bag filters would be used to remove particulates prior to treatment for 1,4-dioxane and VOCs. Under Alternative GW5A, the treated groundwater would be discharged to two proposed on-Site Unit B injection wells, IW-01 and IW-02, and three proposed off-site Unit B injection wells, IW-03, IW-04, and IW-05, via a below-grade HDPE pipeline. The off-site injection well(s) would provide enhanced flushing of the relatively stagnant area observed in Alternative GW4 near the northern extent of the Unit B to the west of the Site. If for any reason the discharge to the injection wells was temporarily not viable, treated water could be discharged for short periods of time at rates of up to 50 gpm to the sanitary sewer under a new SPDP issued by the OCSD. Discharge flowrate to the sanitary sewer under the existing SPDP for the pilot system cannot exceed 50 gpm, mainly due to the capacity of the existing connection.

Groundwater monitoring would be conducted during operation of the groundwater corrective action to monitor performance of the corrective measure alternative. Initial monitoring would include quarterly sampling of selected monitor wells and POCs and less frequent sampling of other wells. Natural attenuation processes would also occur in areas where active groundwater extraction and treatment is implemented although MNA parameters would not be monitored as part of this alternative. The initial monitoring would also include quarterly water level measurements. Overall monitoring frequency would decrease with time.

Following DTSC approval of corrective action termination, the treatment system would be demobilized. Demobilization would include teardown of remediation system equipment, abandonment of the extraction and collection systems, and removal of all equipment from the Site.

Alternative GW5A would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.5.1.1 Overall Protection of Human Health and the Environment

Protection of human health and the environment would likely be achieved under Alternative GW5A as the remedy reduces COCs concentration and mass through the operation of on- and off-site groundwater extraction wellfields.

Alternative GW5A also includes the same Institutional Controls as outlined for the MNA alternative (Section 5.2.2.2).

The treated groundwater discharge option for Alternative GW5A would be managed by meeting discharge requirements specified under a WDR permit issued by RWCQB-SA.

As the groundwater extraction and treatment technologies included for the Site under Alternative GW5A are presumptive and based on standard, accepted treatment practices, this alternative does not pose any unacceptable short-term risks or other adverse impacts.

5.2.5.1.2 Attain Remedial Action Objectives

Prevent unacceptable exposure to groundwater containing COCs. Currently, there are no groundwater production wells within the vicinity of the Site that exceed the MCLs for site-related COCs in drinking water. Alternative GW5A includes active remediation to reduce or control COC migration on- and off-site, and also includes Institutional Controls to monitor and control the pathway by which persons could be exposed to groundwater containing COCs. Shut down of groundwater production wells and/or consumption of groundwater containing COCs exceeding MCLs is not and will not likely occur given existing and planned groundwater production in the area and the groundwater extraction and treatment system that provides hydraulic containment both on- and off-site.

Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas. Alternative GW5A would provide effective, long-term control of the COCs in groundwater through extraction and treatment of groundwater using proven technologies. The projected hydraulic capture zone of the extraction and injection wellfields is based on the groundwater model as shown in Appendix A. It is anticipated that the capture zone would be established in a relatively short time frame (several months) after the extraction wellfield becomes operational.

Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at POCs and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical. The off-site extraction wellfield would contain and treat a large proportion of the COCs in off-site groundwater. In addition, COC mass that is potentially outside the off-site extraction wellfield capture zone would naturally attenuate. COC concentrations could be reduced to levels near or below drinking water MCLs within a period one to several decades assuming the on- and off-site groundwater extraction system is effective in minimizing migration of COCs in groundwater and natural attenuation processes further contribute to the concentration reduction.

The potential risk during implementation of Alternative GW5A would be managed through OCWD monitoring requirements for water production and the SWRCB DDW Program requirement that ensures delivery of safe drinking water, as well as Site-specific Institutional Controls prohibiting installation of water wells on the Site.

5.2.5.1.3 Short-Term Effectiveness

Alternative GW5A incorporates an on- and off-site groundwater extraction and treatment system and naturally occurring processes to reduce the concentration of COCs in groundwater beneath and downgradient of the Site. Performance of Alternative GW5A is monitored on a regular basis (quarterly for the first 5 years then less frequently thereafter).

Protection of Community and Workers. During construction of Alternative GW5A, it is anticipated that there will be limited short-term impacts to the community. These impacts could include temporary road/lane closures, traffic detours, noise associated with drilling and well installation equipment, pipeline installation, and dust. These impacts would be minimized through the implementation of various abatement plans (e.g., traffic control plans, air permits, and building permits).

Workers would be adequately protected during construction by adhering to OSHA practices. Workers would also be protected while operating and maintaining facilities by adhering to appropriate health and safety procedures. In addition, monitor, extraction, and/or injection wells are not planned to be installed in arterial roadways to minimize risks associated with repeated work in high traffic areas over the duration of the project.

Environmental Impacts. There are no adverse long-term environmental impacts anticipated to be associated with Alternative GW5A. However, it is noted that electrical consumption for operation of equipment, submersible pumps, and ancillary equipment will generate GHG emissions, however quantities are expected to be minimal. Treated groundwater from Alternative GW5A will be re-injected into the aquifer, reducing the amount of water use, and maintaining goals of water conservation. Given land use at and surrounding the Site, environmental permitting beyond those required to construct, maintain, and operate the remedy is not anticipated to be required.

5.2.5.1.4 Long-Term Reliability and Effectiveness

With respect to long-term reliability and effectiveness of controls, the technologies and associated equipment and monitoring facilities proposed for Alternative GW5A are proven and reliable. The monitor wells, monitoring equipment, extraction wells and pumps, conveyance piping, transfer pumping, treatment processes for removal of the COCs, treated water management facilities, and associated instrumentation and control systems are common, well established remedy components that have been implemented elsewhere. In general, injection wells are an established method for changing the rate and direction of the groundwater flow, which can decrease the overall treatment period, and increase removal efficiency of COCs.

COC mass in the downgradient lower-concentration portion of the off-site groundwater that is potentially outside the extraction wellfield capture zone would naturally attenuate. Current and proposed Institutional Controls are based on programs currently or anticipated to be implemented and managed by the OCWD and SWRCB DDW. In addition, well permits are required to install and maintain water supply wells and monitor wells within Orange County. These programs are expected to continue; therefore, the long-term permanence of such measures is considered to be high.

Alternative GW5A would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.5.1.5 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

The toxicity of VOCs and 1,4-dioxane in groundwater throughout the wellfield capture area would be irreversibly reduced or eliminated by the treatment process options currently considered for these COCs (i.e., AOP and LPGAC). Use of these treatment processes would satisfy the statutory preference for treatment as a principal element of the remedial action. The majority of VOCs and 1,4-dioxane will be destroyed by the AOP. The remaining VOCs will be removed by adsorption to LPGAC. The VOCs will be thermally destroyed when the LPGAC is reactivated at a permitted off-site facility. The mobility of COCs present in groundwater will be effectively reduced through hydraulic containment using extraction. Additionally, the re-injection of treated water into the off-site injection wells will increase COC mobility toward the extraction wells, potentially reducing overall remedy time.

Under Alternative GW5A, the extraction and treatment system would actively remove volume and mass from throughout the wellfield capture area. Additional mass would be lost through degradation and other natural attenuation processes. Therefore, overall volume and mass of COCs in the groundwater would be reduced over time.

The relative reduction of toxicity, mobility, and volume or mass was assessed based on the estimated percentage of 1,1-DCE and 1,4-dioxane removed using model projected capture zones and measured concentrations within different portions of the groundwater system as described in greater detail in Appendix A. Overall, the relative reduction of toxicity, mobility, and volume or mass for Alternative GW5A was estimated to be high (Appendix A).

5.2.5.1.6 Implementability

Alternative GW5A is implementable both from a technical and an administrative feasibility.

The groundwater remediation system also requires building and/or well construction permits from the Orange County Health Care Agency, City of Fullerton, City of Buena Park, Orange County Flood Control District, a treated water discharge permit from the OCSD (to the extent the treated groundwater is temporarily disposed of to the sewer), registration of extraction wells/treatment system with OCWD, CFFD permits for materials storage, and a WDR permit issued by the RWQCB-SA. The well permits, OCWD registration, and WDR permits are readily attainable and the SPDP to the sanitary sewer is existing, but subject to renewal. A majority of the remediation system construction would occur in areas that are currently developed and would be completed under new and/or existing access agreements with property owners and agencies. The Brea Creek pipeline and well alignment will require a new access agreement with Orange County Flood Control District. Additional monitor, extraction, and injection wells, pipelines and treatment facilities will need to be installed that will require well installation and building permits from Orange County Flood Control District, the City of Fullerton and/or the City of Buena Park. Access agreements may need to be executed for new well locations. New access agreement and permits for this project, if required, should be readily obtainable with the potential exception of permits for pipelines along Orange County Flood Control District right of way adjacent to the Brea Creek Channel. In addition, installation of pipelines may be more difficult in the residential neighborhood where off-site injection wells would be installed.

Ongoing O&M requirements would involve coordination with property owners and tenants.

5.2.5.1.7 Cost

Estimated present worth remedy lifetime costs for Alternative GW5A is $20,600,000 (20 year NPV at 1.4 percent). Detailed cost estimates and a NPV summary are included in Appendix B.

5.2.5.1.8 Green and Sustainable Screening

The energy requirements for Alternative GW5A are high as there are on-Site and off-site extraction wellfields and the capacity of this groundwater extraction and treatment alternative is between Alternatives GW4 and GW6A. This alternative does return treated groundwater to the groundwater basin and therefore preserves the water resource. Discharge of treated groundwater to the sanitary sewer would be temporary in nature and would not exceed 50 gpm. This type of discharge would be minimized to preserve the water resource and a replenishment assessment fee would be paid to OCWD for treated groundwater discharged to the sanitary sewer.

5.2.5.2 Groundwater Alternative GW5B: On-Site and Brea Creek Alignment Extraction with Off-Site Unit B Injection and Non-Potable Water Reuse

Alternative GW5B is similar to GW5A and includes the same on-Site and off-site groundwater extraction wells, flowrates, extraction pipelines and treatment to provide treatment to control COC migration in regional groundwater both on-Site downgradient of former source areas and off-site. Under Alternative GW5B, however, the treated groundwater end use is split between an off-site injection well(s) that still serves to provide enhanced downgradient hydraulic flushing, and the remainder of treated groundwater is provided to the City of Fullerton for non-potable reuse (Figure 19).

The extracted groundwater would be treated using an AOP system to treat 1,4-dioxane and LPGAC to treat VOCs (Figure 20). Multi-bag filters would be used to remove particulates prior to treatment for 1,4-dioxane and VOCs. A portion of the treated groundwater would be discharged to an off-site Unit B injection well, IW-03, and the remainder of the treated groundwater would be provided to the City of Fullerton as non-potable for irrigation, industrial use, and as make-up water for Lake Laguna via a below-grade HDPE pipeline.

Groundwater monitoring would be similar to Alternative GW5A, and include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.5.2.1 Overall Protection of Human Health and the Environment

Protection of human health and the environment is similar to Alternative GW5A as discussed in Section 5.2.5.1.1.

5.2.5.2.2 Attain Remedial Action Objectives

Alternative GW5B would attain RAOs similar to Alternative GW5A as discussed in Section 5.2.5.1.2.

5.2.5.2.3 Short-Term Effectiveness

The short-term effectiveness for Alternative GW5B is similar to Alternative GW5A as discussed in Section 5.2.5.1.3.

5.2.5.2.4 Long-Term Reliability and Effectiveness

The long-term reliability and effectiveness for Alternative GW5B is similar to Alternative GW5A as discussed in Section 5.2.5.1.4.

5.2.5.2.5 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

The reduction of toxicity, mobility, and volume or mass by Alternative GW5B is similar to Alternative GW5A as described in Section 5.2.5.1.5.

5.2.5.2.6 Implementability

Alternative GW5B, like Alternative GW5A, is implementable both from a technical and an administrative feasibility. Implementability of non-potable reuse would depend on the City of Fullerton's capacity to reuse non-potable treated groundwater including obtaining necessary permits for respective non-potable reuse and installation of required infrastructure.

5.2.5.2.7 Cost

Estimated present worth remedy lifetime costs for Alternative GW5B is similar to GW5A, or about $20,600,000. Costs associated with infrastructure to deliver non-potable reuse water, additional permitting, additional treatment, if needed, and/or replenishment fees would be the responsibility of the purveyor of non-potable water and are not included in the cost estimate for Alternative GW5B.

5.2.5.2.8 Green and Sustainable Screening

The energy requirements for Alternative GW5B are similar to Alternative GW5A; however, on an overall perspective would be lower than Alternative GW5A as the energy required to lift the water from the groundwater basin to end user would be implemented in a more sustainable manner. This alternative returns a portion of the treated groundwater to the groundwater basin and uses the treated groundwater in a sustainable manner to off-site existing potable water demand for respective end users.

<u>5.2.6 Groundwater Alternative GW6: On-Site and South of Brea Creek Extraction Pump and Treat</u>

Groundwater Corrective Measure Alternative GW6 consists of on- and off-site groundwater extraction, treatment, and different end use of the treated groundwater (Figures 21 through 24). Off-site extraction wells are all located south of Malvern Avenue. Two options for treated water end use are:

- Alternative GW6A: Injection Well Discharge; on-Site Unit A and Unit B injection; and off-site injection into the shallow zone as well as the Unit B to provide forced-gradient, enhanced hydraulic flushing of the relatively stagnant area downgradient to the west of the Site as observed in Alternative GW4.

- Alternative GW6B: Injection Well Discharge and City of Fullerton Non-Potable Water Reuse; off-site injection into Unit B provides enhanced flushing to the west of the Site, City of Fullerton water re-use for non-potable irrigation and industrial water supply, as well as make-up water for the Laguna Lake.

5.2.6.1 Groundwater Alternative GW6A: On-Site and South of Brea Creek Extraction, with On- and Off-Site Distributed Injection

Groundwater Alternative GW6A is similar to Alternative GW5A with the exception that all of the extraction wells are located south of the Brea Creek alignment which is less efficient for capture of off-site COCs in groundwater as it places the off-site extraction further to the south relative to the higher COC concentration areas and is limited as to how far to the west the extraction wells can be placed and therefore requires higher extraction rates to contain the COC-impacted area.

Alternative GW6A includes on-Site and off-site extraction and treatment to control COC migration in regional groundwater both on-Site downgradient of former source areas and off-site. The objective of Alternative GW6A is to establish hydraulic containment of impacted groundwater located on-Site and hydraulic containment and treatment of impacted groundwater off-site. Alternative GW6A would extract groundwater using five existing wells, EW-01, EW-02, MW-21, MW-29, and MW-31, and three proposed extraction wells, EW-05, EW-06, and EW-07, at a total design flowrate of 590 gpm. The impacted groundwater would be conveyed through a below-grade DCHDPE pipeline to a treatment facility (Figure 21).

The extracted groundwater would be treated using an AOP system to treat 1,4-dioxane and LPGAC to treat VOCs (Figure 22). Multi-bag filters would be used to remove particulates prior to treatment for 1,4-dioxane and VOCs. The treated groundwater would be discharged to five existing shallow groundwater injection wells, UAI-1 through UAI-5, four proposed on-Site injection wells (two Unit A wells, IW-06A and IW-07A, and two Unit B wells, IW-01 and IW-02), and one injection well located downgradient of the Site in the Unit B to enhance hydraulic flushing in this area, IW-03. If for any reason the discharge to the injection wells was temporarily not viable, treated water could be discharged for short periods of time at rates of up to 50 gpm to the sanitary sewer under a new SPDP issued by the OCSD. Discharge flowrate to the sanitary sewer under the existing SPDP for the pilot system cannot exceed 50 gpm, mainly due to the capacity of the existing connection.

Groundwater monitoring would be conducted during operation of the groundwater corrective action to monitor performance of the corrective measure alternative. Initial monitoring would include quarterly sampling of selected monitor wells and POCs and less frequent sampling of other wells. Natural attenuation processes would also occur in areas where active groundwater extraction and treatment is implemented although MNA parameters would not be monitored as part of this alternative. The initial monitoring would also include quarterly water level measurements at accessible wells. Overall monitoring frequency would decrease with time.

Following DTSC approval of corrective action termination, the treatment system would be demobilized. Demobilization would include teardown of remediation system equipment, abandonment of the extraction and collection systems, and removal of all equipment from the Site.

Alternative GW6A would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.6.1.1 Overall Protection of Human Health and the Environment

Protection of human health and the environment would be achieved under Alternative GW6A through similar mechanisms outlined for Alternative GW5A (Section 5.2.5.1.1).

Alternative GW6A also includes the same Institutional Controls as outlined for the MNA alternative (Section 5.2.2.2).

The treated groundwater discharge option for Alternative GW6A would be managed by meeting discharge requirements specified under a WDR permit issued by RWCQB-SA.

As the groundwater extraction and treatment technologies included for the Site under Alternative GW6A are based on standard, accepted treatment practices, this alternative does not pose any unacceptable short-term risks or other adverse impacts.

5.2.6.1.2 Attain Remedial Action Objectives

Prevent unacceptable exposure to groundwater containing COCs. Currently, there are no groundwater production wells within the vicinity of the Site that exceed the MCLs for Site-related COCs in drinking water. Alternative GW6A includes active remediation to reduce or control COC migration on- and off-site, and also includes Institutional Controls to monitor and control the pathway by which persons could be exposed to groundwater containing COCs. Shut down of groundwater production wells and/or consumption of groundwater containing COCs exceeding MCLs is not, and will not likely occur given existing and planned groundwater production in the area and the GETS that provides hydraulic containment both on- and off-site.

Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas. Alternative GW6A would provide effective, long-term control of the COCs in groundwater through extraction and treatment of groundwater using proven technologies. The projected hydraulic capture zone of the extraction and injection wellfields is based on the groundwater model as shown in Appendix A. It is anticipated that the capture zone would be established in a relatively short-time frame (several months) after the extraction wellfield becomes operational.

Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at POCs and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical. The off-site extraction wellfield would contain and treat a large proportion of the COCs in off-site groundwater. In addition, COC mass that is potentially outside the off-site extraction wellfield capture zone would naturally attenuate. COC concentrations could be reduced to levels near or below drinking water MCLs within a period one to several decades assuming the on- and off-site groundwater extraction system is effective in minimizing migration of COCs in groundwater and natural attenuation processes further contribute to the concentration reduction.

The potential risk during implementation of Alternative GW6A would be managed through OCWD monitoring requirements for water production and the SWRCB DDW Program requirement that ensures delivery of safe drinking water, as well as Site-specific Institutional Controls prohibiting installation of water wells on the Site.

5.2.6.1.3 Short-Term Effectiveness

Alternative GW6A incorporates an on- and off-site GETS and naturally occurring processes to reduce the concentration of COCs in groundwater beneath and downgradient of the Site. Performance of Alternative GW6A is monitored on a regular basis (quarterly for the first 5 years then less frequently thereafter).

Protection of Community and Workers. During construction of Alternative GW6A, it is anticipated that there will be limited short-term impacts to the community. These impacts could include temporary road/lane closures, traffic detours, noise associated with drilling and well installation equipment, pipeline installation, and dust. These impacts would be minimized through the implementation of various abatement plans (e.g., traffic control plans, air permits, and building permits).

Workers would be adequately protected during construction by adhering to OSHA practices. Workers would also be protected while operating and maintaining facilities by adhering to appropriate health and safety procedures. In addition, monitor, extraction, and/or injection wells are not planned to be installed in arterial roadways to minimize risks associated with repeated work in high traffic areas over the duration of the project.

Environmental Impacts. There are no adverse long-term environmental impacts anticipated to be associated with Alternative GW6A. However, it is noted that electrical consumption for operation of equipment, submersible pumps, and ancillary equipment will generate GHG emissions, but quantities are expected to be minimal. Treated groundwater will be re-injected into the aquifer for Alternative GW6A, reducing the amount of water use, and maintaining goals of water conservation. Given land use at and surrounding the Site, environmental permitting beyond that required to construct, maintain, and operate the remedy is not anticipated to be required.

5.2.6.1.4 Long-Term Reliability and Effectiveness

With respect to long-term reliability and effectiveness of controls, the technologies and associated equipment and monitoring facilities proposed for Alternative GW6A are proven and reliable. The monitor wells, monitoring equipment, extraction wells and pumps, conveyance piping, transfer pumping, treatment processes for removal of the COCs, treated water management facilities, and associated instrumentation and control systems are common, well established remedy components that have been implemented elsewhere. In general, injection wells are an established method for changing the rate and direction of the groundwater flow, which can decrease the overall treatment period, and increase removal efficiency of COCs.

COC mass in the downgradient lower-concentration portion of the off-site groundwater that is potentially outside the extraction wellfield capture zone would naturally attenuate. Current and proposed Institutional Controls are based on programs currently or anticipated to be implemented and managed by the OCWD and SWRCB DDW. In addition, well permits are required to install and maintain water supply wells and monitor wells within Orange County. These programs are expected to continue; therefore, the long-term permanence of such measures is considered to be high.

Alternative GW6A would include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.6.1.5 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

The toxicity of VOCs and 1,4-dioxane in groundwater throughout the wellfield capture area would be irreversibly reduced or eliminated by the treatment process options currently considered for these COCs (i.e., AOP and LPGAC). Use of these treatment processes would satisfy the statutory preference for treatment as a principal element of the remedial action. The majority of VOCs and 1,4-dioxane will be destroyed by the AOP. The majority of the remaining VOCs will be removed by adsorption to LPGAC. The VOCs will be thermally destroyed when the LPGAC is reactivated at a permitted off-site facility. The mobility of COCs present in groundwater will be effectively reduced through hydraulic containment using extraction.

Under Alternative GW6A, the extraction and treatment systems would actively remove volume and mass from groundwater. Additional mass would be lost through degradation and other natural attenuation processes. Therefore, overall volume and mass of COCs in the groundwater would be reduced over time.

The relative reduction of toxicity, mobility, and volume or mass was assessed based on the estimated percentage of 1,1-DCE and 1,4-dioxane removed using model projected capture zones and measured concentrations within different portions of the groundwater system as described in greater detail in Appendix A. Overall, the relative reduction of toxicity, mobility, and volume or mass for Alternative GW6A was estimated to be high (Appendix A).

5.2.6.1.6 Implementability

Alternative GW6A is implementable both from a technical and an administrative feasibility.

The groundwater remediation system also requires building and/or well construction permits from the Orange County Health Care Agency, City of Fullerton, City of Buena Park, a treated water discharge permit from the OCSD (to the extent the treated groundwater is temporarily disposed of to the sewer), registration of extraction wells/treatment system with OCWD, CFFD permits for materials storage, and a WDR permit issued by the RWQCB-SA. The well permits, OCWD registration, and WDR permits are readily attainable and the SPDP to the sanitary sewer is existing, but subject to renewal. All proposed remediation system construction would occur in areas that are currently developed and would be completed under new and/or existing access agreements with property owners and agencies. Additional monitor, extraction, and injection wells, pipelines and treatment facilities will need to be installed that will require well installation and building permits from the City of Fullerton and/or the City of Buena Park. Access agreements may need to be executed for new well locations. New access agreements and permits for this project, if required, should be readily obtainable. Installation of pipelines may be more difficult in the residential neighborhood where the off-site injection well would be installed.

Ongoing O&M requirements would involve coordination with property owners and tenants.

5.2.6.1.7 Cost

Estimated present worth remedy lifetime cost for Alternative GW6A is $23,800,000 (20 year NPV at 1.4 percent). Detailed cost estimates and a NPV summary are included in Appendix B.

5.2.6.1.8 Green and Sustainable Screening

The energy requirements for Alternative GW6A are the highest of all the alternatives as a greater volume of water is extracted due to less efficient alignment of off-site extraction wells. This alternative does return treated groundwater to the groundwater basin and therefore preserves the water resource. Discharge of treated groundwater to the sanitary sewer would be temporary in nature and would not exceed 50 gpm. This type of discharge would be minimized to preserve the water resource and a replenishment assessment fee would be paid to OCWD for treated groundwater discharged to the sanitary sewer

5.2.6.2 Groundwater Alternative GW6B: On-Site and South of Brea Creek Extraction, with Off-Site Injection and Non Potable Water Reuse

Alternative GW6B is similar to GW6A and includes the same on-Site and off-site groundwater extraction wells, flowrates, extraction pipelines and treatment to provide containment and treatment of COC-impacted groundwater. Under Alternative GW6B, however, the treated groundwater end use is split between an off-site injection well(s) that still serves to provide enhanced downgradient hydraulic flushing, and the remainder of treated groundwater is provided to the City of Fullerton for non-potable reuse (Figure 23)

5.2.6.2.1 Alternative GW6B: On-Site and South of Brea Creek Extraction, with Off-Site Injection and Non Potable Water Reuse Description

Alternative GW6B includes on-Site and off-site extraction and treatment to provide source control and hydraulic containment. The objective of Alternative GW6B is to establish hydraulic containment of impacted groundwater located on-Site and off-site. Alternative GW6B would extract groundwater using five existing wells, EW-01, EW-02, MW-21, MW-29, and MW-31, and three proposed extraction wells, EW-05, EW-06, and EW-07, at a total design flowrate of 590 gpm. The impacted groundwater would be conveyed through a below-grade DCHDPE pipeline to a treatment facility (Figure 23).

The extracted groundwater would be treated using an AOP system to treat 1,4-dioxane and LPGAC to treat VOCs (Figure 24). Multi-bag filters would be used to remove particulates prior to treatment for 1,4-dioxane and VOCs. A portion of the treated groundwater would be discharged to an off-site Unit B injection well, IW-03, and the remainder of the treated groundwater would be provided to the City of Fullerton as non-potable for irrigation, industrial use, and as make-up water for Lake Laguna via a below-grade HDPE pipeline.

Groundwater monitoring would be similar to Alternative GW6A, and include contingencies to alter the remedy in the event that the remedy is not meeting performance goals, as discussed in Section 6.

5.2.6.2.2 Overall Protection of Human Health and the Environment

Protection of human health and the environment is similar to Alternative GW6A as discussed in Section 5.2.6.1.2.

5.2.6.2.3 Attain Remedial Action Objectives

Alternative GW6B would attain RAOs similar to Alternative GW6A as discussed in Section 5.2.6.1.3

5.2.6.2.4 Short-Term Effectiveness

The short-term effectiveness of Alternative GW6B is similar to Alternative GW6A as discussed in Section 5.2.6.1.4.

5.2.6.2.5 Long-Term Reliability and Effectiveness

The long-term reliability and effectiveness for Alternative GW6B is similar to Alternative GW6A as discussed in Section 5.2.6.1.5.

5.2.6.2.6 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

The reduction of toxicity, mobility, and volume or mass by Alternative GW6B is similar to Alternative GW6A as described in Section 5.2.6.1.6.

5.2.6.2.7 Implementability

Alternative GW6B, like Alternative GW6A, is implementable both from a technical and an administrative feasibility. Implementability of non-potable reuse would depend on the City of Fullerton's capacity to reuse non-potable treated groundwater including obtaining necessary permits for respective non-potable reuse and installation of required infrastructure.

5.2.6.2.8 Cost

Estimated present worth remedy lifetime cost for Alternative GW6B is similar to GW6A, or about $23,800,000 (20 year NPV at 1.4 percent). Costs associated with infrastructure to deliver non-potable reuse water, additional permitting, additional treatment, if needed, and/or replenishment fees would be the responsibility of the purveyor of non-potable water and are not included in the cost estimate for GW6B.

5.2.6.2.9 Green and Sustainable Screening

The energy requirements for Alternative GW6B are similar to Alternative GW6A; however, on an overall perspective would be lower than Alternative GW6A as the energy required to lift the water from the groundwater basin to end user would be implemented in a more sustainable manner. Alternative GW6B would use energy to extract the groundwater, then return the groundwater to the basin and the groundwater would then be extracted again from a production well and delivered to end user. This alternative returns a portion of the treated groundwater to the groundwater basin and uses the treated groundwater in a sustainable manner to off-site existing potable water demand for respective end users.

6.0 CONTINGENCIES FOR GROUNDWATER CORRECTIVE MEASURES ALTERNATIVES

Contingencies for groundwater corrective measures alternatives may be implemented in order to address specific human health or environmental concerns. Contingencies may also be implemented to modify the scope of the respective program in response to changes in field conditions or observations during CMI. The ability to implement contingencies increases the flexibility of the respective corrective measure alternative based on an ongoing evaluation of the results of the associated monitoring programs.

The following outlines triggers and a description of associated contingencies for the groundwater corrective alternatives described in Section 5. The initial contingency action would be implemented first with the secondary contingency action being implemented if the initial does not achieve performance requirements. The decision analysis for contingency actions associated with groundwater corrective measures alternatives have been outlined in the following sections for all but the No Action Alternative (GW1).

6.1 GROUNDWATER ALTERNATIVE GW2: MONITORED NATURAL ATTENUATION

Two contingency actions have been identified for Groundwater Alternative GW2: MNA as summarized in the following.

IDENTIFIER	TRIGGER	INITIAL CONTINGENCY ACTION	SECONDARY CONTINGENCY ACTION
GW2a	Increasing concentration trends in one or more of the POC monitor wells at end of first 5 years of monitoring	Evaluate implementation of alternative on-Site and/or off-site groundwater extraction and treatment corrective action	-
GW2b	Fullerton Well 9 Exceeds 50 percent of MCL for more than 6 months	Isolate Unit B in Well 9 and monitor AND Implement groundwater containment	Implement wellhead treatment at Well 9

6.2 GROUNDWATER ALTERNATIVE GW3: ON-SITE EXTRACTION AND INJECTION WITH OFF-SITE MONITORED NATURAL ATTENUATION

Three contingency actions have been identified for On-Site extraction with off-site MNA Alternative GW3 as summarized in the following.

IDENTIFIER	TRIGGER	INITIAL CONTINGENCY ACTION	SECONDARY CONTINGENCY ACTION
GW3a	Increasing concentration trends in one or more of the POC monitor wells at end of first 5 years of monitoring	Evaluate implementation of alternative off-Site groundwater extraction and treatment corrective action	-
GW3b	Fullerton Well 9 Exceeds 50 percent of MCL for more than 6 months	Isolate Unit B in Well 9 and monitor AND Implement off-site groundwater extraction and treatment corrective action	Implement wellhead treatment at Well 9 OR Relocate well
GW3c	Water level, model simulations and/or long-term water quality trends indicating on-Site containment not adequate	Evaluate increasing extraction rate at existing extraction wells	Add additional extraction wells

6.3 GROUNDWATER ALTERNATIVES GW4, GW5 AND GW6: ON- AND OFF-SITE EXTRACTION

Four contingency actions have been identified for the on- and off-site extraction alternatives as summarized in the following.

IDENTIFIER	TRIGGER	INITIAL CONTINGENCY ACTION	SECONDARY CONTINGENCY ACTION
GW4/5/6a	Increasing concentration trends in one or more of the POC monitor wells at end of first 5 years of monitoring	Evaluate increasing extraction rate at existing off-site extraction wells	Add additional off-site extraction wells

IDENTIFIER	TRIGGER	INITIAL CONTINGENCY ACTION	SECONDARY CONTINGENCY ACTION
GW4/5/6b	Fullerton Well 9 Exceeds 50 percent of MCL for more than 6 months	Isolate Unit B in Well 9 and monitor AND evaluate increasing extraction rate at existing off-site extraction wells or adding an additional off-site extraction well	Implement wellhead treatment at Well 9 OR Relocate well
GW4/5/6c	Water level, model simulations and/or long-term water quality trend indicating on-Site containment not adequate	Evaluate increasing extraction rate at existing on-Site extraction wells	Add additional on-Site extraction wells
GW4/5/6d	Water level, model simulations and/or long-term water quality trend indicating off-site containment not adequate	Evaluate increasing extraction rate at existing off-site extraction wells	Add additional off-site extraction wells

7.0 PREFERED GROUNDWATER CORRECTIVE MEASURE

This section provides a comparison of the groundwater corrective measures alternatives and presents the preferred alternative. In addition, an optional reconfiguration of Well 9 is presented in the last section. This optional reconfiguration could minimize hydraulic influences that Well 9 has on the preferred groundwater corrective measure alternative, but is subject to further testing and coordination with the City of Fullerton. The optional reconfiguration is not a required element of the groundwater corrective measure, but if implemented would likely include an additional monitor well to help assess performance of the groundwater corrective measure.

7.1 COMPARISON OF GROUNDWATER CORRECTIVE MEASURES ALTERNATIVES

Corrective measure technologies retained from Section 4 have been assembled into several alternatives. All of the alternatives, with the exception of the No Action Alternative (GW1), incorporate Institutional Controls. All of the alternatives have some degree of natural attenuation, including, but not limited to, the MNA Alternative (GW2). Groundwater alternatives GW3 to GW6 incorporate groundwater extraction and treatment with different methods of managing treated water end use. There are three different extraction wellfield configurations that are being evaluated: on-site extraction wells (GW3 to GW6); off-site extraction wells aligned along Brea Creek Channel (GW4 and GW5); and off-site extraction wells to the south of Brea Creek (GW6). There are multiple end uses of treated groundwater that are evaluated that include use of reinjection only (GW3, GW4, GW5A, and GW6A) or a combination of focused reinjection and non-potable reuse (GW5B and GW6B). The different groundwater extraction and end use configurations were evaluated to assess similarities and differences in performance of the different alternatives to facilitate selection of the preferred alternative as well as acceptable alternate configurations should access limitations prevent implementation of the preferred alternative.

The following sections compare each of the corrective measures alternatives based on the following (Table 2):

- Overall protection of human health and the environment
- Ability to attain RAOs
- Short-term effectiveness
- Long-term reliability and effectiveness
- Reduction of toxicity, mobility, and volume or mass through treatment
- Implementability
- Cost
- Green and Sustainable

7.1.1 Protection of Human Health and the Environment

Currently, there are no groundwater production wells within the vicinity of the Site that exceed MCLs for Site-related COCs in drinking water and no surface waters are affected as Site COCs are constrained to deep groundwater. As such, all of the groundwater corrective measures alternatives are currently protective of human health and ecological receptors.

The No Action Alternative (GW1) for groundwater may be protective of human health in the long-term; however, this alternative does not directly control COC migration in groundwater nor does it include Site-specific Institutional Controls that monitor quality and use of groundwater in the vicinity of the Site. The MNA Alternative (GW2) may be protective of human health in the long-term; however, this alternative does not directly control migration of COCs in groundwater. The on-Site groundwater extraction and treatment with off-site MNA Alternative (GW3) is expected to be similar to the MNA Alternative (GW2) with additional reduction in COC concentration and mass through the operation of an on-Site GETS. The remaining on- and off-site groundwater extraction and treatment alternatives (GW4, GW5A, GW5B, GW6A, and GW6B) are expected to provide the greatest level of long-term protection of human health and the environment (Table 2).

7.1.2 Attain Remedial Action Objectives

RAOs are presented in Section 3. The following lists each RAO and provides a summary for each of the alternatives.

Prevent unacceptable exposure to groundwater containing COCs. As described in the previous section, there are currently no groundwater production wells within the vicinity of the Site that exceed MCLs for Site-related COCs in drinking water. The No Action and MNA Alternatives (GW1 and GW2) could result in shut down of groundwater production wells if natural attenuation is not sufficient to control future migration of COCs in groundwater. Although on-Site groundwater extraction and treatment with off-site MNA (Alternative GW3) would be expected to be overall more protective than the No Action and MNA Alternatives, this alternative could result in shut down of groundwater production wells if natural attenuation is not sufficient to control future migration of COCs in groundwater downgradient of the Site. For the remaining on- and off-site groundwater extraction and treatment alternatives (GW4, GW5A, GW5B, GW6A, and GW6B), shut down of groundwater production wells and/or consumption of groundwater containing COCs exceeding MCLs will not likely occur given existing and planned groundwater production in the area and the GETS that provides hydraulic containment and treatment of groundwater both on- and off-site.

Establish containment areas within the regional groundwater system to control future residual COC migration from former source areas. The No Action and MNA Alternatives (GW1 and GW2) will not achieve this RAO. All of the groundwater extraction and treatment alternatives (GW3, GW4, GW5A, GW5B, GW6A, and GW6B) would provide effective, short- and long-term control of the on-Site COCs in groundwater through extraction and treatment of groundwater using proven technologies. It is anticipated that the capture zone would be established for all these alternatives in a relatively short time frame (several months) after the extraction wellfield becomes operational.

Contain COCs in groundwater to protect current and future uses of groundwater with a short-term goal of not exceeding drinking water MCLs at POCs and a long-term goal of attaining drinking water MCLs in groundwater to the extent practical. The No Action and MNA Alternatives (GW1 and GW2) may meet the short-term goal if future extraction patterns in the groundwater basin in the general vicinity of the Site remain similar to those over the past decade or so. Changes in groundwater extraction patterns could pose a relatively high risk to both of these alternatives in meeting the short-term goal. Both of these alternatives might not meet the long-term goal. For on-Site groundwater extraction and treatment with off-site MNA (Alternative GW3), the off-site lower concentration areas would naturally attenuate over time. COC concentrations may be reduced to levels near or below drinking water MCLs in one to several decades assuming the on-Site groundwater extraction system is effective in minimizing migration of COCs in groundwater downgradient of the former source areas and natural attenuation processes contribute to concentration reduction in off-site groundwater. For the remaining on- and off-site groundwater extraction and treatment alternatives (GW4, GW5A, GW5B, GW6A, and GW6B), the short-term goal is likely to be met and the long-term goal could be met within a period one to several decades assuming the on- and off-site groundwater extraction system is effective in minimizing migration of COCs in groundwater and natural attenuation processes further contribute to the concentration reduction.

The potential risk during implementation of all the alternatives with the exception of the No Action Alternative would be managed through OCWD monitoring requirements for water production and the SWRCB DDW Program requirement that ensures delivery of safe drinking water, as well as Site-specific Institutional Controls prohibiting installation of water wells on the Site. The No Action Alternative, as its name implies, would have no risk management other than existing non-site specific Institutional Controls such as the SWRCB DDW Program.

7.1.3 Short-Term Effectiveness

The No Action Alternative (GW1) does not include any active measures and would pose no short-term risks to the community or to workers as a result of implementing the alternative. The MNA Alternative (GW2) would have similar short-term performance as the No Action Alternative, as no active remediation facilities would be installed. During construction of alternatives with groundwater extraction and treatment (GW3, GW4, GW5A, GW5B, GW6A, and GW6B), it is anticipated that there will be limited short-term impacts to the community which would be minimized through the implementation of various abatement plans (e.g., traffic control plans, air permits, and building permits). Workers would be adequately protected during construction by adhering to OSHA practices. Workers would also be protected while operating and maintaining facilities by adhering to appropriate health and safety procedures.

There were no adverse long-term environmental impacts anticipated to be associated with any of the alternatives. For all of the alternatives with exception of the No Action Alternative, environmental permitting beyond those required to construct, maintain, and/or operate the respective remedy is not anticipated to be required. For the No Action Alternative, no environmental impacts were anticipated as there would be no construction activities associated with this alternative.

7.1.4 Long-Term Reliability and Effectiveness

The No Action and MNA Alternatives (GW1 and GW2) would have minimal effectiveness in reducing the impacted groundwater due to continuing mass flux from the former source areas to the groundwater system and low degradation rates. The technologies and associated equipment, and monitoring facilities proposed for alternatives with groundwater extraction and treatment (portions of GW3, GW4, GW5A, GW5B, GW6A, and GW6B) are proven effective in containing and treating impacted groundwater.

An evaluation of the adequacy and reliability of controls for the No Action Alternative (GW1) is not applicable as there are no controls associated with this alternative. Monitoring facilities associated with the MNA Alternative (GW2) and the off-site portions of Alternative GW3 are proven and reliable. The reliability of natural attenuation to control migration of COCs is considered to be relatively low given the nature and extent of COCs observed in the groundwater at and downgradient of the Site. For alternatives with groundwater extraction and treatment (portions of GW3, GW4, GW5A, GW5B, GW6A, and GW6B), the monitor wells, monitoring equipment, extraction/injection wells and pumps, conveyance piping, treatment processes for removal of the COCs, treated water management facilities, associated instrumentation and control systems are common, well established remedy components that have been implemented and proven elsewhere and are reliable.

For all alternatives with the exception of the No Action Alternative, current and proposed Institutional Controls are based on programs currently implemented and managed by OCWD and SWRCB DDW. In addition, well permits are required to install and maintain water supply wells and monitor wells within Orange County. These programs are expected to continue; therefore, the long-term permanence of such measures is considered to be high.

Alternatives GW2 to GW6 would include contingencies to alter the respective remedy in the event that the respective remedy is not meeting performance goals as outlined in Section 6.

7.1.5 Reduction of Toxicity, Mobility, and Volume or Mass through Treatment

The No Action and MNA Alternatives (GW1 and GW2) do not provide any reduction in toxicity beyond the natural attenuation of COCs that may occur in the groundwater. No reduction of mobility or volume through treatment would occur since no treatment technologies would be implemented. Overall, the relative reduction of toxicity, mobility and volume or mass was estimated to be relatively low for the alternatives that rely solely on natural attenuation processes.

For alternatives with groundwater extraction and treatment (portions of GW3, GW4, GW5A, GW5B, GW6A, and GW6B), the relative reduction of toxicity, mobility, and volume or mass was assessed. Use of treatment processes for each of these alternatives would satisfy the statutory preference for treatment as a principal element of the remedial action. The on-Site groundwater extraction with off-site MNA (GW3) had a relative reduction of toxicity, mobility, and volume or mass that was estimated to be moderate. The relative reduction was estimated to be high for the groundwater extraction and treatment alternatives with on- and off-site extraction wellfields (GW4, GW5A, GW5B, GW6A, and GW6B).

7.1.6 Implementability

All alternatives are implementable both from a technical and administrative feasibility.

No construction permits or off-site access agreements are included in the No Action Alternative (GW1). All construction and monitoring for the MNA Alternative (GW2) and the on-Site groundwater extraction and off-site MNA alternative (GW3) would occur in areas that are currently developed and would be completed under new and/or existing access agreements with property owners, cities, and/or agencies and were considered to be readily obtainable. All construction and monitoring for alternatives with off-site groundwater extraction wellfields (GW4, GW5A, GW5B, GW6A, and GW6B) would occur in areas that are currently developed and would be completed under new and/or existing access agreements with property owners, cities, and/or agencies and were considered to be readily obtainable with the following potential exceptions:

- The alternatives with groundwater extraction along the Brea Creek Channel (GW4, GW5A, and GW5B) could require a new access agreement with Orange County Flood Control District for pipelines along Orange County Flood Control District right of way adjacent to the Brea Creek Channel; and
- Installation of pipelines may be more difficult for alternatives with groundwater injection within the residential neighborhoods to the west of the Site (GW5A, GW5B, GW6A, and GW6B).

No operating permits are required for the No Action or MNA Alternatives (GW1 and GW2). Alternatives that involve groundwater treatment (GW3, GW4, GW5A, GW5B, GW6A, and GW6B) require appropriate permits from CFFD. Alternatives that require groundwater reinjection (GW3, GW4, GW5A, GW5B, GW6A, and GW6B) require a WDR permit which is issued by the RWQCB-SA. Alternatives that have the potential for short-term low flow discharges to the sanitary sewer would require a permit for discharging treated water from the OCSD and registration of extraction wells/treatment system with OCWD. These permits are considered readily obtainable.

Alternatives that include non-potable water reuse (GW5B and GW6B) would also require additional construction and operating permits for distribution of non-potable water. Obtaining the permits would be the responsibility of the purveyor of the non-potable water.

7.1.7 Cost

The No Action Alternative (GW1) does not include any active measures and would have no capital or O&M costs associated with its implementation. The cost estimates for each of the remaining alternatives are summarized below incorporating the NPV using the OMB 2015 discount rate guidelines for use in benefit-cost and other types of economic analysis (1.4 percent).

- MNA (GW2): $9,500,000;
- On-Site Extraction with Injection, Off-Site MNA (GW3): $13,400,000;
- On-Site and Brea Creek Alignment Extraction with On-Site and Shallow Off-Site Injection (GW4): $17,800,000;
- On-Site and Brea Creek Alignment Extraction with On- and Off-Site Unit B Injection (GW5A): $20,600,000;
- On-Site and Brea Creek Alignment Extraction with Off-Site Unit B Injection and Non-Potable Reuse (GW5B): effectively the same as GW5A as costs associated with non-potable reuse would be the responsibility of the purveyor of non-potable water;
- On-Site and South of Brea Creek Extraction with On- and Off-Site Distributed Injection (GW6A): $23,800,000;
- On-Site and South of Brea Creek Extraction with Off-Site Unit B Injection and Non-Potable Reuse (GW6B): effectively the same as GW6A as costs associated with non-potable reuse would be the responsibility of the purveyor of non-potable water.

7.1.8 Green and Sustainable Screening

This type of screening does not apply to the No Action Alternative (GW1) as there is no associated action implemented.

