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FINAL FEASIBILITY STUDY REPORT

ADEQ ESTES LANDFILL WQARF SITE RI/FS
PHOENIX, ARIZONA

July 3, 2002

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LIST OF ACRONYMS

AAAQG	Arizona Ambient Air Quality Guidelines
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
AWQS	Aquifer Water Quality Standards
bgs	below ground surface
COC	Compound of Concern
COP	City of Phoenix
csf	cubic feet per second
1,2-DCA	1,2-Dichloroethane
1,2-DCB	1,2-Dichlorobenzene
1,4-DCB	1,4-Dichlorobenzene
1,1-DCE	1,1-Dichloroethene
1,2-DCE	1,2-Dichloroethene
cis-1,2-DCE	cis-1,2-Dichloroethene
trans-1,2-DCE	trans-1,2-Dichloroethene
DO	Dissolved Oxygen
ECIA	Estes Community Involvement Area
ESE	Environmental Science and Engineering, Inc.
FS	Feasibility Study
FSP	Field Sampling Plan
HBGL	Health Based Guidance Level
HESE	Harding ESE
HLA	Harding Lawson Associates
NPDES	National Pollution Discharge Elimination System
O&M	Operation and Maintenance
ORP	Oxdiation Reduction Potential
PCE	Tetrachloroethene
PRAP	Proposed Remedial Action Plan
PRG	Preliminary Remediation Goal
PRPs	Potentially Responsible Parties
PSHIA	Phoenix Sky Harbor International Airport
QAPP	Quality Assurance Project Plan
RA	Risk Assessment
RI	Remedial Investigation
ROs	Remedial Objectives
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SCM	Site Conceptual Model
SRL	Soil Remediation Level

LIST OF ACRONYMS (Continued)

SWPPP	Storm Water Pollution Prevention Plan
SVOC	Semivolatile Organic Compounds
TCE	Trichloroethene
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
VC	Vinyl Chloride
VOC	Volatile Organic Compounds
WQARF	Water Quality Assurance Revolving Fund

1.0 INTRODUCTION & OBJECTIVES

In accordance with Task 3D of the January 3, 2002, "Feasibility Study Work Plan to Arizona Department of Environmental Quality (ADEQ) Work Assignment # 99-0184 for Estes Landfill Water Quality Assurance Revolving Fund (WQARF) Registry Site," this report presents the results of the Feasibility Study (FS) completed for the Estes Landfill WQARF Site as part of the Remedial Investigation/Feasibility Study (RI/FS) completion process.

Presented in the following sections are: Section 1.0 - an introduction that describes the contents of this report, and objectives section that summarizes the FS objective; Section 2.0 - a description of the site including physical location, and site hydrogeology; Section 3.0 - relevant site background information; Section 4.0 - a description of current site conditions; Section 5.0 - a description of the FS evaluation approach in identifing the remedial alternatives for detailed evaluation; Section 6.0 - a detailed analysis of each alternative; Section 7.0 - a comparison summary of each alternative; and Section 8.0 - referenced documents.

In accordance with Section R18-16-407 of the WQARF Remedy Rules, the objective of the FS is to identify and evaluate remedial alternatives to address the contaminants of concern (COCs) assessed and characterized in the RI that are present in soil, groundwater, and ambient air at the Estes Landfill WQARF Site to achieve Remdial Objectives (ROs) finalized by ADEQ on January 15, 2002 (ADEQ, 2002), and to specify the appropriate perferred remedy to be addressed in the Proposed Remedial Action Plan (PRAP). Specifically, the following three remedial alternatives were evaluated and in this FS report; no interim remedial measures have been identified for this Site:

- **A.1. More Aggressive Alternative - Plume Remediation:** Which features modification of the existing CAP to include erosion protection and storm water run-off control; institutional controls that prevent any developer from altering the integrity of the CAP; groundwater extraction and treatment using Ultraviolet Light Peroxidation; and monitoring.
- **A.2. Reference Alternative - Source Control**: Which features modification of the existing CAP to include storm water run-off control; institutional controls that prevent any developer from altering the integrity of the CAP; natural attenuation; and monitoring.
- **A.3. Less Aggressive Alternative - Monitoring**: Which features institutional controls that prevent any developer from altering the integrity of the CAP; natural attenuation; and monitoring;

A comparative evaluation was conducted for these remedial alternatives in accordance with the following criteria:

- A demonstration that the remedial alternative meets the ROs.
- An evaluation that remedial alternatives consistent with water management plans of affected water providers and the general land use plans of local governments with land use jurisdiction.
- An evaluation of the practicability of implementing the remedial alternative.
- An evaluation of risk associated with 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.

The results of the evaluation and comparison of the three remedial alternatives, are presented in this FS Report, which also identifies the preferred remedy, which may be: 1) the ***reference alternative***, 2) any of the other two alternatives evaluated, or 3) a differenct combination of remedial strategies that were included in the comparative evaluation. In presenting the preferred remedy, the FS report describes the rationale and justification for selection of the said remedy including: 1) how the preferred remedy meets the ROs; 2) how the comparison criteria were considered; and 3) how the preferred remedy meets the requirements of Arizona Revised Statute (ARS) 49-282.06.

2.0 SITE DESCRIPTION

2.1 SITE LOCATION

The Site was defined, by the ADEQ on April 28, 1998, as the Estes Landfill WQARF Registry Site, and 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 and vicinity is shown on Figure 2. 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 result from differences in the degree of sorting of the sediments. The RI report identified three distinct alluvial hydrostratigraphic units in the following order from the ground surface downward:

- Unit Fl, an unconfined, highly permeable aquifer where saturated, from the surface to approximately 60 feet;
- Unit F2, a semi-confined, low permeability aquitard from approximately 60 to 90 feet bgs; and,
- Unit F3, a semi-confined, medium permeability aquitard from approximately 90 feet bgs to the underlying sedimentary bedrock (Unit F4).

Unit F4 is well consolidated and appears to correlate with the Tertiary Tempe Beds and (older) Tertiary Camelshead Formation. The contacts between the alluvial units are gradational, whereas, the contact with underlying bedrock is well defined. Unit F2 is not continuous throughout the Site and vicinity, and where the F2 Unit is absent, Units Fl 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 periods of above-average precipitation and/or releases from upstream reservoirs have caused river flows to occur that have exceeded 100,000 cubic feet per second (cfs). These river flows cause 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 below ground surface (bgs) at the Site and are significantly impacted by recharge from 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 was primarily a municipal waste landfill, however, liquid wastes that would now be classified as hazardous wastes were also accepted. 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 25 to 80 feet.

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 1,2-Dichloroethene (1,2-DCE) and Vinyl Chloride (VC), which are degradation by products of the industrial solvent Trichloroethene (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 on the Estes Landfill.

The discovery of volatile organic compounds (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). 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 river, including Phoenix Sky Harbor International Airport (PSHIA). As a result, the COP, in conjunction with local, State and Federal flood control and transportation agencies, developed a program of 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.

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. 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; and the performances of 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 draft RI report. The SCM provided specific information on the site conditions as it relates to site hydrology, groundwater contamination sources, groundwater chemistry, and human health risk assessment (RA). In addition, the draft RI report provided information on the movement and fate and transport of the groundwater plume. In general, the conclusions reached in the Draft RI report on the source of contamination, groundwater chemistry, and RA evaluation are as follows:

- For onsite sources, the draft report concludes that the source area on the Estes landfill appears to be a liquid waste disposal pit that was located near the southeast corner of the Site.
- For off-site 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 cis-1,2-dichloroethene (cis-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 seven years of groundwater monitoring, the lateral and vertical extent of contamination from the Site is relatively stable with declining VOCs concentrations in wells downgradient to the source area demonstrating that groundwater impacts have decreased over time through natural attenuation. The draft report also concludes that site data demonstrate 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 RAs; one performed by ADHS and the other performed by HLA, concluded that the media of concern was groundwater and the chemical of concern was VC. In addition, both RAs 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 RAs differed. The RA completed by ADHS assumed potential potable use (ingestion) of the groundwater. The RA 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 RA to 1×10^{-4} in HLA's RA.

During the period from May through June 1999 ESE supervised investigative field activities at Estes. All field activities and laboratory analyses were performed following appropriate procedures in the April 30, 1999 Field Sampling Plan (FSP) and the June 7, 1999 Quality Assurance Project Plan (QAPP) for the Estes Landfill, prepared by Environmental Science and Engineering, Inc. (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. 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 Level (SRL). Because these metals are present in subsurface soils, direct human exposure was not a concern. However, the potential of these metals to leachate into the groundwater, and 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 downgradient and cross-gradient wells. In addition, VC and TCE have the two lowest Aquifer Water Quality Standards (AWQSs) of the VOC Compounds of Interest, 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. Other conclusions made in the report regarding the groundwater plume are as follows:
  - 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 river flow event in 1993, concentrations have declined 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. 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 river flow, rapid recharge causes hydraulic loading and upsets the established equilibrium. This effect contributes to the observed VC and DCE concentration spikes at source area wells during or immediately after a major river flow event.
- Natural attenuation of TCE, cis-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 Groundwater Compounds of Interest that met the criteria are as follows: VC; trans-1,2-Dichloroethene (trans-1,2-DCE); cis-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 (1,2-DCA); 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 and 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 build up of methane are currently not an issue. Should future site redevelopment be planned, which includes the construction of enclosed structures, the potential of methane creating an explosive condition would be an issue of concern. Consequently, methods to recover methane in landfills should be evaluated during the performance of the FS.
- Based on the results of the ecological screening, compounds of concern (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 indicate no adverse effects to terrestrial ecological receptors of concern. Groundwater does not pose a threat to amphibians, fish and other aquatic life that may inhabit the surface water of Southbank Lake. Based on this analysis, a more detailed ecological 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 Estes. 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 remedial 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 reevaluation of the 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 reevaluation of the subsurface soil COCs was 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. In terms of 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 and had the most conservative SRL when compared with other Thallium compounds. The results of the reevaluation 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. 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 reducing the concentration of the groundwater 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 8 years (i.e., 2014 for cis-1,2 DCE and 2020 for VC).

On July 9, 2001, a Land and Water Use Study Report was finalized and issued for public comment. This report presented a summary of current and potential future uses of land and water at the Estes Landfill 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. The results of the Use Study indicated that future land use at the Estes Landfill could possibly include: 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 use 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, although no development plans were available. In terms of groundwater use, the study concluded that there were currently no production wells within the Estes Landfill groundwater plume that have been impacted or are likely to be impacted by the plume except for the Bradley Landfill well. The Bradley Landfill immediately south of the Estes Landfill has a production well that is currently used for dust control. The well has been impacted by contaminants from the Estes Landfill, but the contamination levels do not prohibit the use of the water for dust control. No other current public or private groundwater users in the vicinity of the landfill could be identified. The possible future groundwater uses included: use of the old Estes production well; use of wells by private property owners in the vicinity of the Estes Landfill; and the general potential need by the COP, the area water provider for additional groundwater supplies from the central wellfield sometime in the future.

On January 15, 2002, the ROs were finalized by ADEQ for all of the possible uses considered as reasonably foreseeable. In terms of land uses, the ROs required that the selected final remedy must protect against possible exposure to hazardous substances in surface and subsurface soils that could occur if any of the following uses would occur: 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 use 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. 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. The final remedy will be compatible with any applicable developed plans, if available, and remedy plans would be coordinated with the developer/landowner to encourage the development of the property. In term of water uses, 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. The RO for the current use of the Bradley 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 the level of contamination in the Bradley well, coming from the Estes Landfill plume, prohibits its intended use, and would continue as long as the Bradley Well is in use and/or contaminant concentrations prohibit its intended use. The RO for the potential future 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 and the identified water resources is 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.

On February 21, 2002, Harding ESE issued two technical memorandums to ADEQ; one pertaining to the results of the investigation of former liquid disposal pit, and the other pertaining to the results of ambient air 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 Estes Landfill 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 RA, 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.

On July 2002, Harding ESE completed a Human Health Risk Assessment Update (RA Update). The RA 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 RA. This update also compared the toxicity values used in the 1995 Draft RA 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 RA update supported the following conclusions:

- Just as concluded in the draft RA, 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 $1x10^{-6}$ 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 RA of 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, indicate that there is 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 downgradient of the landfill, such an occurrence is considered unlikely.

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 December 2001. 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 and Semivolatile Organic Compound (SVOC) data has confirmed that the Site groundwater TCE plume continues to be confined to the general source area, both horizontally and vertically. The groundwater cis-1,2-DCE plume that exceeds the AWQS is with the boundary of the landfill in the north, east, and west, and extends just beyond the landfill boundary in the south. In general, cis-1,2-DCE concentrations decrease both horizontally away from the source area, and vertically at the source area. The cis-1,2-DCE concentration in well EW-18 (Bradley Well) was well below the AWQS. The groundwater VC plume extends downgradient beyond well EW-23 at concentrations exceeding the AWQS of 2 µg/l. The VC concentration in well EW-18 (Bradley Well) continues to be above the AWQS with the current concentration of 3.7 ug/l. Benzene has, occasionally, been detected in a couple of on-site wells EW-PZ5 and EW-PZ9 at concentrations exceeding the AWQS. However, the sporadic detection of Benzene in on-site wells indicates that there is no plume associated with this compound. The same can be concluded for Bis(2-ethylhexyl)phthalate, which is also sporadically detected in on-site wells occasionally exceeding the U.S Environmental Protection Agency (USEPA) Preliminary Remediation Goal (PRG). Overall, the VOC 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 current VOC 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 (HBGL) 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 RA and RA Update both confirmed that of these detected COCs, VC was the only compound that presented a risk to human health if it were used for consumption.

Review of the analytical data of all surface soil samples collected within the landfill indicates that there are no surface soil COCs that exceeds 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 locations 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 was also detected in the Liquid Disposal Pit at concentrations exceeding their respective non-residential risk-based levels. Comparison of the groundwater data to the soil COCs has confirmed that these compounds do not contribute to Site's groundwater plume. In addition, the RA Update confirmed that there were no other exposure routes associated with the presence of these compounds in subsurface soils.

Review of the analytical results of vapor/air samples 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 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.

5.0 INITIAL TECHNOLOGY SCREENING

The selection of the alternatives that were included in the detailed evaluation (Section 6.0) was based on reevaluating the initial screening of remedial technologies, the results of which were first submitted to ADEQ in Technical Memorandum dated August 25, 1999. Efforts presented and discussed in this report focused on reevaluation of the alternatives and technologies previously screened with the final ROs (ADEQ, 2002). In order to facilitate a rapid evaluation of the screening process, its major highlights and significant conclusions, results were presented primarily in tabular form (Table 1).

In addition to conforming with the approved original Task Assignment Scope of Work (TASOW), this screening process incorporated the stated desire of the ADEQ to address natural attenuation and the CERCLA Presumptive Remedy for landfills as potentially applicable approaches for the Estes Landfill WQARF site. As mentioned above, the ROs served as a primary basis for the technology screening process, as did relevant findings of the prior September 5, 1997, *Estes Landfill RI/FS Remedial Investigaion Draft Report* prepared by HLA (data from the groundwater treatability studies). In order to ensure completeness, several relevant guidance documents were also consulted including, but not limited to, "*Presumptive Remedy for CERCLA Municipal Landfill Sites, September 1993,*" "*Conducting Remedial Investigation Studies of CERCLA Municipal Landfill Sites, February 1991,*" "*Design and Construction of RCRA/CERCLA Final Covers, May 1991,*" "*Draft Process for Selecting Remedial Objectives and General Remedial Alternatives for ADEQ - Lead WQARF Sites, November 1998,*" "*Draft Remediation Risks Committee Concept Paper, May 1997,*" and "*Final Reconsiderations of the Remedy Selection Subcommittee as Approved by the Groundwater Cleanup Task Force, December 1993.*" In addition, the following reports prepared by Harding ESE (HESE) were also consulted when evaluating alternatives/technologies in the screening process: June 2002, "*Human Health Risk Assessment Update, Estes Landfill, Phoenix, Arizona,*" (RA Update); and June 19, 2002, "*Groundwater Modeling Report, Estes Landfill, Phoenix, Arizona.*"

Following assessment of available site data, review of relevant guidance documents and consideration of the final ROs, HESE identified and recommended a reference strategy as well as two alternatives, one more aggressive than the reference strategy and one less aggressive, from among the following general categories (listed in order of most aggressive to least aggressive):

- Plume Remediation;
- Physical Containment;
- Controlled Migration;

- Source Control;
- Institutional Controls;
- Monitoring (w/Institutional Controls); and
- No Action.

These general categories of remedial alternatives were originally set up to address groundwater concerns only. However, because the ROs for the Estes Landfill site indentified potential future land uses that needed to be protected from exposure to COCs in subsurface soils, HESE adjusted the alternative categories to accommodate site-specific needs. These adjustments consisted primarily of adding additional soil (treatment/containment) technology options to a typical alternative (for example, combining capping with groundwater extraction and treatment). Although this expanded the total number of singular options, the net apparent impact on total screening process was minimal. This was due largely to the fact that few technologies can be applied singularly; rather, single options are combined with one another to form effective remedial alternatives. Based upon this screening analysis of the recommended site ROs, the six available remedial alternatives, and the RA Update, HESE selected the following three alternative strategies to be included in the detailed RAE:

- **Reference Alternative - Source Control**: Which features modification of the existing CAP to include storm water run-off controls; institutional controls that prevent any developer from altering the integrity of the CAP; natural attenuation; and monitoring.
- **More Aggressive Alternative - Plume Remediation:** Which features modification of the existing CAP to include erosion protection and storm water run-off control; institutional controls that prevent any developer from altering the integrity of the CAP; groundwater extraction and treatment using Ultraviolet Light Peroxidation; and monitoring.
- **Less Aggressive Alternative - Monitoring:** Which also features institutional controls that prevent any developer from altering the integrity of the CAP; natural attenuation; and monitoring.

It was determined that all three alternative would be appropriate to sites such as Estes, and, if implemented, would achieve the final ROs, as follows:

- The RA Update concluded that health risks associated to direct exposure of surface soil COCs to on-site workers or visitors were negligible($< 1x10^{-6}$ ELCR). The RA Update further concludes that the emissions of organic compounds presented in soil gas, as confirmed by ambient air monitoring, also presents a negligible health risk to on-site workers and visitors. Lastly, the RA Update confirmed that there were no complete exposure pathways to the subsuface COCs. Based on these findings, it was concluded that the existing CAP, currently, provide an adequate barrier to prevent exposure of COCs to on-site workers and visitors. Consequently, the ROs for any land use that does not involve altering the integrity of the CAP, would be satisfied. Based on these findings, the existing CAP was applicable for inclusion in the detailed evaluation in order to satisfy the ROs established for land use.

- ADEQ has the authority in providing on-site restrictions to properties such as the Estes Landfiill. This would conclude that restrictions can be established in the final remedy that prevent any site development that alters the integrity of the CAP. Based on these findings, the implementation of institutional controls was included in the detailed evaluation the to satisfy the ROs established for land use.
- Evaluation of the existing CAP has shown that erosion controls are in place and appears to be effective in reducing the erosion of soils on top and sides of the landfill. However, properly engineered storm water run-off drainage controls have not been established. Historically, at similar landfills located adjacent to the Salt River, uncontrolled storm water run-off resulting from large storm events caused significant erosion from landfills resulting in subsurface landfill wastes and contaminated soil to be exposed, and sometimes discharged into the Salt River. Because hazardous substances have been confirmed in the subsurface soils at the site, protection against erosion of the CAP appears to be warranted to ensure that hazardous substances in subsurface soil do not become exposed or discharged into the Salt River. Based on these findings, modification of the existing CAP to include storm water run-off controls was applicable for inclusion in the detailed evaluation to further satisfy the ROs established for land use. In addition, placement of a new erosion control cover system was also included in the detailed evaluation as a more aggressive alternative.
- Gas venting, which was included for detailed evaluation in the previous screening memorandum was removed from further evaluation, because the results of the RA Update confirmed that any emissions of VOCs to the landfill surface posed a negligible health risk to any on-site worker or site visitors during, and post site development. Consequently, the need for control of VOC gases was not applicable.
- The Draft RA confirmed that the use of the Bradley Well for dust control presented a negligible health risk based on past groundwater conditions. The RA Update confirmed these findings, on current groundwater concentrations, which have significantly decreased from the data evaluated in the Draft RA. Consequently, it was determined that no interim remedial action, except for on-going monitoring, was necessary in satisfying the RO for this use.
- ROs have been established for potential future use of groundwater by the COP, within the vicinity of the Site's plume. Based on water use plans provided by the COP, this anticipated use would 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 will decrease concentrations of these compounds before the year 2020. Based on these findings, natural attenuation of groundwater COCs was included in the detailed evaluation to satisfy the ROs established for future groundwater use. This would require on-going monitoring of the Site plume to ensure that concentrations of the COCs are decreasing as projected in the groundwater model.

