OVERALL OPERATIONAL DESIGN REPORT
BASED ON REMEDIAL WELLFIELD OPTIMIZATION

DUAL SITE GROUNDWATER OPERABLE UNIT
REMEDIAL DESIGN
MONTROSE CHEMICAL AND DEL AMO
SUPERFUND SITES
LOS ANGELES COUNTY, CALIFORNIA

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Region 9
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1. Introduction and Purpose

The objective of this report is to present a set of design specifications for the initial remedial wellfield at the Dual Site Groundwater Operable Unit, Montrose Chemical and Del Amo Superfund Sites, in Los Angeles County California. These specifications are referred to as the "Overall Operational Design" (OOD) in the Statement of Work (SOW) for the Remedial Design Work for the Dual Site Groundwater Operable Unit. This document is kept simple by design; an independent Model Development and Remedial Wellfield Optimization Report will describe in detail the optimization process that led to the OOD.

1.1 Background

The Record of Decision for the Dual Site Groundwater Operable Unit, Montrose Chemical and Del Amo Superfund Sites issued by the United States Environmental Protection Agency (EPA) on March 30, 1999 (ROD) selected a remedy for the dissolved-phase contamination at both of these sites. While more than one physical groundwater treatment system may be constructed and operated as part of the remedial action, the effects of such systems will be interrelated. The performance of all remedial action components operating together must meet the requirements of the ROD.

The detailed requirements of the ROD appear primarily in ROD Section 13. Among those most critical to the development of the OOD are:

- Indefinite containment of all contaminants presently within a zone which the ROD refers to as the "Containment Zone" ("CZ");
- Containment of the overall distribution of Dual-Site contaminants;
- Reduction of the volume of water with concentrations of contaminants above drinking water standards to zero, progress toward which is required within certain timeframes;
- The limiting of adverse migration of significant contaminants, either as concentrations in the dissolved phase, or non-aqueous phase liquids, especially to hydrostratigraphic layers lying below the present contamination; to this end wells and pumping are required to reverse or otherwise control downward gradients; and
- The redistribution of groundwater extraction1 as the contaminant plume shrinks, from newly clean areas of the plume to remaining contaminated areas, so as to expedite overall cleanup and make it more efficient.

The OOD is based on a wellfield optimization process that is mandated by Article 13.11 of the ROD and has been underway since initiation of the remedial design. The focus was to

[1] Redistribution means shutting down a well on the downgradient end of a shrinking plume that is now in clean groundwater, and increasing the pumping rate of other active well(s) within the remaining plume upgradient by an amount required for expediting overall cleanup, making it more efficient, and meeting the requirements of the ROD. The same effect could be achieved through distributing the pumping to a newly installed well.

develop a wellfield that would meet the ROD requirements and design objectives with a sufficient degree of certainty, and in a manner sufficiently robust to succeed even if actual site conditions differ from those assumed or change in the future. The optimization process also was designed to achieve these requirements and objectives in the most cost-effective manner.

The remedial wellfield optimization process included the use of a sophisticated numerical flow and transport computer model ("Remedial Design Model"). The model was constructed and calibrated based on the most complete and comprehensive data set available at the time of modeling. This data set was developed during the extensive remedial investigations performed by Shell, Montrose, and other parties, and included hydrostratigraphic information from numerous soil borings, contaminant concentration and water level measurements collected over a period from 1985 through 2006, and the results of extensive pilot-scale extraction and injection testing. Model calibration and optimization of the remedial wellfield was performed using the parameter estimation software package PEST (Doherty, 2002; Doherty and Johnston, 2003). The use of PEST allowed:

1. Automatic model calibration (versus traditional manual calibration, which is a more time-consuming and less-effective process);
2. Calibration to multiple targets (e.g., hydraulic heads; vertical head differences; pilot test data; and concentrations of chlorobenzene, benzene, and parachlorobenzene sulfonic acid [p-CBSA]);
3. Numerical uncertainty and data gap analysis, which allowed identification of additional contamination in the Gage aquifer; and finally
4. Development and optimization of the remedial wellfield, which is capable of achieving all remedial objectives of the ROD in a cost-effective manner and with a reasonable degree of certainty.

All modeling activities (including model development, model calibration, and remedial wellfield optimization simulations) were conducted with the oversight and regular involvement of Montrose and Shell. All modeling files were provided to Montrose and Shell for review on a regular basis. The results of this review were discussed at modeling meetings and/or regular modeling conference calls, so that input from Shell, Montrose, EPA, and the Department of Toxic Substances Control (DTSC) could be incorporated in a timely manner at every step of the modeling process. A detailed discussion of the numerical model and the remedial design optimization process will be presented in the Model Development and Remedial Wellfield Optimization Report.

1.2 OOD Specifications

The OOD specifies the following aspects of the remedial design:

1. Locations and rationale for the extraction and injection wells in the overall system (in both areal dimensions and depth/hydrostratigraphic unit dimensions), as well as the approximate number of extraction and injection wells based on the assumed or estimated well capacities;

2. Optimized flow rates of the remedial wellfield including the initial total pumping rate of the remedial wellfield, initial rates of extraction and injection wells, and maximum flow rates of individual wells;
3. Operational considerations for the remedial wellfield including concentration target shutdown levels for shutting down extraction wells, general guidance for redistributing flow between the wells, and considerations pertaining to operation of the wells involved in maintaining containment of the CZ as specified in the ROD; and
4. Estimated (modeled) influent concentrations of chlorobenzene, benzene, and p-CBSA, including flow-weighted average concentrations and well-specific concentrations.

However, the OOD does not include engineering specifications for wells, conveyances, or treatment systems; this includes, but is not limited to, such factors as capacities, materials, conveyance alignments, injection controls, equipment, systems design, or any other such engineered characteristics. It also does not include contingencies that should be incorporated in the formal design due to uncertainty in future operational needs and conditions. The formal "pen-to-paper" design will include these components. The OOD provides a basis for the design, but it is recognized that as new information is obtained—especially field operational data during remedy implementation—the wellfield may need to be reoptimized and adjusted to ensure compliance with ROD requirements (for instance, modifying pumping rates and/or adding wells).

1.3 Definition of Terms

The terms used in this report are consistent with those used in the ROD. The ROD provides requirements, some of which differ by areas defined in the ROD such as the chlorobenzene plume, benzene plume, trichloroethene (TCE) plume, and CZ. This document assumes a familiarity with these concepts, which are defined in detail in the ROD.

Here, the term "CZ containment well" means an extraction or injection well that has, as a primary purpose, the maintenance of containment of dissolved-phase contaminants within the CZ, *including* the limiting of vertical adverse migration from shallower to deeper hydrostratigraphic units (for example, reversing downward hydraulic gradients through extraction or injection).

The term "plume-reduction well" means an extraction well that has, as a primary purpose, the reduction of the volume of the chlorobenzene plume outside the CZ, within the target timeframes specified in the ROD.

