amec foster wheeler

Proposed Remedial Action Plan
Estes Landfill WQARF Registry Site
Phoenix, Arizona

Submitted To:

Arizona Department of Environmental Quality
Phoenix, Arizona

Submitted By:

Amec Foster Wheeler Environment & Infrastructure, Inc.
Phoenix, Arizona

February 9, 2015

Project No. 14-2014-2033.03.01

REGISTERED GEOLOGIST
CERTIFICATE NO.
29374
JAMES N.
CLARKE
Date Signed
ARIZONA U.S.A.
Expires 09/30/16

February 9, 2015
Project No. 14-2014-2033.03.01

Arizona Department of Environmental Quality
1110 West Washington Street
Phoenix, Arizona 85007

Attn: Scott Green

Re: Proposed Remedial Action Plan
Estes Landfill WQARF Registry Site
Phoenix, Arizona

Dear Mr. Green:

AMEC Environment and Infrastructure, Inc. (now known as Amec Foster Wheeler Environment & Infrastructure, Inc.) is pleased to submit this *Proposed Remedial Action Plan* (PRAP) for the Estes Landfill WQARF Registry Site (Site) located in Phoenix, Arizona. This PRAP has been prepared in accordance with Arizona Administrative Code (A.A.C.) R18-16-408.

If you have any questions or comments regarding this report, please contact Mr. Jim Clarke at 602-733-6055.

Respectfully submitted,

Amec Foster Wheeler Environment & Infrastructure, Inc.

Reviewed by:

REGISTERED GEOLOGIST CERTIFICATE NO. 29374 JAMES N. CLARKE Date Signed 2/9/16 ARIZONA U.S.A. Expires 09/30/16

REGISTERED GEOLOGIST CERTIFICATE NO. 40811 CHRISTOPHER J. COURTNEY Date Signed 02/09/2015 ARIZONA U.S.A. Expires 06/30/2017

James N. Clarke, PG
Senior Geologist
Arizona Registered Geologist #29374

Chris J. Courtney
Senior Hydrogeologist
Arizona Registered Geologist #40811

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ACRONYMS AND ABBREVIATIONS

1,2-DCB	1,2-dichlorobenzene
1,4,-DCB	1,4-dichlorobenzene
1,1-DCE	1,1,-Dichloroethylene (*aka* 1,1-dichloroethene)
1,2-DCE	1,2-Dichloroethylene (*aka* 1,2-dichloroethene)
AAAQC(s)	Arizona Ambient Air Quality Guideline(s)
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
AMEC Foster Wheeler	AMEC Foster Wheeler Environment and Infrastructure, Inc.
AWQS	Arizona Water Quality Standards
Bgs	below ground surface
c-1,2-DCE	cis-1,2-DCE
COC(s)	compounds(s) of concern
COP	City of Phoenix
DTW	depth-to-water
EPA	United States Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
FS	Feasibility Study
HHRA(s)	Human Health Risk Assessment(s)
HLA	Harding Lawson Associates
µg/L	Micrograms per Liter
MNA	Monitored natural attenuation
PCE	tetrachloroethene (*aka* perchloroethene)
ppbv	parts per billion by volume
PRAP	Proposed Remedial Action Plan
PSHIA	Phoenix Sky Harbor International Airport
RI	Remedial Investigation
RO(s)	Remedial Objective(s)
ROD	Record of Decision
SCM	Site Conceptual Model
Site	Estes Landfill WQARF Site
SRL(s)	Soil Remediation Level(s)
TCE	Trichloroethene (*aka* trichloroethylene)
Use Study	Land and Water Use Study Report
VC	Vinyl Chloride
VOC(s)	Volatile Organic Compound(s)
WQARF	Water Quality Assurance Revolving Fund

1.0 INTRODUCTION

1.1 Summary of Site Activities

The Location Map and Site Plan for the Estes Landfill Water Quality Assurance Revolving Fund (WQARF) Registry Site (Site) are provided as Figure 1. The original Proposed Remedial Action Plan (PRAP) for the Site was prepared in 2002 (ESE, 2002a). Since that time, additional work and groundwater sampling has been done at the Site. Therefore, presenting the early and later site conditions in one report notifies the public and potentially responsible parties (PRPs) of what has been accomplished at the Site.

- Since 2002, the Site has progressed from a WQARF Registry Site, with at least three detected volatile organic compounds (VOCs) classified as compounds of concern (COCs) for the Site (trichloroethene [TCE], cis-1,2-dichloroethene [c-1,2-DCE], and vinyl chloride [VC]) exceeding their respective State Aquifer Water Quality Standards (AWQS), to the present day where only one VOC (VC) exceeds the AWQS.

- The VC groundwater contaminant plume has shrunk from approximately 175 acres in the early 2000's to approximately 18 acres in 2013 (Figures 2 and 3).

- As of 2013, the VC groundwater contaminant plume is located onsite and does not extend across the Salt River and onto the Phoenix Sky Harbor International Airport (PSHIA) and Air National Guard properties (Figure 2).

- The selected groundwater remediation method is monitored natural attenuation (MNA). MNA, when compared to most active remediation options for the Site identified COCs, has very low start-up and maintenance costs. However, MNA requires careful and consistent groundwater monitoring and reporting to document the progress of the remediation.

Since 2002, additional work and groundwater sampling has been done at the Site.

- In February 2013, the groundwater monitor wells were surveyed, conditions evaluated and identified repairs completed (see Section 4.1).

- From 2005 to 2013, additional groundwater sampling was performed and contaminant plumes were sequentially modified based on the groundwater sampling data (Section 4.2).

- In January 2008, additional soil vapor testing was performed (see Section 4.3).

1.2 PRAP Outline

In accordance with the Arizona Department of Environmental Quality (ADEQ), Purchase Order #ADEQ14-077536:5 for the Site, and Section R18-16-408 of the WQARF Remedy Rules, this report presents the PRAP completed for the Site as part of the remedy selection process. The purpose of the PRAP is to inform the public and PRPs of the selected proposed remedy, which was selected during the feasibility study (FS) process.

After receiving public comments on the revised PRAP, ADEQ will prepare a record of decision (ROD) along with a notice of availability, which will be provided to each person who provided comments on the draft PRAP in accordance with the community involvement plan.

The PRAP describes the Site, results of the remedial investigation (RI) and the FS, and the proposed remedy identified in the FS and its estimated cost. In addition, the PRAP describes how the proposed remedy will meet each of the remedial objectives (ROs). The contents of this PRAP are divided among the following sections:

- **Section 1.0**: Introduction to the purpose of this PRAP;
- **Section 2.0**: A site description including physical location and site hydrogeology;
- **Section 3.0**: Relevant site background information, which includes the RI results;
- **Section 4.0**: A description of current site conditions;
- **Section 5.0**: Remedial objectives (ROs) established by ADEQ;
- **Section 6.0**: A brief summary of the results to the FS;
- **Section 7.0**: A detailed description of the proposed remedy, including the remedy description, estimated cost, and any design considerations;
- **Section 8.0**: Description of the proposed remedy's ability to meet ROs; and,
- **Section 9.0**: Referenced documents.

2.0 SITE DESCRIPTION

2.1 Site Location

The Site, as defined by ADEQ on April 28, 1998, was based on inferred distribution of dissolved contaminants in groundwater that were identified as signature compounds to the Estes Landfill. The current boundaries of the Site, as well as the Estes Landfill (landfill), which cover approximately 45 acres, are shown on Figure 1.

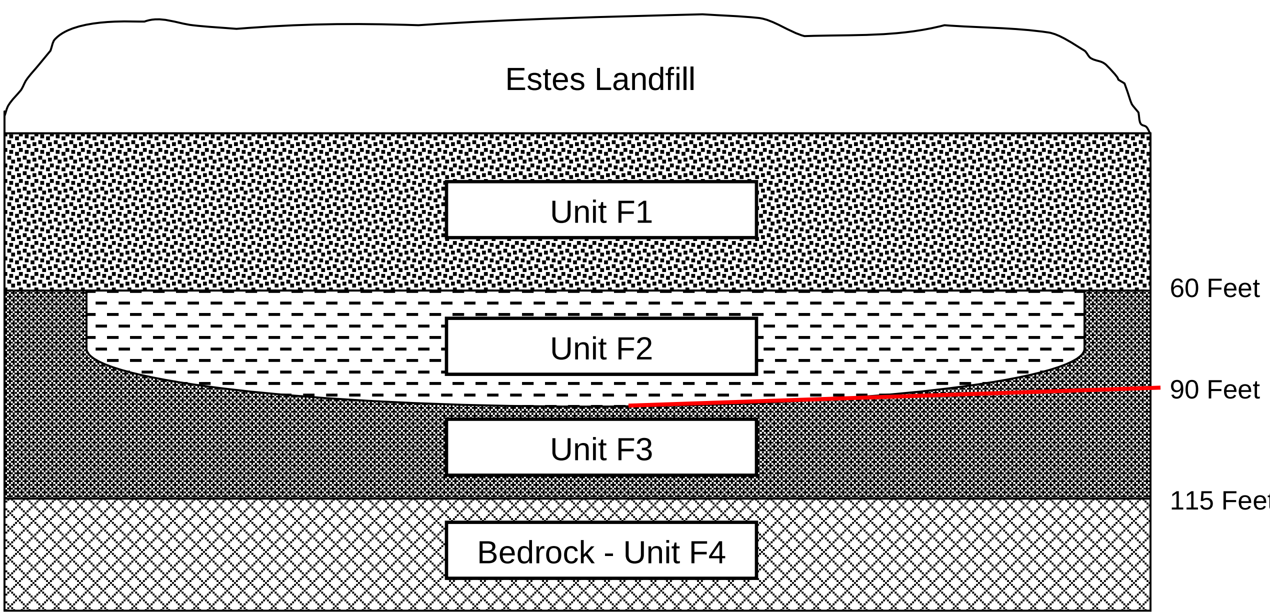
The Site and landfill are located adjacent to and south of the Salt River between 40th and 45th Streets in Phoenix, Arizona (Figure 1). The Site area includes a network of groundwater monitor wells that extends beyond the portion of the aquifer, which is impacted by the Site. The Bradley, or Fortieth Street Landfill, a newer landfill that is also privately owned and operated, lies south of the Estes Landfill. The two are separated by a 50-foot east/west utility easement.

2.2 Site Hydrogeology

As described in the RI report (ESE, 1999), Estes Landfill is underlain by approximately 115 to 175 feet of heterogeneous alluvial sediments and several hundred feet of consolidated sedimentary bedrock. The alluvium beneath the site contains sediments (cobbles, gravel, sand and fines) of similar composition with differing hydraulic properties, which results from differences in the degree of sorting of the sediments. The RI report identified four distinct alluvial hydrostratigraphic units in the following order from the ground surface downward:

- Unit F1, an unconfined highly permeable aquifer where saturated, from the surface to approximately 60 feet below ground surface (bgs);
- Unit F2, a semi-confined low permeability aquitard from approximately 60 to 90 feet bgs;
- Unit F3, a semi-confined medium permeability aquitard from approximately 90 feet bgs to the underlying sedimentary bedrock (Unit F4); and,
- Unit F4, a well consolidated bedrock unit that correlates with the Tertiary Tempe Beds and (older) Tertiary Camelshead Formations.

The contacts between the alluvial units are gradational, whereas, the contact with underlying bedrock (Unit F4) is well defined. Unit F2 is not continuous throughout the Site and vicinity, and where the F2 Unit is absent, Units F1 and F3 are considered to be one unconfined alluvial aquifer.



The major hydrologic feature in the study area is the Salt River immediately adjacent to the Site. The Salt River is normally dry, but infrequent periods of above-average precipitation and/or releases from upstream reservoirs or lakes have caused river flows to occur that have exceeded 100,000 cubic feet per second. These river flows have caused rapid recharge to the underlying aquifer.

Groundwater generally occurs under unconfined conditions, with localized exceptions. Groundwater flow is generally west during “dry” river conditions and southwest during sustained river flow events. Water levels have fluctuated historically between approximately 25 and 80 feet bgs at the Site and are significantly impacted by recharge during river flow events.

