CITY OF SAN DIEGO

EVALUATION MONITORING PROGRAM REPORT

ARIZONA STREET LANDFILL

AUGUST 2005

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TABLE OF CONTENTS

SECTION		PAGE
1.0	INTRODUCTION	1
2.0	LANDFILL DEVELOPMENT AND HISTORY	1
2.1	Site Location and History	1
2.2	Site Use	2
2.3	Adjacent Site Use	2
2.4	Record Review of Landfill and Surrounding Properties	2
2.5	Water Quality Monitoring Network	3
3.0	SUMMARY OF ENVIRONMENTAL SITE CONDITIONS	3
3.1	Topography and Drainage	3
3.2	Geologic Setting	3
3.3	Hydrogeologic Setting	4
4.0	EMP FIELD INVESTIGATION	4
4.1	Drilling Program	5
5.0	EMP LABORATORY ANALYSES	5
5.1	Groundwater	5
5.1.1	Groundwater Analytical Results	6
5.2	Soil-Pore Gas	7
5.2.1	Soil-Pore Gas Analytical Results	7
6.0	GROUNDWATER MODELING	8
6.1	Model Description	8
6.1.1	Input Parameters	8
6.1.2	Solver	9
6.2	Contaminant Transport Modeling	9
6.2.1	Model Calibration	10
6.2.2	Sensitivity Analysis	10
6.3	Remediation Scenarios	11

CITY OF SAN DIEGO
EVALUATION MONITORING PROGRAM REPORT
ARIZONA STREET LANDFILL
AUGUST 2005

TABLE OF CONTENTS (CONT'D)

7.0 CORRECTIVE ACTIONS 12

8.0 CONCLUSIONS AND RECOMMENDATIONS 12

9.0 CLOSURE 13

FIGURES

Figure 1	Site Location Map
Figure 2	November 2004 Groundwater Equipotential Contours
Figure 3	Scenario 1 (Year 2005)
Figure 4	Scenario 1 (Year 2025)
Figure 5	Scenario 2 (Year 2025)

TABLES

Table 1	Groundwater Monitoring Results – AMW-6
Table 2	Comparison Data – Soil-Pore Gas Sample Results – January 2003
Table 3	Comparison Data – Soil-Pore Gas Sample Results – June 2003
Table 4	Comparison Data – Soil-Pore Gas Sample Results – December 2003
Table 5	Comparison Data – Soil-Pore Gas Sample Results – December 2004
Table 6	Flowpath II Sensitivity Analysis

LIST OF APPENDICES

A	Boring Log and Well Completion Summary – AMW-6
B	Field Notes and Laboratory Analytical Results
C	Drilling, Well Construction, Groundwater Sampling, and Laboratory Methods
D	Historical Groundwater Monitoring Results

1.0 INTRODUCTION

The Arizona Street Landfill (ASL) is an inactive, Class III municipal solid waste facility that is monitored in accordance with M&RP Blanket Order 97-11, which was issued by the San Diego Regional Water Quality Control Board (RWQCB). Based on the age of this landfill (inactive prior to November 1984), the ASL is regulated by California Code of Regulations Title 23 (23 CCR). As stated in WDR No. 97-11 pursuant to 23 CCR §2550.1(g) in the event there is evidence of water quality impairment, a corrective action program (CAP) may be required in accordance with Chapter 15, which generally corresponds to 27 CCR which regulates more recent landfills. Therefore, in response to detection of volatile organic compounds (VOCs) primarily in samples from downgradient monitoring wells AMW-4 and AMW-5, and in accordance with 23 CCR and 27 CCR, the City of San Diego (City) submitted an Evaluation Monitoring Program (EMP) workplan to the RWQCB on October 22, 2003. The EMP workplan is the initial step in satisfying the requirements for an EMP as set forth in 23 CCR §2550.1(2) and describes the water quality monitoring and response activities to be initiated by the City following initial indications of a release from the ASL. On March 2, 2005 GeoLogic Associates (GLA) and the City presented the preliminary results of the EMP to the RWQCB and discussed additional workscope elements to complete the EMP. This EMP report presents the results of the proposed workscope elements including:

- Review of the landfill operational history and sequence of landfilling activities.
- Phase I record review of surrounding properties.
- Chemical analyses of soil-pore gas and groundwater samples collected from existing wells/probes.
- Installation of downgradient monitoring well AMW-6.
- Assessment of the vertical extent of contamination, by collecting groundwater samples at discrete depths from well AMW-6.
- Development of a conceptual hydrogeologic model of the area using FLOWPATH II.
- Simulation of the VOC contaminant plume (ppb concentration gradient) transport due to advection and dispersion and projection of plume migration into the future.
- Preparation of this EMP report of findings.

2.0 LANDFILL DEVELOPMENT AND HISTORY

2.1 SITE LOCATION AND HISTORY

The 65-acre site includes two former landfills - the ASL and the underlying Balboa Park Landfill. The landfill is located in the northeastern corner of Balboa Park, to the north and east of downtown San Diego (Figure 1). The landfill is bounded by Pershing Drive on the east and south, Florida Drive on the southwest, Morley Field on the northwest, and Jacaranda Drive on the northeast.

The site was initially developed as the Balboa Park Landfill for disposal of demolition debris from 1935 to 1936. From 1952 to 1974 the site was known as the ASL and operated as a Class III municipal solid waste disposal facility (under the current regulating definition), receiving approximately 1,938,000 tons of waste.

The site is unlined and currently has an interim cover consisting of native onsite soils placed over the refuse. The interim cover varies from three to 15 feet thick and is disked and mulched or vegetated with native grasses and shrubs. There are City Park and Recreation Department trailers and equipment on a portion of the site, and a nursery and recreational areas with buildings are located on perimeter portions of the site.

In 1991, the City installed a landfill gas collection system and flare station. The flare station began operation in July 1991 and is currently operated and maintained by the City. In August 2000, in response to continued landfill gas measurements of up to more than 40 percent methane in perimeter probes, the City completed upgrades to the landfill gas extraction system, including installation of an additional 11 landfill gas extraction wells, new well heads at all existing gas extraction wells, and a landfill gas condensate collection system. The City performed additional repairs to the landfill gas collection system during the summer 2001, including removal of a large rock within one of the header pipes. In July 2003, the City completed drilling and constructing 20 more landfill gas extraction wells.

2.2 SITE USE

The ASL is an inactive landfill. It is equipped with a landfill gas collection system and a flare station. City Park and Recreation Department maintenance staff and equipment occupy a portion of the central landfill site. Several hiking trails traverse the site perimeter. Since the site does not have a perimeter fence, public may gain access to the site.

2.3 ADJACENT SITE USE

The ASL is located entirely within Balboa Park. In this area of the park, recreational facilities include baseball fields, a municipal swimming pool, tennis courts, golf course, a bicycle velodrome, and related facilities. Some of the surrounding area is open space. In addition, a City plant nursery is located between the eastern limits of the landfill and Pershing Drive.

2.4 RECORD REVIEW OF LANDFILL AND SURROUNDING PROPERTIES

GLA reviewed available City records and conducted a site visit to obtain information on the site operations and activities at the ASL. GLA also conducted historical and environmental record searches of the ASL and adjacent properties as defined by ASTM (E1527-97) Standard of Practice for indications of other sites that may have experienced a release to groundwater in the vicinity of the ASL. Based on our review, there are no significant contributors to groundwater impacts upgradient of the site. In addition, there are no groundwater supply wells within one mile of the site. This finding is consistent with the fact that there are no beneficial uses to groundwater in the area of the ASL.

2.5 WATER QUALITY MONITORING NETWORK

As shown on Figure 2, the original site Detection Monitoring Program (DMP) water quality monitoring network, installed in 1993, includes one upgradient well (AMW-1) and five downgradient wells (AMW-2, AMW-3, AMW-4, and AMW-5). The wells were installed at locations intended to provide the required information to evaluate changes in groundwater quality at the site in accordance with 23 CCR §2550.8. Groundwater elevations are measured and groundwater samples are collected in each well on a semi-annual basis, during the second (Spring) and fourth (Fall) quarters of each year. Groundwater samples are analyzed for eight general chemistry parameters (bicarbonate, chloride, electrical conductivity [EC], nitrate as nitrogen, pH, sulfate, and total dissolved solids [TDS], and total organic carbon [TOC]); metals (calcium, magnesium, and sodium); and the 47 volatile organic compounds (VOCs) listed in Title 40, Part 258, Appendix I of the Code of Federal Regulations (40 CFR 258).

3.0 SUMMARY OF ENVIRONMENTAL SITE CONDITIONS

The following description of the topography, geology, and hydrogeology in the vicinity of the ASL is based on information obtained primarily from the Solid Waste Assessment Test (SWAT) investigation (IT, 1994) and the semiannual report (October 2004 through March 2005) groundwater monitoring report (GLA, 2005).

3.1 TOPOGRAPHY AND DRAINAGE

The site occupies the head of a small southwest trending canyon, which is bordered by mesas. Prior to landfill development, the valley supported ephemeral stream flow to the southwest toward Powerhouse Canyon (Figure 1). Elevations at the site range from approximately 140 feet above mean sea level (msl) near the toe at the south west end of the landfill, to 280 feet msl on the northwest side of the landfill. Surface water drainage control is provided by the earthen cover which directs drainage to a channel west of Florida Drive.

3.2 GEOLOGIC SETTING

Geologic units in the area include relatively recent valley-filling alluvial deposits and sedimentary rocks. From youngest to oldest, the geologic units within the vicinity of the site include the Pliocene to early Pleistocene Lindavista Formation and Pliocene San Diego Formation. The Lindavista Formation consists of interbedded sandstone and conglomerate, with ferruginous cementation providing the characteristic reddish color and resistant nature that forms the upper surface of the San Diego Mesa. Based on the borings drilled at the ASL, the Lindavista Formation ranges in thickness from 16 to 40 feet in the vicinity of the ASL. The San Diego Formation lies conformably below the Lindavista Formation and consists primarily of poorly indurated silty sandstone with interbedded cobble conglomerate, and some sporadic zones containing fossil shell fragments. The bedding within the San Diego Formation generally dips about 3 to 6 degrees to the southwest in the vicinity of the Balboa Naval Hospital (Kennedy, 1975). Based on the site boring logs, the San Diego Formation is more than 238 feet thick, and is reported to attain a maximum thickness of about 1300 feet.