2. Locations and Approximate Number of Extraction and Injection Wells

This section presents the optimized locations for the remedial wells, including both extraction and injection wells, which should be used for the formal remedial design. While these locations could be changed slightly based on the findings of the remedial design (such as physical or legal property access restrictions), significant design deviations from the optimized locations because of access, cost, or other considerations should be approved by EPA in accordance with the Remedial Design SOW and may require an additional evaluation with regard to meeting the ROD requirements.

One well per location was assumed for the purposes of the OOD. This assumption was made based on the available data regarding the hydrogeologic properties of the formation and the estimated capacities of the existing wells (Table 1). However, if it is determined during the design or remedy implementation that the required flow rate cannot be achieved at certain locations with just one well, additional wells will need to be installed at these locations to meet the specifications of the OOD. These additional wells should be installed in the general vicinity of the proposed locations, but at a sufficient distance from existing extraction and/or injection wells to avoid interference between the wells (i.e., significant impact on drawdown or buildup in the adjacent wells).

Figures 1 through Figure 3 show the locations of the remedial wells, including injection and extraction wells in the water table, Middle Bellflower C Sand (MBFC), and Gage aquifers, respectively. The coordinates of these wells are presented in Table 2. The overall optimized remedial wellfield includes a total of 17 extraction wells (3 wells in the water table aquifer, 7 wells in the MBFC, and 7 wells in the Gage aquifer), and 6 injection wells (3 wells in the MBFC and 3 wells in the Gage aquifer). Of these wells, 6 extraction wells and 4 injection wells have already been installed as part of the pilot testing program (Figures 1 through 3).

The initial locations for the remedial wells were selected based on the configuration of the contaminant plumes and site access considerations. The CZ extraction wells are located in each impacted aquifer (i.e., water table aquifer, MBFC, and Gage aquifer) within the CZ, downgradient of the source area. The plume-reduction wells, in general, are located along the central axis of the contaminant plumes. The well locations were refined based on the optimization process in order to achieve the requirements and standards of the ROD. For example, the locations of the plume-reduction wells were adjusted and moved further downgradient from the CZ so that these wells would not interfere with the CZ containment wells (i.e., would not pull contaminated groundwater out of the CZ).

The optimization process resulted in the placement of extraction well G-EW-E at the toe of the chlorobenzene plume in the Gage aquifer in order to meet the ROD requirement that the overall chlorobenzene plume needs to be reliably contained and shrinking in volume. A failure of plume containment in this area would pose a significant risk to downgradient receptors and may cause rapid migration of contaminants both laterally and vertically. The Gage aquifer is a drinking water aquifer and several municipal wells are located in

relatively close proximity to the toe of the chlorobenzene plume. The hydraulic gradient is significantly steeper at the downgradient edge of the chlorobenzene plume in the Gage aquifer, possibly due to the impact of the downgradient municipal extraction. This makes hydraulic containment more difficult. Any potential increase in downgradient extraction from the municipal wells could result in further increase of the hydraulic gradient and greater loss of plume containment. Because the existing downgradient well, G-EW-2, has a limited specific capacity (Table 1), an additional extraction well in this area is crucial for the reliable containment and subsequent success of the remedy.

Also as a result of the optimization process, the locations and flow rates of injection wells were adjusted so that these wells would help reduce the adverse impact of remedial pumping on other contaminant plumes such as the TCE and benzene plumes. For example, two Gage injection wells (existing well G-IW-2 and new well G-IW-D) are located at the Del Amo site to reverse the downward gradient between the MBFC and Gage aquifers in the area where elevated concentrations of benzene and TCE are present in the MBFC. Reversing the downward hydraulic gradient in this area will prevent the vertical migration of TCE and benzene into the Gage aquifer and will ensure containment of these contaminants within the CZ in the MBFC.

The primary rationale for the locations of each extraction and injection well is presented in Table 3.

3. Optimized Flow Rates of the Remedial Wellfield

This section discusses the optimized flow rates for the remedial wells, including the total pumping rate of the initial remedial wellfield, the initial rates of individual extraction and injection wells, and the maximum flow rates of individual wells that need to be considered by the formal "pen-to-paper" design. As discussed above, the optimized flow rates presented by the OOD do not include contingencies that should be incorporated in the formal design due to uncertainty in future operational needs and conditions. Any design deviation from the optimized total flow rates, individual flow rates, or maximum flow rates presented here (except for adding the design contingency) should be approved by EPA in accordance with the Remedial Design SOW, and may require additional evaluation with regard to meeting the ROD requirements.

3.1 Total Flow Rate of Initial Remedial Wellfield(s)

Based on the optimization modeling, the total extraction rate of 729 gallons per minute (gpm) is required to achieve the ROD standards (Table 1). This includes extraction of 700 gpm to address the ROD standards for the chlorobenzene and benzene plumes, and extraction of 29 gpm to address the ROD standards for the TCE plume. These flow rates should be used for the formal "pen-to-paper" remedial design of the treatment facilities.

3.2 Initial Flow Rates of Individual Wells

The distribution of flow between extraction and injection wells was optimized during the remedial design modeling. The optimized flow rates of extraction and injection rates are included in Table 1. These include the initial flow rates and subsequent redistribution of pumping and injection after the concentrations in some wells decrease below target shutdown levels and those wells are shut down. The initial flow rates of wells are also shown in Figures 1 through 3 for the water table, MBFC, and Gage aquifers, respectively. These optimized initial flow rates should be used in the formal remedial design.

3.3 Maximum Flow Rates of Individual Wells

The maximum rates for individual wells are provided in Table 1. For some extraction wells, the maximum rates are higher than the initial rates, because additional pumping may need to be added to those wells as part of pumping redistribution to meet ROD standards after shutting down the wells that have achieved cleanup levels (see Section 4). Consequently, the maximum flow rates should be considered performance targets for the formal "pen-to-paper" remedial design of the extraction wells to ensure that the wells have sufficient capacity to achieve these rates, if required. For injection wells, the maximum flow rates shown are the same as the initial rates.

Based on pilot testing data presently available, existing wells appear to have sufficient capacity to achieve maximum flow rates, if required (Table 1). However, actual field conditions may differ from previously estimated values. Consequently, additional contingency should be considered for the formal design of remedial wells. In addition, the maximum flow rates specified in the OOD should not define the capacity of the treatment system and conveyances. As discussed above, treatment system capacity should be designed with a sufficient margin of contingency due to uncertainty in future operational needs and conditions.

4. Operational Considerations for the Remedial Wellfield

The ROD requires reduction in the volume of the chlorobenzene plume outside the CZ to zero over time. The optimization process accounted for this by simulating shutdown of remedial extraction wells at the simulated time when the contaminant concentrations in these wells decreased below a certain target level, as explained below. This level is referred to as the "target shutdown level" in the following discussion.