The energy requirements for each of the remaining alternatives are summarized as follows: MNA (GW2) are low as there is no operating wellfield; on-Site groundwater extraction and treatment with off-site MNA (GW3) are moderate as the extraction wellfield and capacity are relatively small compared to other groundwater and extraction treatment alternatives; and the remaining groundwater extraction and treatment alternatives (GW4, GW5A, GW5B, GW6A, and GW6B) are high (GW6A being highest) with water reuse alternatives (GW5B and GW6B) having lower life cycle energy use than their reinjection counterparts (GW5A and GW6A).

The sustainability of the water resource for the alternatives other than No Action are summarized as follows: the MNA Alternative (GW2) is rated relatively low given the potential for additional migration of COCs in groundwater; the alternatives that rely solely on reinjection (GW3, GW4, GW5A, and GW6A) are rated high as the treated groundwater is returned to the basin; and alternatives that include reinjection and non-potable reuse (GW5B and GW6B) are also rated as high as the non-potable reuse off-sets demand on existing potable water supply.

7.2 PREFERRED GROUNDWATER CORRECTIVE MEASURE

This section describes the preferred groundwater corrective measure alternative along with acceptable modifications to the preferred alternative and provides a general overview of the performance monitoring approach for the preferred alternative.

7.2.1 Selection of Preferred Alternative

The No Action Alternative (GW1) provides a baseline for comparison to other alternatives. This alternative is not proposed for further consideration as it does not establish containment areas within the regional groundwater system to control future residual COC migration from former source areas, nor does it contain COCs in groundwater to protect current and future uses of groundwater.

Processes that naturally attenuate COCs in groundwater are part of all corrective measure alternatives. The MNA Alternative (GW2), which relies solely on natural attenuation processes, is not proposed for further consideration as the natural attenuation processes have not been sufficient to prevent off-site migration of COCs in groundwater. Natural attenuation is retained as part of the remaining containment and treatment alternatives as natural attenuation processes will likely play an increasingly larger role over time as the concentration and mass of COCs in groundwater are reduced by active treatment.

The remaining alternatives include on-Site groundwater extraction and off-site MNA (GW3) and on- and off-site groundwater extraction (GW4, GW5A, GW5B, GW6A, and GW6B). The on- and off-site groundwater alternatives are preferred to the on-Site groundwater extraction and off-site MNA alternative, as these alternatives are expected to provide the greatest level of long-term protection of human health and the environment along with having a greater likelihood of attaining RAOs (Table 2).

All of the on- and off-site groundwater extraction alternatives incorporate the Institutional Controls outlined in Section 4.2.2. The primary differences between the on- and off-site alternatives that rely solely on reinjection (GW4, GW5A, and GW6A) relate to: 1) the location of off-site extraction wells; and 2) the location and groundwater zone in which injection wells are completed. The remaining two alternatives (GW5B and GW6B) include reinjection and non-potable reuse. Overall Alternative 5A/B has the most efficient extraction and injection wellfield configuration. The extraction wells along the Brea Creek Alignment have a lower cumulative rate of extraction and provide a zone of capture that extends further to the west when compared to the extraction wellfield located south of Brea Creek (GW6A/6B) (Table 3; Figures 25 and 26). The injection wellfield configuration for Alternative GW5A/5B includes reinjection of treated groundwater in the residential neighborhood to the west of the Site to improve flushing of groundwater within Unit B in this area when compared to Alternative GW4 (Appendix A).

The preferred groundwater corrective measure alternative is On-Site and Brea Creek Alignment Extraction with On- and Off-Site Unit B Injection (could include non-potable reuse) (Alternatives GW5A/5B). It is understood that there is some uncertainty as to: 1) the ability to obtain access for extraction wells and/or associated pipeline along the Brea Creek Alignment; and/or 2) the ability to obtain access/install injection pipelines in the residential neighborhood to the west of the Site; as such the preferred alternative may be modified during the CMI design. The following sections provide an overview of the extraction wellfield configuration, treatment system location, and end use of treated groundwater for the preferred alternative including potential modifications that may be required during the CMI design.

7.2.1.1 Extraction Wellfields

The configuration of the preferred extraction wellfield and alternative configurations are described in this section.

7.2.1.1.1 Preferred Configuration

Alternatives GW5A/B would extract groundwater using five existing wells, EW-01, EW-02, MW-21, MW-29, and MW-31, and four proposed extraction wells, EW-03, EW-04, EW-06, and EW-07, at a total design flowrate of 490 gpm (Table 3; Figure 17). The five existing wells and proposed extraction well EW-07 are located on-Site. Proposed extraction wells EW-03, EW-04, and EW-06 are located off-site.

7.2.1.1.2 Modifications to Preferred Configuration

The configuration of the on-Site extraction wells is anticipated to be similar for all modified alternatives. The configuration of the off-site extraction wells could be modified based on one or more of the following:

- If access cannot be obtained for pipelines and/or extraction wells along the Brea Creek Alignment, then extraction wells would be located to the south of Brea Creek (Alternative GW6A/B) (Figures 21 and 23); or
- If access cannot be obtained for pipelines and/or injection wells (linked to Section 7.2.1.3.2) in the residential neighborhood to the west of the Site, then proposed extraction well EW-06 would not be required (essentially similar to Alternative GW4) (Figure 15).

7.2.1.2 Treatment System

There are two potential locations for groundwater treatment systems. The groundwater corrective measure alternative allows for use of one or both of these treatment system locations. The extracted groundwater will contain 1,4-dioxane and VOCs. The treatment processes would include filtration of groundwater before treatment, followed by use of an AOP to treat 1,4-dioxane and some of the VOCs; followed by LPGAC to serve as a final polish for VOC treatment and for reduction of residual hydrogen peroxide from the AOP process. The AOP that will be used in the treatment system employs ultraviolet light and hydrogen peroxide. This configuration is currently being used as part of the pilot GETS. It is anticipated that these technologies will be utilized during initial operation of the preferred groundwater corrective measure alternative. It is also recognized that alternate treatment processes may develop and/or portions of the treatment process may not be required over the duration of the groundwater corrective action. As such, the treatment process can be modified as long as the COCs have been treated to meet end use permit conditions.

7.2.1.3 Treated Groundwater End Use

The configuration of the preferred end use of treated groundwater and alternative configurations are described in this section. Note, as described in Section 5, all of the groundwater extraction and treatment alternatives retain the potential for temporary low flow discharge of treated groundwater to the sanitary sewer. This discharge option is retained for flexibility, but is not expected to manage a significant portion of the treated groundwater and is therefore not described in the following sections.

7.2.1.3.1 Preferred End Use

The end use of treated groundwater for the preferred alternative includes reinjection of the entire volume of groundwater that is extracted and treated or a combination of reinjection and non-potable reuse. The location and target zone for injection wells is relatively flexible; however, the preferred alternative incorporates reinjection into Unit B in the residential neighborhood to the west of the Site (GW5A/B). As such, if non-potable reuse of treated groundwater is incorporated into the remedy, reinjection of a portion of the treated groundwater into Unit B is maintained in this area (GW5B).

If non-potable reuse is incorporated into the remedy, the extracted groundwater would be treated to standards required as part of the WDR permit for groundwater reinjection issued by the RWQCB-SA. This treated water would be provided to the purveyor of non-potable water who is responsible for the construction, permitting, and operation of the non-potable distribution system. In addition, any tertiary treatment exceeding WDR standards that may be required for non-potable reuse will be the responsibility of the water purveyor. The determination of whether non-potable water reuse will be incorporated into the remedy will be made by Raytheon and the purveyor of non-potable water during CMI design. This determination could also be made at some time in the future after CMI design is complete as long as initial CMI design incorporated an injection wellfield with sufficient capacity to accept the entire volume of groundwater extracted and treated.

7.2.1.3.2 Modifications to Preferred End Use

The location and/or target zone for reinjection is flexible as the inorganic water quality of groundwater extracted from Unit B is generally of higher quality than that of Unit A and/or than that of the shallow zone groundwater (Section 4.2.4.3). The original injection wellfield configuration will be determined during CMI design and can be modified after CMI design if injection is problematic in one or more of the different locations/target zones. As indicated previously, the preferred alternative incorporates reinjection into Unit B in the residential neighborhood to the west of the Site (GW5A/B) provided that access for pipelines/wells can be obtained. If access cannot be obtained in this area, then injection in this area will not be pursued and the water would be injected into other accessible area(s) and/or provided for non-potable reuse, if applicable.

7.2.2 Overview of Performance Monitoring

An overview of the performance monitoring plan for the preferred alternative is described in the following sections. The Institutional Controls are summarized in Section 7.2.2.1 based on those presented in Section 4.2.2. The containment of COCs from former source areas is described under the former source area containment section (Section 7.2.2.2). The containment of COCs from former source areas is generally achieved by operating the on-Site extraction wellfield. The protection of the current and future groundwater in the area downgradient from the former source area containment area is described under the protection of current and future uses of groundwater section (Section 7.2.2.3). The protection of current and future groundwater uses is generally achieved through operation of the on- and off-site extraction wellfields.

7.2.2.1 Institutional Controls

The Institutional Controls for the preferred groundwater corrective measure alternative consist of the following:

- Submittal of system performance reports to nearby water users (Cities of Fullerton and Buena Park);
- Annual review of water production and water quality data from Well 9 and Buena Park BP-SM1;
- Annual review of well permits issued in areas from near the Site to within 0.5-mile of POC wells to determine if new groundwater extraction wells have been installed in the area; and
- Annual review of water production from OCWD for the wells identified on Figure 7 and any other new production wells that may be installed in this vicinity.

7.2.2.2 Former Source area Containment

Former source area containment areas will be established within the regional groundwater system to control future residual COC migration from former source areas. Establishment of former source containment areas will be demonstrated using three lines of evidence:

1. Monitor water levels in Unit B monitor and extraction wells located within the Site boundaries on a periodic basis. Water levels will be reviewed and water level contour maps prepared to verify a sufficient capture zone is established and maintained;

2. Once the corrective action has been operated for a sufficient amount of time such that useful water level data is available, the existing groundwater flow model will be updated and re-calibrated to actual operations data. The model will be used to project the capture zone for the corrective action using actual operations data; and

3. Every five years COC concentration trends in Unit B monitor wells downgradient of the former source areas will be assessed. It is not anticipated that concentration trends in the downgradient monitor wells would be a reliable line of evidence until a baseline trend has been established after approximately five to ten years of operation.

7.2.2.3 Protection of Current and Future Uses of Groundwater

Protection of current and future uses of groundwater will be achieved by reducing COC mass and concentration in regional groundwater further downgradient from the former source area containment areas. A short-term goal is not exceeding drinking water MCLs at POCs and a long-term goal is attaining drinking water MCLs in regional groundwater, to the extent practical. The short-term goal will be demonstrated by verifying that the extent of impacted groundwater is not progressing further downgradient by monitoring COC concentrations on a periodic basis at two proposed POCs located downgradient of the COC affected groundwater as shown in Figure 17. The two POCs will consist of existing Unit B monitor well MW-39, and one proposed new Unit B monitor well located south of monitor well MW-39 and west of Well 9.

Capture areas will be established within the regional groundwater system to control future residual COC migration. Establishment of regional groundwater capture areas downgradient of the Site will be demonstrated using three lines of evidence:

1. Monitor water levels in on- and off-site Unit B monitor and extraction wells on a periodic basis. Water levels will be reviewed and water level contour maps prepared to verify a sufficient capture zone is established and maintained;

2. Once the corrective action has been operated for a sufficient amount of time such that useful water level data is available, the existing groundwater flow model will be updated and re-calibrated to actual operations data. The model will be used to project the capture zone for the corrective action using actual operations data; and

3. Every five years COC concentration trends in Unit B monitor wells downgradient of the Site will be assessed. It is not anticipated that concentration trends in the monitor wells would be a reliable line of evidence until a baseline trend has been established after approximately five to ten years of operation.

The long-term goal of attaining drinking water MCLs in regional groundwater, to the extent practical, will be demonstrated by evaluating water quality trends in monitor wells at and downgradient of the Site.

7.3 OPTIONAL RECONFIGURATION OF WELL 9

A packer testing program is currently being conducted at the City of Fullerton's Well 9. This program is being conducted and funded by Raytheon and coordinated with the City of Fullerton and is expected to be complete in late 2015/early 2016 during off peak water demand. Well 9 is located on the north boundary of the Fullerton Airport (Figure 2) and is routinely used for municipal water supply. Well 9 is approximately 1,060 feet deep and was constructed with 7 separate screen intervals. The concentration of 1,1-DCE detected in water extracted from Well 9 is and has historically been below the drinking water MCL, and as such meets standards of protection of human health established by the Federal and State agencies for drinking water.

The City of Fullerton is considering sealing off the lower screen interval if it can be demonstrated that doing so will reduce the concentration of 1,1-DCE in the water produced from the well without unduly impacting the well's ability to maintain its current pumping rate or causing other unintended/unacceptable degradation in the quality of the water produced.

Sealing off the lower most screen interval would reduce the quantity of groundwater extracted from Unit B and minimize hydraulic influences that operation of Well 9 has on the selected groundwater corrective measure alternative. Several groundwater model simulations were performed to assess the approximate extent of the capture zone of the on- and off-site groundwater extraction systems with and without the lower screen of Well 9 isolated (Appendix A). The results of the modeling indicate that the capture zone would be larger if the lower screen of Well 9 could be isolated (Figures 27 to 29).

The increased capture zone with Well 9 lower screen isolated would improve the hydraulic capture of the preferred corrective measure alternative; however, the vast majority of the mass is contained by the preferred groundwater corrective measure alternative with Well 9 operating in its current configuration (Figure 28; Appendix A). This indicates that reconfiguration of Well 9 is an optional task and as such would not be a requirement incorporated into the preferred corrective measure alternative and would be subject to separate agreements between Raytheon and the City of Fullerton. It is understood that, if the lower screen of Well 9 were isolated, an additional performance monitor well would assist in assessing performance of the corrective measure alternative. The additional performance monitor well would be located to the west of Well 9 along Artesia Boulevard (Figure 28). To the extent that the lower screen in Well 9 is isolated, the additional performance monitor well would be incorporated into the overall corrective measures implementation process as part of the performance monitoring for the selected groundwater corrective measure alternative.

8.0 REFERENCES

California Department of Water Resources, 1961. Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County; Appendix A: Ground Water Geology. DWR Bulletin No. 104; June 1961.

_____, 1967. Progress Report on Groundwater Geology of the Coastal Plain of Orange County. DWR Southern District; July 1967.

California Environmental Protection Agency, Department of Toxic Substances Control, 1998. Letter from A. Plaza to P. Brewer, Raytheon Company, re: HRA Approval: Raytheon Systems Company (former Hughes Aircraft Company – Fullerton Operations Facility, EPA ID No. CAD063109243). June 26, 1998.

_____, 2002a. Letter from A. Plaza to P. Brewer, Raytheon Systems Company, re: Request for Remediation of the Underground Storage Tanks at former Building 602, Raytheon Systems Company Site 1901 West Malvern Avenue, Fullerton, California, DTSC Case Number 0830002817T. June 6, 2002.

_____, 2002b. Letter from J. Kou to G. Taylor, Raytheon Systems Company, re: Request for Remediation of the Underground Storage Tanks at former Building Addendum to Human Health Risk Assessment, Perched Zone Assessment, Raytheon Company Facility (Formerly Hughes Aircraft Company) Fullerton, California, Dated August 12, 2002. EPA ID No CAD063109243. September 23, 2002.

_____, 2002c. Letter from J. Kou to T. Grabiel, LSF II Fullerton LLC, Re: Amerige Heights Neighborhood 4 Site Plan TTM No 16142 (Also Known As Planning Area 9) Dated December 17, 2002. September 27, 2002

_____, 2003. Corrective Action Consent Agreement, Raytheon Company, 1901 W. Malvern Ave., Fullerton, California 92634, EPA ID No. CAD063109243. Docket HWCA: P3-01/02-001. January 15, 2003.

_____, 2005. Letter from A. Plaza to P. Brewer, Raytheon Systems Company, re: Approval of the RCRA Facility Investigation Reports for the Raytheon Fullerton Facility. April 14, 2005

_____, 2014. Letter from W. Jeffers to P. Brewer, Raytheon Company, re: Approval of Corrective Measures Workplan, Revision No. 1, Raytheon Company Facility, 1901 West Malvern Avenue, Fullerton, California. December 29, 2014.

California Regional Water Quality Control Board, Santa Ana Region, 2001. Letter from G. Thibeault to P. Brewer, Raytheon Systems Company, re: No Further Action for Diesel-Affected Soil, Former Raytheon Facility, 1901 West Malvern Avenue, Fullerton, California, Regional Board Case Number: 083002817T. December 31, 2001

Clayton Group Services, Inc., 2002. Remediation of TPH-Impacted Soil, Former Building 602 Underground Storage Tanks, Raytheon Company (Formerly Hughes Aircraft Company) at 1901 West Malvern Avenue, Fullerton, California. March 11, 2002

Dibblee, T.W., Jr., 2001. Geologic Map of the Whittier and La Habra Quadrangles (Western Puente Hills), Los Angeles and Orange Counties, California. Dibblee Geological Foundation Map 74, scale 1:24,000.

Foster Wheeler Environmental Corporation, 1998. Human Health Risk Assessment for the Hughes Aircraft Company Fullerton Site. March 27, 1998.

Geraghty & Miller, 1996. Field Summary Report, RCRA Facility Investigation, Hughes Aircraft Company, Fullerton, California. July 26, 1996.

Hargis + Associates, Inc., 1998. RCRA Facility Investigation, Raytheon Systems Company (formerly Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. July 10, 1998.

_____, 1999. Treatment System and Well Construction Report, Raytheon Systems Company, 1901 West Malvern Avenue, Fullerton, California. December 15, 1999.

_____, 2000a. Dual Phase Extraction System Closure Report, Raytheon Systems Company, 1901 West Malvern Avenue, Fullerton, California. May 30, 2000.

_____, 2000b. Dual Phase Extraction System and Soil Vapor Extraction System Final Status Report, Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. November 6, 2000.

_____, 2001a. Remediation Plan, former Building 602 Underground Storage Tanks, Raytheon Company, (formerly Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. October 19, 2001.

_____, 2001b. Letter to C. Bernhardt, RWQCB, from C. Ross and H. Wochnick, H+A, re Request for No Further Action – Diesel-Impacted Area – South of Former Buildings 605 and 610, Raytheon Company Site, 1901 West Malvern Avenue, Fullerton, California. November 15, 2001.

_____, 2003a. Corrective Measures Study Workplan, Raytheon Company, (Former Hughes Aircraft Company, 1901 West Malvern Avenue, Fullerton, California. April 25, 2003.

_____, 2003b. Groundwater Monitoring Work Plan and Sampling and Analysis Plan, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. April 25, 2003.

_____, 2003c. Additional Groundwater Assessment Work Plan, *Revision 1.0*, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. April 25, 2003.

_____, 2004a Well Construction and Groundwater Sampling Report, Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. January 30, 2004.

_____, 2004b. Additional Groundwater Assessment Work Plan, Addendum No. 1, Raytheon Company (formerly Hughes Aircraft Company, 1901 West Malvern Avenue, Fullerton, California. March 23, 2004.

_____, 2004c. Groundwater Treatment Pilot Testing Corrective Measures Study Workplan (Revision 1.0), Addendum No. 2, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. April 20, 2004.

_____, 2004d. Letter from C.G.A. Ross to W.F. Jeffers, DTSC, re Amendment A, Additional Groundwater Assessment Workplan Addendum 1, Former Raytheon Company Site, 1901 West Malvern Avenue, Fullerton, California. June 1, 2004.

_____, 2004e. Letter from C.G.A. Ross to W.F. Jeffers, DTSC, re Amendment B, Additional Groundwater Assessment Workplan Addendum 1, Former Raytheon Company Site, 1901 West Malvern Avenue, Fullerton, California. July 29, 2004.

_____, 2004f. Groundwater Treatment Pilot Test Summary Report, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. October 26, 2004.

_____, 2005a. Letter from Mr. Christopher Ross to Mr. William Jeffers, California Environmental Protection Agency, Department of Toxic Substances Control, re. Addendum No. 3, Groundwater Treatment Pilot Testing, Corrective Measures Study Workplan, for Raytheon Company (Former Hughes Aircraft Company Site), 1901 West Malvern Avenue, Fullerton, California. January 18, 2005

_____, 2005b. Groundwater Extraction and Treatment System Pilot Testing Corrective Measures Study Workplan, Addendum No. 4, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. March 11, 2005.

_____, 2005c. Deep Boring and Well Construction and Groundwater Sampling Report, Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. March 28, 2005.

_____, 2005d. Letter to W. Jeffers, DTSC, from C. Ross, H+A 1,4-Dioxane Bench Test Summary, Extended Pilot Test Contingency Plan, Laboratory Confirmation Sample Test Results, and Additional Sampling Summary Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. October 24, 2005

_____, 2006. Letter to W. Jeffers, DTSC, from C. Ross, S. Netto, D. Ondic, H+A Response to DTSC Comments to 1,4-Dioxane Bench Test Summary, Extended Pilot Test Contingency Plan, Laboratory Confirmation Sample Test Results, and Additional Sampling Summary, Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. June 15, 2006

_____, 2008a. Results of Groundwater Monitoring, December 2007, Raytheon Company (former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. January 31, 2008.

_____, 2008b. Additional Groundwater Assessment Work Plan Addendum No. 2, Raytheon Company (formerly Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. February 1, 2008.

_____, 2008c. Letter to W. Jeffers, DTSC, from C. Ross and S. Netto, H+A, re Attachment 1, Additional Groundwater Assessment Work Plan, Addendum No. 2, Raytheon Company (former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. February 29, 2008.

_____, 2008d. Technical Memorandum to W. Jeffers, DTSC, from S. Netto, H+A, re Proposed Location for Downgradient Unit CM1-B Monitor Well, Task 2 of Additional Groundwater Assessment Work Plan, Addendum No. 2, Raytheon Company (former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. September 12, 2008.

_____, 2008e. Results of Groundwater Monitoring and Groundwater Pilot Testing, Third Quarter 2008, Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. December 23, 2008.

_____, 2009a. Additional Groundwater Assessment Work Plan Addendum No. 2A, Raytheon Company (formerly Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. March 26, 2009.

_____, 2009b. Additional Groundwater Assessment Primary Transport Zone (Target Zone) Well Construction and Groundwater Sampling Report, Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. March 26, 2009.

_____, 2009c. Groundwater Extraction and Treatment System Pilot Testing Corrective Measures Study Workplan, Addendum No. 4A, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. March 31, 2009.

_____, 2009d. Letter to W. Jeffers, DTSC, from C. Ross and S. Netto, H+A, re Summary of Monitor Well MW-31 Construction and Testing (Task 1) and Plan to Install and Test Off-Site Monitor Well MW-32 (Task 2), Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. October 22, 2009.

_____, 2010a. Summary of Aquifer Hydraulic Testing and Preliminary Groundwater Capture Zone Analysis, Former Raytheon Company Facility, (Formerly Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. February 16, 2010

_____, 2010b. Additional Groundwater Assessment Work Plan Addendum No. 3, Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. October 15, 2010.

_____, 2010c. Well Construction And Groundwater Sampling Report Additional Groundwater Assessment Primary Transport Zone (Target Zone) And Groundwater Extraction Treatment System Pilot Testing, Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. November 18, 2010.

_____, 2011a. Additional Groundwater Assessment Monitor Well Construction Report (MW-34 and MW-35), Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. April 4, 2011

_____, 2011b. Additional Groundwater Assessment Work Plan Addendum No. 4, Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. April 13, 2011

_____, 2011c. Groundwater Treatment Bench and Pilot Testing Corrective Measures Study Workplan, Addendum No. 5, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. May 6, 2011.

_____, 2011d. Letter to W. Jeffers, DTSC, from C. Ross and S. Netto, H+A, re Amendment A, Additional Groundwater Assessment Work Plan Addendum No. 4, Former Raytheon Company Site, 1901 West Malvern Avenue, Fullerton, California. June 6, 2011.

_____, 2012. Groundwater Extraction and Treatment System Alternative Technology Bench and Pilot Test Summary Report, Raytheon Company, (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. November 30, 2012.

_____, 2013a. Additional Groundwater Assessment Work Plan Addendum No. 5, Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. February 22, 2013.

_____, 2013b. Groundwater Extraction and Treatment System Pilot Testing Corrective Measures Study Workplan Addendum No. 6, Raytheon Company (former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. February 27, 2013.

_____, 2013c. Additional Groundwater Assessment and Monitor Well Construction Report (MW-36 and MW-37), Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. June 13, 2013.

_____, 2013d. Well Construction And Groundwater Sampling Report Additional Groundwater Assessment Primary Transport Zone (Target Zone), Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. October 4, 2013.

_____, 2013e. Additional Groundwater Assessment Work Plan, Addendum No. 6, Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. December 19, 2013.

_____, 2014a. Corrective Measures Study Work Plan Update, Revision 1.0, Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. January 29, 2014.

_____, 2014b. Results of Depth-Discrete Sampling Program, City of Fullerton Production Well No 9, Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. July 10, 2014.

_____, 2014c. Additional Groundwater Assessment and Monitor Well Construction Report (MW-41), Raytheon Company, 1901 West Malvern Avenue, Fullerton, California. December 2, 2014.

_____, 2014d. Letter to W. Jeffers, DTSC, from and S. Netto and M. Rodriguez, H+A, re Data Submittal for Groundwater Monitoring and Groundwater Extraction and Treatment Pilot Testing, Fourth Quarter 2014, Raytheon Company (Former Hughes Aircraft Company) Facility, 1901 West Malvern Avenue, Fullerton, California. December 30, 2014.

_____, 2015. Technical Memorandum Conceptual Site Model and Construction and Calibration of Numerical Groundwater Flow Model, Corrective Measures Study, Raytheon Company (Former Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. February 10, 2015.

Kroll Environmental Enterprises, Inc., 1995a. Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA). 1995.

_____, 1995b. RCRA Facility Investigation (RFI) Work Plan. December 1995.

Montgomery Watson Harza, 2002. Addendum to the Human Health Risk Assessment, Perched Zone Assessment, Raytheon Company Facility (formerly Hughes Aircraft Company), Fullerton, California. September 26, 2002.

Pratt, T.L., J.H. Shaw, J.F. Dolan, S.A. Christofferson, R.A. Williams, J.K. Odum and A. Plesch, 2002. "Shallow seismic imaging of folds above the Puente Hills blind-thrust fault, Los Angeles, California". Geophysical Research Letters, v. 29, no. 9, pp. 18-1 – 18-4.

U.S. Environmental Protection Agency, 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. EPA/600/R-98/128. National Risk Management Research Laboratory, Ada, Oklahoma. 1998.

_____, 2004. Treatment Technologies for Site Cleanup: Annual Status Report (Eleventh Edition). USEPA 542-R03-009. February 2004.

Yerkes, R.F., 1972. Geology and Oil Resources of the Western Puente Hills Area, Southern California. U.S. Geological Survey, Professional Paper 420-C.

TABLE 1
COMPARISON OF INORGANIC WATER QUALITY, SHALLOW ZONE, UNIT A, AND UNIT B

ANALYTE	UNITS	CA EPA MCL	US EPA MCL	US EPA SECONDARY MCL	SHALLOW ZONE			UNIT A			UNIT B		
					MIN	MAX	AVERAGE	MIN	MAX	AVERAGE	MIN	MAX	AVERAGE
Antimony	mg/L	0.006	0.006	--	ND	ND	ND	ND	0.010	0.0029	ND	0.0060	0.0043
Arsenic	mg/L	0.01	0.01	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium	mg/L	1	2	--	ND	ND	ND	0.087	0.39	0.20	0.048	0.22	0.13
Beryllium	mg/L	0.004	0.004	--	0.00017	0.00017[B]	0.00017[B]	ND	ND	ND	ND	ND	ND
Cadmium	mg/L	0.005	0.005	--	ND	ND	ND	ND	ND	ND	ND	0.004	0.0028
Chloride	mg/L	--	--	250	86	360	158	52	140	90	44	140	90
Chlorine	mg/L	--	4	--	--	--	--	ND	ND	ND	ND	ND	ND
Chromium	mg/L	0.05	0.1	--	ND	ND	ND	ND	ND	ND	0.0030	0.0090	0.0060
Chromium, Hexavalent	mg/L	0.01	--	--	--	--	--	0.00060	0.0013	0.0010	ND	0.0055	0.0013
Copper	mg/L	1.3	1.3	--	ND	ND	ND	ND	0.0060[B]	0.0025[A]	0.0072	0.059	0.018
Cyanide, Total	mg/L	0.15	0.2	--	--	--	--	--	--	--	ND	ND	ND
Fluoride	mg/L	2	4	--	0.12	0.46	0.30	ND	1.2	0.66	0.68	0.68	0.68
Iron	mg/L	--	--	0.3	ND	ND	ND	0.10	0.12[B]	0.082[A]	ND	1.2[B]	0.47[B]
Lead	mg/L	0.015	0.015	--	ND	ND	ND	ND	0.010	0.0055	0.0070	0.020	0.014
Manganese	mg/L	--	--	0.05	0.000010	0.000021	0.0000059	ND	ND	ND	ND	ND	ND
Mercury	mg/L	0.002	0.002	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate (as N)	mg/L	--	10	--	--	--	--	5.2	6.0	5.6	ND	6.4	2.5
Nitrite (as N)	mg/L	1	--	--	--	--	--	ND	ND	ND	ND	ND	ND
pH	pH Units	--	--	6.5-8.5	7.3	8.4	7.6	6.0	7.6	6.8	7.3	7.8	7.6
Selenium	mg/L	0.05	0.05	--	ND	0.22	0.070	ND	0.012	0.0066	ND	0.012	0.0066
Silver	mg/L	--	0.1	0.1	0.010	0.010	0.0050	ND	ND	ND	0.0010	0.0030	0.0010
Sulfate	mg/L	--	--	250	193	540	288	128	290	202	53	140	107
Thallium	mg/L	0.002	0.002	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Dissolved Solids	mg/L	--	--	500	720	2275	1309	670	887	800	380	890	694
Zinc	mg/L		--	5	ND	0.65	0.47	0.013	0.15	0.053	ND	0.26	0.054

Notes:

[A] = For analytes with non detect, and detected values, the average was calculated using non detect values multiplied by 0.5, and the full detect values.

[B] = For analytes where detected values were lower than the maximum non detect value, the non detect values greater than the maximum detected value were omitted.

For analytes with only non detect values, the average of all non detect values was calculated.

For analytes with only detected values, the average of all detected values was calculated.

CA EPA = California Environmental Protection Agency
MCL = Maximum Contaminant Level
US EPA = U.S. Environmental Protection Agency
MIN = Minumum
MAX = Maximum
mg/L = Milligrams per liter
N = Nitrogen
ND = Non detect

TABLE 2
CORRECTIVE MEASURES EVALUATION SUMMARY

ALTERNATIVE	ALTERNATIVE DESCRIPTION	OVERALL PROTECTION OF HUMAN HEALTH AND ENVIRONMENT	ABILITY TO ATTAIN REMEDIAL ACTION OBJECTIVES			SHORT TERM EFFECTIVENESS[2]	LONG TERM EFFECTIVENESS	REDUCTION OF TOXICITY, MOBILITY AND VOLUME	IMPLEMENTABILITY	NET PRESENT VALUE (@1.4%)	GREEN AND SUSTAINABLE
			PREVENT EXPOSURE TO GROUNDWATER WITH COCS[1]	CONTAINMENT OF FORMER SOURCE AREA	CONTAIN COCS IN GROUNDWATER AND MEET MCLs						
GW1	No Action	Low	Low	Low	Low	High	Low	Low	High	There is no cost associated with this alternative	Not Applicable
GW2	Monitored Natural Attenuation (MNA)	Low	Low	Low	Low	High	Low	Low	High	$ 9,500,000 (30 yr)	Low
GW3	On-Site Extraction with Injection, Off-Site MNA	Moderate	Moderate	High	Moderate	High	Moderate	Moderate	High	$ 13,400,000 (20 yr)	High
GW4	On-Site and Brea Creek Alignment Extraction with On-Site and Shallow Off-Site Injection	High	High	High	High	High	Moderate	High	Moderate	$ 17,800,000 (20 yr)	High
GW5A	On-Site and Brea Creek Alignment Extraction with On- and Off-Site Unit B Injection	High	High	High	High	High	High	High	Moderate	$ 20,600,000 (20 yr)	High
GW5B	On-Site and Brea Creek Alignment Extraction with Off-Site Unit B Injection and Non-Potable Reuse	High	High	High	High	High	High	High	Moderate	$ 20,600,000 (20 yr)	High
GW6A	On-Site and South of Brea Creek Extraction with On- and Off-Site Distributed Injection	High	High	High	High	High	High	High	Moderate	$ 23,800,000 (20 yr)	Moderate
GW6B	On-Site and South of Brea Creek Extraction with Off-Site Unit B Injection and Non-Potable Reuse	High	High	High	High	High	High	High	Moderate	$ 23,800,000 (20 yr)	Moderate

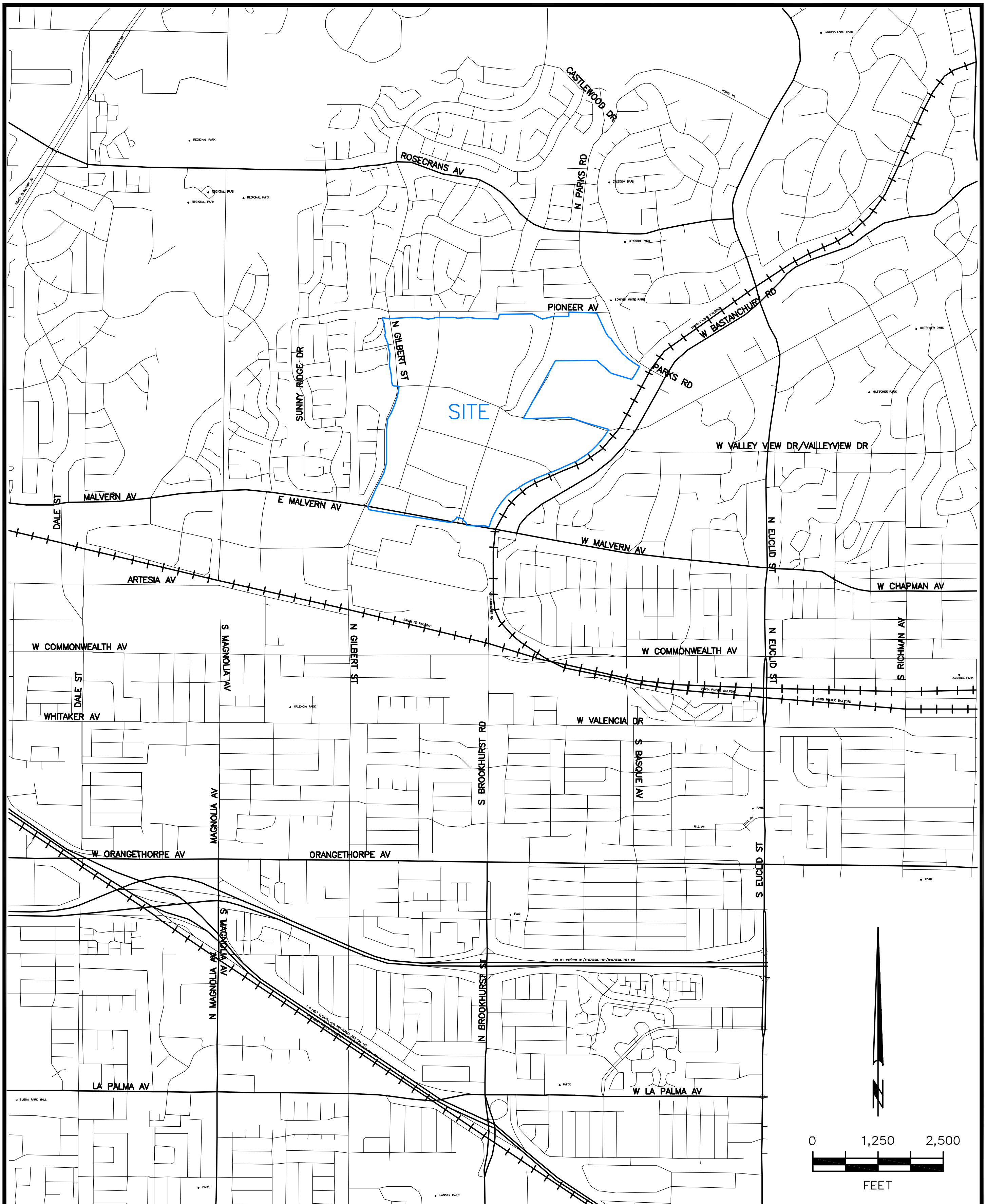
[1] Exposure to groundwater with COCs likely met for all alternatives due to existing non-site specific institutional controls; however, rating incorporates protection of production wells.
[2] Short-term effectiveness for all off-site groundwater extraction and treatment is rated high because short-term impacts during construction would be minimized by abatement plans.

COCs Contaminants of Concern
MCLs Drinking water maximum contaminant levels.
Yr Years

TABLE 3
CORRECTIVE MEASURES ALTERNATIVES RATE SUMMARY

REMEDIAL ALTERNATIVE	DESCRIPTION	EXTRACTION ON-SITE (gpm)	EXTRACTION OFF-SITE (gpm)	END USE SEWER[1]	END USE CITY OF FULLERTON RECLAIM (gpm)	END USE INJECTION ON-SITE (gpm)	END USE INJECTION OFF-SITE (gpm)
GW1	No Action						
GW2	Monitored Natural Attenuation (MNA)						
GW3	On-Site Extraction with Injection, Off-Site MNA	220	-			220	-
GW4	On- Site and Brea Creek Alignment Extraction with On-Site and Shallow Off-Site Injection	220	200			220	200
GW5A	On- Site and Brea Creek Alignment Extraction with On- and Off-Site Unit B Injection	190	300			190	300
GW5B	On- Site and Brea Creek Alignment Extraction with Off-Site Unit B Injection and Non-Potable Reuse	190	300		390	-	100
GW6A	On- Site extraction and South of Brea Creek Extraction with On- and Off-Site Distributed Injection	190	400			290	300
GW6B	On- Site extraction and South of Brea Creek Extraction with Off-Site Unit B Injection and Non-Potable Reuse	190	400		490	-	100

[1] To be retained as a contingency disposal at a maximum rate of 50 gpm
gpm = Gallons per minute

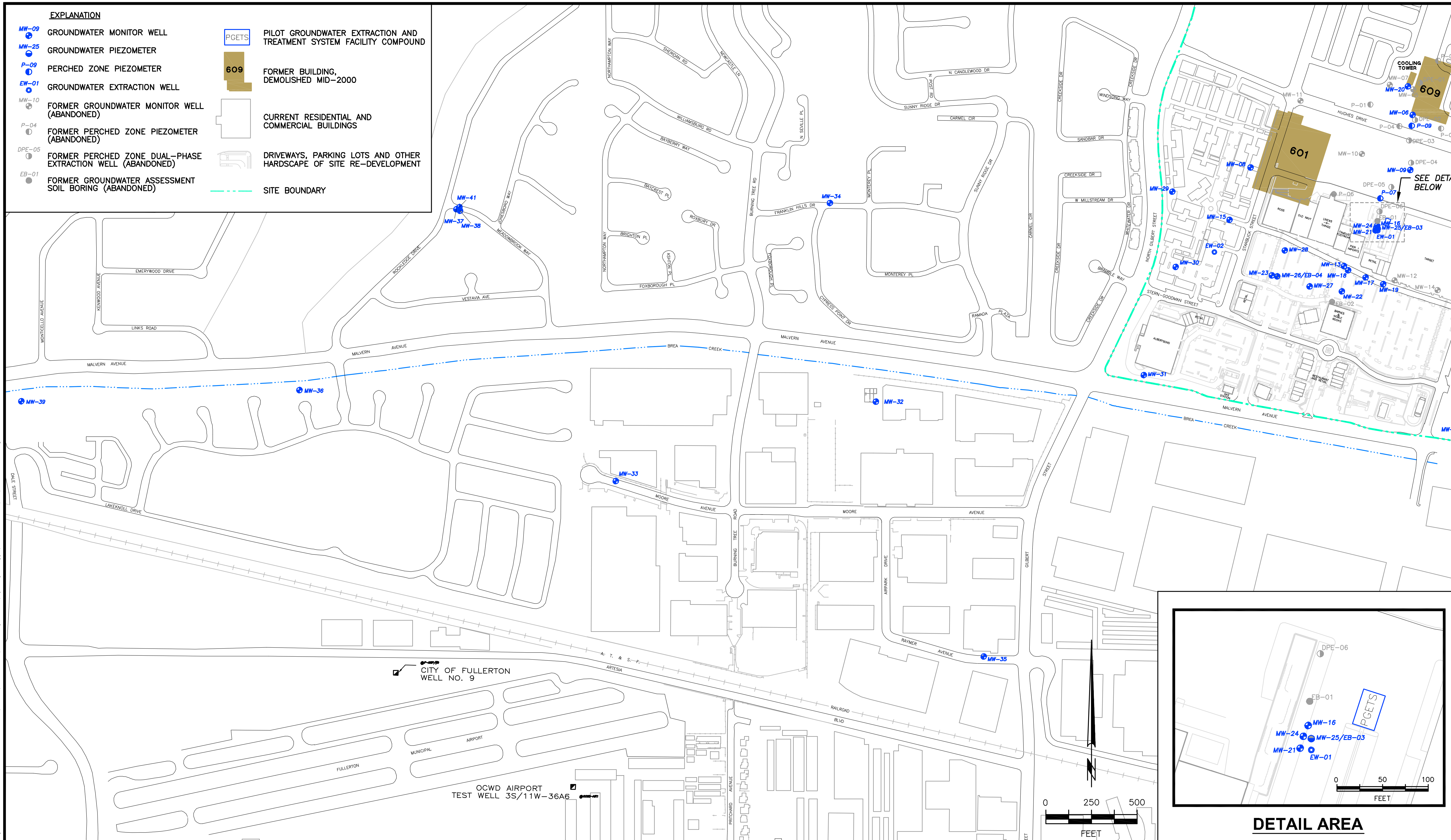


May 15, 2015 - 11:38am ADH - T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9383.dwg

5/15	RPT NO. 532.52	410-9383	A

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

FIGURE 1. SITE LOCATION



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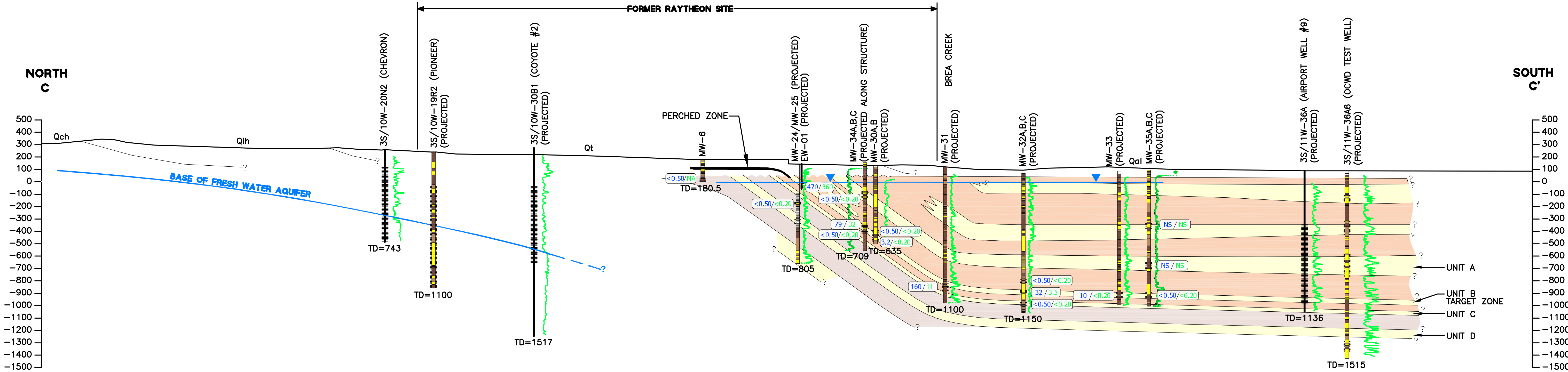
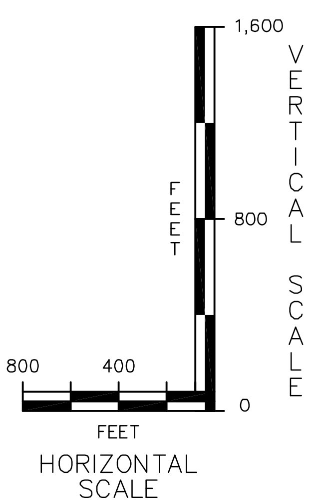
05/15	RPT NO. 532.52	410-9384	A

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

FIGURE 2.
WELL AND PIEZOMETER LOCATIONS





EXPLANATION

RELATIVELY COARSE ZONE, PREDOMINANTLY SANDS WITH LITTLE TO NO SILT OR CLAY

MIXED ZONE, MIXTURES OF SANDS, CLAYS, AND SILTS

RELATIVELY FINE ZONE, PREDOMINANTLY SILTS OR CLAYS WITH LITTLE TO NO SAND

PREDOMINANTLY COARSE ZONE

MIXED ZONE

RELATIVELY FINE ZONE

SCREENED INTERVAL OF MONITOR WELL

LGRD
0 (OHM−M) 100 500

RESISTIVITY LOG (ohm−m) (LATERAL OR SHORT−NORMAL) OF WELL BOREHOLE. RIGHT EDGE OF THE LITHOLOGIC LOG COLUMN IS THE ZERO ohm−m LINE.

