



INTERA Inc.
6000 Uptown Boulevard NE
Suite 220
Albuquerque, NM 87110
Telephone: 505 246 1600
Fax: 505 246 2600

September 20, 2013

Ms. Suzanne Busch
City of Albuquerque
Environmental Health Department
Environmental Services Division
P. O. Box 1293
Albuquerque, New Mexico 87103

Re: Plume Evaluation, Former Los Angeles Landfill, Albuquerque, New Mexico

Ms. Busch,

Per our meeting on July 11, 2013, and directives presented therein, we are hereby submitting this correspondence which updates previous submittals relative to groundwater contamination at the former Los Angeles Landfill (LALF), and also presents new findings.

Introduction

The purpose of this memorandum is to provide an update to material presented in INTERA (2007), and to provide new information collected and analyzed recently relative to the behavior of the groundwater contamination plume in the vicinity of the former LALF.

Specifically, the objectives of this correspondence are to:

- Evaluate the current disposition of contaminants of concern (COCs) in groundwater, with primary emphasis on tetrachloroethene (PCE). Note: PCE and trichloroethylene (TCE) are the primary COCs discussed in this correspondence due to their recalcitrant properties and their comparatively low regulatory cleanup levels. Although the fate and transport of PCE may be different than the other COCs, it is frequently referred to in this document as an indicator of the contaminant plume that contains other COCs..
- Illustrate and quantify the positive impact that the soil vapor extraction (SVE) has had on source removal at the LALF.
- Establish appropriate downgradient monitoring locations to define the eastern and southeastern extent of the groundwater contamination plume, which is currently undefined.



Analysis

Data presented in INTERA (2007) illustrated the extent and degree that PCE was present in groundwater above the United States Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) of 5 micrograms per liter ($\mu\text{g/l}$) over an area southeast of the LALF (Figure 1) based on data primarily from late 2006 and early 2007. Currently, the areal extent over which PCE in groundwater exceeds the MCL is much smaller; however, the eastern and southeastern extents of the plume continue to be poorly defined (Figure 2), although it is clear that the areal extent of the plume has declined significantly (by approximately 73%).

Previously (INTERA, 2007) it was noted that concentrations in some wells to the south (RSMW-5, also referred to as REEVES-5) and east (LALF-09 and LALF-10) of the site exhibited increasing concentrations of COCs, indicating potential further offsite migration of the plume. More recent data (Plate 1) indicate that concentrations are decreasing at these two locations. At REEVES-5, concentrations have dropped below the MCL, likely due to natural attenuation, and INTERA has observed only minor subsequent increases in concentration at REEVES-6, indicating that the southern end of the plume is dissipating via natural attenuation.

At LALF-09 and LALF-10, PCE concentrations peaked in approximately 2007, and have been declining since then (Plate 1). Currently these are the only two wells which exhibit PCE (or any other COC) levels above MCLs. The time-series behavior of PCE concentrations at LALF-09 and LALF-10 illustrates three important points: (1) the center of mass of the PCE plume (the area of highest concentration) has likely moved southeastward from LALF-09 and LALF-10 with regional groundwater flow into an area where there are no monitoring wells; (2) the SVE system has been effective in attenuating the PCE source area beneath the former LALF area, since it is apparent that the area of highest PCE concentrations has moved downgradient with regional groundwater flow; and (3) it appears that there is no contaminated groundwater originating from an upgradient source.

Likewise, at LALF-06, concentrations declined rapidly in conjunction with the initiation of SVE in mid-2005 (Plate 1). LALF-06 is located in an area of formerly high dissolved-phase PCE concentrations (Figure 3). A higher density of SVE wells were installed in this area and the decline in PCE concentrations illustrates the effectiveness of the SVE system (Figure 4). LALF-18, downgradient of LALF-06, shows a similar pattern, with PCE concentrations declining after mid-2005. Downgradient from LALF-18, a minor pulse of dissolved-phase PCE can be observed passing by LALF-12 during the 2008-2010 timeframe. This pulse has not been observed at GWEX-3 (which has not been sampled at the same frequency as LALF-12) which could suggest natural attenuation, heterogeneities in the geology causing changes in plume migration, or the pulse has not passed that point yet (Plate 1).

The conclusion that the SVE system has been effective in removing the source is also supported by an analysis of concentration and flow-rate data from the system. Figure 5 presents calculated cumulative quantities of PCE, TCE, dichloroethene (DCE), and dichloromethane (DCM) removed based on available flow and concentration data. Note that flow data only became available in 2007, and flows prior to 2007 have been estimated based on average flows from



2007. Figure 5 shows clearly that substantial PCE mass has been removed from the subsurface (approximately 1,000 lbs), which further supports the concept that the source of the groundwater contamination historically present in the vadose zone beneath the former LALF has been attenuated and the SVE system is effectively capturing volatile contaminants emanating from the waste prism, which prevents further groundwater contamination.

The estimate of total PCE mass in the vadose zone circa 2000 was approximately 3,400 lbs, based on calculations presented in Hydro Geo Chem (HGC) (2003). INTERA independently verified HGC's results and calculated a similar value (Attachment A). Based on these initial estimates (that did not include flux from the landfill) it appears that one-third of the calculated contaminant mass in the vadose zone has been removed.

While it appears that the source area is no longer contributing COCs to groundwater, mass removal from the vadose zone is still actively occurring, and will continue to do so as long as the COCs leach or emanate from the waste. Figure 6a presents data on the SVE system mass removal rates for PCE, TCE, DCE, and DCM which indicate that while the rate of mass removal is declining, as would be expected, several pounds of PCE per month are still currently being removed (Figure 6b). Similarly, while the slope of the cumulative mass-removal curve is decreasing (Figure 5), it has not yet begun to reach an asymptote. The behavior of both the cumulative mass curve and the mass removal rate curve indicates that contaminant mass is still being actively removed from the vadose zone, while the groundwater data show that contaminants are no longer reaching the saturated zone.

While it appears that dissolved-phase contamination beneath the LALF has been mitigated, there is still a need to delineate the areal extent of the plume to the east and down-gradient. The installation of groundwater monitoring wells is needed to achieve this delineation. The two areas of focus for installing monitoring wells are: the area east of LALF-09/LALF-10 and the area southeast of LALF-09/LALF-10. The most critical area of investigation is the area southeast of LALF-09/LALF-10 because the American Gypsum production well (AGPROD) is just downgradient of the current known extent of the PCE plume in groundwater (Figure 2). This area will be discussed first.

In addition to observed data, contaminant transport modeling presented in HGC (2001) may also shed some light on the current distribution of PCE. HGC (2001) presented results of simulating what they referred to as "Alternative 4," which was described as "...vadose zone source reduction using a deep vadose zone SVE system and the landfill LFGE [landfill-gas extraction] system, and MNA [monitored natural attenuation] of the entire groundwater plume." Alternative 4 presented in HGC (2001) most closely matches the remediation activities applied to the site to date (the groundwater pump and treat system was not operated during that period). Therefore, it is instructive to review simulations which predicted contaminant distribution in approximately 2010 (a 10-year simulation was performed, starting in 2000).

Figure 7 presents an overlay of simulated PCE distribution in 2010 from HGC (2001, Figure 23). The western portion of the simulated plume is more extensive than is currently observed, likely



due to the effectiveness of the SVE system, as discussed above. The eastern portion of the simulated plume appears to track relatively closely to the present-day observed plume, and can potentially be used as one of several pieces of information to provide an estimate as to the present-day downgradient extent of the PCE plume with respect to establishing a downgradient monitoring well location.

To provide additional information with which to locate a monitoring well downgradient of LALF-09/LALF-10, INTERA performed several first-order calculations to determine groundwater flow rate and direction. We calculated a range of groundwater seepage velocities (Attachment B), and then applied a retardation factor. Groundwater seepage velocities were calculated to range from approximately 0.25 feet per day (ft/day) to 0.69 ft/day.

A retardation factor can be used to estimate the rate of movement of a contaminant in the subsurface whose rate of movement may be slowed due to sorption to organic material present in the aquifer. The retardation factor (R_d) of PCE in soil may be calculated as follows:

$$R_d = \frac{\rho_b \times K_{oc} \times f_{oc}}{n_e} + 1$$

where:

R_d = retardation factor

ρ_b = bulk density, 1.86 grams per cubic centimeter (g/cm^3); this was assumed using an average particle density of $2.65 \text{ g}/\text{cm}^3$ and a porosity of 0.3

n_e = effective porosity, 0.3 (HGC, 2003)

K_{oc} = organic carbon distribution coefficient for PCE, 360 milliliters per gram (mL/g) (HGC, 2003)

f_{oc} = organic carbon content of the soil, 0.1% (HGC, 2003)

The resulting retardation factor of 1.2232 is obtained. This may be used to determine the velocity of PCE:

$$V_c = \frac{V_{GW}}{R_d}$$

Where V_c is the velocity of the constituent, V_{GW} is the seepage velocity of the groundwater, and R_d is the retardation factor.

Thus we were able to calculate an approximate minimum (lowest estimated seepage velocity assuming retardation) and maximum (highest estimated seepage velocity assuming no retardation) groundwater seepage velocity of 0.20 ft/day and 0.69 ft/day, respectively.

INTERA also evaluated the range of groundwater flow directions for each month in 2012 using a three-point problem construction for two trios of wells:

- LALF-09, LALF-19, and GWEX-4



- LALF-08, LALF-09, and LALF-19

These wells are all in the vicinity of the area of interest (LALF-09/LALF-10). The groundwater flow directions range from S7E to S38E, with a mean value of S29E and a middle value of S22E. Results of the solution to the three-point problem are presented in Figure 8. Subsequently, the results of the groundwater seepage velocity calculation were combined with the results of the three-point-problem calculations to produce Figure 9, which illustrates the general area over which we expect to currently find the PCE plume previously observed at LALF-09/LALF-10 in 2007.