Based upon the screening process, six technology options were indentified for detailed evaluation (Section 6.0): modification of the existing CAP to include both erosion protection and storm water run-off control; modification of the existing CAP to include a storm water run-off control; groundwater extraction and treatment using Ultraviolet Light Peroxidation; natural attenuation; institutional controls; and monitoring.

6.0 DETAILED EVALUATION APPROACH

Based on the result of technology screening, the six technologies selected for detailed evaluation were combined to form the following three remedial alternatives:

- **A.1. More Aggressive Alternative - Plume Remediation**
  - A.1.a Modification of the existing CAP to include erosion protection and storm water runoff controls;
  - A.1.b Institutional controls that 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 runoff controls;
  - A.2.b Institutional controls that prevent any developer from altering 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.

As stated in the FS objectives (Section 1.0) comparative evaluations were conducted for these remedial alternatives in accordance with the following criteria:

- An evaluation that remedial alternatives are consistent with water management plans of affected water providers and the general land use plans of local governments with land use jurisdiction.
- 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 screening process, it was shown that the three alternatives would meet the ROs. In addition, review of land use and water management plans provided by the local government, and the affected area's water provider (i.e., COP), summarized in Use Study Report finalized by ADEQ on July 9, 2001, has shown that the three alternatives would also be consistent with water management plans of affected water providers and the 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 remaining four criteria:

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

Detailed description of these evaluation criteria are provided in the following sections.

6.1 PRACTICABILITY CRITERIA

Practicability refers to the feasibility, short- and long-term effectiveness, and reliability of the remedial alternative. The practicability of a remedial alternative can be influenced by criteria such as site-specific conditions, the chemical properties and physical distribution of contaminants, the performance capabilities of available technologies, and institutional considerations.

The ***feasibility*** of the remedial alternative can be separated into the following criteria:

- technical feasibility, e.g., the difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, and the ability to monitor the effectiveness of the remedy;
- administrative feasibility includes activities needed to coordinate with other offices and agencies, and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions);
- availability of services and materials includes the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists and provisions to ensure any necessary additional resources; the availability of services and materials; and availability of prospective technologies; and

- ease of undertaking additional remedial actions, if necessary.

The ***short-term effectiveness*** assesses the degree to which alternatives employ recycling or treatment that reduces toxicity, mobility, or volume, and how treatment is used to address the principal threats posed by the site. Factors that may be considered include the following:

- the treatment or recycling processes the alternatives employ and materials they will treat;
- the amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled;
- the type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents (EPA, 1990);
- potential impacts on workers during remedial action and the effectiveness and reliability of protective measures;
- potential environmental impacts of the remedial action, and the effectiveness and reliability of mitigative measures during implementation; and
- time until remedial action objectives are achieved (EPA, 1990).

The ***long-term effectiveness and permanence*** of alternatives are assessed considering the following:

- the degree of expected reduction in toxicity, mobility or volume of the waste due to treatment or recycling and the specification of which reduction(s) are occurring;
- the degree to which the treatment is irreversible; and
- adequacy and reliability of controls such as containment systems, and institutional controls that are necessary to manage treatment residuals and untreated waste (EPA, 1990).

6.2 RISK CRITERIA

Risk refers to the evaluation of the remedial alternatives to determine their overall protectiveness of public health and aquatic and terrestrial biota under reasonably foreseeable land use scenarios and end uses of groundwater. Issues to be considered in the risk evaluation include:

- fate and transport of contaminants, and concentrations and toxicity over life of the remediation;
- present and future land and resource use;
- exposure pathways, duration of exposure, and changes in risk over the life of the remediation;
- protection of human health and aquatic and terrestrial biota while implementing the remedial action; and,
- residual risks in the aquifer and soils at the end of remediation.

In the risk evaluation, alternatives are assessed to determine whether they can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals. The August 1995 Draft "Human Health Risk Assessment," (Draft RA) completed by the Arizona Department of Health Services (ADHS), and the June 2002 "Human Health Risk Assessment Update," (RA Update) completed by Harding ESE (HESE), served as the basis in completing the Risk evaluations in this memorandum.

6.3 COST CRITERIA

Cost refers to the expense associated with a remedial alternative. The cost analysis considers:

- capital costs;
- operating and maintenance (O&M) costs; and
- life cycle costs.

In addition, the cost analysis may also consider any uncertainties, if appropriate, that may affect the cost of a remedial alternative. However, the cost analysis will **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 all three remedial alternatives can reduce the concentrations of the COCs to meet Aquifer Water Quality Standards (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 each cost estimate developed during the detailed evaluation depends upon the assumptions made with respect to the design, implementation, and operation of an alternative; it further depends on the cost information available. To assess the degree of certainty associated with the cost estimates for each alternative, and the impact of changes in underlying assumptions, a cost sensitivity analysis is performed. The sensitivity analysis assesses assumptions associated with individual cost components and the effects they can have on the estimated cost for an alternative.

The cost sensitivity analysis varies certain assumptions to determine potential effects on the cost of each alternative. The assumptions varied include factors that possess the ability to cause significant change to total alternative costs with only small changes in values, and factors with a high degree of uncertainty associated with them. These factors include items such as operation and maintenance costs, the volume of treated material, life of the remedial action, size of the treatment system, and the combination of remedial technologies. Low, medium, and high case scenarios are developed for each alternative. A 30-year present worth cost is then prepared for the low, medium and high case scenarios of each alternative.

Attachment A provides detailed back-up associated with each alternative's cost analyses. Present-worth costs are presented assuming a 30-year operational period, as appropriate, a five percent interest rate and a three percent inflation rate.

6.4 BENEFIT CRITERIA

Benefit refers to the value of the remediation, and considers factors such as:

- lowered risk to human and aquatic and terrestrial biota;
- reduced concentration and/or volume of contaminated soil and water;
- decreased liability;
- acceptance by the public;
- aesthetics;
- preservation of existing uses;
- enhancement of future uses; and
- improvements to local economies.

7.0 DETAILED ANALYSIS OF ALTERNATIVES

The evaluations of the alternatives discussed below also addresses the degree to which the alternative would meet the ROs. Table 1 provides a summary of the detailed analysis of the alternatives and the respective technologies.

7.1 ALTERNATIVE A1 - PLUME REMEDIATION

Alternative A1 involves plume remediation and is the most aggressive alternative under this evaluation. Four separate technologies have been identified for the implementation of this alternative, as follows:

- A.1.a Modification of the existing CAP to include erosion protection, and storm water run-off controls;
- 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.

7.1.1 Description of Alternative A1- Plume Remediation

The detailed description of the four technologies incorporated into Alternative A1 is provided below.

7.1.1.1 Technology A1a - Modification of Existing CAP

Evaluation of the existing CAP on the landfill indicates some eroded areas, especially at the north side of the landfill around the access ramp leading to the top of relocated portion of the landfill. The existing CAP has erosion control, but limited perimeter drainage control of storm water run-off, which is the main cause of the erosion. Without proper storm water run-off control hazardous substance in subsurface soil may become exposed, and may be discharged to the Salt River. Based on these findings, this alternative proposes that the CAP be modified to include storm water run-off controls. In addition, as the more aggressive approach, this alternative also proposes the placement of new erosion control system.

Technology A1a would include the following components:

- filling of the eroded areas with clean fill material;
- placement of top soil on the existing CAP and seeding and mulching;
- construction of drainage swale/storm water controls to properly convey surface water run-off from the landfill CAP; and
- periodic maintenance, including maintenance and repair of the fence and cap system and access

road for 30-years.

Existing Cap Modification

The modified Cap would have an additional 18 inches of thickness to provide an adequate vegetation cover for erosion control, which would consist of the following layers (from top to bottom)

- six inches of topsoil to support a vegetative cover; and
- 12 inches of soil fill to provide a root zone and protect the underlying components;

Prior to placement of the vegetation cover soils over the Cap, on-site fill would be placed into the landfill depressions and eroded areas to the required grade. Fill would also be placed within appropriate areas of the landfill for appropriate sloping to promote proper drainage away from the landfill. It is assumed that this material should be readily available. Soil fill and topsoil would then be placed on the Cap. The topsoil would be conditioned, as needed, to support vegetative growth. The soil fill provides a root zone to establish growth while protecting the underlying Cap. Topsoil and soil fill would be obtained from local borrow sources. A perimeter drainage swale would be constructed around the base of the cap to collect surface water runoff. The swale would be lined with gravel or rip-rap to reduce erosion. Water would be directed away from the landfill through a drainage channel that would ultimately discharge to the Salt River under a National Pollution Discharge Elimination System (NPDES) permit. In addition, results of a Storm water/Erosion Control Management Study (See Following Section) may indicate that lateral drainage channels may be required on top of the Cap to redirect surface flow in areas more prone to erosion to an engineered conveyance system that would appropriately channel the water to the perimeter drainage channel.

The footprint of the cap covers approximately 45 acres. The eroded areas to be filled is assumed to be approximately 5 acres, which was determined based on visual inspections of the landfill. For the cost evaluation presented in this memorandum, it is assumed that an average 1-foot of fill will be required for the 5 acres. Consequently, approximately 8,070 cubic yards of material would be needed for this purpose. The cost evaluation also assumes that no major regrading of the landfill surface will be required. In addition, the cost evaluation assumes that no sedimentation ponds will be required prior to the discharge of the storm water to the Salt River.

Predesign Studies

In order to support the design of Technology A1a, completion of the following predesign studies would be necessary:

- *Storm water/Erosion Control Management Study*: A detailed storm water/erosion control study would be performed to evaluate appropriate design options. The results of this study would be incorporated into the detailed design to provide the erosion and sedimentation controls necessary to prevent impacts to Salt River during and after construction activities. The data collected from this study will also be used to develop a storm water pollution prevention plan (SWPPP) as required for construction sites.
- *Geotechnical Data*: Geotechnical data will be evaluated to determine the engineering properties for foundation soils within the landfill to withstand loads during the CAP modification. Geotechnical data will include evaluation original data and data collected during the RI. If sufficient geotechnical data are not available, additional data may have to be collected.

7.1.1.2 Technology A1b - Implementation of Institutional Controls

Institutional controls, would be used to prevent any development over the landfill that may damage or alter the integrity of the Cap. This form of institutional control would require some form of legal document or set of requirements established by ADEQ that restricts any proposed development of the site that may degrade the integrity of the Cap. In addition, the institutional control should further require that any development plans must address how the proposed site development will not degrade the integrity of the Cap, which will be subject to review and approval by ADEQ.

7.1.1.3 Technology A1c - Groundwater Extraction and Treatment

Based on pilot testing data conducted by HLA, Alternative A1c would include the following measures:

- Installation of eight large diameter (12-inch ID) wells across the impacted portion of the Site, in addition to one existing well (EW-RW2), for a total of nine wells as part of the groundwater extraction system. Each well will be equipped with a 150 gpm rated pump, for a maximum cumulative system flow capacity of 1,350 gpm;
- Installation of a 1,350 gpm rated groundwater treatment system, consisting of UV/peroxidation with provisions for pretreatment of metals, as necessary;
- sampling and analysis of groundwater at the treatment system in accordance with QA/QC and discharge permit requirements;
- discharge of groundwater treatment effluent to either the POTW or to the Salt River via NPDES permit;
- off-site disposal and/or further treatment or destruction of treatment residuals; and,
- operation and maintenance of the groundwater treatment system;

The following discussion provides additional details regarding components of Alternative A1c.

Groundwater Extraction

The intent of the groundwater extraction system will be to remove COCs (predominantly VOCs) from three hydrostratigraphic units identified beneath a significant portion of the Site. Based on data from previous aquifer tests at the Site, the middle unit (comprised of clayey gravel) is the least permeable, and may act as a semi-confining layer to the lower unit. It is estimated that during normal static conditions (no flow in the river), most of the groundwater yield will be from the lower hydrostratigraphic unit, capable of sustaining flow rates of at least 400 gpm.

The extraction wells will be designed to pump water from all three units. Capture zones will likely vary greatly in each of these zones. It was estimated that a conservative (average) capture zone of approximately 300 feet around each well could be achieved, with an average pumping rate of 150 gpm per well.

Influent Concentrations

Influent VOC and metal concentrations were estimated from long-term groundwater monitoring data (ESE, 1999). Actual influent concentrations would be determined during subsequent well installation and groundwater monitoring events. Inorganic concentrations (iron, manganese, hardness) were not present at levels that typically cause fouling of treatment system components via precipitation or sedimentation. Metal COC have been detected sporadically and may not necessarily require treatment to meet discharge standards; however, metals pretreatment was considered in the cost sensitivity analysis, and metals pretreatment would be revisited during the design phase. Pretreatment would address metal COC in extracted groundwater. For the purposes of equipment sizing, worst-case concentrations were used. This ensures that discharge standards can be met from the beginning of treatment system operation.

Groundwater Treatment

Aboveground treatment of extracted groundwater would involve flow equalization, followed by UV/peroxidation with discharge to either the POTW or to the Salt River Channel (under an NPDES permit). The treatment system would be constructed after the Cap modification. A road would be constructed to allow vehicles and utilities to access the facility. Groundwater would be pumped from the wells to the treatment system for treatment prior to discharge to the Salt River. Treated water would be discharged to the POTW, if a NPDES discharge permit could not be obtained.

Groundwater would be conveyed from the wells to a flow equalization tank within the treatment system. The equalization tank serves to provide adequate storage and attenuate fluctuations in flow rates. As a precautionary measure, water would be pumped from the equalization tanks through two in-line bag filters in series. The filters would remove particulates from the aqueous stream that may clog downstream processes. A 50-micron and a 10-micron filter are assumed for this alternative. Depending upon sediment loading, the bag filters would be changed periodically to ensure that flow rates are not affected. If higher sediment loading is determined during predesign studies, other filters (e.g., media filter) may be more effective in removing suspended particles. After flowing through the bag filters, water would be passed through the UV/oxidation unit.

UV/oxidation is a destruction technology that utilizes ultraviolet light and an oxidizer (usually hydrogen peroxide) to break the chemical bonds of organic compounds. The UV light breaks down the hydrogen peroxide to form free hydroxyl radicals. These radicals, coupled with the energy from the UV light, break down organic compounds. The end products from the reaction are CO_2 and water.

A typical UV/oxidation unit consists of a metering pump for the hydrogen peroxide, an in-line mixer, and a UV reactor. The hydrogen peroxide is mixed with the contaminated water prior to entering the UV reactor. The UV reactor operates at a high voltage (typically between 1,000 and 3,000 volts) to produce the energy necessary to break the chemical bonds. Depending on the flow rate and influent concentrations, multiple units may be needed. The reactor is typically housed in a stainless steel shell to prevent corrosion. For a flow rate of 1,350 gpm, 125, 20-KW lamps would be needed to reduce constituents to discharge standards. The actual design may vary based on influent concentrations and pumping rates as determined during the design phase.

After treatment, water would flow to an effluent holding tank. The tank would act as a reservoir for clean water that may be needed for maintenance of the treatment system (e.g., backwashing, cleaning).

Treated Groundwater Discharge

Water would be pumped from the effluent holding tank to the Salt River Channel through a discharge pipe. It is assumed that an NPDES discharge permit would be obtained.

Monitoring and Reviews of Treatment System

Periodic monitoring of both influent and effluent would be used to determine the efficiency of the treatment system as well as compliance with the NPDES discharge permit. Effluent monitoring would be dictated by the discharge permit. For the purposes of this evaluation, monitoring frequency is assumed to be daily for the first week, weekly for the following two months, and monthly thereafter. Samples would be analyzed for the parameters specified in the discharge sampling requirements.

7.1.1.4 Technology A1d - Monitoring and Reviews

A long-term monitoring program would be established for the Site. It is assumed that the long-term monitoring program for this alternative would use the existing monitoring well network. Groundwater would be sampled from a maximum of 31 existing monitoring wells. Samples would be analyzed for VOCs and COC inorganics (arsenic, barium, chromium, manganese, and nitrate). Groundwater monitoring will be conducted annually, however, nine contingent monitoring events will be added, that may be completed at the discretion of ADEQ, after significant storm events in which high level surface water flows are present in the Salt River.

Five-Year Site Reviews would also be performed to confirm the effectiveness and adequacy of measures implemented under Alternative A1.

7.1.2 Detailed Evaluation of Alternative A1

The detailed evaluation presented below addresses all four technologies.

7.1.2.1 Practicability of Alternative A1

Feasibility

Modification of the existing cap would be reliable and could be implemented. All of the modified cap components are well developed and readily available. Cover and storm water control systems have been successfully designed and constructed at similar sites, and experienced subcontractors are available. Periodic inspection of the cover to ensure that its integrity is maintained would be necessary and could be readily implemented. The modification of the cap will require control of dust emissions under Maricopa County regulations, and the development and implementation of a storm water pollution prevention plan (SWPPP). Storm water run-off from the cap will require a NPDES permit to discharge into the Salt River, which may limit the amount of silt being discharged to the river. Consequently, sedimentation ponds may be required before discharge of the storm water is allowed.

Institutional controls placed on property can be easily implemented, are readily enforceable, and fully feasible to restrict access or limit development of on-site land use.

Treatment of extracted groundwater would be conducted in accordance with NPDES permit requirements prior to discharge. Periodic repair of pumps and treatment equipment would be required. In addition, redevelopment of wells may be required if yields significantly decrease due to siltation or other causes. The groundwater treatment system would effectively reduce the concentration of the COC to discharge limits. UV/Oxidation is a well established and readily available groundwater treatment technology that is effective in destroying most organic compounds. Off-gas treatment may be required as well. An NPDES surface water discharge permit would be required.

The effectiveness of this remedy would be assessed through the long-term groundwater and surface water monitoring program and during the Five-Year Site Reviews.

Short-Term Effectiveness
Short-term risks to the community during modification of the cap under A1a would be controlled through special precautions. There would be an increase in truck traffic and associated noise, and an increase in dust levels associated with site preparation and cap modification. Dust control procedures (a moisturizing program) would be used to minimize fugitive dust emissions.

The implementation of A1 would require compliance with health and safety precautions and could be accomplished at minimal risk to construction workers. Safety concerns would involve the potential for normal construction-related injuries. There is little potential (RA Update) that workers may become exposed to vented gases or exposed to explosion hazards. However, open flames and smoking would be prohibited in the work area. In addition, regular monitoring of methane, oxygen, and other gases of concern would be conducted. During trench activities no workers would be allowed to go into the trench. A storm water/erosion control management study would need to be performed to ensure that impacts to Salt River are minimized during cap construction.

The time required to construct the remedy under A1a is estimated to be 20 months. Potential exposure of hazardous substances in subsurface soils due to storm water run-off erosion would be eliminated immediately upon construction of the cap. This in conjunction with institutional controls would achieve the land use ROs in the short-term.

Task	Months
Predesign Activities	5
Design	7
Modification of Cap and Groundwater Extraction and Treatment System Installation	5
Vegetation, Fence and Sign Installation, Implementation of Institutional Control	3
Total Estimated Implementation Time (Calendar)	20

Institutional controls would be effective in preventing public exposure to on-site soils. Institutional controls cannot be used to restrict off-site groundwater use from off-site plumes.