3.0 SITE BACKGROUND

The Estes Landfill was operated by a commercial refuse collection and disposal company from the early 1950s through 1972. The landfill was permanently closed as a commercial disposal site in 1972. The City of Phoenix (COP) purchased the landfill in the early 1980s to re-channel the Salt River to prevent future flooding of Sky Harbor Airport. The Estes Landfill accepted liquid wastes that would now be classified as hazardous wastes. Bulk liquids were discharged into ponds excavated in the refuse pits. Coring data collected in the Estes Landfill suggest that the maximum pit depth was about 50 feet, with approximately 40% of the landfill within the 35 to 50 foot depth range. The depth to groundwater in the vicinity of the landfill ranges from approximately 15 to 83 feet bgs.

Groundwater contamination was discovered in two industrial supply wells located downgradient of the Estes/Bradley Landfills between 1980 and 1982, one on the Bradley Landfill, and one on the former Tanner property west of 40th Street. The primary contaminants detected were c-1,2-DCE and VC, which are degradation byproducts of the industrial solvent TCE. Lower concentrations of other VOCs and metals were also detected. Groundwater sampling of eight monitor wells, four on the Estes Landfill and four on the Bradley Landfill, conducted by the Arizona Department of Health Services (ADHS) through the mid-1980s, confirmed the presence of groundwater contamination in the area. The greatest concentrations of VOCs were detected in monitor well EW-E, located near a former liquid waste disposal pit along the southern boundary of the Estes Landfill (Figure 1).

The discovery of VOCs in groundwater at the Estes Landfill project area and the subsequent groundwater assessment efforts are further summarized in the “Estes Landfill Remedial Investigation Report” (RI Report) (HLA, 1997). As described in the RI Report, flooding along the Salt River in 1978, 1979 and 1980 caused substantial damage to both public and private property along the Salt River, including PSHIA. As a result, the COP, in conjunction with local, State and Federal flood control and transportation agencies, developed a program of Salt River channelization and bank stabilization. To complete the project, a large portion of the Estes Landfill (that was located in the riverbed) had to be moved. In 1982, the COP acquired the Estes Landfill through eminent domain and the landfill relocation project was initiated. Hazardous wastes were segregated and shipped off-site for disposal. Most of the remaining material in the riverbed was excavated and moved onto the southern portion of the property, out of the riverbed (HLA, 1997).

Since 1987, several phases of remedial investigation have been conducted at the Site, ultimately in support of the September 5, 1997 draft RI report prepared by Harding Lawson

Associates (HLA) for the COP (HLA, 1997). Technical activities that were completed included the drilling and installation of numerous groundwater monitor wells and piezometers; collection of numerous soil, groundwater, and soil gas samples; geophysical surveys; and, several aquifer tests (both bench scale and pilot scale treatability tests). The data compiled during this phase of the remedial investigation was used to develop a detailed Site Conceptual Model (SCM) which was presented in the final draft RI report. The SCM provided specific data on site conditions as it relates to site hydrology, groundwater contamination sources, groundwater chemistry, and human health risk assessments (HHRAs). In addition, the draft RI report provided information on the movement and fate and transport of the groundwater COC plume. In general, conclusions reached in the draft RI report on the source of contamination, groundwater chemistry, and HHRA evaluations are as follows:

- For onsite sources, the draft report concludes that the source area on the Estes landfill appears to be a former liquid waste disposal pit that was located near the southeast corner of the Site.

- For offsite sources, the draft report concludes that an offsite groundwater plume from an independent unknown source(s) that contains TCE and 1,1-dichloroethene (1,1-DCE) is present about one-half mile to the south and southwest of the Site. The contaminants associated with the off-site source area flow to the northwest and impact certain wells west of the Site that are also impacted by contaminants apparently attributable to the Site.

- The draft report identified VC and c-1,2-DCE as signature chemicals for the Site used to define the extent of impacts to groundwater. The draft report further concludes that, based on fifteen years of groundwater monitoring, the lateral and vertical extent of contamination from the Site is relatively stable with declining VOC concentrations in wells down gradient to the source area, demonstrating that groundwater impacts have decreased over time through natural attenuation. The draft report also concludes that site data demonstrates that sequential anaerobic degradation followed by aerobic degradation of the more highly chlorinated compounds onsite and less chlorinated compounds offsite, respectively, is occurring.

- The results of two HHRAs; one performed by ADHS (ADHS, 1995) and the other performed by HLA, concluded that the media of concern was groundwater and the chemical of concern was VC. In addition, both HHRAs concluded that there are no current public health risks associated with the Site, and no complete exposure pathway for groundwater. However, in terms of the hypothetical potential future use of groundwater, the two HHRAs differed. The HHRA completed by ADHS assumed potential potable use (ingestion) of the groundwater. The HHRA completed by HLA did not consider potential future use of groundwater. Consequently, the estimates of risk varied significantly, from a determined cancer risk of 2×10^{-3} in ADHS's HHRA to $1x10^{-4}$ in HLA's HHRA.

During the period from May through June 1999, Environmental Science and Engineering, Inc. (ESE) supervised investigative field actives at the Site. All field activities and laboratory analyses were performed following appropriate procedures in the April 30, 1999 Field Sampling Plan and the June 7, 1999 QAPP for the Site, prepared by ESE and approved by ADEQ.

The results of the supplemental RI activities and all past investigation activities were described in the Remedial Investigation Final Report, dated July 30, 1999 (ESE, 1999). The following provides a brief description of the findings contained in the report:

- Review of all soil samples collected from soil borings drilled within the current and former landfill indicated that no significant sources of VOCs were identified in any of the areas sampled. The analytical results for VOCs were all below their respective method reporting limits. Arsenic, Thallium, and Lead were considered compounds of interest in the current and former Landfill because they exceeded appropriate action levels and were detected at a frequency of greater than 5%. The report consequently concluded that metals, in the form of Arsenic and Thallium were present in both the former landfill and the western and central portions of the existing landfill that exceeded their appropriate action level. In addition, Lead was present in the eastern portion of the existing landfill that also exceeded the ADEQ Soil Remediation Levels (SRLs). Because these metals are present in subsurface soils, direct human exposure was not a concern. However, the potential of these metals to leach into the groundwater and the potential future exposure during site redevelopment were of concern. Consequently, further evaluation of the potential risks to human health and the environment was recommended.

- Review of all collected groundwater sample results confirmed that the Site plume is suspected of originating from an onsite former liquid waste disposal pit (primary source). VC, cis-1,2-DCE, and TCE have been identified as signature chemicals that are unique to the Estes Landfill to identify groundwater impacted by the Site. VC and cis-1,2-DCE are the two VOCs with the greatest concentrations in groundwater samples collected from onsite wells and are present in lesser concentrations in groundwater samples from down gradient and cross-gradient wells. In addition, VC and TCE have the two lowest AWQSs of the COCs, which correlates to the higher toxicity value of these compounds. VC, cis-1,2-DCE and TCE will be used to identify the extent of groundwater contamination from the Site.

- In the vicinity of the Site, two plumes of dissolved VOCs in groundwater have been identified through the evaluation of groundwater quality data. One plume is located onsite (Figure 3); the other plume is located to the south and southwest of the Estes Landfill and is considered to have originated from another off-site source.

- The groundwater plume from the Site is stable and not migrating. To the south and southwest, the lateral extent fluctuates a few hundred feet in response to river flow. However, the southern lateral extent is generally defined by wells north of University Drive.

- Based on inferred westerly to southwesterly groundwater flow, the Bradley Landfill is downgradient to cross-gradient of the Estes Landfill. Based on these inferred groundwater flow conditions, it is not likely that any potential VOCs in groundwater from the Bradley Landfill have migrated north onto the Estes Landfill boundary.

- The vertical extent of groundwater contamination is generally limited to the alluvial hydrostratigraphic units F1, F2, and F3.

- Contaminant concentrations in groundwater decline over time and with distance from the source area. Since the last major Salt River flow event in 1993, concentrations have declined up to two orders of magnitude at some locations. It was noted that during large Salt River flow events, groundwater concentrations of VC tend to spike near the source area. This concentration spike is immediately followed by a rapid decline. These spikes do not appear to affect the lateral extent of groundwater contamination over either the short or long term. An evaluation of concentration spikes over time indicates that the magnitude of the spikes is declining.

- The two primary mechanisms controlling the attenuation of VOCs at the Site are physical and biological. The main physical attenuation mechanisms are dissolution and advection. Dissolution occurs primarily in F2 beneath the source and results in the creation of highly contaminated groundwater. This highly contaminated groundwater slowly migrates vertically to the more permeable adjacent units F1 and F3, where it can migrate laterally via advective transport. During periods of Salt River flow, rapid recharge causes hydraulic loading and upsets the established equilibrium. This effect contributes to the observed VC and c-1,2-DCE concentration spikes at source area wells during or immediately after a major Salt River flow event.

- Natural attenuation of TCE, c-1,2-DCE, and to a limited extent, VC, is occurring at the Site.

- A general statistical analysis of the groundwater data was conducted to facilitate the identification of specific chemical compounds in the groundwater that were the result of onsite and offsite activities. The compounds that met the criteria are as follows: VC; trans-1,2-DCE; c-1,2-DCE; TCE; 1,2-Dichlorobenzene (1,2-DCB), Chlorobenzene; 1,1-DCE; 1,4-Dichlorobenzene (1,4-DCB); Tetrachloroethene (PCE); Benzene; 1,2-Dichloroethane; Chloroform; bis (2-ethylhexyl) phthalate; Arsenic; Barium; Chromium; Cadmium; Lead; Manganese; and Nitrate as N.

- Based on comparing methane results of all three rounds, there is no apparent trend of methane production. However, it has been concluded that the highest concentrations of methane production are within the relocated portions of the landfill. It has also been established that methane is not migrating west or east offsite. In addition, the presence of methane or methane production along the southern portion of the landfill is likely influenced by the presence of the Bradley Landfill, which is also a source of methane. The current concentrations of methane could create explosive conditions, if low-lying areas or enclosed structures were present. However, because these types of site conditions are not present, explosion potential due to buildup of methane is currently not an issue.

- Based on the results of the ecological screening, COCs in soil and groundwater at the Estes Landfill do not pose a threat to ecological receptors. Area soils do not pose a threat to invertebrates living in the soil, plants growing in the soil, or terrestrial receptors (i.e., birds, mammals, and reptiles) ingesting soil. Risk analysis of food chain bioaccumulation of COCs at the Estes Landfill indicates no adverse affects to terrestrial ecological receptors of concern. Groundwater does not pose a threat to amphibians, fish or other aquatic life that may inhabit the surface water of Southbank Lake. Based on this analysis, a more detailed RA is not warranted.

On July 10, 2000, Harding ESE issued a Technical Memorandum that presented the results of the evaluation of the COP Rio Salado Project, Assured Water Plan, and Draft WQARF Remedy Selection Rule (Draft Rule) as it relates to the remedy selection process at the Site. Based on this review it was concluded that certain aspects of the FS remedy selection process would need to be changed or modified, as follows:

- During the remedial alternative evaluation, “source control” must be considered for all remedies except for the monitoring and no action strategies.

- All remedial alternatives must be evaluated for consistency with appropriate water management plans of water providers and land use plans of local governments.

- During the remedial alternative evaluation, the cost comparison criteria must include transactional costs to implement the remedy.

- Existing plans for the potential reasonable foreseeable future use of groundwater by COP, within the vicinity of the Site, should be considered in the ROs.

- Current and potential future usage of groundwater by individual property owners within the vicinity of the Estes site must be considered (survey data) in the ROs and during the evaluation of remedial alternatives, which would include conducting groundwater risk evaluations for no-action or natural attenuation alternatives.

- During the remedial alternative evaluation, storm water run-off from the landfill discharging into the Salt River potentially impacting the Rio Salado riparian habitat, newly established wildlife, and wetlands may need to be considered.

On January 25, 2001, Harding ESE issued a Technical Memorandum describing the results of the re-evaluation of soil COCs for the Estes Landfill. The soil COCs were identified in the Final RI Report, and included the following compounds: Arsenic, Lead, and Thallium. The re-evaluation of the subsurface soil COCs as based on comparing results of past soil boring investigations that were outlined in the final RI Report to site-specific background data obtained for Arsenic and Lead. For Thallium, since no action level had been established, the past soil boring investigation results were compared with the residential SRL for Thallium Chloride, which is a compound of Thallium having the most conservative SRL when compared with other Thallium compounds. The results of the re-evaluation indicated that these three metals should continue to be COCs for subsurface soils.