At your request, INTERA also produced two plates (Plate 2 and Plate 3) showing trends in groundwater levels at the site based on available data. While these data were not used specifically in the analyses discussed above, they are provided herein for your use and evaluation. Plate 2 presents the groundwater levels all plotted at the same scale, while Plate 3 presents the groundwater levels at a more detailed scale to highlight some of the changes that have been occurring. In general, groundwater levels declined until 2008 due to regional pumping, but then rebounded somewhat after 2008, which corresponded with the approximate period when the Albuquerque Bernalillo County Water Utility Authority began diverting surface water and decreasing groundwater pumping.

Results

Figure 10 summarizes the analyses performed to estimate the present-day downgradient location of the PCE plume and integrates information about planned construction at the intersection of Paseo del Norte Boulevard and Jefferson Street. This information was then used to guide the selection of a proposed downgradient monitoring well that will be a sentinel well for monitoring plume encroachment on the American Gypsum production well. The proposed location of the monitoring well is shown on Figure 10.

A second proposed monitor-well location is also presented on Figure 10. This location is intended to be located somewhat cross-gradient of the expected present-day location of the PCE plume such that the eastern extent of the plume can be clearly defined.

The design of the proposed monitor wells is based on the need to investigate the interval over which the American Gypsum production well is screened, as well as being consistent with the construction of other existing groundwater monitor wells. The American Gypsum production well is completed to a total depth of 236 feet below ground surface (ft bgs), and has three screened intervals from 186–189 ft bgs, 193–223 ft bgs, and 233–235 ft bgs, respectively. The interval from 193–223 ft bgs is likely the zone with highest production because the majority of the screened interval is installed over that interval. The INTERA proposed monitor-well design includes a dual completion in a single 11-inch borehole. The dual completion will nominally consist of two 3-inch monitor wells completed in the 11-inch borehole, screened at depths of 165–180 ft bgs and 210–225 ft bgs, respectively.



Conclusions

The following conclusions are based on INTERA's review of current data, as well as new analyses performed:

- Groundwater contamination in the vicinity of the LALF appears to be dissipating due to effective source removal (SVE) and natural attenuation.
- The groundwater contamination plume to the east and southeast of LALF-09/LALF-10 is poorly-defined, and thus two additional monitor wells are needed to bound the extent of the plume and confirm that contamination does not encroach upon the nearest production well.
- Two well locations have been proposed. Specific designs for those wells, as well as estimated costs, will be provided in a separate submittal.

References

INTERA, 2007. Deliverable for Existing Data Review Performed as Specified in Subtask 2 of Change Order No. 2 – Repairs to Groundwater Remediation Pump and Treat System. Technical Memorandum submitted to the City of Albuquerque Environmental Health Department, December 7, 2007.

Hydro Geo Chem (HGC), 2001. *Draft Site Investigation and Remedial Alternatives Evaluation, Los Angeles Landfill Site, Albuquerque, New Mexico.* December 8, 2001.

———. 2003. *Conceptual Remedial Design, Los Angeles Landfill.* September 10, 2003.

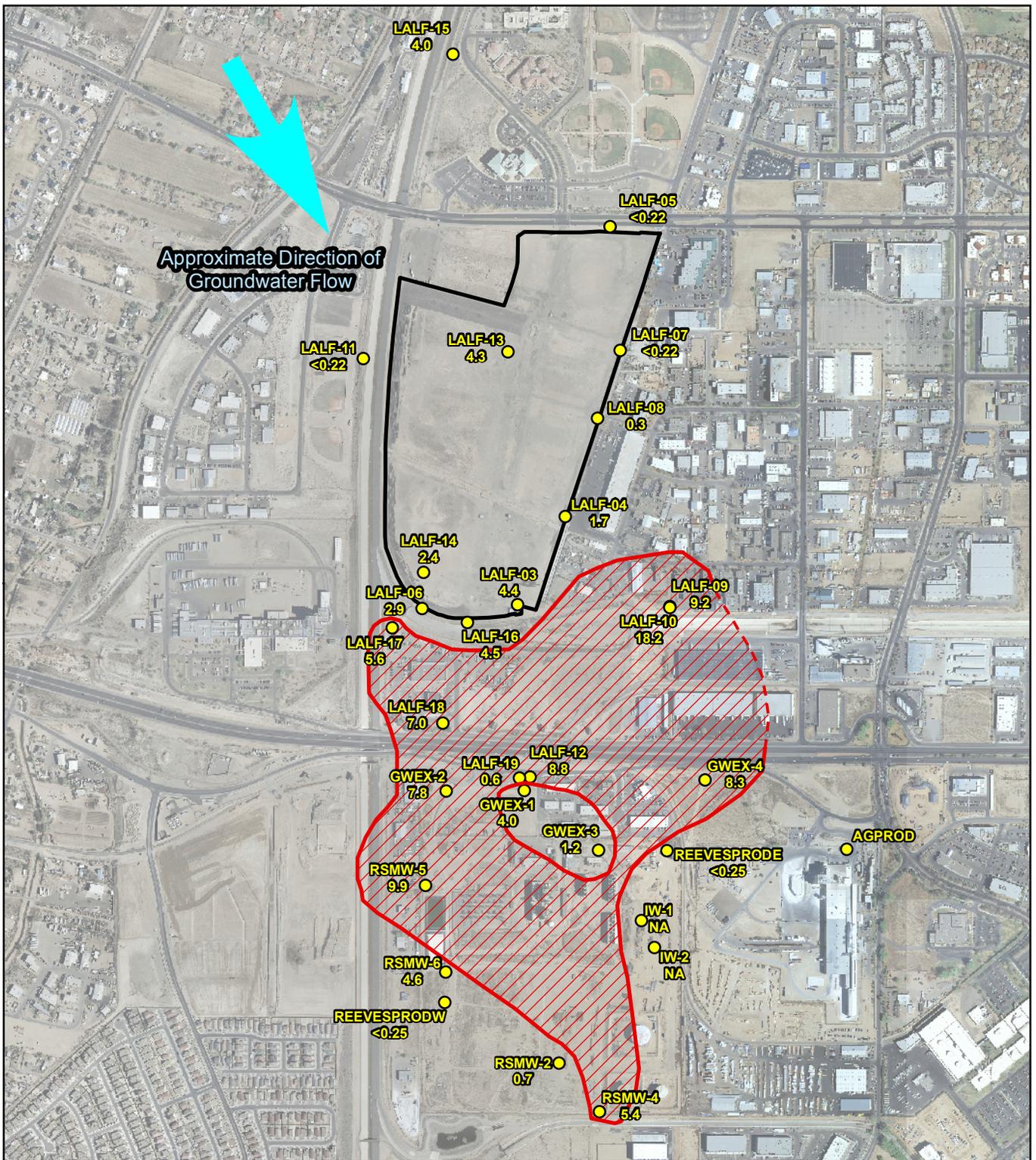
If you have any questions or comments, please do not hesitate to contact me or Mr. James Joseph at (505) 246-1600.

Sincerely,
INTERA Incorporated

A handwritten signature in black ink, appearing to read "David Jordan". The signature is fluid and cursive, with a long horizontal stroke at the end.

David Jordan, PE
Principal Hydrogeologist

cc: Mr. James Joseph, PE, INTERA



Legend

- GW well and PCE value (µg/L)
- ▨ PCE above MCL (≥5 µg/L)
- Landfill Extent

NOTE:
 PCE values are from fourth quarter 2006 and first quarter 2007, except values for GWEX-1, GWEX-3, and GWEX-4, which are from August 2005.



Data Source(s):
 Aerial Imagery - Bernalillo County website, aerial dated 2006.