3.3 HYDROGEOLOGIC SETTING

The ASL is located within the Lindbergh Hydrologic Subarea of the San Diego Mesa Hydrologic Subunit within the Pueblo San Diego Hydrologic Unit (RWQCB, 1994). There are no beneficial use designations assigned by the RWQCB for groundwater within the San Diego Mesa Hydrologic Subunit.

Groundwater beneath the site occurs at depths between 120 and 125 feet below ground surface within the San Diego Formation and appears to be unconfined. The aquifer consists of poorly-indurated, silty sandstone with interbedded cobble conglomerate. As shown on Figure 2, groundwater flows to the southwest, with an average hydraulic gradient of approximately 0.003 ft/ft. As described in the SWAT (IT, 1994), the hydraulic conductivity of the water-bearing interval screened by the site monitoring wells is estimated to be 1×10^{-4} to 1×10^{-6} centimeters per second (cm/sec), with an estimated effective porosity of 20 percent. Using a conservative hydraulic conductivity value of 1×10^{-4}, the linear groundwater flow velocity for the site is calculated at 0.004 feet/day (1.6 feet/year).

No surface water or major steam systems are located within one mile down slope of the site. Drainage at the site is directed to a City-maintained storm drain.

4.0 EMP FIELD INVESTIGATION

As described in the EMP Workplan, the EMP investigation was designed to better characterize the site geologic, hydrogeologic, and groundwater chemistry conditions, and to provide data to identify the nature and extent of the observed groundwater contamination. To accomplish these objectives the EMP Workplan identified both field and laboratory work phases. Since VOC impacts have been recognized only at the southwestern toe of the landfill in wells AMW-4 and AMW-5, the EMP field investigation focused on characterizing the hydrogeologic and groundwater quality conditions in this area of the site.

The EMP subsurface investigation included provisions for sampling hydrostratigraphic and vadose zone intervals to better characterize the horizontal and vertical extent of groundwater impacts and nature of the release. The procedures and methods employed during the EMP drilling and well construction program are detailed in the EMP Workplan. Boring logs and well completion logs developed as part of the EMP study are presented in Appendix A together with logs for the facility's DMP groundwater monitoring wells constructed in 1993. Laboratory analyses for the EMP investigation were completed by Enviromatrix Analytical, Inc. of San Diego, California, a state certified laboratory and are provided in Appendix B along with the field data sheets. Tables summarizing the results of historical groundwater and landfill gas monitoring at the site are included in Tables 1 through 6, and the procedures and methods employed during the EMP drilling, well construction, groundwater sampling are detailed in Appendix C.

4.1 DRILLING PROGRAM

Having established that groundwater in both wells AMW-4 and AMW-5 are impacted, monitoring well AMW-6 was sited approximately 750 feet downgradient of well AMW-4 to determine the lateral extent of the release (Figure 2). In order to verify stratigraphic and water chemistry conditions, well AMW-6 was drilled using air rotary casing hammer (ARCH) drilling methods. The ARCH technique employs 9-5/8-inch OD drive casing to support the borehole, and has the advantage of providing relatively undisturbed lithologic samples while not requiring use of injected drilling fluids. As a consequence, accurate determination of both the stratigraphy and occurrence of water-bearing units within the borehole is possible.

During the construction of well AMW-6, groundwater was first encountered at a depth of 133 feet below ground surface (fbgs) in a thick sequence of gravelly sandstone within the San Diego Formation. Groundwater was found to be unconfined and exhibited an upward gradient, which ultimately yielded a static water elevation of about 113 fbgs or 24 feet msl.

During the drilling of AMW-6, grab samples were collected at ten foot intervals and checked for the presence of VOCs using a photoionization detector (PID) and these measurements are included in the boring log for well AMW-6. VOCs were first detected in the vadose zone at a depth of 70 fbgs and continued to be detected until groundwater was encountered at 133 fbgs. VOC concentrations (in the grab samples) ranged between 3.1 to 5.9 ppm.

5.0 EMP LABORATORY ANALYSES

5.1 GROUNDWATER

To evaluate the vertical and lateral extent of groundwater impacts downgradient of the ASL, the EMP investigation focused on groundwater sampling of EMP well AMW-6 and was conducted in two phases. The Phase I groundwater sampling event was intended to determine the lateral extent of groundwater impacts. If VOCs were confirmed during the Phase I groundwater sampling event, a second Phase II groundwater sampling event would be performed to define the vertical distribution of VOCs. As summarized in Table 1 and detailed in Appendix B, Phase I laboratory analyses included routine general chemistry (bicarbonate, chloride, electrical conductivity, nitrate as nitrogen, pH, sulfate, TDS, and TOC), metals (calcium, magnesium, and sodium), and VOCs (by EPA method 8260B). Phase II laboratory analyses included only VOCs (by EPA method 8260B). During the EMP investigation, laboratory results were obtained from sampling points as follows:

Phase	Sample	Sample Date	Sample Depth (fbgs)	Purge Method
I	AMW-6	11/30/04	128	Micro-Purge
I	AMW-6A	1/20/05	128	Micro-Purge
I	AMW-6B	1/20/05	128	1.5 BV
I	AMW-6C	1/20/05	128	3.0 BV
II	AMW-6A	5/19/05	121	Micro-Purge
II	AMW-6B	5/19/05	128	Micro-Purge
II	AMW-6C	5/19/05	135	Micro-Purge

Notes: BV - Borehole Volume

5.1.1 Groundwater Analytical Results

Initially, groundwater sampling was performed concurrent with the DMP sampling event on November 30, 2004. As shown on Table 1 (Appendix B), nine VOCs were detected in the primary sample collected from well AMW-6 with seven of the VOCs (benzene, cis-1,2-dichloroethene [cis-1,2-DCE], dichlorodifluoromethane [DCDFM], methylene chloride, tetrachloroethene [PCE], trans-1,2-dichloroethene [trans-1,2-DCE], and trichloroethene [TCE]) measured at concentrations greater than the analytical practical quantitation limit (PQL).

In response to the detection of these seven VOCs above their respective PQL's, confirmation sampling was performed on January 20, 2005. The initial VOC values range from about 1 µg/L to 29 µg/L. To evaluate the effect that sampling protocols may have on the confirmation samples, three discrete samples were collected using different sampling protocols. The first sample was collected using low-flow (micro-purge) sampling procedures; the second confirmation sample was then collected after purging 1.5 BV; and the third discrete confirmation sample was collected after a total of 3 BV were purged. All confirmation samples were collected at the same depth as the primary sample at 128 fbgs. As shown in Table 1, each discrete retest confirmed the presence of the nine VOCs measured in the primary sample collected on November 30, 2004.

The Phase II groundwater sampling program consisted of collecting discrete samples from different depths within the screened section of well AMW-6 to evaluate the vertical distribution of VOCs. Phase II groundwater sampling was performed on May 19, 2005, and used low-flow (micro-purge) sampling procedures so that samples could be collected at discrete depths. The first sample was collected at the top of the screened section at 121 fbgs; the second sample was collected in the middle of the screened section at 128 fbgs; and the third sample was collected at the bottom of the screened section at 135 fbgs. As shown in Table 1, each discrete sample interval contained all nine VOCs at concentrations ranging from less than 1 µg/L to 24 µg/L, and with the exception of DCDFM, the concentrations of VOCs within the screened section appear to be evenly distributed. Concentrations appear to be greatest at the top of the screened section for DCDFM, a halogenated methane compound, which is commonly found in landfill gas (LFG).

As shown in Table 1, the results of the inorganic analyses indicate that general chemistry constituents are also evenly distributed through the screened section. However, concentrations of dissolved metals appear to be slightly elevated in the middle and bottom of the screened

section. Of note, the significant decrease in metals concentrations between the Phase I sample event in November 2004 and the Phase II sample event in May 2005 appears to be related to dilution from the winter rains, since all wells at the ASL have reported similar results.

5.2 SOIL-PORE GAS

Because the Arizona Street Landfill is known to be generating a significant volume of LFG (in excess of 40% methane in some soil-pore gas probes), the EMP investigation included collection of four rounds of soil-pore gas sampling between January 2003 and December 2004 to determine if there is a correlation between the analytical results in soil-pore gas and groundwater. As summarized in Tables 2 through 5, five soil-pore gas probes were used in the comparison. The following table summarizes the groundwater monitoring well and adjacent landfill gas probes. For this program the only locations where a gas probe was not present near a groundwater well were in the vicinity of wells AMW-3 and AMW-4. Therefore, soil-pore gas samples were obtained from the available gas well (GW-8D) for well AMW-3 and from inside the casing of well AMW-4 using tubing lowered to the well screen depth.

Groundwater Well	Adjacent Landfill Gas Probe
AMW-1	P-15D
AMW-2	P-7
AMW-3	GW-8D
AMW-5	P-11D

As provided in Appendix B, the laboratory analyses were completed by Enviromatrix Analytical, Inc. of San Diego, California, a state certified laboratory. Laboratory analyses of soil-pore gas included fixed gases (methane, oxygen, nitrogen and carbon dioxide) and VOCs (by method TO-15).

5.2.1 Soil-Pore Gas Analytical Results

As shown in Tables 2 through 5, the soil-pore gas data suggests a relatively consistent list of VOC constituents are present in the soil-pore gas with many of the higher concentrations (e.g., PCE and DCDFM) also measured in samples from the groundwater monitoring wells. In addition, the highest gas concentrations were measured in the southeastern section of the site at probe P-11D. It should be noted that during each sampling event, the soil-pore gas concentrations in well AMW-4 (where groundwater impacts by VOCs had been greatest) are low, likely as a result of the fact that this is a groundwater monitoring well with limited screen for collection of a robust soil-pore gas samples. However, based on the findings, GLA concludes that sufficient gas sample data have been obtained to confirm similar VOC constituents are present in the gas and can be correlated to VOC impacts in groundwater.