On February 21, 2001 (revised and reissued on June 19, 2002), Harding ESE submitted the Final Groundwater Modeling Report for the Estes Landfill Site (HESE, 2002b). The primary objective of this task was to develop groundwater flow and contaminant transport models capable of simulating current and future TCE, cis-1,2-DCE and VC concentrations in the overburden aquifer underlying the Site. Specifically, Visual MODFLOW MT3D99 software was used in conducting the modeling, which was calibrated to match existing data and used to conduct 100-year simulations of concentration changes resulting from flow and natural attenuation mechanisms. The results of the modeling demonstrated that natural attenuation was effectively decreasing the concentrations of the COCs. Model simulations indicated that: by the year 2006 cis-1,2-DCE concentrations were expected to be less than the AWQS; and, VC concentrations would be less than the AWQS by 2012. In a worse case scenario, if significantly less than measured biodegradation rates were utilized, these anticipated timeframes would be increased by eight years (i.e., 2014 for cis-1,2-DCE and 2020 for VC) (HESE, 2002a).

On July 9, 2001, a Land and Water Use Study Report (Use Study) was finalized and issued for public comment (ADEQ and HESE, 2002). This report presented a summary of current and potential future uses of land and water at the Site as required in the WQARF Remedy Rules (R18-16-406). The Use Study was intended to be an inclusive summary of information gathered from discussions with property owners, water providers, municipalities, and well owners. In general, the study did not discriminate between "reasonably foreseeable" uses and other uses that were identified. A summary of the results of the Use Study is provided in Section 5.0 of this PRAP.

On January 15, 2002, the ROs were finalized by ADEQ for all of the possible uses considered as reasonably foreseeable (ADEQ, 2002). A summary of the ROs is provided in Section 5.0 of this PRAP.

On February 21, 2002, Harding ESE issued two technical memorandums to ADEQ; one pertaining to the results of the investigation of the former liquid disposal pit, and the other pertaining to the results of ambient air quality monitoring conducted at the landfill surface. The findings presented in these memorandums are as follows:

- The objective of the former liquid disposal pit investigation was to characterize the extent to which hazardous substances are present within the vadose zone and vadose/saturated zone interface of the liquid disposal pit located on the Site. The report concluded that the following compounds should be added to the subsurface soil COC list: Benzene; 1,2,4-Trimethylbenzene; Chromium, Isopropylbenzene; p-Isopropyltoluene; n-Propylbenzene; and 1,2,3-Trichlorobenzene. The updated baseline HHRA should include these soil COCs as part of the updated exposure and toxicological evaluations.

- The objective of the ambient air monitoring was to determine if VOC vapors were migrating to the landfill surface at concentrations exceeding the Arizona Ambient Air Quality Guidelines (AAAQGs), as recommended in the 2nd Quarter 2001 Groundwater Monitoring Report. The results of sampling showed that all detected compounds were well below their respective AAAQG. Consequently, further assessment of the potential health effects associated with exposure to these compounds was not recommended.

In June 2002, Harding ESE completed a Human Health Risk Assessment Update (HHRA Update) (HESE, 2002c). The HHRA update evaluated potential exposure and risk from contaminants present in various media in and adjacent to the Estes Landfill that were not addressed in the original August 1995 Draft HHRA report. This update also compared the toxicity values used in the 1995 Draft HHRA with current values to determine if they had become more stringent as to impact any conclusions made in the original report. The results of the HHRA update supported the following conclusions (HESE, 2002c):

- As concluded in the Draft HHRA report, no current risk is known to exist from exposure to contaminants in groundwater through registered private domestic wells within the portion of the aquifer contaminated by the Estes/Bradley Landfills.

- Use of the Bradley Landfill production well for dust control purposes currently presents a negligible health risk (i.e., less than 1×10^{-6} excess lifetime cancer risk).

- Emissions of organic compounds present in the soil gas at the Estes Landfill currently presents a negligible health risk, as verified by the ambient air monitoring results that showed COCs detected in the air are significantly less than their respective AAAQGs. The Draft HHRA report on soil gas presenting a negligible risk is confirmed.

- Potential exposure to surface soil via incidental ingestion, inhalation of fugitive dust and volatiles, and dermal contact on the Estes Landfill presents a negligible health risk.

- While some contaminants were identified in subsurface soils, including the area of the liquid disposal pit, the absence of an effective exposure pathway, indicates that there is a negligible health risk.

- If unregistered private domestic wells exist in the area of contaminated groundwater, then some risk may be presented by contaminants from the landfill. However, given the nature of land uses down gradient of the landfill, such an occurrence is considered unlikely.

On June 2002, Harding ESE completed the FS of three remedial alternatives, which included a reference remedy (Source Control), a more aggressive remedy (Plume Remediation), and a less aggressive remedy (Monitoring). A summary of the FS results is presented in Section 6.0 of this PRAP (HESE, 2002d).

4.0 CURRENT SITE CONDITIONS

The following description of the current groundwater conditions at the Site is based on the evaluation of groundwater data from June 1999 through February 2013. Evaluation of these data has shown that inferred groundwater flow directions and gradients varied slightly between the three hydrostratigraphic Units during the monitoring periods. In all three Units, groundwater appears to consistently flow west across the site and changed directions slightly west-northwest west of 40th Street. Evaluation of the VOC data has confirmed that the Site groundwater TCE plume continues to be confined to the general source area, both horizontally and vertically. The groundwater c-1,2-DCE plume is within the boundary of the landfill in the north, east, and west, and extends just beyond the landfill boundary in the south. In general, c-1,2-DCE concentrations decrease both horizontally away from the source area, and vertically at the source area. The c-1,2-DCE concentration in EW-18 (Bradley Well) was well below the AWQS. The groundwater VC plume extends downgradient beyond EW-23 at concentrations exceeding the AWQS of 2 micrograms per liter (µg/l). The VC concentration in well EW-18 (Bradley Well) was above the AWQS with a concentration of 3.7 µg/l in 2001.

Benzene has, occasionally, been detected in two on-site wells, specifically EW-PZ5 and EW-PZ9, at concentrations exceeding the AWQS. Benzene is typically associated with fuel releases and the sporadic detection of benzene in on-site wells indicates that there is no nearby fuel release source associated with this compound. The presence of benzene above the AWQS of 5.0 µg/L in samples collected from on-site monitoring wells represents an issue of concern to ADEQ, primarily regarding the potential source of the benzene. Review of the historic data noted that when a sample was detected with elevated benzene concentrations, that sample was also detected with elevated concentrations of chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene. According to available information, the same bacteria that reductively dechlorinate TCE and c-1,2-DCE to VC also reductively dechlorinate dichlorobenzene to chlorobenzene. As with VC, chlorobenzene is readily degraded in an aerobic environment and will accumulate in an anaerobic environment.

Although the reductive dechlorination process in an anaerobic environment typically stops at chlorobenzene, it may be reductively dechlorinated to benzene as an intermediary. If the benzene remains in the anaerobic environment, similar to VC, it may accumulate because of the slower degradation rate. Therefore, the benzene has likely originated from the chlorobenzene and dichlorobenzene compounds that have also been detected in the groundwater. The same can be concluded for bis (2-ethylhexl) phthalate, which is also sporadically detected in on-site wells occasionally exceeding the U.S. Environmental Protection Agency (USEPA) Regional Screening Levels. Overall, the VC plume is stable and appears to show a declining trend in concentrations near the source and at the fringe of the plume. Figure 3 provides a boundary of the maximum extent of the VC plume compared to the boundary of the March 2013 plume.

Evaluation of the inorganic groundwater data has confirmed that well EW-12 has consistently had nitrate concentrations just above the AWQS. The Barium concentration in well EW-16 also has consistently exceeded the AWQS. Manganese has consistently exceeded the ADEQ‘s Health Based Guidance Level in wells EW-4. EW-6, EW-9, EW-16, EW-18, EW-24, EW-PZ1, EW-PZ3 EW-PZ5 and EW-PZ9. Arsenic was occasionally detected in wells EW-16 and EW-PZ9 exceeding the AWQS. The Draft HHRA and HHRA Update both confirmed that of these detected COCs, VC was the only compound that presented a risk to human health if the groundwater was used for consumption (HESE, 2002c).

Review of the analytical data of all surface soil samples collected within the landfill indicates that there are no surface soil COCs that exceed the non-residential SRL. Review of the analytical data of all subsurface soil samples collected within the landfill indicates that Arsenic is present at some location of the former and current landfill (including the Liquid Disposal Pit) at concentrations exceeding the non-residential SRL. In addition, Chromium and 1,2,4-Trimethylbenzene were also detected in the Liquid Disposal Pit at concentrations exceeding their respective non-residential risk-based levels. Comparison of the groundwater data to soil COCs has confirmed that these compounds do not contribute to the Site's groundwater plume. In addition, the HHRA Update confirmed that there were no other exposure routes associated with the presence of these compounds in subsurface soils (HESE, 2002c).

Review of the analytical results of vapor/air collected from soil-gas, gas monitoring probes, and ambient air has confirmed that detected VOCs at the surface or boundary of the landfill are below AAAQGs. Review of the methane data indicates that methane gas does not appear to be migrating beyond the eastern and western boundaries of the landfill. However, a determination of methane migration within the north and south boundaries of the landfill could not be confirmed because it is suspected the probes located within these areas may be in landfilled trash and/or influenced by potential methane generation from the Bradley Landfill. When comparing the methane results to previous sampling events, it was confirmed that the probes installed within the eastern portion of the landfill have consistently had the highest methane concentrations. In addition, it is also confirmed that probes located within the east and west boundaries of the landfill have continually not detected the presence of methane.

4.1 Monitoring Well Survey (February 2013)

A monitoring well survey was conducted in February 2013 by Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler). ADEQ asked AMEC Foster Wheeler to survey the Site monitor wells and determine why 19 wells were no longer in the monitoring program (AMEC, 2013).

Reasons why the monitor wells had been removed from the monitoring program were as follows:

- Some wells had inoperable pumps (i.e., EW-16, EW-25);
- Wells had insufficient water in them to collect a sample (EW-PZ4);
- Monitor wells were abandoned (i.e., EW-24, EW-16);
- Wells were unable to be located and may have been buried or paved over (i.e., EW-NE, EW-18, EW-4, EW-PZ12);
- Wells were located in inaccessible areas (i.e., Phoenix Sky Harbor International Airport and the Air National Guard property [i.e., ANG-02, EW-22, EW-23]); or
- Wells were located in areas outside of the VC groundwater contaminant plumes (i.e., EW-12) and no longer provided meaningful data.