Qal — ALLUVIUM, HOLOCENE: UNCONSOLIDATED AND POORLY CONSOLIDATED GRAVEL, SAND AND SILT.

Qt/ Qoa — TERRACE DEPOSITS/OLDER ALLUVIUM, UPPER PLEISTOCENE TO HOLOCENE: POORLY CONSOLIDATED GRAVEL, SAND AND SILT, COMMONLY REDDISH−BROWN; LOCALLY RED−BROWN SILT.

Qlh — LA HABRA FORMATION, UPPER PLEISTOCENE: OLIVE−GRAY TO RED−BROWN SILTSTONE; PALE YELLOW−BROWN TO RED−BROWN THICK−BEDDED FRIABLE SANDSTONE; PALE−YELLOW−GRAY POORLY BEDDED PEBBLY SANDSTONE; AND PALE−YELLOW−BROWN UNSORTED PEBBLE−COBBLE CONGLOMERATE; BASAL PART FILLS IRREGULAR CHANNELS CUT INTO UNDERLYING STRATA.

Qch — COYOTE HILLS FORMATION, UPPER PLEISTOCENE: MODERATE YELLOW−BROWN TO MODERATE BROWN THICK−BEDDED TO MASSIVE FRIABLE PEBBLY SANDSTONE; OLIVE−GRAY TO GRAY−BROWN MASSIVE SILTSTONE; AND YELLOW−BROWN MASSIVE SANDSTONE AND PEBBLE CONGLOMERATE.

470 — 1,1−DICHLOROETHYLENE CONCENTRATION, MICROGRAMS PER LITER, FEBRUARY 2015 UNLESS OTHERWISE INDICATED

NA — NOT ANALYZED FOR (SPECIFIC ANALYTE) IN FEBRUARY 2015

NS — NOT SAMPLED IN FEBRUARY 2015

360 — 1,4−DIOXANE CONCENTRATION, MICROGRAMS PER LITER, FEBRUARY 2015 UNLESS OTHERWISE INDICATED

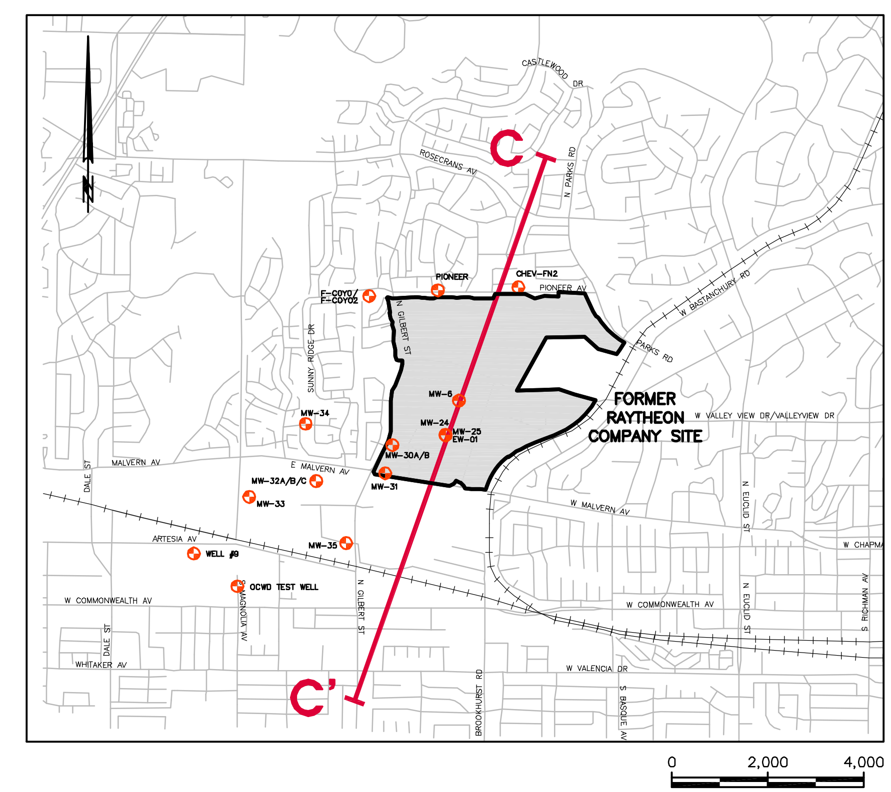
NOTE: SURFACE DISTRIBUTION OF STRATIGRAPHIC UNITS AND DESCRIPTIONS OF STRATIGRAPHIC UNITS EXCERPTED FROM YERKES, 1972.

APPROXIMATE UNIT B GROUNDWATER LEVEL, FEBRUARY 2015

? — QUERIED WHERE INFERRED

NOTE: NOT ALL ON−SITE WELLS ARE DEPICTED ON CROSS SECTION

CROSS SECTION LOCATION



05/15 | RPT NO. 532.52 | 310-1311 | A

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Hydrogeology/Engineering

FIGURE 3.
REGIONAL CONCEPTUAL GROUNDWATER MODEL HYDROGEOLOGIC CROSS−SECTION C−C'

May 15, 2015 − 11:45am ADH − T:\2015\500−599\532 Raytheon\Hydrogeology\X Sections\310−1311.dwg

<table>
<tr><th>SERIES</th><th>GEOLOGIC FORMATION</th><th>AQUIFER SYSTEM (OCWD)</th><th>HYDROSTRATIGRAPHIC UNIT (RAYTHEON SITE)</th><th>NUMERICAL MODEL LAYER</th></tr>
<tr><td rowspan="2">UPPER PLEISTOCENE</td><td rowspan="2">OLDER ALLUVIUM/ LA HABRA FM (UNDIVIDED)
UNCONFORMITY</td><td rowspan="2">UPPER AQUIFER SYSTEM</td><td rowspan="4"></td><td>1</td></tr>
<tr><td>2</td></tr>
<tr><td rowspan="12">LOWER PLEISTOCENE</td><td rowspan="2">COYOTE HILLS FM/ SAN PEDRO FM (UNDIVIDED)</td><td rowspan="12">MIDDLE AQUIFER SYSTEM
(MAIN AQUIFER SILVERADO)</td><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td rowspan="10">SAN PEDRO FORMATION</td><td>A</td><td>5</td></tr>
<tr><td rowspan="3">A/B</td><td>6</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td></tr>
<tr><td>B (TARGET ZONE)</td><td>9</td></tr>
<tr><td rowspan="3">B/C</td><td>10</td></tr>
<tr><td>11</td></tr>
<tr><td>12</td></tr>
<tr><td>C</td><td>13</td></tr>
<tr><td>C/D, D</td><td>14</td></tr>
</table>

EXPLANATION

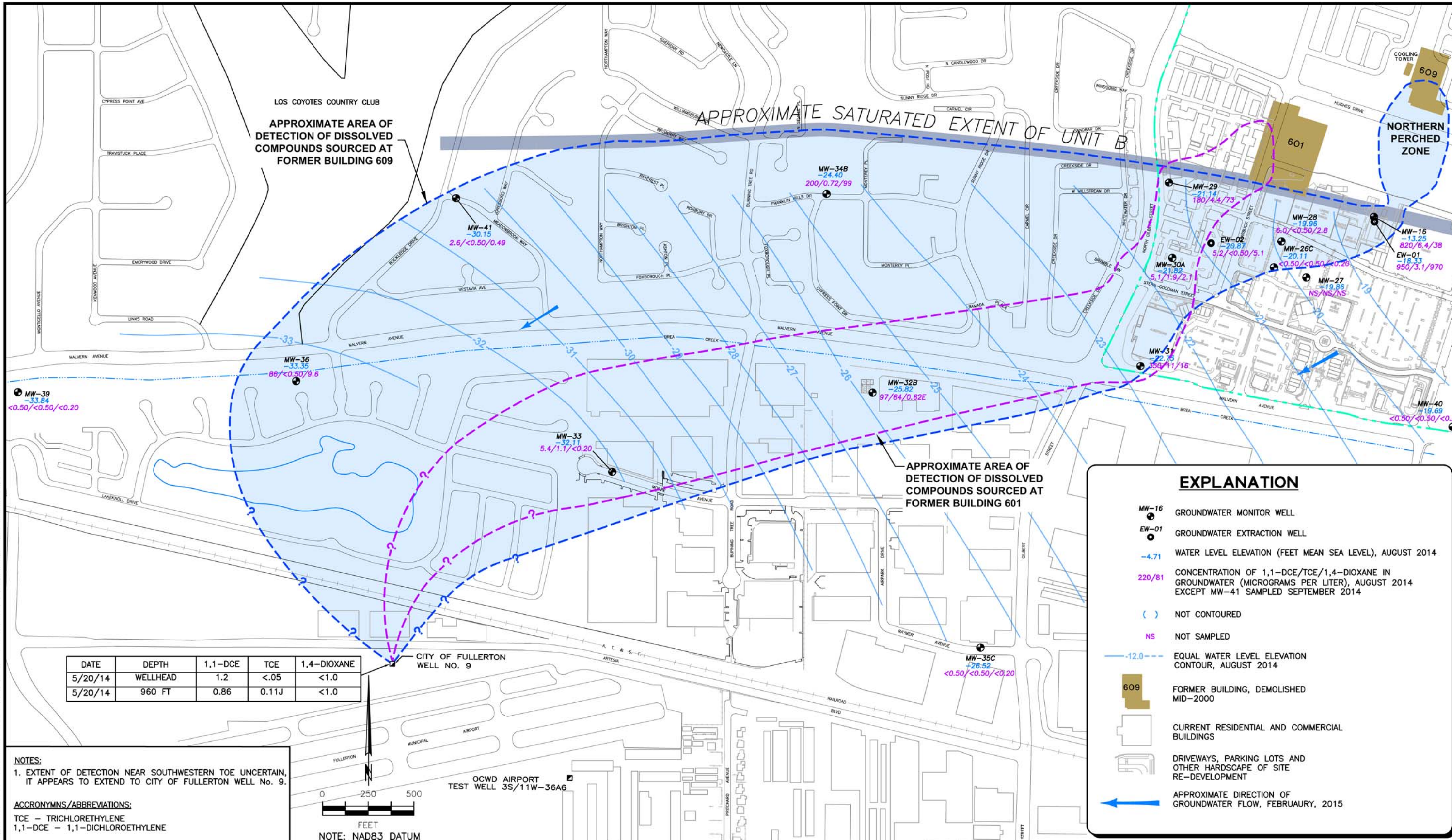
OCWD - ORANGE COUNTY WATER DISTRICT

FM - FORMATION

5/15 | RPT NO. 532.52 | 310-1312 | A

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

FIGURE 4.
GENERALIZED STRATIGRAPHIC COLUMN



DATE	DEPTH	1,1-DCE	TCE	1,4-DIOXANE
5/20/14	WELLHEAD	1.2	<.05	<1.0
5/20/14	960 FT	0.86	0.11J	<1.0

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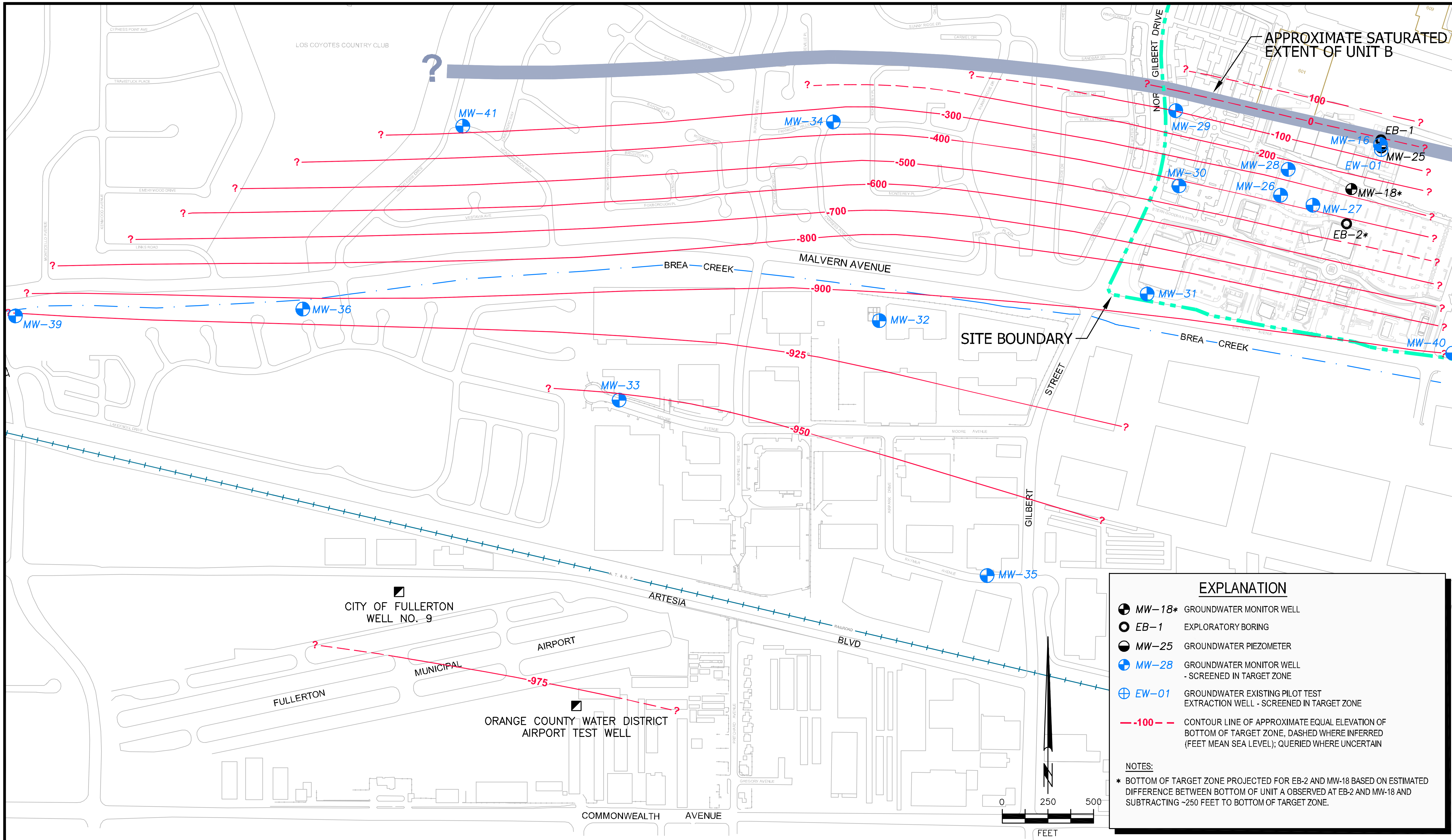
05/15 | RPT NO. 532.52 | 220-2283 | A

FIGURE 5.
CONCEPTUAL SITE MODEL OVERVIEW, UNIT B/TARGET ZONE



Jun 05, 2015 - 3:17pm ADH - T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9385.dwg

06/15 | RPT NO. | 410-9385 | A

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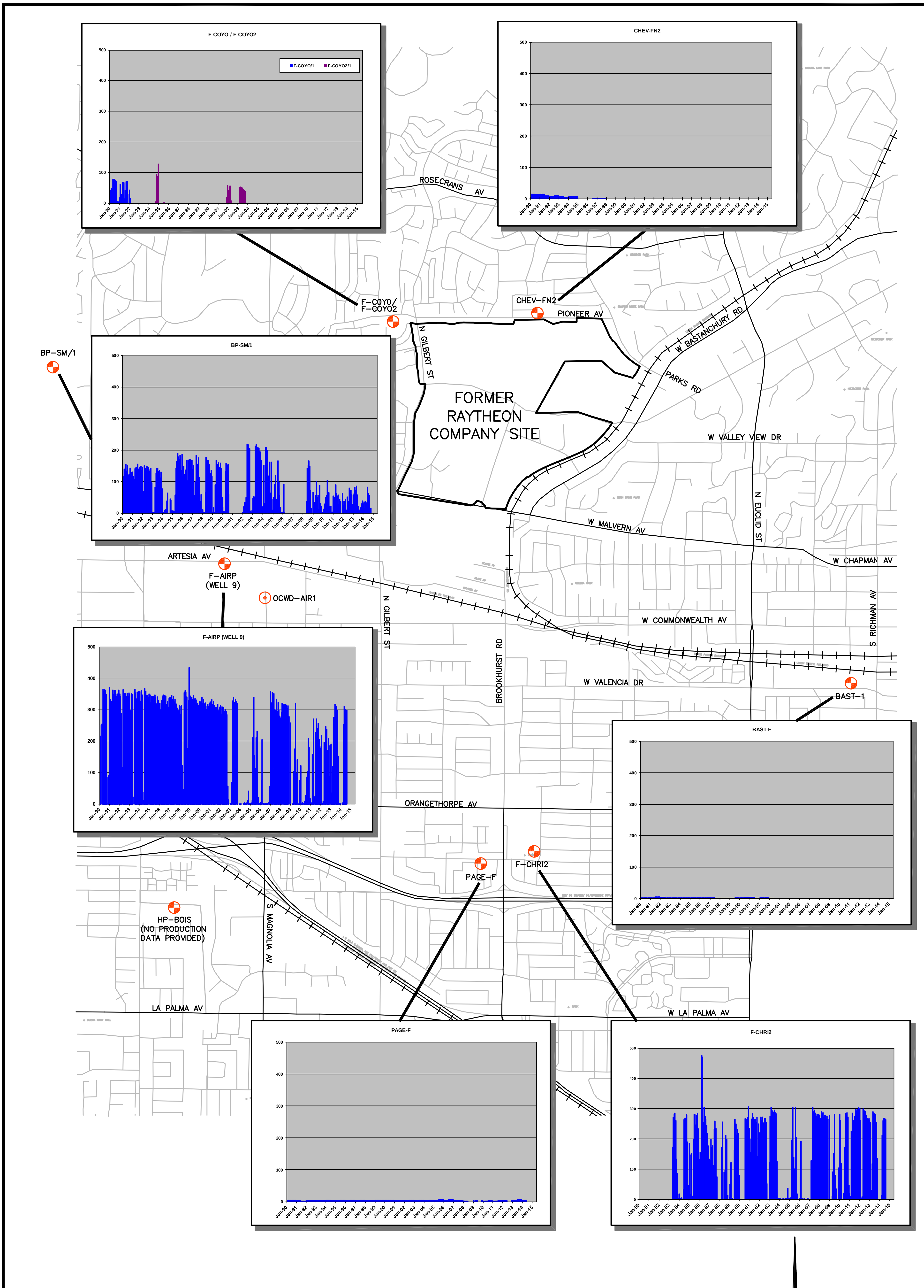
Hydrogeology/Engineering

FIGURE 6.
ELEVATION OF THE BASE OF THE TARGET ZONE (UNIT B)



EXPLANATION

ACTIVE OR RECENTLY ACTIVE PRODUCTION WELL

REGIONAL OBSERVATION WELL

NOTE: GRAPHS INDICATE MONTHLY GROUNDWATER PRODUCTION IN ACRE-FEET

May 15, 2015 – 11:54am ADH – T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9386.dwg

05/15	RPT NO. 532.52	410-9386	B

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FIGURE 7.
REGIONAL PRODUCTION WELLS

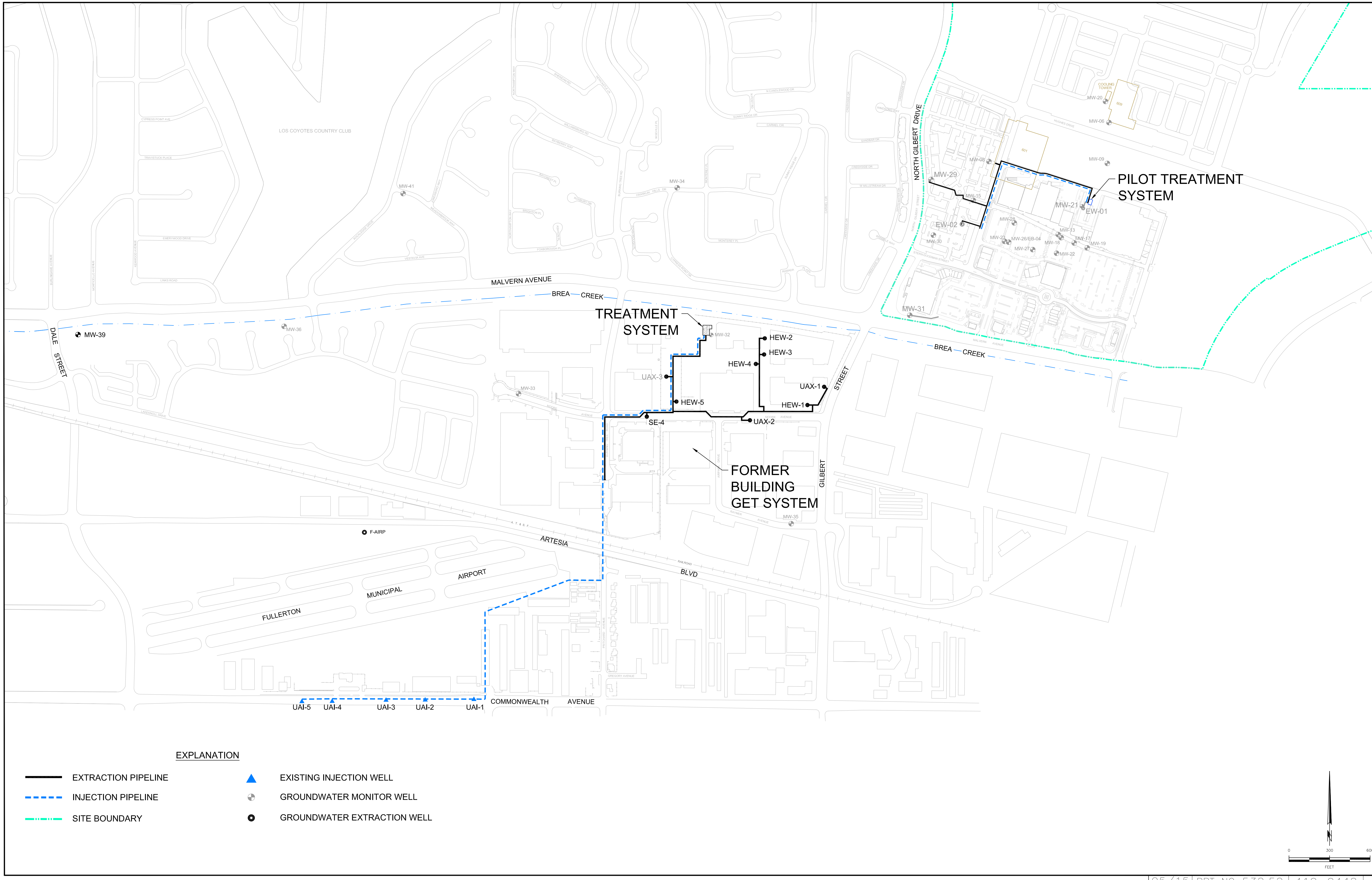


FIGURE 8. RAYTHEON PILOT AND FORMER BUILDING 684 SITE GROUNDWATER EXTRACTION AND TREATMENT SYSTEM

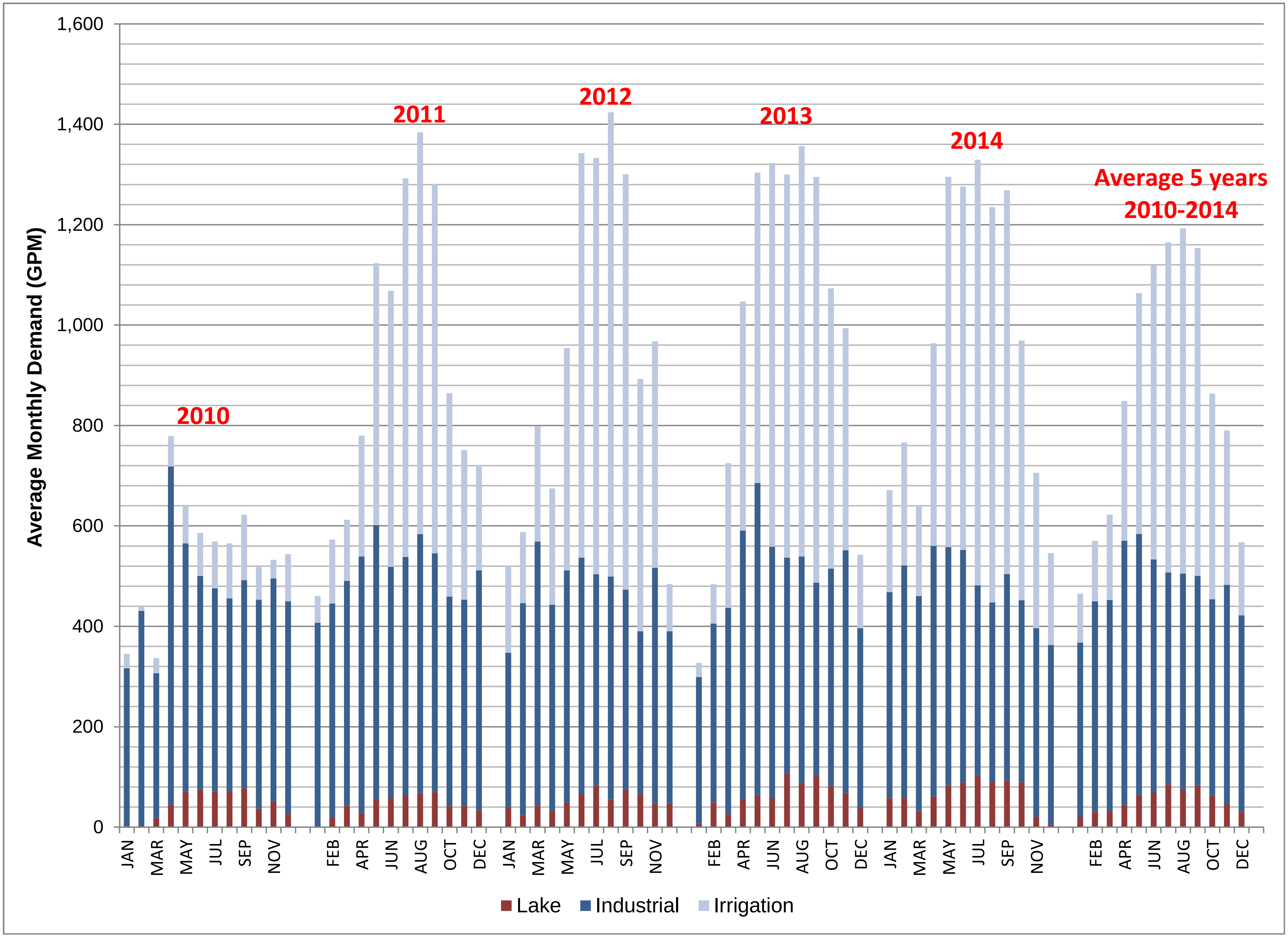
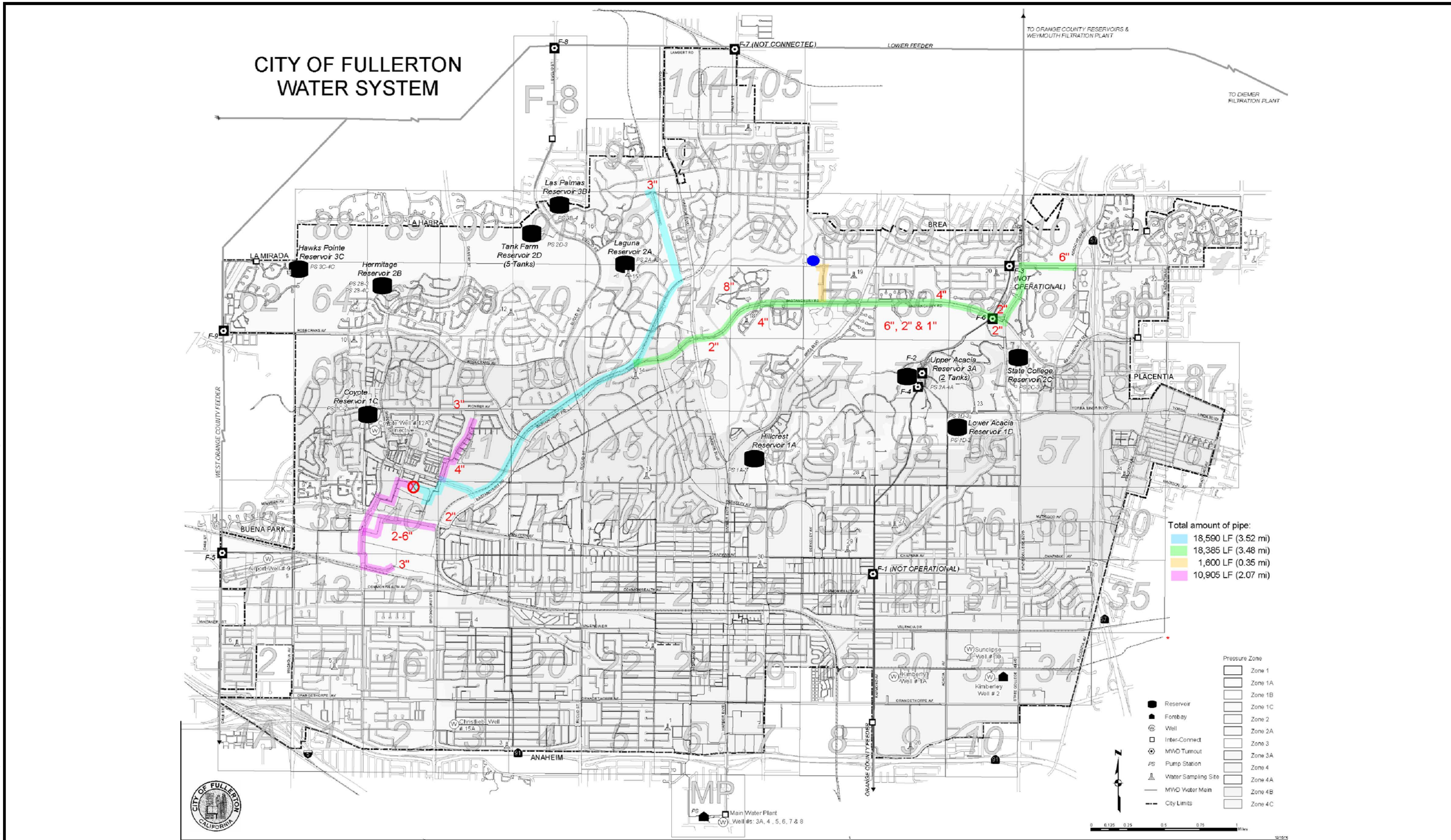


FIGURE 9. POTENTIAL NON-POTABLE WATER END-USE DEMAND

May 15, 2015 – 1:55pm ADH – T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9443.dwg



05/15	RPT NO. 532.52	410-9443	A

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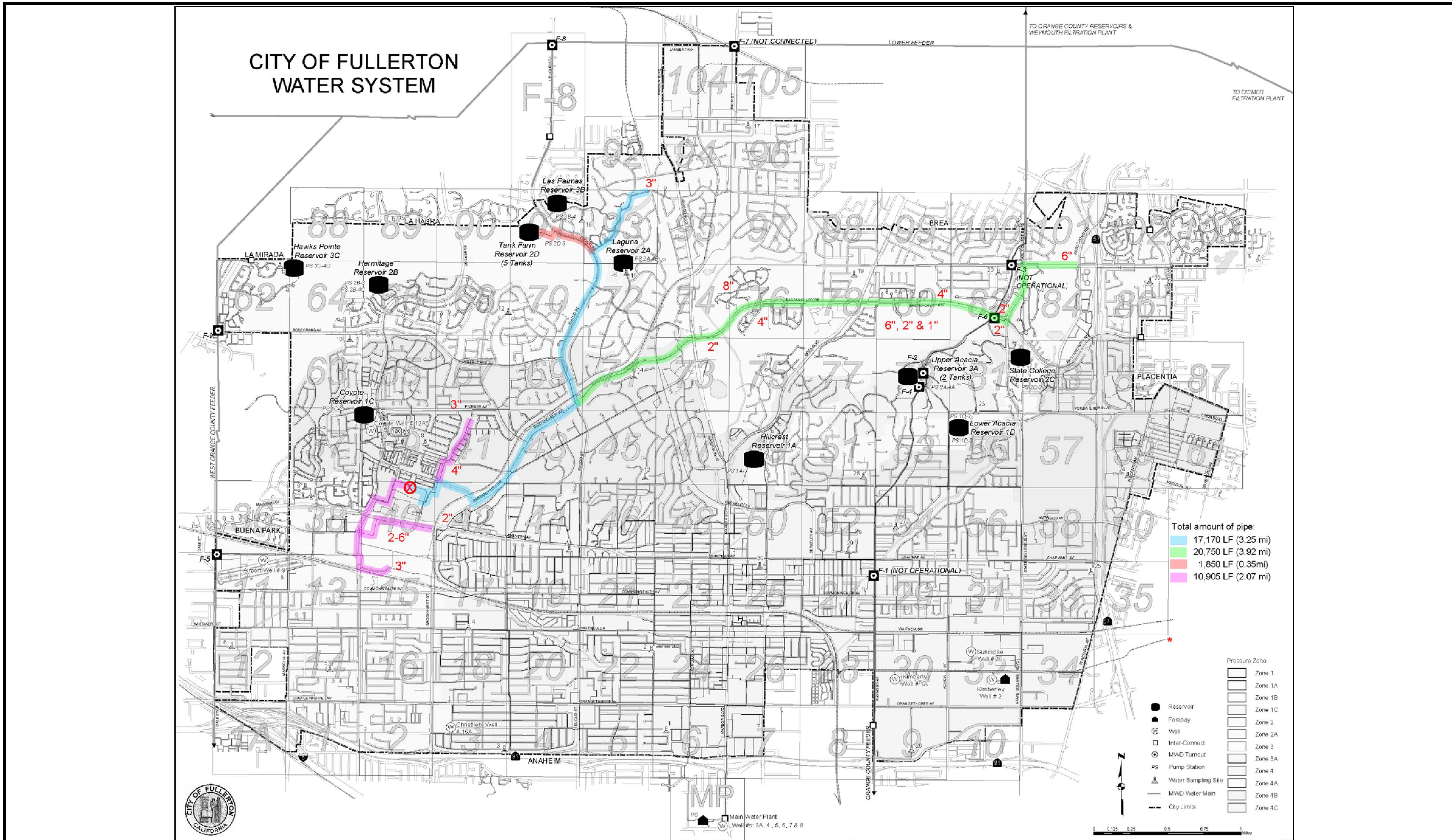
Hydrogeology/Engineering

FIGURE 10.
INFRASTRUCTURE TO SUPPORT NON-POTABLE REUSE, OPTION 1



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Hydrogeology/Engineering

05/15 | RPT NO. 532.52 | 410-9444 | A

FIGURE 11.
INFRASTRUCTURE TO SUPPORT NON-POTABLE REUSE, OPTION 2

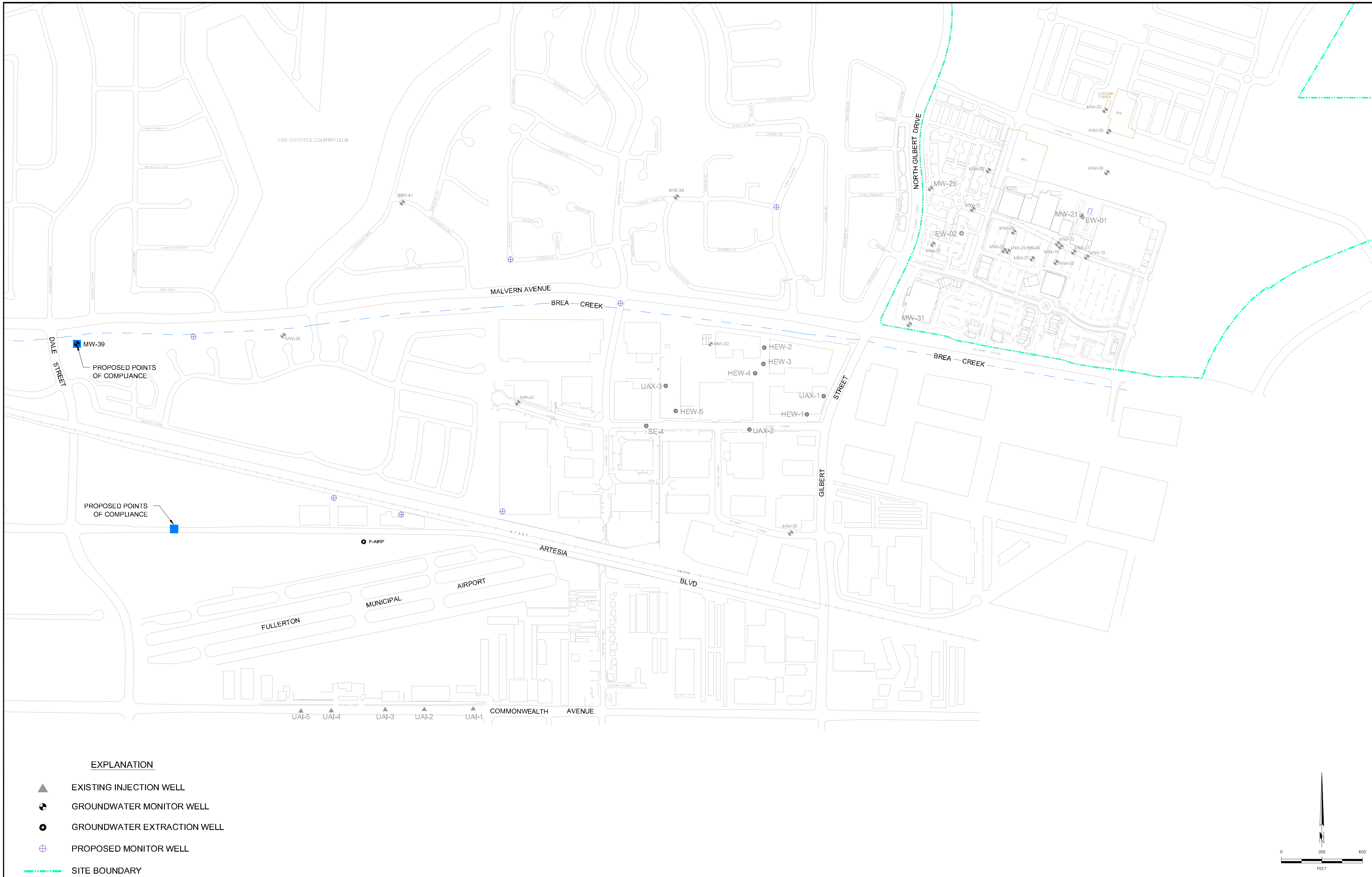


FIGURE 12. ALTERNATIVE GW2: MONITORED NATURAL ATTENUATION

06/15 | RPT NO. 532.52 | 410-9445 | A

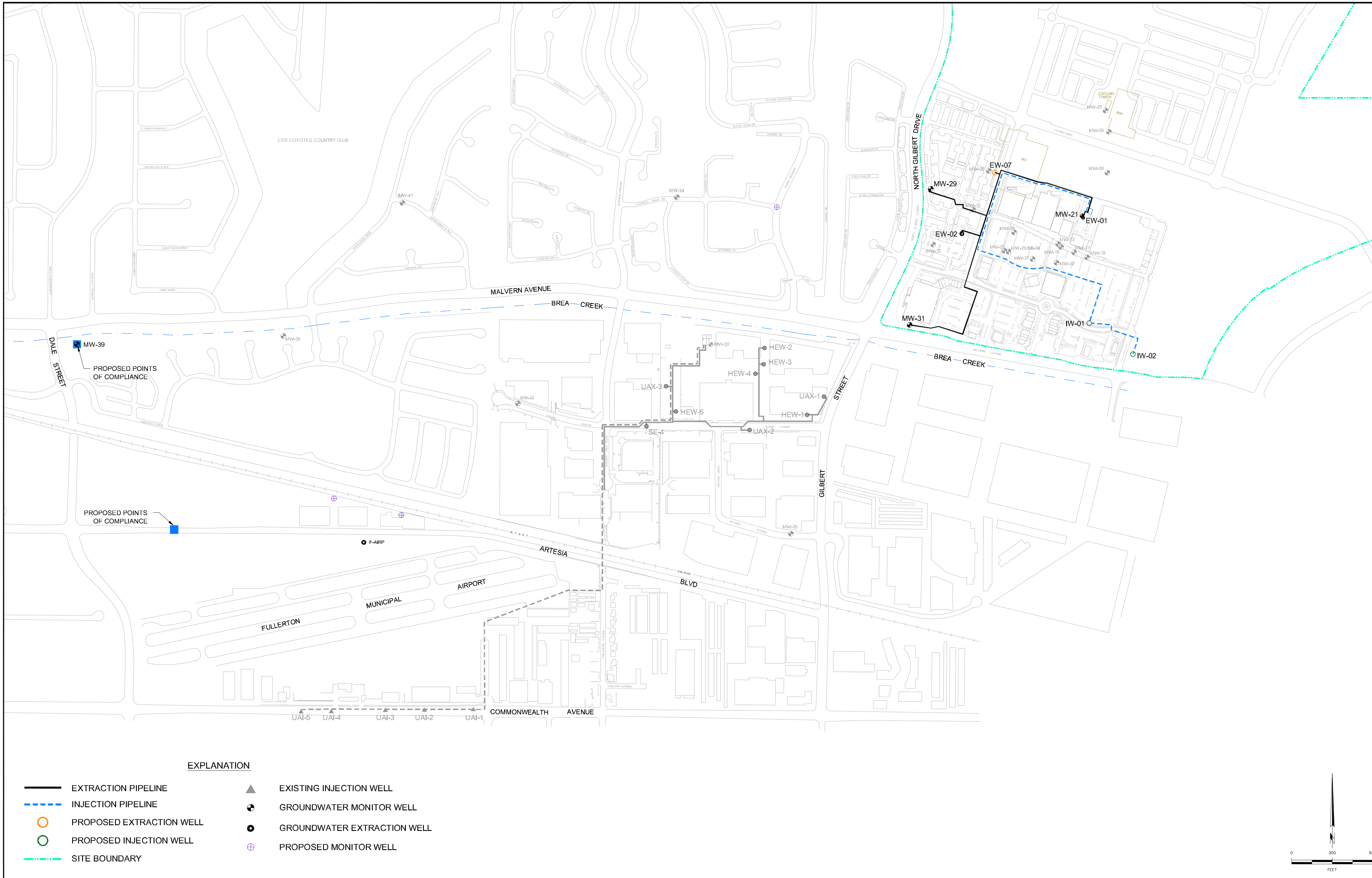
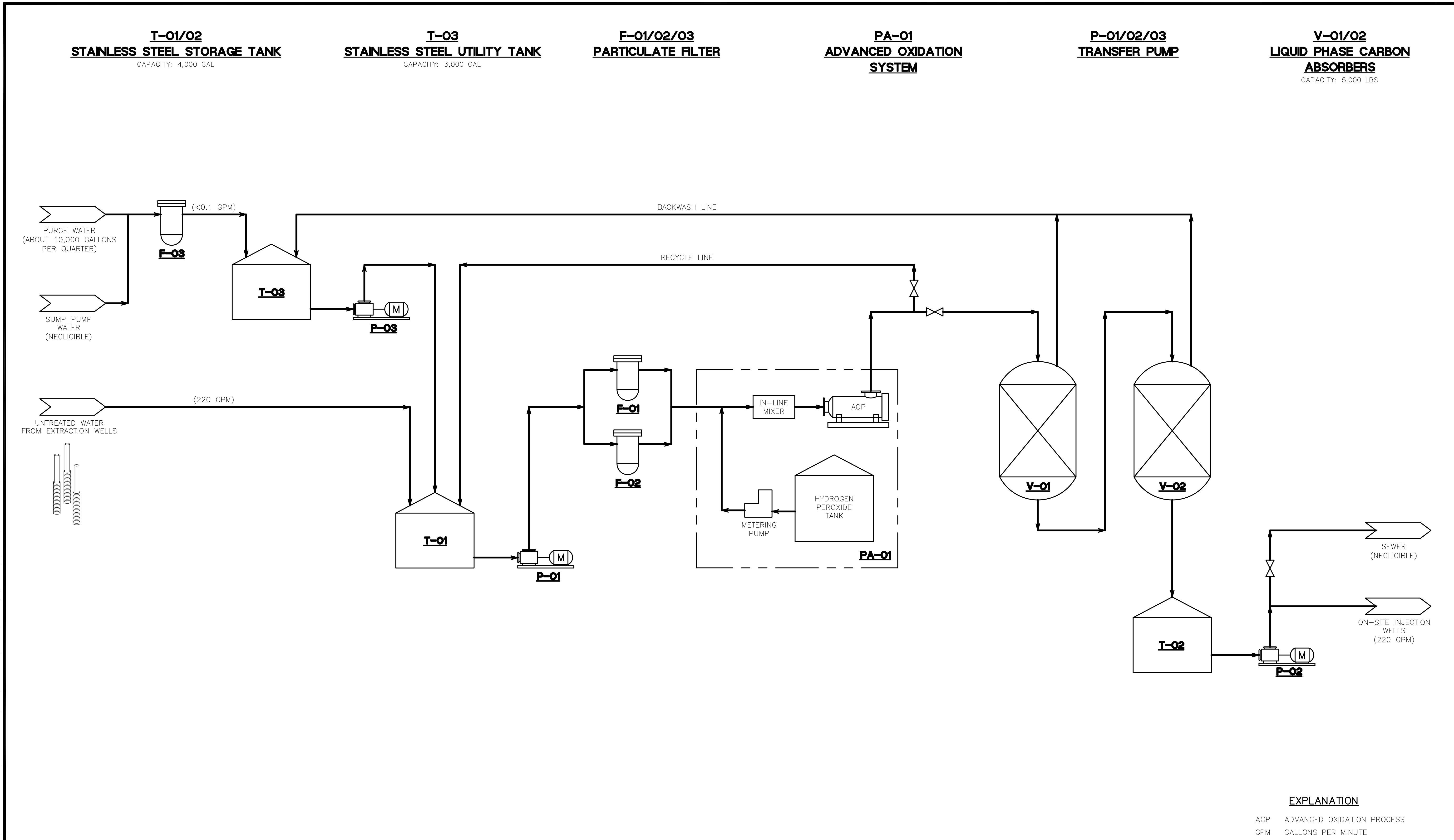