Under Alternative A1, ROs would be met in the short-term. In terms of land use ROs, the RA Update has concluded that health risks associated to direct exposure of surface soil COCs to on-site workers or visitors were negligible. The RA Update further concludes that the emissions of organic compounds presented in soil gas, as confirmed by ambient air monitoring, also presents a negligible health risk to on-site workers and visitors. Lastly, the RA Update confirmed that there were no complete exposure pathways to the subsurface COCs. Based on these findings, it must be concluded that the existing CAP appears to, currently, provide an adequate barrier to prevent exposure of COCs to on-site workers and visitors. Consequently, the ROs for any land use that does not involve altering the integrity of the CAP, would be satisfied. Institutional controls, would therefore, need to be established that would prevent any site development that alters the integrity of the CAP. Evaluation of the existing CAP has shown that erosion control has been provided for, however, proper management of storm water run-off has not been established. Historically, significant erosion of landfills due to improper control of storm water run-off during heavy storm events has resulted in subsurface landfill wastes and contaminate soil to be exposed, and sometimes discharged into the Salt River. Because hazardous substances have been confirmed in the subsurface soils at the site, providing proper storm water run-off drainage controls on the CAP appears to be necessary to ensure that hazardous substances in subsurface soil do not become exposed or discharged into the Salt River. In addition, because this alterative is considered more aggressive, placement of a new erosion protection cover is also appropriate. Based on these findings, alternative A1 would meet, in the short and long-term, the ROs established for land use.

In terms of the groundwater use ROs, the RA Update confirmed that current use of the Bradley Well for dust control presented a negligible health risk based on current site groundwater conditions. In addition, 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. Based on these findings, alternative A1 would meet, in the short and long-term, the ROs established for groundwater use.

Long-Term Effectiveness and Reliability
The performance of the modified cap system is proven, in general, to be excellent in providing a physical barrier preventing public exposure to hazardous substances including protection against erosion of the cap exposing hazardous substances in subsurface soils. The long-term effectiveness of a cap would depend on ensuring that any planned development of the landfill will not alter the integrity of the cap. This can be accomplished by implementing institutional controls that requires any planned development have plans, subject to approval by the ADEQ, to address and maintain the cap's integrity. The modified cap in conjunction with institutional control would prevent future activities that might penetrate the cap. In addition, periodic monitoring and maintenance of the cap would ensure that any integrity issues associated with the cap be identified and repaired.

As stated above implementation of institutional controls will be effective and reliable in the long-term in preventing public exposure to on-site soils.

Implementation of a groundwater extraction and treatment system under this alternative would prevent potential further migration of the Site-related VOC plume and should result in a shorter groundwater remediation time frame relative to Alternatives A2 and A3. Groundwater extraction systems have been proven reliable for the containment of contaminated groundwater; therefore, the extraction system should reliably prevent the movement of groundwater containing COC above remediation goals beyond the capture zone of the system. There would also be a reduction of the toxicity, mobility and volume of VOC COC through groundwater treatment. Only metals treatment residuals would be generated.

Under Alternative A1, ROs would be met in the long-term. As previously stated, alternative A1 would meet, in the short and long-term, the ROs established for land use. In terms of the groundwater use ROs, the RA Update confirmed that current use of the Bradley Well for dust control presented a negligible health risk based on current site groundwater conditions. Anticipated future use of the Bradley 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 biodegradation of organic COCs in the Site plume will decrease concentrations of these compounds below AWQSs before the year 2020. Implementation of the groundwater extraction and treatment system would decrease the natural attenuation remedial timeframe of COCs in reaching AWQSs. Based on these findings, alternative A1 would meet, in the long-term, the ROs established for groundwater use.

7.1.2.2 Risk Evaluation of Alternative A1

Fate and Transport of COCs

The permeability of the modified cap (A1a) at some locations within the landfill will not mitigate the transport of soil COCs to groundwater. However, the final RI (ESE, 1999) has concluded that vertical migration of soil COCs to groundwater does not occur, as verified by comparing landfill soil organic COCs to groundwater organic COCs, which has no correlation. Consequently, fate and transport of soil COCs to groundwater was not evaluated. In addition, because there are no designated surface soil COCs that present any exposure health risk (RA Update), further evaluation of the direct exposure to these COCs was not completed. The modified cap will also serve to prevent erosion of the cap to uncover COCs present in subsurface soil, thereby preventing exposure.

With regard to the organic COCs being emitted to the landfill surface, the existing cap provides an adequate barrier preventing VOCs from migrating to the landfill surface at concentrations exceeding the AAAQGs. The Draft RA and confirmed in the RA Update, also concluded that potential exposure of the VOCs in soil gas, would pose negligible health risk. Consequently, further evaluation of the fate and transport of these COCs was not completed. In terms of methane, because the modified cap will not add any layers designed to decrease the permeability of the cover, this compound was not identified as a true COC, and further evaluation on the fate and transport of methane was not completed.

In terms of the fate and transport of the groundwater organic COCs, the results of the June 2002, Groundwater Modeling Report demonstrated that, not only was the off-site plume stabile (i.e., not migrating), but that natural attenuation was effectively reducing the concentration of the groundwater COCs. Model simulations showed that: by the year 2006 the cis-1,2 DCE concentrations were expected to be less than the AWQS; and Vinyl Chloride 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 8 years (i.e., 2014 for cis-1,2 DCE and 2020 for Vinyl

Chloride). The most striking and substantial finding to the modeling conclusions is that actual site groundwater data provides documentation of a stable COC groundwater plume for the last seven years. Groundwater monitoring has provided confirming data indicating that natural attenuation processes are controlling and reducing the COC groundwater plume. The introduction of the groundwater extraction and treatment system proposed in alternative A1 would serve only to enhance and accelerate the clean up timeframe associated with these groundwater COCs.

Present and Future Land and Resource Use

The RA Update addressed the risks associated with land uses established as ROs. Implementation of alternative A1 would provide a sufficient barrier that will prevent exposure to COCs present in subsurface soils, and soil gas. In addition alternative A1 will also ensure that future exposure to subsurface soil COCs due to erosion is eliminated, and institutional controls will prevent future land development from altering the cap integrity.

For groundwater uses established as ROs, the RA Update has concluded that current use of the Bradley well is not restricted by the current concentrations of the COCs. Consequently, no interim action is necessary to provide for or replace this use. In addition, because there is no anticipated change on the use of the Bradley well, no long-term action is necessary to provide for or replace this use. The ROs was identified for potential future use of groundwater by the COP within the vicinity of the Site's plume, which would not be needed prior to the year 2020. Consequently, no interim action is necessary to provide for or replace this use. For the long-term groundwater uses established in the ROs, natural attenuation data collected from groundwater samples as verified in the June 2002, "Groundwater Modeling Report," indicates that natural biodegradation of organic COCs in the Site plume will decrease concentrations of these compounds below AWQSs before the year 2020. Implementation of the groundwater extraction and treatment system (A1) would decrease the natural attenuation remedial timeframe of COCs in reaching AWQSs.

Based on these findings, alternative A1 would not present any short-term or long-term risks to the ROs established for land and groundwater uses.

Exposure Pathways, Duration of Exposure, and Changes in Risk Over Life of Technology Implementation

The RA Update has confirmed that currently, there are no risks to exposure of surface soil COCs, and soil gas COCs. In addition, the RA Update also confirmed that there were no exposure pathways associated with subsurface soil COCs. Modification of the cap in providing storm water run-off erosion control will ensure that the existing physical barrier is properly designed to ensure future subsurface soil COCs do not become exposed. Periodic inspection and maintenance of the cap will ensure that the protectiveness and integrity of the cap is maintained. In addition, implementation of institutional controls will also ensure future site development is planned, designed, and implemented not to negatively impact the protectiveness and integrity of the cap. Implementation of Alternative A1 will ensure that no exposure pathways to subsurface soil COCs will occur in the future.

The only current exposure pathway of the groundwater COCs is the Bradley well, which is used for dust control. The RA Update has concluded that there is negligible risk associated with concentrations of the COCs present in the Bradley well and its corresponding use. In addition, because the anticipated long-term of use of the Bradley will not change, there would also be negligible risk associated with future use of the Bradley well provided that the COC concentrations do not significantly increase, or the assumed long-term usage of the Bradley well does not change. In terms of groundwater use by the COP, because there are no current production wells within or near the vicinity of the groundwater plume, there is no current compete exposure pathway for exposure to the groundwater COCs. In addition, since anticipated use of groundwater within or near the vicinity of the Estes groundwater plume would not occur until the year 2020, exposure pathways would not be complete until these wells are installed. Consequently, the main objective of the groundwater remedy from a risk standpoint would be to ensure groundwater COCs are reduced to acceptable risk exposure levels (i.e., AWQS) before the exposure pathway is completed (by 2020). Because groundwater modeling has already demonstrated that natural attenuation would achieve the risk-based objective, implementation of A1 would reduce the risk/hazard for the groundwater pathway more quickly than natural attenuation. Consequently, the primary benefit of A1 when compared to the other two alternatives (i.e., A2 and A3) is providing accelerated protection of the groundwater resource.

Protection of Human Health and Environment

Implementation of A1a and A1b would prevent the potential for direct exposure with soil and soil gas COCs. No COCs for surface soil have been identified, so no exposure or risk/hazard is associated with surface soil. Direct exposure to COCs in soil gas, as verified by ambient air monitoring does not pose a risk. In addition, there are no complete exposure pathways for COCs present in subsurface soils. In addition, implementation of A1c would reduce the exposure risk for the groundwater COCs before the exposure pathway is completed. Lastly, while monitoring (A1d) cannot achieve protection of human health and the environment, it will provide on-going data to demonstrate that groundwater COCs are being reduced to insure ROs are being met.

Residual Risk at End of Remediation
Upon completion of A1, the residual COC concentrations in the landfill soils will degrade over time while the landfill is under the control of an O&M program. Institutional controls will provide an important role for the control of residual risk going forward.

With focused remedial action such as implementation of pump-and-treat technologies as proposed in A1, cleanup objectives (AWQSs in groundwater) will be met sooner than the timeframe established for natural attenuation. The residual risk associated with attaining AWQSs in the groundwater is expected, in general, to be acceptable although some MCLs (e.g., arsenic) are also based on economic and technological feasibility. Because the remedial action to control the COC groundwater plume is a specific action to control risk/hazard from a portion of the landfill constituents, the end of remediation should be followed by monitoring of the groundwater as part of the landfill O&M program. Monitoring is expected to be a necessary component of the landfill O&M program now and in the future. It will help to document the end of the remedial action for current groundwater COC concentrations as well as provide documentation of protective conditions as time passes.

7.1.2.3 Cost Evaluation of Alternative A1
In accordance with EPA guidelines, a cost sensitivity analysis was performed, resulting in the preparation of low-, medium-, and high-cost scenarios. The costs are summarized in the table below. Back up cost tables and assumptions are presented in Attachment A.

Cost Case Scenario	Capital Cost	Present Worth O&M Cost	Total Present Worth
A1 High	$ 14,825,988	$ 13,202,113	$ 28,028,101
A1 Actual	$ 9,883,992	$ 8,801,409	$ 18,685,401
A1 Low	$ 6,918,794	$ 6,160,986	$ 13,079,780

7.1.2.4 Benefit Evaluation of A1
This action presents an advantage over a natural attenuation option (A2) or a monitoring option (A3) because it offers the potential for:

- remediating "hot spot"groundwater COC concentrations apparently associated with selected areas

of the landfill (a one-time need);
- effecting that remediation in a shorter time frame than natural attenuation; and
- when compared to A3, A1 provides a higher level of exposure protection to subsurface soil COCs.

Since the groundwater is not currently used for consumption and potential future use of groundwater for consumption would not be until 2020, a primary benefit of the groundwater cleanup is protection of the groundwater resource.

Lowered Risk to Human Health and Environment

There are no differences to the risk potential of exposure to soil COCs in alternatives A1 and A2. Implementation of both of these alternatives would lower risk to human health and environment to a degree that negligible risk would be observed for all land use ROs. However, when comparing A1 to A3, the risk to human health and environment in A1 is lower because the potential of subsurface soils COCs being exposed or discharged into the Salt River due to storm water run-off erosion has been eliminated in A1 but not in A3.

Since the groundwater is not used for consumption, and will not be used for that purpose until the year 2020, implementation of A1 would not substantially lower the risk to human health and environment when compared to A2 and A3. All three alternatives have the potential to meet groundwater use ROs.

Reduction in Concentration and/or Volume of Contaminants

Reduction of soil COC concentrations through natural biodegradation would occur at the same rate in all three alternatives. However, for groundwater COCs, alternative A1 would result in a faster reduction of groundwater concentrations in meeting AWQSs than the other two alternatives. All three alternatives can meet the groundwater use ROs.

Decreased Liability

There is less liability in implementing alternatives A1 and A2 in meeting land use ROs than alternative A3, because the potential for exposure to subsurface soil COCs in A1 and A2 have been eliminated.

A potential benefit could be realized in the faster reduction of the groundwater COC concentrations as proposed in A1, so that off-site groundwater used could be made available quickly for industrial or irrigation purposes. Consequently, there is decreased liability in the implementation of A1 versus the other two alternatives.

Public Acceptance
The activities envisioned in Alternative A1 would not need to be imposed on the public, either for traffic flow, or additional taxes beyond current conditions. A new management initiative to augment the current landfill O&M program should be comforting to the public. On this basis, public acceptance is likely to be favorable.

Aesthetics
There are no differences in aesthetics associated with alternatives A1 and A2 in that placement of a new erosion protection cover (A1) would not improve the aesthetics of the property when compared to the existing erosion protection cover (A2). However, the aesthetics of the landfill would be improved for A1 verses A3, because modification of the cap will provide engineered storm water run-off controls and greatly improved the overall appearance of the property, making future site development more attractive. In addition, some anticipated uses established in the ROs (i.e., trails) could be developed more easily. Future land use development would mean improved appearance and usefulness, thereby contributing to a net benefit in the aesthetics of the property.

Preservation of Existing Uses
The activity and use limitations necessary to control site access and prohibit the use of the groundwater in the vicinity proposed in A1 will not impair existing uses. The industrial properties in the vicinity all use municipal water. The landfill has been used as a controlled area for years. Therefore, existing uses will be preserved in Alternative A1.

Enhancement of Future Uses
Future property use has been established in the ROs. The technologies addressed in A1 would not imped future development of this property, because site development on any type of landfill would require that provisions are in place to maintain the protectiveness and integrity of the cap, which is normally funded by the site developer. Modification to the cap as proposed in A1 would enhance future uses because engineered storm water run-off controls and erosion protect controls will already be provided. If bond monies are necessary in the future for property development, or if investors might be needed, the modified control program as proposed in A1 for the landfill will facilitate the success of these efforts.

Improvements to Local Economy
Any time that property value can be enhanced, the local economy benefits. Alternative A1 is consistent with that principle in that modification of the cap will not only prevent exposure of hazardous substances

to on-site worker and/or visitors, but overall the landfill will be more aesthetically pleasing. In addition, engineered storm water controls will be provided for, making future site development more attractive. An aging landfill can be a nuisance and potential danger from exposure, or it can be a resource of property for business or the public good. Characteristics of an aging landfill must be managed, including subsidence and erosion, but a positive effort to develop the facility can result in returning the land to commerce with benefit to the City of Phoenix.

7.2 ALTERNATIVE A2 - SOURCE CONTROL

Alternative A2 involves source control with natural attenuation and is the referenced alternative under this evaluation. Four separate technologies have been identified for the implementation of this alternative, as follows:

- A.2.a Modification of the existing CAP to include storm water run-off controls;
- A.2.b Institutional controls that prevent any developer from altering the integrity of the CAP (Same as A1b);
- A.2.c Natural Attenuation; and
- A.2.d Monitoring (Same as A1d).

7.2.1 Description of Alternative A2 - Source Control

The detailed descriptions of the four technologies incorporated into Alternative A2 is provided below.

7.2.1.1 Technology A2a - Modification of Existing CAP

Evaluation of the existing CAP on the landfill indicates some eroded areas, especially at the north side of the landfill around the access ramp leading to the top of relocated portion of the landfill. The existing CAP has erosion control, but limited perimeter drainage control of storm water run-off, which is the main cause of the erosion. Without proper storm water run-off control hazardous substance in subsurface soil may become exposed, and may be discharged to the Salt River. Based on these findings, this alternative proposes that the CAP be modified to include storm water run-off controls.

Technology A2a would include the following components:

- filling of the eroded areas with clean fill material;
- construction of drainage swale/storm water controls to properly convey surface water run-off from the landfill CAP; and
- periodic maintenance, including maintenance and repair of the fence and cap system and access

road for 30-years.

Existing Cap Modification

The existing Cap would be modified to include a perimeter stormwater run-off drainage control system. Prior to the installation of the drainage system, fill would be placed into the eroded areas to the required grade. It is assumed that this material should be readily available. A perimeter drainage swale would then be constructed around the base of the cap to collect surface water runoff. The swale would be lined with gravel or rip-rap to reduce erosion. Water would be directed away from the landfill through a drainage channel that would ultimately discharge to the Salt River under a National Pollution Discharge Elimination System (NPDES) permit. In addition, results of a Storm Water Control Management Study (See Following Section) may indicate that lateral drainage channels may be required on top of the Cap to redirect surface flow in areas more prone to erosion to an engineered conveyance system that would appropriately channel the water to the perimeter drainage channel.

The footprint of the cap covers approximately 45 acres. The eroded areas to be filled is assumed to be approximately 5 acres, which was determined based on visual inspections of the landfill. For the cost evaluation presented in this memorandum, it is assumed that an average 1-foot of fill will be required for the 5 acres. Consequently, approximately 8,070 cubic yards of material would be needed for this purpose. The cost evaluation also assumes that no major regrading of the landfill surface will be required. In addition, the cost evaluation assumes that no sedimentation ponds will be required prior to the discharge of the storm water to the Salt River.

Predesign Studies

In order to support the design of Technology A2a, a *Storm Water Control Management Study* should be performed. This study would evaluate appropriate control and drainage design options based on the storm water run-off volume, pathways, flowrates, and seepage rates. The results of this study would be incorporated into the detailed design to provide the necessary controls to prevent impacts to Salt River during and after construction activities. The data collected from this study will also be used to develop a storm water pollution prevention plan (SWPPP) as required for construction sites.

7.2.1.2 Technology A2b - Implementation of Institutional Controls

The same Institutional controls described in Alternative A1b would be used to protect and preserve the integrity of the cap during site use development. Further description of this technology is provided in Section 7.1.1.2.

7.2.1.3 Technology A2c - Natural Attenuation of VOCs

The plume of dissolved VOCs in groundwater as of December 2001 that originates from the Site is depicted on Figure 1. 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 river.

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

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 (see Figure 1). Since the last major river flow event in 1993, concentrations of COC 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.

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 the F2 hydrogeologic unit beneath the source area 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 river flow, rapid recharge causes hydraulic loading and upsets the established equilibrium. This effect contributes to the observed VC and 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 the presence of a unique set of environmental conditions that creates a sequential anaerobic-aerobic groundwater system. Biotic transformations caused by microorganisms are generally the most important transformation mechanisms in groundwater systems (Wiedemeier et 1996). Biodegradation of the signature compounds has been shown to occur via three mechanisms: use as an electron acceptor (reductive dechlorination), use as an electron donor (primary substrate oxidation), and through cometabolism. These mechanisms can work alone or in combination (Wiedemeier et al., 1998).