6.0 GROUNDWATER MODELING

Preliminary results from the EMP workplan were presented in a meeting with the City and RWQCB staff on March 2, 2005. In the meeting results from the record review and surrounding properties, soil-pore gas laboratory results, and construction and sampling of well AMW-6 were discussed. It was concluded that BIOCHLOR modeling could not effectively model the specific site conditions and accurately model the distribution of VOCs in groundwater (at levels measured from about 1 to 24 µg/L), and therefore, a more sophisticated groundwater model was required. GLA proposed to perform groundwater modeling of the VOC plume (for defining the lateral extent of VOC impacts) using either FLOWPATH II (2-dimentional) or MODFLOW (3-dimentional) numerical flow and transport models to evaluate potential flow paths beyond the current understanding of the existing contaminant plume distribution and to simulate VOC plume transport.

6.1 MODEL DESCRIPTION

For this project, the groundwater flow system was simulated in two-dimensions using the finite-difference computer code FLOWPATH II, developed by Waterloo Hydrogeologic (1998). The modeling process typically includes developing a conceptual model of the flow system that is based on the available geology, hydrogeology, and field data of the study area. This information is used to discretize, or design, the model domain and grid, which divides a two-dimensional study area into cells defined by a series of rows and columns. Regions of the model grid are assigned hydraulic properties based on the conceptual model, and boundary conditions are assigned to represent flux into and out of the model, barriers to flow (e.g., faults, bedrock), surface water features, and flow lines. Generally, the model must then be calibrated, meaning the results of simulations should match measured VOC and head values (from a specific time) as closely as possible, while maintaining hydraulic parameter values that are reasonable (i.e., not significantly different than calculated/measured or literature values). Calibration is thus an iterative process, whereby the model is run multiple times to find the optimum values and distribution of parameters. The sensitivity of model output to variations in these values is then tested via additional model runs to determine the parameters upon which the simulation results most depend.

6.1.1 Input Parameters

Model Area – The model area is situated within east-central Balboa Park, extending from Powerhouse Canyon/Florida Drive to the west, Balboa Park Municipal Golf Course to the south and east, and Morley Field to the north, and encompasses approximately 0.54 square miles (Figure 3). The model area was kept as small as possible to allow for a reasonable estimation of the boundary conditions, while still allowing for contaminant transport modeling.

Boundary Conditions – The boundary conditions selected for the steady-state model represent hydraulic conditions at the limits of the model domain. The steady-state model used constant head boundaries, which were extrapolated from known head values of existing DMP wells at the ASL.

Wells – In order to ensure that the steady-state model represents a reasonable estimation of groundwater flow conditions in the aquifer, X-Y coordinates and measured head levels for downgradient groundwater monitoring wells AMW-2, AMW-3, AMW-4, AMW-5, and AMW-6 were included in the model.

Recharge – Aerial recharge (i.e., infiltration from irrigation) is assumed to take place at the Balboa Park Municipal Golf Course in the southeastern area of the model. Infiltration rates were included in the sensitivity analysis to evaluate the effects that irrigation from the golf course may have on the modeled results.

Aquifer Properties - Field observations made during the drilling of well AMW-6 confirm earlier hydrogeologic interpretations (IT, 1994) that groundwater beneath the site is unconfined within the San Diego Formation, and that the water bearing unit within the San Diego Formation consists of a poorly indurated, silty sandstone to gravelly sandstone. Aquifer properties assigned for the model are generally consistent with these field observations and are summarized below.

Aquifer Property	Assigned Value/Condition
Layers/Type	1/Unconfined
Hydraulic Conductivity	1.0E-03
Effective Porosity	20 Percent

6.1.2 Solver

The Preconditioned Conjugant-gradient (PCG) solver was used to solve the groundwater flow matrix equations for hydraulic head produced by FLOWPATH II. The PCG solver works on a two-tier approach to calculate a solution at one time step. Outer iterations are used to vary the preconditioned parameter matrix in an approach toward an acceptable solution. Convergence of the solver is determined using both the head-change and residual criteria. For the model default PCG solver parameters were chosen.

6.2 CONTAMINANT TRANSPORT MODELING

Contaminant transport modeling for the EMP project was modeled using hydrodynamic advection and dispersion using the Random Walk Method (RWM) and a total VOC load. This approach is considered conservative since the model accounts for all VOCs detected in the groundwater monitoring wells at the ASL and doesn't account for the natural degradation of VOCs. Of note, the total VOC load or VOC (total) is defined as the sum of VOCs measured in a single groundwater sample. RWM is a module that operates within the FLOWPATH II platform and is capable of simulating the movement of contaminants under the influence of advection and dispersion. Advection, is the process by which solutes are transported by the bulk motion of flowing groundwater, while, dispersivity (or dispersion) is generally an important factor in distribution of solutes introduced into groundwater, and occurs as a result of the tortuous nature of groundwater flow through a porous media, such as, sand, gravel, and silt where water cannot travel along a straight path.

6.2.1 Model Calibration

For model calibration purposes, groundwater potentiometric surface elevations measured in November 2004 were used. This time period was selected because it includes the most complete set of groundwater elevation data for the ASL (including EMP well AMW-6). Initial simulations were used to adjust solver parameters to attain model convergence with reasonable convergence criteria and without excessive iterations. Successive simulations initially incorporated an average hydraulic conductivity value (5.0E-05 cm/sec) and varying boundary conditions (constant head values) until the model generally reflected the approximate groundwater contours and the hydraulic head configurations conformed roughly to target values. However, due to the models complexity, the effects were often more subtle, so even though calibration statistics may have shown an overall calibration with hydraulic head configurations, the calibration may have decreased in the area of most concern (i.e., Wells AMW-4, AMW-5, and AMW-6) when simulating contaminant transport. Therefore, further calibration of the model was performed during contaminant transport modeling.

To simulate contaminant transport, a VOC source was placed in the southwest corner of the ASL within the old tributary canyon (east of well AMW-4). As discussed in Section 2.1, historical records indicate that municipal solid waste was disposed of at the site between 1952 and 1974, and therefore, the VOC plume was estimated to be approximately 40 years old for calibrating the contaminant transport model. Calibration of the contaminant transport model involved varying the VOC (total) concentration and distribution at the source until the modeled concentrations at wells AMW-4, AMW-5, and AMW-6 matched the measured VOC (total) concentrations observed during the EMP investigation. For well AMW-6, the total VOC load was calculated as an average from the seven samples collected from well AMW-6 (Table 1), while the total VOC loads for wells AMW-4 and AMW-5 were calculated from the November 2004 semiannual monitoring results. For well AMW-6, the average total VOC load was calculated to be 92.4 µg/L; for well AMW-4 the total VOC load was calculated to be 14.21 µg/L; and for well AMW-5 the total VOC load was calculated to be 4.22 µg/L. The calibrated contaminant transport model is shown on Figure 3. As shown on this figure, it is estimated that the current total VOC plume is migrating southwest from the source and approaches zero µg/L approximately 1000 feet south, 700 feet east, and 400 feet west of well AMW-6.

6.2.2 Sensitivity Analysis

The following section addresses the selection of variables used in contaminant transport modeling and the sensitivity of the modeled results with respect to variable selection. The results of the sensitivity analyses are discussed below and presented in Table 6.

Hydraulic Conductivity --Calibration of the steady-state model was relatively insensitive using the range of published hydraulic conductivity values discussed in Section 3.3. However, in contaminant transport simulations, changes in hydraulic conductivity values resulted in significant impacts to contaminant transport distances. Generally, lower hydraulic conductivity values resulted in poor correlation with measured VOC concentrations. Therefore, during model calibration the range of hydraulic conductivity values was expanded to include a conservative

value of 1.0E-03 cm/sec, which is consistent with the range of published values (Freeze and Cherry, 1979) for gravelly sands. Based on the calibration and sensitivity analyses a conservative hydraulic conductivity of 1.0E-03 cm/sec was used for the steady-state model.

Recharge – Recharge as a result of irrigation from the Balboa Park Municipal Golf Course varied significantly. Values for recharge ranged from 0 to 1.0E-03 mm/year. As expected, higher recharge values resulted in higher hydraulic head values, which resulted in poor correlation with historical groundwater contours and hydraulic head distribution calculations. Based on the calibration results and sensitivity analyses, recharge was set at 0.

Porosity - In contaminant transport simulations changes in porosity yielded significant impacts to transport distances. For example, lower porosity values resulted in further plume migration, as would be expected. Typical published values for porosity in sand and gravel mixes varies from 10 to 35 percent (Driscoll, 1986). Based on the observed formational materials, and the calibration and sensitivity analyses, a porosity of 20 percent was used in the contaminant transport model.

Dispersivity - Model calibration varied considerably using a range of longitudinal dispersivity values ranging from 10 to 1000. Likewise, transverse dispersivity values also varied considerably. For example, higher dispersivity values resulted in further plume migration. For calibration and modeling purposes, a 10:1 ratio (longitudinal to transverse dispersivity) was used (Gelhar et al., 1992). Based on the calibration and sensitivity analyses dispersivity values of 200 feet longitudinal and 20 feet transverse were used.

6.3 REMEDIATION SCENARIOS

Given that the ASL site is within a non-beneficial use groundwater zone, and the City is currently involved in source control remediation, two contaminant transport scenarios were simulated.

- Scenario 1 - "worst case" scenario assumes no additional remediation occurs;
- Scenario 2 – "source control" scenario assumes that the plume source is cut off within five years.

Scenario 1 - This scenario was modeled by assuming no additional remediation occurs and that a release from the source will continue for an additional 20 years (year 2025). The resulting VOC (total) plume is shown on Figure 4, and indicates that it extends approximately 800 feet south, 700 feet east, and 450 feet west of well AMW-6.

Scenario 2 – This scenario was modeled by simulating a release from the source for 45 years until approximately 2010. This timing assumes that it will take the City 5 years to complete landfill gas source control measures. For comparative purposes the model was allowed to run an additional 15 years, so a comparison could be made with the "worst case" scenario at year 2025. The resulting VOC (total) plume is shown on Figure 5. As shown on this figure, the VOC (total) plume extends approximately 900 feet south, 800 feet east, and 450 feet west of well AMW-6. While the distribution of VOCs (total) is slightly larger than the "worst case" scenario at the year

2025, concentrations are lower in the area depicting the highest concentrations as a result of natural attenuation. In addition, the area within the 95 µg/L isoconcentration contour is approximately 37,980 ft^2 smaller than the "worst case" scenario.

7.0 CORRECTIVE ACTIONS

The most common mechanism for determining potential site corrective actions is the comparison of various remedies in terms of effectiveness, implementability, and cost.