FIGURE 13. ALTERNATIVE GW3: ON-SITE EXTRACTION WITH INJECTION, OFF-SITE MNA

06/15 RPT NO. 532.52 410-9446 A



EXPLANATION

AOP ADVANCED OXIDATION PROCESS
GPM GALLONS PER MINUTE

May 15, 2015 - 2:03pm ADH - T:\2015\500-599\532 Raytheon\Engineering\P&IDs\560-0349.dwg

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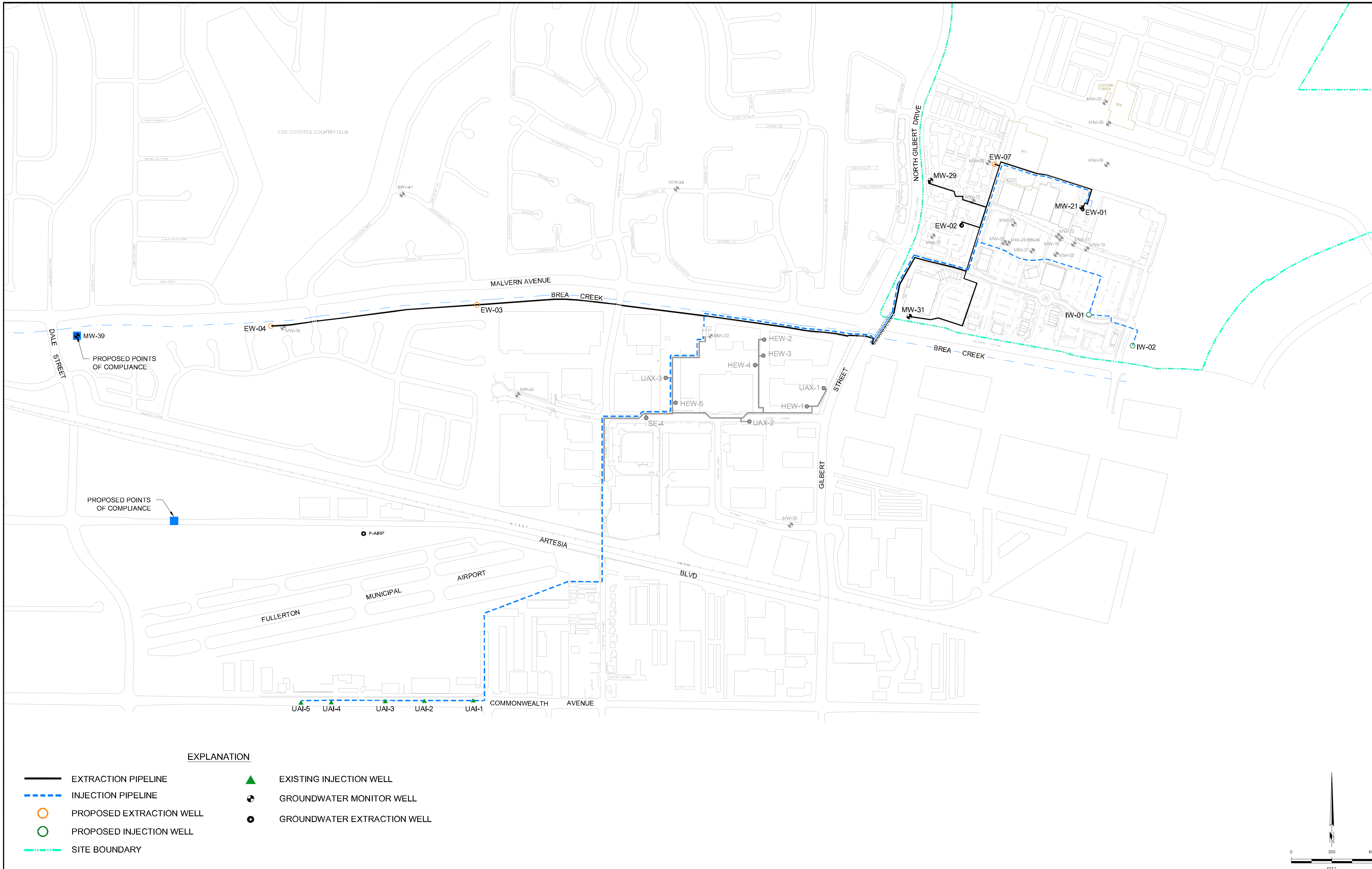
Hydrogeology/Engineering

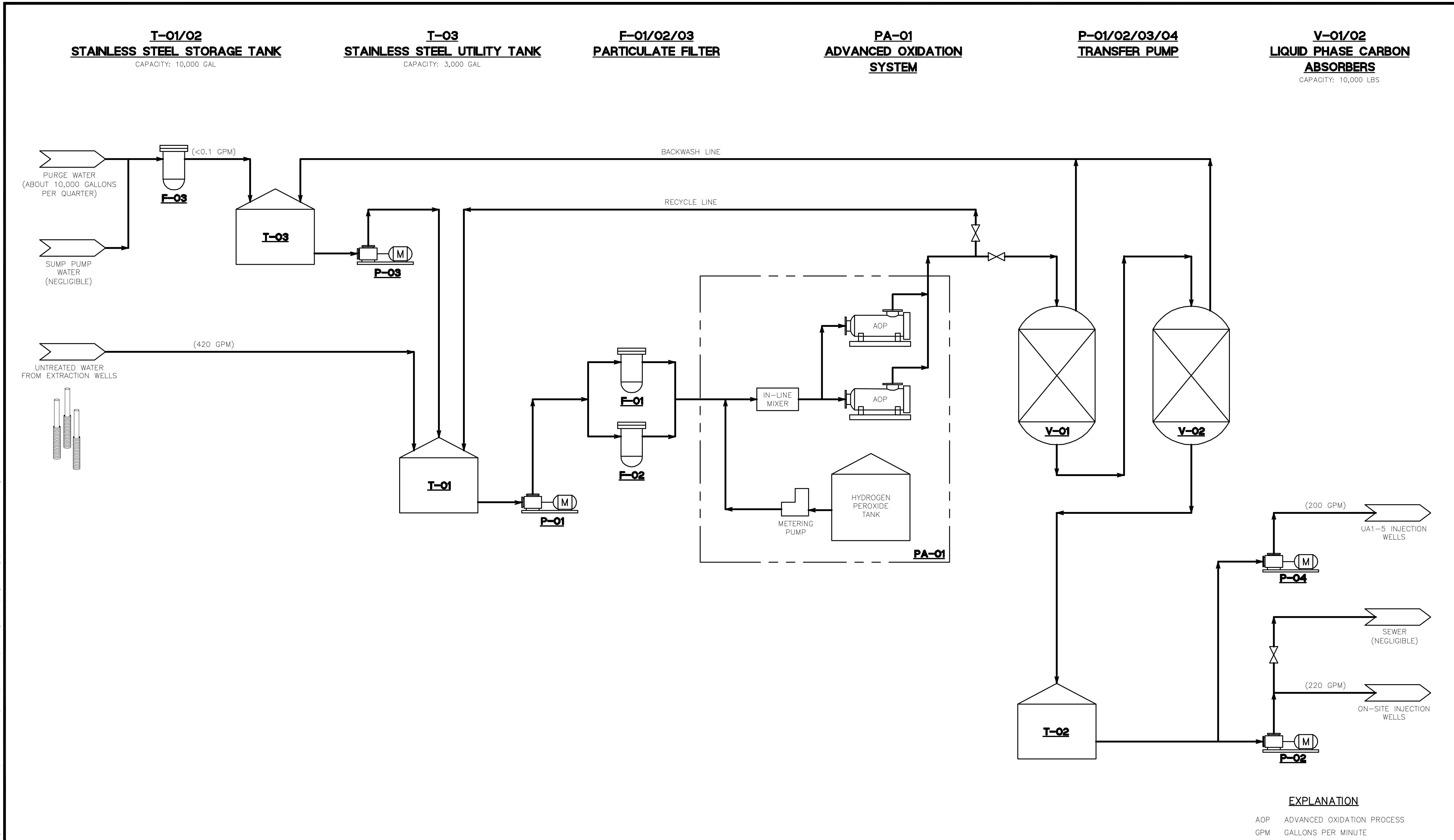
05/15 | RPT NO. 532.15 | 560-0349 | A

FIGURE 14.
ALTERNATIVE GW3: ON-SITE EXTRACTION WITH INJECTION, OFF-SITE MNA
SIMPLIFIED PROCESS FLOW DIAGRAM



05/15	RPT NO. 532.52	410–9447	A

FIGURE 15. ALTERNATIVE GW4: ON–SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON–SITE AND SHALLOW OFF–SITE INJECTION



May 28, 2015 - 4:47pm ADH - T:\2015\500-599\532 Raytheon\Engineering\P&IDs\560-0349.dwg

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Hydrogeology/Engineering

05/15	RPT NO. 532.15	560-0349	A

FIGURE 16.
ALTERNATIVE GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION
SIMPLIFIED PROCESS FLOW DIAGRAM

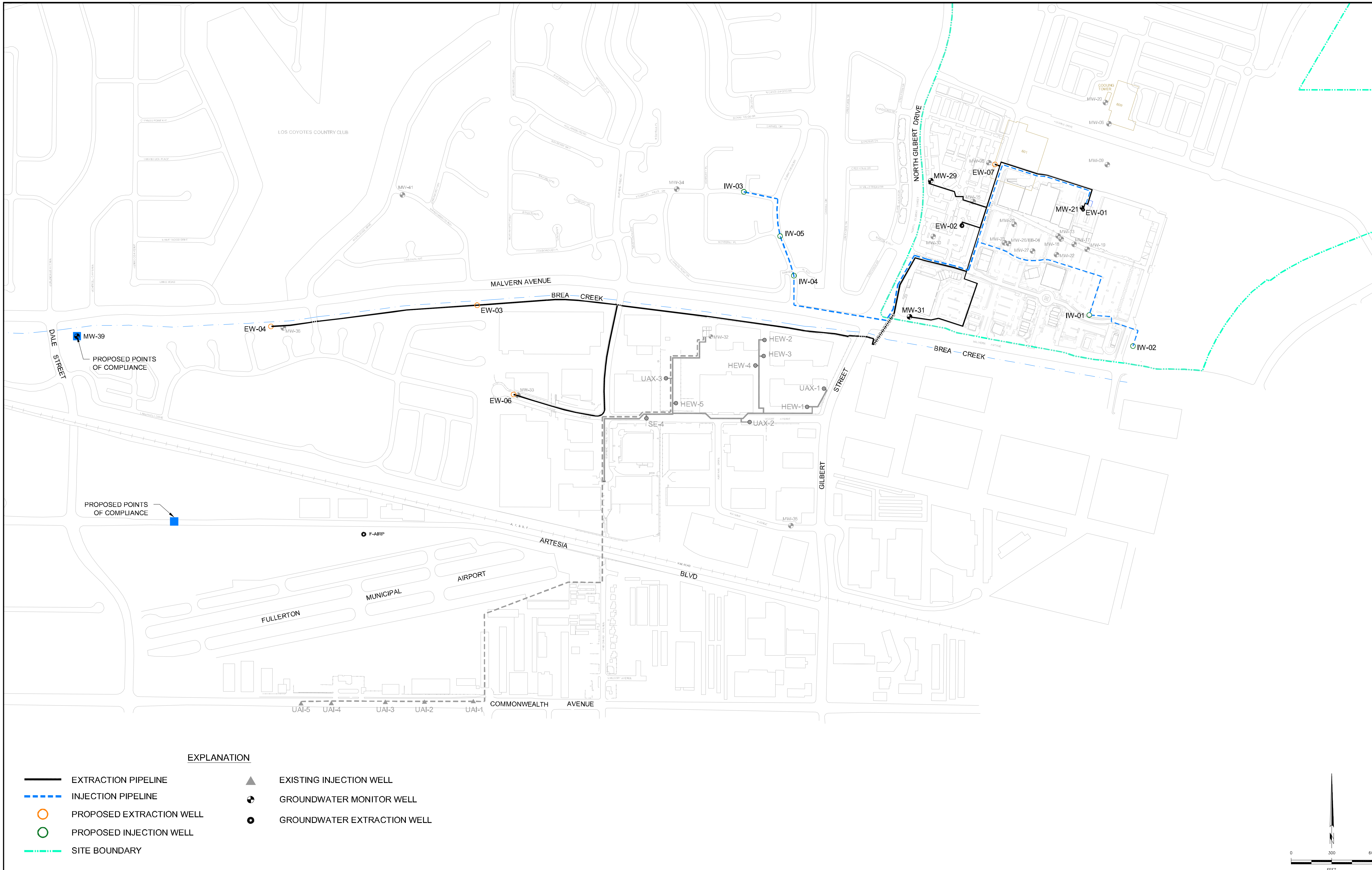
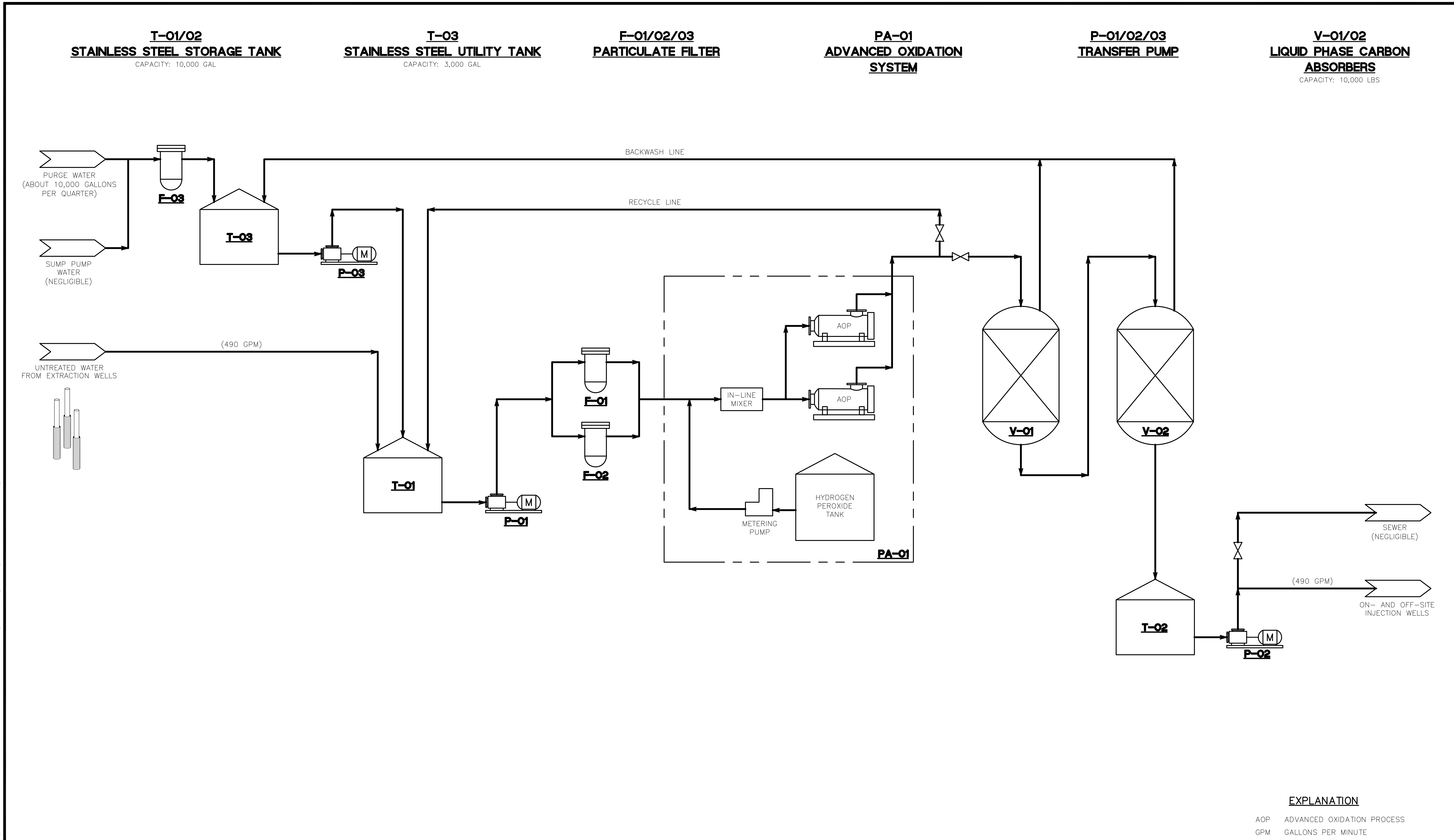


FIGURE 17. ALTERNATIVE GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

06/15 | RPT NO. 532.52 | 410-9448 | A



May 15, 2015 – 1:27pm ADH – T:\2015\500-599\532 Raytheon\Engineering\P&IDs\560-0349.dwg

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Hydrogeology/Engineering

05/15	RPT NO. 532.15	560-0349	A

FIGURE 18.
ALTERNATIVE GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND OFF-SITE UNIT B INJECTION
SIMPLIFIED PROCESS FLOW DIAGRAM

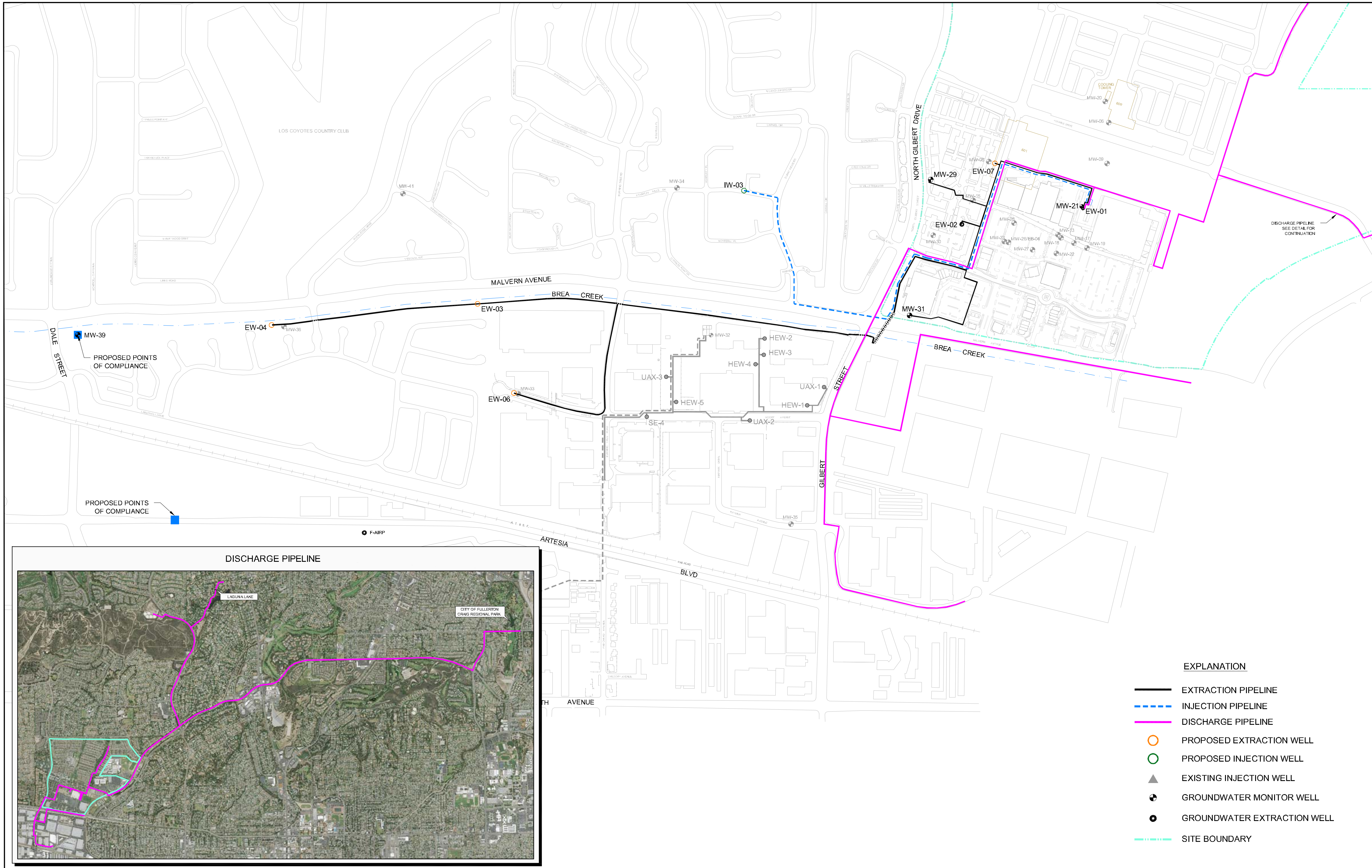
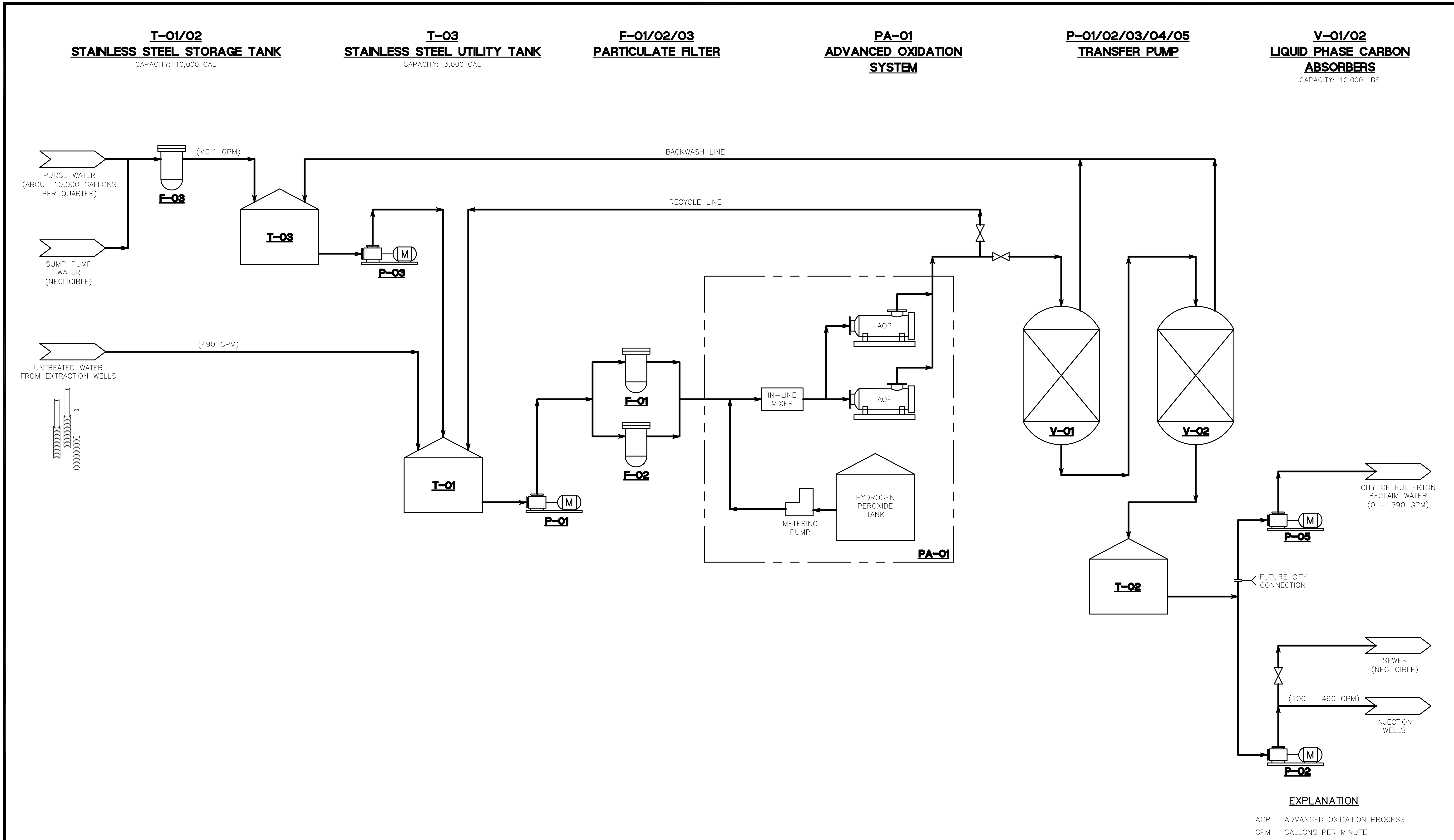


FIGURE 19. ALTERNATIVE GW5B: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH OFF-SITE UNIT B INJECTION AND NON-POTABLE REUSE

06/15 | RPT NO. 532.52 | 410-9449 | A



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HARGIS + ASSOCIATES, INC
Hydrogeology/Engineering

05/15	RPT NO. 532.15	560-0349	A

FIGURE 20.
ALTERNATIVE GW5B: ON-SITE AND BREA CREEK EXTRACTION WITH OFF-SITE UNIT B INJECTION AND NON-POTABLE REUSE
SIMPLIFIED PROCESS FLOW DIAGRAM

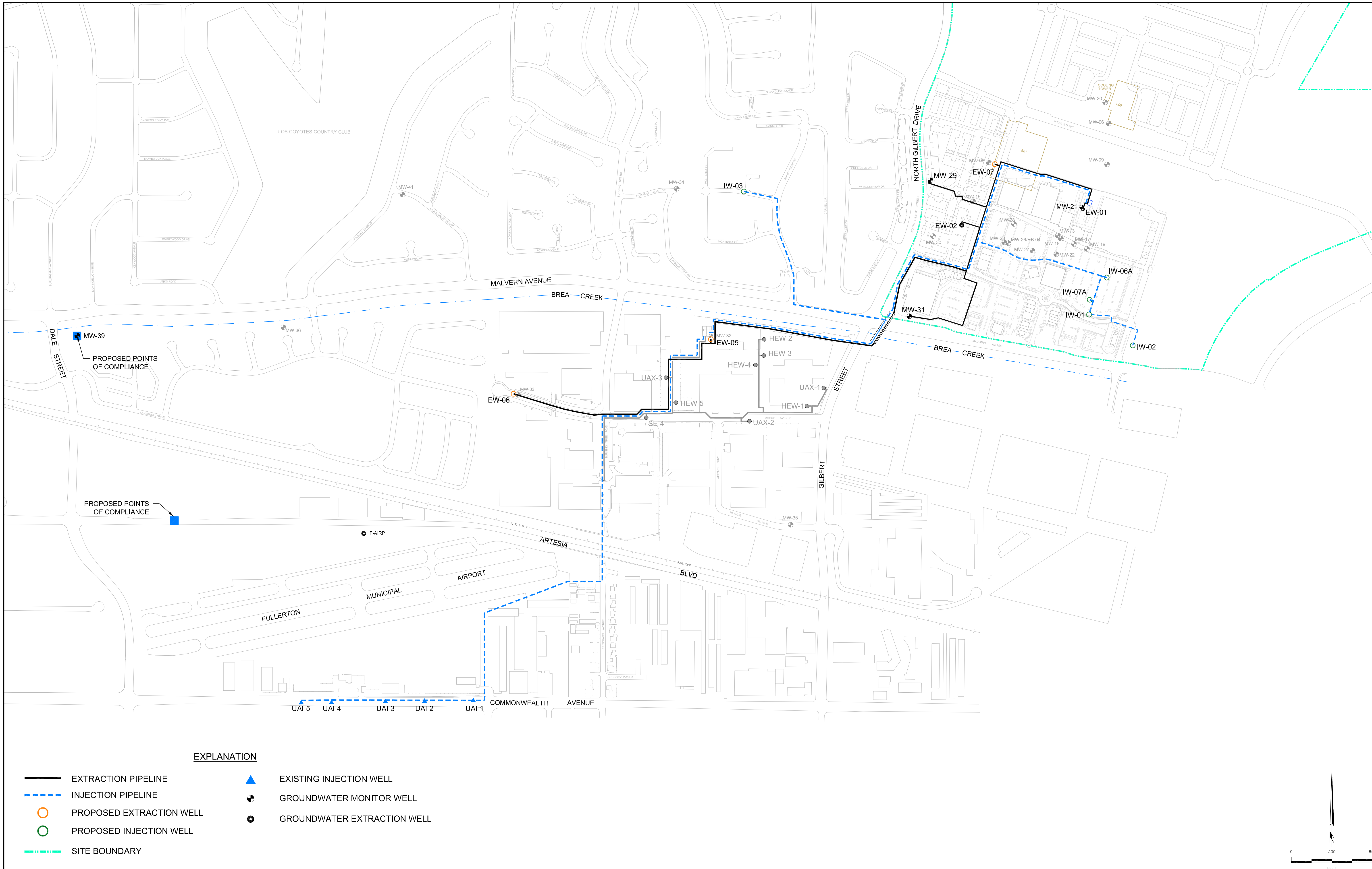
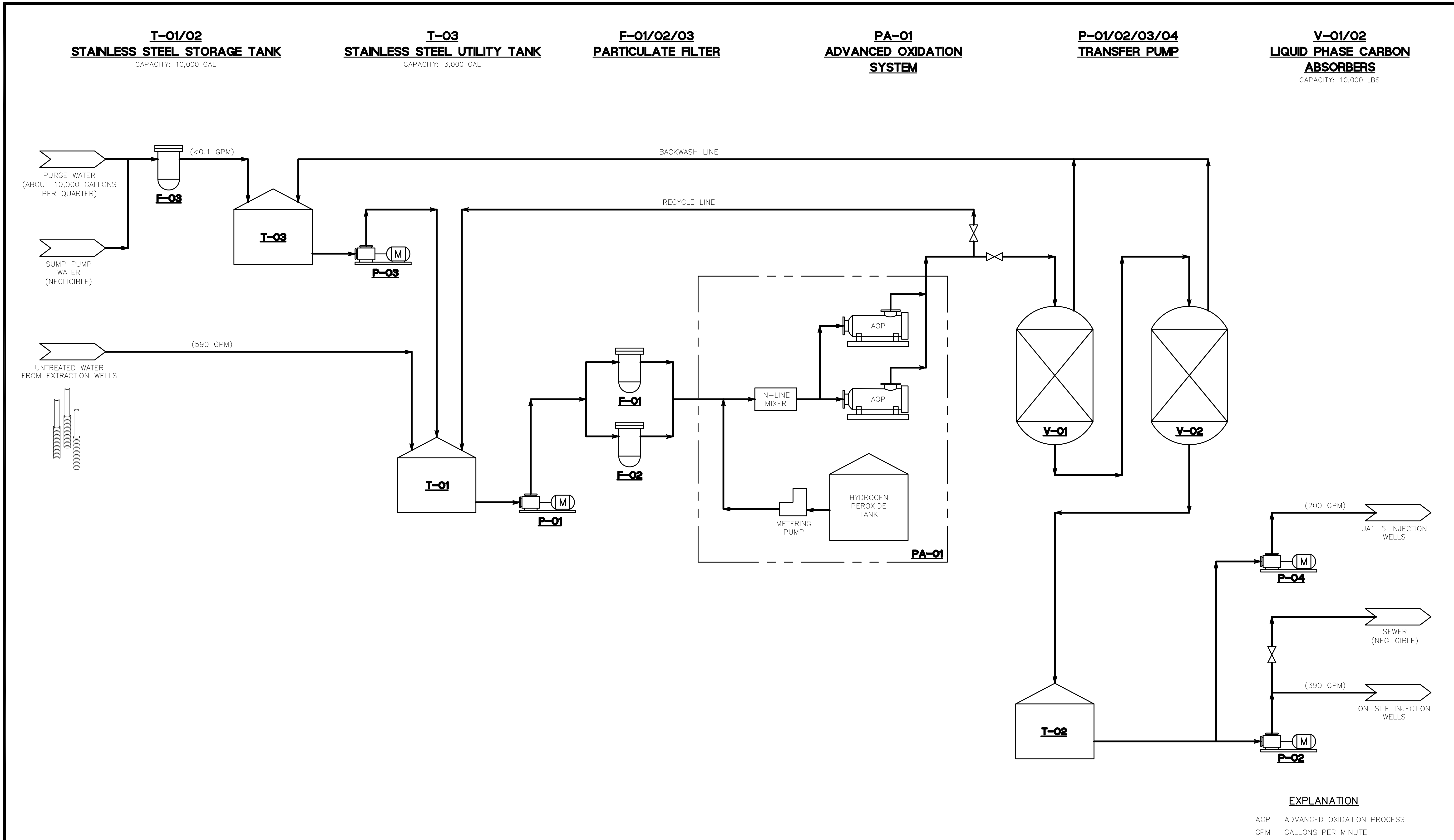


FIGURE 21. ALTERNATIVE GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

06/15 RPT NO. 532.52 410-9450 A



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05/15	RPT NO. 532.15	560-0349	A

HARGIS + ASSOCIATES, INC
Hydrogeology/Engineering

FIGURE 22.

ALTERNATIVE GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTION INJECTION

SIMPLIFIED PROCESS FLOW DIAGRAM

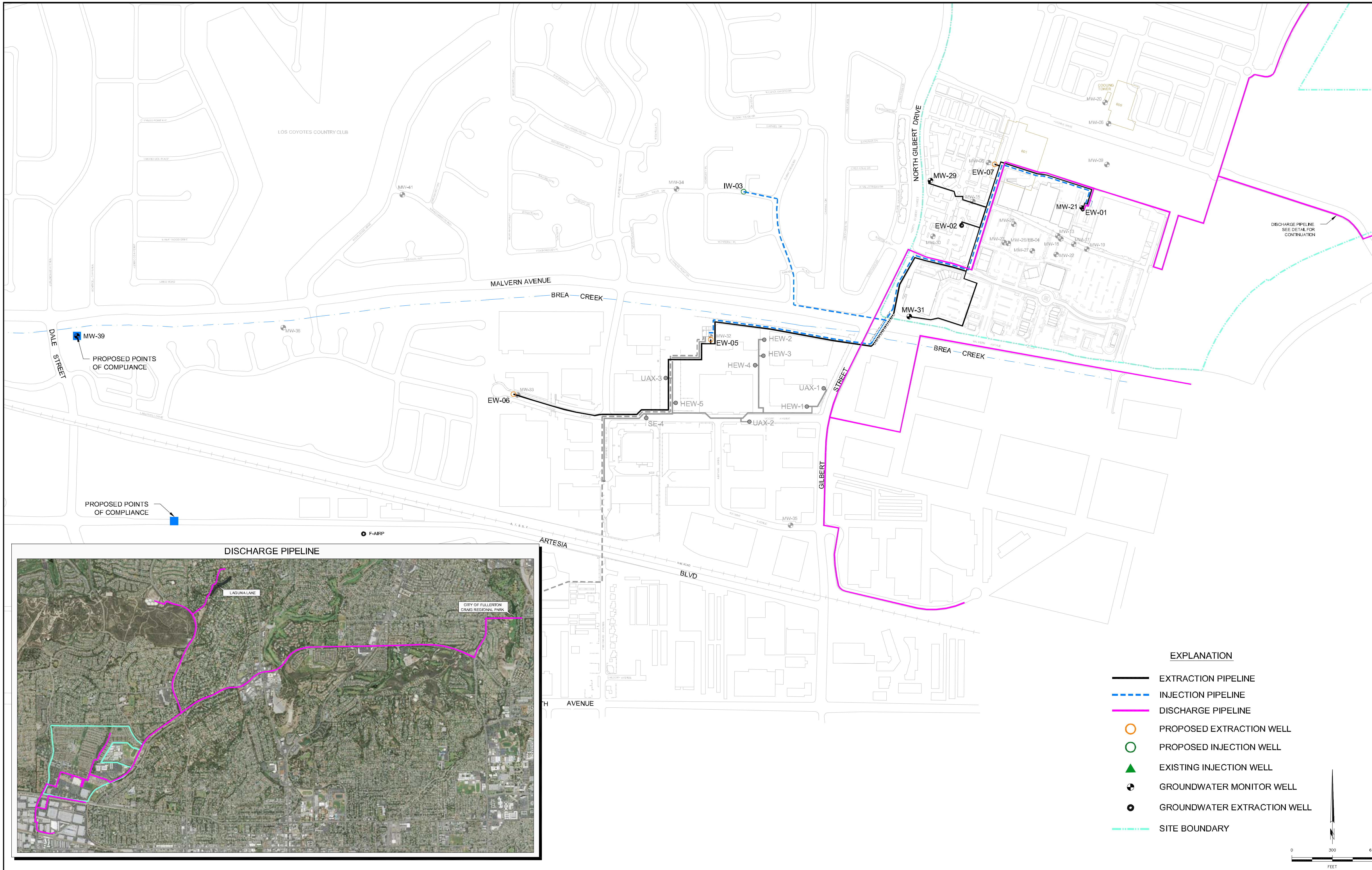
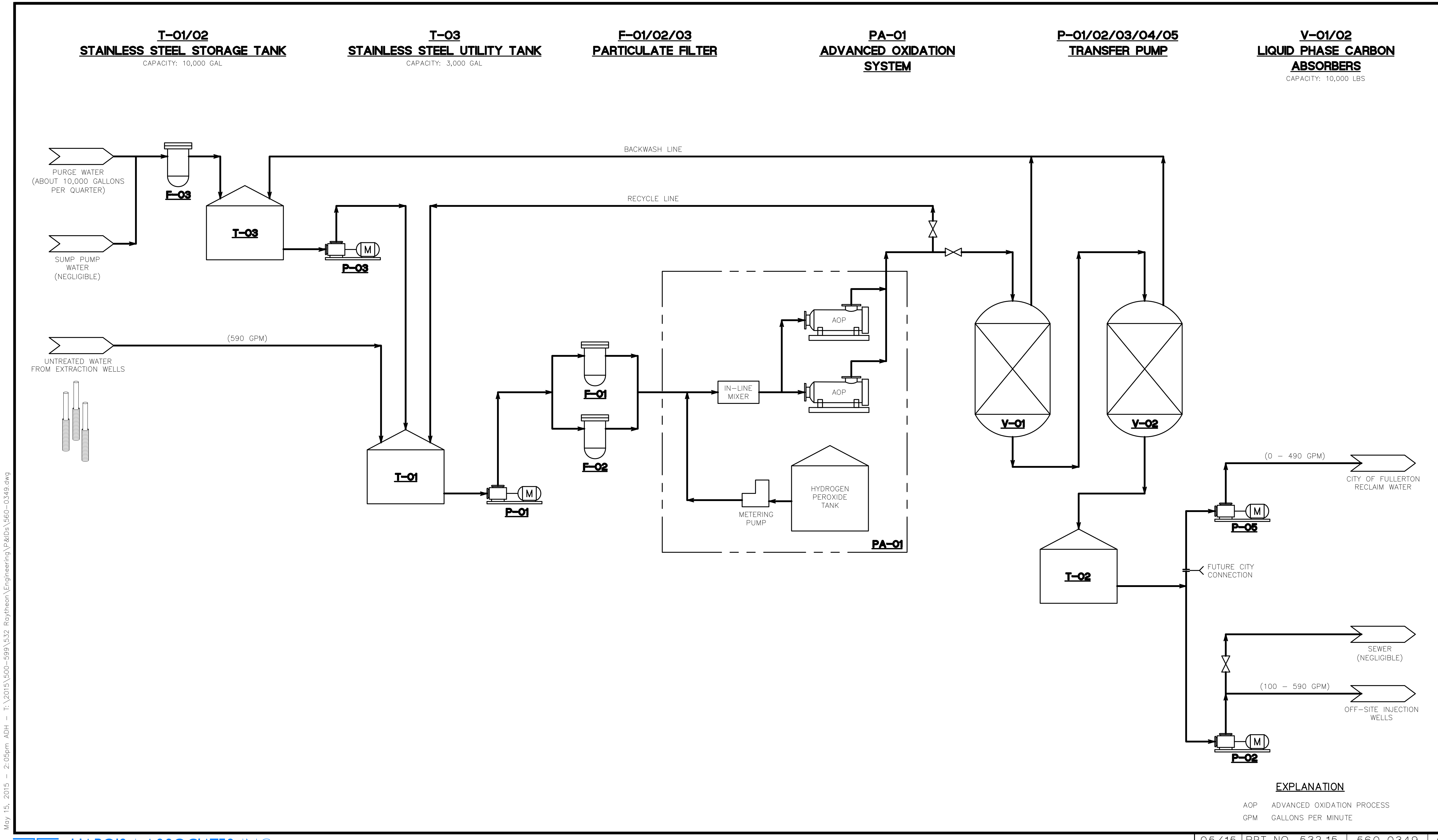


FIGURE 23. ALTERNATIVE GW6B: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH OFF-SITE UNIT B INJECTION AND NON-POTABLE REUSE



HARGIS + ASSOCIATES, INC
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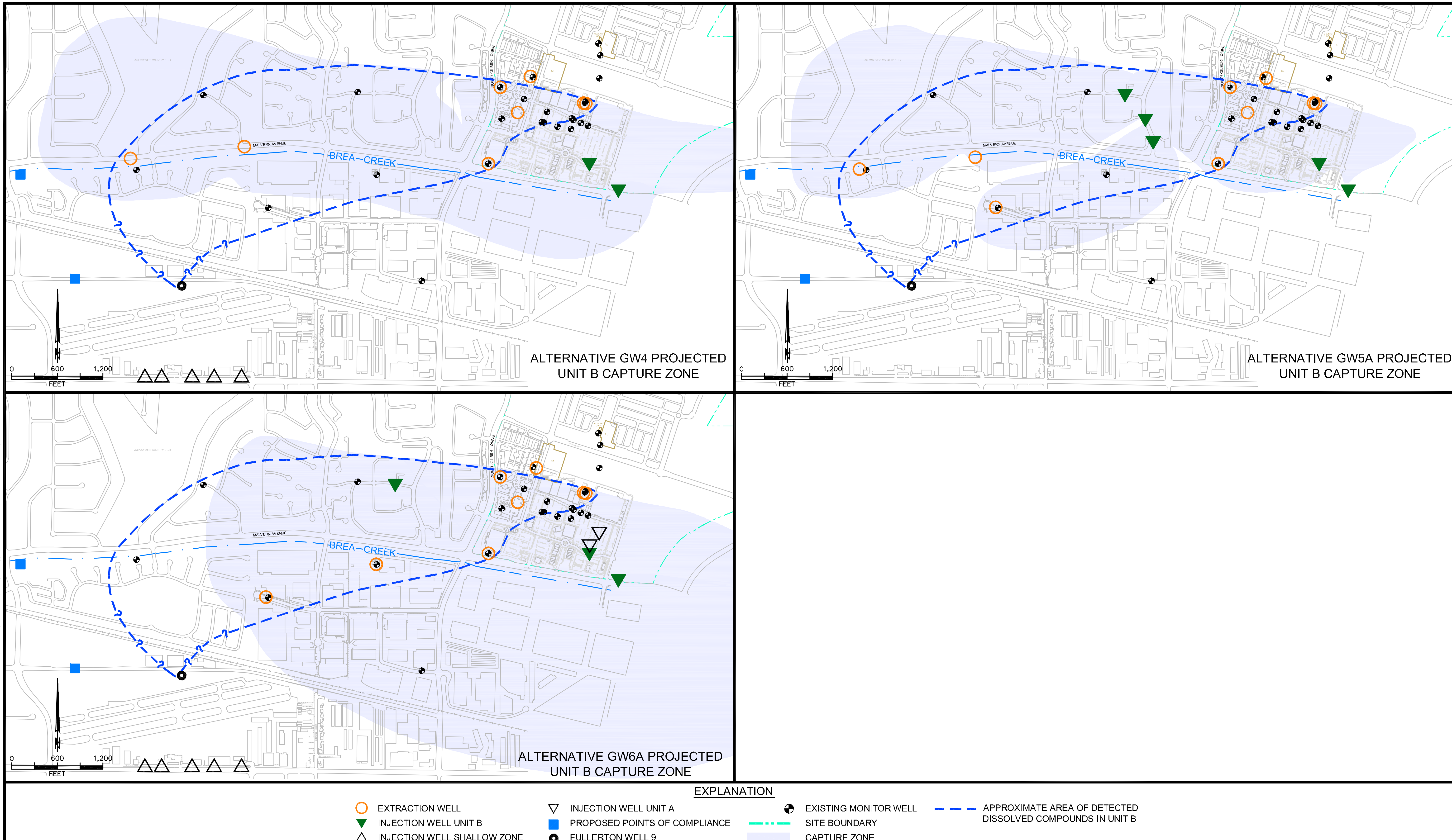
FIGURE 24.
ALTERNATIVE GW6B: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH OFF-SITE UNIT B INJECTION AND NON-POTABLE REUSE
SIMPLIFIED PROCESS FLOW DIAGRAM