As the simulation proceeded after the shutdown, the flow was then redistributed among the remaining extraction wells. Considering the redistribution of flow (pumping) in the optimization process allowed for the more effective use of extraction wells and resulted in a lower optimized total flow rate for the remedial wellfield required to achieve the ROD standards than that estimated without considering flow redistribution. Further evaluation of the optimized flow redistribution modeling runs indicated that the following aspects pertaining to the operation of the remedial wellfield should be considered and accounted for during the remedial design and remedy implementation:

- Target shutdown levels for extraction wells
- General guidance for redistributing flow between the wells
- Operation of CZ containment wells

4.1 Target Shutdown Levels for Extraction Wells

The optimization simulations of the remedial wellfield indicated that the target shutdown level for contaminant concentrations, at which extraction wells can be turned off, is an important parameter that should be considered for the development of the performance monitoring program and during remedy implementation. Specifically, the modeling results indicated that shutting off extraction wells at concentrations equal to the in situ groundwater standard (ISGS)[2] level for chlorobenzene (70 micrograms per liter [µg/L]) would result in a loss of hydraulic containment for part of the chlorobenzene plume. As this uncaptured portion of the plume migrates downgradient, previously cleaned areas of the aquifer would become recontaminated. This is because the need for downgradient containment is not eliminated when the contaminant concentration in a plume-reduction well reaches the ISGS level. For example, an extraction well located at the toe of the chlorobenzene plume could extract groundwater from both upgradient locations with contaminant concentrations above ISGS and from downgradient locations where groundwater is already below ISGS levels. In this case, the resulting diluted contaminant concentrations in this well could be below the ISGS levels. However, if this well is shut off, the above-ISGS concentrations from the upgradient areas can escape the extraction system. Based on the modeling optimization runs, using a target shutdown level of 10 to 15 µg/L of

[2] ISGS levels are cleanup levels specified in the ROD.

chlorobenzene is more appropriate than the ISGS level, because it does not result in the contaminant plume escaping downgradient containment. A detailed discussion pertaining to the monitoring and sampling procedures required for shutting down remedial wells, and the rationale for the concentration target shutdown levels will be included in the Monitoring and Aquifer Compliance Plan.

4.2 Redistributing Flow

The modeled distribution of flow between the extraction and injection wells for five consecutive simulated time periods is presented in Table 1. The initial time period terminates after 15 years, when the concentration in well G-EW-E decreases below the target shutdown level of 10 µg/L. The second time period starts with well G-EW-E being shut down and the flow from this well being redistributed between the remaining wells. The second time period and each subsequent time period also terminate when the concentrations in at least one extraction well drop below the target shutdown level. Each time, the flow is redistributed between the remaining wells in a manner that allows the most cost-effective achievement of ROD standards.

A detailed discussion of the modeling optimization runs will be presented in the Model Development and Remedial Wellfield Optimization Report. The discussion in this OOD report is limited to several operational issues that have been identified by modeling and should be considered during the design and operation of the remedial wellfield. These operational considerations include the following:

- Additional pumping should not be redistributed to the CZ containment wells (unless monitoring during remedy implementation demonstrates the lack of capture) as it may induce horizontal and/or vertical gradients in the dense nonaqueous phase liquid (DNAPL) source area.
- Flow redistribution should be performed in a manner that does not result in creating interference (i.e., competition for capture) between the CZ containment wells and the wells located downgradient of the CZ. The significant increase in flow rates in wells located downgradient of the CZ containment wells may cause a loss of capture in the CZ and result in contaminated groundwater bypassing CZ containment wells and migrating toward the wells with increased extraction. Consequently, only a portion of the flow from the cleaned up wells may need to be redistributed between the remaining wells. Additional modeling runs using the revised numerical model of the site should be performed each time the flow from clean wells needs to be redistributed between the remaining wells to optimize the performance of the remedial wellfield.
- The optimized amount of injection into the Gage aquifer significantly exceeds injection into the MBFC. This distribution of injection helps to mitigate the adverse vertical migration of DNAPL and dissolved contaminants into the Gage aquifer. When the amount of water available for injection decreases because of reduced extraction, injection in the MBFC wells should be stopped or reduced first. Injection in the Gage well located west of the Montrose site (well G-IW-1) can be reduced with further reduction of pumping. However, injection rates should be maintained at Gage injection wells

(G-IW-2 and G-IW-D) located at the Del Amo site to prevent vertical migration of TCE and benzene from the CZ in the MBFC into the Gage aquifer.

4.3 Operation of CZ Containment Extraction and Injection Wells

Most plume-reduction wells will be shut down after meeting the ROD requirements. However, as required by the ROD, the CZ containment wells will operate indefinitely or until the sources of contamination are removed and the groundwater within the CZ is remediated. This includes the CZ containment extraction wells UBA-EW-A, MBFB-EW-1, and UBA-EW-B in the water table aquifer; BF-EW-1, BF-EW-M, and BF-EW-N in the MBFC; and G-EW-1 in the Gage aquifer. In addition, Gage injection wells G-IW-2 and G-IW-D are also considered to be CZ containment wells because these wells prevent vertical migration of TCE and benzene from the CZ in the MBFC into the Gage aquifer (Table 3). Extraction and injection rates of the CZ containment wells can be adjusted upon shutting down other remedial extraction wells. It is expected that the amount of extraction from the CZ containment wells will be sufficient to maintain adequate injection into the CZ injection wells at the Del Amo site.

It is assumed for the purposes of this remedial design, that the TCE containment wells BF-EW-TCE and G-EW-TCE will also operate indefinitely or until the upgradient sources of contamination are removed and the groundwater at the upgradient locations is remediated.

Additional modeling runs using the revised numerical model of the site can be performed to determine the flow rates of the CZ containment wells and TCE containment wells when the chlorobenzene plume-reduction wells achieve cleanup standards and are no longer in operation.

5. Simulated Influent Concentrations

Simulated influent concentrations of chlorobenzene, benzene, and p-CBSA for each well are presented in Tables 4 through 6. These tables also present the flow-weighted average concentration for each of these constituents. The estimates of contaminant concentrations are presented for a simulated duration of remedial action of 32 years. Modeling results indicate that the ROD requirements pertaining to the reduction of the chlorobenzene plume will be met after 32 years and most remedial wells will be shut down at that time. The CZ containment wells will be in operation indefinitely, and it can be assumed for the purposes of the design that the concentrations in these wells will stay constant.

The estimates of contaminant concentrations presented in Tables 4 through 6 should be used for the design of the treatment facility. However, as with other aspects of the OOD, these estimates do not include contingency that should be incorporated in the formal design due to uncertainty associated with modeling estimates of contaminant concentrations and future operational needs and conditions. In general, the early-time estimates of influent concentrations are expected to be more accurate than the late-time concentrations, because they are less impacted by the modeling uncertainties and uncertainties associated with future conditions. A detailed discussion of the modeling uncertainties will be included in the Model Development and Remedial Wellfield Optimization Report.