Effectiveness is a relative evaluation of the remedial technology based on the site-specific contaminants and ability of the proposed process to treat the volumes of contaminated material to the remediation goals, the potential impact or risk posed by the implementation, construction, and operation of the selected alternative based on human health and environment, and the reliability and proven ability of the technology.

Factors to be considered pertaining to implementability are institutional factors such as permits and requirements; and availability of services, equipment, technology, skilled labor, and utilities.

Given these three criteria and the fact that impacts to groundwater at the ASL appear to be largely due to LFG dissolution, the most effective corrective actions to control groundwater impacts will be those that control LFG migration to groundwater. The City has already performed a variety of LFG related corrective actions including:

- Increasing the level of maintenance of the existing LFG collection system;
- Completing upgrades to the LFG extraction system, including installation of 11 additional gas extraction wells, installation of new well heads at all existing gas extraction wells, and the installation of a landfill gas condensate collection system in October 2000, followed by repairs to the header pipes during the summer 2001 to further enhance the efficiency of the landfill gas extraction system.
- Completing drilling and constructing 20 additional landfill gas extraction wells in July 2003.
- Continued evaluation of the LFG system for optimum performance.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The results of this EMP investigation indicate that the lateral extent of impacts to groundwater at the ASL have migrated approximately 1000 feet south and 300 feet west of the southwestern perimeter of the site. Although the modeled plume extends beyond the perimeter of the ASL it largely remains within City-owned properties. The field investigation, performed as part of this EMP, indicates that these impacts occur within an unconfined, porous, aquifer consisting of interbedded sands and gravel of the San Diego Formation. The laboratory analyses indicate that the impacts to groundwater are organic constituents, most likely associated with landfill gas migration and dissolution. Taking into account the relatively low organic constituent concentrations measured in groundwater, the fact that no groundwater wells exist within one mile of the site, and the aquifer is classified as having no beneficial uses, the potential for natural attenuation (diffusion/degradation) of VOC impacts is high. Modeling of the VOC (total) plume

for an additional 20 years indicates that the plume may extend further south; however, the highest constituent concentrations may be reduced by effective source control.

In addition, to the existing source control measures that the City currently performs, the City is proposing additional source control measures to reduce landfill gas generation at the ASL. These additional source control measures include:

- Proper maintenance of landfill slope and deck areas to promote runoff and reduce infiltration of surface water into the waste prism.
- Continued maintenance and adjustments to landfill gas and condensate systems for optimum performance.
- Construction of additional landfill gas extraction wells.

9.0 CLOSURE

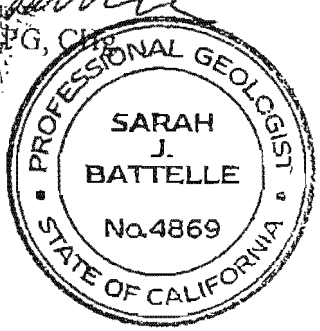
This EMP for the ASL is based on the regulations contained in 40 CFR Part 258 and CCR Title 27, discussions with the City of San Diego, and RWQCB. The conclusions and recommendations presented in this EMP were prepared in accordance with generally accepted professional geotechnical and hydrogeologic principals and practices. This EMP makes no other warranties, either expressed or implied as to the professional advice or data included in it. Our firm should be notified of any pertinent change in the project, or if conditions are found to differ from those described herein, since this may require a reevaluation of the conclusions and recommendations.

This EMP has not been prepared for use by parties or projects other than those named or described herein. It may not contain sufficient information for other parties or purposes.