Based on the locations of the above wells, previous analytical results, and current VC distribution at the Site, additional wells were identified that could provide additional data regarding contaminant distribution at the Site. Necessary repairs were made and the wells were put back into the monitoring program. Based on the 2013 well condition survey, the following 20 wells were put back into the monitoring program:

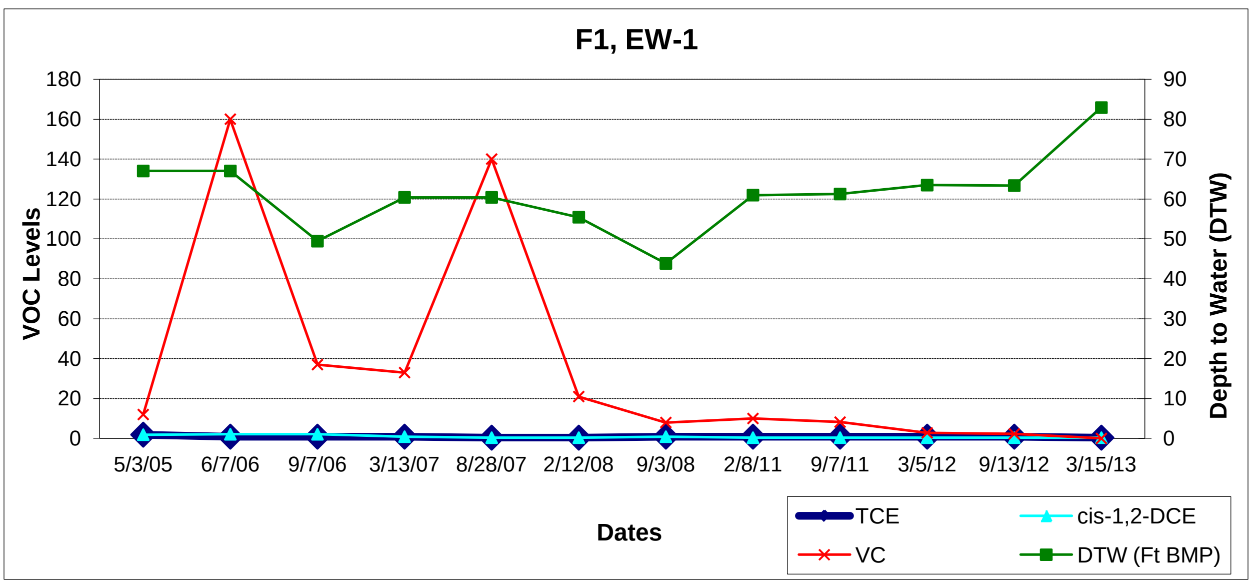
- Wells Screened Within Unit F1: EW-1, EW-14, and EW-PZ6;
- Wells Screened Within Unit F2: EW-PZ1, EW-PZ2, EW-PZ5, and EW-PZ9;
- Wells Screened Within Unit F3: EW-5, EW-6, EW-9, EW-17, EW-19, EW-27, EW-NW, EW-E, EW-PZ3, and EW-PZ10; and,
- Wells Screened Within Unit F4: EW-8, EW-15, and EW-26.

4.2 Groundwater Monitoring 2005-2013

Since 2005, twelve sampling events have been completed. Bi-annual sampling was completed in 2006, 2007, 2008, 2011, 2012 and 2013. Sampling was not completed in 2009 and 2010 due to lack of project funding.

Results from the March 2005 to March 2013 groundwater sampling events are presented in the tables and graphs below. The tables and graphs are listed for each of the four hydrostratigraphic units at the Site. Each hydrostratigraphic unit (F1, F2, F3 and F4) has a table and graph describing the water levels and the contaminant concentrations found at each level since 2005. The tables and graphs are described with the hydrostratigraphic unit (F1, F2, F3 and F4) along with the monitoring well or piezometer screened at that level.

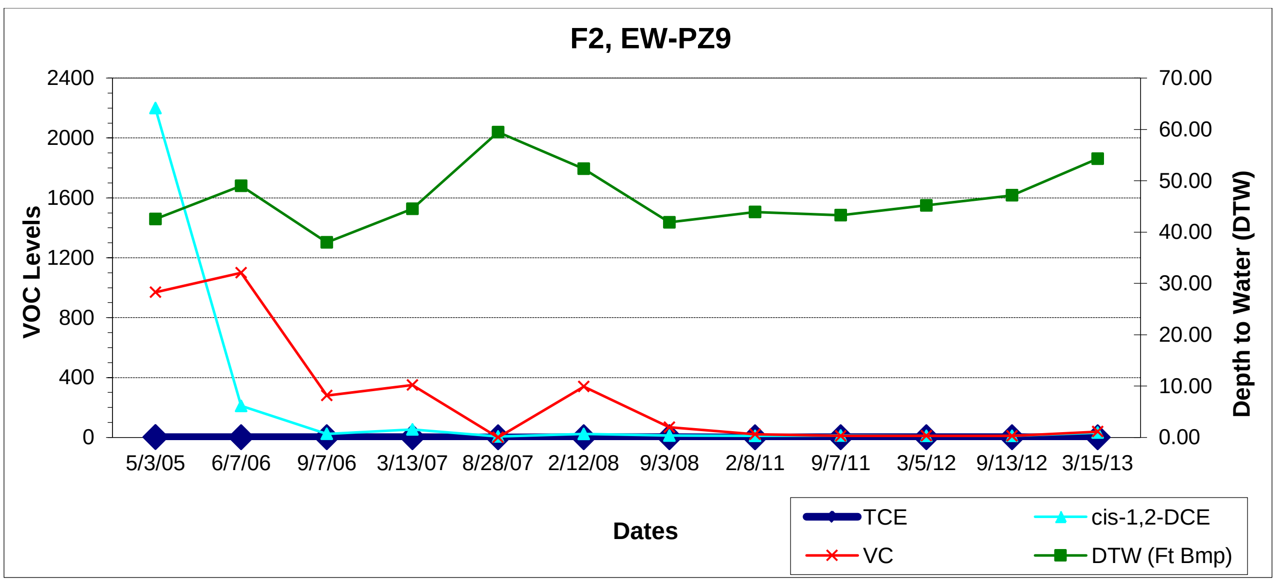
4.2.1 F1, EW-1



F1, EW-1				
DATES	TCE	cis-1,2-DCE	VC	DTW (Ft BMP)
5/3/2005	<2.0	<2.0	**12**	67.02
6/7/2006	<1.0	2.10	**160**	67.02
9/7/2006	<1.0	2.10	**37**	49.44
3/13/2007	<1.0	<1.0	**33**	60.41
8/28/2007	<0.5	<0.5	**140**	60.41
2/12/2008	<0.5	<0.5	**21**	55.44
9/3/2008	<1.0	<1.0	**8**	43.86
2/8/2011	<1.0	<0.5	**10**	60.97
9/7/2011	<1.0	<0.5	**8.2**	61.25
3/5/2012	<1.0	<0.5	**2.8**	63.48
9/13/2012	<1.0	<0.5	**2.3**	63.36
3/15/2013	<0.5	<0.5	<0.5	82.90

Notes:
TCE AWQS = 5 ppb
cis-1,2-DCE AWQS = 70 ppb
VC AWQS = 2.0 ppb
DTW = Depth to Water
Ft BMP = Ft below Measuring Point

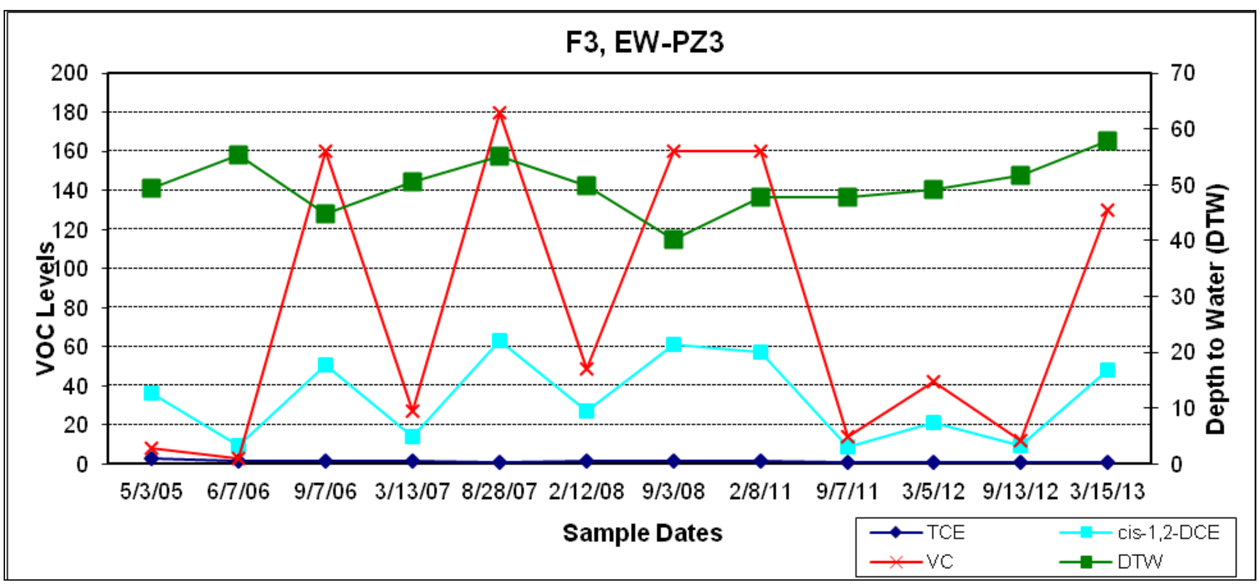
4.2.2 F2, EW-PZ9



F2, EW-PZ9				
DATES	**TCE**	**cis-1,2-DCE**	**VC**	**DTW (Ft Bmp)**
5/3/2005	<2.0	**2200**	**970**	42.55
6/7/2006	<1.0	**210**	**1100**	49.02
9/7/2006	<1.0	24	**280**	38.00
3/13/2007	<1.0	53	**350**	44.54
8/28/2007	<0.5	6	0.5	59.47
2/12/2008	0.8	23	**340**	52.35
9/3/2008	<1.0	12	**68**	41.90
2/8/2011	<0.5	10	**21**	43.92
9/7/2011	0.76	12	**9.7**	43.3
3/5/2012	0.77	10	**11**	45.2
9/13/2012	0.76	10	**9.7**	47.18
3/15/2013	<0.5	32	**39**	54.30

Notes:
TCE AWQS = 5 ppb
cis-1,2-DCE AWQS = 70 ppb
VC AWQS = 2.0 ppb
DTW = Depth to Water
Ft BMP = Ft below Measuring Point

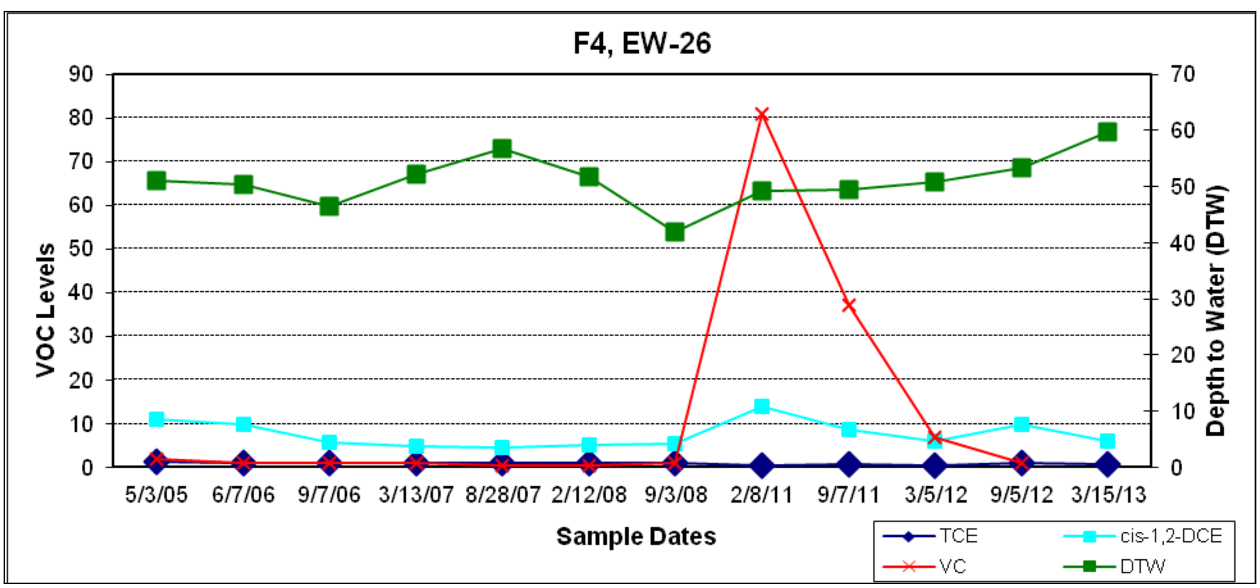
4.2.3 F3, EW-PZ3



F3, EW-PZ3				
DATES	TCE	cis-1,2-DCE	VC	DTW (Ft Bmp)
5/3/2005	3.2	36.0	**8**	49.42
6/7/2006	1.6	9.3	**3.2**	55.28
9/7/2006	1.5	51.0	**160**	44.84
3/13/2007	1.4	14.0	**27**	50.50
8/28/2007	0.7	63.0	**180**	55.21
2/12/2008	1.6	27.0	**49**	49.93
9/3/2008	1.5	61.0	**160**	40.31
2/8/2011	1.4	57.0	**160**	47.69
9/7/2011	1.0	8.6	**14**	47.80
3/5/2012	1.1	21.0	**42**	49.08
9/13/2012	0.75	9.30	**12**	51.63
3/15/2013	1.2	48	**130**	57.79