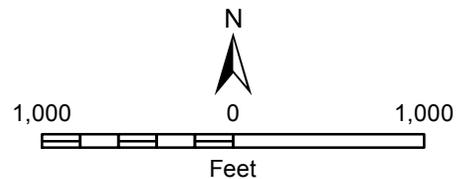
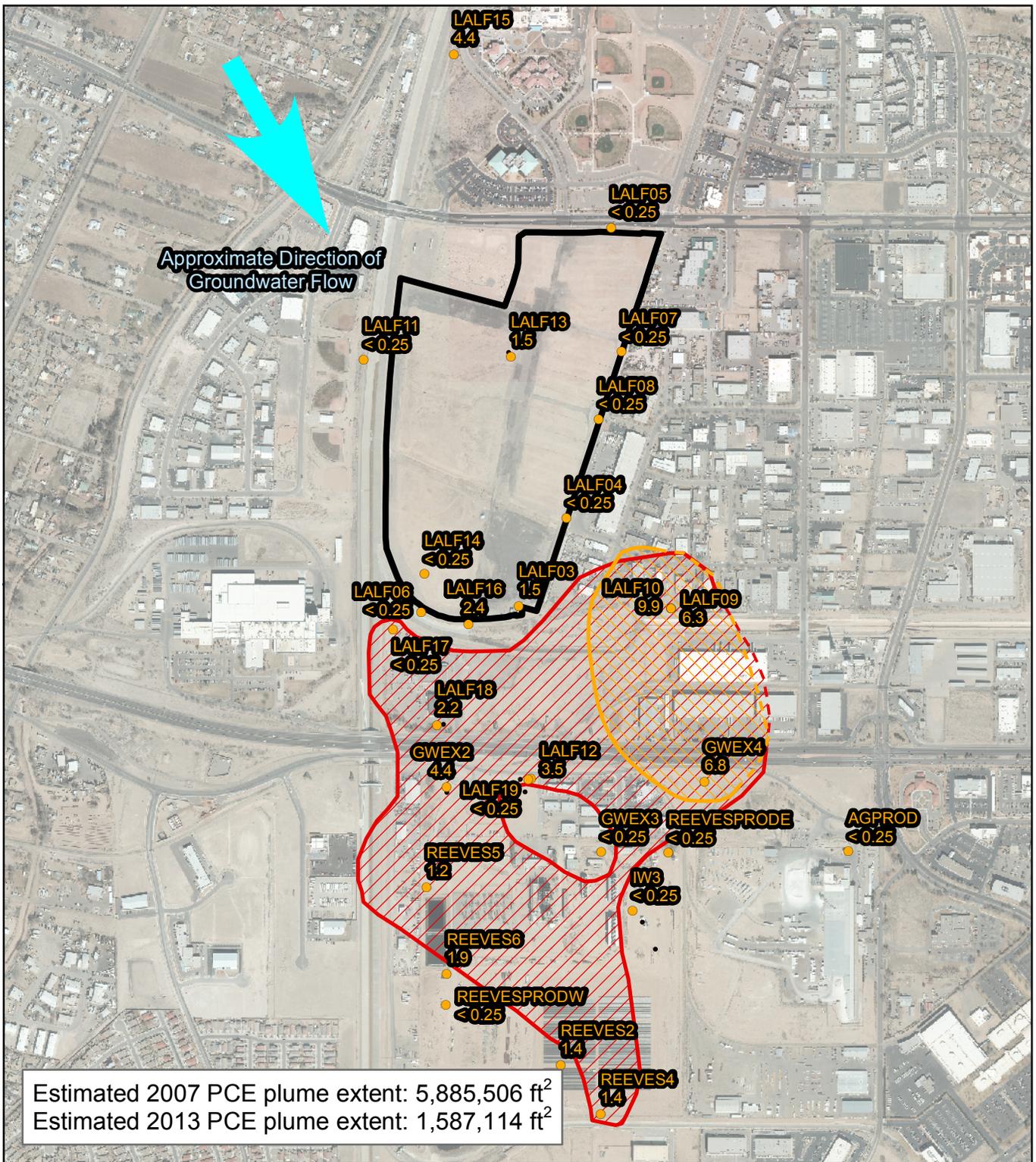


Figure 1
 Area above MCL for PCE in 2007
 COA Los Angeles Landfill



Legend

- GW well and PCE value (µg/L)
- ▨ 2013 PCE above MCL (≥5 µg/L)
- ▨ 2007 PCE above MCL (≥5 µg/L)
- ▭ Los Angeles Landfill boundary

NOTE:
PCE values are from second quarter 2013

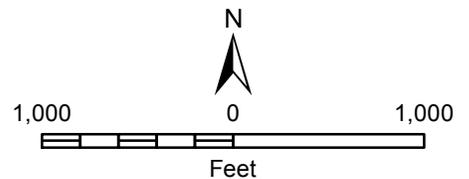


Figure 2
Area above MCL for PCE in 2013
COA Los Angeles Landfill



Data Source(s):
Aerial Imagery - Bernalillo County website, aerial dated 2012.

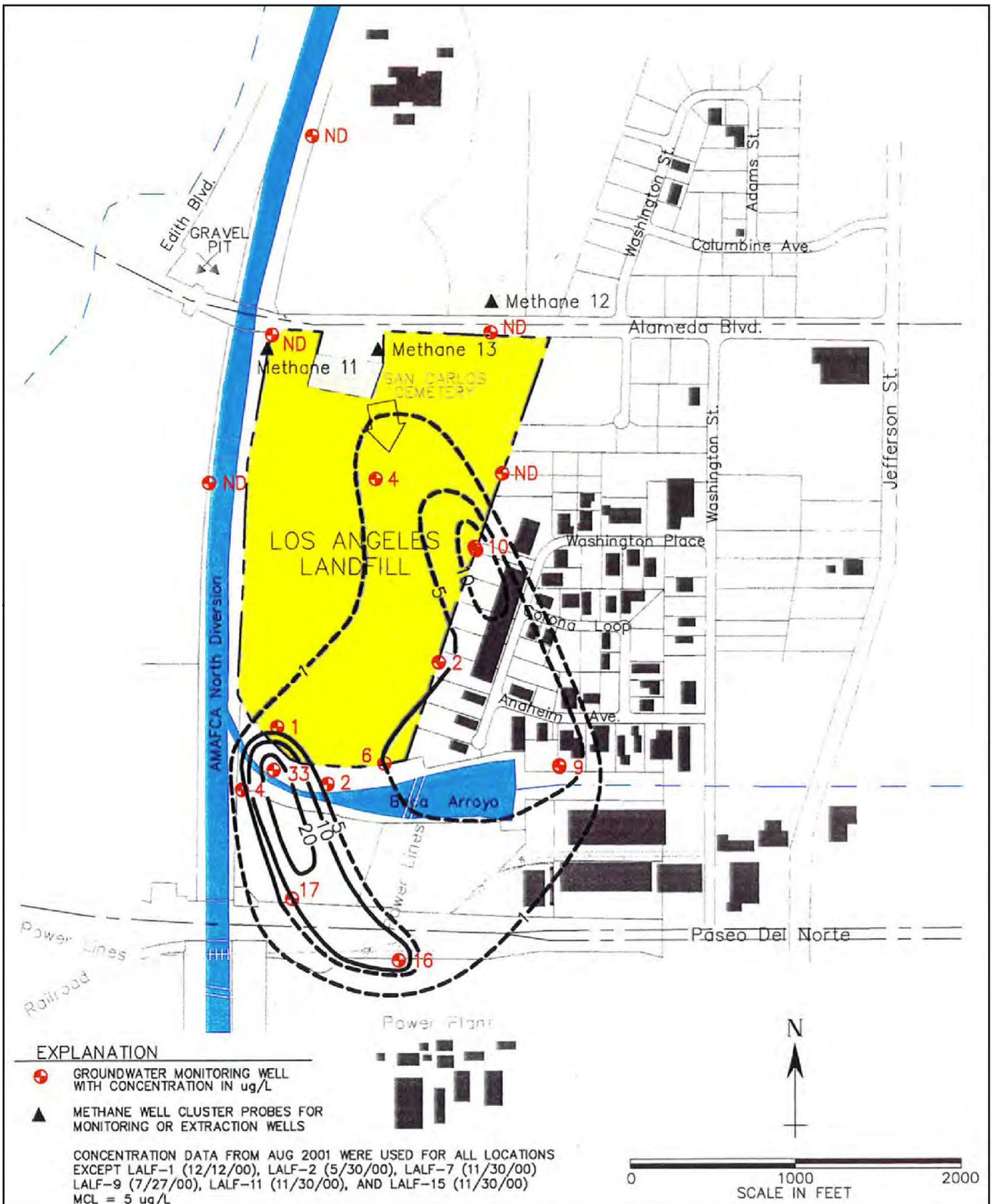


Figure 3
PCE in Groundwater 2000/2001
COA Los Angeles Landfill



Data Source:
Hydro Geo Chem, 2001, Figure 5b



Legend

-  Nested soil vapor extraction location
-  Blower building
-  Groundwater monitoring wells
-  Underground SVE Pipe

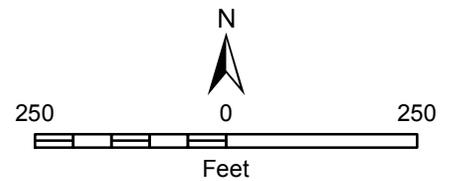


Figure 4
 SVE Wells in the Vicinity of LALF06
 COA Los Angeles Landfill



Data Source(s):
 Aerial Imagery - Bernalillo County website, aerial dated 2012.