Microbial populations use a variety of electron acceptors. Elucidating the relative importance of the terminal electron-accepting processes is key to understanding which biodegradation mechanisms may be important at the site. Generally, microorganisms use the electron acceptor that will provide them with the most energy. Consequently, electron acceptors are used, as available, in the following order of preference (beneath each electron acceptor is its resulting reduced metabolic by-product):

Dissolved oxygen (O_2) → Nitrate (NO_3^-) → Manganese (IV) (MnO_2) → Iron (III) (FeOOH) → Sulfate (SO_4^{2-}) → Carbon dioxide (CO_2)

↓ ↓ ↓ ↓ ↓ ↓

CO_2 Nitrite Manganese (II) Iron (II) Sulfite Methane

To confirm that natural attenuation through biodegradation was occurring at the Site, during the period from November 1999 to November 2000, five rounds of natural attenuation parameters were collected, the results of which were presented in applicable Groundwater Monitoring Reports issued for the period sampled.

Examining biodegradation indicator parameter measurements and signature compound concentrations provides some insight into the geochemical environment in groundwater at the Site. The following table provides a comparison between the geochemical conditions within the core of the plume and background conditions using the November 2000 analytical results (HESE, 2000).

Parameter	Units	Core of Plume (EW-PZ-1)	Background (EW-2)
TCE	(μg/L)	6.9	<2.0
Cis-1,2-DCE	(μg/L)	310	<2.0
VC	(μg/L)	99	<2.0
Ethene	(μg/L)	1.885	NA
ORP	MV	-90.3	NA
DO	(mg/L)	1.03	NA
Nitrate	(mg/L)	4.5	4
Nitrite	(mg/L)	<0.10	<0.10
Manganese (dissolved)	(mg/L)	0.20	0.039
Iron(II) – Field Measurement	(mg/L)	0.8	0.0
Sulfate	(mg/L)	88	80
Sulfide	(mg/L)	<0.10	<0.10
CO_2	(mg/L)	52	55
Methane	(mg/L)	0.06336	NA
Chloride	(mg/L)	190	190
Alkalinity	(mg/L)	270	290
TOC	(mg/L)	1.3	6.6
Hydrogen	(mg/L)	6.80	NA

The data presented in the above table show that the core of the plume is anaerobic (i.e., low dissolved oxygen [DO] concentrations and negative oxidation-reduction potential [Eh]). The parameters consistently point to the core of the plume being under more highly reducing conditions than background, which is consistent with the groundwater analytical results from previous sampling events. The data also suggest a manganese and or iron-reducing environment within the core of the plume. However, based on the data collected, it is not possible to determine which terminal electron acceptor process is most important. High concentrations of nitrate (1.8 to 6.1 milligrams per liter [mg/l]) were detected in groundwater at the background well and the wells located in the core of the plume. At these concentrations, nitrate may compete with the reductive pathways, thus inhibiting the biodegradation process. Nitrate was not detected in monitoring wells EW-9, EW-16, and EW-PZ5. Nitrite was not detected in any of the groundwater samples above the laboratory's reporting limit (i.e., less than 0.10

mg/L), except for well EW-15 in which Nitrite was detected at a concentration of 0.17 mg/l. Low concentrations of manganese (II) were detected in groundwater at all locations sampled. Sulfate concentrations in groundwater are similar throughout the site. Sulfide was detected in only one well (EW-27) at a concentration that just exceeded the detection limit; indicating sulfate reduction is not an important process at the site. Methane, ethene, and ethane were detected within the core of the plume at low concentrations. Methane, ethene, and ethane would normally be generated under methanogenic conditions. However, other indicator parameters (i.e., under methanogensis typical Eh measurements are less than –200 millivolts) indicate that methanogenesis is not prevalent within the plume.

Hydrogen, often a strong indicator of which terminal electron-accepting process is dominant, was detected at concentrations significantly higher than would be expected from the other site data. The high hydrogen concentrations may be only partly the result of native microbial process since metal buried in the landfill could result in hydrogen production and lead to the high hydrogen concentrations.

The following sections discuss how geochemical conditions at the site may relate to the three methods of biodegradation of the signature compounds.

Reductive Dechlorination

During reductive dechlorination an available organic carbon source is used as the primary substrate (electron donor) and the signature compounds or chlorinated aliphatic hydrocarbons (CAHs) are used as the terminal electron acceptor. Because the CAHs are used as the electron acceptor, for the process to occur there must be a carbon source to support microbial growth. The carbon source can be natural organic matter or anthropogenic sources such as petroleum hydrocarbons or landfill leachate. Transformation of CAHs under anaerobic conditions proceeds by sequential dechlorination through the stepwise transfer of two electrons from the donor to the CAHs, forming intermediate daughter products (Sewall and Gibson, 1997). At the Estes Landfill Site, reductive dechlorination of parent products (e.g., TCE) may occur through the series of reactions shown below:

$$\text{TCE} \Rightarrow \text{DCE} \Rightarrow \text{VC} \Rightarrow \textit{ethene}$$

Cis-1,2-DCE is the predominate form of dichloroethene (DCE) produced, when TCE undergoes reductive dechlorination and VC are both intermediates in the reductive dechlorination of TCE. Their presence at the site is strong evidence of reductive dechlorination.

Reductive dechlorination occurs most rapidly under sulfate reducing and methanogenic conditions (i.e., oxidation-reduction potentials [ORP] less than -200 millivolts [MV]), but has been demonstrated under denitrification and iron (III) reducing conditions. Reductive dechlorination will result in a decrease of parent compounds and accumulation of daughter products and chloride ions. All of the chlorinated ethenes may be degraded by reductive dechlorination, though the rate of transformation typically decreases with decreased chlorination (Wiedemeier et al., 1996). Consequently, dechlorination of TCE to DCE can occur under moderate reducing conditions whereas dechlorination of DCE to VC generally requires more strongly reducing conditions. Specifically, methanogenic conditions are reportedly required to further reduce DCE and VC (Semprini et al., 1995). If reducing conditions are not strong enough, DCE and VC will not be degraded through reductive dechlorination. These intermediates may then either accumulate or be degraded through other mechanisms. The presence of ethene in the plume suggests that there is some reductive dechlorination of VC occurring. The reductive dechlorination of VC may be occurring in pockets of methanogenic activity within the plume. Perhaps more likely, reductive dechlorination of VC may be ongoing at a slow rate within the more iron reducing conditions that are more prevalent in the plume.

With methanogenic conditions apparently rare within the plume, DCE and VC would be expected to accumulate, if reductive dechlorination was the dominant degradation mechanism. However, evaluation of CAH concentrations over time in monitoring well EW-PZ1 located near the source suggests that, not only is DCE and VC are not accumulating, all of the CAH concentrations appear to be declining at similar rates. This is further confirmed by examining the trend of one year's data (2000) of the CAHs in other source wells, which also indicates that the CAHs are declining. The absence of daughter compounds accumulating in the aquifer is therefore conspicuous, and suggests that mechanisms other than reductive dechlorination are acting upon DCE and VC to reduce their concentrations.

To further evaluate reductive dechlorination, a screening of the November 2000 groundwater sampling results for evidence of reductive dechlorination was conducted as described in United States Environmental Protection Agency (USEPA's) *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water* (Weidemeier et al., 1998). The screening process utilizes indicator parameters, including natural electron acceptors, to recognize geochemical environments, where reductive dechlorination is possible. The summary of the indicator parameters and weighting factors used for the preliminary screening for anaerobic biodegradation processes is provided in the following Table. It is important to note that this analysis does not factor in any other transformation mechanisms besides reductive dechlorination (Weidemeier et al., 1998).

Analyte	Concentration in Most Contaminated Zone	Interpretation	Points Awarded
Oxygen	<0.5 mg/L	Tolerated; suppresses reductive (dechlorination) pathway at higher concentrations	3
Oxygen	>5 mg/L	Not tolerated; however, vinyl chloride may be oxidized aerobically	-3
Nitrate	<1 mg/L	At higher concentrations may compete with reductive pathway	2
Iron (II)	>1 mg/L	Reductive pathway possible; vinyl chloride may be oxidized under Fe(III)-reducing conditions	3
Sulfate	<20 mg/L	At higher concentrations may compete with reductive pathway	2
Sulfide	>1 mg/L	Reductive pathway possible	3
Methane	<0.5 mg/L >0.5 mg/L	Vinyl chloride oxidizes Ultimate reductive daughter product, Vinyl chloride accumulates	0 3
Oxidation Reduction Potential (ORP) against Ag/AgCI electrode	<50 millivolts (mV) <-100 mV	Reductive pathway possible Reductive pathway likely	1 2
PH	5<pH<9 5>pH>9	Optimal range for reductive pathway Outside optimal range for reductive pathway	0 -2
TOC	>20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	2
Temperature	>20EC (68EF)	At T>20EC, biochemical process is accelerated	1
Carbon Dioxide	>2x background	Ultimate oxidative daughter product	1
Alkalinity	>2x background	Results from interaction of carbon dioxide with aquifer minerals	1
Chloride	>2x background	Daughter product of organic chlorine	2
Hydrogen	>1 nM	Reductive pathway possible; vinyl chloride may accumulate	3
Hydrogen	<1 nM	Vinyl chloride oxidized	0

Analyte	Concentration in Most Contaminated Zone	Interpretation	Points Awarded
Volatile Fatty Acids	>0.1 mg/L	Intermediates resulting from biodegradation of more complex compounds; carbon and energy source	2
BTEX	>0.1 mg/L	Carbon and energy source; drives dechlorination	2
Tetrachloroethene (PCE)		Material released	0
Trichloroethene (TCE)		Material released Daughter product of PCE	0 2
Dichloroethene (DCE)		Material released Daughter product of TCE If cis is >80% of total DCE it is likely a daughter product 1,1-DCE can be a chemical reaction product of TCA	0 2
Vinyl Chloride (VC)		Material released Daughter product of DCE	0 2
1,1,1-Trichloroethane (TCA)		Material released	0
Dichloroethane (DCA)		Daughter product of TCA under reducing conditions	2
Ethene/Ethane	>0.01 mg/L >0.1 mg/L	Daughter product of vinyl chloride/ethene	2 3

The weighting factors used for the preliminary screening for anaerobic biodegradation processes are then totaled and the points are compared to evidence of biodegradation as follows:

- 0 - 5 Points: Inadequate Evidence of Biodegradation;
- 6 - 14 Points: Limited Evidence of Biodegradation;
- 15 - 20 Points: Adequate Evidence of Biodegradation; and
- > 20 Points: Strong Evidence of Biodegradation.

Examination of the November 2000 site data for wells considered representative of background, source, leading edge and downgradient areas of the Site in accordance with the biodegradation screening protocol, showed limited evidence that reductive dechlorination is still occurring within the CAH plume.

Currently, reductive dechlorination may be contributing to the degradation of TCE, DCE, and VC but other mechanisms may also be significant to the degradation process. Review of all the year 2000 data also confirms that there is limited evidence that reductive dechlorination is occurring within the CAH plume.

Primary Substrate Oxidation

In the process of direct oxidation, microorganisms utilize the CAH as the electron donors in a series of oxidation-reduction (redox) reactions. Unlike reductive dechlorination, the CAH are oxidized (i.e., used as the primary growth substrate by the microbial consortium) instead of being reduced. Compounds such as *cis*-1,2-DCE and VC may be directly metabolized by subsurface microorganisms, resulting in mineralization to carbon dioxide, water, and chloride. The lesser chlorinated ethenes (e.g., DCE and VC) can be used as primary substrates. The more highly chlorinated ethenes (TCE) are not likely to serve as primary substrates or electron donors. It is important to note that this process may be either aerobic or anaerobic. For example, direct oxidation of *cis*-1,2-DCE has been shown to occur either aerobically (Bradley and Chapelle, 1998, Sewall and Gibson, 1997) or anaerobically during the reduction of manganese and naturally occurring organic matter (Bradley, Chapelle and Lovley, 1998; Bradley, Lanmeyer and Dinicola, 1998). Several studies have indicated that DCE and VC can be oxidized in iron reducing and methanogenic conditions in addition to aerobic conditions (Bradley and Chapelle, 1997, 1996; Klier et al., 1998).

A plausible explanation for the apparent lack of daughter product accumulation, which would be expected for reductive dechlorination under mildly reducing conditions, is that DCE and VC are being oxidized to carbon dioxide, water and chloride. As noted previously, this metabolism of DCE or VC may occur in either aerobic or anaerobic conditions. Increased concentrations of carbon dioxide and chloride, two of the ultimate end products of the mineralization of DCE and VC, would provide direct evidence that direct oxidation is occurring at this site. Carbon dioxide concentrations do appear to be elevated within the plume (i.e., monitoring well EW-PZ8). However, the background concentration variability of these two analytes at the site is significant enough to mask any change in concentration potentially produced by primary substrate oxidation. Therefore, while appropriate conditions exist at the site to support direct oxidation of DCE and VC, it is not possible to determine conclusively whether this mechanism is occurring. Nonetheless, due to the continued decrease in DCE and VC concentrations, and the general absence (or low concentrations) of ethane and ethene across the site, there is a strong possibility that direct oxidation of DCE and VC may be occurring.

Cometabolism
A CAH biodegraded through cometabolism is degraded by an enzyme or cofactor that is fortuitously produced by organisms for other purposes. During cometabolism CAHs are indirectly transformed by bacteria using another substrate to meet their energy requirements. The bacteria then derive no benefit from the degradation of CAHs. Cometabolism is best documented under aerobic conditions but may occur under anaerobic conditions. The rate of cometabolism of CAH compounds is reported to increase as the degree of chlorination decreases (for example VC will degrade by cometabolism more quickly than TCE) (Wiedemeier, 1998). Because cometabolism is typically an aerobic process and that the core of the plume at the site is primarily anaerobic, it is unlikely that cometabolism is an important degradation mechanism at the site.

Natural Attenuation Conclusion
Based on the evaluation of three methods of biodegradation compared to actual site data, it has been 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 addition, the natural attenuation groundwater modeling of the signature compounds, presented in the June 2002, Groundwater Modeling Report, demonstrated that natural attenuation was effectively reducing the concentration of the groundwater compounds. Model simulations also indicated that: by the year 2006 cis-1,2 DCE concentrations were expected to be less than the AWQS; and Vinyl Chloride 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 8 years (i.e., 2014 for cis-1,2 DCE and 2020 for Vinyl Chloride). All of these findings would be evaluated by conducting annual monitoring for natural attenuation parameters. Consequently, implementation of A2c appears to be a viable option in addressing the groundwater plume. However, implementation of this technology will require on-going evaluation and assessment of natural attenuation indicator parameters during the monitoring program.

7.2.1.4 Technology A2d - Monitoring and Reviews
The same monitoring and review program described in Alternative A1d would be used to monitor the decrease of groundwater organic COCs, through natural attenuation. Further description of this technology is provided in Section 7.1.1.4.

7.2.2 Detailed Evaluation of Alternative A2
The detailed evaluation presented below addresses all four technologies.

7.2.2.1 Practicality of Alternative A2

Feasibility

Modification of the existing cap would be reliable and could be implemented. All of the modified cap components are well developed and readily available. Storm water control systems have been successfully designed and constructed at similar sites, and experienced subcontractors are available. Periodic inspection of the cover to ensure that its integrity is maintained would be necessary and could be readily implemented. The modification of the cap will require control of dust emissions under Maricopa County regulations and the development and implementation of a storm water pollution prevention plan (SWPPP). Storm water run-off from the cap will require a NPDES permit to discharges into the Salt River, which may limit the amount of silt being discharged to the river. Consequently, sedimentation ponds may be required before discharge of the storm water is allowed. Institutional controls placed on property can be easily implemented, are readily enforceable, and fully feasible to restrict access or limit development to on-site land.

No active remediation of contaminated groundwater would be undertaken as part of the alternative, but concentrations of COCs in groundwater would continue to decrease via natural attenuation processes and dilution. Periodic monitoring of groundwater (A2d) would be easily implemented using standard, reliable techniques. Materials and qualified personnel to conduct the monitoring would be readily available. In addition, the effectiveness of this remedy would be assessed through the long-term groundwater and surface water monitoring program and during the Five-Year Site Reviews.

Short-Term Effectiveness

Short-term risks to the community during modification of the cap under A2a would be controlled through special precautions. There would be an increase in truck traffic and associated noise, and an increase in dust levels associated with site preparation and cap modification. Dust control procedures (a moisturizing program) would be used to minimize fugitive dust emissions.

The implementation of A2 would require compliance with health and safety precautions and could be accomplished at minimal risk to construction workers. Safety concerns would involve the potential for normal construction-related injuries. There is little potential (RA Update) that workers may become exposed to vented gases or exposed to explosion hazards. However, open flames and smoking would be prohibited in the work area. In addition, regular monitoring of methane, oxygen, and other gases of concern would be conducted. During trench activities no workers would be allowed to go into the trench. A storm water/erosion control management study would need to be performed to ensure that impacts to

Salt River are minimized during cap construction.

The time required to construct the remedy under A2 is estimated to be 15 months. Potential exposure of hazardous substances in subsurface soils due to storm water run-off erosion would be eliminated immediately upon construction of the cap. This in conjunction with institutional controls would achieve the land use ROs in the short-term.

Task	Months
Predesign Activities	4
Design	5
Modification of the Cap	3
Fence and Sign Installation, Implementation of Institutional Controls	3
Total Estimated Implementation Time (Calendar)	15

Institutional controls (A2b) would be effective in preventing public exposure to on-site soils. Institutional controls cannot be used to restrict off-site groundwater use from off-site plumes.

Under Alternative A2, ROs would be met in the short-term. In terms of land use ROs, the RA Update has concluded that health risks associated to direct exposure of surface soil COCs to on-site workers or visitors were negligible. The RA Update further concludes that the emissions of organic compounds presented in soil gas, as confirmed by ambient air monitoring, also presents a negligible health risk to on-site workers and visitors. Lastly, the RA Update confirmed that there were no complete exposure pathways to the subsurface COCs. Based on these findings, it must be concluded that the existing CAP appears to, currently, provide an adequate barrier to prevent exposure of COCs to on-site workers and visitors. Consequently, the ROs for any land use that does not involve altering the integrity of the CAP, would be satisfied. Institutional controls, would therefore, need to be established that would prevent any site development that alters the integrity of the CAP. Evaluation of the existing CAP has shown that erosion control has been provided for, however, proper management of storm water run-off has not been established. Historically, significant erosion of landfills due to improper control of storm water run-off during heavy storm events has resulted in subsurface landfill wastes and contaminate soil to be exposed, and sometimes discharged into the Salt River. Because hazardous substances have been confirmed in the subsurface soils at the site, providing a proper engineered storm water control system to minimize erosion appears to be necessary to ensure that hazardous substances in subsurface soil do not become exposed or discharged into the Salt River. Based on these findings, alternative A2 would meet, in the short and long-term, the ROs established for land use.

In terms of the groundwater use ROs, the RA Update confirmed that current use of the Bradley Well for dust control presented a negligible health risk based on current site groundwater conditions. In addition, 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. Based on these findings, alternative A2 would meet, in the short-term, the ROs established for groundwater use.

Long-Term Effectiveness and Reliability
The peformance of the existing cap system has proven, in general, to be excellent in providing a physical barrier preventing public exposure to hazardous substances, and in providing adequate erosion control. The placement of an engineered storm water run-off control system will ensure long-term protection against erosion of the cap exposing hazardous substances in subsurface soils. The long-term effectiveness of a cap would depend on ensuring that any planned development of the landfill will not alter the integrity of the cap. This can be accomplished by implementing institutional controls that requires any planned development have plans, subject to approval by the ADEQ, to address and maintain the cap's integrity. The modified cap in conjunction with institutional control would prevent future activities that might penetrate the cap. In addition, periodic monitoring and maintenance of the cap would ensure that any integrity issues associated with the cap be identified and repaired.

As stated above implementation of institutional controls will be effective and reliable in the long-term in preventing public exposure to on-site soils.

Under alternative A2, no active remedial measures of the contaminated ground water will be conducted. However, evaluation of monitoring data (HESE, 2000) as confirmed by groundwater modeling (HESE, 2002) has shown that natural attenuation mechanisms have prevented further migration of the plume and is continuing to reduce the concentrations of the groundwater COCs. This rate of reduction is assumed to be slower than alternative A1. Consequently, natural attenuation is a viable remedial option, which has been proven reliable, based on site conditions (like Estes), for the containment of contaminated groundwater, and reduction of the toxicity, mobility and volume of VOC COC. Inorganic COCs present in the groundwater plume would not be addressed. However, the Draft RA and RA Update have concluded that there is negligible risk associated with exposure to the concentrations of these compounds found in the off-site plume.