Please note that the influent concentrations of TCE are not presented in this report, because modeling of the solute transport of TCE was not included in the scope of optimization modeling. The simulation of TCE migration was performed using particle tracking (i.e., by assessing advective transport of TCE, which does not account for dilution, retardation, and biodegradation) to develop OOD specifications for the TCE containment wells. The influent concentrations of TCE for the remedial design can be approximated from the available monitoring data and/or additional modeling runs can be performed using the known distribution of TCE. A detailed discussion of the TCE simulations will be included in the Model Development and Remedial Wellfield Optimization Report.

Tables

TABLE 1
Optimized Flow Rates for Remedial Wells

Aquifer	Well Identification	Time Period/ Duration					Maximum Flow Rate (gpm)	Estimated Capacity
		Initial Flow Rates (0 to 15)	Redistribution of Pumping after Clean Wells Start Shutting Down					
			15 – 18/ 3 years	18 – 26/ 8 years	26 – 30/ 4 years	30 – 32/ 2 years		
Extraction Well Rates (gpm)								
Water Table	UBA-EW-A	**6.0**	6.0	6.0	6.0	6.0	**6.0**	12
	UBA-EW-B	**12.0**	12.0	12.0	12.0	12.0	**12.0**	24
	MBFB-EW-1*	**4.0**	4.0	4.0	4.0	4.0	**4.0**	4
MBFC	BF-EW-1*	**35.0**	35.0	35.0	35.0	35.0	**35.0**	35
	BF-EW-2*	**67.6**	68.5	75.1	77.0	79.9	**79.9**	90
	BF-EW-B	**63.9**	64.8	71.0	72.9	75.6	**75.6**	80
	BF-EW-D	**132.4**	134.2	Well shut down	Well shut down	Well shut down	**134.2**	140
	BF-EW-M	**35.0**	35.0	35.0	35.0	35.0	**35.0**	NA
	BF-EW-N	**35.0**	35.0	35.0	35.0	35.0	**35.0**	NA
	BF-EW-TCE	**12.0**	12.0	12.0	12.0	12.0	**12.0**	NA
Gage Aquifer	G-EW-1*	**120.0**	120.0	120.0	120.0	120.0	**120.0**	250
	G-EW-2*	**29.5**	29.9	32.7	33.6	Well shut down	**33.6**	70
	G-EW-3*	**24.9**	25.3	27.7	Well shut down	Well shut down	**27.7**	30
	G-EW-B	**57.1**	57.9	63.5	65.1	67.6	**67.6**	80
	G-EW-E	**29.5**	Well shut down	Well shut down	Well shut down	Well shut down	**29.5**	50
	G-EW-O	**48.1**	48.7	53.4	54.8	56.8	**56.8**	60
	G-EW-TCE	**17.0**	17.0	17.0	17.0	17.0	**17.0**	NA
Total Extraction Rate of the Remedial Wellfield		**729.0**	705.4	599.4	579.5	555.9		
Injection Well Rates (gpm)								
MBFC	BF-IW-1*	**39.9**	38.6	32.6	31.4	30.1	**39.9**	130
	BF-IW-2*	**39.9**	38.6	32.6	31.4	30.1	**39.9**	150
	BF-IW-E	**56.8**	54.8	46.3	44.7	42.7	**56.8**	70
Gage Aquifer	G-IW-1*	**312.5**	302.0	254.8	245.9	235.3	**312.5**	610
	G-IW-2*	**125.4**	121.2	102.2	98.7	94.5	**125.4**	350
	G-IW-D	**125.4**	121.2	102.2	98.7	94.5	**125.4**	260

Note:
* Wells installed for pilot testing

TABLE 2
Coordinates of Proposed Locations for Extraction and Injection Wells

Well-ID	Easting (feet)	Northing (feet)
UBA-EW-A	4196962	4056685
UBA-EW-B	4197737	4056797
MBFB-EW-1	4197447	4056528
BF-EW-1	4197422	4056537
BF-EW-2	4198681	4054093
BF-EW-B	4197901	4055049
BF-EW-D	4199017	4053193
BF-EW-M	4196962	4056685
BF-EW-N	4197737	4056797
BF-EW-TCE	4197700	4058500
G-EW-1	4197413	4056557
G-EW-2	4199810	4053771
G-EW-3	4197124	4054177
G-EW-B	4198806	4055526
G-EW-E	4200180	4053281
G-EW-O	4198712	4054397
G-EW-TCE	4197700	4058500
BF-IW-1	4194654	4057024
BF-IW-2	4200276	4054984
BF-IW-E	4194114	4057626
G-IW-1	4194654	4057065
G-IW-2	4199886	4056660
G-IW-D	4199664	4057762

Note: Datum used for well coordinates is MNAD27 (Modified State Plane Zone VII North American Datum [NAD] 27 feet).

TABLE 3
Rationale for Locations of Remedial Wells

Location	Rationale
MBFB-EW-1	Containment of the chlorobenzene plume within the CZ in the water table aquifer
UBA-EW-A	Containment of the chlorobenzene plume within the CZ in the water table aquifer
UBA-EW-B	Containment of the chlorobenzene plume within the CZ in the water table aquifer
BF-EW-1	Containment of the chlorobenzene plume within the CZ in the MBFC
BF-EW-M	Containment of the chlorobenzene plume within the CZ in the MBFC
BF-EW-N	Containment of the chlorobenzene plume within the CZ in the MBFC
BF-EW-B	Reduction of the chlorobenzene plume outside the CZ in the MBFC
BF-EW-2	Reduction and containment of the chlorobenzene plume outside the CZ in the MBFC
BF-EW-D	Reduction and containment of the chlorobenzene plume outside the CZ in the MBFC
BF-EW-TCE	Containment of the TCE plume migration from upgradient sources in the MBFC
G-EW-1	Containment of the chlorobenzene plume within the CZ in the Gage aquifer
G-EW-B	Reduction and containment of the chlorobenzene plume outside the CZ in the Gage aquifer
G-EW-3	Reduction and containment of the chlorobenzene plume outside the CZ in the Gage aquifer
G-EW-O	Reduction and containment of the chlorobenzene plume outside the CZ in the Gage aquifer
G-EW-2	Reduction and containment of the chlorobenzene plume outside the CZ in the Gage aquifer
G-EW-E	Reduction and containment of the chlorobenzene plume outside the CZ in the Gage aquifer
G-EW-TCE	Containment of the TCE plume migration from upgradient sources in the Gage aquifer
BF-IW-1	Disposal of treated groundwater and mitigation of adverse TCE migration from upgradient sources in the MBFC
BF-IW-E	Disposal of treated groundwater and mitigation of adverse TCE migration from upgradient sources in the MBFC
BF-IW-2	Disposal of treated groundwater and flushing the plume toward extraction wells in the MBFC
G-IW-1	Disposal of treated groundwater and mitigation of adverse TCE migration from upgradient sources in the Gage aquifer
G-IW-2	Disposal of treated groundwater and maintaining upward gradient between the Gage aquifer and MBFC to prevent vertical migration of benzene into the Gage aquifer (i.e., contain benzene within the CZ)
G-IW-D	Disposal of treated groundwater and maintaining upward gradient between the Gage aquifer and MBFC to prevent vertical migration of benzene into the Gage aquifer (i.e., contain benzene within the CZ)