GeoLogic Associates

William B. Lopez, CEG, CHg
Project Hydrogeologist

Sarah J. Battelle, PG, CHg
Vice President



FIGURES

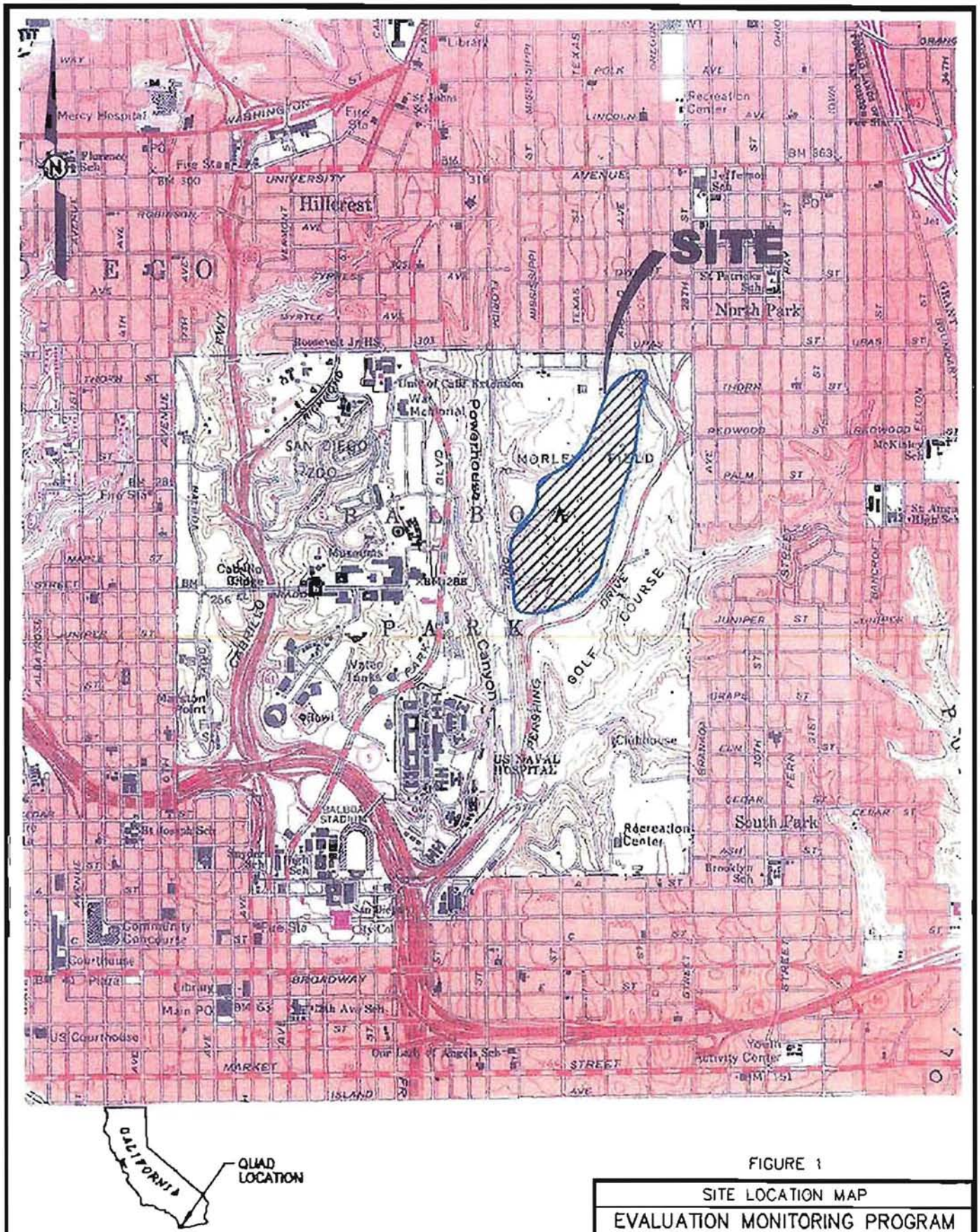


FIGURE 1

SITE LOCATION MAP

EVALUATION MONITORING PROGRAM
ARIZONA STREET LANDFILL
SAN DIEGO, CALIFORNIA

SCALE 1:24,000

SCALE

0 2000 4000 FEET

SOURCE:
IT CORPORATION, 2000

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	JUNE 2005	2001-007

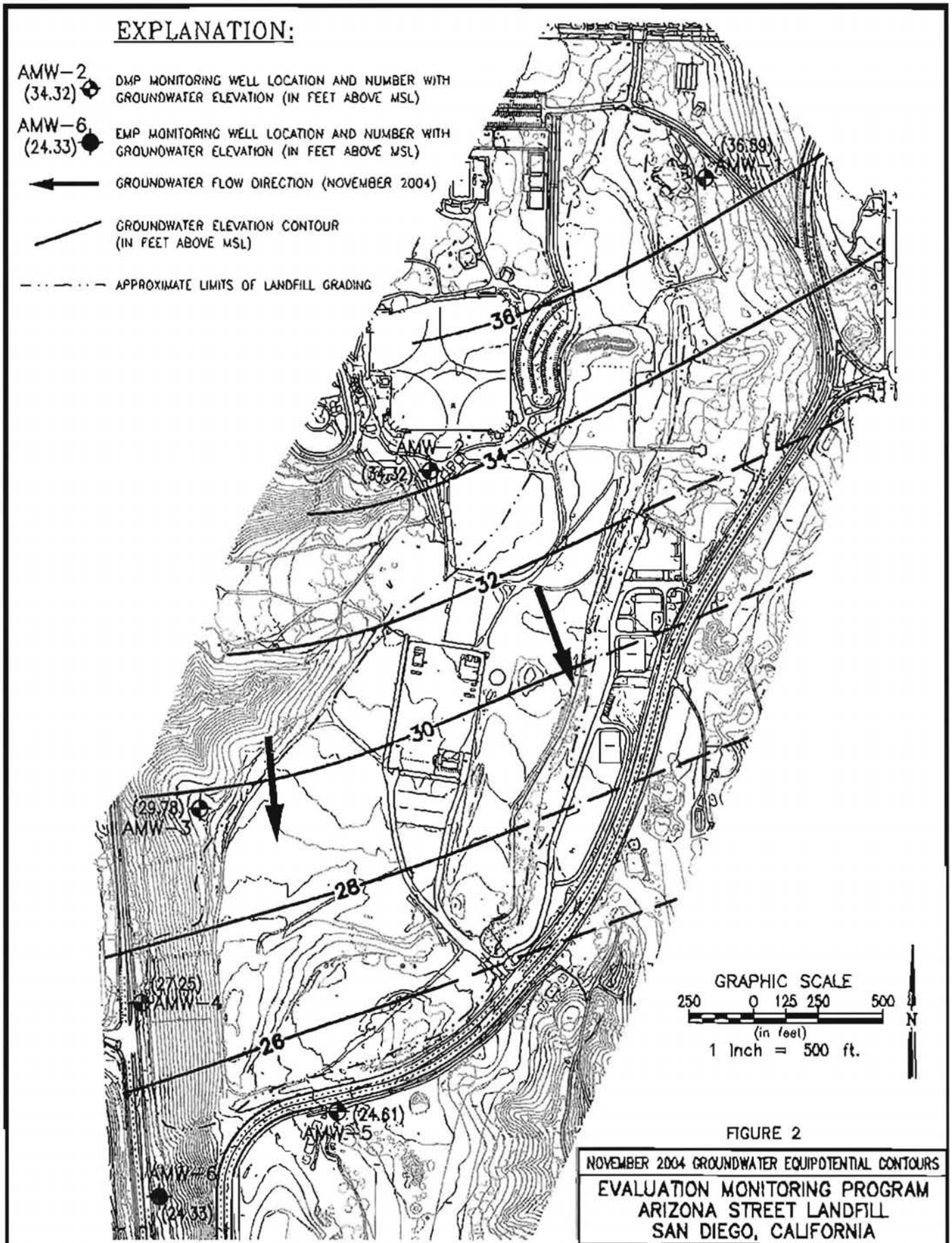


FIGURE 2

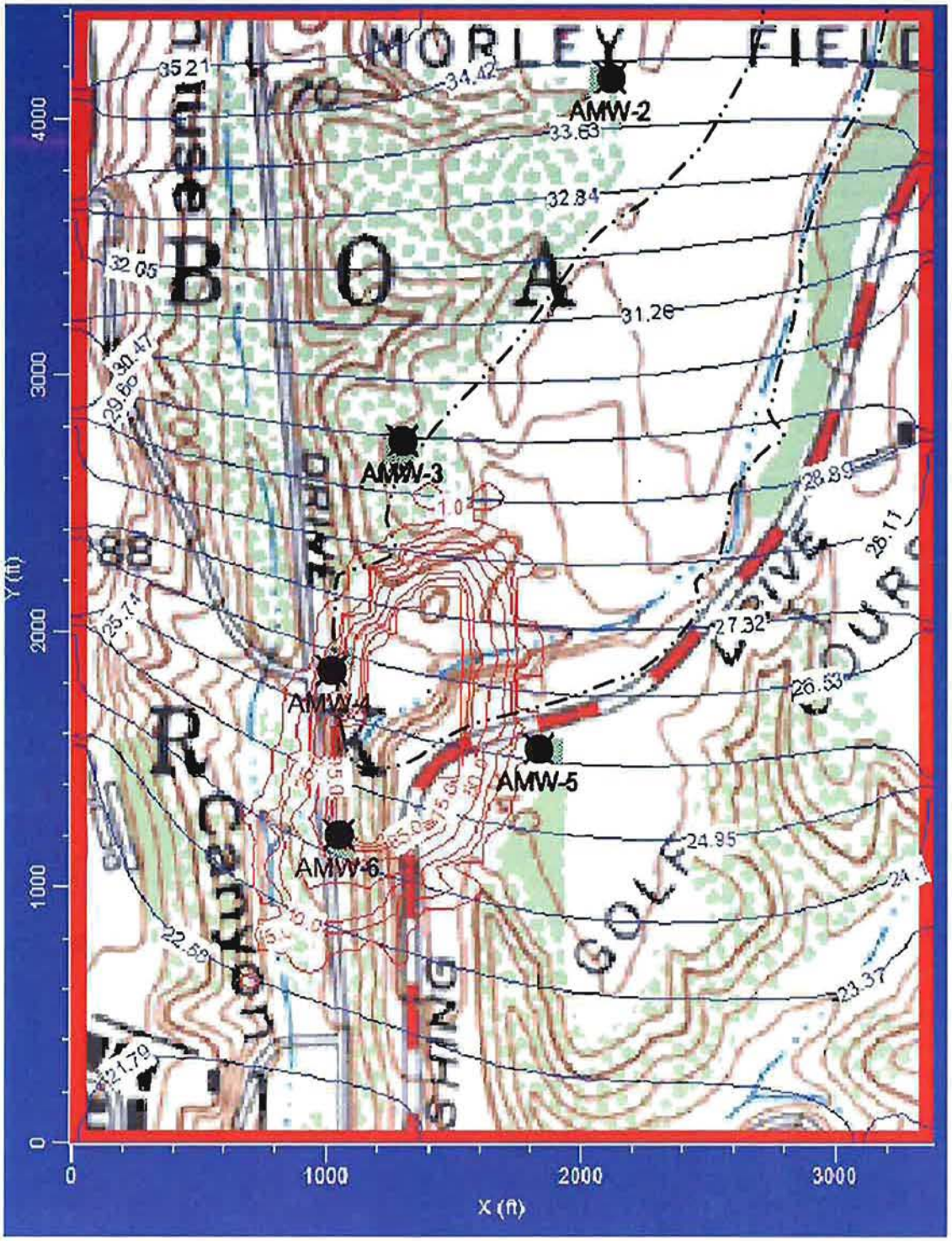
NOVEMBER 2004 GROUNDWATER EQUIPOTENTIAL CONTOURS

EVALUATION MONITORING PROGRAM
ARIZONA STREET LANDFILL
SAN DIEGO, CALIFORNIA

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	JUNE 2005	2001-007

REFERENCE:
TOPOGRAPHIC MAP AS OF 2004 PROVIDED BY THE CITY OF SAN DIEGO



GRAPHIC SCALE
300 0 150 300 600
(in feet)
1 inch = 600 ft.

FIGURE 3

EXPLANATION:

AMW-2 GROUNDWATER MONITORING WELL

GROUNDWATER ELEVATION CONTOUR (IN FEET ABOVE MSL)

TOTAL VOC ISOCONCENTRATION CONTOUR (ppb)

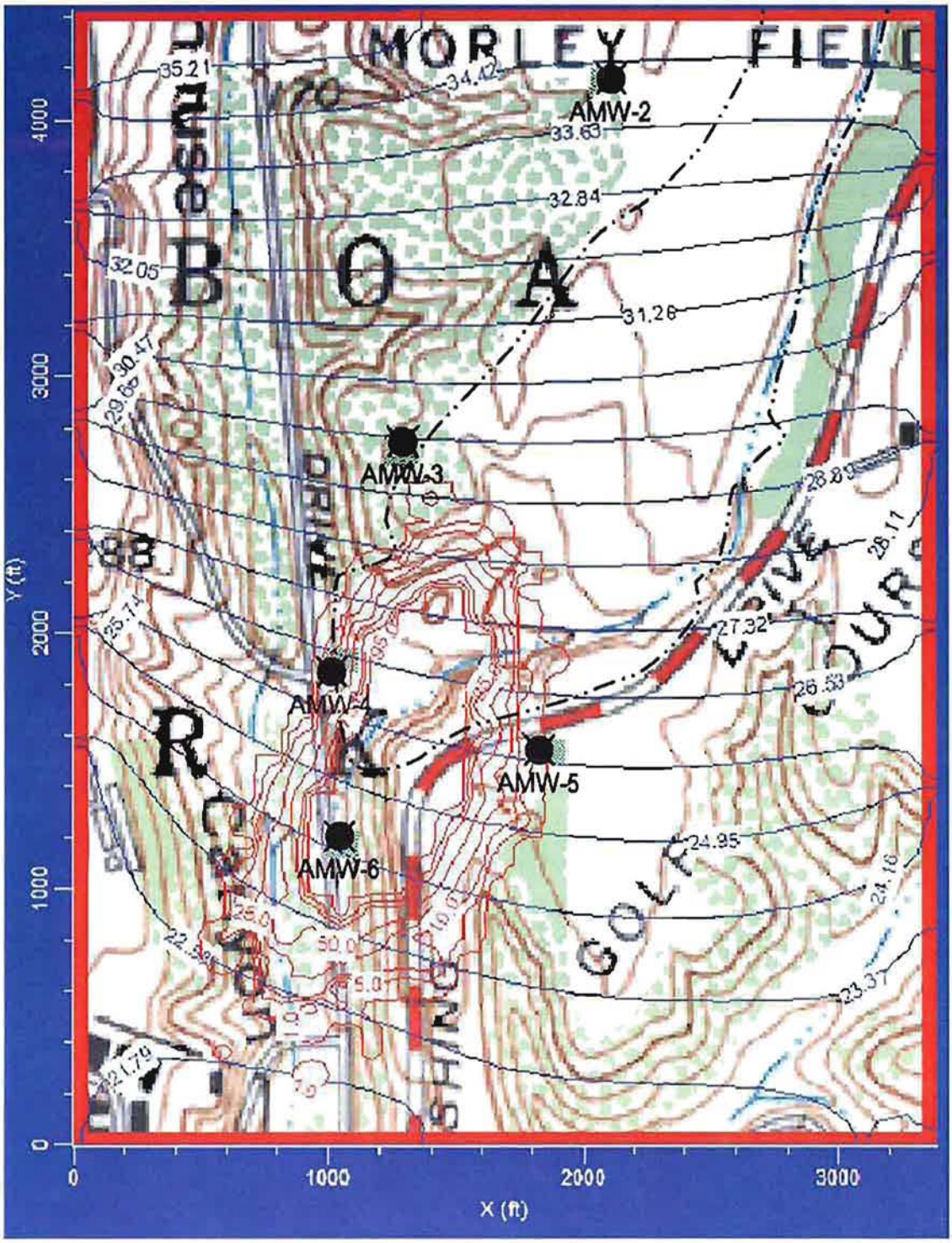
APPROXIMATE LIMITS OF LANDFILL GRADING

SCENARIO 1 (YEAR 2005)

EVALUATION MONITORING PROGRAM
ARIZONA STREET LANDFILL
SAN DIEGO, CALIFORNIA

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	JULY 2005	2001-007



GRAPHIC SCALE

300 0 150 300 600

(in feet)

1 inch = 600 ft.