Under Alternative A2, ROs would be met in the long-term. As previously stated, alternative A2 would meet, in the short and long-term, the ROs established for land use. In terms of the groundwater use ROs, the RA Update confirmed that current use of the Bradley Well for dust control presented a negligible health risk based on current site groundwater conditions. Anticipated future use of the Bradley 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 2002, "Groundwater Modeling Report," indicates that natural biodegradation of organic COCs in the Site plume will decrease concentrations of these compounds below AWQSs before the year 2020. This decrease of the signature compounds will be continuously monitored (A2d) in order to confirm COC concentrations will meet AWQSs before the anticipated use date. Based on these findings, alternative A2 would meet, in the long-term, the ROs established for groundwater use.

7.2.2.2 Risk Evaluation of Alternative A2

Fate and Transport of COCs

The permeability of the modified cap (A2a) at some locations within the landfill will not mitigate the transport of soil COCs to groundwater. However, the final RI (ESE, 1999) has concluded that vertical migration of soil COCs to groundwater does not occur, as verified by comparing landfill soil organic COCs to groundwater organic COCs, which has no correlation. Consequently, fate and transport of soil COCs to groundwater was not evaluated. In addition, because there are no designated surface soil COCs that present any exposure health risk (RA Update), further evaluation of the direct exposure to these COCs was not completed. The modified cap will also serve to prevent erosion of the cap to uncover COCs present in subsurface soil, thereby preventing exposure.

With regard to the organic COCs being emitted to the landfill surface, the existing cap provides an adequate barrier preventing VOCs from migrating to the landfill surface at concentrations exceeding the AAAQGs. The Draft RA and confirmed in the RA Update, also concluded that potential exposure of the VOCs in soil gas, would pose negligible health risk. Consequently, further evaluation of the fate and transport of these COCs was not completed. In terms of methane, because the modified cap will not add any layer that is designed to decrease the permeability of the cover, this compound was not identified as a true COC, and further evaluation on the fate and transport of methane was not completed.

In terms of the fate and transport of the groundwater organic COCs, the results of the June 2002, Groundwater Modeling Report demonstrated that, not only was the off-site plume stabile (i.e., not migrating), but that natural attenuation was effectively reducing the concentration of the groundwater COCs. Model simulations showed that: by the year 2006 the cis-1,2 DCE concentrations were expected to be less than the AWQS; and Vinyl Chloride 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 8 years (i.e., 2014 for cis-1,2 DCE and 2020 for Vinyl Chloride). The most striking and substantial finding to the modeling conclusions is that actual site groundwater data provides documentation of a stable COC groundwater plume for the last seven years. Groundwater monitoring has provided confirming data indicating that natural attenuation processes are controlling and reducing the COC groundwater plume.

Present and Future Land and Resource Use

The RA Update addressed the risks associated with land uses established as ROs. Implementation of alternative A2 would provide a sufficient barrier that will prevent exposure to COCs present in subsurface soils, and soil gas. In addition alternative A2 will also ensure that future exposure to subsurface soil COCs due to erosion is eliminated, and institutional controls will prevent future land development from altering the cap integrity.

For groundwater uses established as ROs, the RA Update has concluded that current use of the Bradley well is not restricted by the current concentrations of the COCs. Consequently, no interim action is necessary to provide for or replace this use. In addition, because there is no anticipated change on the use of the Bradley well, no long-term action is necessary to provide for or replace this use. The ROs was identified for potential future use of groundwater by the COP within the vicinity of the Site's plume, which would not be needed prior to the year 2020. Consequently, no interim action is necessary to provide for or replace this use. For the long-term groundwater uses established in the ROs, natural attenuation data collected from groundwater samples as verified in the February 21, 2001, "Groundwater Modeling Report," indicates that natural biodegradation of organic COCs in the Site plume will decrease concentrations of these compounds below AWQSs before the year 2020.

Based on these findings, alternative A2 would not present any short-term or long-term risks to the ROs established for land and groundwater uses.

Exposure Pathways, Duration of Exposure, and Changes in Risk Over Life of Technology Implementation

The RA Update has confirmed that currently, there are no risks to exposure of surface soil COCs, and soil gas COCs. In addition, the RA Update also confirmed that there were no exposure pathways associated with subsurface soil COCs. Modification of the cap in providing storm water run-off control will ensure that the existing physical barrier is properly designed to ensure future subsurface soil COCs do not become exposed. Periodic inspection and maintenance of the cap will ensure that the protectiveness and integrity of the cap is maintained. In addition, implementation of institutional controls will also ensure future site development is planned, designed, and implemented not to negatively impact the protectiveness and integrity of the cap. Implementation of Alternative A2, will ensure that no exposure pathways to subsurface soil COCs will occur in the future.

The only current exposure pathway of the groundwater COCs is the Bradley well, which is used for dust control. The RA Update has concluded that there is negligible risk associated with concentrations of the COCs present in the Bradley well and its corresponding use. In addition, because the anticipated long-term of use of the Bradley will not change, there would also be negligible risk associated with future use of the Bradley well provided that the COC concentrations do not significantly increase, or the assumed long-term usage of the Bradley well does not change. In terms of groundwater use by the COP, because there are no current production wells within or near the vicinity of the groundwater plume, there is no current compete exposure pathway for exposure to the groundwater COCs. In addition, since anticipated use of groundwater within or near the vicinity of the Estes groundwater plume would not occur until the year 2020, exposure pathways would not be complete until these wells are installed. Consequently, the main objective of the groundwater remedy from a risk standpoint would be to ensure groundwater COCs are reduced to acceptable risk exposure levels (i.e., AWQS) before the exposure pathway is completed (by 2020). Groundwater modeling has already demonstrated that natural attenuation would achieve the risk-based objective, for the organic COCs. Consequently only inorganic groundwater COCs would remain, which have been demonstrated in the Draft RA and RA Update to have negligible heath effects if exposed.

Protection of Human Health and Environment

Implementation of A2a and A2b would prevent the potential for direct exposure with soil and soil gas COCs. No COCs for surface soil have been identified, so no exposure or risk/hazard is associated with surface soil. Direct exposure to COCs in soil gas, as verified by ambient air monitoring does not pose a health risk. In addition, there are no complete exposure pathways for COCs present in subsurface soils.

In addition, implementation of A2c would reduce the exposure risk for the groundwater organic COCs before the exposure pathway is completed. Consequently only inorganic groundwater COCs would remain, which have been demonstrated in the Draft RA and RA Update to have negligible heath effects if consumed. Lastly, while monitoring (A2d) cannot achieve protection of human health and the environment, it will provide on-going data to demonstrate that groundwater COCs are being reduced to insure ROs are being met. Overall implementation of A2 would be protective of human health and environment in the short and long-term.

Residual Risk at End of Remediation

Upon completion of A2, the residual organic COC concentrations in the landfill soils will eventually degrade over time while the landfill is under the control of an O&M program. Institutional controls will provide an important role for the control of residual risk going forward.

As previously stated, natural attenuation would be effective in reducing the concentration of organic COCs in groundwater to meet AWQSs before the anticipated use date. The residual risk associated with attaining AWQSs in the groundwater is expected, in general, to be acceptable although some AWQSs (e.g., arsenic) are also based on economic and technological feasibility. Inorganic COCs would also represent residual risk since natural attenuation would not address these compounds. The concentrations of the inorganic groundwater COCs found within the off-site plume have been demonstrated in the Draft RA and RA Update to have negligible heath effects if consumed. Monitoring is expected to be a necessary component of the landfill O&M program now and in the future. It will help to document the end of the remedial action for current groundwater COC concentrations and to provide documentation of protective conditions as time passes.

7.2.2.3 Cost Evaluation of Alternative A2

In accordance with EPA guidelines, a cost sensitivity analysis was performed, resulting in the preparation of low-, medium-, and high-cost scenarios. The costs are summarized in the table below. Back up cost tables and assumptions are presented in Attachment A.

Cost Case Scenario	Capital Cost	Present Worth O&M Cost	Total Present Worth
A2 High	$ 3,111,048	$ 4,429,442	$ 7,540,490
A2 Actual	$ 2,074,032	$ 2,952,962	$ 5,026,994
A2 Low	$ 1,451,822	$ 2,067,073	$ 3,518,895

7.2.2.4 Benefit Evaluation of Alternative A2

There is no additional benefit in providing a new erosion control cover as proposed in A1 versus utilizing the existing erosion protection system as proposed in A2. In terms of addressing the groundwater contamination, Implementation of Alternative A2 will result in the same benefits as Alternative A1 (See Section 5.1.2.4), but in a longer time frame for natural attenuation to meet AWQSs. Although the groundwater remedial timeframe for this alternative is longer than A1, because groundwater use ROs will be met before the anticipated use date there is no additional benefit, other than reducing potential for litigation of groundwater use, in providing a more aggressive technology (i.e., A1) cleaning up the contaminated more quickly. Benefits relating to specific topics are discussed below.

Lowered Risk to Human Health and Environment

There are no differences to the risk potential of exposure to soil COCs in alternatives A2 and A1. Implementation of both of these alternatives would lower risk to human health and environment to a degree that negligible risk would be observed for all land use ROs. However, when comparing A2 to A3, the risk to human health and environment in A2 is lower because the long-term potential of subsurface soils COCs being exposed or discharged into the Salt River due to erosion caused by improper storm water run-off drainage control has been eliminated in A2 but not in A3.

Since the groundwater is not used for consumption, and will not be used for that purpose until the year 2020, implementation of A2 would lower the risk to human health and environment, because groundwater COC concentrations will have met AWQSs before the anticipated use date (2020).

Reduction in Concentration and/or Volume of Contaminants

Reduction of soil COC concentrations through natural biodegradation would occur at the same rate in all three alternatives. However, for groundwater COCs, alternative A2 would result in a slower reduction of groundwater concentrations in meeting AWQSs than A1. However, alternative A2 will meet the groundwater use ROs.

Decreased Liability

There is less liability in implementing alternatives A1 and A2 in meeting land use ROs than alternative A3, because the long-term potential for exposure to subsurface soil COCs in A1 and A2 have been eliminated.

Public Acceptance

The activities envisioned in Alternative A2 would not need to be imposed on the public, either for traffic flow, or additional taxes beyond current conditions. On this basis, public acceptance is likely to be favorable.

Aesthetics

There are no significant differences in aesthetics associated with alternatives A2 and A1. However, the aesthetics of the landfill would be improved for A2 verses A3, because modification of the cap will provide engineered storm water run-off controls and greatly improved the overall appearance of the property, making future site development more attractive. In addition, some anticipated uses established in the ROs (i.e., trails) could be developed more easily. Future land use development would mean improved appearance and usefulness, thereby contributing to a net benefit in the aesthetics of the property.

Preservation of Existing Uses

The activity and use limitations necessary to control site access and prohibit the use of the groundwater in the vicinity proposed in A2 will not impair existing uses. The industrial properties in the vicinity all use municipal water. The landfill has been used as a controlled area for years. Therefore, existing uses will be preserved in Alternative A2.

Enhancement of Future Uses

Future property use has been established in the ROs. The technologies addressed in A2 would not impede future development of this property, because site development on any type of landfill would require that provisions are in place to maintain the protectiveness and integrity of the cap, which is normally funded by the site developer. Modification to the cap as proposed in A2 would enhance future uses because engineered storm water run-off controls will have already been provided for. If bond monies are necessary in the future for property development, or if investors might be needed, the modified control program as proposed in A2 for the landfill will facilitate the success of these efforts. Lastly, because no active groundwater remedial action is proposed in this alternative, there will be no groundwater treatment plant located on-site that may interfere with development plans.

Improvements to Local Economy

Any time that property value can be enhanced, the local economy benefits. Alternative A2 is consistent with that principle in that modification of the cap will not only prevent exposure of hazardous substances to on-site worker and/or visitors, but overall the landfill will be more aesthetically pleasing. In addition, engineered storm water controls will be provided for, making future site development more attractive. An aging landfill can be a nuisance and potential danger from exposure, or it can be a resource of property for business or the public good. Characteristics of an aging landfill must be managed, including subsidence and erosion, but a positive effort to develop the facility can result in returning the land to commerce with benefit to the COP.

7.3 ALTERNATIVE A3 - MONITORING ONLY

Alternative A3 involves monitoring with natural attenuation and is the least aggressive alternative under this evaluation. Three separate technologies have been identified for the implementation of this alternative, as follows:

- A.3.a Institutional controls that prevent any developer from altering the integrity of the CAP (Same as A1b and A2b);
- A.3.b Natural Attenuation (Same as A2c); and
- A.3.c Monitoring (Same as A1d and A2d).

7.3.1 Description of Alternative A3

The detailed description of the three technologies incorporated into Alternative A3 is provided below.

7.3.1.1 Technology A3a - Institutional Controls

The same institutional controls as alternatives A1 and A2 are proposed for this alternative. Detailed description of institutional controls that will be applied to the site is addressed in Sections 7.1.1.2 and 7.2.1.2.

7.3.1.2 Technology A3b - Natural Attenuation of VOCs

The natural attenuation of groundwater proposed in alternative A3 is the same as alternative A2. Detailed description of natural attenuation is addressed in Section 7.2.1.3.

7.3.1.3 Technology A3c - Monitoring and Reviews

The monitoring and reviews proposed in alternative A3 is the same as alternatives A1 and A2. Detailed descriptions of monitoring and review requirements are addressed in Sections 7.1.1.4 and 7.2.1.4.

7.3.2 Detailed Evaluation of Alternative A3

The detailed evaluation presented below addresses the three technologies.

7.3.2.1 Practicality of Alternative A3

Feasibility

Institutional controls will be applied to the existing landfill and cap that would prevent any site development that alters the protectiveness and integrity of the CAP. No active remediation of contaminated groundwater would be undertaken as part of the alternative, but concentrations of COCs in groundwater would continue to decrease via natural attenuation processes and dilution. Periodic monitoring of groundwater (A3c) would be easily implemented using standard, reliable techniques. Materials and qualified personnel to conduct the monitoring would be readily available.

Because there is no active modification to the cap or installation of groundwater remedial system proposed in this alternative, implementation of A3 is highly feasible. No permits or authorization would be required to implement this alternative. However, the reliability of this alternative to protect exposure or subsurface soil COCs is questionable because proper erosion and storm water runoff controls have not been provided.

Short-Term Effectiveness

There are no short-term risks to the community because all technologies proposed in A3 do not involve any construction and/or installation activities. Under Alternative A3, ROs may not be met in the short-term. In terms of land use ROs, the RA Update has concluded that health risks associated to direct exposure of surface soil COCs to on-site workers or visitors were negligible. The RA Update further concludes that the emissions of organic compounds presented in soil gas, as confirmed by ambient air monitoring, also presents a negligible health risk to on-site workers and visitors. Lastly, the RA Update confirmed that there were no complete exposure pathways to the subsurface COCs. Based on these findings, it must be concluded that the existing CAP appears to, currently, provide an adequate barrier to prevent exposure of COCs to on-site workers and visitors. Consequently, the ROs for any land use that does not involve altering the integrity of the CAP, would be satisfied. Institutional controls would establish conditions that would prevent any site development that alters the integrity of the CAP, which would further meet land use ROs. However, because the existing CAP has no storm water run-off control, significant erosion of the landfill caused by uncontrolled run-off during heavy storm events, could result in subsurface landfill wastes and contaminate soil to be exposed and potentially discharged into the Salt River. Because hazardous substances have been confirmed in the subsurface soils at the site, providing proper storm water run-off control to minimize erosion of the CAP appears to be necessary to ensure that hazardous substances in subsurface soil do not become exposed or discharged into the Salt River. Based on these findings, alternative A3 may not meet, in the short-term, the ROs established for land use.

In terms of the groundwater use ROs, the RA Update confirmed that current use of the Bradley Well for dust control presented a negligible health risk based on current site groundwater conditions. In addition, 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. Based on these findings, alternative A3 would meet, in the short-term, the ROs established for groundwater use.

Long-Term Effectiveness and Reliability
Implementation of institutional controls will be effective and reliable in the long-term in preventing public exposure to on-site soils. The institutional control will require that any future development must have plans (to be approved by ADEQ) to address and maintain the cap's integrity. However, the long-term effectiveness and reliability of the cap is in question because the existing CAP has no storm water run-off control. Significant erosion of the landfill due to improper storm water run-off controls during heavy storm events could result in subsurface landfill wastes and contaminate soil to be exposed and potentially discharged into the Salt River. Because hazardous substances have been confirmed in the subsurface soils at the site, providing an engineered storm water control system to minimize erosion of the CAP appears to be necessary to ensure that hazardous substances in subsurface soil do not become exposed or discharged into the Salt River.

Under alternative A3, no active remedial measures of the contaminated ground water will be conducted. However, evaluation of monitoring data (HESE, 2000) as confirmed by groundwater modeling (HESE, 2002) has shown that natural attenuation mechanisms have prevented further migration of the plume and is continuing to reduce the concentrations of the groundwater COCs. This rate of reduction is assumed to be slower than alternative A1. Consequently, natural attenuation is a viable remedial option, which has been proven reliable, based on site conditions (like Estes), for the containment of contaminated groundwater, and reduction of the toxicity, mobility and volume of VOC COC. Inorganic COCs present in the groundwater plume would not be addressed. However, the Draft RA and RA Update have concluded that there is negligible risk associated with exposure to the concentrations of these compounds found in the off-site plume.

Under Alternative A3, ROs may not be met in the long-term. The future potential of subsurface soil COCs being exposed due to improper storm water drainage controls causing erosion of the cap is possible. Consequently, alternative A3 may not meet, in the long-term, the ROs established for land use. In terms of the groundwater use ROs, the RA Update confirmed that current use of the Bradley Well for dust control presented a negligible health risk based on current site groundwater conditions. Anticipated future use of the Bradley 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 2002, "Groundwater Modeling Report," indicates that natural biodegradation of organic COCs in the Site plume will decrease concentrations of these compounds below AWQSs before the year 2020. This decrease of the signature compounds will be continuously monitored (A3c) in order to confirm COC concentrations will meet AWQSs before the anticipated use date. Based on these findings, alternative A3 would meet, in the long-term, the ROs established for groundwater use.

7.3.2.2 Risk Evaluation of Alternative A3

Fate and Transport of COCs

The existing cap at some locations within the landfill will not mitigate the transport of subsurface soil COCs to groundwater. However, the final RI (ESE, 1999) has concluded that vertical migration of soil COCs to groundwater does not occur, as verified by comparing landfill soil organic COCs to groundwater organic COCs, which has no correlation. Consequently, fate and transport of soil COCs to groundwater was not evaluated. However, erosion of the landfill due to improper storm water drainage controls has the potential of exposing these COCs to on-site worker and visitors during and post site-development in accordance with the land use ROs. There are no designated surface soil COCs that present any exposure health risk (RA Update), further evaluation of the direct exposure to these COCs was not completed.

With regard to the organic COCs being emitted to the landfill surface, the existing cap provides an adequate barrier preventing VOCs from migrating to the landfill surface at concentrations exceeding the AAAQGs. The Draft RA and confirmed in the RA Update, also concluded that potential exposure of the VOCs in soil gas, would pose negligible health risk. Consequently, further evaluation of the fate and transport of these COCs was not completed. In terms of methane, because no modification to the cap will be conducted under this alternative, this compound was not identified as a true COC, and further evaluation on the fate and transport of methane was not completed.