TABLE 4
Simulated Chlorobenzene Influent Concentrations

Elapsed Time (years)	Simulated Chlorobenzene Influent Concentrations (µg/L)															
	Flow-Weighted Average Concentration (µg/L)	UBA-EW-A	UBA-EW-B	MBFB-EW-1	BF-EW-1	BF-EW-2	BF-EW-B	BF-EW-D	BF-EW-M	BF-EW-N	G-EW-1	G-EW-2	G-EW-3	G-EW-B	G-EW-E	G-EW-O
0	7,711	1,746	4,449	2,010	22,974	17,361	11,677	1,838	28,912	19,003	4,581	294	660	1,595	236	179
1	4,490	13,172	3,565	7,275	17,199	8,882	6,250	1,405	12,556	7,044	3,094	157	910	1,915	167	114
2	3,242	21,038	3,050	12,017	12,522	4,938	4,287	880	7,625	5,775	2,470	118	927	1,674	126	105
3	2,648	25,533	2,593	16,388	9,731	2,865	3,076	543	6,265	5,147	2,416	94	896	1,371	96	114
4	2,306	27,723	2,246	20,196	8,079	1,744	2,238	339	5,825	4,726	2,398	76	842	1,095	75	132
5	2,091	28,615	2,029	23,491	7,071	1,120	1,630	217	5,658	4,426	2,370	64	775	873	59	157
6	1,953	28,892	1,942	26,399	6,443	759	1,181	144	5,584	4,213	2,341	54	700	701	47	184
7	1,863	28,937	1,970	29,019	6,044	538	850	99	5,548	4,062	2,318	46	621	570	38	212
8	1,805	28,929	2,083	31,401	5,790	395	610	70	5,527	3,958	2,300	40	540	466	31	239
9	1,769	28,926	2,252	33,547	5,627	297	437	52	5,514	3,886	2,286	35	460	385	25	264
10	1,746	28,937	2,450	35,443	5,521	228	315	40	5,504	3,835	2,276	31	386	320	21	286
11	1,732	28,949	2,651	37,074	5,452	177	229	31	5,497	3,800	2,269	28	318	267	17	304
12	1,723	28,950	2,840	38,435	5,405	139	170	25	5,490	3,775	2,263	25	258	223	15	318
13	1,717	28,930	3,008	39,537	5,374	111	129	21	5,485	3,758	2,259	23	207	186	12	326
14	1,712	28,888	3,151	40,401	5,351	91	100	17	5,479	3,745	2,256	21	164	156	11	329
15	1,708	28,823	3,268	41,058	5,335	75	80	15	5,475	3,736	2,254	19	129	131	9	327
16	1,759	28,815	3,346	41,345	5,295	62	66	13	5,480	3,696	2,247	16	100	110	9	315
17	1,753	28,744	3,408	41,592	5,283	53	56	11	5,480	3,684	2,246	14	78	92	9	301
18	1,748	28,650	3,458	41,748	5,274	46	49	10	5,477	3,677	2,245	13	60	77	9	283
19	2,021	28,839	3,376	39,847	5,010	35	40	7	5,445	3,464	2,227	14	45	71	9	256
20	2,005	28,831	3,340	39,179	4,975	31	34	5	5,442	3,426	2,229	14	34	60	9	229
21	1,994	28,755	3,329	38,668	4,960	27	30	4	5,440	3,409	2,231	14	26	51	9	203
22	1,985	28,652	3,327	38,241	4,951	25	27	3	5,437	3,402	2,232	14	20	43	9	178
23	1,977	28,539	3,327	37,880	4,945	23	24	2	5,435	3,397	2,232	14	16	37	8	154
24	1,970	28,425	3,327	37,576	4,940	21	22	2	5,433	3,395	2,232	13	13	32	8	133
25	1,963	28,315	3,327	37,324	4,935	20	21	2	5,431	3,393	2,231	12	10	28	8	114
26	1,958	28,210	3,327	37,115	4,932	18	19	1	5,428	3,392	2,231	12	8	24	8	97
27	2,009	27,827	3,357	36,766	4,893	17	18	1	5,326	3,418	2,212	11	7	22	7	83
28	2,003	27,641	3,375	36,594	4,883	17	18	1	5,307	3,428	2,211	11	6	20	7	71
29	1,999	27,499	3,391	36,477	4,878	16	17	1	5,301	3,432	2,213	10	5	17	7	60
30	1,996	27,381	3,407	36,397	4,874	15	16	1	5,298	3,435	2,213	9	4	15	6	51
31	2,078	27,343	3,402	36,223	4,854	14	15	1	5,305	3,409	2,207	8	4	13	6	41
32	2,075	27,271	3,404	36,135	4,849	14	15	1	5,306	3,403	2,208	7	4	12	6	35

