Henderson Landfill Response Program Site Soils Criteria

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1 Introduction

1.1 Requested Approvals

The objectives of this Approvable Deliverable, presented as a technical memorandum (TM), are to provide the Nevada Division of Environmental Protection (NDEP) and the Southern Nevada Health District (SNHD) with the information needed to evaluate and concur with recommended site soils criteria and the related soils management strategy for the Henderson Landfill Response Program. The City of Henderson (City) seeks approval of the following items:

i) Use of United States Environmental Protection Agency (EPA) Region 9 Industrial Preliminary Remediation Goals (PRGs) as the clean soil criteria except for dioxins and arsenic, as described below;

ii) The clean soil criteria for dioxin and dioxin-like compounds (including 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), chlorinated dibenzofurans (CDFs), and other structurally related groups of chemicals from the family of halogenated aromatic hydrocarbons) will be 50 parts per trillion (ppt) of toxicity equivalents (TEQ) based on the Agency for Toxic Substances and Disease Registry (ATSDR) Interim Policy Guideline (1997); and

iii) There will be no site-specific clean soil criteria for arsenic based on the occurrence of variable naturally occurring concentrations found in the onsite soils.

1.2 Contents of Technical Memorandum

This TM presents the following information and discussions:

- Regulatory framework related to the development and use of clean soil criteria to define soil action levels and associated clean-up requirements.
- The applicability and use of EPA Region 9 Industrial PRGs to site soils based on likely future site users and trespassers.
- The applicability and use of the ATSDR Interim Policy Guideline to site soils based on site conditions, previous precedents with NDEP and CERCLA guidance.

- Detailed presentation of arsenic, characterizing regional geologic setting, and the presence of naturally occurring arsenic in area and site soils.

Based on these discussions, recommendations for clean soil criteria are presented.

1.3 Regulatory Framework

The development of clean soil criteria is based upon the regulations, rules and guidance that exist at a federal, state and local level regarding soil action levels and soil clean-up levels. Specifically, the applicable or relevant and appropriate requirements (ARARs) that exist with respect to soil, as presented in the Henderson Landfill Engineering Evaluation and Cost Analysis (EE/CA) (CDM, 2001), include the Nevada Administrative Code (NAC) provisions related to soil (445A.2272). By reference within this section of the NAC, there are other criteria that are to be considered (TBC) when establishing clean soil criteria, including:

- USEPA Region 9 Preliminary Remediation Goals (PRGs);
- ATSDR Interim Policy Guideline for dioxin and dioxin-like chemicals; and
- Background conditions.

The NAC Section 445A.2272 and each of the three TBCs are discussed in the subsections that follow.

1.3.1 Nevada Administrative Code (NAC) Section 445A.2272

The NAC Section 445A.2272 is a “chemical specific” ARAR for the Henderson Landfill closure and selected response actions. This Nevada state environmental law specifically addresses the clean-up standards, standards of control, and other substantive environmental pollution requirements (in this case, soil action levels) for hazardous substances, hazardous wastes or regulated substances.

This section of the NAC defines the criteria upon which soil action levels must be established. There are four different criteria defined in the statute that may apply when developing soil action levels. As specified in NAC Section 445A.2272.2, if one or more criteria are used to establish soil action levels, such that more than one action level is calculated or defined, the most restrictive action level must be used. In no case, however, may the action level be more restrictive than the background concentration of the hazardous substances, hazardous wastes, or regulated substances.

The criteria that are set forth in NAC Section 445A.2272.1 to establish soil action levels are as follows:

i) Based on a background concentration or volume

ii) For TPH, anything in excess of 100 mg/kg (or parts per million – ppm) in the soil

iii) For situations where contaminated surface water or groundwater is the primary pathway of concern, the leachability of the analyte or compound must be compared to the levels of concentrations provided in the Toxicity Characteristic Leaching Procedure (TCLP) Rule (40 CFR Part 261.24) (Note that this is not a pathway of concern for the Henderson Landfill)

iv) For situations where inhalation, ingestion, and/or dermal exposure are/is the primary pathway(s) of concern (i.e., human exposures), or an analyte or compound is not listed in the TCLP Rule, the presence of the hazardous substances, hazardous wastes or regulated substance in soil is based on the protection of public health and safety and the environment. The appropriate level of contaminant will be developed using the Integrated Risk Information System (IRIS) or an equivalent method chosen by NDEP

For the Henderson Landfill site, the clean soil criteria will be developed for situations where inhalation, ingestion, and/or dermal exposure are the primary pathways of concern. This includes all target analyte list and target compound list (TAL/TCL) analytes and compounds with the exception of arsenic, which will be addressed through an assessment of background conditions. Clean soil criteria will also need to include reference to soil that exceeds 100 ppm TPH in accordance with NAC Section 445A.2272.1.b.

1.3.2 Preliminary Remediation Goals (PRGs)

PRGs are tools for evaluating and cleaning up contaminated sites for future residential and industrial site uses (www.epa.gov/region9/waste/sfund/prg/index.html). They are risk-based concentrations, developed based on inhalation, ingestion, and dermal exposure assumptions, that are intended to assist risk assessors and others in initial screening-level evaluations of environmental measurements. The PRGs developed by EPA Region 9 are generic; they are calculated without site-specific information, using assumed exposure scenarios and target risk levels to establish criteria for typical industrial and residential settings. However, where more refined and realistic risk estimates are appropriate to evaluate practical remediation options at the Henderson Landfill, the PRGs may be re-calculated using site-specific data and exposure assumptions.