In terms of the fate and transport of the groundwater organic COCs, the results of the June 2002, Groundwater Modeling Report demonstrated that, not only was the off-site plume stabile (i.e., not migrating), but that natural attenuation was effectively reducing the concentration of the groundwater COCs. Model simulations showed that: by the year 2006 the cis-1,2 DCE concentrations were expected to be less than the AWQS; and Vinyl Chloride 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 8 years (i.e., 2014 for cis-1,2 DCE and 2020 for Vinyl Chloride). The most striking and substantial finding to the modeling conclusions is that actual site groundwater data provides documentation of a stable COC groundwater plume for the last seven years. Groundwater monitoring has provided confirming data indicating that natural attenuation processes are controlling and reducing the COC groundwater plume.

Present and Future Land and Resource Use

The RA Update addressed the risks associated with land uses established as ROs. Implementation of alternative A3 may not provide a sufficient barrier that will prevent exposure to subsurface soil COCs, because sufficient storm water control of the existing cap has not been provided for.

For groundwater uses established as ROs, the RA Update has concluded that current use of the Bradley well is not restricted by the current concentrations of the COCs. Consequently, no interim action is necessary to provide for or replace this use. In addition, because there is no anticipated change on the use of the Bradley well, no long-term action is necessary to provide for or replace this use. The ROs was identified for potential future use of groundwater by the COP within the vicinity of the Site's plume, which would not be needed prior to the year 2020. Consequently, no interim action is necessary to provide for or replace this use. For the long-term groundwater uses established in the ROs, natural attenuation data collected from groundwater samples as verified in the June 2002, "Groundwater Modeling Report," indicates that natural biodegradation of organic COCs in the Site plume will decrease concentrations of these compounds below AWQSs before the year 2020.

Based on these findings, implementation of alternative A3 may present some short-term or long-term risks to the ROs established for land uses, and no short-term or long-term risks to the ROs established for groundwater uses.

Exposure Pathways, Duration of Exposure, and Changes in Risk Over Life of Technology Implementation

The RA Update has confirmed that currently, there are no risks to exposure of surface soil COCs, and soil gas COCs. In addition, the RA Updates also confirmed that there were no exposure pathways associated with subsurface soil COCs. Implementation of institutional controls will also ensure future site development is planned, designed, and implemented not to negatively impact the protectiveness and integrity of the existing cap. However, as previously stated, future exposure pathways may be complete to subsurface COCs if proper storm water run-off controls are not provided to minimize erosion of the cap that may result in exposure of and/or discharge to the Salt River of, subsurface soils COCs.

The only current exposure pathway of the groundwater COCs is the Bradley well, which is used for dust control. The RA Update has concluded that there is negligible risk associated with concentrations of the COCs present in the Bradley well and its corresponding use. In addition, because the anticipated long-term of use of the Bradley will not change, there would also be negligible risk associated with future use of the Bradley well provided that the COC concentrations do not significantly increase, or the assumed long-term usage of the Bradley well does not change. In terms of groundwater use by the COP, because there are no current production wells within or near the vicinity of the groundwater plume, there is no current compete exposure pathway for exposure to the groundwater COCs. In addition, since anticipated use of groundwater within or near the vicinity of the Estes groundwater plume would not occur until the year 2020, exposure pathways would not be complete until these wells are installed. Consequently, the main objective of the groundwater remedy from a risk standpoint would be to ensure groundwater COCs are reduced to acceptable risk exposure levels (i.e., AWQS) before the exposure pathway is completed (by 2020). Groundwater modeling has already demonstrated that natural attenuation would achieve the risk-based objective, for the organic COCs. Consequently only inorganic groundwater COCs would remain, which have been demonstrated in the Draft RA and RA Update to have negligible heath effects if exposed.

Protection of Human Health and Environment

Implementation of A3a may not prevent the future potential for direct exposure with subsurface soil COCs. No COCs for surface soil have been identified, so no exposure or risk/hazard is associated with surface soil. Direct exposure to COCs in soil gas, as verified by ambient air monitoring does not pose a health risk. In addition, implementation of A3b would reduce the exposure risk for the groundwater organic COCs before the exposure pathway is completed. Consequently only inorganic groundwater COCs would remain, which have been demonstrated in the Draft RA and RA Update to have negligible heath effects if consumed. Lastly, while monitoring (A3c) cannot achieve protection of human health and the environment, it will provide on-going data to demonstrate that groundwater COCs are being reduced to insure ROs are being met.

Residual Risk at End of Remediation

For on-site soils, upon completion of A3, there may still be an on-going risk from exposure to subsurface soil COCs that exceeds ADEQ's SRLs. For on-site and off-site groundwater, natural attenuation would be effective in reducing the concentration of organic COCs in groundwater to meet AWQSs before the anticipated use date. The residual risk associated with attaining AWQSs in the groundwater is expected, in general, to be acceptable although some AWQSs (e.g., arsenic) are also based on economic and technological feasibility. Inorganic COCs would also represent residual risk since natural attenuation would not address these compounds. The concentrations of the inorganic groundwater COCs found within the off-site plume have been demonstrated in the Draft RA and RA Update to have negligible heath effects if consumed. Monitoring is expected to be a necessary component to document the end of the remedial action for current groundwater COC concentrations and to provide documentation of protective conditions as time passes.

7.3.2.3 Cost Evaluation of Alternative A3

In accordance with EPA guidelines, a cost sensitivity analysis was performed, resulting in the preparation of low-, medium-, and high-cost scenarios. The costs are summarized in the table below. Back up cost tables and assumptions are presented in Attachment A.

Cost Case Scenario	Capital Cost	Present Worth O&M Cost	Total Present Worth
A3 High	$ 348,478	$ 4,046,731	$ 4,395,209
A3 Actual	$ 232,318	$ 2,697,821	$ 2,930,139
A3 Low	$ 162,623	$ 1,888,475	$ 2,051,097

7.3.2.4 Benefit Evaluation of Alternative A3

Implementation of Alternative A3 will result in the same benefits as Alternative A2 (See Section 5.2.2.4), however there would be no additional benefit to the land for site development because no improvement of the cap is proposed in this alternative.

Benefits relating to specific topics are discussed below.

Lowered Risk to Human Health and Environment
When comparing A3 to A1 and A2 (A1/A2), the risk to human health and environment in A1/A2 is lower because the potential of subsurface soils COCs being exposed or discharged into the Salt River due to storm water run-off erosion has been eliminated in A1/A2 but not in A3.

Since the groundwater is not used for consumption, and will not be used for that purpose until the year 2020, implementation of A3 (like A2) would lower the risk to human health and environment, because groundwater COC concentrations will have met AWQSs before the anticipated use date (2020).

Reduction in Concentration and/or Volume of Contaminants
Reduction of soil COC concentrations through natural biodegradation would occur at the same rate in all three alternatives. For groundwater COCs, alternative A3 would result in a slower reduction of groundwater concentrations in meeting AWQSs than A1. However, alternative A3 will meet the groundwater use ROs.

Decreased Liability
There is less liability in implementing alternatives A1 and A2 in meeting land use ROs than alternative A3, because the potential for exposure to subsurface soil COCs in A1 and A2 have been eliminated.

Public Acceptance
The activities envisioned in Alternative A3 would not need to be imposed on the public, either for traffic flow, or additional taxes beyond current conditions. However, since no modifications are proposed for the cap that would assist in future site development, public acceptance may likely be unfavorable.

Aesthetics
There would be no improvements to the aesthetics of the landfill in implementing alternative A3.

Preservation of Existing Uses
The activity and use limitations necessary to control site access in the vicinity proposed in A3 will not impair existing uses. The industrial properties in the vicinity all use municipal water. The landfill has been

used as a controlled area for years. Therefore, existing uses will be preserved in Alternative A3.

Enhancement of Future Uses

Future property use has been established in the ROs. The technologies addressed in A3 would not impede future development of this property, because site development on any type of landfill would require that provisions are in place to maintain the protectiveness and integrity of the cap, which is normally funded by the site developer. In addition, because no active groundwater remedial action is proposed in this alternative, there will be no groundwater treatment plant located on-site that may interfere with development plans. However, since no modification to the cap will be completed, there would be no enhancement to future uses because engineered storm water run-off controls addressed in alternatives A1 and A2 will not be provided for in alternative A3.

Improvements to Local Economy

Any time that property value can be enhanced, the local economy benefits. An aging landfill can be a nuisance and potential danger from exposure, or it can be a resource of property for business or the public good. Characteristics of an aging landfill must be managed, including subsidence and erosion, but a positive effort to develop the facility can result in returning the land to commerce with benefit to the COP. Alternative A3 will not improve the property and will not assist in enhancing the local economy.

8.0 COMPARISON OF ALTERNATIVES

A comparative summary of the three remedial alternatives, based on the detailed evaluation, is provided in Table 2. When comparing the practicability, risk, cost, and benefit associated with each alternative; and the ability to meet ROs, the reference alternative (i.e., A2 - Source Control) remains the preferred 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 other two alternatives, the difference in risk reduction and benefits from implementing these alternatives were minimal, except that COCs in groundwater would be reduced in the shorter time frame 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 timeframe, there is no valid justification to expend the significant higher cost in the implementation of A1 versus A2.

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FIGURES

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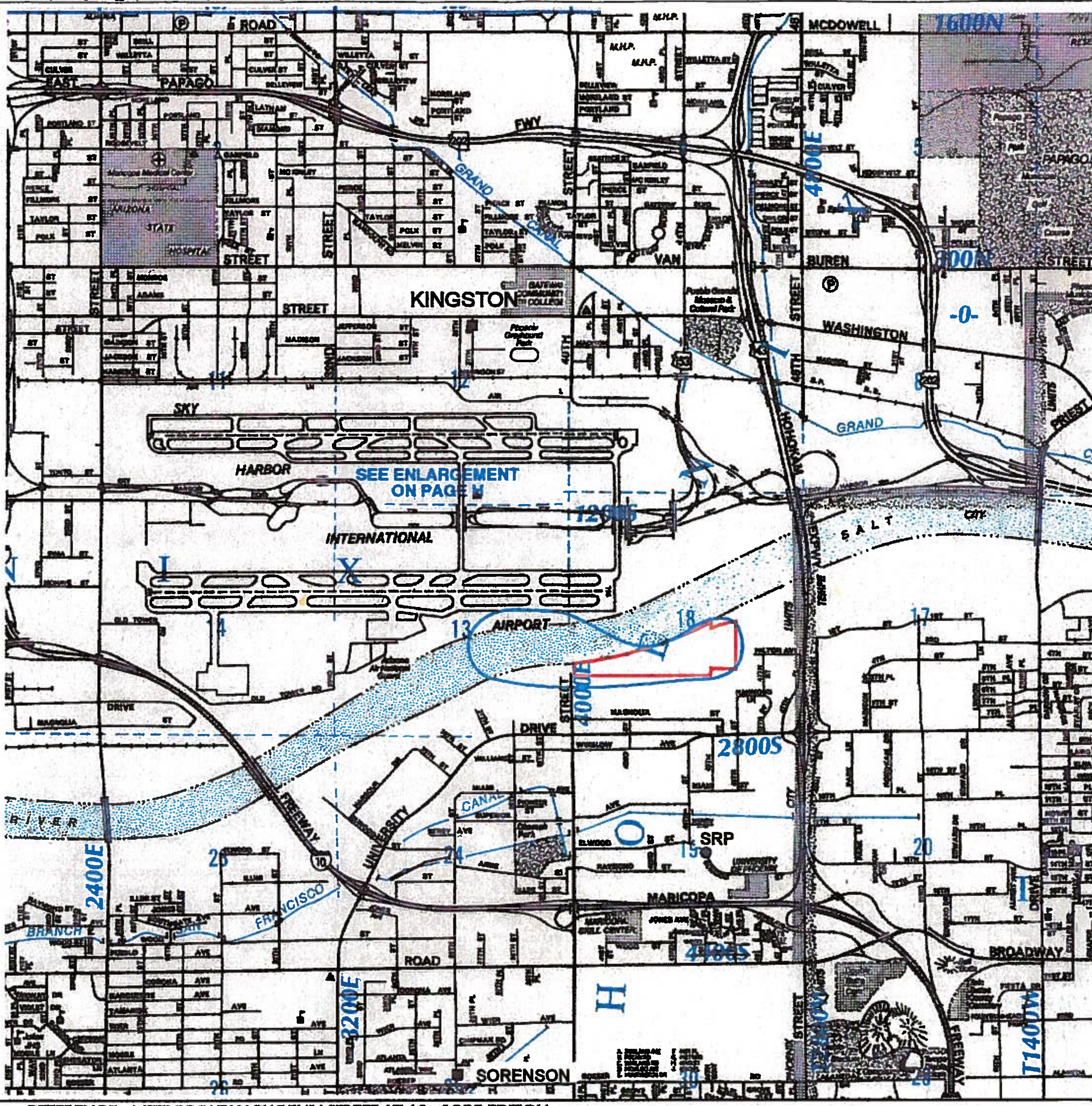

REFERENCE: METROPOLITAN PHOENIX STREET ATLAS, 1995 EDITION

- ■ Domestic Supply Well Location
- ● Production Well Location
- Estes Landfill Boundry
- Estes WQARF Site Boundry

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SCALE IN MILES

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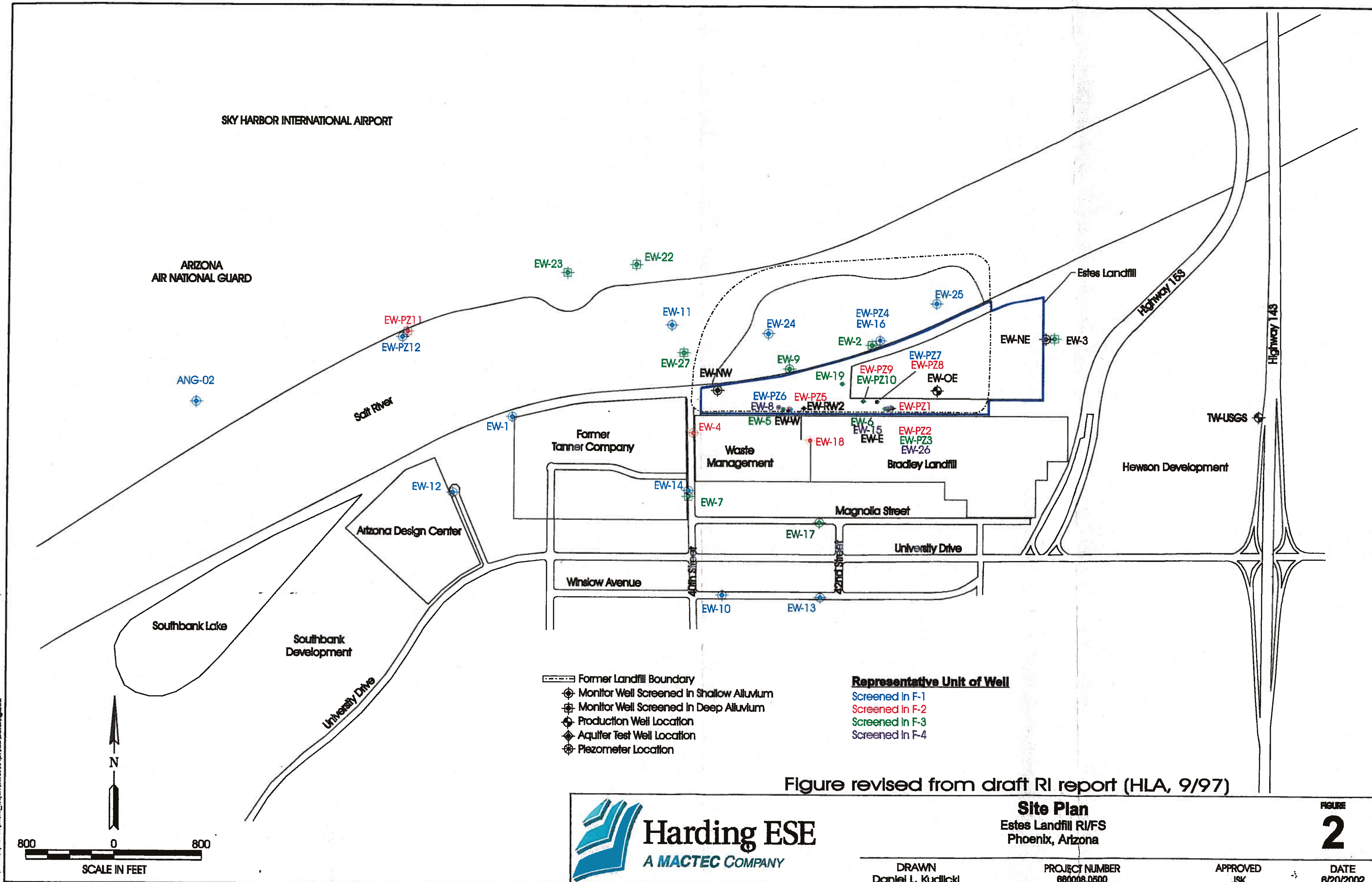
Harding ESE
A MACTEC COMPANY

Location Map
Estes Landfill
Phoenix, Arizona

Figure 1

Drawn	Project Number	Approved	Date
Daniel L. Kudlicki	660008.1100	JSK	6/20/2002



SKY HARBOR INTERNATIONAL AIRPORT
ARIZONA AIR NATIONAL GUARD
ANG-02
EW-PZ11
EW-PZ12
Salt River
EW-23
EW-22
EW-11
EW-27
EW-24
EW-9
EW-NW
EW-PZ4
EW-16
EW-2
EW-25
EW-19
EW-PZ9
EW-PZ10
EW-PZ7
EW-PZ8
EW-OE
EW-NE
EW-3
Estes Landfill
Highway 153
Highway 143
TW-USGS
EW-PZ6
EW-PZ5
EW-8
EW-RW2
EW-PZ1
EW-5
EW-W
EW-6
EW-15
EW-E
EW-PZ2
EW-PZ3
EW-26
EW-4
EW-18
EW-1
Former Tanner Company
Waste Management
Bradley Landfill
Hewson Development
EW-12
EW-14
EW-7
Magnolia Street
EW-17
Arizona Design Center
University Drive
Winslow Avenue
40th Street
42nd Street
EW-10
EW-13
Southbank Lake
Southbank Development
University Drive
Former Landfill Boundary
Monitor Well Screened in Shallow Alluvium
Monitor Well Screened in Deep Alluvium
Production Well Location
Aquifer Test Well Location
Piezometer Location
Representative Unit of Well
Screened in F-1
Screened in F-2
Screened in F-3
Screened in F-4
N
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SCALE IN FEET
Figure revised from draft RI report (HLA, 9/97)
Harding ESE
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Site Plan
Estes Landfill RI/FS
Phoenix, Arizona
FIGURE
2
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Daniel L. Kudlicki
PROJECT NUMBER
660008.0500
APPROVED
JSK
DATE
6/20/2002