Notes:
TCE AWQS = 5 ppb
cis-1,2-DCE AWQS = 70 ppb
VC AWQS = 2.0 ppb
DTW = Depth to Water
Ft BMP = Ft below Measuring Point

4.2.4 F4, EW-26



F4, EW-26				
DATES	TCE	cis-1,2-DCE	VC	DTW (Ft BMP)
5/3/2005	1.2	11.0	<2.0	51.06
6/7/2006	1.1	9.7	<1.0	50.37
9/7/2006	<1.0	5.8	<1.0	46.42
3/13/2007	<1.0	4.9	<1.0	52.23
8/28/2007	1.0	4.4	<0.5	56.85
2/12/2008	0.9	5.0	<0.5	51.77
9/3/2008	<1.0	5.4	<1.0	41.85
2/8/2011	<0.5	14.0	**81**	49.25
9/7/2011	0.72	8.5	**37**	49.35
3/5/2012	<0.5	6.0	**6.9**	50.92
9/5/2012	0.86	9.7	1.1	53.36
3/15/2013	0.77	6.0	**2.8**	59.70

Notes:
TCE AWQS = 5 ppb
cis-1,2-DCE AWQS = 70 ppb
VC AWQS = 2.0 ppb
DTW = Depth to Water
Ft BMP = Ft below Measuring Point

As indicated by the figures for the four hydrostratigraphic units (F1, F2, F3 and F4), concentrations of VOCs have been detected in all four hydrostratigraphic units. However, in the two uppermost units (F1 and F2), contaminant concentrations (including VC) have decreased and dropped off to near "non-detect" in many cases (figures and tables, pages 14 and 15).

In Units F3 and F4, detected concentrations of TCE and cis-1,2-DCE have remained well below their AWQS. However, detected concentrations of VC have fluctuated over the nine years from 2005 to 2013 (figures and tables, pages 16 and 17).

On all four graphs (pages 14 through 17), the DTW measurements have remained higher than the VOC readings and do not appear to affect the VOC readings.

4.3 Soil Vapor Monitoring (January 2008)

On January 23-25, 2008, soil vapor sampling was conducted at the Site. The objective of the soil vapor monitoring was to obtain a consistent group of data across the Site in order to:

- Evaluate the presence of VOCs and methane in landfill gas at the Site;
- Evaluate specific soil vapor quality parameters, contaminant distribution, and trends at the Site; and,

- Identify potential air quality treatment requirements should a methane collection or extraction system be installed at the Site.

Soil vapor samples were collected and analyzed during this sampling event. The samples were analyzed for VOCs using EPA Method TO-15. The soil vapor samples were collected from shallow and deep landfill gas sampling probes at the Site. The distribution of the soil vapor COCs is provided as Figure 4.

The following summary and conclusions are provided based on data collected and evaluated during the January 2008 soil vapor monitoring event. Detected VOC concentrations are summarized on Table 4-1 below.

- PCE was detected in soil vapor samples PP-2S/D, PP-3S/D, PP-5S/D, PP-10D, PP-14D, PP-15-S/D, PP-16 S/D and PP-17S. PCE concentrations detected appear to the west and east at shallow and deeper depths of the Site.

- TCE was detected in all soil vapor samples with the exception of PP-7D, PP-11D and PP-13S/D. TCE concentrations ranged from a maximum concentration of 42 parts per billion by volume (ppbv) in PP-16S to a minimum concentration of 0.70 ppbv in PP-11S. Detected TCE concentrations appear throughout the Site.

- Cis-1,2-DCE was detected in soil vapor samples PP-3S, PP-4S/D, PP-5D, PP-6S/D, PP-7D, PP-11D, PP-12D and PP-13D. Cis-1,2-DCE concentrations ranged from a maximum concentration of 34 ppbv in PP-4D to a minimum concentration of 0.67 ppbv in PP-3S. Cis-1,2-DCE concentrations appear to the west, south, and slightly east of the Site.

- VC was detected in soil vapor samples PP-3S, PP-4S/D, PP-5D, PP-6S/D, PP-7D, PP-11D, PP-12D and PP-13D. VC concentrations ranged from a maximum concentration of 430 ppbv in PP-11D to a minimum concentration of 15 ppbv in PP-12D. VC concentrations detected at shallow and deeper depths to the west and south of the Site and at deeper depths to the east of the Site.

- Other VOCs were reported in several soil vapor samples. These VOCs were detected a low concentrations and below applicable action levels. Therefore, none of these VOCs were considered Site COCs in regards to soil vapor.

TABLE 1
SUMMARY OF VOCS OF CONCERN
EPA METHOD TO-15
SOIL VAPOR ANALYTICAL DATA

PROBES	TCE	cis-1,2-DCE	VC	Methane
PP-2S	1.2	<0.50	<0.50	0
PP-2D	0.90	<0.50	<0.50	0
PP-3S	35	0.67	20	100
PP-3D	4.2	<0.50	<0.50	0
PP-4S	10	11	20	8
PP-4D	11	34	76	0
PP-5S	0.71	<0.50	<0.50	0
PP-5D	9.6	25	240	100
PP-6S	6.6	16	170	100
PP-6D	5.5	9.7	53	100
PP-7S	2.7	<0.50	<0.50	0
PP-7D	<5.0	<5.0	6.9	0
PP-10S	1.1	<0.50	<0.50	19
PP-10D	6.9	<0.50	<0.50	1
PP-11S	0.70	<0.50	<0.50	0
PP-11D	<50	<50	430	100
PP-12S	25	<10	<10	100
PP-12D	41	14	15	100
PP-13S	<10	<10	<10	100
PP-13D	<10	14	150	100
PP-14D	1.8	<0.50	<0.50	0
PP-15S	0.94	<0.50	<0.50	0
PP-15D	6.9	<0.50	<0.50	0
PP-16S	42	<0.50	<0.50	0
PP-16D	4.4	<0.50	<0.50	0
PP-17S	2.3	<0.50	<0.50	0
PP-17D	1.5	<0.50	<0.50	0

Notes:
Concentrations are in parts per billion by volume (ppbv)

5.0 REMEDIAL OBJECTIVES

ADEQ evaluated all of the uses identified in the Use Study to determine the current uses, and potential future uses that were considered reasonably foreseeable (ADEQ and HESE, 2001). ROs were then established for these current and reasonably foreseeable uses (ADEQ, 2002).

5.1 Land Use ROs

The results of the Use Study indicated that future land use at the Estes Landfill could possibly include the following:

- A trail linkage between the Tempe Town Lake and the Phoenix Rio Salado Project for pedestrian, bike, and equestrian use;
- Redevelopment of the landfill for commercial or recreational by an outside developer;
- Surface or structure parking, surface storage, or construction of buildings and structures by the COP Aviation Department; and,
- Temporary use for material processing and a concrete batch plant.

All of the above land uses were considered reasonably foreseeable by ADEQ (ADEQ and HESE, 2001), and land use ROs were established (ADEQ, 2002). However, any stabilization of soils to support structures and removal of non-hazardous substance containing landfilled waste and debris would be conducted at the expense of the developer and/or landowner.

5.2 WATER USE ROs

ADEQ established ROs for the current use of the Bradley Production Well and future reasonably foreseeable uses by the COP, the area water provider for additional groundwater supplies potentially within the vicinity of the landfill, as follows (ADEQ, 2002):

- The RO for the current use of the Bradley Production Well for dust control is to protect, replace, or otherwise provide alternative water supply should use of the Bradley Well be lost in the future due to change in the concentration of contaminants. This action would be needed at the time when level of contamination in the Bradley Production Well, coming from the Estes Landfill plume, prohibits its intended use, and would continue as long as the Bradley Production Well is in use and/or contaminant concentrations prohibit its intended use.
- The RO for the potential use of groundwater by the COP is to restore, replace, or otherwise provide for the COP water supply if the COP needs groundwater in the vicinity of the Estes Landfill area if the identified water resources are impaired or lost by contamination emanating from the Site. The water supply to be provided for may include the potential production of one well pumping approximately 2 million gallons per day, with a utilization factor of 75%. This action would not be needed prior to the year 2020 and will be needed for as long as the level of contamination originating

from the Estes Landfill plume in the identified groundwater resource prohibits or limits its use.

6.0 FEASIBILITY STUDY RESULTS SUMMARY

During the FS, three alternatives were included based on the initial screening of remedial technologies, as summarized in Table 1 of the FS (HESE, 2002c). Based on this screening analysis, five technology options were identified for detailed examination. These technologies included the following:

1. Modification of the existing cap to include both erosion protection and storm water run-off control;
2. Groundwater extraction and treatment using Ultraviolet Light Peroxidation;
3. Natural attenuation;
4. Institutional controls; and,
5. Monitoring.

The five technologies were combined to form the following three remedial alternatives that were included in the detailed evaluation (HESE, 2002d):

A.1. More Aggressive Alternative – Plume Remediation

A.1.a. Modification of existing cap to include erosion protection and storm water runoff control;

A.1.b. Institutional controls that prevent use of on-site groundwater, and prevent any developer from altering the integrity of the cap;

A.1.c. Groundwater extraction and treatment using Ultraviolet Light Peroxidation; and,

A.1.d. Monitoring.

A.2. Reference Alternative – Source Control

A.2.a. Modification of the existing cap to include storm water run-off controls;

A.2.b. Institutional controls that prevent alteration of the integrity of the cap;

A.2.c. Natural attenuation; and,

A.2.d. Monitoring.

A.3. Less Aggressive Alternative – Monitoring

A.3.a. Institutional controls that prevent any developer from altering the integrity of the cap;

A.3.b. Natural attenuation; and,

A.3.c. Monitoring.

Detailed comparative evaluations were conducted for these remedial alternatives in accordance with the following criteria:

- A demonstration that the remedial alternative meets the ROs.
- An evaluation of the practicability in carrying out the remedial alternative.
- An evaluation of risk associated with the implementation of the remedial alternative to the overall protectiveness of public health, and aquatic and terrestrial biota under reasonably foreseeable land use scenarios and end uses of water.
- An evaluation of cost of the remedial alternative, including capital, operating, maintenance, and life cycle costs (and cost uncertainties).
- An evaluation of the benefit, or value of implementing the remedial alternative.

In the evaluation process, it was shown that the alternatives would meet the ROs (See Section 8.0). In addition, the alternatives would also be consistent with water management plans of affected water providers and general land use plans of local governments with land use jurisdiction. Based on these determinations, the detailed analysis of remedial alternatives focused on the assessment of each alternative's feasibility and overall effectiveness, based on the following four criteria:

1. Practicability;
2. Risk;
3. Cost; and,
4. Benefit.

Detailed descriptions of these evaluation criteria are provided in the FS report (HESE, 2002d).

The results of the comparative summary of the three remedial alternatives, as presented in the FS report, are provided in Table 2 of the FS (HESE, 2002d). When comparing the practicability, risk, cost, and benefit associated with each alternative; and the ability to meet ROs, the FS report surmised that the reference alternative (i.e., A2-Source Control) remained the preferred alternative. Alternative A3 was immediately ruled out because land use ROs may not be met and the risks associated with this alternative outweighed the benefits. In terms of the other two alternatives, the differences in risk reduction and benefits from implementing these alternatives were minimal, except that COCs in groundwater would be reduced in the shorter timeframe using A1 versus A2. This would potentially accelerate the remediation time frame that returns the groundwater to beneficial uses. However, because anticipated future use of groundwater within the off-site groundwater plume will not occur until 2020 and both alternatives would adequately reduce concentrations to meet AWQSs before that time-frame, there was no valid justification to expend the significantly higher costs in the implementation of A1 versus A2.