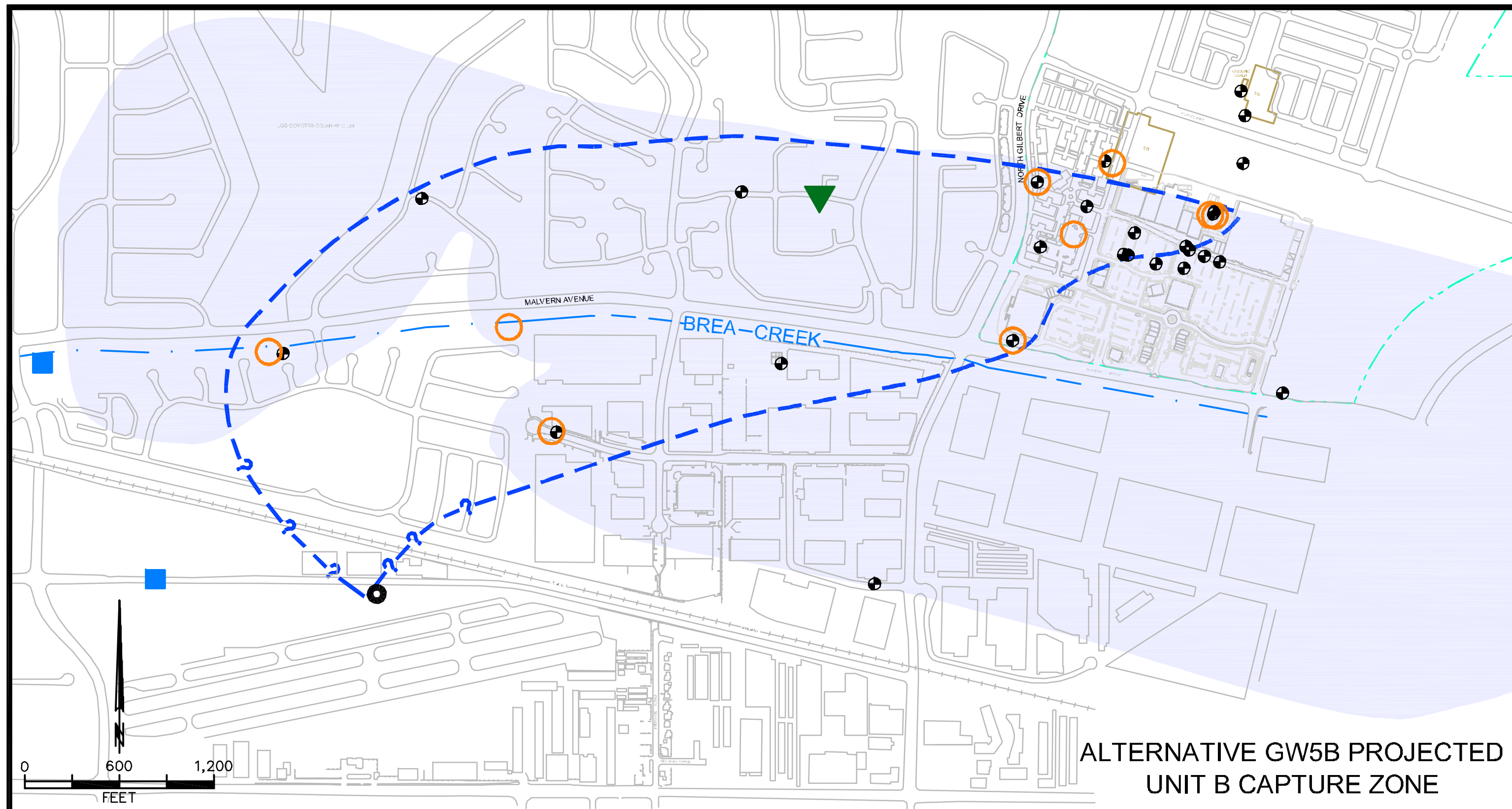


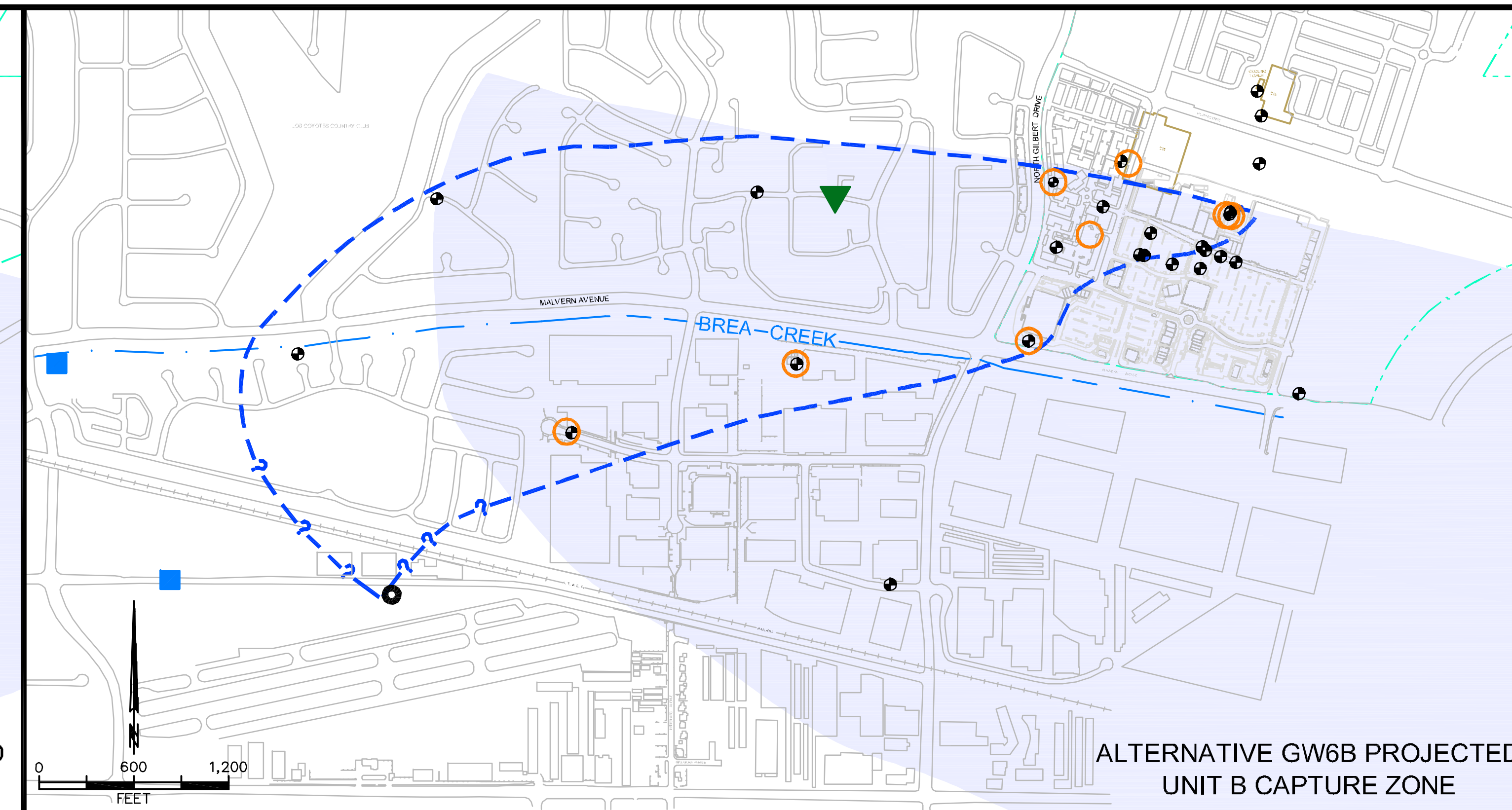
Jun 05, 2015 – 5:32pm ADH – T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9452.dwg

05/15	RPT NO. 532.52	410-9452	A

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

FIGURE 25.
PROJECTED CAPTURE ZONES FOR ON- AND OFF-SITE
GROUNDWATER EXTRACTION ALTERNATIVES (GW4, GW5A AND GW6A)





EXPLANATION

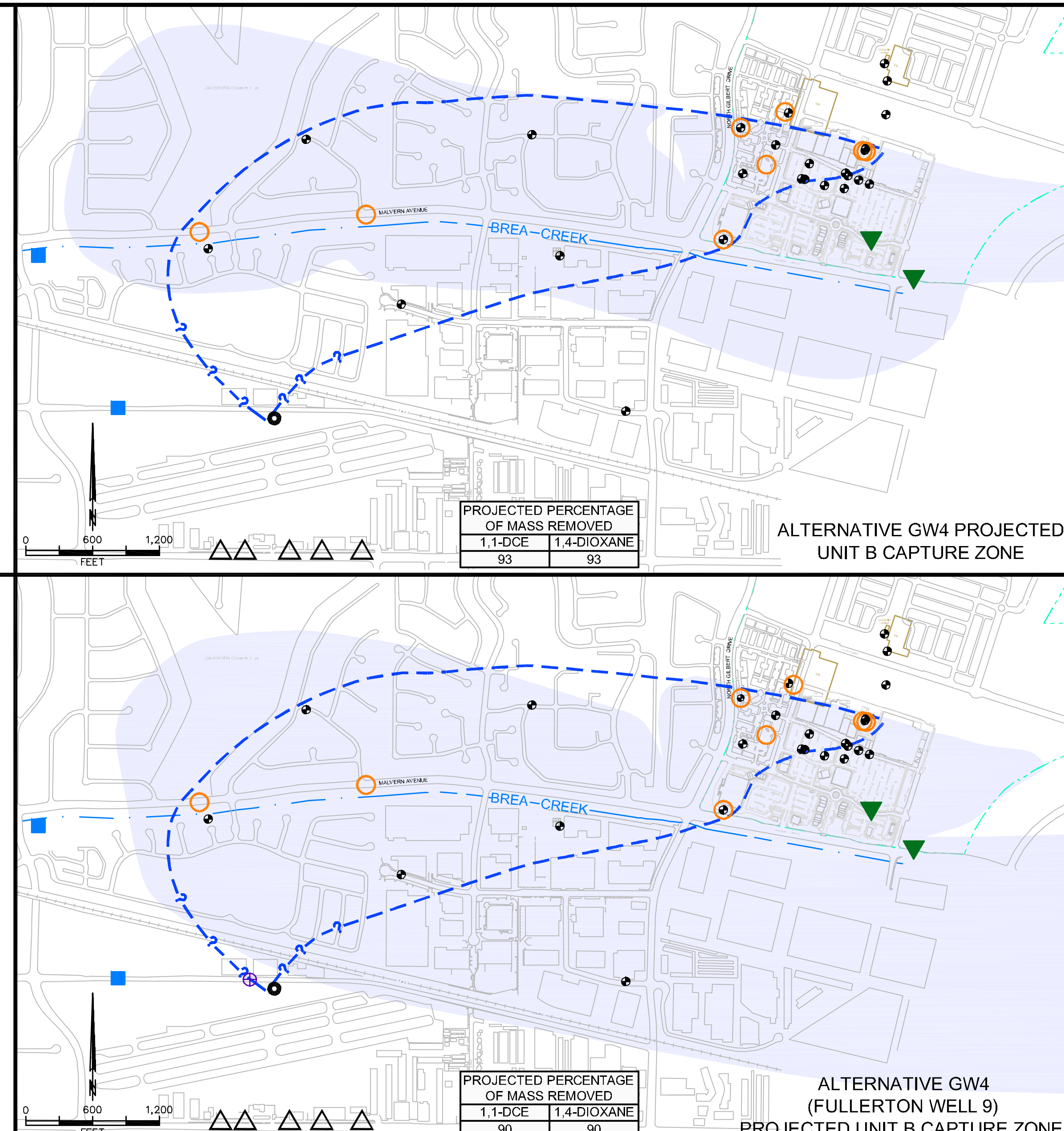
- EXTRACTION WELL
- INJECTION WELL UNIT B
- INJECTION WELL SHALLOW ZONE
- INJECTION WELL UNIT A
- PROPOSED POINTS OF COMPLIANCE
- FULLERTON WELL 9
- EXISTING MONITOR WELL
- SITE BOUNDARY
- CAPTURE ZONE
- APPROXIMATE AREA OF DETECTED DISSOLVED COMPOUNDS IN UNIT B

Jun 08, 2015 – 8:52am ADH – T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9453.dwg

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

06/15	RPT NO. 532.52	410-9453	A

FIGURE 26.
PROJECTED CAPTURE ZONES FOR ON- AND OFF-SITE GROUNDWATER EXTRACTION ALTERNATIVES (GW5B AND GW6B)



EXPLANATION

1,1-DCE = 1,1-DICHLOROETHENE

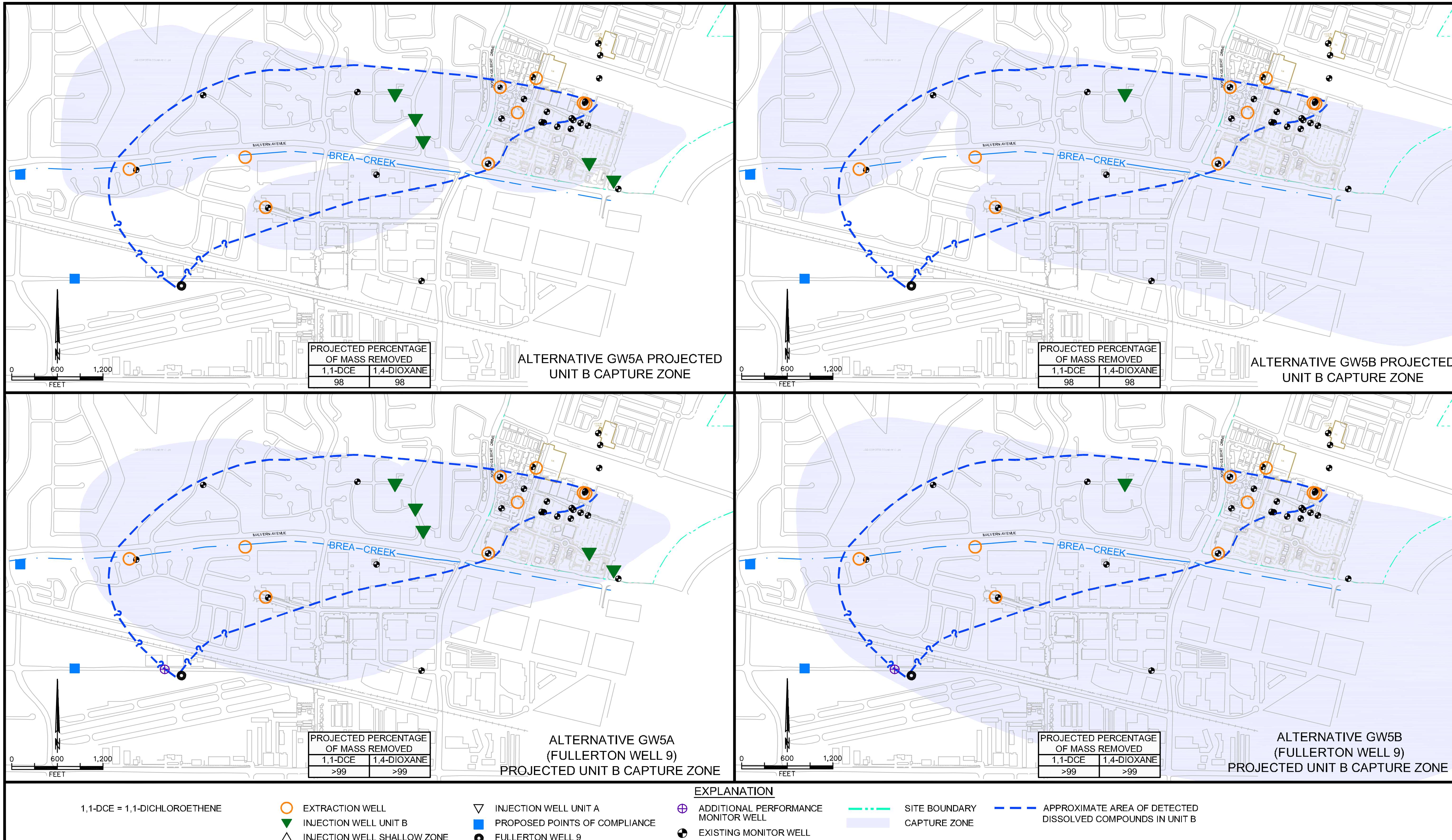
- EXTRACTION WELL
- INJECTION WELL UNIT B
- INJECTION WELL SHALLOW ZONE
- INJECTION WELL UNIT A
- PROPOSED POINTS OF COMPLIANCE
- FULLERTON WELL 9
- ADDITIONAL PERFORMANCE MONITOR WELL
- EXISTING MONITOR WELL
- SITE BOUNDARY
- CAPTURE ZONE
- APPROXIMATE AREA OF DETECTED DISSOLVED COMPOUNDS IN UNIT B

Jun 08, 2015 – 9:10am ADH – T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9454.dwg

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

06/15 | RPT NO. 532.52 | 410-9454 | A

FIGURE 27.
PROJECTED CAPTURE ZONES FOR ON- AND OFF-SITE GROUNDWATER EXTRACTION ALTERNATIVES WITH AND WITHOUT WELL 9 LOWER SCREEN ISOLATION (GW4)



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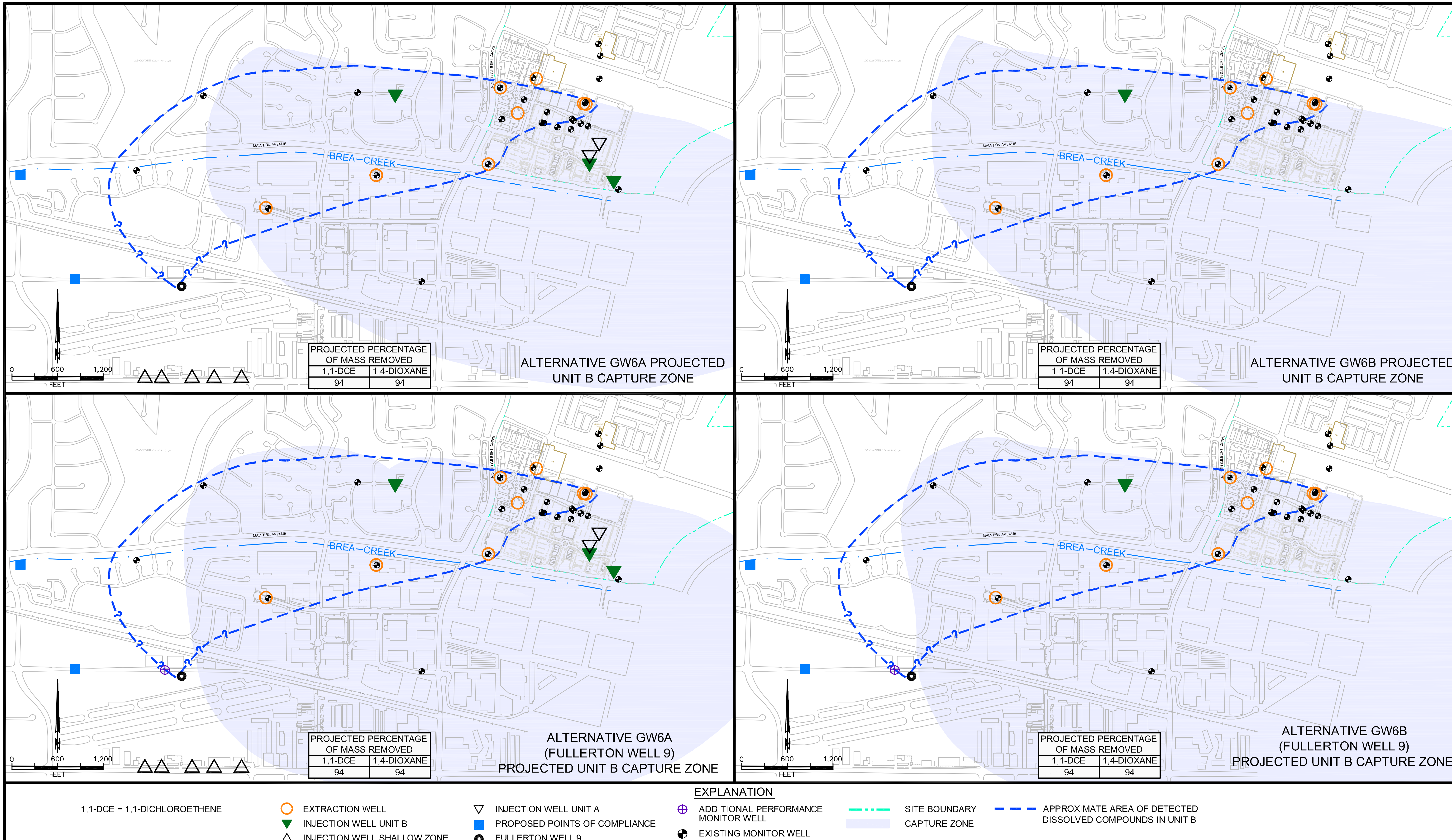
HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

06/15 | RPT NO. 532.52 | 410-9455 | A

FIGURE 28.
PROJECTED CAPTURE ZONES FOR ON- AND OFF-SITE GROUNDWATER EXTRACTION ALTERNATIVES WITH AND WITHOUT WELL 9 LOWER SCREEN ISOLATION (GW5A AND GW5B)



Jun 08, 2015 - 9:34am ADH - T:\2015\500-599\532 Raytheon\Hydrogeology\H+A BaseMaps\410-9456.dwg

05/15 | RPT NO. 532.52 | 410-9456 | A

HARGIS + ASSOCIATES, INC.
Hydrogeology/Engineering

FIGURE 29.
PROJECTED CAPTURE ZONES FOR ON- AND OFF-SITE GROUNDWATER EXTRACTION ALTERNATIVES WITH AND WITHOUT WELL 9 LOWER SCREEN ISOLATION (GW6A AND GW6B)

APPENDIX A

GROUNDWATER FLOW MODELING

APPENDIX A

GROUNDWATER FLOW MODELING

TABLE OF CONTENTS

Section Page

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TABLES

FIGURES

TABLE OF CONTENTS (continued)

FIGURES (continued)

ACRONYMS AND ABBREVIATIONS

CMS	Corrective Measures Study
COPCs	Compounds of potential concern
1,1-DCE	1,1-Dichloroethene
HGL	Hydrogeologic, Inc.
OCWD	Orange County Water District

APPENDIX A

GROUNDWATER FLOW MODELING

1.0 INTRODUCTION

A groundwater flow model was developed based on the Site hydrogeologic conceptual model of the regional groundwater system. The following computer modeling codes were used in the study: 1) the Hydrogeologic, Inc. (HGL), finite difference code MODFLOW-SURFACT (HGL, 1996); MODFLOW-SURFACT is based on, and constitutes additional modules to, the U.S. Geological Survey code MODFLOW (McDonald and Harbaugh, 1988); and 2) MODPATH for particle tracking to evaluate flow direction and vertical gradients (Pollock, 1994).

A transient, three-dimensional groundwater flow model was developed to simulate groundwater flow, recharge, and groundwater withdrawal within the model domain. Development of the flow model required definition of the geometry of hydrostratigraphic units; the hydraulic parameters that control groundwater flow; the rates and locations of recharge and groundwater withdrawal; and the water level conditions along the model boundary. Rather than assigning a unique value to every cell in the model with an infinite spectrum in the range of property values, regions within the model were defined as “zones” with similar hydraulic properties, and a single representative property value was assigned to each zone. The flow model was calibrated to the following: 1) September 2005 to May 2012 measured water levels and flow conditions in the study area; 2) projected drawdown observed during aquifer testing at extraction well EW-02 in October 2009; and 3) projected drawdown observed as a result of extraction at Well 9 from March 30, 2012 to April 2, 2012, by varying the above parameters within reasonable ranges supported by measured data. Information compiled for model construction consisted of groundwater assessment data collected at the Site through 2012; model layering and hydraulic property information for the calibrated Orange County Groundwater Basin three dimensional groundwater flow model prepared by the Orange County Water District (OCWD) (OCWD, 2008); and published literature regarding hydrogeology and regional well logs and water levels in the Site vicinity provided by OCWD.

As discussed during the September 25, 2013 meeting with the California Environmental Protection Agency, Department of Toxic Substances Control, the current groundwater flow model is adequate to support evaluation of groundwater corrective action alternatives using capture zone analysis. The model construction and results of calibration were documented in a technical memorandum along with the current understanding of the Conceptual Site Model (Hargis + Associates, Inc., 2015). Results of future model projections to aid in the evaluation of corrective action alternatives are discussed herein.

1.1 MODEL OBJECTIVES

The objective of the regional flow model is to simulate a transient flow field that is representative of dynamic groundwater flow conditions at the Site to provide a tool that will aid in evaluation of corrective action alternatives and remedial design.

The groundwater flow model was used during the Corrective Measures Study (CMS) to develop groundwater extraction wellfield alternatives that are able to control future migration of residual compounds of concern (COCs) from former source areas and contain COCs in groundwater to protect current and future uses of groundwater under the varying hydraulic conditions. The evaluations are based on model-projected water levels and particle tracking using a flow-modeling approach. Based on the complexity of the hydrogeologic conditions and uncertainty regarding the degree to which various fate and transport mechanisms may impact the rate of solute migration at the Site, solute transport modeling is not expected to provide any more meaningful design information than particle tracking using the flow model.

The results of groundwater modeling will also be used to support the design of the selected corrective measure alternative. It is understood that the results of groundwater flow modeling provide an approximation of groundwater extraction rates and projections of wellfield performance. With this understanding, the wellfield and associated piping will be designed with excess capacity, as a contingency, in the event that increased flow is required to meet the remedial action objectives based on performance monitoring. Performance monitoring data will be collected during the remediation system operation to reliably assess remediation performance and identify whether future modifications to the extraction rate and/or locations are necessary to ensure remedial action objectives are met.

1.2 FUTURE MODEL PROJECTIONS

The calibrated groundwater flow model and associated particle tracking were used to simulate alternative wellfield configurations to evaluate potential corrective action alternatives. For each alternative, reverse particle tracking was conducted to project potential capture zones. Each alternative was simulated assuming extraction from Well 9 is not isolated from Unit B (i.e. current well screen configuration). Alternatives that include off-Site extraction (Alternatives GW4 through GW6B) were also simulated assuming extraction from Well 9 is isolated from Unit B (i.e. the current well screen configuration is altered such that extraction is limited to the screened zones above Unit B). Projected capture zones for the corrective action alternatives evaluated in this CMS are presented in Figures A-1 to A-7A. Refer to the CMS main text for a description of each alternative.

1.3 PROJECTED MASS REMOVED

The percentage of current 1,1-dichloroethene (1,1-DCE) and 1,4-dioxane mass in Unit B groundwater that is projected to be removed was estimated for each alternative using the model projected capture zones (Table A-1). To estimate the percentage of mass removed, the area of groundwater contamination was split into 6 polygons (Figure A-8). A description of the procedure for estimating the percentage of mass removed by each alternative follows.

For the purposes of this evaluation, it was assumed that the total amount of Unit B mass available for capture is equal to the current mass in Unit B groundwater plus the additional mass added from residual sources over the next 20 years. The current amount of 1,1-DCE and 1,4-dioxane mass in Unit B groundwater within each polygon was estimated as the product of the volume of water and the average historical groundwater concentrations in Unit B monitor wells located within each respective polygon (Figure A-8). The volume of groundwater in each polygon was estimated as the product of the polygon area, Unit B thickness and porosity. An estimated Unit B thickness of 50 feet, and a porosity of 30 percent were used for all polygons.

The residual 1,1-DCE and 1,4-dioxane source loading rates were estimated from the asymptotic concentrations observed in former source area extraction wells EW-01 and MW-21 during operation of these wells from July 2008 to March 2010 and assuming a nominal flow of 10 gallons per minute through the residual source (Figure A-9). The amount of additional mass added to Unit B groundwater over 20 years was then estimated from the source loading rates. This mass was added to the current mass in groundwater estimated for polygon 6.

The percentage of the total mass occurring within each polygon was estimated (Table A-1). For each alternative, it was determined which polygons fall within the projected capture zones. The percentage of total available mass captured for each alternative was then calculated by summing the percent of mass occurring within the polygons that are captured (Table A-1).

2.0 REFERENCES

Hargis + Associates, Inc., 2015. Technical Memorandum, Conceptual Site Model and Construction and Calibration of Numerical Groundwater Flow Model, Corrective Measures Study, Raytheon Company (Formerly Hughes Aircraft Company), 1901 West Malvern Avenue, Fullerton, California. February 10, 2015.

Hydrogeologic, Inc. (HGL), 1996. MODFLOW-SURFACT Software (Version 4.0).

McDonald, M.G., and A.W. Harbaugh, 1988. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. U.S. Geological Survey, Washington, D.C. 1988.

Orange County Water District, 2008. Transmittal of OCWD Basin Groundwater Model AutoCAD files, Tim Sovich. January 2008.

Pollock, D.W., 1994. User's Guide for MODPATH/MODPATH-PLOT, Version 3: A particle tracking post-processing package for MODFLOW, the U.S. Geological Survey finite-difference ground-water flow model. September 1994.

TABLE A-1

PROJECTED PERCENTAGE OF DISSOLVED 1,1-DICHLOROETHENE AND 1,4-DIOXANE UNIT B MASS REMOVED

	Poly 1	Poly 2	Poly 3	Poly 4	Poly 5	Poly 6		
Percentage of 1,1-Dichloroethene Mass in Polygon	4	2	9.5	7	5	73		
Percentage of 1,4-Dioxane Mass in Polygon	0.4	0.4	5	6	1	87		
Option	**Poly 1**	**Poly 2**	**Poly 3**	**Poly 4**	**Poly 5**	**Poly 6**	**Total Percentage of 1,1-Dichloroethene Mass Removed**	**Total Percentage of 1,4-Dioxane Mass Removed**
1 and 2	N	N	N	N	N	N	**0**	**0**
3	N	N	N	N	N	Y	**73**	**73**
4	Y	N	Y	Y	N	Y	**93**	**93**
4 Iso	Y	Y	N	Y	Y	Y	**90**	**90**
5a	Y	N	Y	Y	Y	Y	**98**	**98**
5a Iso	Y	Y	Y	Y	Y	Y	**>99**	**>99**
5b	Y	N	Y	Y	Y	Y	**98**	**98**
5b Iso	Y	Y	Y	Y	Y	Y	**>99**	**>99**
6a	N	N	Y	Y	Y	Y	**94**	**94**
6a Iso	N	N	Y	Y	Y	Y	**94**	**94**
6b	N	N	Y	Y	Y	Y	**94**	**94**
6b Iso	N	N	Y	Y	Y	Y	**94**	**94**

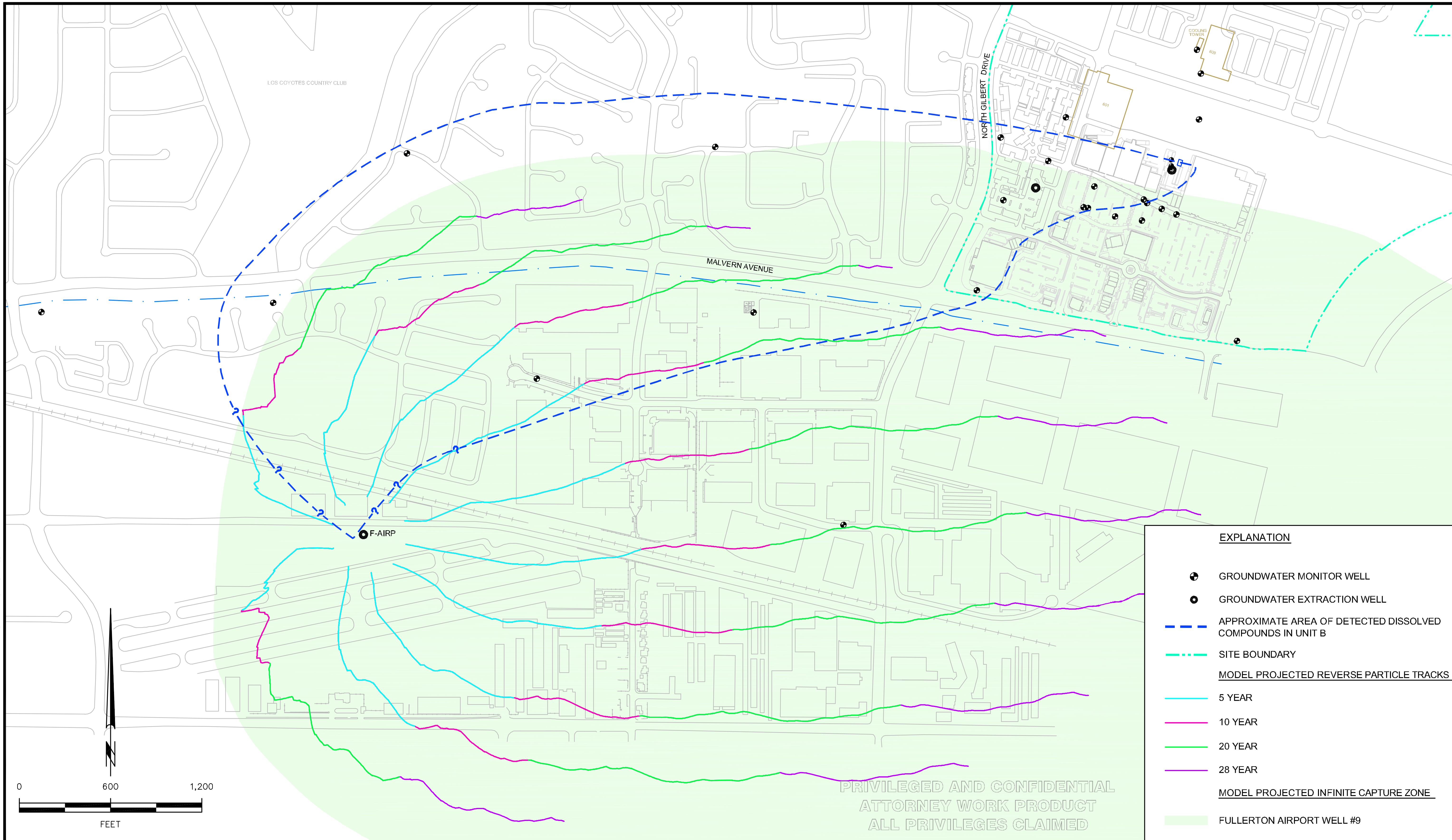

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FIGURE A-1.
ALTERNATIVES GW1 AND GW2 PROJECTED UNIT B CAPTURE ZONE

PROPOSED WELL RATES (gpm)

Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	50
EW-07	10
TOTAL:	**220**
Injection Wells	
IW-01	110
IW-02	110
TOTAL:	**220**

gpm = gallons per minute

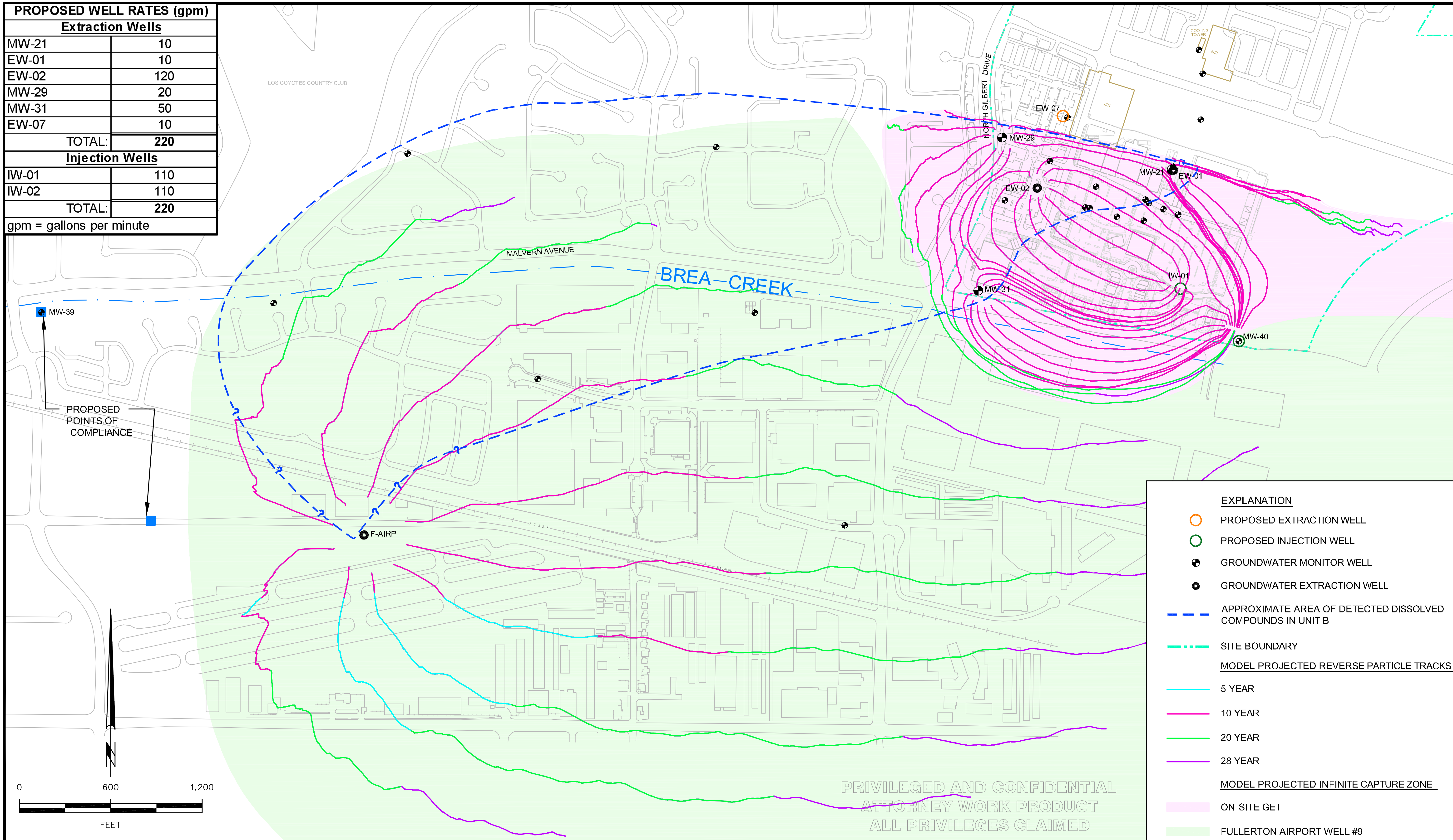

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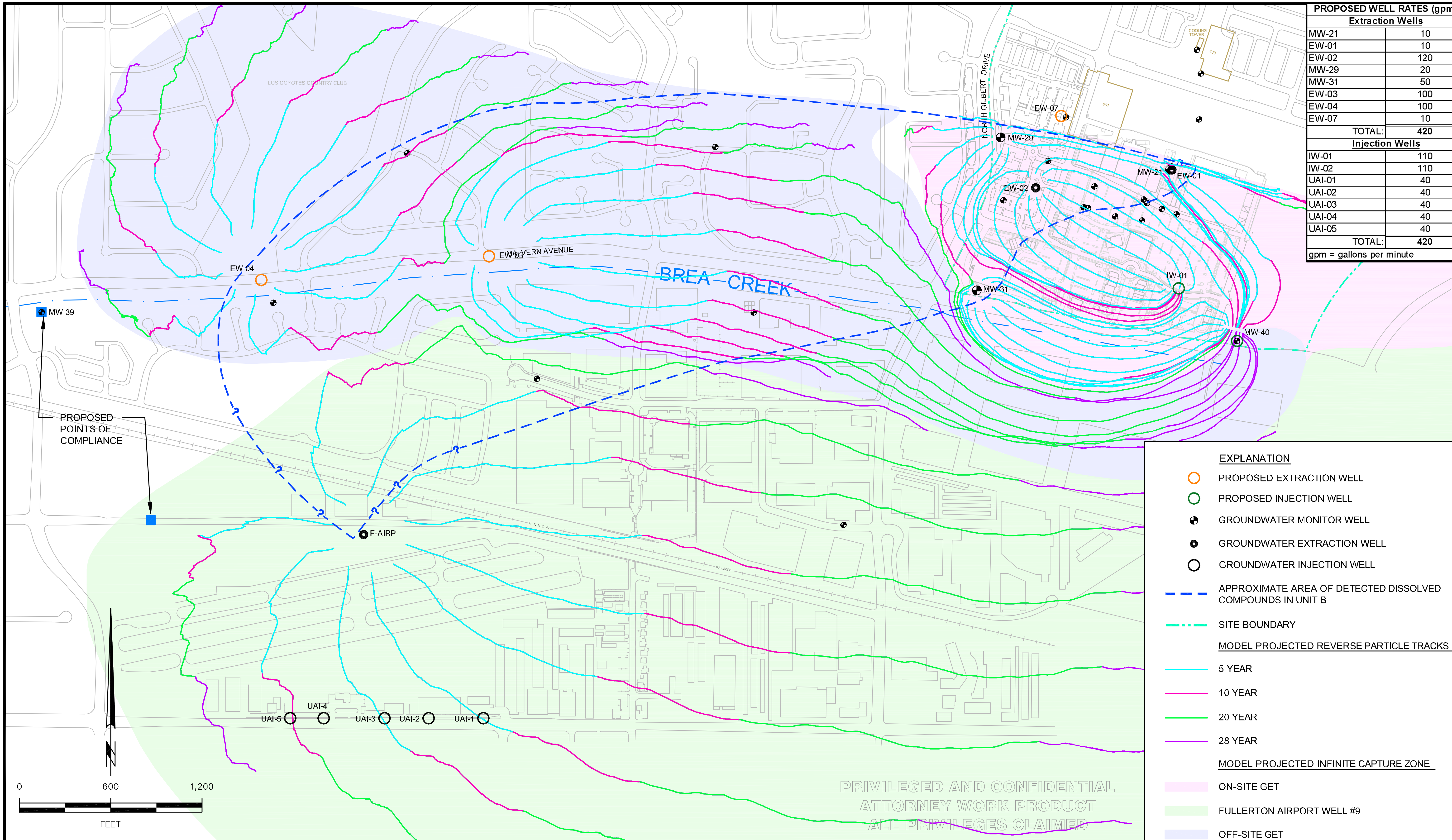
FIGURE A-2.
ALTERNATIVE GW3 PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	50
EW-03	100
EW-04	100
EW-07	10
TOTAL:	**420**
Injection Wells	
IW-01	110
IW-02	110
UAI-01	40
UAI-02	40
UAI-03	40
UAI-04	40
UAI-05	40
TOTAL:	**420**
gpm = gallons per minute	