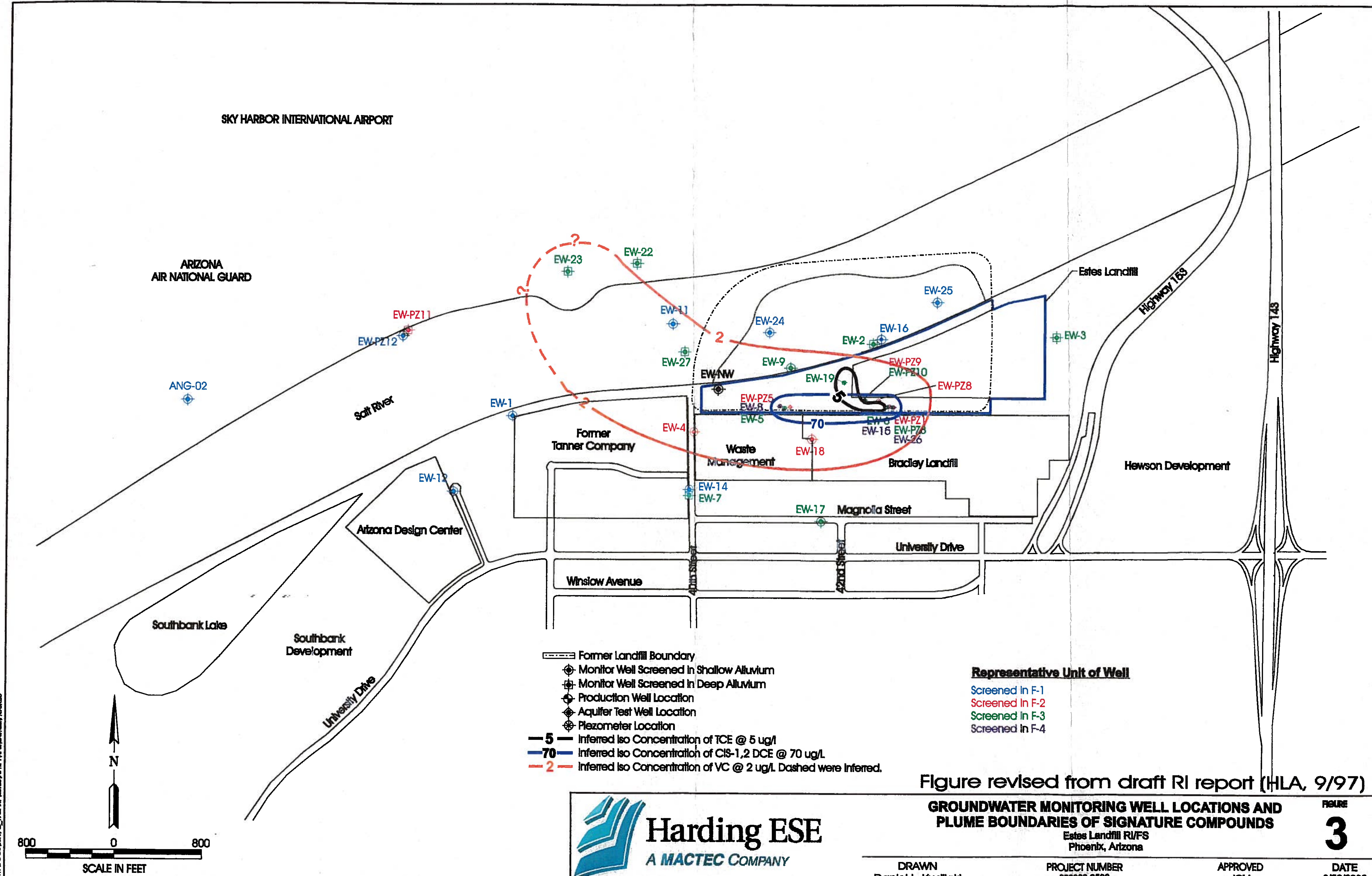

Figure revised from draft RI report (HLA, 9/97)

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GROUNDWATER MONITORING WELL LOCATIONS AND PLUME BOUNDARIES OF SIGNATURE COMPOUNDS
Estes Landfill RI/FS
Phoenix, Arizona

FIGURE	DRAWN	PROJECT NUMBER	APPROVED	DATE
3	Daniel L. Kudlicki	660008.0500	JCM	6/20/2002

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TABLES

Table 1. Remedial Alternatives Screening Process
Estes Landfill Site

Alternative[1]	Treatment Technology[2]	Selection Criteria Screening (Practicality, Risk, Cost)	Ability to Meet the Remedial Objectives Issued January 15, 2002					
			Protect against possible exposure to COCs in surface and subsurface soils if a trail were installed along the northern boundary of the landfill for pedestrian, bike, or equestrian use.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is redeveloped by an outside developer to include buildings, structures, and other infrastructures.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is used for parking, surface storage, or construction of buildings by the COP Aviation Department.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is used for material processing.	Protect, restore, replace or otherwise provide a water supply should the current use of the Bradley well be impaired or lost due to the COCs emanating from the Site.	Restore, replace or otherwise provide for COP water supply after the year 2020 if groundwater is needed in the vicinity of the Site and the identified water resources is impaired or lost by the COC plume.
Plume Remediation: Proposed More Aggressive Remedy (capping, or modification of existing cap with gas control combined with groundwater extraction and treatment)	Soil Cover (Subtitle D)	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, effective in protecting against exposure to COCs for land uses. • Low capital cost relative to other alternatives; relatively low O&M cost	yes	yes	yes	yes	n/a	n/a
	Impermeable Cap (Subtitle C)	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, effective in protecting against exposure to COCs for land uses. • Moderate to high capital cost relative to other alternatives; relatively low O&M cost	yes	yes	yes	yes	n/a	n/a
	Modified Cap with Storm Water Control and Erosion Protection	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, effective in protecting against exposure to COCs for land uses. • Low capital cost relative to other alternatives; relatively low O&M cost	yes	yes	yes	yes	n/a	n/a
	Existing Cap	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, less effective in protecting against exposure to COCs for land uses should storm water erosion of the cap expose subsurface soil COCs. • Low capital cost relative to other alternatives; relatively low O&M cost	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	n/a	n/a
	Gas Venting	• Proven technology that is common component of most landfill caps. • Effective in reducing/eliminating VOC emissions to landfill surface. • Low to moderate capital cost; low to moderate O&M cost	limited - vapor exposure only	limited - vapor exposure only	limited - vapor exposure only	limited - vapor exposure only	n/a	n/a
	Institutional Controls (CAP Integrity Requirements)	• Readily implemented • In conjuction with physical engineered barriers (i.e., Subtitle C, D, or Modified Cap), effective in further preventing exposure to subsurface soils. • Low capital cost	yes	yes	yes	yes	n/a	n/a
	Groundwater extraction and treatment with ultraviolet light (UV) peroxidation	• Requires pretreatment due to presence of metals; system would require long-term maintenance • Would successfully treat COCs to meet AWQS by 2020 • High O&M cost relative to other alternatives	n/a	n/a	n/a	n/a	yes	yes
	Groundwater extraction and treatment with Air Stripping	• Not as effective as UV Peroxidation; system would require long-term maintenance • In conjunction w/ natural attenuation, will be able to meet AWQS by 2020. • High O&M cost relative to other alternatives	n/a	n/a	n/a	n/a	yes	yes
	Groundwater extraction and treatment with ozonation	• Not as effective as UV Peroxidation; system would require long-term maintenance • In conjunction w/ natural attenuation, should be able to meet AWQS by 2020. • High O&M cost relative to other alternatives	n/a	n/a	n/a	n/a	yes	likely
	Groundwater extraction and treatment with bioremediation	• Feasible technology but has not been pilot tested; system would require long-term maintenance • In conjunction w/ natural attenuation, should be able to meet AWQS by 2020. • High O&M cost relative to other alternatives	n/a	n/a	n/a	n/a	yes	likely
	Monitoring	• Readily implemented; existing wells would continue to be monitored • Effective in tracking migration and reduction of the concentrations of COCs to AWQSs by 2020. • Moderate O&M cost	n/a	n/a	n/a	n/a	n/a	n/a

Table 1. Remedial Alternatives Screening Process
Estes Landfill Site

Alternative[1]	Treatment Technology[2]	Selection Criteria Screening (Practicality, Risk, Cost)	Ability to Meet the Remedial Objectives Issued January 15, 2002					
			Protect against possible exposure to COCs in surface and subsurface soils if a trail were installed along the northern boundary of the landfill for pedestrian, bike, or equestrian use.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is redeveloped by an outside developer to include buildings, structures, and other infrastructures.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is used for parking, surface storage, or construction of buildings by the COP Aviation Department.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is used for material processing.	Protect, restore, replace or otherwise provide a water supply should the current use of the Bradley well be impaired or lost due to the COCs emanating from the Site.	Restore, replace or otherwise provide for COP water supply after the year 2020 if groundwater is needed in the vicinity of the Site and the identified water resources is impaired or lost by the COC plume.
Physical Containment (modification or no modification of existing cap and vertical barrier	Existing Cap with Storm Water Erosion Protection	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, effective in protecting against exposure to COCs for land uses. • Low capital cost relative to other alternatives; relatively low O&M cost	yes	yes	yes	yes	n/a	n/a
	Existing Cap	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, less effective in protecting against exposure to COCs for land uses should storm water erosion of the cap expose subsurface soil COCs. • Low capital cost relative to other alternatives; relatively low O&M cost	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	n/a	n/a
	Institutional Controls (CAP Integrity Requirements)	• Readily implemented • In conjuction with physical engineered barriers (i.e., Modified Cap), effective in further preventing exposure to subsurface soils. • Low capital cost	yes	yes	yes	yes	n/a	n/a
	Slurry Wall or Sheet Pile Barrier	• Impractical because depth to groundwater is about 50 feet and wall would need to be keyed into bedrock which is approximately 100 feet below surface • Would prevent off-site migration of COCs; natural attenuation would then reduce off-site COCs to AWQSs by 2020. • Very high capital cost but low O&M cost relative to other alternatives	n/a	n/a	n/a	n/a	yes	yes
	Monitoring	• Readily implemented; existing wells would continue to be monitored • Effective in tracking migration and reduction of the concentrations of COCs to AWQSs by 2020. • Moderate O&M cost	n/a	n/a	n/a	n/a	n/a	n/a
Controlled Migration (modification or no modification of existing cap and permeable reaction wall)	Existing Cap with Storm Water Erosion Protection	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, effective in protecting against exposure to COCs for land uses. • Low capital cost relative to other alternatives; relatively low O&M cost	yes	yes	yes	yes	n/a	n/a
	Existing Cap	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, less effective in protecting against exposure to COCs for land uses should storm water erosion of the cap expose subsurface soil COCs. • Low capital cost relative to other alternatives; relatively low O&M cost	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	n/a	n/a
	Institutional Controls (CAP Integrity Requirements)	• Readily implemented • In conjuction with physical engineered barriers (i.e., Modified Cap), effective in further preventing exposure to subsurface soils. • Low capital cost	yes	yes	yes	yes	n/a	n/a
	Permeable Reaction Wall	• Impractical because depth to groundwater is about 50 feet and wall would need to be keyed into bedrock, which is approximately 100 feet below surface • Would prevent off-site migration of COCs • Very high cost capital cost relative to other alternatives; relatively low O&M cost	n/a	n/a	n/a	n/a	yes	yes
	Monitoring	• Readily implemented; existing wells would continue to be monitored • Effective in tracking migration and reduction of the concentrations of COCs to AWQSs by 2020. • Moderate O&M cost	n/a	n/a	n/a	n/a	n/a	n/a

Table 1. Remedial Alternatives Screening Process
Estes Landfill Site

Alternative[1]	Treatment Technology[2]	Selection Criteria Screening (Practicality, Risk, Cost)	Ability to Meet the Remedial Objectives Issued January 15, 2002					
			Protect against possible exposure to COCs in surface and subsurface soils if a trail were installed along the northern boundary of the landfill for pedestrian, bike, or equestrian use.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is redeveloped by an outside developer to include buildings, structures, and other infrastructures.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is used for parking, surface storage, or construction of buildings by the COP Aviation Department.	Protect against possible exposure to COCs in surface and subsurface soils if the landfill is used for material processing.	Protect, restore, replace or otherwise provide a water supply should the current use of the Bradley well be impaired or lost due to the COCs emanating from the Site.	Restore, replace or otherwise provide for COP water supply after the year 2020 if groundwater is needed in the vicinity of the Site and the identified water resources is impaired or lost by the COC plume.
Source Control: Proposed Reference Remedy (modification or no modification of existing cap and natural attenuation)	**Modified Cap with Storm Water Control**	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, effective in protecting against exposure to COCs for land uses. • Low capital cost relative to other alternatives; relatively low O&M cost	yes	yes	yes	yes	n/a	n/a
	Existing Cap	• Readily implemented since materials and services are commonly available • In conjunction w/Institutional controls, less effective in protecting against exposure to COCs for land uses should storm water erosion of the cap expose subsurface soil COCs. • Low capital cost relative to other alternatives; relatively low O&M cost	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	n/a	n/a
	Institutional Controls (CAP Integrity Requirements)	• Readily implemented • In conjuction with physical engineered barriers (i.e., Modified Cap), effective in further preventing exposure to subsurface soils. • Low capital cost	yes	yes	yes	yes	n/a	n/a
	Natural Attenuation	• Readily implemented • Reduction of COCs would continue to take place due to biodegradation and groundwater flushing by 2020 as verified by groundwater modeling results. Natural attenuation must be implemented in conjuction with groundwater monitoring. • Low cost	n/a	n/a	n/a	n/a	yes	likely
	Monitoring	• Readily implemented; existing wells would continue to be monitored • Effective in tracking migration and reduction of the concentrations of COCs to AWQSs by 2020. • Moderate O&M cost	n/a	n/a	n/a	n/a	n/a	n/a
Monitoring Only: Proposed Less Aggressive Remedy (Provide institutional control to the existing cap, while monitoring natural attenuation of groundwater COCs)	**Institutional Controls (CAP Integrity Requirements)**	• Readily implemented • In conjuction with existing physical engineered barriers (i.e., Cap), effective in further preventing exposure to subsurface soils. However, does not prevent potential exposure to subsurface soil COCs due to erosion of the existing cap from storm water run-off. • Low capital cost	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	limited - potenital exposure to COCs from cap erosion	n/a	n/a
	Natural Attenuation	• Readily implemented • Reducion of COCs would continue to take place due to biodegradation and groundwater flushing by 2020 as verified by groundwater modeling results. Natural attenuation must be implemented in conjuction with groundwater monitoring. • Low cost	n/a	n/a	n/a	n/a	yes	likely
	Monitoring	• Readily implemented; existing wells would continue to be monitored • Effective in tracking migration and reduction of the concentrations of groundwater COCs to AWQSs by 2020. • Moderate O&M cost	n/a	n/a	n/a	n/a	n/a	n/a
No Action	No Action	• Readily implemented • No institutional controls to prevent exposure to subsurface soil COCs. There would be no reduction in groundwater COCs through treatment, although COCs would continue to decrease via natural degradation processes and dilution; however no monitoring would be conducted to verify reduction of COCs to AWQS by 2020. • No costs are associated with this alternative	unlikely	unlikely	unlikely	unlikely	likely - continued natural attentuation of the groundwater COCs will not prohibit use of the Bradley Well for dust control; however, cannot be monitored to show reduction of COCs.	likely - groundwater modeling results confirm that COCs should decrease to below AWQSs by 2020; however this progress cannot be assessed w/o monitoring.

Notes:

1. The alternatives listed above are consistent with ADEQ Draft Remedy Rule. Certain technologies, such as capping, monitoring and institutional controls, are usually a component of more aggressive remedial alternatives, and therefore are listed under more than one alternative.
2. Technologies that are retained for detailed evaluation are shown in bold.
3. COC - Constituents of Concern
4. O&M - Operations & Maintenance
5. VOCs - Volatile Organic Compounds
6. AWQS - Aquifer Water Quality Standards

TABLE 2. SUMMARY OF DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES
Estes Landfill Site
Phoenix, Arizona

Assessment Factor	Alternative A1: Plume Remediation (modified cap with institutional control combined with groundwater extraction and treatment)	Alternative A2: Source Control (modified cap with insitutional control and natural attenuation)	Alternative A3: Monitoring (institutional control and natural attenuation)
Major Components	• A1a - Existing cap will be modified to include erosion and storm water run-off controls • A1b - Institutional controls would be placed on affected properties to prevent any site development from altering the protectiveness and integrity of the cap, and to prohibit use of on-site groundwater • A1c - The groundwater plume would be remediated via groundwater extraction and treatment with ultraviolet light (UV) peroxidation • A1d - Long term groundwater monitoring would be used to evaluate effectiveness of remedial measures	• A2a - Existing cap will be modified to include storm water run-off controls • A2b - Institutional controls would be placed on affected properties to prevent any site development from altering the protectiveness and integrity of the cap, and to prohibit use of on-site groundwater • A2c - Natural attenuation of groundwater plume • A2d - Long term groundwater monitoring would be used to evaluate effectiveness of remedial measures	• A3a - Institutional controls would be placed on affected properties to prevent any site development from altering the protectiveness and integrity of the cap, and to prohibit use of on-site groundwater • A3b - Natural attenuation of groundwater plume • A3c - Long term groundwater monitoring would be used to evaluate effectiveness of remedial measures natural attenuation
Practicability: • **Feasibility** • **Short-term effectiveness** • **Long-term effectiveness** • **Reliability**	• Moderately difficult to implement since permits would be required and a treatment building and extraction wells would need to be built • Potential short term risks during construction minimized through adherence to health and safety plan • All components are proven technologies that are typically used for landfill closures and groundwater extraction and treatment • Effective in reducing potential exposure to subsurface soil COCs • Effective in preventing migration of groundwater COCs and reducing groundwater COCs concentrations to AWQSs • Groundwater extraction and treatment system and modified cap would require long-term maintenance • Remedial objectives would be achieved in the short-term and long-term..	• Readily implemented since materials and services are commonly available • Potential short term risks during construction minimized through adherence to health and safety plan • All components are proven technologies that are typically used for landfill closures and groundwater remediation • Effective in reducing potential exposure to subsurface soil COCs • Effective in preventing migration of groundwater COCs and reducing groundwater COCs concentrations to AWQSs • Modified cap would require long-term maintenance • Remedial objectives would be achieved in the short-term and long-term..	• Readily implemented • No short term risks during construction • Existing cap does not meet typical landfill closure requirements. • Natural attentuation is a proven technology that has typically been used for groundwater remediation • Not effective in reducing potential exposure to subsurface soil COCs • Effective in preventing migration of groundwater COCs and reducing groundwater COCs concentrations to AWQSs • No long-term maintenance required • Land use remedial objectives would not be achieved in the short-term and long-term.
Risk: • **Overall protection of human health and environment**	• Would successfully reduce COCs concentrations in groundwater to meet AWQSs more rapidly than Alternatives A2 and A3 • Would reduce/eliminate risks associated with potential exposure to subsurface soil COCs • Would reduce groundwater COCs to AWQSs before future exposure pathways are completed in the year 2020. • Long-term monitoring would be necessary to confirm that levels of COCs are declining	• COCs would continue to decrease via natural degradation processes and dilution to meet AWQSs • Would reduce/eliminate risks associated with potential exposure to subsurface soil COCs • Would reduce groundwater COCs to AWQSs before future exposure pathways are completed in the year 2020. • Long-term monitoring would be necessary to confirm that levels of COCs are declining	• COCs would continue to decrease via natural degradation processes and dilution to meet AWQSs • Would not reduce/eliminate risks associated with potential exposure to subsurface soil COCs • Would reduce groundwater COCs to AWQSs before future exposure pathways are completed in the year 2020. • Long-term monitoring would be necessary to confirm that levels of COCs are declining
Cost: • **Capital costs** • **O&M** • **Life cycle costs**	• Moderate to high capital cost relative to other alternatives ($ 13.1 MM to $ 28.1 MM) • High O&M cost for maintaining cap and groundwater extraction and treatment relative to other alternatives	• Moderate cost relative to other alternatives ($ 3.5 MM to $ 7.6 MM) • Relatively low O&M costs for maintaining cap as compared with Alternative A1.	• Low cost relative to other alternatives ($ 2.1 MM to $ 4.5 MM)
Benefit: • **Lowered risk to human health and environment** • **Reduction in COCs concentration and/or volume Decreased liability** • **Public acceptance** • **Aesthetics** • **Preservation of existing uses** • **Enhancement of future uses** • **Improvement to local economy**	• Would successfully lower risk to human health and environment by remediating impacted groundwater. • Would successfully lower risk to human health and environment by reducing exposure potential to subsurface soil COCs. • Effective in reducing groundwater COCs to meet AWQS before anticipated use dates established in the remedial objectives, more quickly than the other two Alternatives. • Faster remediation of groundwater would decrease liability when compared to the other two Alternatives. • Management controls should foster public acceptance • Modified cap could be designed to be aesthetically pleasing • Will not impair existing uses • Institutional controls would not impede future development, since typical site development on any landfill would require that provisions are in place to maintain the protectiveness and integrity of the cap. Groundwater treatment building may interfer with future development plans. • Improvements to the cap and clean up of impacted groundwater will enhance the local economy.	• Would successfully lower risk to human health and environment by remediating impacted groundwater. • Would successfully lower risk to human health and environment by reducing exposure potential to subsurface soil COCs. • Effective in reducing groundwater COCs to meet AWQS before anticipated use dates established in the remedial objectives. • Slower remediation of groundwater would increase liability when compared to A1 • Management controls should foster public acceptance • Modified cap could be designed to be aesthetically pleasing • Will not impair existing uses • Institutional controls would not impede future development, since typical site development on any landfill would require that provisions are in place to maintain the protectiveness and integrity of the cap. No aboveground treatment plant to interfer with future site development. • Improvements to the cap and clean up of impacted groundwater will enhance the local economy.	• Would successfully lower risk to human health and environment by remediating impacted groundwater. • Would not lower risk to human health and environment of potential exposure to subsurface soil COCs. • Effective in reducing groundwater COCs to meet AWQS before anticipated use dates established in the remedial objectives. • Slower remediation of groundwater would increase liability when compared to A1 • Lack of management controls may foster public dissapproval • No aesthetic changes • Will not impair existing uses • No enhancement of future uses • No enhancement to the local economy.