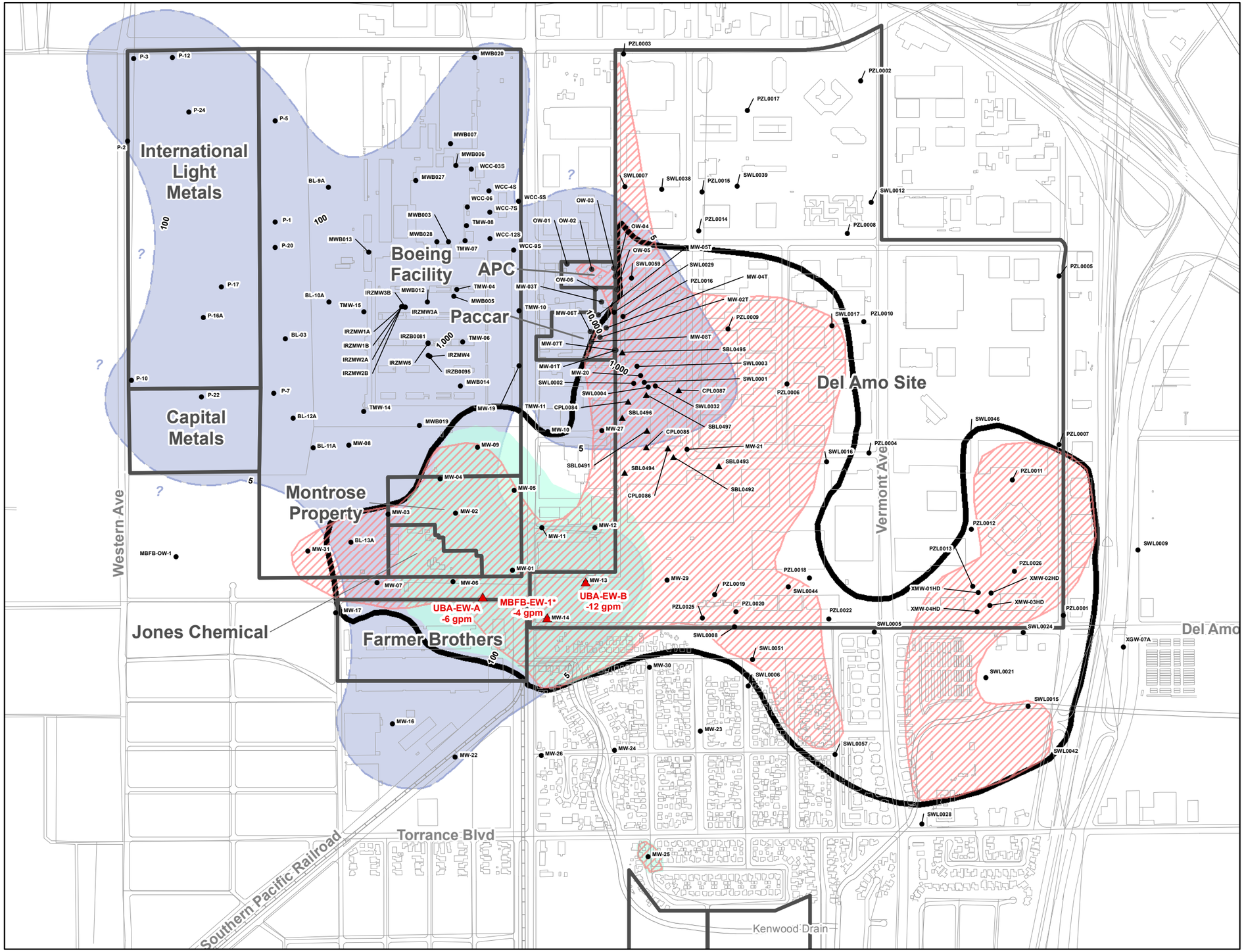
TABLE 5
Simulated Benzene Influent Concentrations

Elapsed Time (years)	Benzene Concentrations (µg/L)															
	Flow-Weighted Average Concentration (µg/L)	UBA-EW-A	UBA-EW-B	MBFB-EW-1	BF-EW-1	BF-EW-2	BF-EW-B	BF-EW-D	BF-EW-M	BF-EW-N	G-EW-1	G-EW-2	G-EW-3	G-EW-B	G-EW-E	G-EW-O
0	48	1,210	0	4,872	74	19	22	0	34	17	0	0	0	0	0	0
1	7.2	216	0	791	10	3	3	0	6	-15	0	0	0	2	0	0
2	3.1	139	0	257	5	1	1	0	4	-7	0	0	0	3	0	0
3	2.5	127	0	141	4	0	0	0	4	1	0	0	0	2	0	0
4	2.4	125	0	117	4	0	0	0	4	3	0	0	0	2	0	0
5	2.4	125	0	111	4	0	0	0	4	4	0	0	0	1	0	0
6	2.4	125	0	110	4	0	0	0	4	4	0	0	0	1	0	0
7	2.4	125	0	110	4	0	0	0	4	4	0	0	0	1	0	0
8	2.4	125	0	110	4	0	0	0	4	4	0	0	0	0	0	0
9	2.4	125	0	110	4	0	0	0	4	4	0	0	0	0	0	0
10	2.4	125	0	110	4	0	0	0	4	4	0	0	0	0	0	0
11	2.4	125	0	110	4	0	0	0	4	4	0	0	0	0	0	0
12	2.4	125	0	110	4	0	0	0	4	4	0	0	0	0	0	0
13	2.3	125	0	110	4	0	0	0	4	4	0	0	0	0	0	0
14	2.3	125	0	110	4	0	0	0	4	4	0	0	0	0	0	0
15	2.3	125	0	110	4	0	0	0	4	4	0	0	0	0	0	0
16	2.4	126	0	108	4	0	0	0	4	4	0	0	0	0	0	0
17	2.4	126	0	108	4	0	0	0	4	4	0	0	0	0	0	0
18	2.4	126	0	108	4	0	0	0	4	4	0	0	0	0	0	0
19	2.7	126	0	97	4	0	0	0	4	4	0	0	0	0	0	0
20	2.7	126	0	95	4	0	0	0	4	4	0	0	0	0	0	0
21	2.7	126	0	95	4	0	0	0	4	4	0	0	0	0	0	0
22	2.7	125	0	94	4	0	0	0	4	3	0	0	0	0	0	0
23	2.6	125	0	94	4	0	0	0	4	3	0	0	0	0	0	0
24	2.6	125	0	94	4	0	0	0	4	3	0	0	0	0	0	0
25	2.6	125	0	94	4	0	0	0	4	3	0	0	0	0	0	0
26	2.6	125	0	94	4	0	0	0	4	3	0	0	0	0	0	0
27	2.7	124	0	94	4	0	0	0	4	3	0	0	0	0	0	0
28	2.7	124	0	94	4	0	0	0	4	3	0	0	0	0	0	0
29	2.7	124	0	94	4	0	0	0	4	3	0	0	0	0	0	0
30	2.7	124	0	94	4	0	0	0	4	3	0	0	0	0	0	0
31	2.8	124	0	93	4	0	0	0	4	3	0	0	0	0	0	0
32	2.8	124	0	93	4	0	0	0	4	3	0	0	0	0	0	0