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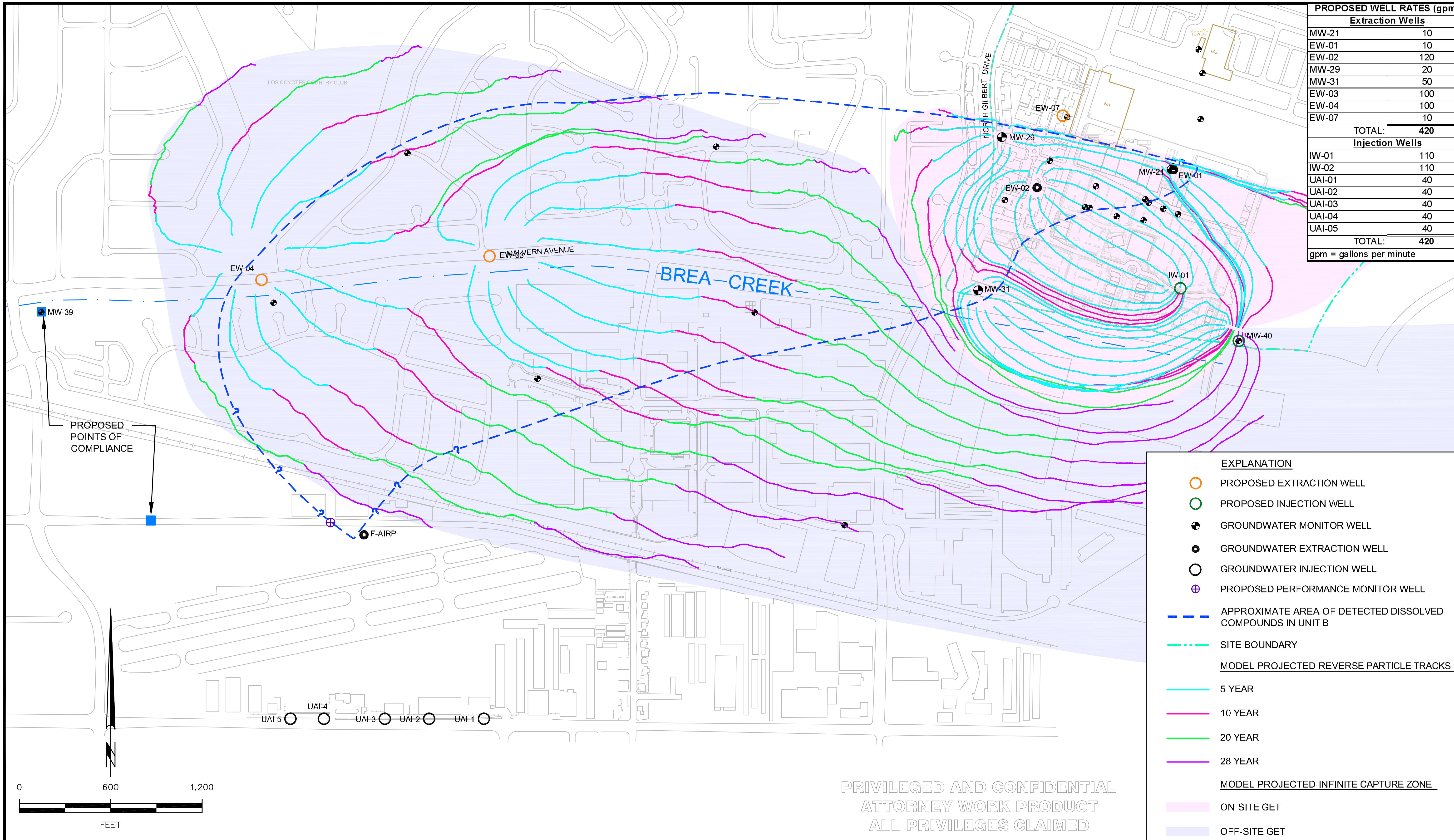
FIGURE A-3.
ALTERNATIVE GW4 PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	50
EW-03	100
EW-04	100
EW-07	10
TOTAL:	**420**
Injection Wells	
IW-01	110
IW-02	110
UAI-01	40
UAI-02	40
UAI-03	40
UAI-04	40
UAI-05	40
TOTAL:	**420**
gpm = gallons per minute	

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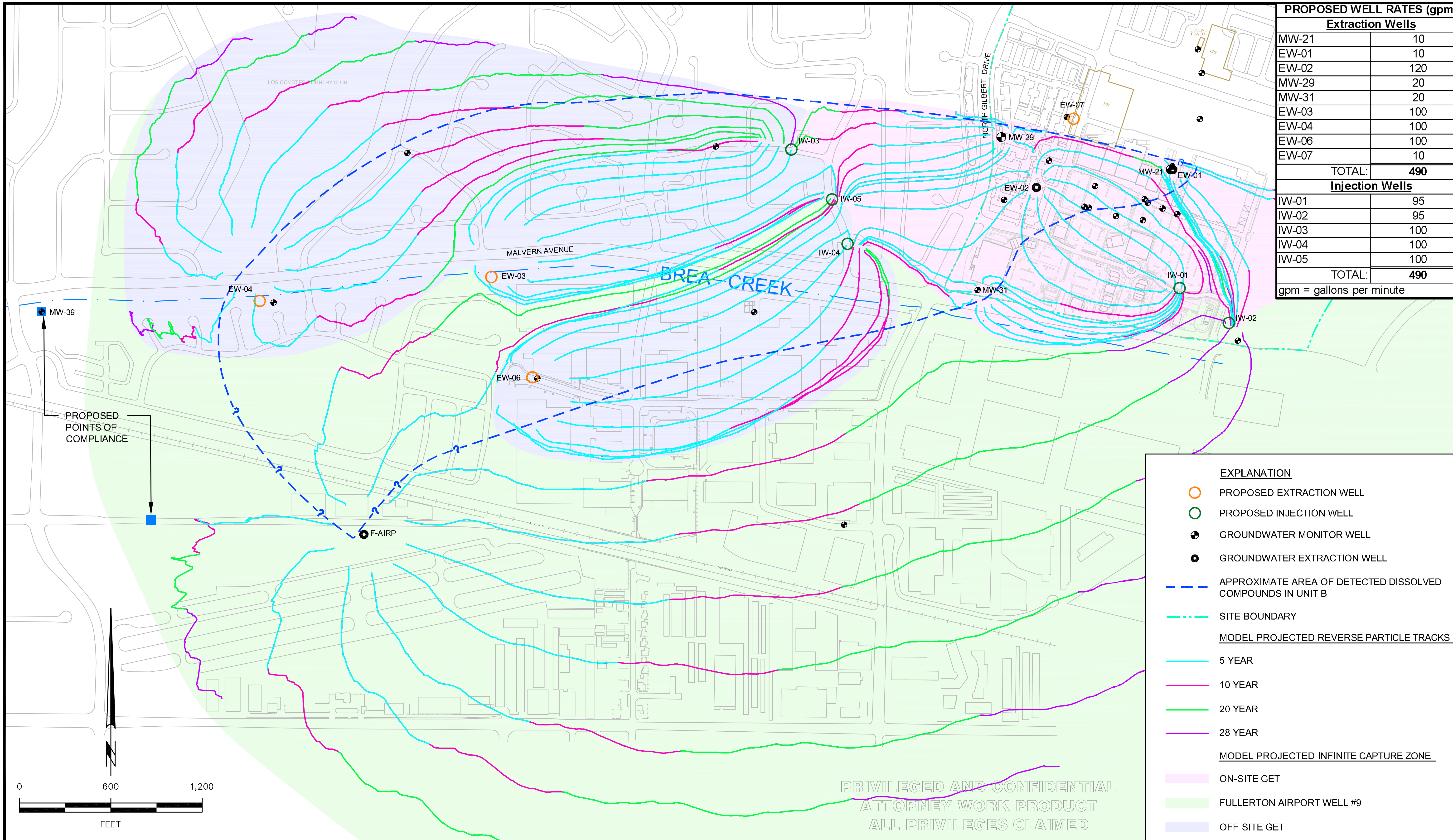
FIGURE A-3A.
ALTERNATIVE GW4 (AIRPORT WELL ISOLATED) PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	20
EW-03	100
EW-04	100
EW-06	100
EW-07	10
TOTAL:	**490**
Injection Wells	
IW-01	95
IW-02	95
IW-03	100
IW-04	100
IW-05	100
TOTAL:	**490**
gpm = gallons per minute	

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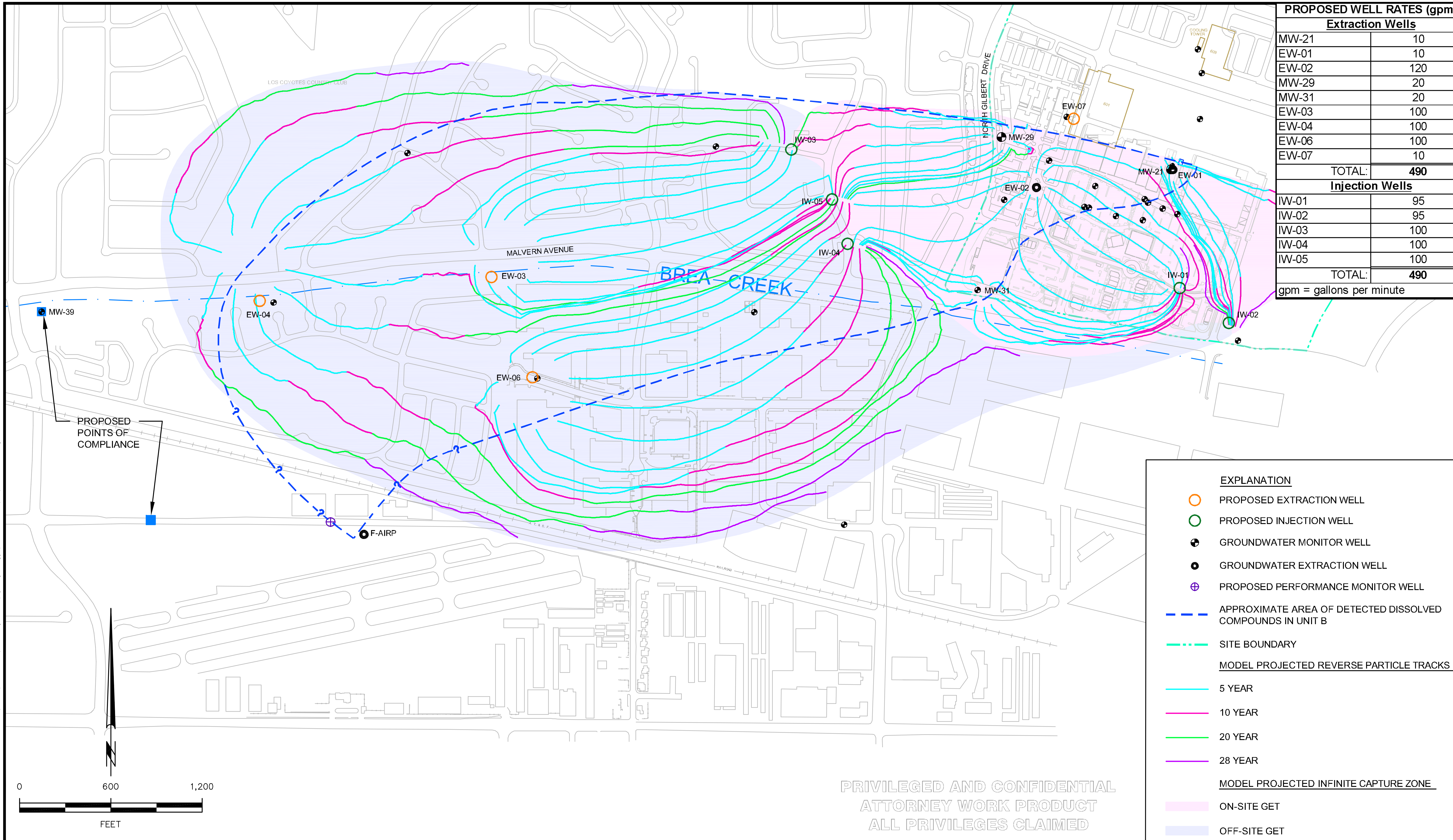
FIGURE A-4.
ALTERNATIVE GW5A PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	20
EW-03	100
EW-04	100
EW-06	100
EW-07	10
TOTAL:	**490**
Injection Wells	
IW-01	95
IW-02	95
IW-03	100
IW-04	100
IW-05	100
TOTAL:	**490**
gpm = gallons per minute	

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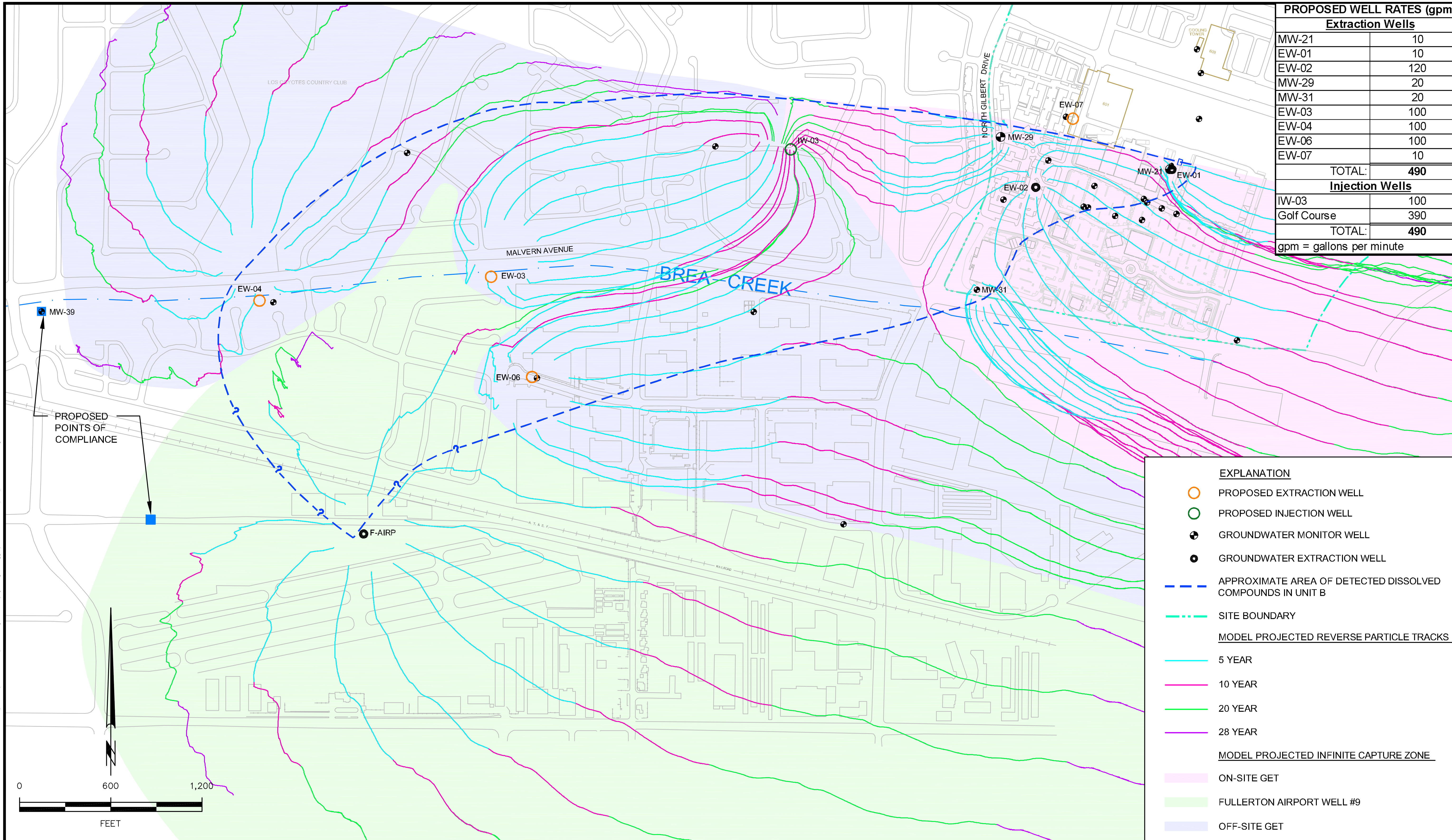
FIGURE A-4A.
ALTERNATIVE GW5A (AIRPORT WELL ISOLATED) PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	20
EW-03	100
EW-04	100
EW-06	100
EW-07	10
TOTAL:	**490**
Injection Wells	
IW-03	100
Golf Course	390
TOTAL:	**490**
gpm = gallons per minute	

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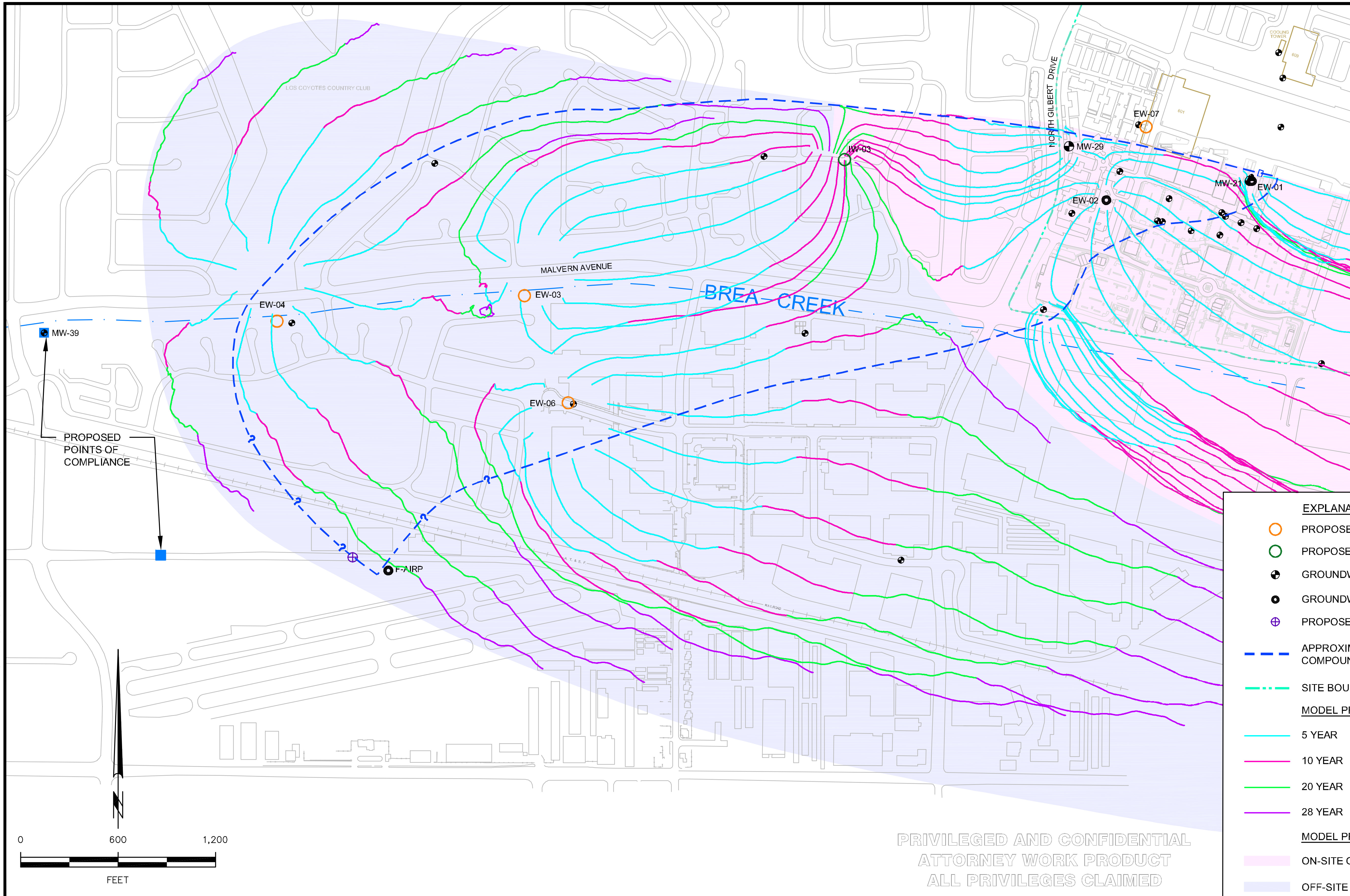
FIGURE A-5.
ALTERNATIVE GW5B PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	20
EW-03	100
EW-04	100
EW-06	100
EW-07	10
TOTAL:	**490**
Injection Wells	
IW-03	100
Golf Course	390
TOTAL:	**490**
gpm = gallons per minute	

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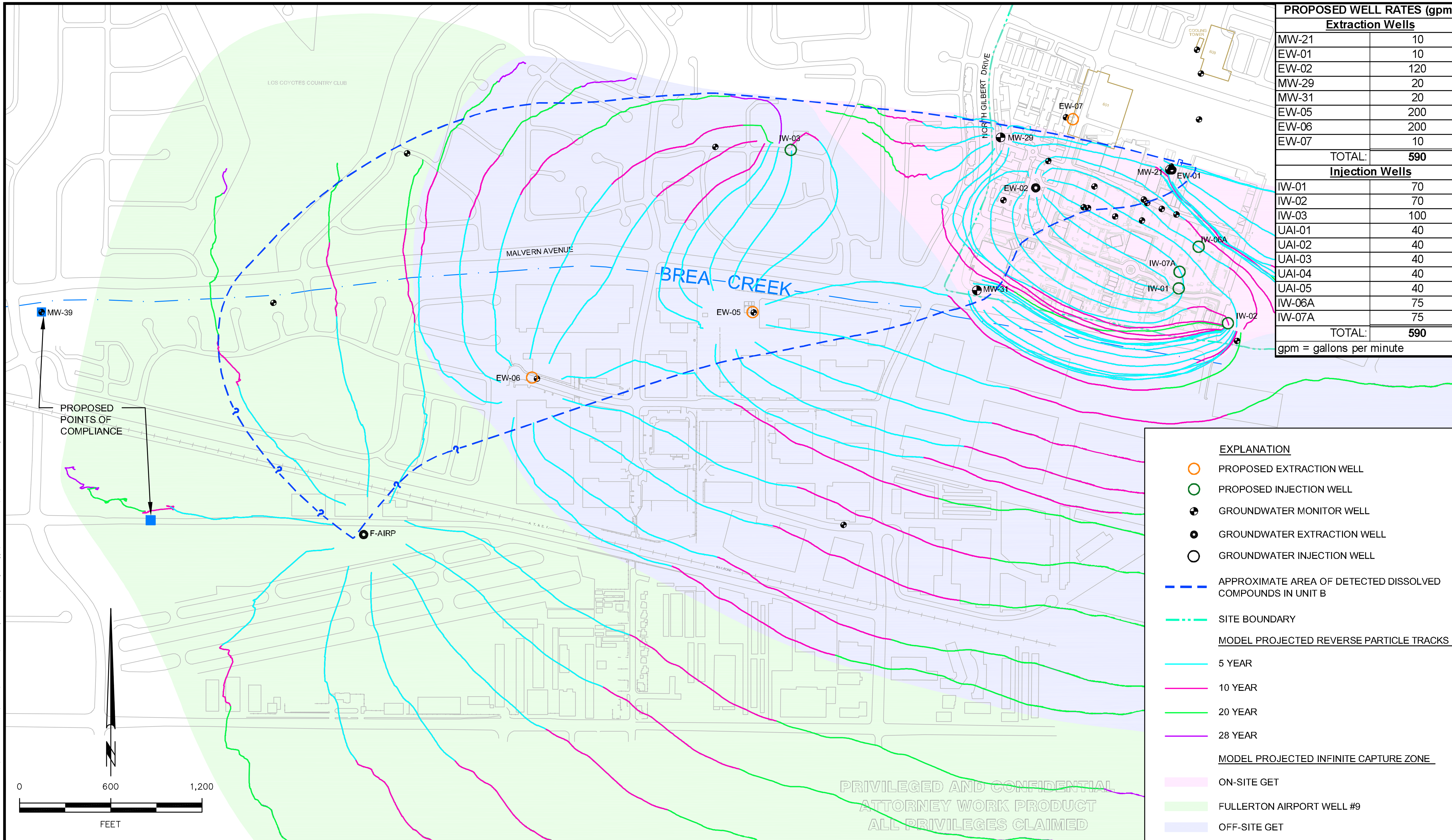
FIGURE A-5A.
ALTERNATIVE GW5B (AIRPORT WELL ISOLATED) PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	20
EW-05	200
EW-06	200
EW-07	10
TOTAL:	**590**
Injection Wells	
IW-01	70
IW-02	70
IW-03	100
UAI-01	40
UAI-02	40
UAI-03	40
UAI-04	40
UAI-05	40
IW-06A	75
IW-07A	75
TOTAL:	**590**
gpm = gallons per minute	

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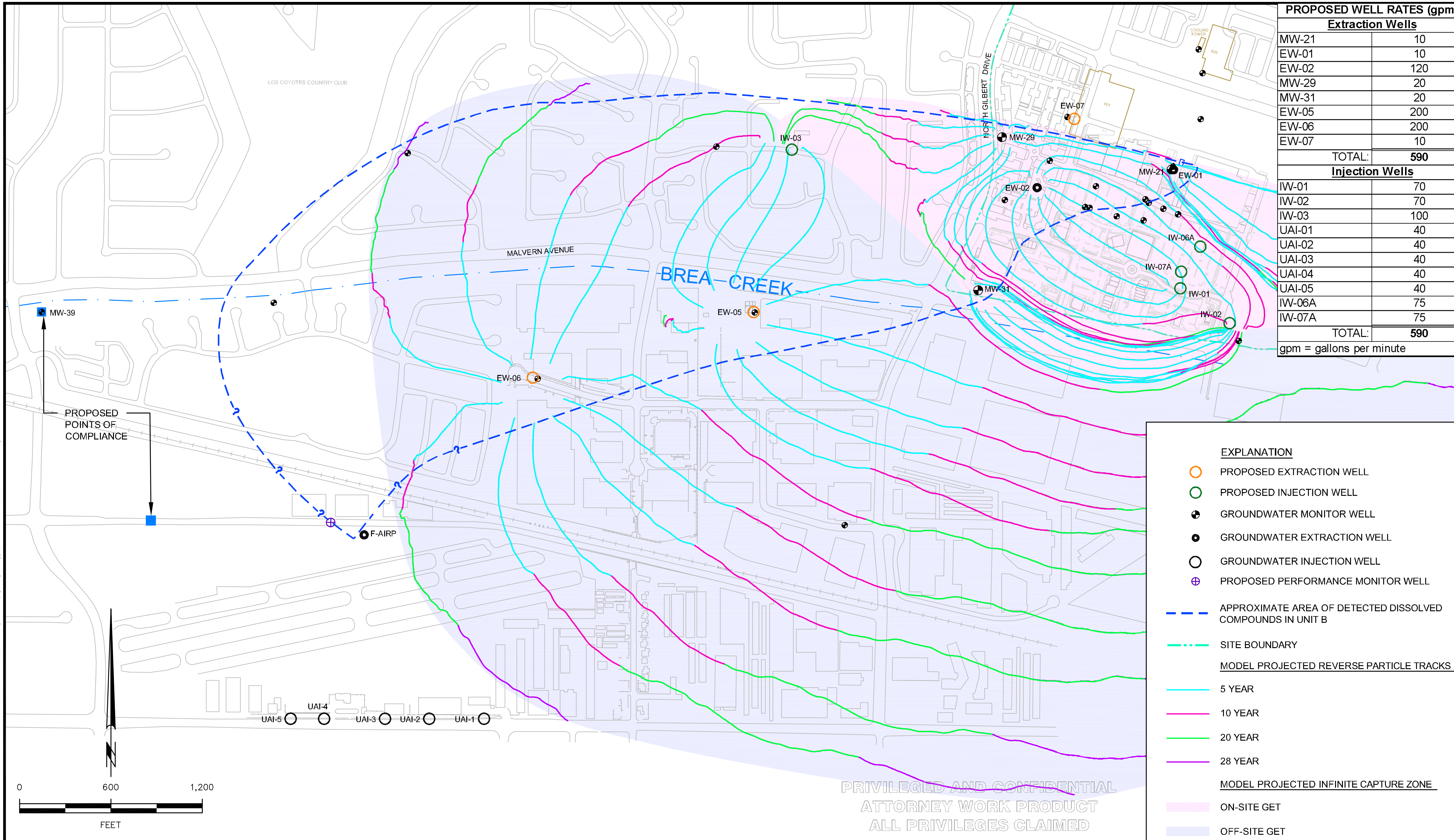
FIGURE A-6.
ALTERNATIVE GW6A PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	20
EW-05	200
EW-06	200
EW-07	10
TOTAL:	**590**
Injection Wells	
IW-01	70
IW-02	70
IW-03	100
UAI-01	40
UAI-02	40
UAI-03	40
UAI-04	40
UAI-05	40
IW-06A	75
IW-07A	75
TOTAL:	**590**
gpm = gallons per minute	

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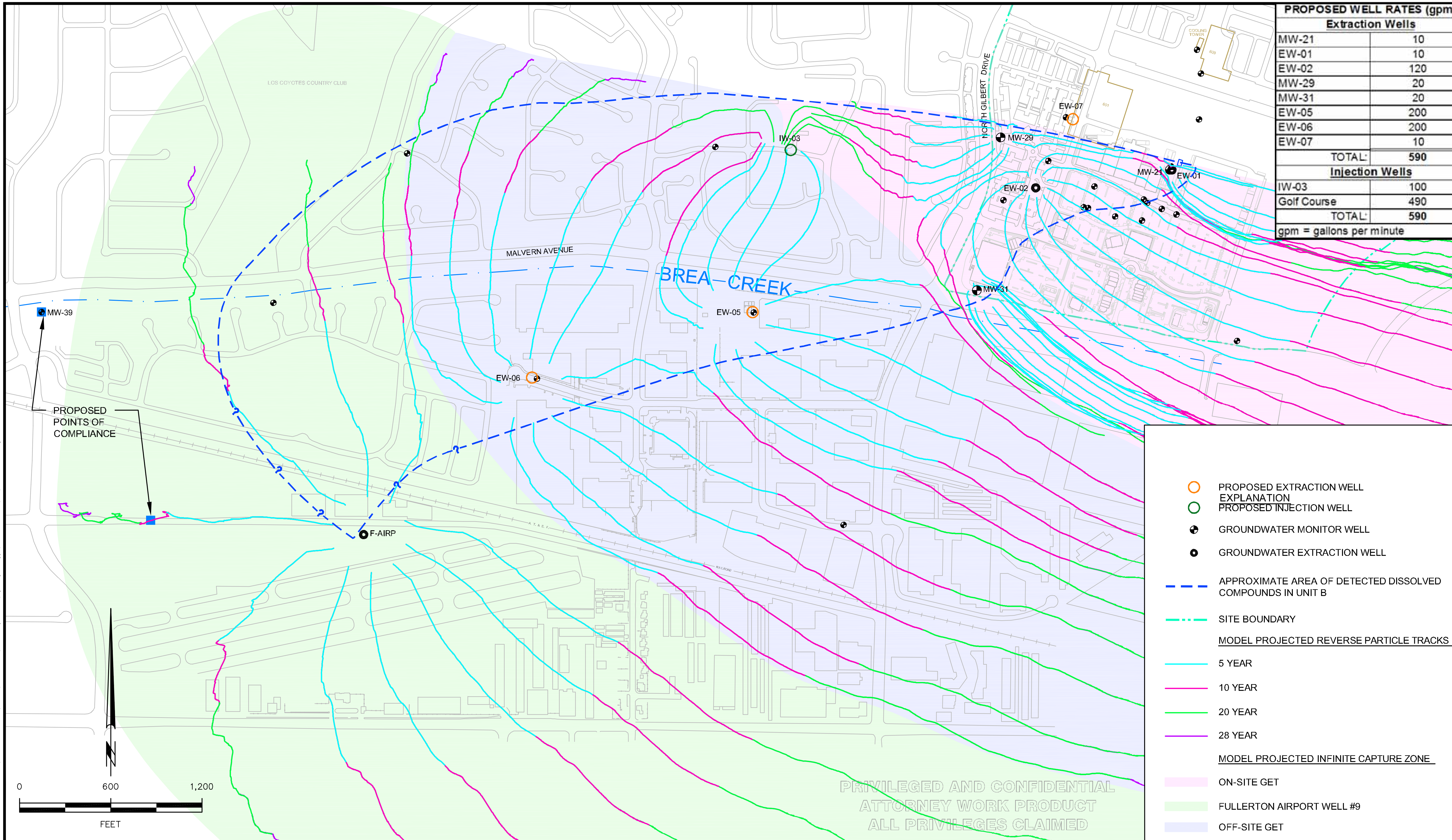
FIGURE A-6A.
ALTERNATIVE GW6A (AIRPORT WELL ISOLATED) PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	20
EW-05	200
EW-06	200
EW-07	10
TOTAL:	590
Injection Wells	
IW-03	100
Golf Course	490
TOTAL:	590
gpm = gallons per minute	

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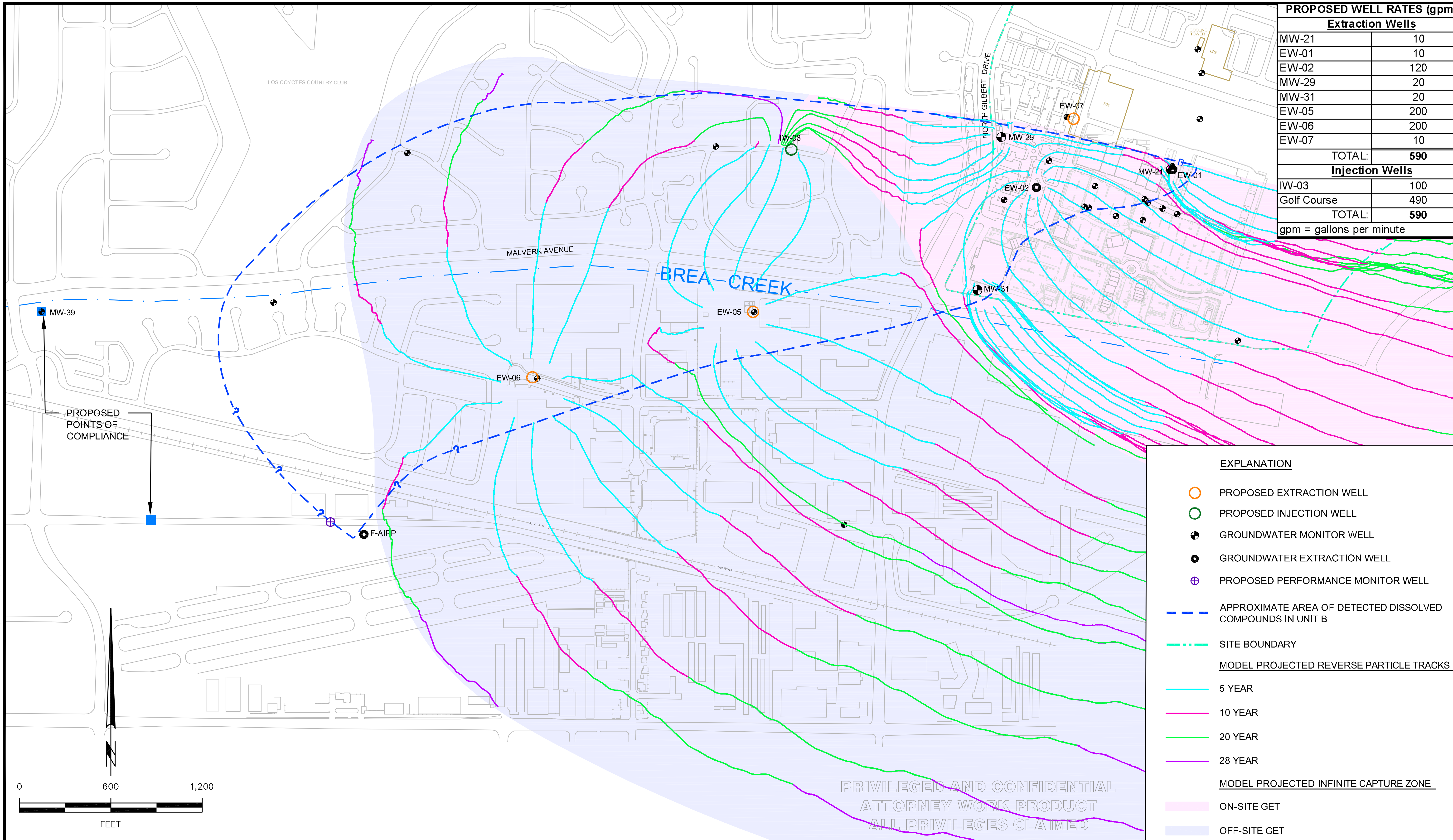
FIGURE A-7.
ALTERNATIVE GW6B PROJECTED UNIT B CAPTURE ZONE



PROPOSED WELL RATES (gpm)	
Extraction Wells	
MW-21	10
EW-01	10
EW-02	120
MW-29	20
MW-31	20
EW-05	200
EW-06	200
EW-07	10
TOTAL:	**590**
Injection Wells	
IW-03	100
Golf Course	490
TOTAL:	**590**
gpm = gallons per minute	

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FIGURE A-7A.
ALTERNATIVE GW6B (AIRPORT WELL ISOLATED) PROJECTED UNIT B CAPTURE ZONE

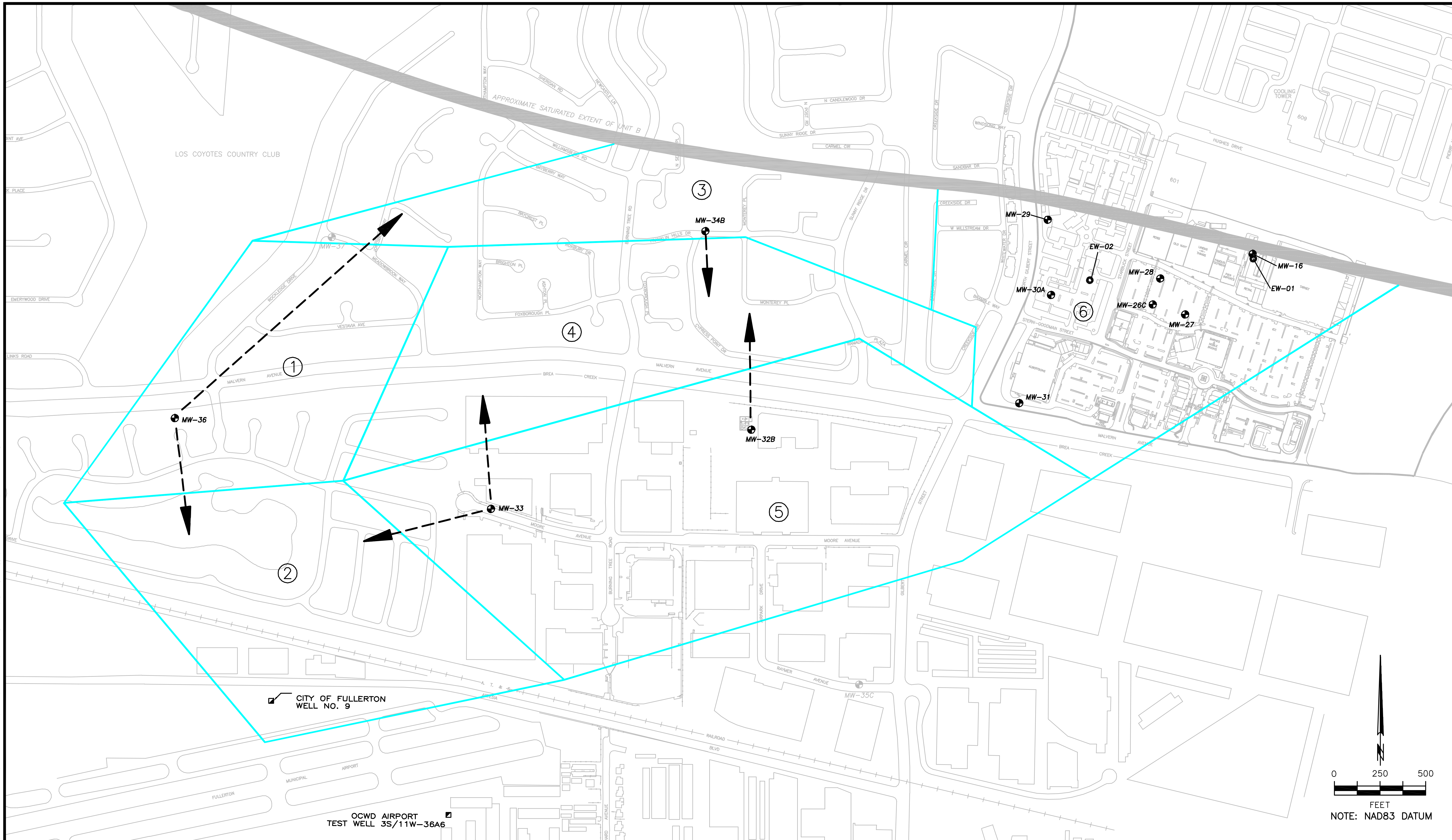

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FIGURE A-8.
POLYGONS USED FOR MASS ESTIMATES

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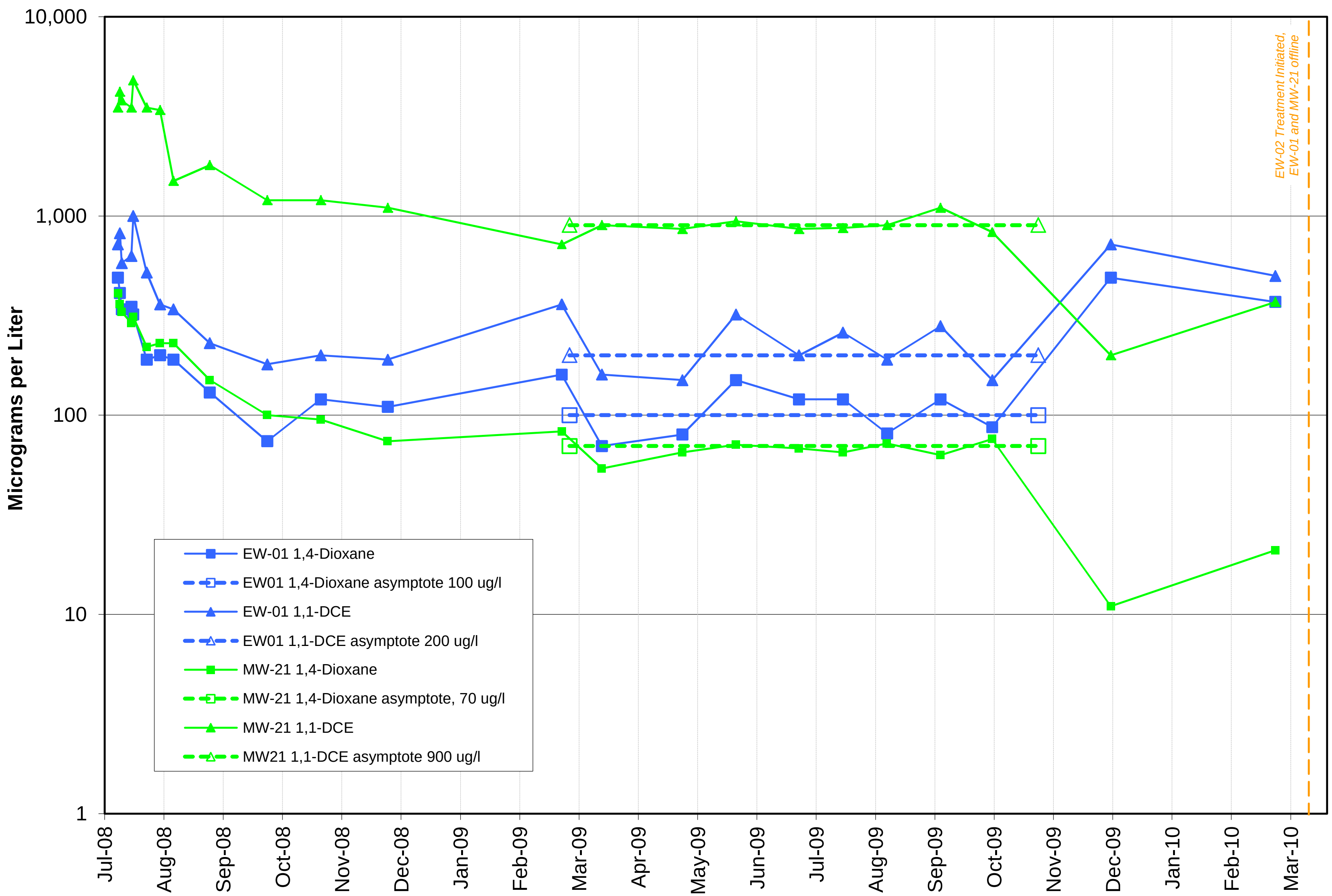

1,1-DCE = 1,1-Dichloroethene
ug/l = Microgram per liter

FIGURE A-9. 1,1-DICHLOROETHENE AND 1,4-DIOXANE IN EXTRACTION WELLS EW-01 AND MW-21

APPENDIX B

CORRECTIVE MEASURES ALTERNATIVES COST ESTIMATES

APPENDIX B

CORRECTIVE MEASURES ALTERNATIVES COST ESTIMATES

TABLE OF CONTENTS

Table

TABLE B-1

COST ESTIMATE ALTERNATIVE - GW1: NO ACTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

Capacity (gpm)		Description/Segment	Extraction		Injection		Units	Quantity	Unit Cost	Cost	Source of Estimate
Extraction	Injection		Size (inches)	Material	Size (inches)	Material					
				DCHDPE		HDPE	Feet			$ -	
										$ -	
										$ -	
										$ -	
										$ -	
										$ -	
									Subtotal	**$ -**	