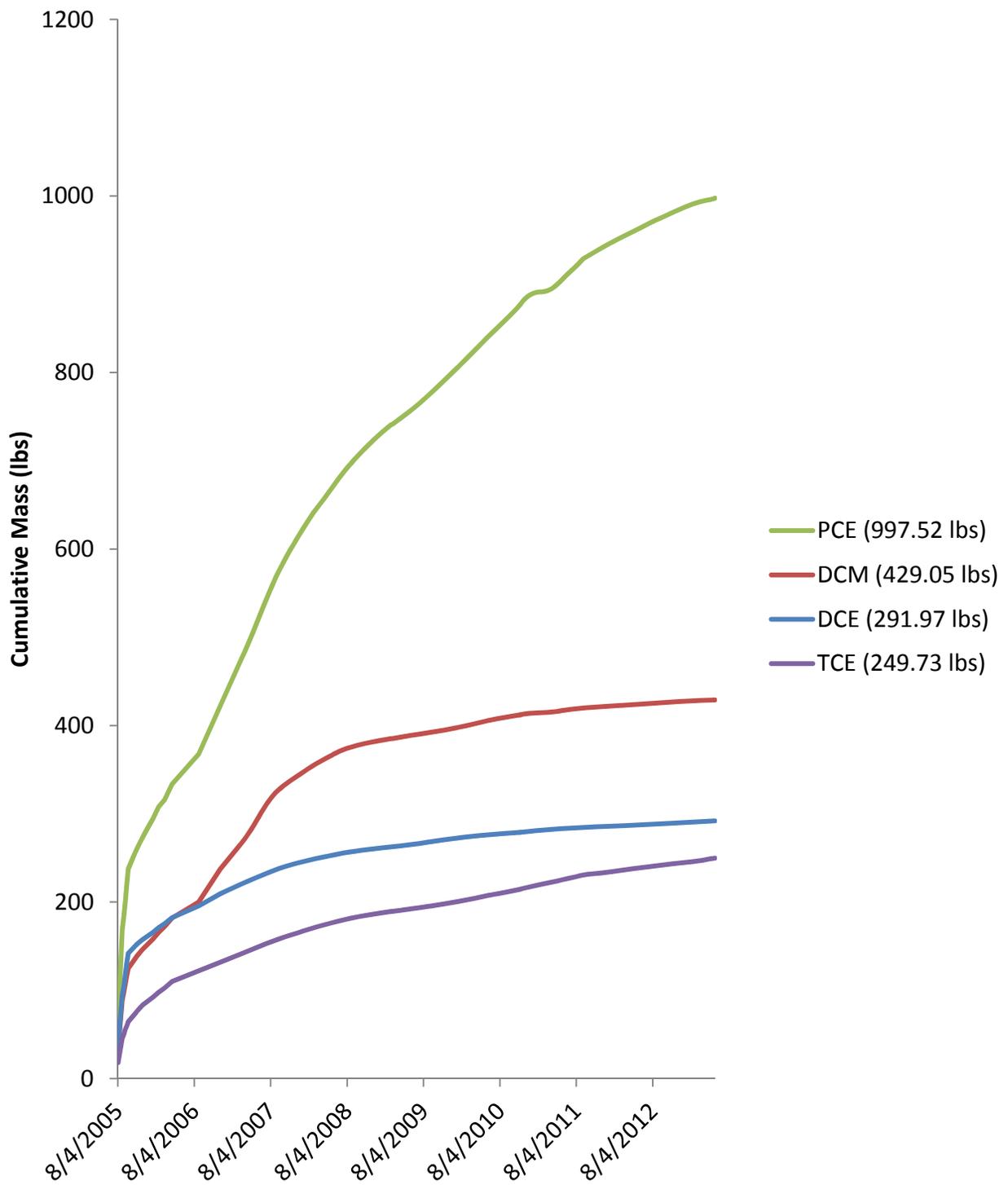


Figure 5
 Cumulative Mass of COCs Removed
 Between July 2005 and May 2013
 COA Los Angeles Landfill



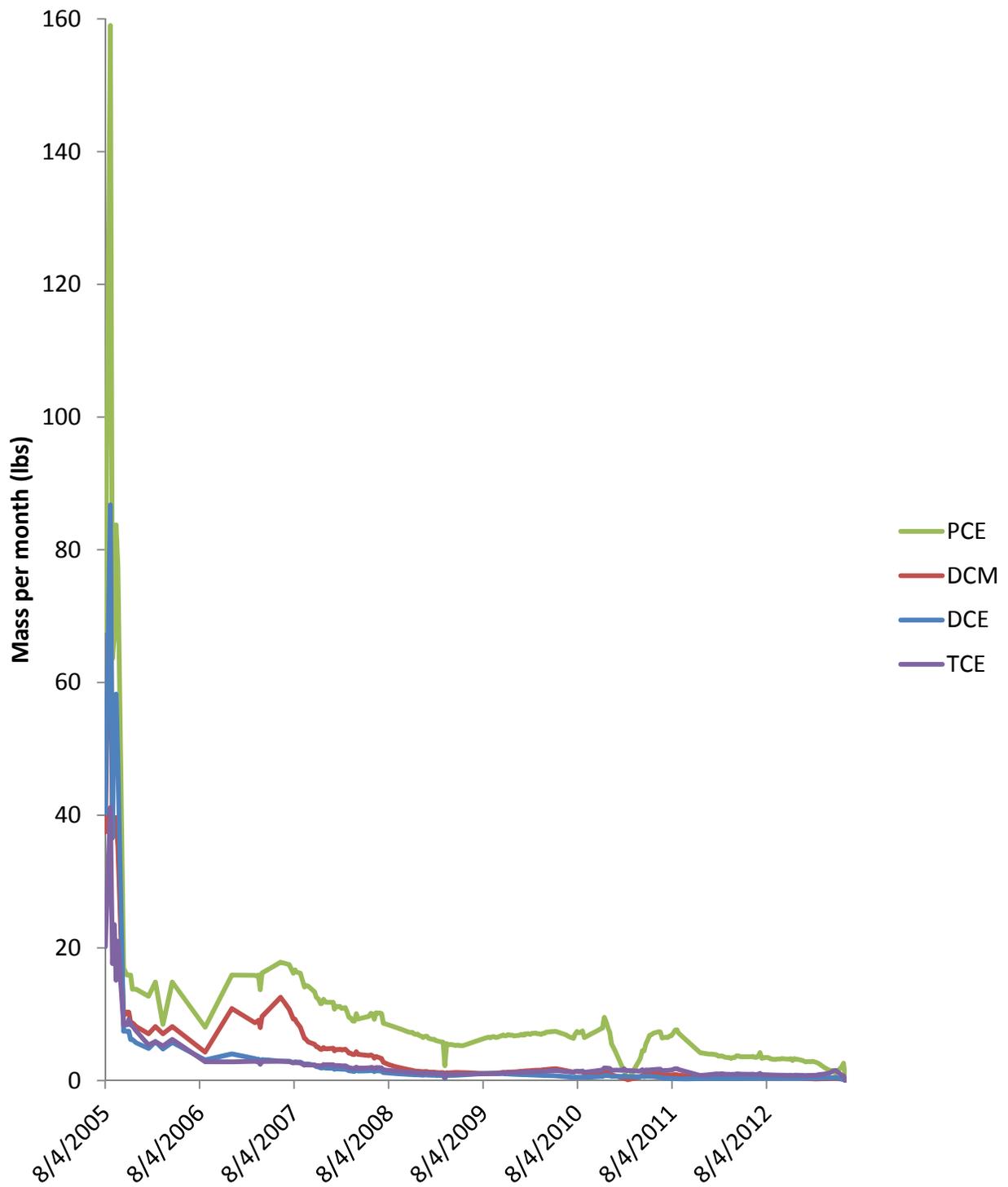


Figure 6a
 Mass per Month of COCs Removed
 Between July 2005 and May 2013
 COA Los Angeles Landfill