Since the FS was completed in 2002, the final proposed remedy for the Site has been changed. As concluded by the investigations that have been completed and the FS, the source of the groundwater contamination is the former liquid waste disposal pit and not the current capped landfill. The current capped landfill only contains the debris and refuse that was disposed at Estes Landfill and there is no indication that the current capped landfill is impacting groundwater quality. The location of the former liquid waste disposal pit is also no longer covered by the current capped landfill. Therefore, landfill actions such as cap maintenance, methane management, storm water management, institutional controls, and security would not be a concern of the ADEQ WQARF program and would be the responsibility of the property owner. However, restoration of the aquifer is the concern of the Arizona WQARF program. Even though a PRAP and ROD have not been finalized, ADEQ performed regular groundwater monitoring from March 2005 to March 2008, and from March 2011 to March 2013 per A2 and A3. Groundwater monitoring was not conducted during 2009 and 2010 due to lack of project funding.

The on-going groundwater monitoring program has indicated that TCE and c-1,2-DCE have been remediated below AWQSs via natural attenuation. VC is currently the only Site COC that is consistently detected in samples collected from Site monitoring wells. However, with the exception of well EW-PZ3, the VC concentrations are decreasing and are not migrating off-site. VC has fluctuated in EW-PZ3. Based on the current data, natural attenuation is currently meeting the ROs for groundwater in that COC plume remediation and migration control are occurring. Based on the current trends, the AWQS for VC should be achieved at all monitoring wells within a 15 year monitoring period. Benzene may also periodically be detected in a limited number of groundwater samples above the AWQS. However, the same bacteria that are degrading VC will remove benzene.

Considering that Land Use ROs are not required and landfill actions are not the responsibility of WQARF, the only remedy selected by this PRAP is A.3.b, Natural Attenuation and A.3.c, Monitoring.

7.0 DETAILED DESCRIPTION OF PROPOSED REMEDY

7.1 Proposed Remedy Description

The proposed remedy generally involves plume remediation by natural attenuation. The only component is performance of groundwater monitoring to evaluate trends and achievement of cleanup goals and reporting of the Site COCs. A 15 year monitoring program is proposed; however, based on the trends observed since 2005, cleanup goals will likely be achieved in less time.

7.1.1 Groundwater Monitoring and Natural Attenuation of VOCs

The proposed remedy has identified natural attenuation as the mechanism to address the VOC groundwater plume originating from the Estes Landfill. The plume of dissolved VOCs in groundwater that originates from the Site as of March 2013 is depicted on Figure 2. Groundwater is encountered beneath the Site at depths ranging from 25 to 80 feet bgs. The Salt River has the greatest hydrologic impact on local groundwater movement. During periods of no river flow, which is the dominant flow regime, groundwater flow is to the west and water levels generally decline. During periods of river flow, groundwater flow shifts to the southwest and water levels rise. The degree to which the groundwater flow direction shifts and the magnitude of the water level rise is dependent on the amount and duration of flow in the Salt River.

As discussed in the RI report (ESE, 1999) and subsequent Groundwater Monitoring Reports, VC, cis-1,2-DCE and TCE have been identified as signature compounds that are unique to the Estes Landfill plume. VC and cis-1,2-DCE were the two VOCs with the greatest concentrations in groundwater samples collected from on-site wells. These concentrations are present in lesser concentrations in groundwater samples from down gradient and cross-gradient wells. All three compounds were detected above their respective AWQS in more than one monitoring well during the December 2001 sampling event

Contaminant concentrations in groundwater have been declining over time and with distance from the source area, which is presumed to be the former liquid disposal pit located in the southern portion of the landfill. Since the last major river flow event in 1993, concentrations of COCs have declined by up to two orders of magnitude at some locations. It was noted that during large river flow events, groundwater concentrations of VC tend to spike near the source area. This concentration spike is immediately followed by a rapid decline. These spikes do not appear to affect the lateral extent of groundwater contamination over either the short or long term. Groundwater concentrations generally decline by about two orders of magnitude from the source area to the western edge of the landfill (approximately 1,700 feet). Groundwater concentrations generally decline another order of magnitude to generally below detection in an additional 1,600 feet from the western edge of the Site. Based on these findings, Site conditions supporting natural attenuation processes for the reduction of VOC concentrations appear to be present.

The two primary mechanisms controlling the attenuation of VOCs at the Site are physical and biological. The main physical attenuation mechanisms are dissolution and advection. Dissolution occurs primarily in Unit F2 beneath the source area and results in the creation of highly contaminated groundwater. This contaminated groundwater slowly migrates vertically to the more permeable adjacent Units F1 and F3, where it can migrate laterally via advective transport. During periods of river flow, rapid recharge causes hydraulic loading and upsets the established equilibrium. This effect contributes to the observed VC and Cis-1,2-DCE concentration spikes at source area wells during or immediately after a major river flow event.

An evaluation of concentration spikes over time indicates that the magnitude of the spikes is declining as a result of the reduction in contaminant mass in Unit F2. In addition, after a spike event occurs, the concentrations rapidly decline to pre-spike levels or lower. The attenuation mechanism responsible for the rapid decline in concentrations appears to be primarily related to a unique set of environmental conditions that create a sequential anaerobic-aerobic groundwater system. Biotic transformations caused by microorganisms are generally the most important transformation mechanisms in groundwater systems (Wiedemeier et. al., 1996). Detailed description of natural attenuation of VOCs at the Site is provided in the FS Report (ESE, 2001d).

Based on the evaluation of three methods of biodegradation compared to actual site data, it was concluded that there is strong evidence that natural attenuation of the signature compounds is occurring through a combination of reductive dechlorination and direct oxidation. In order to establish the clean-up timeframe in which natural attenuation would decrease the concentrations of the VOCs below their respective AWQSs, groundwater modeling was performed, which was presented in the June 19, 2002, Groundwater Modeling Report, prepared by Harding ESE (HESE, 2002a). The results of this modeling demonstrated that natural attenuation was effectively decreasing the concentration of the groundwater compounds. Model simulations indicated that: by the year 2006 cis-1,2-DCE concentrations were expected to be less than the AWQS; and VC concentrations would be less than the AWQS by 2012. In a worse case scenario, if significantly less than measured biodegradation rates were utilized, these anticipated timeframes would be increased by eight years (i.e., 2014 for cis-1,2-DCE and 2020 for VC). Actual data collected through March 2013 indicates cis-1,2-DCE concentrations are below the AWQS. Additional time will be required for VC concentrations to naturally attenuate below its AWQS.

A 15-year, long-term groundwater monitoring program will be established for the Site. However, as previously stated, it is believed that the cleanup goals for the Site can be achieved in a shorter timeframe. Groundwater monitoring will be conducted bi-annually from 2014 through 2018, and then annually from 2018 through 2028. It is assumed that the long-term monitoring program would use the existing monitoring well network, as follows:

- Wells Screened Within Unit F1: EW-1, EW-14, and EW-PZ6;
- Wells Screened Within Unit F2: EW-PZ1, EW-PZ2, EW-PZ5, and EW-PZ9;
- Wells Screened Within Unit F3: EW-5, EW-6, EW-9, EW-19, EW-27, EW-W, EW-NW, EW-E, EW-PZ3, and EW-PZ10; and,
- Wells Screened Within Unit F4: EW-8, EW-15, and EW-26.

Based on the above list, there are a total of 20 monitoring wells and piezometers to be sampled. In addition, 2 duplicate and 2 rinsate blank samples will also be collected, making a total of 24 samples collected for analysis during each monitoring event.

Each groundwater monitoring event will consist of taking groundwater elevation measurements at each of the monitoring wells. The depth to water at all of the wells will be measured within a limited time frame (12 hours or less) to reduce potential effects of barometric pressure on calculated water level evaluations. The results of the water level measurements will be properly recorded in a Field Log book. After groundwater elevation measurements have been collected, each well will be purged and groundwater samples collected and analyzed for VOCs, EPA Method 8260B.

7.1.2 Periodic Site Reviews

During the 15-year groundwater monitoring period, Periodic Site Reviews will be performed to confirm the effectiveness and adequacy of the implemented remedy in meeting ROs. Generally, the Periodic Site Reviews will be performed approximately every five years and will be conducted in accordance with the most recent guidelines provided by the ADEQ, and must include time versus concentration trends associated with the Site COCs. In addition, as part of each Periodic Site Review, it is recommended that a groundwater use survey of the Estes Community Involvement Area (ECIA) be performed in order to identify any changes to groundwater usage by the public. The first Periodic Site Review will be prepared during Fiscal Year 2019. The subsequent Periodic Site Review will be prepared during Fiscal Year 2024.

7.2 Proposed Remedy Estimated Cost

The estimated cost refers to the expense associated with the proposed remedy. The cost estimate considers capital costs and life cycle costs. The cost estimate also considered any uncertainties, if appropriate, that may affect the cost of a remedial alternative. However, the cost estimate did not consider the following criteria because the anticipated groundwater use data established in the ROs will not be until the year 2020 and it has already been determined that the proposed remedy can likely reduce the concentrations of the COCs to meet AWQSs by that date:

- Analysis of projected groundwater uses and costs associated with use-based treatment;
- Resource impairment cost of groundwater not remediated to ambient water quality; or,
- Cost of alternative water supply or wellhead treatment.

In addition, since no financial mechanism is required, transactional costs were not considered. The accuracy of the proposed remedy cost estimate developed depended upon the assumptions made with respect to the design, implementation, and operation of the remedy; it further depended on cost information available. The cost estimate based on the remedy description provided in Section 7.1 is provided below:

Table 2
Cost Estimate for Selected Remedy

Payment Period	ADEQ Fiscal Year	Groundwater Monitoring and Reporting
1	2014	$24,514
2	2015	$32,763
3	2016	$44,000
4	2017	$45,320
5	2018	$46,680
6	2019	$28,340
7	2020	$24,040
8	2021	$24,761
9	2022	$25,504
10	2023	$26,269
11	2024	$32,057
12	2025	$27,869
13	2026	$28,705
14	2027	$29,566
15	2028	$30,453
	Total Cost:	**$470,841.00**
	Average Annual Costs:	$31,389

Notes:
(1) Assumes an annual inflation rate of 3%.
(2) The present value is the amount needed to be set aside at the beginning of the remedy to assure that funds will be available in the future as they are needed; assuming certain market conditions.

The cost estimate is based on actual fees invoiced by AMEC Foster Wheeler for 2014 and the approved budget for 2015. A 3% annual inflation rate has been applied to 2016-2018. Starting in 2019, the frequency of monitoring will be decreased to once annually; therefore, the cost for the bi-annual program presented for 2018 was decreased by 50% plus a 3% annual inflation rate. From Years 7-15, a 3% annual inflation rate has been applied. Cost is increased by $5,000 in 2019 and 2024 to allow completion of the Periodic Site Review.

8.0 PROPOSED REMEDY'S ABILITY TO MEET ROS

8.1 Land Use ROs

As concluded by the investigations that have been completed and the FS, the source of the groundwater contamination is the former liquid waste disposal pit and not the current capped landfill. The current capped landfill only contains the debris and refuse that was disposed at

Estes Landfill and there is no indication that the current capped landfill is impacting groundwater quality. The location of the former liquid waste disposal pit is also no longer covered by the current capped landfill. Therefore, landfill actions such as cap maintenance, methane management, storm water management, institutional controls, and security would not be a concern of the ADEQ WQARF program and would be the responsibility of the property owner. Based on this, as of the date of this PRAP, the Land Use ROs presented by the RO Report (ADEQ, 2002) and the FS Report (HESE, 2002d) are no longer applicable.

8.2 Water Use ROs

The HHRA Update confirmed that current use of the Bradley Production Well for dust control presented a negligible health risk based on current Site groundwater conditions. Anticipated future use of the Bradley Production Well should not change. Potential future use of groundwater by the COP, within the vicinity of the Site's plume, will not be needed prior to the year 2020. Natural attenuation data collected from groundwater samples as verified in the June 19, 2002, "Groundwater Modeling Report" indicates that natural attenuation of organic COCs in the Site plume should decrease concentrations of these compounds below AWQSs before the year 2020 (HESE, 2002a). Model simulations showed that: by the year 2006, the cis-1,2-DCE concentrations were expected to be less than the AWQS; and VC concentrations would be less than the AWQS by 2012. In a worse case scenario, if significantly less than measured biodegradation rates were utilized, these anticipated timeframes would be increased by eight years (i.e., 2014 for cis-1,2-DCE and 2020 for VC).