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Engineer-Design and Technical Support	Percent			$ -	
Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent			$ -	
Contractor Profit	Percent			$ -	
Construction Oversight	Percent			$ -	
Construction Contingency	Percent			$ -	
Total Conveyance				$ -	

WELLS

Extraction/Injection Well Installation

Well Type	Capacity (gpm)	Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
								$ -	H+A estimate
								$ -	H+A estimate
								$ -	
								$ -	
								$ -	
		Subtotal Extraction/Injection Well Installation						**$ -**	

DESIGN AND CONSTRUCTION (CAPITAL)

Monitor Well Installation

Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
							H+A estimate
							H+A estimate
						$ -	
						$ -	
Subtotal Monitor Well Installation						**$ -**	

TABLE B-1

COST ESTIMATE ALTERNATIVE - GW1: NO ACTION

Extraction/Injection Well Equipment

Well Type	Capacity (gpm)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
		Subtotal Extraction/Injection Well Equipment				**$ -**	
		Engineer-Design and Technical Support	Percent			$ -	
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent			$ -	
		Contractor Profit	Percent			$ -	
		Construction Oversight	Percent			$ -	
		Construction Contingency	Percent			$ -	
		Total Extraction/Injection Well Equipment				$ -	
		Total Wells				$ -	

TABLE B-1

COST ESTIMATE ALTERNATIVE - GW1: NO ACTION

DESIGN AND CONSTRUCTION (CAPITAL)

GROUNDWATER TREATMENT SYSTEM

Capacity (gpm)	Reduction (log)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
					Subtotal Major Equipment	$ -	
		Mechanical miscellaneous and Installation	Percent			$ -	
		Electrical Upgrade	Percent			$ -	
		Instrumentation and Control	Percent			$ -	
						$ -	
						$ -	
						$ -	
					Subtotal Treatment System	$ -	
		Engineer-Design and Technical Support	Percent			$ -	
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent			$ -	
		Contractor Profit	Percent			$ -	
		Construction Oversight	Percent			$ -	
		Construction Contingency	Percent			$ -	
					Total Treatment System	$ -	

GRAND TOTAL CONVEYANCE, WELLS AND TREATMENT SYSTEM COST (CAPITAL)	$ -

TABLE B-1

COST ESTIMATE ALTERNATIVE - GW1: NO ACTION

OPERATION, MAINTENANCE, AND MONITORING

Categories with assumed constant use for years 1 to 30

Utilities

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	

Consumables

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	

Permits/Access Agreements

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	

Well Development

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	

Non-Routine O+M

Percent of treatment system cost and well equipment costs	Percent			$ -	

Subtotal Yearly OMM Costs (constant through years 1 to 30) $ -

TABLE B-1

COST ESTIMATE ALTERNATIVE - GW1: NO ACTION

OPERATION, MAINTENANCE, AND MONITORING

Categories with decreasing use for years 1 to 30

Annual Costs - Years 1 and 2

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
			Annual Variable Costs for Years 1 and 2	$ -	

Annual Costs - Years 3 to 5

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
			Annual Variable Costs for Years 3 to 5	$ -	

Annual Costs - Years 6 to 15

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
			Annual Variable Costs for Years 6 to 15	$ -	

TABLE B-1

COST ESTIMATE ALTERNATIVE - GW1: NO ACTION

OPERATION, MAINTENANCE, AND MONITORING

Annual Costs - Years 15 to 30

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
			Annual Variable Costs for Years 6 to 15	$ -	

ANNUAL OMM ESTIMATE		
	YEARS 1 and 2	$ -
	YEARS 3 to 5	$ -
	YEARS 6 to 15	$ -
	YEARS 15 to 30	$ -

Acronyms and Abbreviations

gpm = Gallons per minute
DCHDPE = Double-contained high density polyethylene
HDPE = High density polyethylene
H+A = Hargis + Associates, Inc.
I.D. = Inner diameter
PVC = Polyvinyl chloride
ROM = Rough order of magnitude
UV = Ultraviolet
OCWD = Orange County Water District
kw/hr = Kilowatts per hour
HP = Horsepower
WDR = Waste Discharge Requirements
TTWQ = Threat to water quality
CPLX = Complexity
RWQCB = Regional Water Quality Control Board
EW = Extraction well
VOCs = Volatile organic compounds
O+M = Operation and maintenance
OMM = Operation, maintenance, and monitoring
NA = Not applicable

TABLE B-2

COST ESTIMATE ALTERNATIVE - GW2: MONITORED NATURAL ATTENUATION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

Capacity (gpm)		Description/Segment	Extraction		Injection		Units	Quantity	Unit Cost	Cost	Source of Estimate
Extraction	Injection		Size (inches)	Material	Size (inches)	Material					
										$ -	
										$ -	
									Subtotal	**$ -**	
		Engineer-Design and Technical Support					Percent			$ -	
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities					Percent			$ -	
		Contractor Profit					Percent			$ -	
		Construction Oversight					Percent			$ -	
		Construction Contingency					Percent			$ -	
									Total Conveyance	$ -	

WELLS

Extraction/Injection Well Installation

Well Type	Capacity (gpm)	Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
								$ -	
								$ -	
			Subtotal Extraction/Injection Well Installation					**$ -**	

Monitor Well Installation

Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of monitor well vault, installation of submersible sample pump, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	4 inch	1,000	Each	4	$ 385,000	$ 1,540,000	H+A estimate
Same as above (with or without sound barriers)	4 inch	1,000	Each	4	$ 335,000	$ 1,340,000	H+A estimate
			Each			$ -	
						$ -	
						$ -	
	Subtotal Monitor Well Installation					**$ 2,880,000**	

TABLE B-2

COST ESTIMATE ALTERNATIVE - GW2: MONITORED NATURAL ATTENUATION

DESIGN AND CONSTRUCTION (CAPITAL)

Extraction/Injection Well Equipment

Well Type	Capacity (gpm)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
						$ -	
					Subtotal Extraction/Injection Well Equipment	**$ -**	
		Engineer-Design and Technical Support	Percent			$ -	
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent			$ -	
		Contractor Profit	Percent			$ -	
		Construction Oversight	Percent			$ -	
		Construction Contingency	Percent			$ -	
					Total Extraction/Injection Well Equipment	$ -	
					Total Wells	$ 2,880,000	

TABLE B-2

COST ESTIMATE ALTERNATIVE - GW2: MONITORED NATURAL ATTENUATION

DESIGN AND CONSTRUCTION (CAPITAL)

GROUNDWATER TREATMENT SYSTEM

Capacity (gpm)	Reduction (log)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
			Each			$ -	
			Subtotal Major Equipment			$ -	
		Mechanical miscellaneous and Installation	Percent			$ -	
		Electrical Upgrade	Percent			$ -	
		Instrumentation and Control	Percent			$ -	
						$ -	
						$ -	
			Subtotal Treatment System			$ -	
		Engineer-Design and Technical Support	Percent			$ -	
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent			$ -	
		Contractor Profit	Percent			$ -	
		Construction Oversight	Percent			$ -	
		Construction Contingency	Percent			$ -	
			Total Treatment System			$ -	

GRAND TOTAL CONVEYANCE, WELLS AND TREATMENT SYSTEM COST (CAPITAL)	$ 2,880,000

OPERATION, MAINTENANCE, AND MONITORING

Categories with assumed constant use for years 1 to 30
Utilities

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	

TABLE B-2

COST ESTIMATE ALTERNATIVE - GW2: MONITORED NATURAL ATTENUATION

OPERATION, MAINTENANCE, AND MONITORING

Consumables

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	
				$ -	
				$ -	
				$ -	

Permits/Access Agreements

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well easement (City of Buena Park)	per well	3	$ 15,000	$ 45,000	Rough estimate for deep well
Mark-up, percent of above	Percent	8%		$ 3,600	

Well Development

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
				$ -	
				$ -	

Non-Routine O+M

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
	Percent			$ -	

Subtotal Yearly OMM Costs (constant through years 1 to 30)	**$ 48,600**

Categories with decreasing use for years 1 to 30
Annual Costs - Years 1 and 2

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	129	$ 2,000	$ 258,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
Annual Variable Costs for Years 1 and 2				$ 318,000	

TABLE B-2

COST ESTIMATE ALTERNATIVE - GW2: MONITORED NATURAL ATTENUATION

OPERATION, MAINTENANCE, AND MONITORING

Annual Costs - Years 3 to 5

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	129	$ 2,000	$ 258,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
Annual Variable Costs for Years 3 to 5				$ 318,000	

Annual Costs - Years 6 to 15

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	93	$ 2,000	$ 186,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
Annual Variable Costs for Years 6 to 15				$ 226,000	

Annual Costs - Years 15 to 30

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per month	Per day		$ 1,200	$ -	H+A Estimate
Project Management and Technical Evaluations Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month		$ 2,800	$ -	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit		$ 2,000	$ -	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, annual EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample		$ 350	$ -	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	81	$ 2,000	$ 162,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
Annual Variable Costs for Years 6 to 15				$ 202,000	

ANNUAL OMM ESTIMATE		
	YEARS 1 and 2	$ 366,600
	YEARS 3 to 5	$ 366,600
	YEARS 6 to 15	$ 274,600
	YEARS 15 to 30	$ 250,600

TABLE B-2

COST ESTIMATE ALTERNATIVE - GW2: MONITORED NATURAL ATTENUATION

Acronyms and Abbreviations

gpm = Gallons per minute
H+A = Hargis + Associates, Inc.
NA = Not applicable
I.D. = Inner diameter
PVC = Polyvinyl chloride
ROM = Rough order of magnitude
UV = Ultraviolet
OCWD = Orange County Water District
kw/hr = Kilowatts per hour
lb = Pound
WDR = Waste Discharge Requirements
TTWQ = Threat to water quality
CPLX = Complexity
RWQCB = Regional Water Quality Control Board
EW = Extraction well
GAC = Granular activated carbon
ppm = Parts per million
VOCs = Volatile organic compounds

HARGIS + ASSOCIATES, INC.

TABLE B-3

COST ESTIMATE ALTERNATIVE - GW3: ON-SITE EXTRACTION AND INJECTION, OFF-SITE MONITORED NATURAL ATTENUATION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE - Unit Rate Installed Cost

Capacity (gpm)			Extraction		Injection						
Extraction	Injection	Description/Segment	Size (inches)	Material	Size (inches)	Material	Units	Quantity	Unit Cost	Cost	Source of Estimate
50		MW-31 to EW-02 tie-in	3"x6"	DCHDPE			linear feet	1,235	$ 97	$ 120,093	
		90 deg el	3"x6"	DCHDPE			Each	3	$ 587	$ 1,761	
		45 deg el	3"x6"	DCHDPE			Each	2	$ 523	$ 1,046	
		flange	3"x6"	DCHDPE			Each	1	$ 442	$ 442	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
170		EW-02 to MW-29 tie-in	4"x8"	DCHDPE			linear feet	160	$ 153	$ -	Existing from Pilot Test
		tee	4"x8"	DCHDPE			Each	1	$ 965	$ -	Existing from Pilot Test
		90 deg el	4"x8"	DCHDPE			Each	1	$ 635	$ -	Existing from Pilot Test
		flange	4"x8"	DCHDPE			Each	1	$ 465	$ -	Existing from Pilot Test
190		MW-29 tie-in to EW-07 tie-in	6"x10"	DCHDPE			linear feet	325	$ 153	$ -	Existing from Pilot Test
		tee	6"x10"	DCHDPE			Each	1	$ 965	$ -	Existing from Pilot Test
200		EW-07 tie-in to Treatment System	6"x10"	DCHDPE			linear feet	920	$ 153	$ -	Existing from Pilot Test
		45 deg el	6"x10"	DCHDPE			Each	4	$ 695	$ -	Existing from Pilot Test
		90 deg el	6"x10"	DCHDPE			Each	1	$ 885	$ -	Existing from Pilot Test
		flange	6"x10"	DCHDPE			Each	1	$ 520	$ -	Existing from Pilot Test
10		EW-07 to EW-07 tie-in	1"x3"	DCHDPE			linear feet	40	$ 80	$ 3,211	
		flange	1"x3"	DCHDPE			Each	1	$ 276	$ 276	
		reducer	1x3 to 2x4	DCHDPE			Each	1	$ 424	$ 424	
		reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
20		MW-29 to MW-29 tie-in	2"x4"	DCHDPE			linear feet	525	$ 82	$ -	Existing from Pilot Test
		flange	2"x4"	DCHDPE			Each	1	$ 292	$ -	Existing from Pilot Test
		45 deg el	2"x4"	DCHDPE			Each	4	$ 454	$ -	Existing from Pilot Test
		90 deg el	2"x4"	DCHDPE			Each	1	$ 493	$ -	Existing from Pilot Test
		reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ -	Existing from Pilot Test
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ -	Existing from Pilot Test
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ -	Existing from Pilot Test
120		EW-02 to EW-02 tie-in	4"x8"	DCHDPE			linear feet	170	$ 97	$ -	Existing from Pilot Test
		90 deg el	4"x8"	DCHDPE			Each	1	$ 635	$ -	Existing from Pilot Test
		flange	4"x8"	DCHDPE			Each	1	$ 465	$ -	Existing from Pilot Test
	220	Treatment System to IW-01			6"	HDPE	linear feet	1,300	$ 84	$ 108,750	
		90 deg el			6"	HDPE	Each	2	$ 400	$ 800	
		45 deg el			6"	HDPE	Each	2	$ 390	$ 780	
		flange			6"	HDPE	Each	1	$ 216	$ 216	
		tee			6"	HDPE	Each	1	$ 563	$ 563	
	110	IW-01 to IW-02			4"	HDPE	linear feet	540	$ 79	$ 42,425	
		90 deg el			4"	HDPE	Each	3	$ 359	$ 1,076	
		flange			4"	HDPE	Each	1	$ 210	$ 210	
		reducer			4"x6"	HDPE	Each	1	$ 364	$ 364	
		Electrical pull boxes, assume 1 per 250 foot of trench					Each	13	$ 2,965	$ 38,540	H+A estimate
		Air eliminators, assume 1 per 500 foot of trench					Each	7	$ 5,058	$ 35,407	H+A estimate
									Subtotal	**$ 358,485**	

TABLE B-3

COST ESTIMATE ALTERNATIVE - GW3: ON-SITE EXTRACTION AND INJECTION, OFF-SITE MONITORED NATURAL ATTENUATION

DESIGN AND CONSTRUCTION (CAPITAL)

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Engineer-Design, Permitting and Technical Support	Percent	8%		$ 28,679	
Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 53,773	
Contractor Profit	Percent	8%		$ 28,679	
Construction Oversight	Percent	10%		$ 35,848	
Construction Contingency	Percent	20%		$ 71,697	
Total Conveyance				**$ 577,160**	

WELLS

Extraction/Injection Well Installation

Well Type	Capacity (gpm)	Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Inj	110	IW-01: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	6 inch	1,000	Each	1	$ 350,000	$ 350,000	H+A estimate; no sound barrier
Ext	10	EW-07: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	4 inch	250	Each	1	$ 135,000	$ 135,000	H+A estimate; plus sound barrier
Subtotal Extraction/Injection Well Installation								**$ 485,000**	

Monitor Well Installation

Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Construct 1,000-foot POC MW on Artesia Boulevard and three additional monitor wells: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility, surveying, installation of monitor well vault, installation of submersible sample pump, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	4 inch	1,000	Each	4	$ 385,000	$ 1,540,000	H+A Estimate: Includes well at $340,000 + 45 days of traffic control at $1,000 per day. No sound barrier.
Subtotal Monitor Well Installation						**$ 1,540,000**	

TABLE B-3

COST ESTIMATE ALTERNATIVE - GW3: ON-SITE EXTRACTION AND INJECTION, OFF-SITE MONITORED NATURAL ATTENUATION

DESIGN AND CONSTRUCTION (CAPITAL)

Extraction/Injection Well Equipment

Well Type	Capacity (gpm)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Ext	10	EW-07: Vault + wellhead equipment + Injection well down hole equipment, stainless steel injection tubing, PVC sounder tube and transducer & cable (assume set depth at 150 feet below land surface)	Each	1	$ 65,990	$ 65,990	H+A Estimate
Ext	50	MW-31 (Extraction Well): Vault + wellhead equipment + Injection well down hole equipment, stainless steel injection tubing, PVC sounder tube and transducer & cable (assume set depth at 150 feet below land surface)	Each	1	$ 72,960	$ 72,960	H+A Estimate
Inj	110	IW-01 and IW-02: Vault + wellhead equipment + Injection well down hole equipment, stainless steel injection tubing, PVC sounder tube and transducer & cable	Each	2	$ 56,541	$ 113,082	H+A Estimate
Ext	20	MW-29 (Extraction well): New piping and equipment	Each	1	$ 6,513	$ 6,513	H+A Estimate
Ext	120	EW-02 (Extraction well): New piping and equipment	Each	1	$ 12,056	$ 12,056	H+A Estimate
Ext	10	EW-01 (Extraction well): New piping and equipment	Each	1	$ 6,155	$ 6,155	H+A Estimate
Ext	10	MW-21 (Extraction well): New piping and equipment	Each	1	$ 6,155	$ 6,155	H+A Estimate
					Subtotal Extraction/Injection Well Equipment	**$ 282,911**	
		Engineer-Design and Technical Support	Percent	8%		$ 22,633	Equipment only
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 42,437	Equipment only
		Contractor Profit	Percent	8%		$ 22,633	Equipment only
		Construction Oversight	Percent	5%		$ 14,146	Equipment only
		Construction Contingency	Percent	20%		$ 56,582	Equipment only
					Total Extraction/Injection Well Equipment	**$ 441,341**	
					Total Wells	**$ 2,466,341**	

TABLE B-3

COST ESTIMATE ALTERNATIVE - GW3: ON-SITE EXTRACTION AND INJECTION, OFF-SITE MONITORED NATURAL ATTENUATION

DESIGN AND CONSTRUCTION (CAPITAL)

GROUNDWATER TREATMENT SYSTEM

Advanced Oxidation Process

Capacity (gpm)	Reduction (log)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
220	2.5	UV system modular upgrade includes control panel, double contained peroxide tank, ancillary equipment and instrumentation	Each	1	$ 220,000	$ 220,000	Trojan quote 2013
220	NA	Liquid Phase Carbon Adsorbers (5,000 lb)	Each	1	$ 95,500	$ 95,500	includes initial GAC fill and manifold (Evoqua Quote - 6/24/14)
220	NA	Storage tank, stainless steel (4,000 gallon)	Each	2	$ 35,000	$ 70,000	H+A Estimate
		Utility Tank	Each	1	$ 30,000	$ 30,000	H+A Estimate
220	NA	Transfer pump (influent) w/ VFD	Each	1	$ 18,201	$ 18,201	Full Scale GETS Unit Cost Rev032714
NA	NA	Transfer pump (injection) w/ VFD- UA1-UA5 injection wells	Each	0	$ 17,972	$ -	Full Scale GETS Unit Cost Rev032714
220	NA	Transfer pump (injection) w/ VFD - onsite wells	Each	1	$ 15,358	$ 15,358	Full Scale GETS Unit Cost Rev032714
		Multi strainer particulate filter	Each	2	$ 12,000	$ 24,000	H+A Estimate (225-300 gpm)
		Control System Upgrade	Each	1	$ 200,000	$ 200,000	H+A Estimate
				Subtotal Major Equipment		**$ 673,059**	
		Mechanical miscellaneous and Installation	Percent	30%		$ 201,918	Percent of major equipment
		Electrical Upgrade	Percent	15%		$ 100,959	Percent of major equipment
		Instrumentation	Percent	10%		$ 67,306	Percent of major equipment
		Treatment Compound Upgrade	Each	1	$ 312,753	$ 312,753	ROM estimate
				Subtotal Treatment System		**$ 1,355,994**	
		Engineer-Design and Technical Support	Percent	8%		$ 53,845	Equipment only
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 100,959	Equipment only
		Contractor Profit	Percent	8%		$ 53,845	Equipment only
		Construction Oversight	Percent	5%		$ 33,653	Equipment only
		Construction Contingency	Percent	20%		$ 134,612	Equipment only
				Total Treatment System		**$ 1,732,907**	

GRAND TOTAL CONVEYANCE, WELLS AND TREATMENT SYSTEM COST (CAPITAL)	**$ 4,776,408**

TABLE B-3

COST ESTIMATE ALTERNATIVE - GW3: ON-SITE EXTRACTION AND INJECTION, OFF-SITE MONITORED NATURAL ATTENUATION

OPERATION, MAINTENANCE, AND MONITORING

Categories with assumed to be relatively constant (years 1 to 5 = 100%, years 6 to 15 =90% and years 16 to 20 = 80%)

Utilities

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Electricity (UV System) Annual Operation, 90% uptime	kwhr	299,592	$ 0.13	$ 38,947	Trojan 2013 estimate
Electricity (Submersible Pumps, 90% uptime)	kwhr	146,977	$ 0.13	$ 19,107	Total 60 HP
Electricity (Transfer Pumps, 90% uptime)	kwhr	117,582	$ 0.13	$ 15,286	Total 30 HP
Electricity (Lights and Control System)	kwhr	17,637	$ 0.13	$ 2,293	ROM estimate
Water	Per month	12	$ 100	$ 1,200	ROM estimate
Telephone/Data Line	Per month	12	$ 150	$ 1,800	ROM estimate
Site Security	Per month	12	$ 100	$ 1,200	ROM estimate
OCWD Sewer Discharge Fees and Replenishment Assessment (0.5 gpm/yr)	Per year	1	$ 300	$ 300	OCWD estimate
Mark-up, percent of above	Percent	8%		$ 6,410.60	

Consumables

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Carbon Usage (5,000lb GAC change-out non-hazardous)	change out/ vessel	2	$ 11,100	$ 22,200	Siemens estimate 2015
UV Lamps	Per year	3	$ 13,000	$ 39,000	Trojan estimate 2013
Chemicals (hydrogen peroxide 27% solution, to make up 7.3 ppm dose)	Per year	3	$ 14,000	$ 42,000	Trojan estimate 2013
Bag filters	Per year	6	$ 500	$ 3,000	ROM estimate
Mark-up, percent of above	Percent	8%		8,496	

Permits/Access Agreements

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well easement (City of Buena Park)	per well	1	$ 15,000	$ 15,000	Rough estimate for deep well
Waste Discharge Permit Fee, per permit (assuming general WDR TTWQ and CPLX rating of 3-A).	per year	1	$ 5,000	$ 5,000	2013 fee schedule
Mark-up, percent of above	Percent	8%		$ 1,600	
Waste Discharge Permit Monitoring and Reporting, include monthly effluent samples for Site VOCs + 1,4-Dioxane, daily measurement of total flow, quarterly reports to RWQCB.	Per year	1	$ 33,000	$ 33,000	H+A Estimate

TABLE B-3

COST ESTIMATE ALTERNATIVE - GW3: ON-SITE EXTRACTION AND INJECTION, OFF-SITE MONITORED NATURAL ATTENUATION

OPERATION, MAINTENANCE, AND MONITORING

Well Development

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Injection well redevelopment, assumes all injection wells redeveloped once per year	per well	2	$ 15,000	$ 30,000	H+A estimate
Extraction well redevelopment, assumes all extraction wells redeveloped once every five years	per well	1.2	$ 10,000	$ 12,000	H+A estimate

Non-Routine O+M

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Percent of treatment system cost and well equipment costs	Percent	2%	$ 2,174,248	$ 43,485	
Subtotal Yearly OMM Costs (constant through years 1 to 20)				**$ 341,324**	

Categories with decreasing use for years 1 to 20

Annual Costs - Years 1 and 2

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per week	Per day	52	$ 1,200	$ 62,400	H+A Estimate
Project Management and Technical Evaluations Manager (16 hours/month) + Staff engineer (32 hours/month)	Per month	12	$ 5,600	$ 67,200	H+A Estimate
Trojan UV Tech Site Visit (One site visit per month 1st quarter, quarterly thereafter)	Per visit	6	$ 2,000	$ 12,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, Monthly EW sampling; weekly system sampling (3 locations) for first quarter, monthly thereafter (includes 8% mark-up and supplies)	Per sample	135	$ 350	$ 47,250	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	93	$ 1,500	$ 139,500	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
Annual Variable Costs for Years 1 and 2				**$ 388,350**	

TABLE B-3

COST ESTIMATE ALTERNATIVE - GW3: ON-SITE EXTRACTION AND INJECTION, OFF-SITE MONITORED NATURAL ATTENUATION

OPERATION, MAINTENANCE, AND MONITORING

Annual Costs - Years 3 to 5

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); two days per month	Per day	24	$ 1,200	$ 28,800	H+A Estimate
Project Management and Technical Evaluations Manager (12 hours/month) + Staff engineer (24 hours/month)	Per month	12	$ 3,200	$ 38,400	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + laboratory analysis, VOCs and 1,4-Dioxane, Quarterly EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	60	$ 350	$ 21,000	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	56	$ 1,500	$ 84,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
			Annual Variable Costs for Years 3 to 5	**$ 236,200**	

Annual Costs - Years 6 to 15

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); two days per month	Per day	24	$ 1,200	$ 28,800	H+A Estimate
Project Management and Technical Evaluations (Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month	12	$ 2,800	$ 33,600	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, Semi-annual EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	48	$ 350	$ 16,800	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	46	$ 1,500	$ 69,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
			Annual Variable Costs for Years 6 to 15	**$ 192,200**	

TABLE B-3

COST ESTIMATE ALTERNATIVE - GW3: ON-SITE EXTRACTION AND INJECTION, OFF-SITE MONITORED NATURAL ATTENUATION

OPERATION, MAINTENANCE, AND MONITORING

Annual Costs - Years 16 to 20

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per month	Per day	12	$ 1,200	$ 14,400	H+A Estimate
Project Management and Technical Evaluations (Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month	12	$ 2,800	$ 33,600	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, annual EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	42	$ 350	$ 14,700	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	27	$ 1,500	$ 40,500	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
Annual Variable Costs for Years 16 to 20				**$ 147,200**	

ANNUAL OMM ESTIMATE		
	YEARS 1 and 2	$ 729,674
	YEARS 3 to 5	$ 577,524
	YEARS 6 to 15	$ 499,392
	YEARS 16 to 20	$ 420,259

Acronyms and Abbreviations

gpm = Gallons per minute
H+A = Hargis + Associates, Inc.
NA = Not applicable
HP = Horsepower
PVC = Polyvinyl chloride
ROM = Rough order of magnitude
UV = Ultraviolet
OCWD = Orange County Water District
kw/hr = Kilowatts per hour
lb = Pound
WDR = Waste Discharge Requirements
TTWQ = Threat to water quality
Ext = Extraction
Inj = Injection
VFD = Variable frequency drive
yr = Year

CPLX = Complexity
RWQCB = Regional Water Quality Control Board
EW = Extraction well
GAC = Granular activated carbon
ppm = Parts per million
VOCs = Volatile organic compounds
MW = Monitor well
IW = Injection well
deg el = Degree elevation
DCHDPE = Double-contained high density polyethylene
HDPE = High density polyethylene
POC = Point of Compliance
GETS = Groundwater extraction and treatment system
O+M = Operation and maintenance
OMM = Operation, maintenance, and monitoring

HARGIS + ASSOCIATES, INC.

TABLE B-4

COST ESTIMATE ALTERNATIVE - GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

Capacity (gpm)		Description/Segment	Extraction		Injection						
Extraction	Injection		Size (inches)	Material	Size (inches)	Material	Units	Quantity	Unit Cost	Cost	Source of Estimate
50		MW-31 to EW-03/04 tie-in	3"x6"	DCHDPE			linear feet	990	$ 97	$ 96,269	
		90 deg el	3"x6"	DCHDPE			Each	3	$ 587	$ 1,761	
		45 deg el	3"x6"	DCHDPE			Each	2	$ 523	$ 1,046	
		flange	3"x6"	DCHDPE			Each	1	$ 442	$ 442	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
370		EW-02 to MW-29 tie-in	6"x10"	DCHDPE	6"	HDPE	linear feet	160	$ 163	$ -	Existing from Pilot Test
		tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ -	Existing from Pilot Test
		90 deg el	6"x10"	DCHDPE			Each	1	$ 885	$ -	Existing from Pilot Test
		flange	6"x10"	DCHDPE			Each	1	$ 1,108	$ -	Existing from Pilot Test
390		MW-29 tie-in to EW-07 tie-in	6"x10"	DCHDPE			linear feet	325	$ 163	$ -	Existing from Pilot Test
		tee	6"x10"	DCHDPE			Each	1	$ 965	$ -	Existing from Pilot Test
400		EW-07 tie-in to Treatment System	6"x10"	DCHDPE			linear feet	920	$ 153	$ -	Existing from Pilot Test
		45 deg el	6"x10"	DCHDPE			Each	4	$ 695	$ -	Existing from Pilot Test
		90 deg el	6"x10"	DCHDPE			Each	1	$ 885	$ -	Existing from Pilot Test
		flange	6"x10"	DCHDPE			Each	1	$ 520	$ -	Existing from Pilot Test
		45 deg el			6"	HDPE	Each	2	$ 390	$ -	Existing from Pilot Test
		90 deg el			6"	HDPE	Each	4	$ 400	$ -	Existing from Pilot Test
		flange			6"	HDPE	Each	1	$ 216	$ -	Existing from Pilot Test
10		EW-07 to EW-07 tie-in	1"x3"	DCHDPE			linear feet	40	$ 80	$ 3,211	
		flange	1"x3"	DCHDPE			Each	1	$ 276	$ 276	
		reducer	1x3 to 2x4	DCHDPE			Each	1	$ 424	$ 424	
		reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
20		MW-29 to MW-29 tie-in	2"x4"	DCHDPE			linear feet	525	$ 82	$ -	Existing from Pilot Test
		flange	2"x4"	DCHDPE			Each	1	$ 292	$ -	Existing from Pilot Test
		45 deg el	2"x4"	DCHDPE			Each	4	$ 454	$ -	Existing from Pilot Test
		90 deg el	2"x4"	DCHDPE			Each	1	$ 493	$ -	Existing from Pilot Test
		reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ -	Existing from Pilot Test
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ -	Existing from Pilot Test
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ -	Existing from Pilot Test
120		EW-02 to EW-02 tie-in	4"x8"	DCHDPE			linear feet	170	$ 97	$ -	Existing from Pilot Test
		90 deg el	4"x8"	DCHDPE			Each	1	$ 635	$ -	Existing from Pilot Test
		flange	4"x8"	DCHDPE			Each	1	$ 465	$ -	Existing from Pilot Test

TABLE B-4

COST ESTIMATE ALTERNATIVE - GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

Capacity (gpm)		Description/Segment	Extraction		Injection						
Extraction	Injection		Size (inches)	Material	Size (inches)	Material	Units	Quantity	Unit Cost	Cost	Source of Estimate
200		Branch from Building 684 injection line to to EW-03	6"x10"	DCHDPE			linear feet	1,685	$ 116	$ 195,829	
		tee	6"x10"	DCHDPE			Each	1	$ 965	$ 965	
		reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
		flange	2"x4"	DCHDPE			Each	1	$ 292	$ 292	
100		EW-03 to EW-04	4"x8"	DCHDPE			linear feet	1,600	$ 97	$ 155,586	
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
		reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
		flange	2"x4"	DCHDPE			Each	1	$ 292	$ 292	
250		MW-31 tie-in to EW-02 tie in	6"x10"	DCHDPE			linear feet	340	$ 116	$ 39,514	
		tee	6"x10"	DCHDPE			Each	2	$ 965	$ 1,931	
	220	Treatment System to IW-01			6"	HDPE	linear feet	1,300	$ 84	$ 108,750	
		90 deg el			6"	HDPE	Each	2	$ 400	$ 800	
		45 deg el			6"	HDPE	Each	2	$ 390	$ 780	
		flange			6"	HDPE	Each	1	$ 216	$ 216	
		tee			6"	HDPE	Each	1	$ 563	$ 563	
	110	IW-01 to IW-02			4"	HDPE	linear feet	540	$ 79	$ 42,425	
		90 deg el			4"	HDPE	Each	3	$ 359	$ 1,076	
		flange			4"	HDPE	Each	1	$ 210	$ 210	
		reducer			4"x6"	HDPE	Each	1	$ 364	$ 364	
200	200	Branch from IW-01 to 684 treatment system	6"x10"	DCHDPE	6"	HDPE	linear feet	2,800	$ 152.93	$ 428,200	Includes extraction pipeline
		Jack & Bore across Malvern					lump sum	1	$ 135,438.51	$ 135,439	Includes extraction pipeline
		tee	6"x10"	DCHDPE			Each	1	$ 965	$ 965	
		90 deg el	6"x10"	DCHDPE			Each	6	$ 885	$ 5,309	
		45 deg el	6"x10"	DCHDPE			Each	2	$ 695	$ 1,389	
		tee			6"	HDPE	Each	1	$ 563	$ 563	
		90 deg el			6"	HDPE	Each	6	$ 400	$ 2,400	
		45 deg el			6"	HDPE	Each	2	$ 390	$ 780	
		flange			6"	HDPE	Each	1	$ 216	$ 216	
		Electrical pull boxes, assume 1 per 250 foot of trench					Each	38	$ 2,965	$ 112,655	H+A estimate
		Air eliminators, assume 1 per 500 foot of trench					Each	20	$ 5,058	$ 101,162	H+A estimate
									Subtotal	**$ 1,447,401**	

TABLE B-4

COST ESTIMATE ALTERNATIVE - GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Engineer-Design and Technical Support	Percent	8%		$ 115,792	
Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 217,110	
Contractor Profit	Percent	8%		$ 115,792	
Construction Oversight	Percent	5%		$ 72,370	
Construction Contingency	Percent	20%		$ 289,480	
			Total Conveyance	**$ 2,257,945**	

WELLS

Extraction/Injection Well Installation

Well Type	Capacity (gpm)	Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Inj	110	IW-01: Well installation including planning, encroachment permits, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	6 inch	1,000	Each	1	$ 350,000	$ 350,000	H+A estimate; no sound barrier
Ext	10	EW-07: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting.	4 inch	250	Each	1	$ 135,000	$ 135,000	H+A estimate; plus sound barrier
Ext	100	EW-03 and EW-04: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting.	6 inch	1,000	Each	2	$ 400,000	$ 800,000	H+A estimate; no sound barrier
							Subtotal Extraction/Injection Well Installation	**$ 1,285,000**	

Monitor Well Installation

Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility, surveying, installation of monitor well vault, installation of submersible sample pump, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	4 inch	1,000	Each	1	$ 335,000	$ 335,000	H+A estimate
					Subtotal Monitor Well Installation	**$ 335,000**	

TABLE B-4

COST ESTIMATE ALTERNATIVE - GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

Extraction/Injection Well Equipment

Well Type	Capacity (gpm)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Ext	10	EW-07: Vault; pump and equipment and tie-in to existing piping	Each	1	$ 65,990	$ 65,990	H+A Estimate
Ext	50	MW-31 (Extraction Well): Vault; pump and equipment	Each	1	$ 72,960	$ 72,960	H+A Estimate
Inj	110	IW-01 and IW-02: Vault + wellhead equipment + Injection well down hole equipment, stainless steel injection tubing, PVC sounder tube and transducer & cable (assume set depth at 300 feet below land surface	Each	2	$ 56,541	$ 113,082	H+A Estimate
Ext	20	MW-29: New piping and equipment	Each	1	$ 6,513	$ 6,513	H+A Estimate
Ext	120	EW-02: New piping and equipment	Each	1	$ 12,056	$ 12,056	H+A Estimate
Ext	10	EW-01: New piping and equipment	Each	1	$ 6,155	$ 6,155	H+A Estimate
Ext	10	MW-21: New piping and equipment	Each	1	$ 6,155	$ 6,155	H+A Estimate
Ext	100	EW-03 and EW-04: Vault, extraction well down hole equipment, includes submersible pump, electrical wire, stainless steel riser pipe, PVC sounder tube and transducer & cable (assume pump set depth at 300 feet below land surface)	Each	2	$ 89,359	$ 178,717	H+A Estimate
						$ -	
					Subtotal Extraction/Injection Well Equipment	**$ 461,628**	
		Engineer-Design and Technical Support	Percent	8%		$ 36,930	Equipment only
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 69,244	Equipment only
		Contractor Profit	Percent	8%		$ 36,930	Equipment only
		Construction Oversight	Percent	5%		$ 23,081	Equipment only
		Construction Contingency	Percent	20%		$ 92,326	Equipment only
					Total Extraction/Injection Well Equipment	**$ 720,139**	
					Total Wells	**$ 2,340,139**	

TABLE B-4

COST ESTIMATE ALTERNATIVE - GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

GROUNDWATER TREATMENT SYSTEM

Advanced Oxidation Process

Capacity (gpm)	Reduction (log)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
420	2.5	UV system modular upgrade includes control panel, double contained peroxide tank, ancillary equipment and instrumentation	Each	1	$ 312,850	$ 312,850	Trojan quote 2013
420	NA	Liquid Phase Carbon Adsorbers (10,000 lb)	Each	1	$ 173,000	$ 173,000	includes initial GAC fill and manifold (Evoqua Quote - 6/24/14)
420	NA	Storage tank, stainless steel (10,000 gallon)	Each	2	$ 75,000	$ 150,000	H+A estimate
		Utility Tank, stainless steel (3,000 gallon)	Each	1	$ 30,000	$ 30,000	H+A estimate
420	NA	Transfer pump (influent) w/ VFD	Each	1	$ 18,201	$ 18,201	Full Scale GETS Unit Cost Rev032714
420	NA	Transfer pump (injection) w/ VFD- UA1-UA5 injection wells	Each	1	$ 17,972	$ 17,972	Full Scale GETS Unit Cost Rev032714
420	NA	Transfer pump (injection) w/ VFD - onsite wells	Each	1	$ 15,358	$ 15,358	Full Scale GETS Unit Cost Rev032714
420		Multi strainer particulate filter	Each	2	$ 18,500	$ 37,000	Pentek HIF 150FL (400-600 gpm)
420		Control System upgrade	Each	1	$ 250,000	$ 250,000	
				Subtotal Major Equipment		**$ 1,004,381**	
		Mechanical misc. and Installation	Percent	30%		$ 301,314	Percent of major equipment
		Electrical Upgrade	Percent	10%		$ 100,438	Percent of major equipment
		Instrumentation	Percent	10%		$ 100,438	Percent of major equipment
		Treatment Compound Upgrade	Each	1	$ 459,069	$ 459,069	ROM estimate
				Subtotal Treatment System		**$ 1,965,640**	
		Engineer-Design and Technical Support	Percent	8%		$ 80,350	Equipment only
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 150,657	Equipment only
		Contractor Profit	Percent	8%		$ 80,350	Equipment only
		Construction Oversight	Percent	5%		$ 50,219	Equipment only
		Construction Contingency	Percent	20%		$ 200,876	Equipment only
				Total Treatment System		**$ 2,528,093**	

GRAND TOTAL CONVEYANCE, WELLS AND TREATMENT SYSTEM COST (CAPITAL)	**$ 7,126,178**

TABLE B-4

COST ESTIMATE ALTERNATIVE - GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Categories with assumed to be relatively constant (years 1 to 5 = 100%, years 6 to 15 =90% and years 16 to 20 = 80%)

Utilities

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Electricity (UV System) Annual Operation, 90% uptime	kwhr	299,592	$ 0.13	$ 38,947	Trojan 2013 estimate
Electricity (Submersible Pumps, 90% uptime)	kwhr	352,746	$ 0.13	$ 45,857	Total 60 HP
Electricity (Transfer Pumps, 90% uptime)	kwhr	146,977	$ 0.13	$ 19,107	Total 25 HP
Electricity (Lights and Control System)	kwhr	17,637	$ 0.13	$ 2,293	ROM estimate
Water	Per month	12	$ 100	$ 1,200	ROM estimate
Telephone/Data Line	Per month	12	$ 150	$ 1,800	ROM estimate
Site Security	Per month	12	$ 100	$ 1,200	ROM estimate
OCWD Sewer Discharge Fees and Replenishment Assessment (1 gpm/yr)	Per year	2	$ 300	$ 600	OCWD estimate
Mark-up, percent of above	Percent	8%		$ 8,880	

Consumables

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Carbon Usage (10,000lb GAC change-out non-hazardous)	change out/ vessel	3	$ 11,100	$ 33,300	Siemens estimate 2015
UV Lamps	Per year	3	$ 13,000	$ 39,000	Trojan estimate 2013
Chemicals (hydrogen peroxide 27% solution, to make up 7.3 ppm dose)	Per year	3	$ 14,000	$ 42,000	Trojan estimate 2013
Bag filters	Per year	12	$ 500	$ 6,000	ROM estimate
Mark-up, percent of above	Percent	8%		9,624	

Permits/Access Agreements

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well easement (City of Buena Park)	per well	1	$ 15,000	$ 15,000	Rough estimate for deep well
Waste Discharge Permit Fee, per permit (assuming general WDR TTWQ and CPLX rating of 3-A).	per year	1	$ 5,000	$ 5,000	2013 fee schedule
Mark-up, percent of above	Percent	8%		$ 1,600	
Waste Discharge Permit Monitoring and Reporting, include monthly effluent samples for Site VOCs + 1,4-Dioxane, daily measurement of total flow, quarterly reports to RWQCB.	Per year	1	$ 33,000	$ 33,000	H+A Estimate

Well Development

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Injection well redevelopment, assumes all injection wells redeveloped once per year	per well	7	$ 15,000	$ 105,000	H+A estimate
Extraction well redevelopment, assumes all extraction wells redeveloped once every five years	per well	1.6	$ 10,000	$ 16,000	H+A estimate

Non-Routine O+M

Percent of treatment system cost and well equipment costs	Percent	2%		$ 50,561.87	

Subtotal Yearly OMM Costs (constant through years 1 to 30) $ 475,970

TABLE B-4

COST ESTIMATE ALTERNATIVE - GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Categories with decreasing use for years 1 to 20

Annual Costs - Years 1 and 2

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); two days per week	Per day	104	$ 1,200	$ 124,800	H+A Estimate
Project Management and Technical Evaluations Manager (16 hours/month) + Staff engineer (32 hours/month)	Per month	12	$ 5,600	$ 67,200	H+A Estimate
Trojan UV Tech Site Visit (One site visit per month 1st quarter, quarterly thereafter)	Per visit	6	$ 2,000	$ 12,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, Monthly EW sampling; weekly system sampling (3 locations) for first quarter, monthly thereafter (includes 8% mark-up and supplies)	Per sample	159	$ 350	$ 55,650	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	81	$ 1,500	$ 121,500	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
			Annual Variable Costs for Years 1 and 2	$ 441,150	

Annual Costs - Years 3 to 5

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per week	Per day	52	$ 1,200	$ 62,400	H+A Estimate
Project Management and Technical Evaluations Manager (12 hours/month) + Staff engineer (24 hours/month)	Per month	12	$ 3,200	$ 38,400	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + laboratory analysis, VOCs and 1,4-Dioxane, Quarterly EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	68	$ 350	$ 23,800	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	50	$ 1,500	$ 75,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
			Annual Variable Costs for Years 3 to 5	$ 263,600	

Annual Costs - Years 6 to 15

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); two days per month	Per day	24	$ 1,200	$ 28,800	H+A Estimate
Project Management and Technical Evaluations Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month	12	$ 2,800	$ 33,600	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, Semi-annual EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	52	$ 350	$ 18,200	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	40	$ 1,500	$ 60,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
			Annual Variable Costs for Years 6 to 15	$ 184,600	

TABLE B-4

COST ESTIMATE ALTERNATIVE - GW4: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON-SITE AND SHALLOW OFF-SITE INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Annual Costs - Years 16 to 20

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per month	Per day	12	$ 1,200	$ 14,400	H+A Estimate
Project Management and Technical Evaluations Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month	12	$ 2,800	$ 33,600	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, annual EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	44	$ 350	$ 15,400	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	24	$ 1,500	$ 36,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
			Annual Variable Costs for Years 16 to 30	$ 143,400	

ANNUAL OMM ESTIMATE		
	YEARS 1 and 2	$ 917,120
	YEARS 3 to 5	$ 739,570
	YEARS 6 to 15	$ 612,973
	YEARS 16 to 20	$ 524,176

Acronyms and Abbreviations

gpm = Gallons per minute
H+A = Hargis + Associates, Inc.
NA = Not applicable
HP = Horsepower
PVC = Polyvinyl chloride
ROM = Rough order of magnitude
UV = Ultraviolet
OCWD = Orange County Water District
lb = Pound
WDR = Waste Discharge Requirements
TTWQ = Threat to water quality
Ext = Extraction
Inj = Injection
VFD = Variable frequency drive
yr = Year
CPLX = Complexity
RWQCB = Regional Water Quality Control Board
EW = Extraction well
GAC = Granular activated carbon
ppm = Parts per million
VOCs = Volatile organic compounds
MW = Monitor well
IW = Injection well
deg el = Degree elevation
DCHDPE = Double-contained high density polyethylene
HDPE = High density polyethylene
GETS = Groundwater extraction and treatment system
O+M = Operation and maintenance
OMM = Operation, maintenance, and monitoring