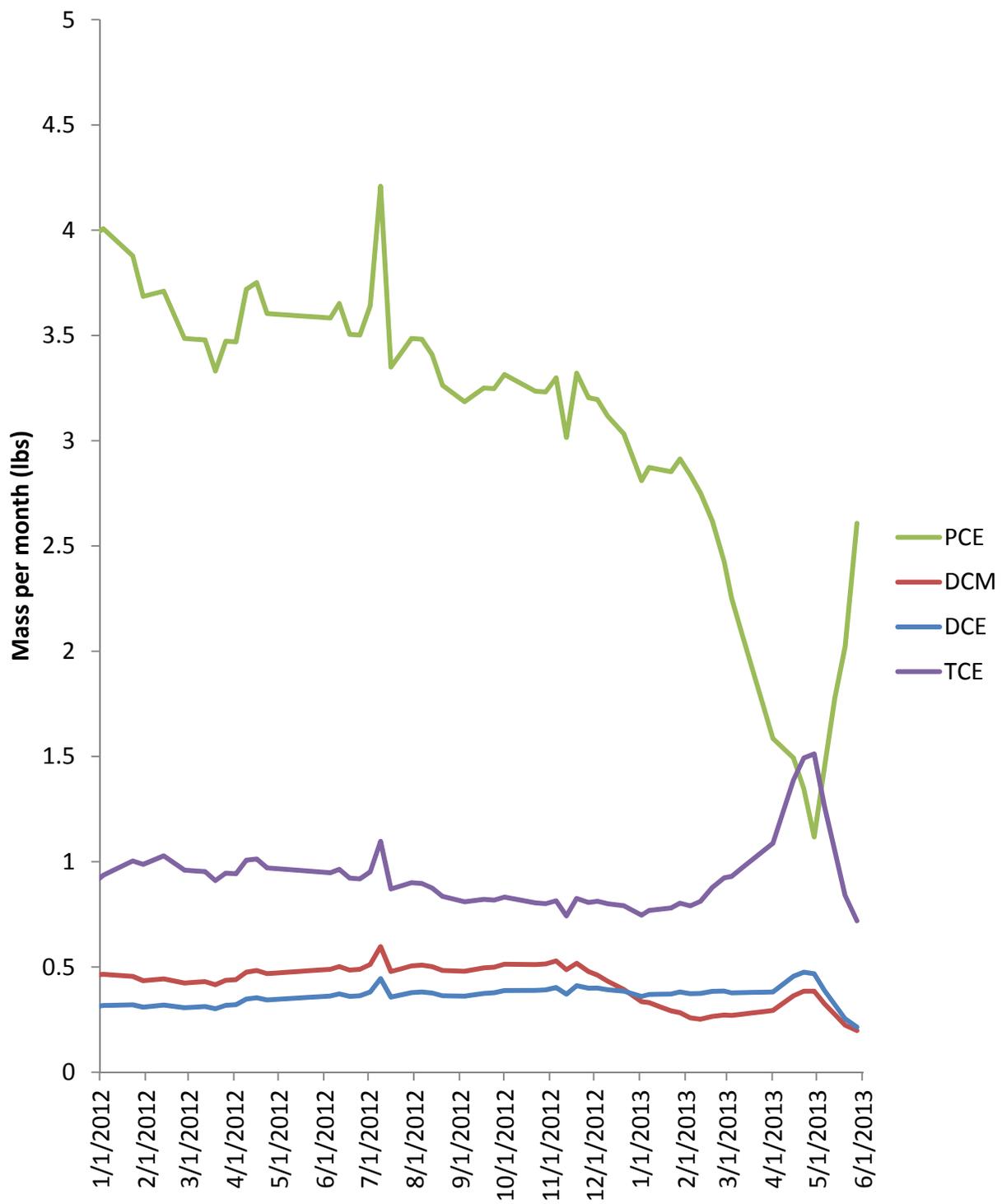
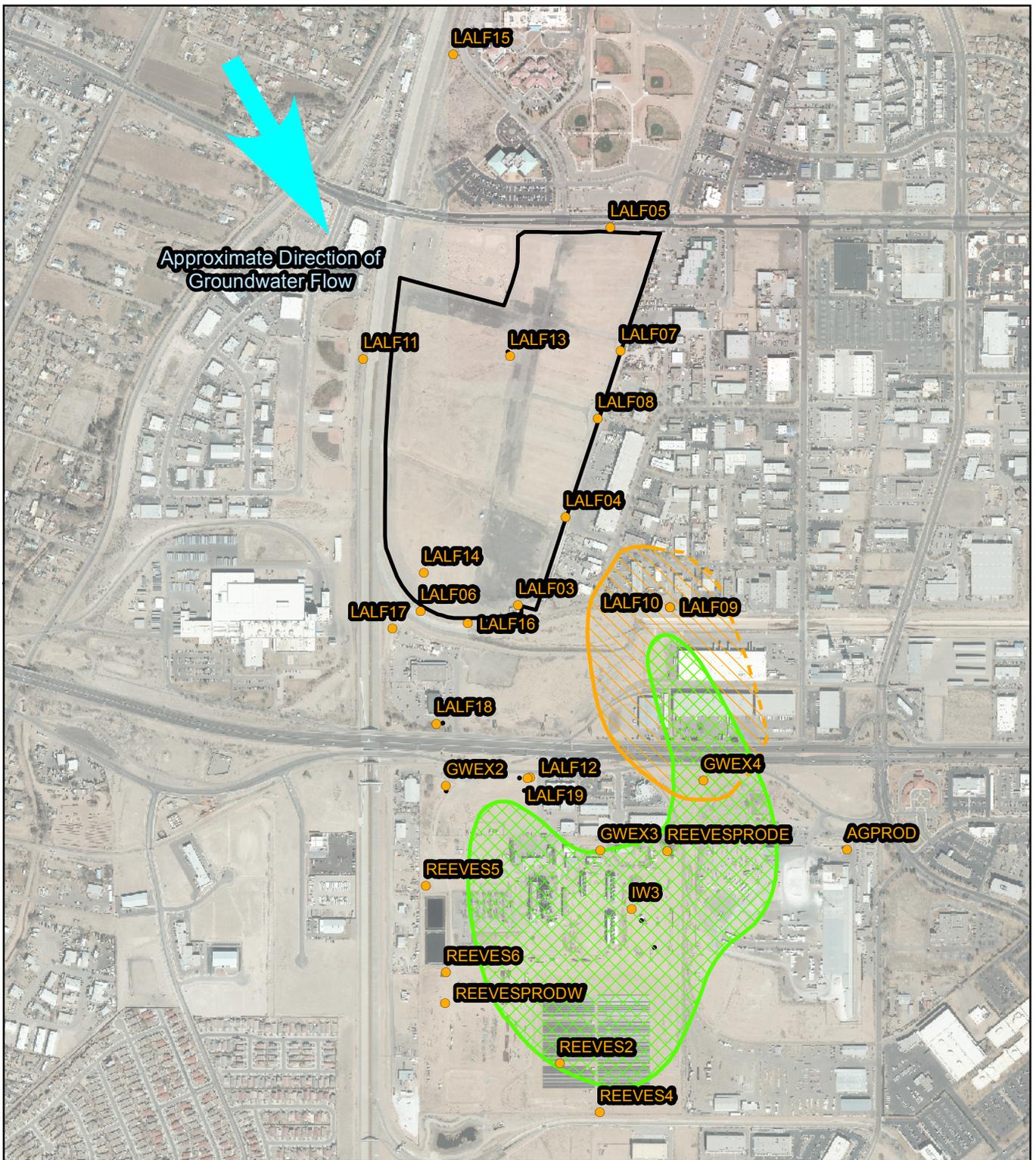


Figure 6b
 Mass per Month of COCs Removed
 Between January 2012 and May 2013
 COA Los Angeles Landfill





Legend

- GW well location
- ▨ Modeled 5 ppb PCE in ~2010
- ▨ 2013 PCE above MCL ($\geq 5 \mu\text{g/L}$)
- ▭ Los Angeles Landfill boundary

NOTE:
Model plume taken from Hydro Geo Chem, Inc., 2001

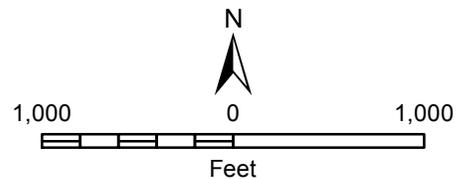


Figure 7
Comparison Between Modeled
and Estimated PCE Plumes
COA Los Angeles Landfill



Data Source(s):
Aerial Imagery - Bernalillo County website, aerial dated 2012.



Groundwater flow directions:
 S7°E to S38°E
 Mean direction: S29°E
 Middle direction: S22°E

Legend

-  Locations used in three-point problem
-  Resulting groundwater flow directions

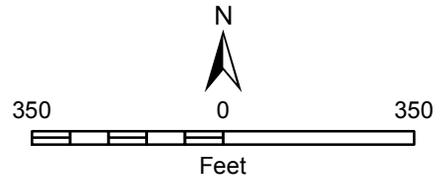
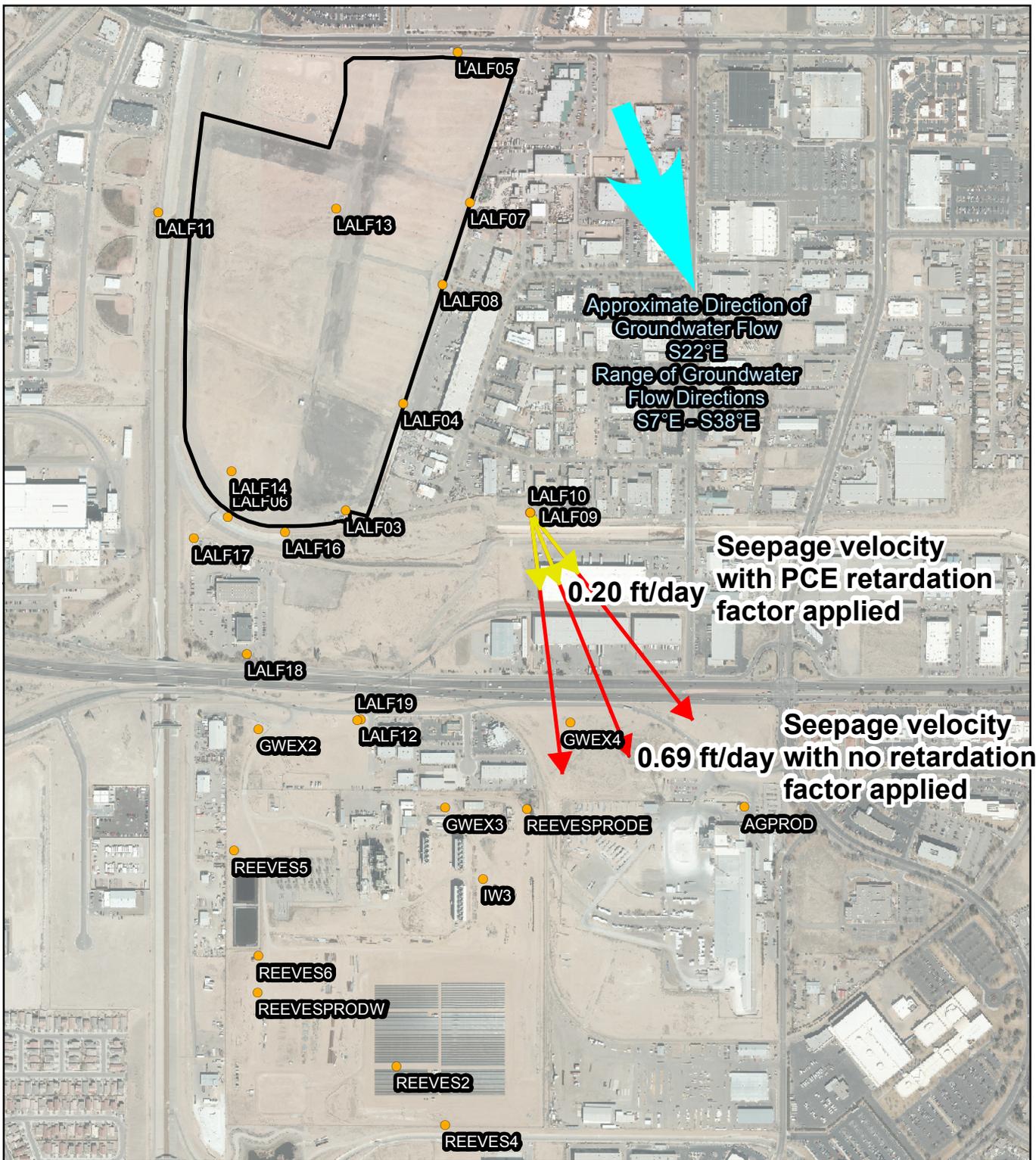


Figure 8
 Groundwater Flow Directions 2012
 Three-Point Problem Results
 COA Los Angeles Landfill



Data Source(s):
 Aerial Imagery - Bernalillo County website, aerial dated 2012.