Groundwater monitoring conducted from 2005 to March 2013 indicates that c-1,2-DCE has been remediated below the AWQS and that VC concentrations are decreasing. The decrease of the signature compounds will be continuously monitored in order to confirm organic COC concentrations will meet AWQSs before the anticipated use date. In terms of the inorganic groundwater COCs, the Draft HHRA, as confirmed by the HHRA Update, has demonstrated that exposure to these inorganic COCs will have negligible health effects (HESE, 2002b). Because the groundwater model has evaluated worse case scenarios, which have also resulted in concentrations of COCs meeting AWQS by the anticipated groundwater use date, the probability of implementing a more aggressive remedy in the future is very low. In terms of the fate and transport of the groundwater Site COCs, results of groundwater monitoring conducted at the Site, as verified in the June 19, 2002 Groundwater Modeling Report demonstrated that the off-site plume is stable (i.e., not migrating) and that concentrations are decreasing (HESE, 2002). Based on these findings, the proposed remedy would meet, in the short and long-term, the ROs established for groundwater use (see Section 5.2).

9.0 REFERENCES

AMEC, 2013, Groundwater Monitoring Report, March 2013 Monitoring Event, Estes Landfill WQARF Registry Site, Phoenix, Arizona, June 26

Arizona Department of Environmental Quality (ADEQ) and Harding ESE (HESE), 2001, Land and Water Study, A Supplement to the RI Report, Estes Landfill WQARF Site, Phoenix, Arizona, July 9.

Arizona Department of Environmental Quality (ADEQ), 2002, Final Remedial Objectives Report, Estes Landfill WQARF Site, Phoenix, Arizona, January 15.

Arizona Department of Health Services (ADHS), 1995, Draft Human Health Risk Assessment, Estes Landfill, Phoenix, Arizona, August.

Environmental Science and Engineering (ESE), 1999. Remedial Investigation, Final Report, Estes Landfill, Phoenix, Arizona, July 30.

Harding ESE (HESE) 2002a, Final Proposed Remedial Action Plan, Estes Landfill WQARF Registry Site, Phoenix, Arizona, June 27.

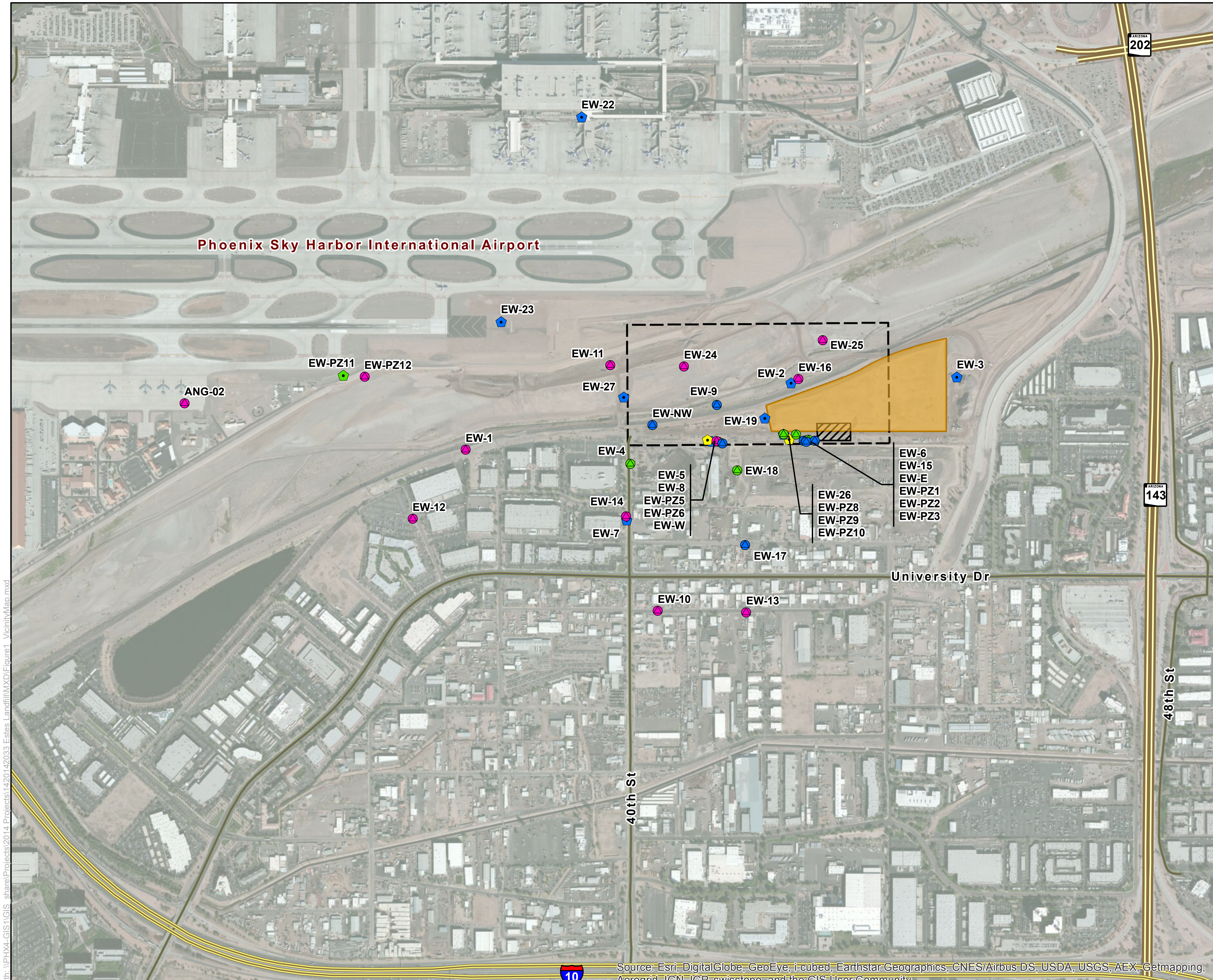
Harding ESE (HESE) 2002b, Groundwater Modeling Report, Estes Landfill WQARF Registry Site, Phoenix, Arizona, June 19.

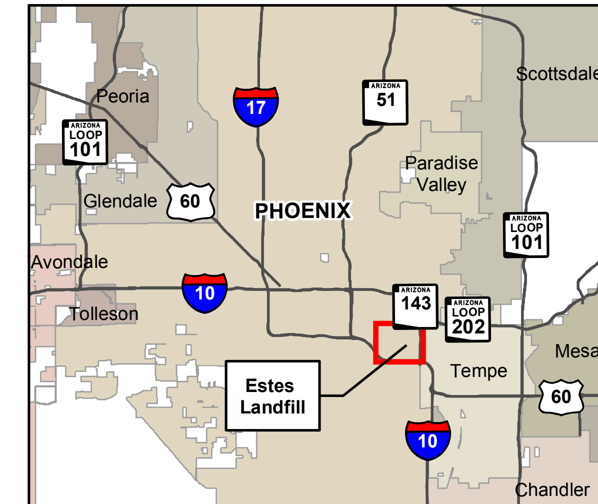
Harding ESE (HESE) 2002c, Human Health Risk Assessment Update, Estes Landfill WQARF Registry Site, Phoenix, Arizona, June.

Harding ESE (HESE) 2002d, Final Feasibility Study Report, Estes Landfill WQARF Registry Site, Phoenix, Arizona, July.

Weidemeier, T.H., Swanson, M.A., Moutoux, D.E., Wilson, J.T., Kampbell, D.H., Hanson, J.E. and Hass, 1996. “Overview of the Technical Protocol for Natural Attenuation of Chlorinated Aliphatic Hydrocarbons in Groundwater Under Development for the U.S. Air Force Center for Environmental Excellence”. In Symposium on Natural Attenuation of Chlorinated Organics in Groundwater. EPA/540/R-96/509.

FIGURES





Phoenix Metropolitan Area

Legend

Monitor Well Screened in Shallow Alluvium

- Screened in Unit F-1
- Screened in Unit F-2
- Screened in Unit F-3
- Screened in Unit F-4

Monitor Well Screened in Deep Alluvium

- Screened in Unit F-2
- Screened in Unit F-3
- Screened in Unit F-4
- Existing Boundary of Landfill
- Approximate Boundary of Former Landfill
- Former Liquid Disposal Pit

0 500 1,000 2,000 Feet

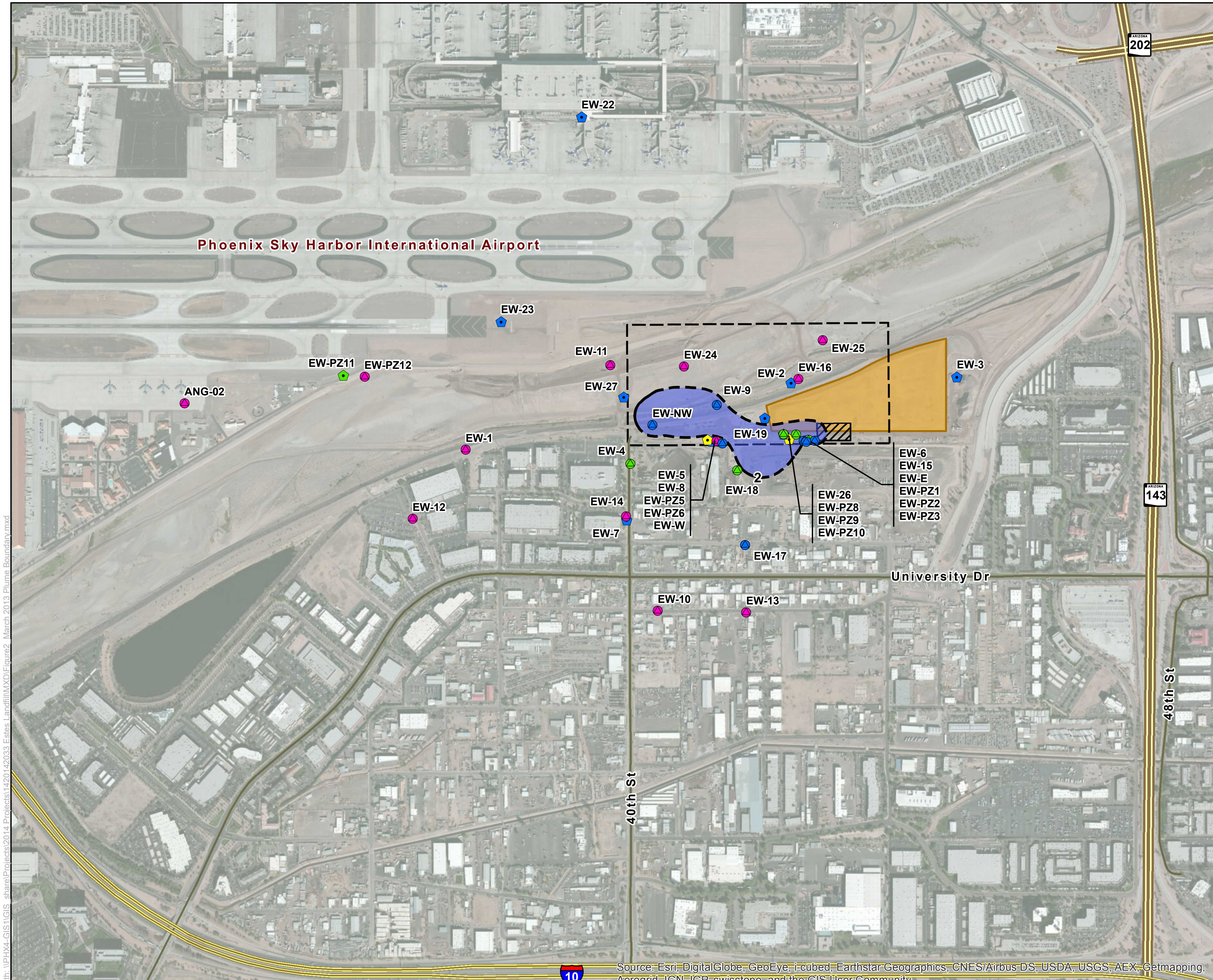
N

Proposed Remedial Action Plan
Estes Landfill, Phoenix, Arizona

Vicinity Map and Site Plan

FIGURE
1

Job No.:	1420142033
PM:	JC
Date:	1/7/2015
Scale:	1" = 1000 feet



Legend

Monitor Well Screened in Shallow Alluvium

- Screened in Unit F-1
- Screened in Unit F-2
- Screened in Unit F-3
- Screened in Unit F-4