FIGURE 4

EXPLANATION:

AMW-2 GROUNDWATER MONITORING WELL

GROUNDWATER ELEVATION CONTOUR (IN FEET ABOVE MSL)

TOTAL VOC ISOCONCENTRATION CONTOUR (ppb)

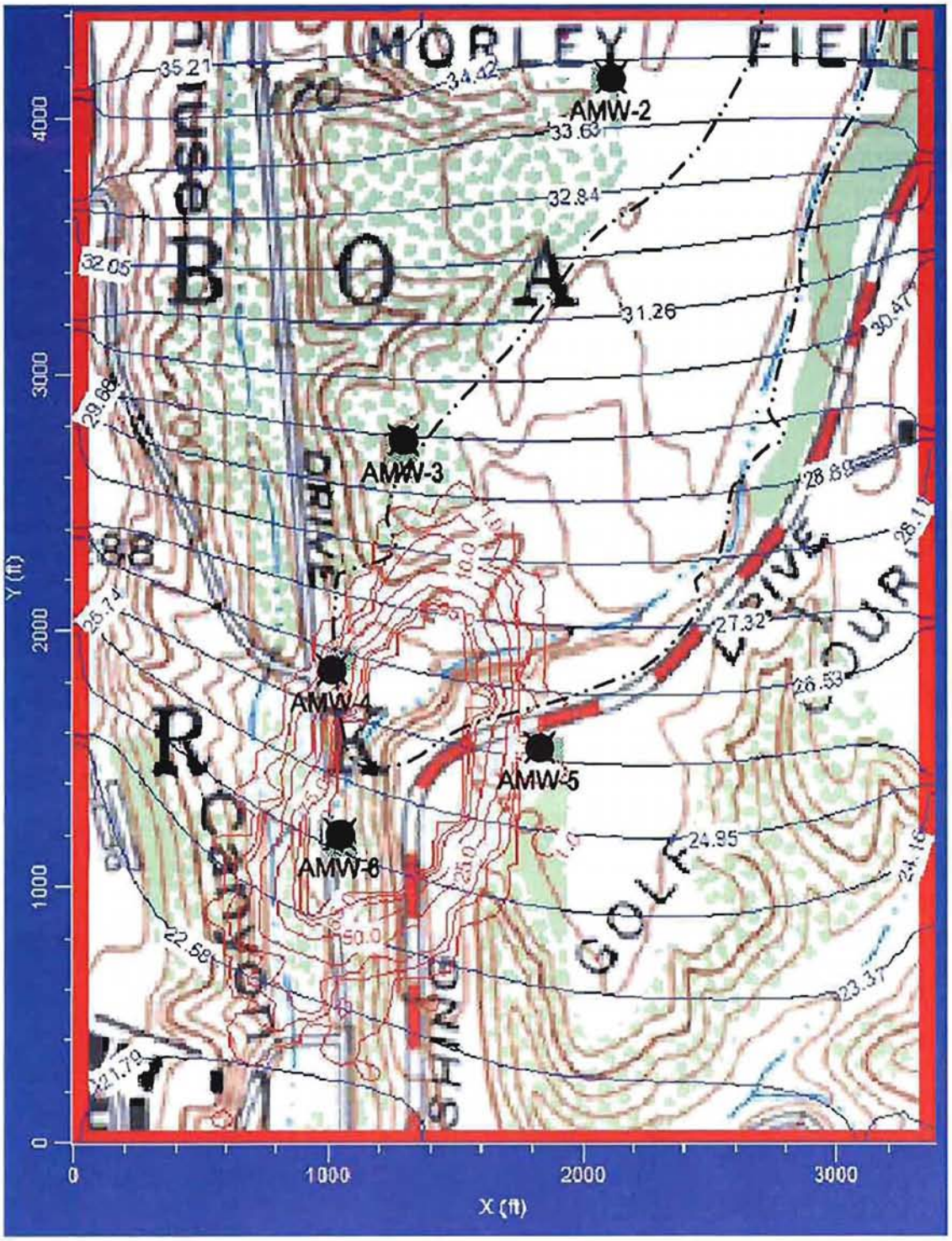
APPROXIMATE LIMITS OF LANDFILL GRADING

SCENARIO 1 (YEAR 2025)

EVALUATION MONITORING PROGRAM
ARIZONA STREET LANDFILL
SAN DIEGO, CALIFORNIA

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	JULY 2005	2001-007



N

GRAPHIC SCALE

300 0 150 300 600

(in feet)

1 inch = 600 ft.

FIGURE 5

EXPLANATION:

AMW-2 GROUNDWATER MONITORING WELL

GROUNDWATER ELEVATION CONTOUR (IN FEET ABOVE MSL)

TOTAL VOC ISOCONCENTRATION CONTOUR (ppb)

APPROXIMATE LIMITS OF LANDFILL GRADING

SCENARIO 2 (YEAR 2025)

EVALUATION MONITORING PROGRAM
ARIZONA STREET LANDFILL
SAN DIEGO, CALIFORNIA

GeoLogic Associates
Geologists, Hydrogeologists, and Engineers

DRAWN BY:	DATE:	JOB NO.
VL	JULY 2005	2001-C07

TABLES

TABLE 1
ARIZONA STREET LANDFILL EMP
GROUNDWATER MONITORING RESULTS
EMP WELL AMW-6

ANALYTE	UNIT	Nov 2004	Jan 2005	Jan[3] 2005	Jan[3] 2005	May 2005	May 2005	May 2005	MED.	AVG.	STD. DEV.	MIN.	MAX.
GENERAL CHEMISTRY													
Bicarbonate Alkalinity	mg CACO3/l	730	NA	NA	NA	442	497	460	479	532	134	442	730
Chemical Oxygen Demand	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Chloride	mg/l	260	NA	NA	NA	230	206	220	225	229	23	206	260
Conductivity	umhos/cm	2600	2400	2400	2400	2300	2300	2300	2400	2386	107	2300	2600
Fluoride	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Nitrate (as N)	mg/l	0.009	NA	NA	NA	0.009	0.009	0.009	NC	NC	NC	NC	NC
pH	units	6.35	6.4	6.3	6.3	6.45	6.51	6.50	6.4	6.40	0.09	6.3	6.51
Sulfate	mg/l	190	NA	NA	NA	498	484	184	337	339	176	184	498
Total Dissolved Solids	mg/l	1410	NA	NA	NA	1430	1380	1400	1405	1405	20.8	1380	1430
Total Organic Carbon	mg/l	13.8	NA	NA	NA	11.0	8.42	5.08	9.71	9.58	3.72	5.08	13.8
METALS													
Aluminum	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Antimony	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Arsenic	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Barium	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Beryllium	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Cadmium	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Calcium	mg/l	238	NA	NA	NA	25.0	27.4	27.8	27.6	79.6	105.6	25.0	238
Chromium	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Chromium (Hexavalent)	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Cobalt	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Copper	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Iron	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Lead	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Magnesium	mg/l	26.9	NA	NA	NA	2.72	2.77	2.82	2.8	8.8	12.1	2.72	26.9
Manganese	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Mercury	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Molybdenum	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Nickel	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Potassium	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Selenium	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Silver	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Sodium	mg/l	253	NA	NA	NA	24.8	26.5	26.5	26.5	82.7	113.5	24.8	253
Thallium	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Vanadium	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
Zinc	mg/l	NA	NA	NA	NA	NA	NA	NA	NC	NC	NC	NC	NC
VOLATILE ORGANIC COMPOUNDS													
1,1-Dichloroethane	µg/l	0.95	0.81	1.10	1.04	0.79	0.73	0.63	0.81	0.86	0.17	0.63	1.10
1,4-Dichlorobenzene	µg/l	0.21	0.21	0.21	0.21	0.32	0.35	0.36	0.35	0.34	0.02	0.32	0.36
Benzene	µg/l	1.67	1.53	1.88	1.87	1.32	1.27	1.32	1.53	1.55	0.26	1.27	1.88
cis-1,2-Dichloroethene	µg/l	11.6	9.39	10.7	10.6	7.97	7.88	8.13	9.39	9.47	1.52	7.88	11.6
Dichlorodifluoromethane	µg/l	7.41	5.15	11.3	11.7	17.3	11.9	11.2	11.3	10.85	3.83	5.15	17.3
Methylene Chloride	µg/l	29.3	19.8	23.5	23.1	13.9	13.7	11.6	19.8	19.3	6.5	11.6	29.3
Tetrachloroethene	µg/l	17.8	20.7	39.3	40.2	24.4	23.3	24.3	24.3	27.1	8.9	17.8	40.2
trans-1,2-Dichloroethene	µg/l	1.78	1.59	1.81	1.74	1.31	1.20	0.99	1.39	1.46	0.32	0.99	1.81
Trichloroethene	µg/l	17.4	16.3	23.8	22.9	19.9	18.4	19.0	19.0	19.7	2.8	16.3	23.8
Vinyl Chloride	µg/l	1.84	1.36	2.19	2.20	1.76	2.62	1.68	1.76	1.81	0.30	1.36	2.20
		89.96	76.64	115.79	115.56	88.97	80.35	79.21	646.48				
SEMI-VOLATILE ORGANIC COMPOUNDS (µg/l): None Detected													
HERBICIDES, PESTICIDES, & PCBs (µg/l): None Detected													

NOTES:

NA = Not Analyzed/Not Applicable

Indicates that the analyte was not detected above laboratory practical quantitation limit.
Value listed is laboratory detection limit or estimated trace (BOLDED) concentration

[3] Sampled using standard purging methods.