TABLE 6
Simulated p-CBSA Influent Concentrations

Elapsed Time (years)	p-CBSA Concentrations (µg/L)															
	Flow-Weighted Average Concentration (µg/L)	UBA-EW-A	UBA-EW-B	MBFB-EW-1	BF-EW-1	BF-EW-2	BF-EW-B	BF-EW-D	BF-EW-M	BF-EW-N	G-EW-1	G-EW-2	G-EW-3	G-EW-B	G-EW-E	G-EW-O
0	39,989	68,022	28,607	12,086	86,737	98,080	113,356	12,013	99,514	38,787	17,264	7,300	5,687	22,155	4,824	297
1	23,821	73,417	15,494	71,516	75,177	48,303	46,404	10,355	62,022	21,919	10,206	3,581	6,785	16,269	4,295	755
2	17,622	64,895	11,512	87,800	63,133	26,706	27,326	6,921	46,371	24,554	10,625	2,749	5,861	11,164	3,551	1,082
3	13,951	58,248	8,978	87,227	53,334	14,914	17,254	4,354	41,350	25,933	10,656	2,071	4,938	7,402	2,857	1,673
4	11,738	54,448	7,466	82,275	46,733	8,639	11,159	2,693	39,751	26,322	10,501	1,538	4,069	4,951	2,287	2,329
5	10,412	52,703	6,790	78,210	42,701	5,260	7,255	1,672	39,204	26,368	10,358	1,141	3,268	3,413	1,843	2,914
6	9,613	52,103	6,692	76,174	40,339	3,362	4,718	1,057	39,000	26,333	10,259	854	2,552	2,429	1,504	3,351
7	9,123	52,021	6,909	75,726	38,979	2,236	3,078	686	38,916	26,293	10,195	650	1,935	1,775	1,245	3,614
8	8,812	52,109	7,243	76,138	38,200	1,533	2,029	458	38,876	26,266	10,154	505	1,427	1,321	1,047	3,710
9	8,608	52,206	7,579	76,860	37,752	1,078	1,365	316	38,854	26,252	10,127	400	1,025	997	892	3,661
10	8,466	52,257	7,865	77,582	37,492	777	947	224	38,839	26,246	10,110	323	720	761	771	3,492
11	8,361	52,257	8,090	78,177	37,339	575	683	164	38,828	26,246	10,099	264	497	588	673	3,230
12	8,280	52,216	8,261	78,622	37,246	438	515	123	38,819	26,250	10,091	219	338	460	594	2,902
13	8,214	52,149	8,392	78,936	37,188	344	406	94	38,810	26,255	10,087	184	228	364	528	2,535
14	8,159	52,070	8,495	79,153	37,150	279	333	74	38,803	26,262	10,083	157	153	291	473	2,155
15	8,112	51,987	8,582	79,304	37,124	234	284	59	38,795	26,268	10,081	135	103	235	426	1,786
16	8,311	52,049	8,600	78,930	36,901	197	246	49	38,869	26,020	10,057	111	69	195	519	1,411
17	8,275	52,001	8,639	78,805	36,870	172	219	41	38,881	25,981	10,056	103	47	161	555	1,111
18	8,247	51,933	8,684	78,716	36,853	153	198	35	38,879	25,969	10,055	99	33	133	567	861
19	9,474	52,392	8,365	74,251	34,919	117	167	22	38,662	24,373	9,984	106	23	135	575	619
20	9,418	52,377	8,257	72,674	34,738	102	145	15	38,662	24,158	10,000	106	16	119	565	457
21	9,385	52,272	8,215	71,569	34,678	91	128	10	38,662	24,089	10,005	103	12	102	548	341
22	9,362	52,147	8,196	70,782	34,653	83	116	8	38,660	24,066	10,006	98	9	87	526	258
23	9,346	52,024	8,190	70,235	34,638	76	105	6	38,657	24,059	10,006	91	8	75	502	200
24	9,334	51,908	8,191	69,862	34,627	69	97	5	38,654	24,057	10,006	84	6	64	478	158
25	9,324	51,799	8,199	69,613	34,619	64	90	4	38,650	24,058	10,006	77	5	56	453	128
26	9,317	51,698	8,211	69,448	34,612	59	84	3	38,647	24,059	10,006	70	4	50	429	106
27	9,571	51,010	8,308	68,922	34,337	55	79	2	37,870	24,281	9,917	65	5	46	406	87
28	9,563	50,756	8,373	68,816	34,289	51	74	2	37,778	24,357	9,924	59	5	42	384	73
29	9,560	50,578	8,431	68,803	34,272	47	70	2	37,757	24,391	9,929	53	5	39	362	63
30	9,558	50,439	8,481	68,828	34,263	44	66	1	37,750	24,408	9,932	48	5	37	342	55
31	9,956	50,446	8,468	68,609	34,130	41	63	1	37,821	24,207	9,903	47	5	35	319	49
32	9,950	50,364	8,478	68,526	34,111	38	59	1	37,837	24,168	9,903	45	5	34	299	44

Figures



Legend

- TI Waiver Zone
- MW-10 Monitoring Well
- Temporary Sampling Location
- Schematic TCE Plume (above 5 µg/L)
- Schematic Benzene Plume (above 1 µg/L)
- Schematic Chlorobenzene Plume (above 70 µg/L)
- Extraction Well

Note:
* - Wells installed for pilot testing.