Legend

- GW well location
- Los Angeles Landfill boundary

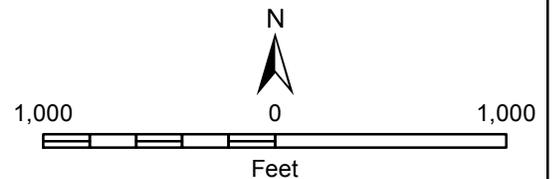
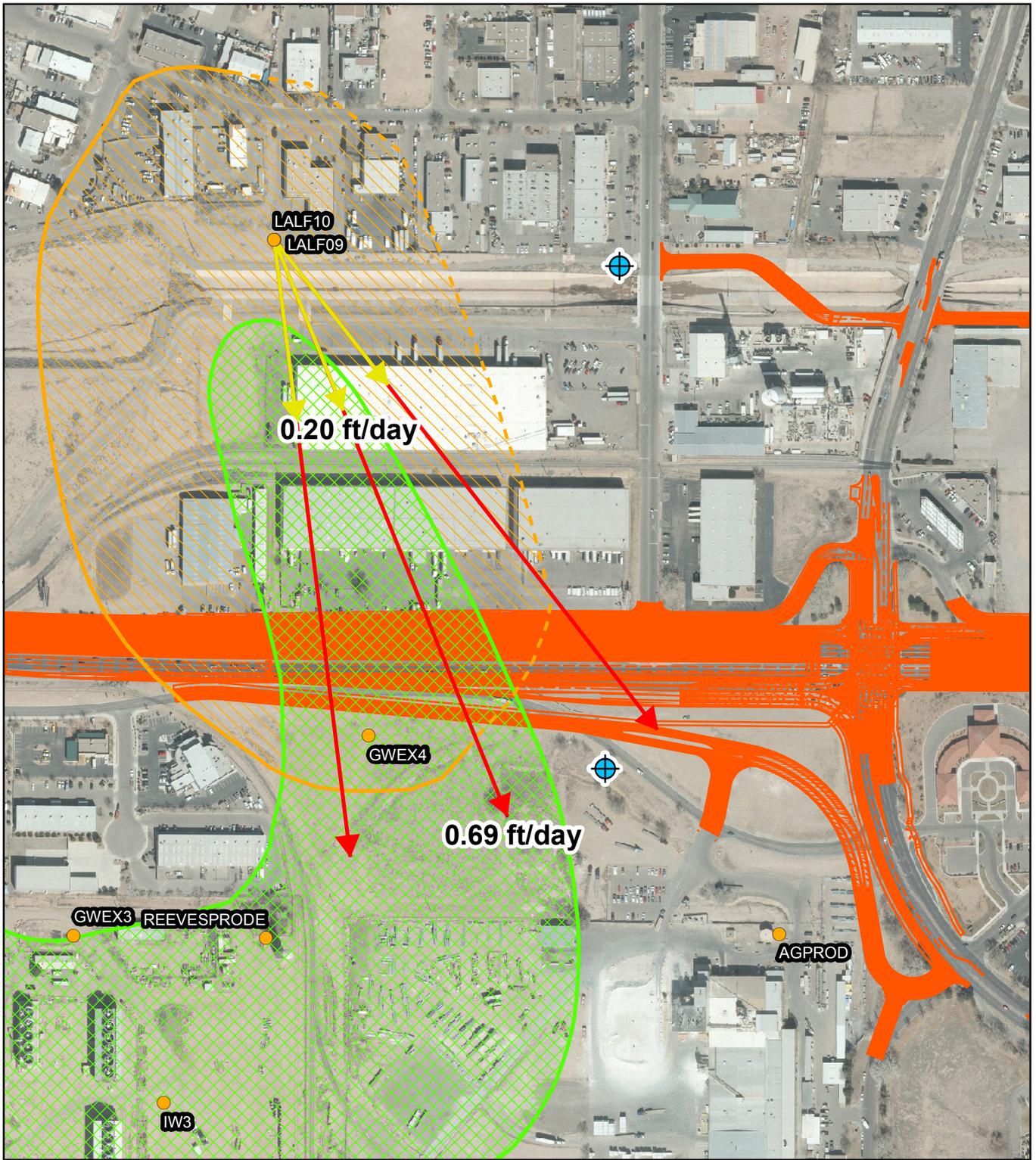


Figure 9
 Range of
 PCE Migration Estimates
 September 2007 to August 2013
 COA Los Angeles Landfill



Data Source(s):
 Aerial Imagery - Bernalillo County website, aerial dated 2012.



Legend

-  Proposed well location
-  GW well location
-  2013 inferred extent of PCE above MCL ($\geq 5 \mu\text{g/L}$)
-  Modeled 5 ppb PCE in ~2010
-  Planned Paseo del Norte improvements

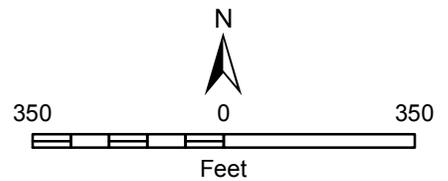


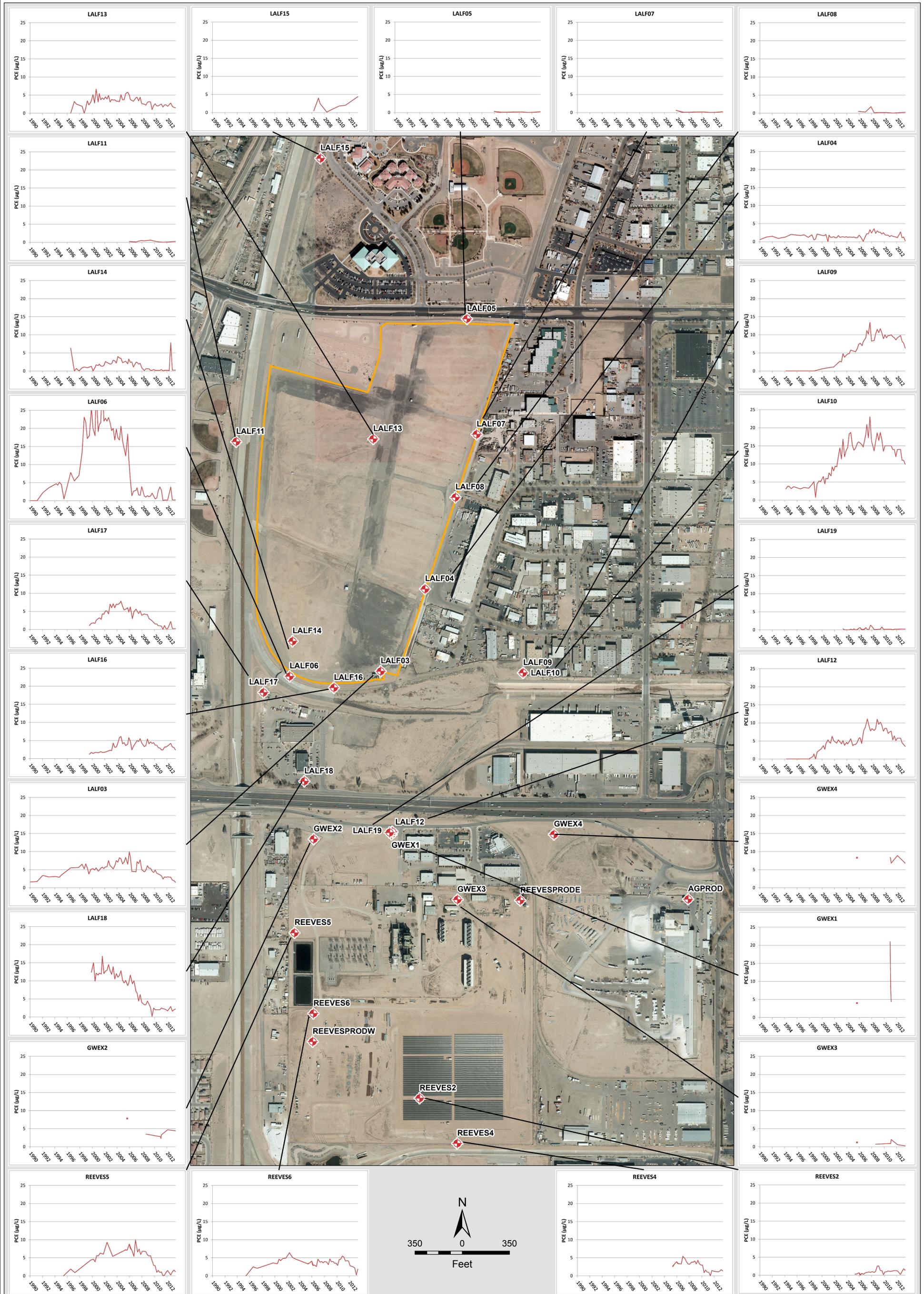
Figure 10
Proposed Locations for
New Groundwater Monitoring Wells
COA Los Angeles Landfill



Data Source(s):
 Aerial Imagery - Bernalillo County website, aerial dated 2012.