TABLE 2
ARIZONA STREET LANDFILL EMP
COMPARISON DATA
SOIL-PORE GAS SAMPLE RESULTS
JANUARY 2003

ANALYTE	PROBE	AMW-1 (P-15D)	AMW-2 (P-7)	AMW-3 (P-8D)	AMW-4 (AMW-4)	AMW-5 (P-11D)
Carbon Dioxide, CO_2	V%	19	8.7	32	4.5	20
Methane, CH_4	V%	2.4	0.036	43	0.068	19
Nitrogen, N_2	V%	80	84	25	83	61
Oxygen, O_2	V%	1.5	11	1.4	16	1.4
VOLATILE ORGANIC COMPOUNDS						
1,1,2-Trichlorotrifluoroethane	ppb (V/V)	3.6	1.8	13	5.5	7.6
1,2,4-Trimethylbenzene	ppb (V/V)	3.6	1.0	420	5.5	56
1,3,5-Trimethylbenzene	ppb (V/V)	3.6	0.40	170	5.5	38
1,1-Dichloroethane	ppb (V/V)	3.6	0.20	13	2.8	7.8
1,2-Dichloroethane	ppb (V/V)	3.6	0.26	13	2.8	7.6
1,2-Dichlorotetrafluoroethane	ppb (V/V)	120	79	530	27	450
1,4-Dichlorobenzene	ppb (V/V)	3.6	0.20	130	2.8	10
4-Ethyltoluene	ppb (V/V)	3.6	0.83	340	2.8	45
Acetone	ppb (V/V)	580	8.3	190	14	38
Benzene	ppb (V/V)	17	1.1	68	2.8	41
Chlorobenzene	ppb (V/V)	3.6	0.20	30	2.8	7.6
Chloroform	ppb (V/V)	4.1	0.21	13	10	7.6
Chloromethane	ppb (V/V)	7.3	0.55	26	5.5	15
cis-1,2-Dichloroethene	ppb (V/V)	9.4	0.20	66	2.8	290
Dichlorodifluoromethane	ppb (V/V)	2700	9.6	1600	330	8600
Ethylbenzene	ppb (V/V)	4.5	0.50	1000	2.8	190
Methylene Chloride	ppb (V/V)	110	6.9	19	2.8	24
Styrene	ppb (V/V)	3.6	0.25	13	2.8	7.6
Tetrachloroethene	ppb (V/V)	690	0.50	45	17	900
Toluene	ppb (V/V)	5.2	2.9	900	48	71
trans-1,2-Dichloroethene	ppb (V/V)	3.7	0.20	13	2.8	20
Trichloroethene	ppb (V/V)	110	0.20	73	11	250
Trichlorofluoromethane	ppb (V/V)	20	0.40	13	5.5	150
Vinyl Chloride	ppb (V/V)	42	0.20	230	2.8	140
Xylenes (Total)	ppb (V/V)	12	2.9	1900	6.9	300

Notes:
Indicates that analyte was not detected above Reporting Limit.
Value listed is laboratory reporting limit or estimated trace (BOLDED) concentration.

TABLE 3
ARIZONA STREET LANDFILL EMP
COMPARISON DATA
SOIL-PORE GAS SAMPLE RESULTS
JUNE 2003

ANALYTE	PROBE	AMW-1 (P-15D)	AMW-2 (P-7)	AMW-3 (P-8D)	AMW-4 (AMW-4)	AMW-5 (P-11D)
Carbon Dioxide, CO_2	V%	17	14	16	0.037	19
Methane, CH_4	V%	2.1	0.0010	7.4	0.00045	18
Nitrogen, N_2	V%	75	80	67	76	58
Oxygen, O_2	V%	1.8	2.5	5.2	22	0.91
VOLATILE ORGANIC COMPOUNDS						
1,2,4-Trimethylbenzene	ppb (V/V)	3.6	0.40	300	0.40	42
1,3,5-Trimethylbenzene	ppb (V/V)	3.6	0.40	97	0.40	32
1,1-Dichloroethane	ppb (V/V)	3.6	0.20	9.9	0.20	11
1,1-Dichloroethene	ppb (V/V)	3.6	0.20	9.9	0.20	6.9
1,2-Dichlorotetrafluoroethane	ppb (V/V)	130	38	180	0.20	510
1,4-Dichlorobenzene	ppb (V/V)	3.6	0.20	270	0.20	11
2-Butanone (MEK)	ppb (V/V)	18	1.0	49	4.8	22
4-Ethyltoluene	ppb (V/V)	3.6	0.40	180	0.40	51
Acetone	ppb (V/V)	23	5.8	49	3.8	22
Benzene	ppb (V/V)	9.9	0.26	35	1.3	45
Chlorobenzene	ppb (V/V)	3.6	0.20	28	0.20	4.5
Chloroform	ppb (V/V)	5.1	0.20	9.9	0.20	6.7
Chloromethane	ppb (V/V)	7.3	0.40	20	0.81	9.0
cis-1,2-Dichloroethene	ppb (V/V)	11	0.20	19	0.20	340
Dichlorodifluoromethane	ppb (V/V)	2500	27	1000	0.59	8500
Ethylbenzene	ppb (V/V)	3.6	0.20	560	0.20	170
Methylene Chloride	ppb (V/V)	120	0.20	9.9	0.58	30
Tetrachloroethene	ppb (V/V)	640	0.20	17	0.56	830
Toluene	ppb (V/V)	3.6	0.30	92	1.0	86
trans-1,2-Dichloroethene	ppb (V/V)	4.3	0.20	9.9	0.20	25
Trichloroethene	ppb (V/V)	110	0.20	19	0.20	260
Trichlorofluoromethane	ppb (V/V)	24	0.40	9.9	0.40	160
Vinyl Chloride	ppb (V/V)	45	0.20	66	0.20	160
Xylenes (Total)	ppb (V/V)	11	0.50	810	0.50	300

Notes:
Indicates that analyte was not detected above Reporting Limit.

TABLE 4
ARIZONA STREET LANDFILL EMP
COMPARISON DATA
SOIL-PORE GAS SAMPLE RESULTS
DECEMBER 2003

ANALYTE	PROBE	AMW-1 (P-15D)	AMW-2 (P-7)	AMW-3 (P-8D)	AMW-4 (AMW-4)	AMW-5 (P-11D)
Carbon Dioxide, CO_2	V%	3.5	1.5	8.5	0.034	19
Methane, CH_4	V%	0.16	0.00035	7.4	0.00033	17
Nitrogen, N_2	V%	80	79	69	79	63
Oxygen, O_2	V%	17	20	14	22	1.1
VOLATILE ORGANIC COMPOUNDS						
1,2,4-Trimethylbenzene	ppb (V/V)	1.0	0.40	120	0.40	67
1,3,5-Trimethylbenzene	ppb (V/V)	0.40	0.40	33	0.40	48
1,2-Dichlorotetrafluoroethane	ppb (V/V)	8.4	3.2	120	0.20	360
1,4-Dichlorobenzene	ppb (V/V)	0.20	0.20	120	0.20	18
4-Ethyltoluene	ppb (V/V)	0.51	0.40	75	0.40	72
2-Butanone (MEK)	ppb (V/V)	1.1	2.3	33	3.8	66
Acetone	ppb (V/V)	4.7	8.0	110	7.9	800
Benzene	ppb (V/V)	0.27	0.20	19	2.2	48
Chlorobenzene	ppb (V/V)	0.20	0.20	11	0.20	11
Chloroform	ppb (V/V)	0.24	0.30	9.3	0.20	11
Chloromethane	ppb (V/V)	0.40	0.40	13	0.57	23
cis-1,2-Dichloroethene	ppb (V/V)	0.20	0.20	7.7	0.20	290
Dichlorodifluoromethane	ppb (V/V)	210	1.1	410	0.64	2300
Ethylbenzene	ppb (V/V)	0.50	0.67	250	0.29	190
Methylene Chloride	ppb (V/V)	0.23	0.20	6.6	0.22	25
Tetrachloroethene	ppb (V/V)	38	0.20	6.6	1.0	840
Toluene	ppb (V/V)	3.5	7.7	39	5.9	83
trans-1,2-Dichloroethene	ppb (V/V)	0.20	0.20	6.6	0.20	20
Trichloroethene	ppb (V/V)	2.9	0.20	6.6	0.20	230
Trichlorofluoromethane	ppb (V/V)	1.7	0.40	6.6	0.40	100
Vinyl Chloride	ppb (V/V)	0.23	0.20	36	0.20	120
Xylenes (Total)	ppb (V/V)	3.5	3.5	290	1.2	360

Notes:

Indicates that analyte was not detected above Reporting Limit.

TABLE 5
ARIZONA STREET LANDFILL EMP
COMPARISON DATA
SOIL-PORE GAS SAMPLE RESULTS
DECEMBER 2004

ANALYTE	PROBE	AMW-1 (P-15D)	AMW-2 (P-7)	AMW-3 (P-8D)	AMW-4 (AMW-4)	AMW-5 (P-11D)	AMW-6
Carbon Dioxide, CO_2	V%	15	12	13	0.11	17	8.2
Methane, CH_4	V%	1.94	0.0010	7.92	0.0065	15.2	3.95
Nitrogen, N_2	V%	86	85	79	84	72	83
Oxygen, O_2	V%	3.0	7.5	9.7	22	2.7	12
VOLATILE ORGANIC COMPOUNDS							
Dichlorodifluoromethane	ppb (V/V)	4300	200	390	200	11,300	4300
Tetrachloroethene	ppb (V/V)	280	150	150	150	370	150

Notes:
[ ] Indicates that analyte was not detected above Reporting Limit.

TABLE 6
ARIZONA STREET LANDFILL EMP
FLOWPATH II SENSITIVITY ANALYSIS

File	Hydraulic Conductivity (cm/sec)	Recharge (mm/year)	Effective Porosity (%)	Dispersion (Feet)	Observed Results
Arizona EMP1a	5.0E-03	0	20	200/20	Area of plume is too small; MAE - 0.4941
Arizona EMP1b	1.0E-03	0	20	200/20	Area of plume is a close match; MAE - 0.4941
Arizona EMP1c	1.0E-04	0	20	200/20	Area of plume is too small. MAE - 0.4941
Arizona EMP2a	1.0E-03	0	10	200/20	Area of plume is too large
Arizona EMP1b	1.0E-03	0	20	200/20	Area of plume is a close match
Arizona EMP2b	1.0E-03	0	30	200/20	Area of plume is too small
Arizona EMP3a	1.0E-03	0	20	10/1	Area of plume is too small
Arizona EMP3b	1.0E-03	0	20	500/50	Area of plume is too large
Arizona EMP3c	1.0E-03	0	20	100/10	Transverse area of plume is too small
Arizona EMP1b	1.0E-03	0	20	200/20	Area of plume is a close match
Arizona EMP4a	1.0E-03	1.0E-05	20	200/20	MAE - 0.4977 Feet
Arizona EMP4b	1.0E-03	1.0E-04	20	200/20	MAE - 0.5303 Feet
Arizona EMP4c	1.0E-03	1.0E-03	20	200/20	MAE - 0.9442 Feet
Arizona EMP4d	1.0E-03	1.0E-03	20	200/20	MAE - 0.4941 Feet