APPENDIX A
REMEDIAL ALTERNATIVES EVALUATION
COST ESTIMATE SUPPORT DATA

Appendix A
Feasibility Study Cost Support Data

COST SUMMARY
A1 - PLUME REMEDIATION

Breakdown	Technology	Capital	O&M	Total
Actual	A1a	6,825,480	255,141	7,080,621
	A1b	167,712	2,630	170,342
	A1c	2,878,800	6,049,730	8,928,530
	A1d	12,000	2,493,908	2,505,908
	A1 Total	**$ 9,883,992**	**$ 8,801,409**	**$ 18,685,401**
Low	A1a	4,777,836	178,599	4,956,435
	A1b	117,398	1,841	119,240
	A1c	2,015,160	4,234,811	6,249,971
	A1d	8,400	1,745,736	1,754,136
	A1 Total	**$ 6,918,794**	**$ 6,160,986**	**$ 13,079,780**
High	A1a	10,238,220	382,711	10,620,931
	A1b	251,568	3,945	255,513
	A1c	4,318,200	9,074,594	13,392,794
	A1d	18,000	3,740,862	3,758,862
	A1 Total	**$ 14,825,988**	**$ 13,202,113**	**$ 28,028,101**

Cost Analysis of Alternative A1 - Plume Remediation

Technology A1a; Design and Installation of Modified Cap

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown		
				Actual	Low	High
1. Design						
- Pre-design Studies	1	EA	60,000	60,000	42,000	90,000
- Design	1	EA	80,000	80,000	56,000	120,000
- Construction QA Plan	1	EA	25,000	25,000	17,500	37,500
2. Mobilization/Demobilization	1	EA	200,000	200,000	140,000	300,000
3. Site Preparation	1	LS	130,000	130,000	91,000	195,000
4. Staging Area	1	LS	30,000	30,000	21,000	45,000
5. Modified Cap Installation						
- Import/Placement/Compaction Fill	8,070	CY	20	161,400	112,980	242,100
- Field Compaction Verification	100	Days	120	12,000	8,400	18,000
- Import/Placement Fill	94,380	CY	20	1,887,600	1,321,320	2,831,400
- Import/Placment Top Soil	65,340	CY	30	1,960,200	1,372,140	2,940,300
- Seeding	45	Acres	2,500	112,500	78,750	168,750
- Drainage Swales Excavation	8,000	LF	34	272,000	190,400	408,000
- Rip-Rap Installation in Swales	36,000	CY	17	612,000	428,400	918,000
6. Stormwater Outfall Installation	1	EA	7,200	7,200	5,040	10,800
7. Dust Suppression	100	Days	1,000	100,000	70,000	150,000
8. Air Monitoring	100	Days	150	15,000	10,500	22,500
9. NPDES Permit Application	1	EA	15,000	15,000	10,500	22,500
10. SWPPP for Construction Activities	1	EA	8,000	8,000	5,600	12,000
11. Contingency	1	EA	20%	1,137,580	796,306	1,706,370
12. A1a Capital Costs				6,825,480	4,777,836	10,238,220

OPERATIONS AND MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30)		
				Actual	Low	High
13. NPDES Discharge Monitoring	60	EA	1,500	32,879	23,015	49,318
14. NPDES Annual Reporting	30	EA	1,200	26,303	18,412	39,455
15. Five Year Site Review & Report	6	EA	2,000	43,839	30,687	65,758
16. O & M (Cap & Drainage Swales)	30	YR	5,000	109,597	76,718	164,395
17. Contingency	1	EA	20%	42,523	29,766	63,785
18. A1a O&M Costs				255,141	178,599	382,711

A1a Total Costs	**$ 7,080,621**	**$ 4,956,435**	**$ 10,620,931**

Cost Analysis of Alternative A1 - Plume Remediation

Technology A1b; Implementation of Institutional Controls

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown		
				Actual	Low	High
1. Filing of Institutional Controls	1	EA	2,000	2,000	1,400	3,000
2. Perimeter Fencing (12' High)	8,000	LF	17	136,000	95,200	204,000
3. Warning Signs	80	EA	22	1,760	1,232	2,640
4. Five Year Site Review & Report	Included w/Cap Installation Costs					
5. Contingency	1	EA	20%	27,952	19,566	41,928
6. A1b Captial Costs				167,712	117,398	251,568

OPERATIONS & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30)		
				Actual	Low	High
7. O & M (Fencing & Signs)	30	YR	100	2,192	1,534	3,288
8. Contingency	1	EA	20%	438	307	658
9. A1b O&M Costs				2,630	1,841	3,945

A1b Total Costs	**$ 170,342**	**$ 119,240**	**$ 255,513**

Cost Analysis of Alternative A1 - Plume Remediation

Technology A1c; Groundwater Extraction and Treatment with UV Peroxidation

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown Actual	Low	High
1. Workplan & Design	1	EA	500,000	500,000	350,000	750,000
2. Permitting	1	EA	100,000	100,000	70,000	150,000
3. System Construction						
- Well Installation (10 wells)	10	EA	50000	500,000	350,000	750,000
- Trenching & Piping	3000	LF	32	96,000	67,200	144,000
- Equipment Compound	1	EA	30,000	30,000	21,000	45,000
- Utilities (Water)	1	EA	20,000	20,000	14,000	30,000
- Utilities (Electric)	1	EA	75,000	75,000	52,500	112,500
- Utilities (Phone)	1500	LF	12	18,000	12,600	27,000
- Discharge System	1	EA	10,000	10,000	7,000	15,000
- Treatment Equipment	1	EA	1,000,000	1,000,000	700,000	1,500,000
4. System Startup	1	EA	50,000	50,000	35,000	75,000
5. Contingency	1	EA	20%	479,800	335,860	719,700
6. A1c Captial Costs				2,878,800	2,015,160	4,318,200

OPERATION & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30) Actual	Low	High
7. O & M						
- Operation (labor)	15	YR	50,000	1,095,966	767,176	1,643,948
- Repair	15	YR	35,000	767,176	537,023	1,150,764
- Utilities	15	YR	100,000	2,191,931	1,534,352	3,287,897
- Materials	15	YR	25,000	547,983	383,588	821,974
- Project Management	15	YR	15,000	328,790	230,153	493,184
- Reporting	15	YR	5,000	109,597	76,718	164,395
8. Contingency	1	EA	20%	1,008,288	705,802	1,512,432
9. A1c O&M Costs				6,049,730	4,234,811	9,074,594

A1c Total Costs	$ 8,928,530	$ 6,249,971	$ 13,392,794

Cost Analysis of Alternative A1 - Plume Remediation

Technology A1d; Groundwater Monitoring

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown Actual	Low	High
1. Workplan	1	EA	10,000	10,000	7,000	15,000
2. Contingency	1	EA	20%	2,000	1,400	3,000
3. A1d Captial Costs				12,000	8,400	18,000

OPERATION & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30) Actual	Low	High
4. Well Sampling/Analysis						
- Quarterly	0	YR	0	-	-	0
- Contingent Monitoring	9	YR	50,000	382,291	267,604	573,437
- Annually	30	YR	50000	1,095,966	767,176	1,643,948
5. Well Maintenance	30	YR	2,000	60,000	42,000	90,000
6. Project Management	30	YR	8,000	240,000	168,000	360,000
7. Reporting	30	YR	10,000	300,000	210,000	450,000
8. Contingency	1	EA	20%	415,651	290,956	623,477
9. A1d O&M Costs				2,493,908	1,745,736	3,740,862

A1d Total Costs	$ 2,505,908	$ 1,754,136	$ 3,758,862

ALTERNATIVE A1 TOTAL COSTS	$ 18,685,401	$ 13,079,780	$ 28,028,101

Appendix A
Feasibility Study Cost Support Data

COST SUMMARY
A2 - SOURCE CONTROL

Breakdown	Technology	Capital	O&M	Total
Actual	A2a	1,894,320	255,141	2,149,461
	A2b	167,712	2,630	170,342
	A2c	0	201,283	201,283
	A2d	12,000	2,493,908	2,505,908
	A2 Total	**$ 2,074,032**	**$ 2,952,962**	**$ 5,026,994**
Low	A2a	1,326,024	178,599	1,504,623
	A2b	117,398	1,841	119,240
	A2c	0	140,898	140,898
	A2d	8,400	1,745,736	1,754,136
	A2 Total	**$ 1,451,822**	**$ 2,067,073**	**$ 3,518,895**
High	A2a	2,841,480	382,711	3,224,191
	A2b	251,568	3,945	255,513
	A2c	-	301,924	301,924
	A2d	18,000	3,740,862	3,758,862
	A2 Total	**$ 3,111,048**	**$ 4,429,442**	**$ 7,540,490**

Appendix A
Cost Analysis of Alternative A2 - Source Control

Technology A2a; Design and Installation of Modified Cap

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown Actual	Low	High
1. Design						
- Pre-design Studies	1	EA	30,000	30,000	21,000	45,000
- Design	1	EA	50,000	50,000	35,000	75,000
- Construction QA Plan	1	EA	25,000	25,000	17,500	37,500
2. Mobilization/Demobilation	1	EA	150,000	150,000	105,000	225,000
3. Site Preparation	1	LS	100,000	100,000	70,000	150,000
4. Staging Area	1	LS	30,000	30,000	21,000	45,000
5. Storm Water Run-Off Control Installation						
- Import/Placement/Compaction Fill	8,070	CY	20	161,400	112,980	242,100
- Field Compaction Verification	25	Days	120	3,000	2,100	4,500
- Import/Placement Fill (NA)	0	CY	20	-	-	-
- Import/Placment Top Soil (NA)	0	CY	30	-	-	-
- Seeding (NA)	0	Acres	2,500	-	-	-
- Drainage Swales Excavation	8,000	LF	34	272,000	190,400	408,000
- Rip-Rap Installation in Swales	36,000	CY	17	612,000	428,400	918,000
6. Stormwater Outfall Installation	1	EA	7,200	7,200	5,040	10,800
7. Dust Suppression	100	Days	1,000	100,000	70,000	150,000
8. Air Monitoring	100	Days	150	15,000	10,500	22,500
9. NPDES Permit Application	1	EA	15,000	15,000	10,500	22,500
10. SWPPP for Construction Activities	1	EA	8,000	8,000	5,600	12,000
11. Contingency	1	EA	20%	315,720	221,004	473,580
12. A2a Capital Costs				1,894,320	1,326,024	2,841,480

OPERATIONS AND MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30) Actual	Low	High
13. NPDES Discharge Monitoring	60	EA	1,500	32,879	23,015.28	49,318
14. NPDES Annual Reporting	30	EA	1,200	26,303	18,412	39,455
15. Five Year Site Review & Report	6	EA	2,000	43,839	30,687	65,758
16. O & M (Cap & Drainage Swales)	30	EA	5,000	109,597	76,718	164,395
17. Contingency	1	EA	20%	42,523	29,766	63,785
18. A2a O&M Costs				255,141	178,599	382,711

A2a Total Cost	**$ 2,149,461**	**$ 1,504,623**	**$ 3,224,191**

Appendix A
Cost Analysis of Alternative A2 - Source Control

Technology A2b; Implementation of Institutional Controls

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown Actual	Low	High
1. Filing of Institutional Controls	1	EA	2,000	2,000	1,400	3,000
2. Perimeter Fencing (12' High)	8,000	LF	17	136,000	95,200	204,000
3. Warning Signs	80	EA	22	1,760	1,232	2,640
4. Five Year Site Review & Report	Included w/Cap Installation Costs					
5. Contingency	1	EA	20%	27,952	19,566	41,928
6. A2b Captial Costs				167,712	117,398	251,568

OPERATIONS & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30) Actual	Low	High
7. O & M (Fencing & Signs)	30	YR	100	2,192	1,534	3,288
8. Contingency	1	EA	20%	438	307	658
9. A2b O&M Costs				2,630	1,841	3,945

	Actual	Low	High
A2b Total Cost	**$ 170,342**	**$ 119,240**	**$ 255,513**

Appendix A
Cost Analysis of Alternative A2 - Source Control

Technology A2c; Natural Attenuation of VOCs in Groundwater (No Captial Costs)

OPERATIONS & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30)		
				Actual	Low	High
1. Analysis and Evaluation of Natural Attenuation Parameters - Annually	30	YR	8000	167,735	117,415	251,603
2. Contingency	1	EA	20%	33,547	23,483	50,321
3. A2c O&M Costs				201,283	140,898	301,924

A2c Total Cost	$ 201,283	$ 140,898	$ 301,924

Appendix A
Cost Analysis of Alternative A2 - Source Control

Technology A2d; Groundwater Monitoring

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown		
				Actual	Low	High
1. Workplan	1	EA	10,000	10,000	7,000	15,000
2. Contingency	1	EA	20%	2,000	1,400	3,000
3. A2d Captial Costs				12,000	8,400	18,000

OPERATION & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30)		
				Actual	Low	High
4. Well Sampling/Analysis						
- Quarterly	0	YR	0	-	-	0
- Contingent Monitoring	9	YR	50,000	382,291	267,604	573,437
- Annually	30	YR	50,000	1,095,966	767,176	1,643,948
5. Well Maintenance	30	YR	2,000	60,000	42,000	90,000
6. Project Management	30	YR	8,000	240,000	168,000	360,000
7. Reporting	30	YR	10,000	300,000	210,000	450,000
8. Contingency	1	EA	20%	415,651	290,956	623,477
9. A2d O&M Costs				2,493,908	1,745,736	3,740,862

A2d Total Cost	**$ 2,505,908**	**$ 1,754,136**	**$ 3,758,862**

ALTERNATIVE A2 TOTAL COST	**$ 5,026,994**	**$ 3,518,895**	**$ 7,540,490**

Appendix A
Feasibility Study Cost Support Data

COST SUMMARY
A3 - MONITORING ONLY

Breakdown	Technology	Capital	O&M	Total
Actual	A3a	220,318	2,630	222,949
	A3b	-	201,283	201,283
	A3c	12,000	2,493,908	2,505,908
	A3 Total	**$ 232,318**	**$ 2,697,821**	**$ 2,930,139**
Low	A3a	154,223	1,841	156,064
	A3b	-	140,898	140,898
	A3c	8,400	1,745,736	1,754,136
	A3 Total	**$ 162,623**	**$ 1,888,475**	**$ 2,051,097**
High	A3a	330,478	3,945	334,423
	A3b	-	301,924	301,924
	A3c	18,000	3,740,862	3,758,862
	A3 Total	**$ 348,478**	**$ 4,046,731**	**$ 4,395,209**

Cost Analysis of Alternative A3 - Monitoring Only

Technology A3a; Implementation of Institutional Controls (Same as A1b & A2b)

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown		
				Actual	Low	High
1. Filing of Institutional Controls	1	EA	2,000	2,000	1,400	3,000
2. Perimeter Fencing (12' High)	8,000	LF	17	136,000	95,200	204,000
3. Warning Signs	80	EA	22	1,760	1,232	2,640
4. Five Year Site Review & Report	6	EA	2,000	43,839	30,687	65,758
5. Contingency	1	EA	20%	36,720	25,704	55,080
6. A3a Captial Costs				220,318	154,223	330,478

OPERATIONS & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30)		
				Actual	Low	High
7. O & M (Fencing & Signs)	30	YR	100	2,192	1,534	3,288
8. Contingency	1	EA	20%	438	307	658
9. A3a O&M Costs				2,630	1,841	3,945

A3a Total Costs	**$ 222,949**	**$ 156,064**	**$ 334,423**

Cost Analysis of Alternative A3 - Monitoring Only

Technology A3b; Natural Attenuation of VOCs in Groundwater (Same as A2c No Captial Costs)

OPERATIONS & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30) Actual	Low	High
1. Analysis and Evaluation of Natural Attenuation Parameters - Annually	30	YR	8000	167,735	117,415	251,603
2. Contingency	1	EA	20%	33,547	23,483	50,321
3. A3b O&M Costs				201,283	140,898	301,924

	Actual	Low	High
A3b Total Costs	**$ 201,283**	**$ 140,898**	**$ 301,924**

Cost Analysis of Alternative A3 - Monitoring Only

Technology A3c; Monitoring (Same as A1d & A2d)

CAPTIAL COSTS

Task/Item Description	Quantity	Units	Unit Rate	Cost Breakdown		
				Actual	Low	High
1. Workplan	1	EA	10,000	10,000	7,000	15,000
2. Contingency	1	EA	20%	2,000	1,400	3,000
3. A3c Captial Costs				12,000	8,400	18,000

OPERATION & MAINTENANCE COSTS

Task/Item Description	Quantity	Units	Annual Cost	NPV Lifecycle Costs (Year 1-30)		
				Actual	Low	High
4. Well Sampling/Analysis						
- Quarterly	0	YR	0	-	-	0
- Contingent Monitoring	9	YR	50,000	382,291	267,604	573,437
- Annually	30	YR	50,000	1,095,966	767,176	1,643,948
5. Well Maintenance	30	YR	2,000	60,000	42,000	90,000
6. Project Management	30	YR	8,000	240,000	168,000	360,000
7. Reporting	30	YR	10,000	300,000	210,000	450,000
8. Contingency	1	EA	20%	415,651	290,956	623,477
9. A3c O&M Costs				2,493,908	1,745,736	3,740,862

A3c Total Costs	$ 2,505,908	$ 1,754,136	$ 3,758,862

ALTERNATIVE A3 TOTAL COSTS	$ 2,930,139	$ 2,051,097	$ 4,395,209

Appendix A - Feasibility Study Cost Estimate Support Data
Example Net Percent Value 30-Year Lifecycle Cost
Estes Landfill WQARF Site

Annual Groundwater Monitoring Sample Calculation

Yearly O&M	50,000
Inflation	3%
Interest rate	5%

Year	O&M	Geometric NPV Factor
1	50,000	0.952380952
2	51,500	1.886621315
3	53,045	2.803066623
4	54,636	3.702055831
5	56,275	4.583921434
6	57,964	5.448989597
7	59,703	6.297580271
8	61,494	7.130007314
9	63,339	7.946578603
10	65,239	8.747596154
11	67,196	9.533356227
12	69,212	10.30414944
13	71,288	11.06026088
14	73,427	11.8019702
15	75,629	12.52955172
16	77,898	13.24327454
17	80,235	13.94340265
18	82,642	14.63019498
19	85,122	15.30390555
20	87,675	15.96478354
21	90,306	16.61307338
22	93,015	17.24901483
23	95,805	17.87284312
24	98,679	18.48478897
25	101,640	19.0850787
26	104,689	19.67393435
27	107,830	20.25157369
28	111,064	20.81821038
29	114,396	21.374054
30	117,828	21.91931011
Yr 1 O&M	50,000	
Sum 2-30	2,328,771	
Total O&M	2,378,771	
NPV O&M*	1,095,966	

Note:
NPV - Net Percent Value
O&M - Operation and Maintenance
* - Geometric NPV factor calculates the NPV of an annually increasing cost at a set annual rate for a given interest rate