ATTACHMENT A

Plates

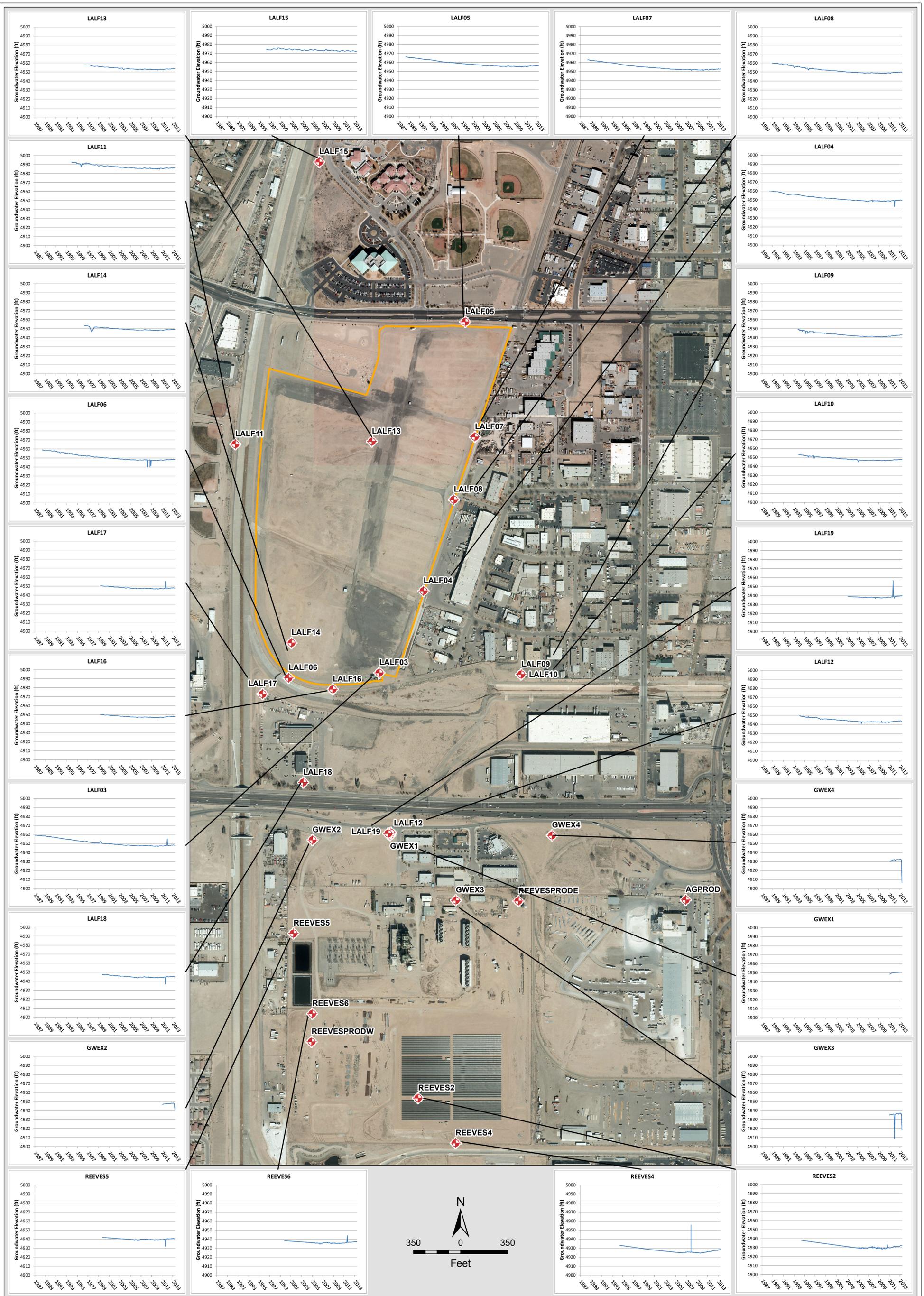


Monitoring Wells
 Landfill Extent



Non-detects plotted as half the method detection limit

Plate 1
 Tetrachloroethene (PCE)
 Los Angeles Landfill
 1990 - 2013
 COA Los Angeles Landfill

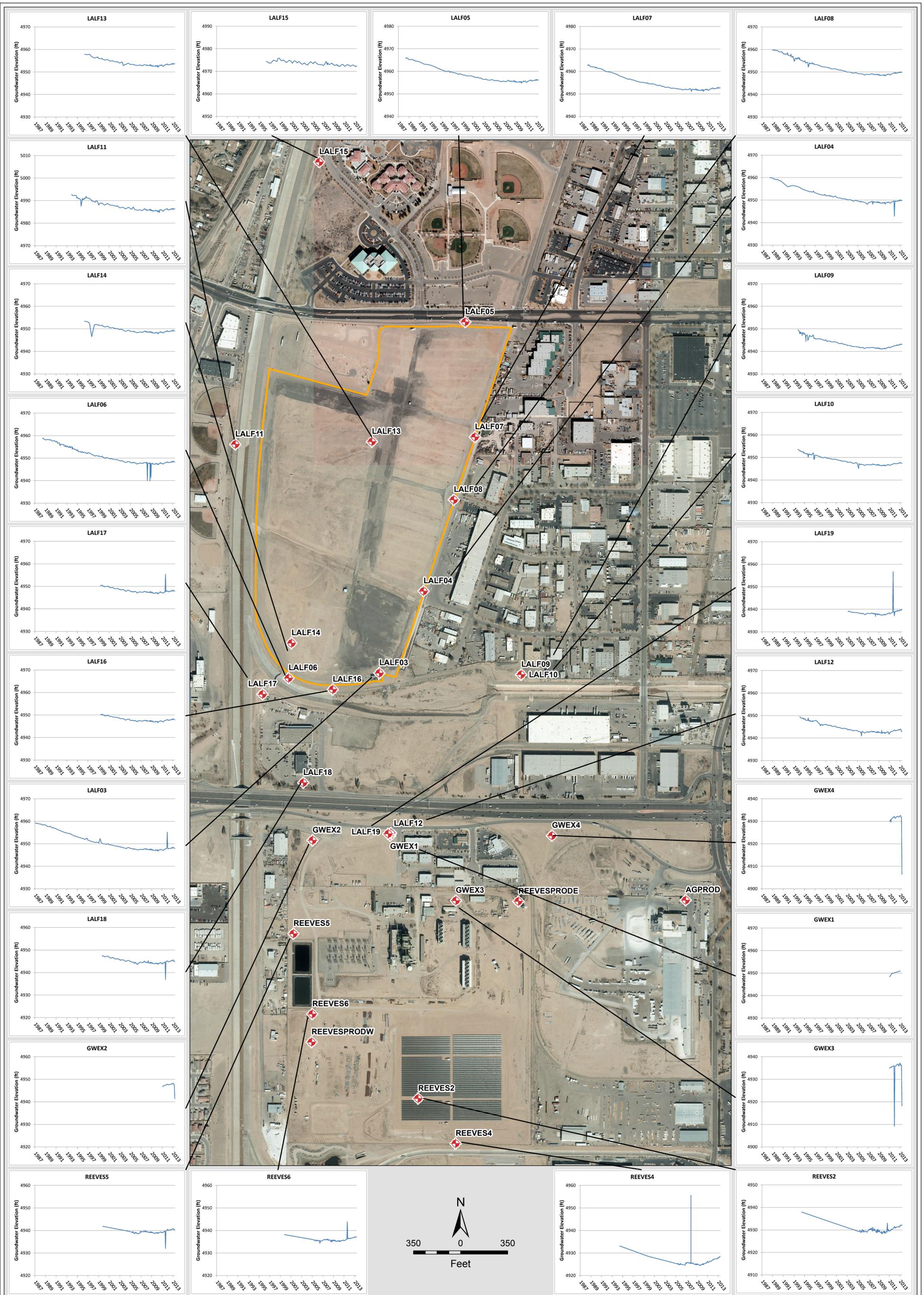


- Monitoring Wells
- Landfill Extent



Non-detects plotted as half the method detection limit

Plate 2
 Water Levels (Common Scale)
 Los Angeles Landfill
 1987 - 2013
 COA Los Angeles Landfill



Monitoring Wells
 Landfill Extent



Non-detects plotted as half the method detection limit

Plate 3
 Water Levels (Focused Graph Scale)
 Los Angeles Landfill
 1987 - 2013
 COA Los Angeles Landfill

ATTACHMENT B

Calculation Sets



1. Purpose

The purpose of this calculation is to estimate a range of groundwater seepage velocities for the former Los Angeles Landfill. The groundwater seepage velocities from this calculation will be used for the purpose of identifying locations for proposed additional monitoring wells near the southeastern extent of the landfill, and for investigating whether contaminant mass remains in that area.

2. Background

INTERA is considering installing additional monitoring wells near the southeast extent of the former Los Angeles Landfill in order to characterize any remaining contaminant mass from the contaminant plume. The first order calculations in this document will help to identify potential locations for the aforementioned proposed monitoring wells.

This calculation will be used as part of an exercise to determine probable locations for the remaining contaminant mass near the southeastern extent of former landfill. Additional site background information can be found in the Site Investigation and Remedial Alternatives Evaluation (Hydro Geo Chem, 2001). Calculations will be made using a range of appropriate assumptions such that a range of locations for the contaminant mass can be identified.

3. Data and Assumptions

For this bracketing calculation the following assumptions have been made:

- The aquifer beneath the site is homogeneous and isotropic.
- Hydraulic Conductivity of the aquifer beneath and near the site could range from 14.5 ft/day to 40 ft/day (Hydro Geo Chem, 2001).
- The average Hydraulic Gradient near the southeastern extent of the site is 0.0052 ft/ft. Estimated from December, 2012 groundwater contours (City of Albuquerque, 2013).
- The effective porosity of the aquifer beneath and near the site is 30 percent (Hydro Geo Chem, 2001).

Rev.	Orig.	Date	Chkd.	Date	Client/Project:
0	SKW	08/20/2013			COA-C002-LALF
			CC	08/20/2013	Subject: Estimated Seepage Velocities near southeaster extent of Site
					Calc. No. COA-C002-LALF-1
					Sheet 1 of 3



4. Calculations

The seepage velocity (ft/day) of an aquifer is defined as:

$$V = q/n$$

Where:

- $q = -K dh/dl =$ darcy velocity (ft/day)
- $n =$ effective porosity of the formation.
- $K =$ Hydraulic Conductivity of the formation (ft/day)
- $dh/dl =$ average hydraulic gradient in the area of calculation (ft/ft)

Since the negative term in the equation for q above simply signifies that groundwater flows from an area of high head to an area of low head, it will be removed from the calculations, groundwater flow is at south 22° east (Hydro Geo Chem, 2001).