N

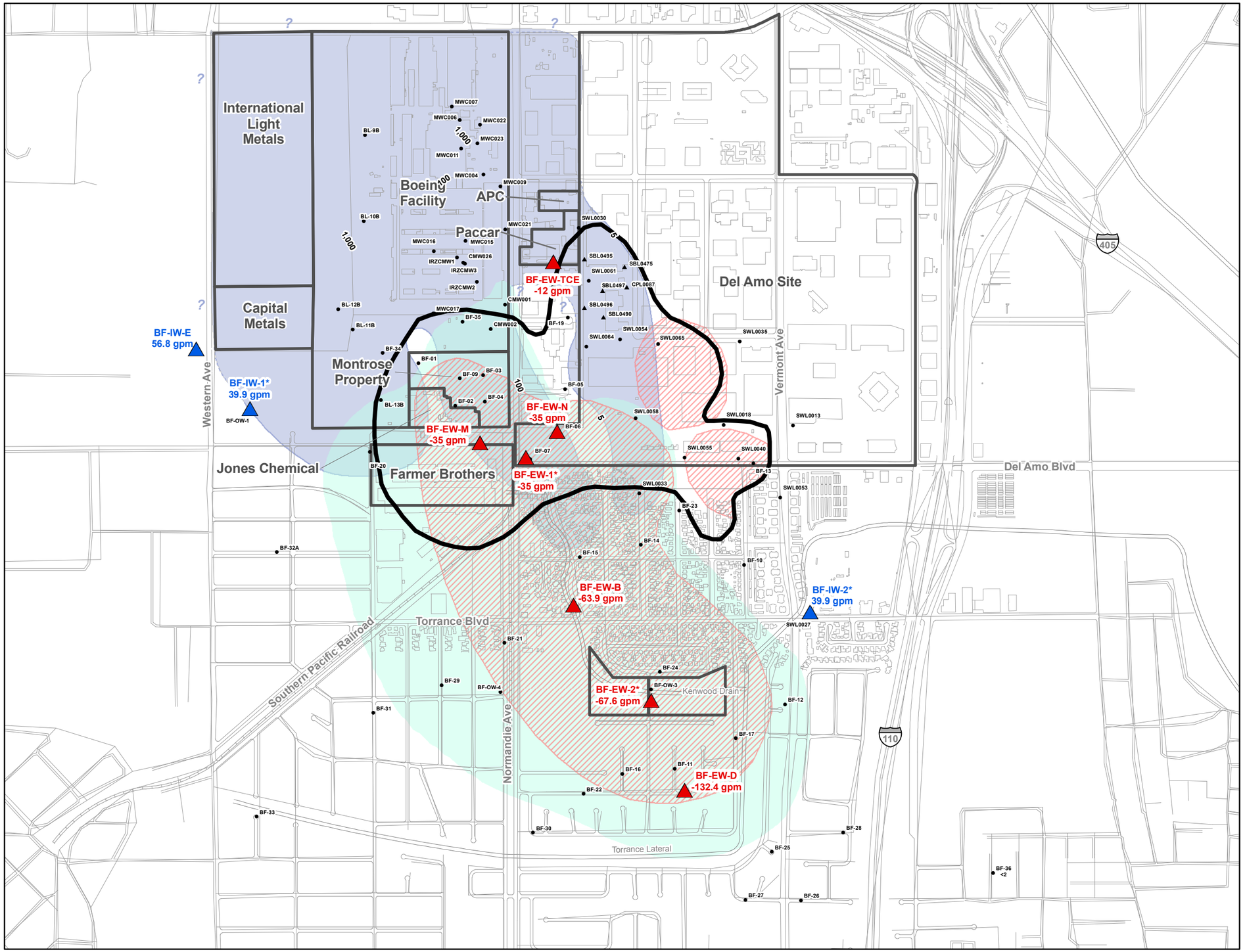
0 375 750 1,125 1,500
Feet

Figure 1
Locations of Remedial Wells
Water Table Aquifer

CH2MHILL

Prepared by CH2M Hill, April 2007

\\galt\proj\Montrose_GW_Remedy\plots\2007\TCE_WT_otherplumes_b_v2.mxd



Legend

- TI Waiver Zone
- BF-03 Monitoring Well 2006 value (µg/L)
- Temporary Sampling Location
- Schematic TCE Plume (above 5 µg/L)
- Schematic Benzene Plume (above 1 µg/L)
- Schematic Chlorobenzene Plume (above 70 µg/L)
- Extraction Well
- Injection Well

Note:
* - Wells installed for pilot testing.

N

0 500 1,000 1,500 2,000
Feet

Figure 2
Locations of Remedial Wells
Middle Bellflower C Sand

Prepared by CH2M Hill, April 2007

CH2MHILL

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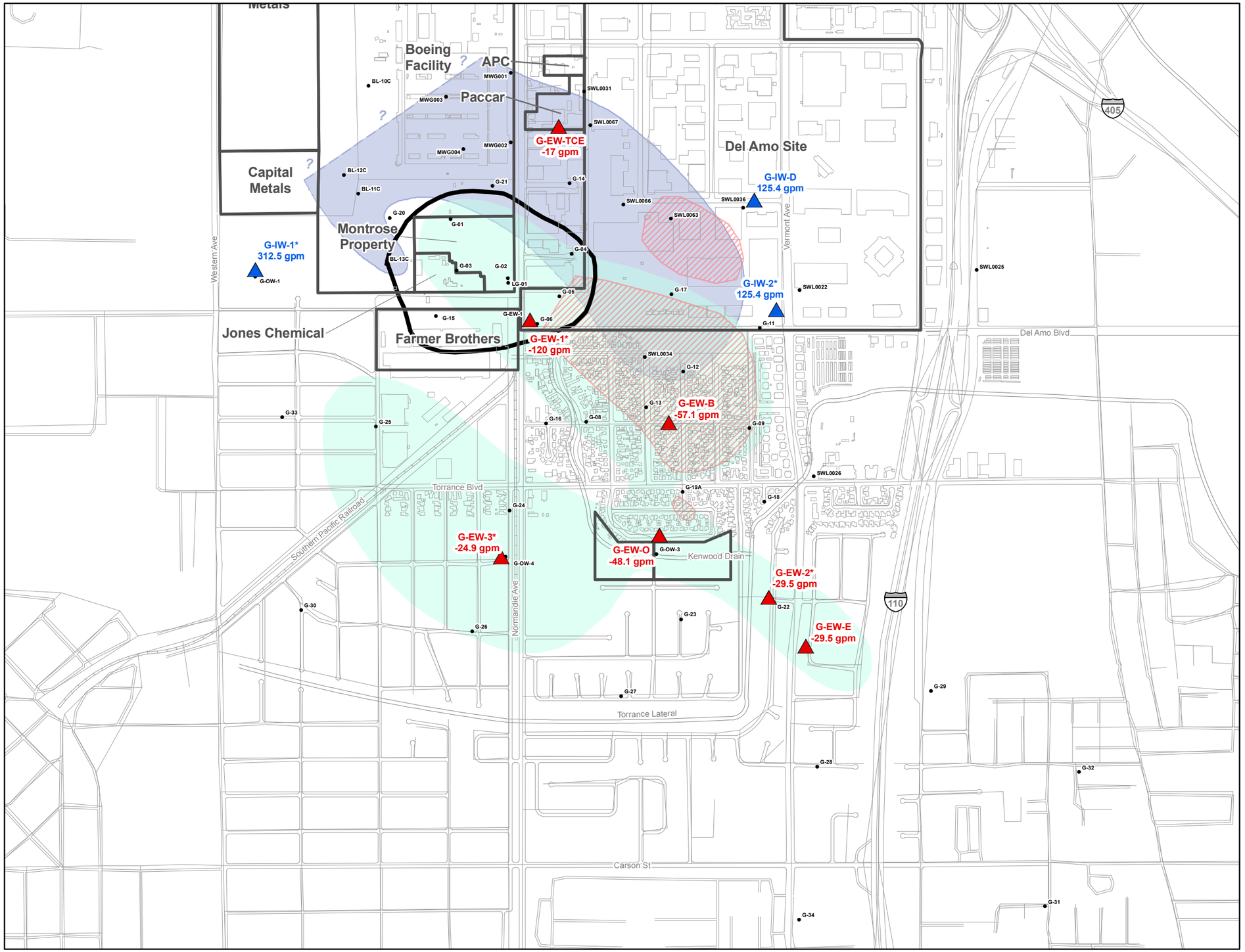

Legend

- TI Waiver Zone
- G-17 Monitoring Well
- Extraction or Injection Well
- Temporary Sampling Location
- Schematic TCE Plume (above 5 µg/L)
- Schematic Benzene Plume (above 1 µg/L)
- Schematic Chlorobenzene Plume (above 70 µg/L)
- Extraction Well
- Injection Well

Note:
* - Wells installed for pilot testing.

N

0 500 1,000 1,500 2,000
Feet

Figure 3
Locations of Remedial Wells
Gage Aquifer

CH2MHILL

Prepared by CH2M Hill, April 2007

\\galt\proj\Montrose_GW_Remedy\plots\2007\TCE_Gage_otherplumes_b_v2.mxd