Monitor Well Screened in Deep Alluvium

- Screened in Unit F-2
- Screened in Unit F-3
- Screened in Unit F-4

VC concentration of 2 µg/L in groundwater (dashed where inferred)

- March 2013
- Existing Boundary of Landfill
- Approximate Boundary of Former Landfill
- Former Liquid Disposal Pit

Notes:

µg/L Microgram per liter
VC Vinyl Chloride

0 500 1,000 2,000 Feet

N

Proposed Remedial Action Plan
Estes Landfill, Phoenix, Arizona

March 2013 VC Plume Boundary

FIGURE **2**

Job No.:	1420142033
PM:	JC
Date:	1/7/2015
Scale:	1" = 1000 feet

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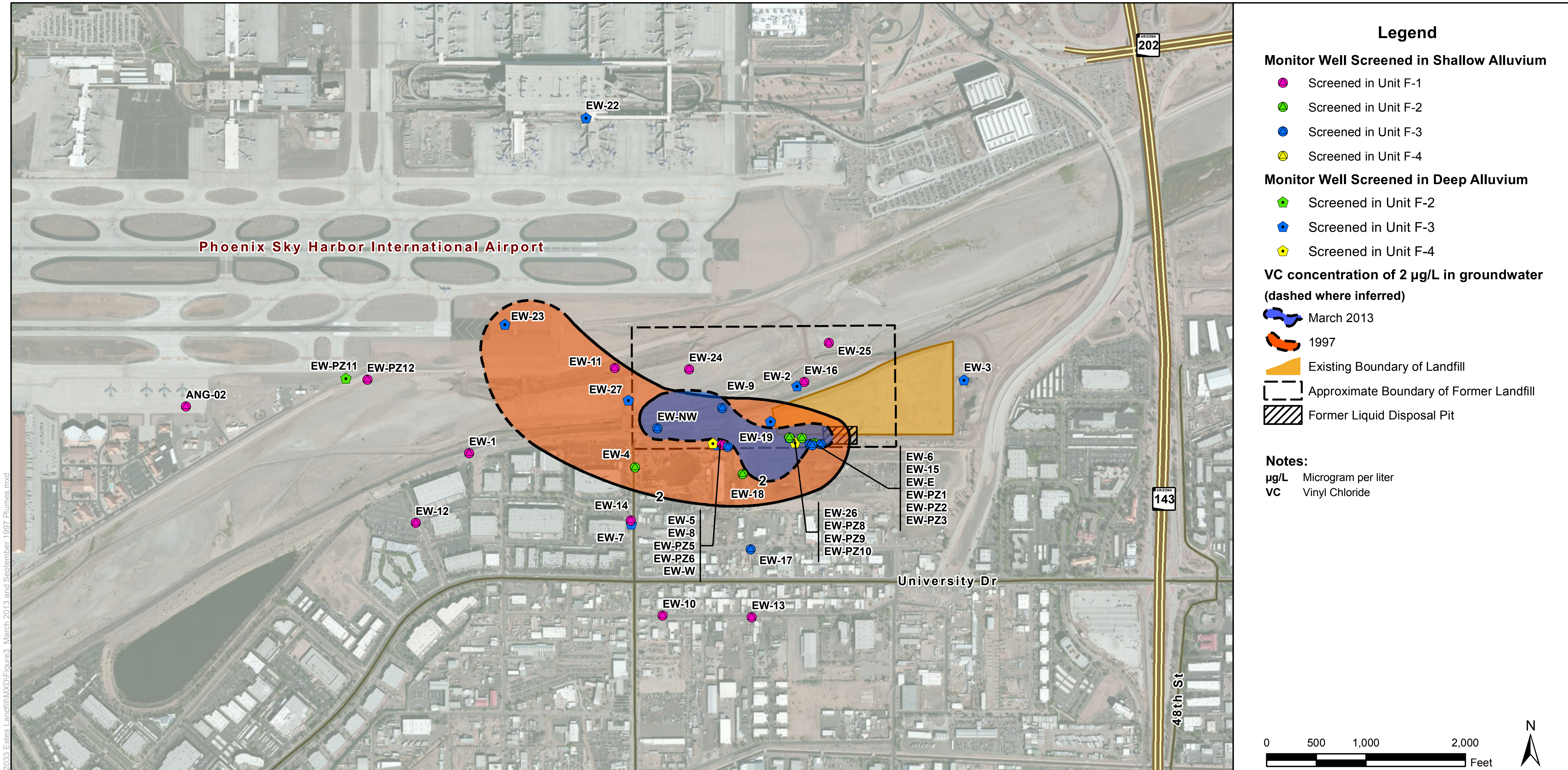
Path: \\PHX4-GIS1\GIS_share\Projects\2014 Projects\1420142033 Estes Landfill\MXD\Figure2_March 2013 Plume Boundary.mxd



Proposed Remedial Action Plan
Estes Landfill, Phoenix, Arizona

March 2013 and 1997
VC Plume Boundaries

FIGURE 3	Job No.:	1420142033
	PM:	JC
	Date:	1/7/2015
	Scale:	1" = 1000 feet

The map shown here has been created with all due and reasonable care and is strictly for use with Amec Foster Wheeler Project Number 1420142033. This map has not been certified by a licensed land surveyor, and any third party use of this map comes without warranties of any kind. Amec Foster Wheeler assumes no liability, direct or indirect, whatsoever for any such third party or unintended use.

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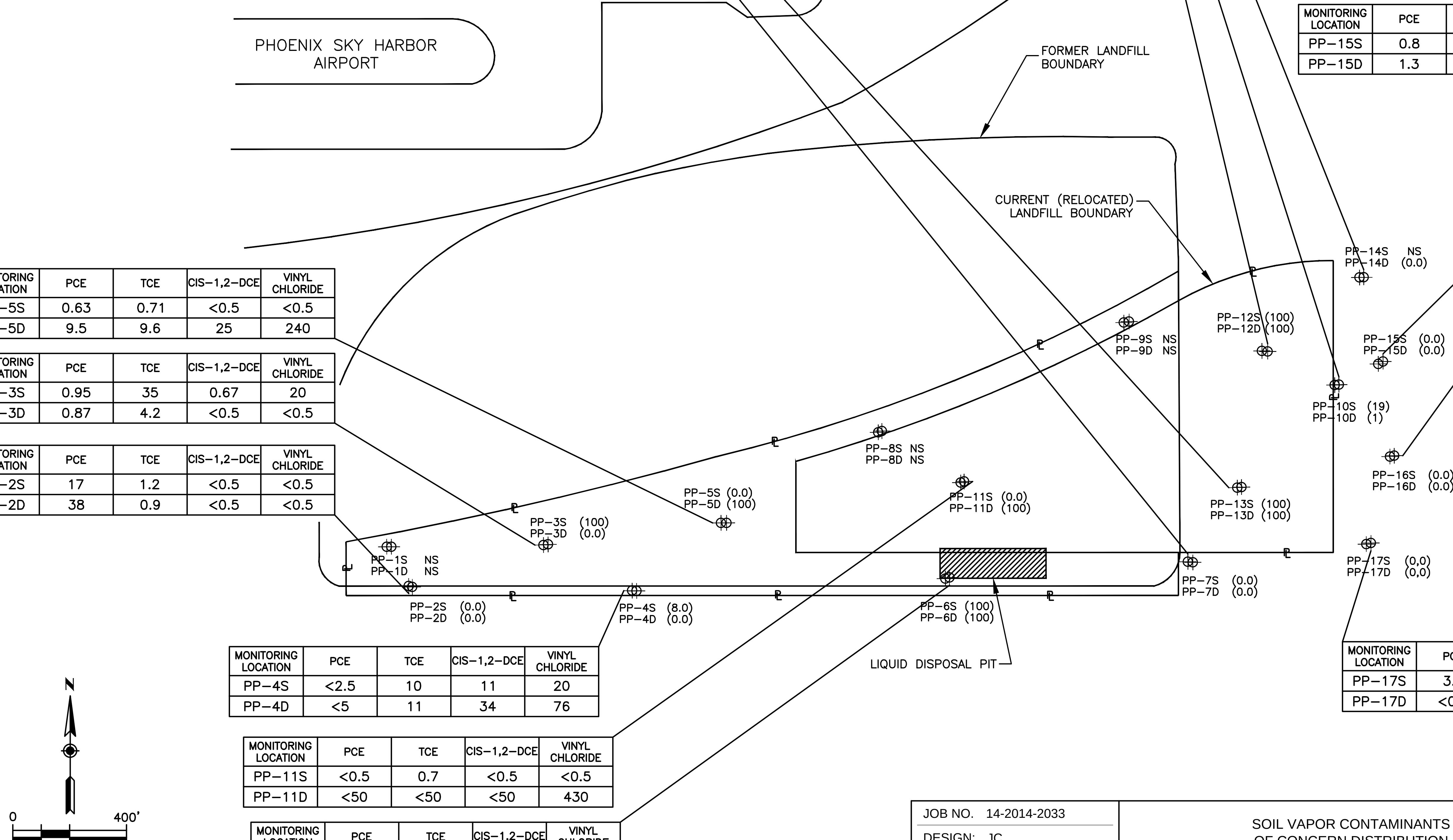
EXPLANATION

Symbol	Meaning
PP-1S / PP-1D	PERMANENT METHANE GAS MONITORING LOCATION; WHERE "S" INDICATES SHALLOW PROBE & "D" INDICATES DEEP PROBE
(0.0)	FIELD OBTAINED READINGS, IN PERCENT METHANE
<0.05	LABORATORY RESULTS
PCE	TETRACHLOROETHENE
TCE	TRICHLOROETHENE
CIS-1,2-DCE	CIS-1,2-DICHLOROETHENE
NS	NOT SAMPLED
PPbv	LABORATORY UNITS



MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-14D	0.77	1.8	<0.5	<0.5

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-13S	0.63	0.71	<0.5	<0.5
PP-13D	9.5	9.6	25	240

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-10S	<0.5	1.1	<0.5	<0.5
PP-10D	2.4	6.9	<0.5	<0.5

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-7S	0.63	0.71	<0.5	<0.5
PP-7D	9.5	9.6	25	240

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-12S	<10	25	<10	<10
PP-12D	<10	41	14	15

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-16S	4.4	42	<0.5	<0.5
PP-16D	4.1	4.4	<0.5	<0.5

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-15S	0.8	0.94	<0.5	<0.5
PP-15D	1.3	6.9	<0.5	<0.5

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-5S	0.63	0.71	<0.5	<0.5
PP-5D	9.5	9.6	25	240

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-3S	0.95	35	0.67	20
PP-3D	0.87	4.2	<0.5	<0.5

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-2S	17	1.2	<0.5	<0.5
PP-2D	38	0.9	<0.5	<0.5

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-4S	<2.5	10	11	20
PP-4D	<5	11	34	76

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-17S	3.5	2.3	<0.5	<0.5
PP-17D	<0.5	1.5	<0.5	<0.5

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-11S	<0.5	0.7	<0.5	<0.5
PP-11D	<50	<50	<50	430

MONITORING LOCATION	PCE	TCE	CIS-1,2-DCE	VINYL CHLORIDE
PP-6S	<5	6.6	16	170
PP-6D	<5	5.5	9.7	53

JOB NO.	14-2014-2033
DESIGN:	JC
DRAWN:	GWH
DATE:	1/2015
SCALE:	AS SHOWN

SOIL VAPOR CONTAMINANTS OF CONCERN DISTRIBUTION

ADEQ ESTES LANDFILL 2008

FIGURE 4

Environment & Infrastructure
4600 E. Washington St.,
Suite 600
Phoenix, Arizona
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G:\Environmental-Development\2014 Projects\14-2014-2033 Estes Landfill WQARF 2015\4.0 Project Deliverables\4.3 Drawings\Fig 4.dwg