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE	Capacity (gpm)			Extraction		Injection						
	Extraction	Injection	Description/Segment	Size (inches)	Material	Size (inches)	Material	Units	Quantity	Unit Cost	Cost	Source of Estimate
	20		MW-31 to EW-03/04/06 tie-in	2"x4"	DCHDPE			linear feet	990	$ 82	$ 81,208	
			90 deg el	2"x4"	DCHDPE			Each	3	$ 493	$ 1,480	
			45 deg el	2"x4"	DCHDPE			Each	2	$ 454	$ 908	
			flange	2"x4"	DCHDPE			Each	1	$ 292	$ 292	
			reducer	3"x6" to 2"x4"	DCHDPE			Each	1	$ 450		
			reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
	440	490	EW-02 tie in to MW-29 tie-in	6"x10"	DCHDPE	6"	HDPE	linear feet	160	$ 153	$ -	Existing from Pilot Test
			tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ -	Existing from Pilot Test
			90 deg el	6"x10"	DCHDPE			Each	1	$ 885	$ -	Existing from Pilot Test
			flange	6"x10"	DCHDPE			Each	1	$ 520	$ -	Existing from Pilot Test
	460	490	MW-29 tie-in to EW-07 tie-in	6"x10"	DCHDPE	6"	HDPE	linear feet	325	$ 153	$ -	Existing from Pilot Test
			tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ -	Existing from Pilot Test
	470		EW-07 tie-in to Treatment System	6"x10"	DCHDPE	6"	HDPE	linear feet	920	$ 153	$ -	Existing from Pilot Test
			45 deg el	6"x10"	DCHDPE			Each	2	$ 695	$ -	Existing from Pilot Test
			90 deg el	6"x10"	DCHDPE			Each	4	$ 885	$ -	Existing from Pilot Test
			flange	6"x10"	DCHDPE			Each	1	$ 520	$ -	Existing from Pilot Test
			45 deg el			6"	HDPE	Each	2	$ 390	$ -	Existing from Pilot Test
			90 deg el			6"	HDPE	Each	4	$ 400	$ -	Existing from Pilot Test
			flange			6"	HDPE	Each	1	$ 216	$ -	Existing from Pilot Test
	10		EW-07 to EW-07 tie-in	1"x3"	DCHDPE			linear feet	40	$ 80	$ 3,211	
			flange	1"x3"	DCHDPE			Each	1	$ 276	$ 276	
			reducer	1x3 to 2x4	DCHDPE			Each	1	$ 424	$ 424	
			reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
			reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
			reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
	20		MW-29 to MW-29 tie-in	2"x4"	DCHDPE			linear feet	525	$ 82	$ -	Existing from Pilot Test
			flange	2"x4"	DCHDPE			Each	1	$ 292	$ -	Existing from Pilot Test
			45 deg el	2"x4"	DCHDPE			Each	4	$ 454	$ -	Existing from Pilot Test
			90 deg el	2"x4"	DCHDPE			Each	1	$ 493	$ -	Existing from Pilot Test
			reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ -	Existing from Pilot Test
			reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ -	Existing from Pilot Test
			reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ -	Existing from Pilot Test
	120		EW-02 to EW-02 tie-in	4"x8"	DCHDPE			linear feet	170	$ 97	$ -	Existing from Pilot Test
			90 deg el	4"x8"	DCHDPE			Each	1	$ 635	$ -	Existing from Pilot Test
			flange	4"x8"	DCHDPE			Each	1	$ 465	$ -	Existing from Pilot Test

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

	Capacity (gpm)			Extraction		Injection						
	Extraction	Injection	Description/Segment	Size (inches)	Material	Size (inches)	Material	Units	Quantity	Unit Cost	Cost	Source of Estimate
	200		EW-03 to EW-06 tie in	6"x10"	DCHDPE			linear feet	835	$ 116	$ 97,043	
			tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ 1,108	
			reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
			reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
			reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
			flange	2"x4"	DCHDPE			Each	1	$ 292	$ 292	
	100		EW-04 to EW-03	4"x8"	DCHDPE			linear feet	1,600	$ 97	$ 155,586	
			reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
			reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
			reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
			flange	2"x4"	DCHDPE			Each	1	$ 292	$ 292	
	100		EW-06 to EW-03/04 tie in	4"x8"	DCHDPE			linear feet	1,500	$ 97	$ 145,862	
			tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ 1,108	
			90 deg el	4"x8"	DCHDPE			Each	1	$ 635		
			reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
			reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
			reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
			flange	2"x4"	DCHDPE			Each	1	$ 292	$ 292	
	300		EW-06 tie in to Jack & Bore	6"x10"	DCHDPE			linear feet	2,580	$ 122	$ 313,721	
			90 deg el	6"x10"	DCHDPE			Each	4	$ 885	$ 3,539	
			45 deg el	6"x10"	DCHDPE			Each	2	$ 695	$ 1,389	
	300	300	Jack and Bore to MW-31 tie in	6"x10"	DCHDPE	6"	HDPE	linear feet	500	$ 153	$ 76,464	
			Jack & Bore					lump sum	1	$ 135,438.51	$ 135,439	
			90 deg el	6"x10"	DCHDPE			Each	3	$ 885	$ 2,654	
			45 deg el	6"x10"	DCHDPE			Each	2	$ 695	$ 1,389	
			tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ 1,108	
			90 deg el			6"	HDPE	Each	3	$ 400	$ 1,200	
			45 deg el			6"	HDPE	Each	2	$ 390	$ 780	
	320	490	MW-31 tie-in to EW-02 tie in	6"x10"	DCHDPE	6"	HDPE	linear feet	340	$ 153	$ 51,996	
			tee			6"	HDPE	Each	1	$ 563	$ 563	
			tee	6"x10"	DCHDPE			Each	2	$ 965	$ 1,931	
		220	Treatment System to IW-01			6"	HDPE	linear feet	1,300	$ 84	$ 108,750	
			90 deg el			6"	HDPE	Each	2	$ 400	$ 800	
			45 deg el			6"	HDPE	Each	2	$ 390	$ 780	
			flange			6"	HDPE	Each	1	$ 216	$ 216	
			tee			6"	HDPE	Each	1	$ 563	$ 563	

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

	Capacity (gpm)			Extraction		Injection						
	Extraction	Injection	Description/Segment	Size (inches)	Material	Size (inches)	Material	Units	Quantity	Unit Cost	Cost	Source of Estimate
		110	IW-01 to IW-02			4"	HDPE	linear feet	540	$ 79	$ 42,425	
			90 deg el			4"	HDPE	Each	3	$ 359	$ 1,076	
			flange			4"	HDPE	Each	1	$ 210	$ 210	
			reducer			4"x6"	HDPE	Each	1	$ 364	$ 364	
		300	Jack & Bore injection line branch to IW-04			8"	HDPE	linear feet	882	$ 91	$ 79,945	
			tee			8"	HDPE	Each	1	$ 688	$ 688	
			90 deg el			8"	HDPE	Each	2	$ 525	$ 1,050	
			reducer			8"x6"	HDPE	Each	2	$ 395	$ 790	
			reducer			6"x4"	HDPE	Each	1	$ 364	$ 364	
			reducer			2"x4"	HDPE	Each	1	$ 343	$ 343	
			flange			2"	HDPE	Each	1	$ 190	$ 190	
		200	IW-04 to IW-05			6"	HDPE	linear feet	300	$ 84	$ 25,096	
			tee			6"	HDPE	Each	1	$ 563	$ 563	
			flange			2"	HDPE	Each	1	$ 190		
			reducer			8"x6"	HDPE	Each	1	$ 395	$ 395	
			reducer			6"x4"	HDPE	Each	1	$ 364	$ 364	
			reducer			4"x2"	HDPE	Each	1	$ 343	$ 343	
		100	IW-05 to IW-03			4"	HDPE	linear feet	500	$ 79	$ 39,283	
			90 deg el			4"	HDPE	Each	1	$ 359	$ 359	
			reducer			2"x4"	HDPE	Each	1	$ 343	$ 343	
			flange			2"	HDPE	Each	1	$ 190	$ 190	
			Electrical pull boxes, assume 1 per 250 foot of trench					Each	30	$ 2,965	$ 88,938	H+A estimate
			Air eliminators, assume 1 per 500 foot of trench					Each	16	$ 5,058	$ 80,930	H+A estimate
										Subtotal	**$ 1,563,814**	
			Engineer-Design and Technical Support					Percent	8%		125,105	
			Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities					Percent	15%		234,572	
			Contractor Profit					Percent	8%		125,105	
			Construction Oversight					Percent	5%		78,191	
			Construction Contingency					Percent	20%		312,763	
										Total Conveyance	**$ 2,439,550**	

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

WELLS

Extraction/Injection Well Installation

Well Type	Capacity (gpm)	Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Inj	110	IW-01: Well installation including planning, encroachment permits, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	6 inch	1,000	Each	1	$ 350,000	$ 350,000	H+A estimate; no sound barrier
Inj	110	IW-03 through IW-05: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	6 inch	1,000	Each	3	$ 400,000	$ 1,200,000	H+A estimate; sound barrier
Ext	10	EW-07: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	4 inch	250	Each	1	$ 135,000	$ 135,000	H+A estimate; plus sound barrier
Ext	100	EW-03, EW-04, EW-06: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting.	6 inch	1,000	Each	3	$ 400,000	$ 1,200,000	H+A estimate; no sound barrier
							Subtotal Extraction/Injection Well Installation	**$ 2,885,000**	

Monitor Well Installation

Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of monitor well vault, installation of submersible sample pump, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	4 inch	1,000	Each	1	$ 335,000	$ 335,000	H+A estimate
					Subtotal Monitor Well Installation	**$ 335,000**	

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

Extraction/Injection Well Equipment

Well Type	Capacity (gpm)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Ext	10	EW-07: Vault, extraction well down hole equipment, includes submersible pump, electrical wire, stainless steel riser pipe, PVC sounder tube and transducer & cable (assume pump set depth at 150 feet below land surface)	Each	1	$ 65,990	$ 65,990	H+A Estimate
Ext	20	MW-31 (Extraction Well): Vault, extraction well down hole equipment, includes submersible pump, electrical wire, stainless steel riser pipe, PVC sounder tube and transducer & cable (assume pump set depth at 150 feet below land surface)	Each	1	$ 72,960	$ 72,960	H+A Estimate
Inj	100	IW-01 through IW-05: Vault + wellhead equipment + Injection well down hole equipment, stainless steel injection tubing, PVC sounder tube and transducer & cable	Each	5	$ 56,541	$ 282,706	H+A Estimate
Ext	20	MW-29: New piping and equipment	Each	1	$ 6,513	$ 6,513	H+A Estimate
Ext	120	EW-02: New piping and equipment	Each	1	$ 12,056	$ 12,056	H+A Estimate
Ext	10	EW-01: New piping and equipment	Each	1	$ 6,155	$ 6,155	H+A Estimate
Ext	10	MW-21: New piping and equipment	Each	1	$ 6,155	$ 6,155	H+A Estimate
Ext	100	EW-03, EW-04, and EW-06: Vault, extraction well down hole equipment, includes submersible pump, electrical wire, stainless steel riser pipe, PVC sounder tube and transducer & cable (assume pump set depth at 300 feet below land surface)	Each	3	$ 89,359	$ 268,076	H+A Estimate
		Subtotal Extraction/Injection Well Equipment				**$ 720,610**	
		Engineer-Design and Technical Support	Percent	8%		$ 57,648.78	Equipment only
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 108,091.46	Equipment only
		Contractor Profit	Percent	8%		$ 57,648.78	Equipment only
		Construction Oversight	Percent	5%		$ 36,030.49	Equipment only
		Construction Contingency	Percent	20%		$ 144,121.94	Equipment only
		Total Extraction/Injection Well Equipment				**$ 1,124,151**	
		Total Wells				**$ 4,344,151**	

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

GROUNDWATER TREATMENT SYSTEM

Advanced Oxidation Process

Capacity (gpm)	Reduction (log)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
490	2.5	UV system modular upgrade includes control panel, double contained peroxide tank, ancillary equipment and instrumentation	Each	1	$ 312,850	$ 312,850	Trojan quote 2013
490	NA	Liquid Phase Carbon Adsorbers (10,000 lb)	Each	1	$ 173,000	$ 173,000	includes initial GAC fill and manifold (Evoqua Quote - 6/24/14)
490	NA	Storage tank, stainless steel (10,000 gallon)	Each	2	$ 75,000	$ 150,000	H+A estimate
		Utility Tank, stainless steel (3,000 gallon)	Each	1	$ 30,000	$ 30,000	H+A estimate
490	NA	Transfer pump (influent) w/ VFD	Each	1	$ 18,201	$ 18,201	Rev032714
490	NA	Transfer pump (injection) w/ VFD- Utility tank	Each	1	$ 17,972	$ 17,972	Full Scale GETS Unit Cost Rev032714
490	NA	Transfer pump (injection) w/ VFD - onsite wells	Each	1	$ 15,358	$ 15,358	Full Scale GETS Unit Cost Rev032714
490	NA	Multi strainer particulate filter	Each	2	$ 18,500	$ 37,000	Pentek HIF 150FL (400-600 gpm)
	NA	Control System upgrade	Each	1	$ 250,000	$ 250,000	
					Subtotal Major Equipment	**$ 1,004,381**	
		Mechanical misc. and Installation	Percent	30%		$ 301,314.30	Percent of major equipment
		Electrical Upgrade	Percent	10%		$ 100,438.10	Percent of major equipment
		Instrumentation	Percent	10%		$ 100,438.10	Percent of major equipment
		Treatment Compound Upgrade	Each	1	$ 459,069	$ 459,069	ROM estimate
					Subtotal Treatment System	**$ 1,965,640**	
		Engineer-Design and Technical Support	Percent	8%		$ 80,350.48	Equipment only
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 150,657.15	Equipment only
		Contractor Profit	Percent	8%		$ 80,350.48	Equipment only
		Construction Oversight	Percent	5%		$ 50,219.05	Equipment only
		Construction Contingency	Percent	20%		$ 200,876.20	Equipment only
					Total Treatment System	**$ 2,528,093**	

GRAND TOTAL CONVEYANCE, WELLS AND TREATMENT SYSTEM COST (CAPITAL)	**$ 9,311,794**

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Categories with assumed to be relatively constant (years 1 to 5 = 100%, years 6 to 15 =90% and years 16 to 20 = 80%)

Utilities

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Electricity (UV System) Annual Operation, 90% uptime	kw/hr	449,388	$ 0.13	$ 58,420	Trojan 2013 estimate
Electricity (Submersible Pumps, 90% uptime)	kw/hr	411,537	$ 0.13	$ 53,500	Total 70 HP
Electricity (Transfer Pumps, 90% uptime)	kw/hr	440,932	$ 0.13	$ 57,321	Total 75 HP
Electricity (Lights and Control System)	kw/hr	17,637	$ 0.13	$ 2,293	ROM estimate
Water	Per month	12	$ 100	$ 1,200	ROM estimate
Telephone/Data Line	Per month	12	$ 150	$ 1,800	ROM estimate
Site Security	Per month	12	$ 100	$ 1,200	ROM estimate
OCWD Sewer Discharge Fees and Replenishment Assessment (1 gpm/yr)	Per year	2	$ 300	$ 600	OCWD estimate
Mark-up, percent of above	Percent	8%		$ 14,107	

Consumables

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Carbon Usage (10,000lb GAC change-out non-hazardous)	change out/ vessel	3	$ 11,100	$ 33,300	Siemens estimate 2015
UV Lamps	Per year	3	$ 13,000	$ 39,000	Trojan estimate 2013
Chemicals (hydrogen peroxide 27% solution, to make up 7.3 ppm dose)	Per year	3	$ 14,000	$ 42,000	Trojan estimate 2013
Bag filters	Per year	12	$ 500	$ 6,000	ROM estimate
Mark-up, percent of above	Percent	8%		9,624	

Permits/Access Agreements

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well easement (City of Buena Park)	per well	1	$ 15,000	$ 15,000	Rough estimate for deep well
Waste Discharge Permit Fee, per permit (assuming general WDR TTWQ and CPLX rating of 3-A).	per year	1	$ 5,000	$ 5,000	2013 fee schedule
Mark-up, percent of above	Percent	8%		$ 1,600	
Waste Discharge Permit Monitoring and Reporting, include monthly effluent samples for Site VOCs + 1,4-Dioxane, daily measurement of total flow, quarterly reports to RWQCB.	Per year	1	$ 33,000	$ 33,000	H+A Estimate

Well Development

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Injection well redevelopment, assumes all injection wells redeveloped once per year	per well	5	$ 15,000	$ 75,000	H+A estimate
Extraction well redevelopment, assumes all extraction wells redeveloped once every five years	per well	1.8	$ 10,000	$ 18,000	H+A estimate

Non-Routine O+M

Percent of treatment system cost and well equipment costs	Percent	2%		$ 50,561.87	

Subtotal Yearly OMM Costs (constant through years 1 to 30) $ 518,527

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Categories with decreasing use for years 1 to 20

Annual Costs - Years 1 and 2

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); two days per week	Per day	104	$ 1,200	$ 124,800	H+A Estimate
Project Management and Technical Evaluations Manager (16 hours/month) + Staff engineer (32 hours/month)	Per month	12	$ 5,600	$ 67,200	H+A Estimate
Trojan UV Tech Site Visit (One site visit per month 1st quarter, quarterly thereafter)	Per visit	6	$ 2,000	$ 12,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, Monthly EW sampling; weekly system sampling (3 locations) for first quarter, monthly thereafter (includes 8% mark-up and supplies)	Per sample	171	$ 350	$ 59,850	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	81	$ 1,500	$ 121,500	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
			Annual Variable Costs for Years 1 and 2	$ 445,350	

Annual Costs - Years 3 to 5

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per week	Per day	52	$ 1,200	$ 62,400	H+A Estimate
Project Management and Technical Evaluations Manager (12 hours/month) + Staff engineer (24 hours/month)	Per month	12	$ 3,200	$ 38,400	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + laboratory analysis, VOCs and 1,4-Dioxane, Quarterly EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	72	$ 350	$ 25,200	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	50	$ 1,500	$ 75,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
			Annual Variable Costs for Years 3 to 5	$ 265,000	

Annual Costs - Years 6 to 15

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); two days per month	Per day	24	$ 1,200	$ 28,800	H+A Estimate
Project Management and Technical Evaluations Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month	12	$ 2,800	$ 33,600	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, Semi-annual EW sampling; monthly	Per sample	54	$ 350	$ 18,900	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	40	$ 1,500	$ 60,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
			Annual Variable Costs for Years 6 to 15	$ 185,300	

TABLE B-5

COST ESTIMATE ALTERNATIVE - GW5A: ON-SITE AND BREA CREEK ALIGNMENT EXTRACTION WITH ON- AND OFF-SITE UNIT B INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Annual Costs - Years 16 to 30

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per month	Per day	12	$ 1,200	$ 14,400	H+A Estimate
Project Management and Technical Evaluations Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month	12	$ 2,800	$ 33,600	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, annual EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	45	$ 350	$ 15,750	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment	Per sample	24	$ 1,500	$ 36,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
Annual Variable Costs for Years 16 to 30				$ 143,750	

ANNUAL OMM ESTIMATE		
	YEARS 1 and 2	$ 963,877
	YEARS 3 to 5	$ 783,527
	YEARS 6 to 15	$ 651,974
	YEARS 16 to 20	$ 558,572

Acronyms and Abbreviations

gpm = Gallons per minute
H+A = Hargis + Associates, Inc.
NA = Not applicable
HP = Horsepower
PVC = Polyvinyl chloride
ROM = Rough order of magnitude
UV = Ultraviolet
OCWD = Orange County Water District
lb = Pound
WDR = Waste Discharge Requirements
TTWQ = Threat to water quality
Ext = Extraction
Inj = Injection
VFD = Variable frequency drive
yr = Year
CPLX = Complexity
RWQCB = Regional Water Quality Control Board
EW = Extraction well
GAC = Granular activated carbon
ppm = Parts per million
VOCs = Volatile organic compounds
MW = Monitor well
IW = Injection well
deg el = Degree elevation
DCHDPE = Double-contained high density polyethylene
HDPE = High density polyethylene
GETS = Groundwater extraction and treatment system
O+M = Operation and maintenance
OMM = Operation, maintenance, and monitoring
kw/hr = Kilowatts per hour

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

Capacity (gpm)		Description/Segment	Extraction		Injection						
Extraction	Injection		Size (inches)	Material	Size (inches)	Material	Units	Quantity	Unit Cost	Cost	Source of Estimate
20		MW-31 to EW-05/06 tie-in	2"x4"	DCHDPE			linear feet	990	$ 82	$ 81,208	
		90 deg el	2"x4"	DCHDPE			Each	3	$ 493	$ 1,480	
		45 deg el	2"x4"	DCHDPE			Each	2	$ 454	$ 908	
		flange	2"x4"	DCHDPE			Each	1	$ 292	$ 292	
		reducer	3"x6" to 2"x4"	DCHDPE			Each	1	$ 450		
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
540	590	EW-02 tie in to MW-29 tie-in	6"x10"	DCHDPE	6"	HDPE	linear feet	160	$ 153	$ -	Existing from Pilot Test
		tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ -	Existing from Pilot Test
		90 deg el	6"x10"	DCHDPE			Each	1	$ 885	$ -	Existing from Pilot Test
		flange	6"x10"	DCHDPE			Each	1	$ 520	$ -	Existing from Pilot Test
560	590	MW-29 tie-in to EW-07 tie-in	6"x10"	DCHDPE	6"	HDPE	linear feet	325	$ 153	$ -	Existing from Pilot Test
		tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ -	Existing from Pilot Test
570	590	EW-07 tie-in to Treatment System	6"x10"	DCHDPE	6"	HDPE	linear feet	920	$ 153	$ -	Existing from Pilot Test
		45 deg el	6"x10"	DCHDPE			Each	2	$ 695	$ -	Existing from Pilot Test
		90 deg el	6"x10"	DCHDPE			Each	4	$ 885	$ -	Existing from Pilot Test
		flange	6"x10"	DCHDPE			Each	1	$ 520	$ -	Existing from Pilot Test
		45 deg el			6"	HDPE	Each	2	$ 390	$ -	Existing from Pilot Test
		90 deg el			6"	HDPE	Each	4	$ 400	$ -	Existing from Pilot Test
		flange			6"	HDPE	Each	1	$ 216	$ -	Existing from Pilot Test
10		EW-07 to EW-07 tie-in	1"x3"	DCHDPE			linear feet	40	$ 80	$ 3,211	
		flange	1"x3"	DCHDPE			Each	1	$ 276	$ 276	
		reducer	1x3 to 2x4	DCHDPE			Each	1	$ 424	$ 424	
		reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ 450	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
20		MW-29 to MW-29 tie-in	2"x4"	DCHDPE			linear feet	525	$ 82	$ -	Existing from Pilot Test
		flange	2"x4"	DCHDPE			Each	1	$ 292	$ -	Existing from Pilot Test
		45 deg el	2"x4"	DCHDPE			Each	4	$ 454	$ -	Existing from Pilot Test
		90 deg el	2"x4"	DCHDPE			Each	1	$ 493	$ -	Existing from Pilot Test
		reducer	2x4 to 3x6	DCHDPE			Each	1	$ 450	$ -	Existing from Pilot Test
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ -	Existing from Pilot Test
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ -	Existing from Pilot Test
120		EW-02 to EW-02 tie-in	4"x8"	DCHDPE			linear feet	170	$ 97	$ -	Existing from Pilot Test
		90 deg el	4"x8"	DCHDPE			Each	1	$ 635	$ -	Existing from Pilot Test
		flange	4"x8"	DCHDPE			Each	1	$ 465	$ -	Existing from Pilot Test

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

Capacity (gpm)		Description/Segment	Extraction		Injection		Units	Quantity	Unit Cost	Cost	Source of Estimate
Extraction	Injection		Size (inches)	Material	Size (inches)	Material					
200		EW-06 to EW-05 tie in	6"x10"	DCHDPE			linear feet	2,000	$ 116	$ 232,437	
		tee	6"x10"	DCHDPE			Each	1	$ 1,108	$ 1,108	
		90 deg el	6"x10"	DCHDPE			Each	4	$ 885	$ 3,539	
		45 deg el	6"x10"	DCHDPE			Each	4	$ 695	$ 2,778	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
		flange	3"x6"	DCHDPE			Each	1	$ 442	$ 442	
200		EW-005 to EW-05 tie in	6"x10"	DCHDPE			linear feet	30	$ 116	$ 3,487	
		reducer	3x6 to 4x8	DCHDPE			Each	1	$ 501	$ 501	
		reducer	4x8 to 6x10	DCHDPE			Each	1	$ 649	$ 649	
		flange	3"x6"	DCHDPE			Each	1	$ 442	$ 442	
400	200	EW-05 tie in to Jack & Bore	8"x12"	DCHDPE	6"	HDPE	linear feet	1,330	$ 181	$ 240,869	
		90 deg el	8"x12"	DCHDPE			Each	3	$ 1,059	$ 3,178	
		90 deg el			6"	HDPE	Each	4	$ 400	$ 1,600	
		Flange	8"x12"	DCHDPE			Each	1	$ 684	$ 684	
		Flange			6"	HDPE	Each	2	$ 216	$ 432	
400	200	Jack & Bore					lump sum	1	$ 135,438.51	$ 135,439	
		90 deg el	8"x12"	DCHDPE			Each	4	$ 1,059	$ 4,237	
		Flange	8"x12"	DCHDPE			Each	1	$ 684	$ 684	
		tee			6"	HDPE	Each	1	$ 563	$ 563	
		90 deg el			6"	HDPE	Each	4	$ 400	$ 1,600	
		Flange			6"	HDPE	Each	1	$ 216	$ 216	
400	300	Jack & Bore to MW-31 tie-in	8"x12"	DCHDPE	6"	HDPE	linear feet	870	$ 181	$ 157,561	
		90 deg el	8"x12"	DCHDPE			Each	3	$ 1,059	$ 3,178	
		tee	8"x12"	DCHDPE			Each	1	$ 1,337	$ 1,337	
		45 deg el	8"x12"	DCHDPE			Each	2	$ 821	$ 1,643	
		90 deg el			6"	HDPE	Each	4	$ 400	$ 1,600	
		45 deg el			6"	HDPE	Each	2	$ 390	$ 780	
	100	Jack & Bore to IW-03			4"	HDPE	linear feet	1,750	$ 79	$ 137,490	
		90 deg el			4"	HDPE	Each	2	$ 400	$ 800	
		45 deg el			4"	HDPE	Each	2	$ 390	$ 780	
		flange			4"	HDPE	Each	1	$ 216	$ 216	
	290	Tie in near EW-02 to IW-06A			6"	HDPE	linear feet	1,000	$ 91	$ 90,641	
		45 deg el			6"	HDPE	Each	2	$ 390	$ 780	
		tee			6"	HDPE	Each	2	$ 563	$ 1,126	
		flange			2"	HDPE	Each	1	$ 190	$ 190	
		reducer			4"x2"	HDPE	Each	1	$ 343	$ 343	
		reducer			4"x6"	HDPE	Each	1	$ 364	$ 364	
	215	IW-06A to IW-07A			6"	HDPE	linear feet	200	$ 91	$ 18,128	
		tee			6"	HDPE	Each	1	$ 563	$ 563	
		flange			2"	HDPE	Each	1	$ 190	$ 190	
		reducer			4"x2"	HDPE	Each	1	$ 343	$ 343	
		reducer			4"x6"	HDPE	Each	1	$ 364	$ 364	

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

CONVEYANCE

Capacity (gpm)		Description/Segment	Extraction		Injection						
Extraction	Injection		Size (inches)	Material	Size (inches)	Material	Units	Quantity	Unit Cost	Cost	Source of Estimate
	140	IW-07A to IW01			4"	HDPE	linear feet	110	$ 79	$ 8,642	
		tee			4"	HDPE	Each	1	$ 522	$ 522	
		flange			2"	HDPE	Each	1	$ 190	$ 190	
		reducer			4"x2"	HDPE	Each	1	$ 343	$ 343	
	70	IW-01 to IW-02			4"	HDPE	linear feet	500	$ 79	$ 39,283	
		90 deg el			4"	HDPE	Each	3	$ 359	$ 1,076	
		reducer			2"x4"	HDPE	Each	1	$ 343	$ 343	
		flange			2"	HDPE	Each	1	$ 190	$ 190	
		Electrical pull boxes, assume 1 per 250 foot of trench					Each	39	$ 2,965	$ 115,619	H+A estimate
		Air eliminators, assume 1 per 500 foot of trench					Each	20	$ 5,058	$ 101,162	H+A estimate
									Subtotal	**$ 1,411,718**	

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Engineer-Design and Technical Support	Percent	8%		$ 112,937	
Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 211,758	
Contractor Profit	Percent	8%		$ 112,937	
Construction Oversight	Percent	5%		$ 70,586	
Construction Contingency	Percent	20%		$ 282,344	
			Total Conveyance	**$ 2,202,281**	

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

WELLS

Extraction/Injection Well Installation

Well Type	Capacity (gpm)	Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Inj	110	IW-01, IW-06A, IW-07A: Well installation including planning, encroachment permits, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting.	6 inch	1,000	Each	3	$ 350,000	$ 1,050,000	H+A estimate; no sound barrier
Inj	110	IW-03: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting.	6 inch	1,000	Each	1	$ 400,000	$ 400,000	H+A estimate; sound barrier
Ext	10	EW-07: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting.	4 inch	250	Each	1	$ 135,000	$ 135,000	H+A estimate; plus sound barrier
Ext	100	EW-05 and EW-06: Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility), surveying, installation of temporary vault, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting.	6 inch	1,000	Each	2	$ 400,000	$ 800,000	H+A estimate; no sound barrier
							Subtotal Extraction/Injection Well Installation	**$ 2,385,000**	

Monitor Well Installation

Description	Size (Inches)	Depth (feet)	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well installation including planning, encroachment permits, sound barriers, well construction, waste disposal (drilling mud and cuttings), well development/pump test (water treated at existing treatment facility, surveying, installation of monitor well vault, installation of submersible sample pump, temporary facilities, overhead and profit, fencing and security, oversight and well completion reporting	4 inch	1000	Each	2	$ 385,000	$ 770,000	H+A estimate
Same as above (with or without sound barriers)	4 inch	1000	Each		$ 335,000	$ -	H+A estimate
						$ -	
					Subtotal Monitor Well Installation	**$ 770,000**	

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

Extraction/Injection Well Equipment

Well Type	Capacity (gpm)	Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Ext	10	EW-07: Vault, extraction well down hole equipment, includes submersible pump, electrical wire, stainless steel riser pipe, PVC sounder tube and transducer & cable (assume pump set depth at 150 feet below land surface)	Each	1	$ 65,990	$ 65,990	H+A Estimate
Ext	20	MW-31 (Extraction Well): Vault, extraction well down hole equipment, includes submersible pump, electrical wire, stainless steel riser pipe, PVC sounder tube and transducer & cable (assume pump set depth at 150 feet below land surface)	Each	1	$ 72,960	$ 72,960	H+A Estimate
Inj	75	IW-01, IW-02, IW-03, IW-06A, IW-07A: Vault + wellhead equipment + Injection well down hole equipment, stainless steel injection tubing, PVC sounder tube and transducer & cable	Each	5	$ 56,541	$ 282,706	H+A Estimate
Ext	200	EW-05 and EW-06: Vault, extraction well down hole equipment, includes submersible pump, electrical wire, stainless steel riser pipe, PVC sounder tube and transducer & cable (assume pump set depth at 300 feet below land surface)	Each	2	$ 89,359	$ 178,717	H+A Estimate
Ext	20	MW-29: New piping and equipment	Each	1	$ 6,513	$ 6,513	H+A Estimate
Ext	120	EW-02: New piping and equipment	Each	1	$ 12,056	$ 12,056	H+A Estimate
Ext	10	EW-01: New piping and equipment	Each	1	$ 6,155	$ 6,155	H+A Estimate
Ext	10	MW-21: New piping and equipment	Each	1	$ 6,155	$ 6,155	H+A Estimate
					Subtotal Extraction/Injection Well Equipment	**$ 631,251**	
		Engineer-Design and Technical Support	Percent	8%		$ 50,500	Equipment only
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 94,688	Equipment only
		Contractor Profit	Percent	8%		$ 50,500	Equipment only
		Construction Oversight	Percent	5%		$ 31,563	Equipment only
		Construction Contingency	Percent	20%		$ 126,250	Equipment only
					Total Extraction/Injection Well Equipment	**$ 984,752**	
					Total Wells	**$ 4,139,752**	

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

DESIGN AND CONSTRUCTION (CAPITAL)

GROUNDWATER TREATMENT SYSTEM

Advanced Oxidation Process

Capacity (gpm)	Reduction (log)	Description					
590	2.5	UV system modular upgrade includes control panel, double contained peroxide tank, ancillary equipment and instrumentation	Each	1	$ 395,000	$ 395,000	Trojan quote 2013
590	NA	Liquid Phase Carbon Adsorbers (20,000 lb)	Each	1	$ 300,000	$ 300,000	includes initial GAC fill and manifold (Evoqua Quote - 6/24/14)
590	NA	Storage tank, stainless steel (10,000 gallon)	Each	2	$ 75,000	$ 150,000	H+A estimate
		Utility Tank, stainless steel (3,000 gallon)	Each	1	$ 30,000	$ 30,000	H+A estimate
590	NA	Transfer pump (influent) w/ VFD	Each	1	$ 18,201	$ 18,201	Rev032714
590	NA	Transfer pump (injection) w/ VFD- Utility tank	Each	1	$ 17,972	$ 17,972	Full Scale GETS Unit Cost Rev032714
590	NA	Transfer pump (injection) w/ VFD - onsite wells	Each	1	$ 18,201	$ 18,201	Full Scale GETS Unit Cost Rev032714
590	NA	Multi strainer particulate filter	Each	2	$ 21,200	$ 42,400	Pentek HIF 150FL (400-600 gpm)
	NA	Control System upgrade	Each	1	$ 250,000	$ 250,000	
					Subtotal Major Equipment	**$ 1,221,774**	
		Mechanical misc. and Installation	Percent	30%		$ 366,532	Percent of major equipment
		Electrical Upgrade	Percent	10%		$ 122,177	Percent of major equipment
		Instrumentation	Percent	10%		$ 122,177	Percent of major equipment
		Treatment Compound Upgrade	Each	1	$ 616,361	$ 616,361	ROM estimate
						$ -	
					Subtotal Treatment System	**$ 2,449,022**	
		Engineer-Design and Technical Support	Percent	8%		$ 195,922	Equipment only
		Contractors Overhead, General Conditions, Mobilization / Demobilization, Temporary Facilities	Percent	15%		$ 367,353	Equipment only
		Contractor Profit	Percent	8%		$ 195,922	Equipment only
		Construction Oversight	Percent	5%		$ 122,451	Equipment only
		Construction Contingency	Percent	20%		$ 489,804	Equipment only
					Total Treatment System	**$ 3,820,475**	

GRAND TOTAL CONVEYANCE, WELLS AND TREATMENT SYSTEM COST (CAPITAL)	**$ 10,162,508**

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Categories with assumed to be relatively constant (years 1 to 5 = 100%, years 6 to 15 =90% and years 16 to 20 = 80%)

Utilities

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Electricity (UV System) Annual Operation, 90% uptime	kwhr	599,184	$ 0.13	$ 77,894	Trojan 2013 estimate
Electricity (Submersible Pumps, 90% uptime)	kwhr	529,119	$ 0.13	$ 68,785	Total 90 HP
Electricity (Transfer Pumps, 90% uptime)	kwhr	411,537	$ 0.13	$ 53,500	Total 70 HP
Electricity (Lights and Control System)	kwhr	17,637	$ 0.13	$ 2,293	ROM estimate
Water	Per month	12	$ 100	$ 1,200	ROM estimate
Telephone/Data Line	Per month	12	$ 150	$ 1,800	ROM estimate
Site Security	Per month	12	$ 100	$ 1,200	ROM estimate
OCWD Sewer Discharge Fees and Replenishment Assessment (1 gpm/yr)	Per year	2	$ 300	$ 600	OCWD estimate
Mark-up, percent of above	Percent	8%		$ 16,581.76	

Consumables

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Carbon Usage (10,000lb GAC change-out non-hazardous)	change out/ vessel	3	$ 11,100	$ 33,300	Siemens estimate 2015
UV Lamps	Per year	4	$ 13,000	$ 52,000	Trojan estimate 2013
Chemicals (hydrogen peroxide 27% solution, to make up 7.3 ppm dose)	Per year	4	$ 14,000	$ 56,000	Trojan estimate 2013
Bag filters	Per year	3	$ 500	$ 1,500	ROM estimate
Mark-up, percent of above	Percent	8%		11,424	

Permits/Access Agreements

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Well easement (City of Buena Park)	per well	1	$ 15,000	$ 15,000	Rough estimate for deep well
Waste Discharge Permit Fee, per permit (assuming general WDR TTWQ and CPLX rating of 3-A).	per year	1	$ 5,000	$ 5,000	2013 fee schedule
Mark-up, percent of above	Percent	8%		$ 1,600	
Waste Discharge Permit Monitoring and Reporting, include monthly effluent samples for Site VOCs +1,4-Dioxand, daily measurement of total flow, quarterly reports to RWQCB.	Per year	1	$ 33,000	$ 33,000	H+A Estimate

Well Development

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Injection well redevelopment, assumes all injection wells redeveloped once per year	per well	10	$ 15,000	$ 150,000	H+A estimate
Extraction well redevelopment, assumes all extraction wells redeveloped once every five years	per well	1.6	$ 10,000	$ 16,000	H+A estimate

Non-Routine O+M

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Percent of treatment system cost and well equipment costs	Percent	2%		$ 76,409.50	

Subtotal Yearly OMM Costs (constant through years 1 to 30) $ 675,087

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Categories with decreasing use for years 1 to 20

Annual Costs - Years 1 and 2

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); two days per week	Per day	104	$ 1,200	$ 124,800	H+A Estimate
Project Management and Technical Evaluations Manager (16 hours/month) + Staff engineer (32 hours/month)	Per month	12	$ 5,600	$ 67,200	H+A Estimate
Trojan UV Tech Site Visit (One site visit per month 1st quarter, quarterly thereafter)	Per visit	6	$ 2,000	$ 12,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, Monthly EW sampling; weekly system sampling (3 locations) for first quarter, monthly thereafter (includes 8% mark-up and supplies)	Per sample	159	$ 350	$ 55,650	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	85	$ 1,500	$ 127,500	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per submittal	3	$ 10,000	$ 30,000	H+A Estimate
			Annual Variable Costs for Years 1 and 2	$ 447,150	

Annual Costs - Years 3 to 5

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per week	Per day	52	$ 1,200	$ 62,400	H+A Estimate
Project Management and Technical Evaluations Manager (12 hours/month) + Staff engineer (24 hours/month)	Per month	12	$ 3,200	$ 38,400	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + laboratory analysis, VOCs and 1,4-Dioxane, Quarterly EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	68	$ 350	$ 23,800	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	52	$ 1,500	$ 78,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, quarterly data submittal	Per	3	$ 10,000	$ 30,000	H+A Estimate
			Annual Variable Costs for Years 3 to 5	$ 266,600	

Annual Costs - Years 6 to 15

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); two days per month	Per day	24	$ 1,200	$ 28,800	H+A Estimate
Project Management and Technical Evaluations Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month	12	$ 2,800	$ 33,600	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, Semi-annual EW sampling; monthly	Per sample	52	$ 350	$ 18,200	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment system	Per sample	42	$ 1,500	$ 63,000	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
			Annual Variable Costs for Years 6 to 15	$ 187,600	

TABLE B-6

COST ESTIMATE ALTERNATIVE - GW6A: ON-SITE AND SOUTH OF BREA CREEK EXTRACTION WITH ON- AND OFF-SITE DISTRIBUTED INJECTION

OPERATION, MAINTENANCE, AND MONITORING

Annual Costs - Years 16 to 20

Description	Units	Quantity	Unit Cost	Cost	Source of Estimate
Treatment system operation and monitoring (Includes materials and equipment); one day per month	Per day	12	$ 1,200	$ 14,400	H+A Estimate
Project Management and Technical Evaluations (Manager (8 hours/month) + Staff engineer (16 hours/month)	Per month	12	$ 2,800	$ 33,600	H+A Estimate
Trojan UV Tech Site Visit (One site visit every six months)	Per visit	2	$ 2,000	$ 4,000	
Sample collection (1 hour per sample) + Laboratory analysis, VOCs and 1,4-Dioxane, annual EW sampling; monthly system sampling (3 locations) (includes 8% mark-up and supplies)	Per sample	44	$ 350	$ 15,400	
Groundwater sampling; coordination, site access, deep well sampling standard purge, analytical, water transfer to treatment	Per sample	25	$ 1,500	$ 37,500	H+A Estimate
Groundwater and treatment system reporting, annual report	Per report	1	$ 30,000	$ 30,000	H+A Estimate
Groundwater and treatment system reporting, semi-annual data submittal	Per submittal	1	$ 10,000	$ 10,000	H+A Estimate
			Annual Variable Costs for Years 16 to 30	$ 144,900	

ANNUAL OMM ESTIMATE		
	YEARS 1 and 2	$ 1,122,237
	YEARS 3 to 5	$ 941,687
	YEARS 6 to 15	$ 795,179
	YEARS 16 to 20	$ 684,970

Acronyms and Abbreviations

gpm = Gallons per minute
H+A = Hargis + Associates, Inc.
NA = Not applicable
HP = Horsepower
PVC = Polyvinyl chloride
ROM = Rough order of magnitude
UV = Ultraviolet
OCWD = Orange County Water District
lb = Pound
WDR = Waste Discharge Requirements
TTWQ = Threat to water quality
Ext = Extraction
Inj = Injection
VFD = Variable frequency drive
yr = Year
CPLX = Complexity
RWQCB = Regional Water Quality Control Board
EW = Extraction well
GAC = Granular activated carbon
ppm = Parts per million
VOCs = Volatile organic compounds
MW = Monitor well
IW = Injection well
deg el = Degree elevation
DCHDPE = Double-contained high density polyethylene
HDPE = High density polyethylene
GETS = Groundwater extraction and treatment system
O+M = Operation and maintenance
OMM = Operation, maintenance, and monitoring
kw/hr = Kilowatts per hour

TABLE B-7
CORRECTIVE MEASURES ALTERNATIVES NET PRESENT VALUE

Year	GW2	GW3	GW4	GW5A	GW6A
0	$288,000	$477,641	$712,618	$931,179	$1,016,251
1	$1,008,000	$1,671,743	$2,494,162	$3,259,128	$3,556,878
2	$1,584,000	$2,627,025	$3,919,398	$5,121,487	$5,589,379

CAPITAL NPV	$2,783,673.71	$4,616,653.66	$6,887,831.40	$9,000,345.99	$9,822,606.06

Year	GW2	GW3	GW4	GW5A	GW6A
1	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0
3	$366,600	$729,674	$917,120	$963,877	$1,122,237
4	$366,600	$729,674	$917,120	$963,877	$1,122,237
5	$366,600	$577,524	$739,570	$783,527	$941,687
6	$366,600	$577,524	$739,570	$783,527	$941,687
7	$366,600	$577,524	$739,570	$783,527	$941,687
8	$274,600	$499,392	$612,973	$651,974	$795,179
9	$274,600	$499,392	$612,973	$651,974	$795,179
10	$274,600	$499,392	$612,973	$651,974	$795,179
11	$274,600	$499,392	$612,973	$651,974	$795,179
12	$274,600	$499,392	$612,973	$651,974	$795,179
13	$274,600	$499,392	$612,973	$651,974	$795,179
14	$274,600	$499,392	$612,973	$651,974	$795,179
15	$274,600	$499,392	$612,973	$651,974	$795,179
16	$274,600	$499,392	$612,973	$651,974	$795,179
17	$274,600	$499,392	$612,973	$651,974	$795,179
18	$250,600	$420,259	$524,176	$558,572	$684,970
19	$250,600	$420,259	$524,176	$558,572	$684,970
20	$250,600	$420,259	$524,176	$558,572	$684,970
21	$250,600	$420,259	$524,176	$558,572	$684,970
22	$250,600	$420,259	$524,176	$558,572	$684,970
23	$250,600				
24	$250,600				
25	$250,600				
26	$250,600				
27	$250,600				
28	$250,600				
29	$250,600				
30	$250,600				
31	$250,600				
32	$250,600				
30 YR NPV (OMM)	$6,680,181				
20 YR NPV (OMM)		$8,776,219	$10,929,492	$11,598,203	$14,019,652
NPV Lifetime	$9,463,854	$13,392,873	$17,817,323	$20,598,549	$23,842,258
NPV Percentage	1.40%				

NPV = Net present value
OMM = Operations, maintenance, and monitoring