Notes: MAE Mean Absolute Error (Observed vs. Calculated Heads)
☐ Indicates the variable that was changed

APPENDIX A

BORING LOG AND WELL COMPLETION SUMMARY - AMW-6

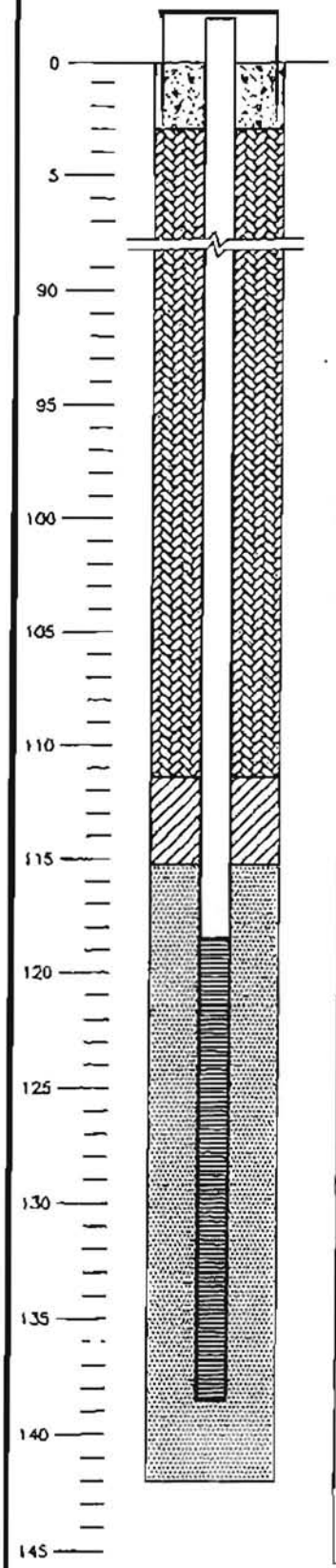
GeoLogic Associates

MONITORING WELL COMPLETION SUMMARY

WELL NO.: AMW-6

JOB NO.: 2004-203
PROJECT: ARIZONA STREET LANDFILL EMP
LOCATION: ARIZONA STREET LANDFILL, SAN DIEGO, CA
INSPECTOR: W. LOPEZ, CHG
CHECKED BY: W. LOPEZ, CHG

ELEVATION GROUND LEVEL: 136.12 feet
ELEVATION TOP OF CASING: 138.12 feet
DATE STARTED: 09/30/04
DATE FINISHED: 10/04/04
TOTAL DEPTH: 138.55 feet



DRILLING SUMMARY:

Total Depth: 142 feet
Borehole diameter: 9-5/8"
Driller: WEST HAZMAT DRILLING

Rig: AIR ROTARY CASING HAMMER
Bit(s): DOWNHOLE HAMMER

Drilling Fluid: AIR

Protective Casing: 9-5/8" ø STEEL CASING

WELL CONSTRUCTION DETAILS:

Casing: 4-inch diameter, flush threaded, Schedule 80 PVC. (From +2 to 118.55 feet.)

Screen: 4-inch diameter, flush threaded, Schedule 40 PVC with 0.020-inch slots. (From 118.55 to 138.55 feet.)

Filter Pack: Washed and graded #3 Monterey type sand; 11.5 ft³. (From 115.2 to 142 feet.)

Bentonite Seal: Medium chipped bentonite; 1.6 ft³. (From 111.3 to 115.2 feet.)

Grout Seal: Neat cement slurry with 5% bentonite; 45 ft³. (From 3 to 111.3 feet.)

Concrete: From 0 to 3 feet; 1.2 ft³.

WELL CONSTRUCTION LOG:

	Start Date	Start Time	Finish Date	Finish Time
Drilling:	9/30/04	13:20	10/01/04	9:40
Coring:	-	-	-	-
Ream:	-	-	-	-
Casing Install:	10/01/04	13:13	10/01/04	13:25
Filter Placement:	10/01/04	13:40	10/01/04	14:20
Seal Placement: (Bentonite)	10/01/04	14:30	10/01/04	14:34
Seal Placement: (Grout)	10/04/04	8:45	10/04/04	11:00

WELL DEVELOPMENT LOG:

	Date	Start Time	Finish Time
Surge Block	11/18/04	7:45	8:00
Pumping	11/18/04	11:30	11:55
Other - Bailer	11/18/04	8:00	9:00

Total Gallons Removed: 120

STABILIZATION TEST DATA:

Gallons	pH	Spec. Cond. (µs/cm)	Temp (°F)
20	6.62	293	22.6
60	5.89	259	23.1
80	5.33	283	24.4
100	5.43	258	24.3
120	6.45	255	23.9

Comments:
Well purged at 2.2 gpm.

WELL MONITORING DATA:

Date	Time	Description	Corr.	Depth (feet)	SWL (feet)	By
10/01/04	12:00	Prior to well construction	NA	112.75 bgs	23.37	WBL
11/18/04	7:00	Prior to well development	-2	113.68 TOC	24.44	WBL
11/18/04	12:00	After well development	-2	113.63 TOC	24.49	WBL

GeoLogic Associates
Boring Log

BORING NO.: AMW-6

JOB NO.: 2004-203
SITE LOCATION: ARIZONA STREET
DRILLING METHOD: 8" ø ARCH
CONTRACTOR: WEST HAZMAT DRILLING
LOGGED BY: W. LOPEZ, CHG

DATE STARTED: 09/30/04
DATE FINISHED: 10/01/04
ELEVATION: 138.12
NORTHING: 1846123.30
EASTING: 6287127.61

GW DEPTH: 112.75 feet
TOTAL DEPTH: 142 feet

TIME	DRY DENSITY (LBS/CU. FT.)	MOISTURE (%)	BLOWS (COUNT/FT.)	SAMPLE SIZE (INCHES)	PID (PPM)	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
13:20						0				SAN DIEGO FORMATION: Light yellowish brown (10YR6/4) GRAVELLY SANDSTONE. SAND is very fine to fine, poorly graded, friable; GRAVEL is fine to medium, well rounded.	Dry.
						5					
13:33			50/2"	SPT	0	10					
						15				...(14') – color change to light yellowish brown (2.5YR6/4).	Slightly moist.
13:50											
14:25										...(17'-20') – CONGLOMERATE bed.	Very hard, switch to downhole hammer.
14:32					0	20				...(20') – color change to light gray (2.5YR7/2).	Moist.
						25					
14:55					0	30					
						35					
15:15					0	40					
						45				...(45'-52') – SAND is fine to coarse with abundant shell fragments (oyster), decreasing GRAVEL.	
15:34					0	50					

CONTINUED ON NEXT PAGE

The data presented on this log is a simplification of actual conditions encountered and applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change with the passage of time.

GeoLogic Associates
Boring Log

BORING NO.: AMW-6

JOB NO.: 2004-203
SITE LOCATION: ARIZONA STREET
DRILLING METHOD: 8" # ARCH
CONTRACTOR: WEST HAZMAT DRILLING
LOGGED BY: W. LOPEZ, CHG

DATE STARTED: 09/30/04
DATE FINISHED: 10/01/04
ELEVATION: 136.12
NORTHING: 1846123.30
EASTING: 6287127.61

GW DEPTH: 112.75 feet
TOTAL DEPTH: 142 feet

TIME	DRY DENSITY (LBS/CU. FT.)	MOISTURE (%)	BLOWS (COUNT/FT.)	SAMPLE SIZE (INCHES)	PID (PPM)	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
15:34						50				...same as above.	
						55					
15:52					0	60				Light olive brown (2.5YR5/6) SILTY SANDSTONE, fine to coarse with abundant shell fragments, well graded, friable.	Moist.
10/01 7:10						65				...(64') – grades to light olive brown (2.5YR5/6) GRAVELLY SANDSTONE, SAND is fine to coarse with abundant shell fragments, well graded, friable, GRAVEL is fine to medium, well rounded.	Moist.
7:23					3.1	70					
						75				Gray (2.5Y6/1) SANDSTONE with trace of GRAVEL. SAND is very fine to fine, poorly graded, friable; GRAVEL is fine to medium, well rounded.	Moist.
7:36					5.8	80				...(82') – color change to light olive brown (2.5Y5/6).	
						85					
7:58					4.0	90					
						95				...(94'-103') – increasing GRAVEL.	
8:14					4.9	100					

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GeoLogic Associates
Boring Log

BORING NO.: AMW-6

JOB NO.: 2004-203
SITE LOCATION: ARIZONA STREET
DRILLING METHOD: 8" ø ARCH
CONTRACTOR: WEST HAZMAT DRILLING
LOGGED BY: W. LOPEZ, CHG

DATE STARTED: 09/30/04
DATE FINISHED: 10/01/04
ELEVATION: 138.12
NORTHING: 1848123.30
EASTING: 6287127.61

GW DEPTH: 112.75 feet
TOTAL DEPTH: 142 feet

TIME	DRY DENSITY (LBS/CU. FT.)	MOISTURE (%)	BLOWS (COUNT/FT.)	SAMPLE SIZE (INCHES)	PID (PPM)	DEPTH IN FEET	ELEVATION IN FEET	MATERIAL SYMBOL	USCS/GEOLOGIC FORMATION	DESCRIPTION	COMMENTS
8:14						100				...same as above.	
						105					
8:30					3.5	110				...(111') - interbedded, dark gray (2.5Y4/1), plastic, thinly bedded CLAYEY SILTSTONE.	
						115				Pale olive (5Y6/4) SILTY SANDSTONE with trace of GRAVEL. SAND is very fine to fine with shell fragments, poorly graded, friable,.	Very moist.
9:00					5.9	120					
						125				Olive (5Y5/4) GRAVELLY SANDSTONE. SAND is poorly graded, very fine to fine with shell fragments and trace of SILT; GRAVEL is fine to medium, well rounded.	Wet.
9:19						130					
											Free water.
						135					
						140					
9:40											
						145				Notes: 1. Total depth of boring 142 feet. 2. Groundwater first encountered at 133 feet below ground surface (bgs) on 10/01/04; static water measured at 112.75 feet bgs on 10/01/04. 3. Groundwater monitoring well constructed in boring (see well completion summary).	
						150					

The data presented on this log is a simplification of actual conditions encountered and applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations and may change with the passage of time.