Calculation using lowest estimate of hydraulic conductivity:

$$V = 14.5 \frac{ft}{day} \times 0.0052 \frac{ft}{ft} \times \frac{1}{0.3} = 0.25 ft/day$$

Using Lower End of Likely Hydraulic conductivities:

$$V = 30 \frac{ft}{day} \times 0.0052 \frac{ft}{ft} \times \frac{1}{0.3} = 0.52 ft/day$$

Using Upper End of Likely Hydraulic conductivities:

$$V = 40 \frac{ft}{day} \times 0.0052 \frac{ft}{ft} \times \frac{1}{0.3} = 0.69 ft/day$$

Using hydraulic conductivity from (Hydro Geo Chem, 2001) model:

$$V = 36 \frac{ft}{day} \times 0.0052 \frac{ft}{ft} \times \frac{1}{0.3} = 0.62 ft/day$$

Rev.	Orig.	Date	Chkd.	Date	Client/Project:
0	SKW	08/20/2013			COA-C002-LALF
			CC	08/20/2013	Subject: Estimated Seepage Velocities near southeaster extent of Site
					Calc. No. COA-C002-LALF-1
					Sheet 2 of 3



5. Summary

The range of calculated seepage velocities for the aquifer near the southeastern extent of the site is 0.25-0.69 ft/day. However, based on slug test data analysis and travel times reported by the City of Albuquerque, the more likely range for Hydraulic conductivities is 30-40 ft/day (Hydro Geo Chem, 2001). This equates to seepage velocities in the range of 0.52- 0.69 ft/day.

7. References

Hydro Geo Chem, 2001. Site Investigation and Remedial Alternatives Evaluation, Los Angeles Landfill Site, Albuquerque, New Mexico. December 8, 2001.

City of Albuquerque, 2013. 4th Quarter 2012 Groundwater Monitoring Report – Los Angeles Landfill Stage 2 Abatement Plan and Discharge Permit 1468. January 31, 2013.

Rev.	Orig.	Date	Chkd.	Date	Client/Project:
0	SKW	08/20/2013			COA-C002-LALF
					Subject: Estimated Seepage Velocities near southeaster extent of Site
			CC	08/20/2013	Calc. No. COA-C002-LALF-1
					Sheet 3 of 3



1. Purpose

The purpose of this exercise was to verify the calculations done by Hydro Geo Chem, Inc., (Table 13, 2001) estimating the total mass of PCE found in the vadose zone beneath Los Angeles Landfill in 2001.

2. Background

The City of Albuquerque has been removing volatile organic compounds (VOCs) from the Los Angeles Landfill via wells in a landfill gas extraction system since 1997 and via a soil vapor extraction system since 2005. Prior to the installation of the SVE system, Hydro Geo Chem, Inc., conducted a full study and conceptual model of the VOC content and transport within the landfill. Part of this study was a determination of the total mass of PCE found in the vadose zone. Table 13 (Hydro Geo Chem, 2001) shows the following results:

PCE	
Sample ID	PCE, µg/L
LALF-13-60	75.0
LALF-13-74	76.0
LALF-13-105	0.3
LALF-14-60	71.0
Calculated Variable	Value
Average soil gas concentration, µg/L	55.6
Average soil concentration, mg/kg	0.300
Average mass, g	1.54 x 10 ⁶
Average mass, lbs	3,389

3. Data and Assumptions

To verify the calculation of total mass of PCE, the following assumptions have been made:

- The porosity of the vadose zone beneath the site is 35 percent (Hydro Geo Chem, 2001).
- The organic carbon content is 1.0% (Hydro Geo Chem, 2001).
- The density of the soil is 1.8 g/cm³ (Hydro Geo Chem, 2001).
- The maximum volumetric water content of the soil at the site is 0.25 (Table 4, Hydro Geo Chem, 2001).
- The soil organic carbon-water partitioning coefficient for PCE is 360 ml/g (Table 13, Hydro Geo Chem, 2003).
- The dimensionless Henry's Law constant for PCE is 0.75 at 25°C (EPA, 2013). This value was not provided in Hydro Geo Chem (2001).

Rev.	Orig.	Date	Chkd.	Date	Client/Project:
0	ATHW	09/11/2013	FGR	09/11/2013	COA-C002-LALF
					Subject: Verification of the calculation for total PCE mass
					Calc. No.: COA-C002-LALF-2
					Sheet: 1 of 3



- The area of the contaminated soil at the time of the calculation was 1,677,060 ft² (Hydro Geo Chem, 2001).
- The thickness of the contaminated soil at the time of calculation was 60 ft (Hydro Geo Chem, 2001).
- The conversion of grams to pounds is: 1 pound = 453.59 grams (www.onlineconversion.com).

4. Calculations

The average soil gas concentration in µg/L is simply an average of the four sample results:

$$(75.0 + 76.0 + 0.3 + 71.0) / 4 = 55.6 \text{ } \mu\text{g/L}$$

The volume of the plume is calculated first as cubic feet and converted to cubic centimeters:

$$60 \text{ ft} \times 1,677,060 \text{ ft}^2 = 100,623,600 \text{ ft}^3 = 2.85 \times 10^{12} \text{ cm}^3$$

The mass of the contaminated soil, given a density of 1.8 g/cm³, is then:

$$2.85 \times 10^{12} \text{ cm}^3 \times 1.8 \text{ g/cm}^3 = 5.13 \times 10^{12} \text{ g} = 5.13 \times 10^9 \text{ kg}$$

To calculate the average soil concentration in mg/kg, a linear sorption partitioning equation normalized with respect to organic carbon and Henry's Law was used (ADEQ, 2008):

$$C_t = \frac{C_g \left[\frac{K_{oc} f_{oc} \rho_b}{H_0} + \frac{\theta_w}{H_0} + (\theta_t - \theta_w) \right]}{\rho_b}$$

where:

C_t – total concentration in soil (µg/kg)

C_g – concentration in soil vapor (µg/L)

f_{oc} – mass fraction of natural soil organic carbon content (g organic carbon/g soil)

K_{oc} – soil organic carbon-water partitioning coefficient (ml/g)

ρ_b – dry bulk density (kg/L)

H_0 – Henry's Law constant (dimensionless)

θ_t – total soil porosity (volume of voids/volume total)

θ_w – volumetric water content (volume of water/volume of soil)

Plugging in the assumed values to calculate the average soil concentration of PCE yields:

$$\frac{55.6 \left[\frac{360 \times 0.01 \times 1.8}{0.75} + \frac{0.25}{0.75} + (0.35 - 0.25) \right]}{1.8} = 280 \text{ } \mu\text{g/kg} = 0.280 \text{ mg/kg}$$

Continuing the calculation for the average mass of PCE with this value, 0.280 mg/kg, yields:

$$5.13 \times 10^9 \text{ kg of soil} \times 0.280 \text{ mg/kg} = 1.44 \times 10^9 \text{ mg PCE} = 1.44 \times 10^6 \text{ g PCE}$$

Rev.	Orig.	Date	Chkd.	Date	Client/Project:
0	ATHW	09/11/2013	FGR	09/11/2013	COA-C002-LALF
					Subject: Verification of the calculation for total PCE mass
					Calc. No.: COA-C002-LALF-2
					Sheet: 2 of 3



$$1.44 \times 10^6 \text{ g PCE} \times 1 \text{ lb}/453.59 \text{ g} = 3,169 \text{ lbs PCE}$$

Completing the calculation for the average mass of PCE with Hydro Geo Chem's (2001) value for average soil concentration of PCE, 0.300 mg/kg, yields:

$$5.13 \times 10^9 \text{ kg of soil} \times 0.300 \text{ mg/kg} = 1.54 \times 10^9 \text{ mg PCE} = 1.54 \times 10^6 \text{ g PCE}$$

$$1.54 \times 10^6 \text{ g PCE} \times 1 \text{ lb}/453.59 \text{ g} = 3,392 \text{ lbs PCE}$$

5. Summary

The values calculated during this exercise do not exactly match the Hydro Geo Chem (2001) results, but, given assumptions and rounding, they are sufficiently similar to verify their calculated values.

Calculated Variable	PCE		
	Hydro Geo Chem Value	INTERA Value 1	INTERA Value 2
Average soil gas concentration, $\mu\text{g/L}$	55.6	55.6	
Average soil concentration, mg/kg	0.300	0.280	(0.300)
Average mass, g	1.54×10^6	1.44×10^6	1.54×10^6
Average mass, lbs	3,389	3,169	3,392

Notably, Hydro Geo Chem seemed to use a rounded value of 1 lb = 454 grams for their conversion from mass in grams to mass in pounds; this accounts for the difference between 3,392 lbs and 3,389 lbs.

6. References

Arizona Department of Environmental Quality (ADEQ), 2008. Soil Vapor Sampling Guidance. July 10, 2008.

EPA, 2013. <http://www.epa.gov/athens/learn2model/part-two/onsite/esthenry.html>, website accessed August, 2013.

Hydro Geo Chem, Inc., 2001. Site Investigation and Remedial Alternatives Evaluation, Los Angeles Landfill Site, Albuquerque, New Mexico. December 8, 2001.

Hydro Geo Chem, Inc., 2003. Conceptual Remedial Design, Los Angeles Landfill. September 10, 2003.

Rev.	Orig.	Date	Chkd.	Date	Client/Project:
0	ATHW	09/11/2013	FGR	09/11/2013	COA-C002-LALF
					Subject: Verification of the calculation for total PCE mass
					Calc. No.: COA-C002-LALF-2
					Sheet: 3 of 3