For the case of the Henderson Landfill site, the EPA Region 9 Industrial PRGs are considered conservative estimates of potential site-specific “clean soil criteria” since the generic exposure assumptions used by the EPA to develop the Industrial PRGs include greater individual exposures to contaminants than will be likely to occur during postclosure activities (based on assumptions consistent with EPA guidelines). In addition, the Industrial PRGs use a more stringent target risk level than is required by EPA in identifying, evaluating, and selecting remedial measures. To this point, the Industrial PRGs can be used as conservative clean soil criteria and soil action levels for the Henderson Landfill in accordance with the fourth NAC Section 445A.2272 criteria listed in the above section. Further discussions of the applicability of Industrial PRGs to site clean soils criteria are presented in Section 2.

The EPA Region 9 PRGs are not necessarily appropriate, however, for all the analytes and compounds on the TAL and TCL. For example, where background levels of a contaminant of concern are already at or near the established PRG, or where other state or local requirements or precedent make the PRG standard impractical, alternate methodologies may be more appropriate. As discussed further in later sections, such is the case for arsenic and dioxin at the Henderson Landfill site.

1.3.3 ATSDR Interim Policy Guideline Regarding Dioxin and Dioxin-Like Compounds

In 1997, at the request of EPA, the Agency for Toxic Substances and Disease Registry (ATSDR), an agency operating under the Department of Health and Human Services

(DHHS), released an "Interim Policy Guideline relating to Dioxin and Dioxin-Like Compounds in Soil" (ATSDR 1997). ATSDR developed these guidelines "to assess the public health implications of dioxin and dioxin-like compounds in residential soils near or on hazardous waste sites." While developed for use in residential scenarios, the methodology remains relevant for sites intended for commercial, industrial, or recreational use. In fact, this guideline has already been used at other sites in the Las Vegas Valley by NDEP to establish soil action and clean-up levels, such as the Levy Trust property located at the southwest corner of the intersection of U.S. 95 and Lake Mead Drive in Henderson. A discussion of the ATSDR Interim Policy Guideline for dioxin and dioxin-like compounds as it relates to the development of clean soil criteria is presented in Section 3.

1.3.4 Background Concentrations of Arsenic in Soil

Application of the Industrial PRGs to arsenic found at the Henderson Landfill is not appropriate given that naturally occurring concentrations of arsenic present onsite and in the vicinity of the site exist at levels significantly above the EPA Region 9 Industrial PRGs for both residential and industrial land uses. Arsenic concentrations found onsite are consistent in both concentration and distribution with naturally occurring minerals found in the Las Vegas Valley. Naturally occurring levels of arsenic at the site will be managed in accordance with NAC Section 445A.2272.2, which requires that in no case may action levels be more restrictive than the background concentration. A discussion of the data available to characterize background concentrations of arsenic in the Las Vegas area, and a presentation of site-specific arsenic data, are both provided in Section 4.

2 Region 9 PRGs as Standards

2.1 Purpose of Section

This subsection discusses how the EPA Region 9 Industrial PRGs (hereafter Industrial PRGs) are appropriate for use as *de facto* standards (i.e., clean soil criteria) for all analytes and compounds except for dioxin and dioxin-like compounds, and arsenic, since the Industrial PRGs are more conservative than would be developed using site-specific assumptions.

2.2 Comparison of Region 9 PRGs to Site-specific Conditions

The Industrial PRGs are appropriate for this use because they have been developed using non site-specific exposure scenarios that are more conservative than site-specific PRGs that would have been developed in accordance with EPA guidelines (EPA, 1997) using site-specific exposure assumptions. This is in part due to the fact that the Industrial PRGs were developed using EPA guidelines developed in 1991 (EPA, 1991), which are generally more stringent than the 1997 guidelines, especially with regard to exposure inhalation rate.

To illustrate this point, Table 2-1 presents a comparison of the exposure scenario assumptions used to develop the Industrial PRGs to those that would be used to develop site-specific PRGs given the likely future site users, with the differences in exposure assumptions highlighted in bold. Likely future site users, from highest potential risk to lowest potential risk, include:

- A **post-closure golf course grounds keeper or maintenance worker** assuming that the site is closed in accordance with the selected response action and a golf course is built over the top of the Henderson Landfill, as well as the remainder of the site, allowing for post-closure recreational use of the site.
- A **post-closure maintenance worker** assuming that the site is closed in accordance with the selected response action and is fenced for purposes of limiting all future site access.
- A **post-closure golfer or other regular recreational user** assuming that the site is closed in accordance with the selected response action and a golf course is then built over the top of the Henderson Landfill, as well as the remainder of the site, allowing for post-closure recreational use of the site.

These potential future site users are consistent with the two likely end uses of the site – the landfill closed in accordance with the selected response action, which is either fenced to limit public access or used as a golf course, or some other recreational use facility, consistent with the selected response action.

A comparison of the site-specific exposure scenario assumptions for the potential future site users presented in Table 2-1 illustrates that the future golf course grounds keeper or maintenance worker represents the highest exposure for any potential future site use since of the three potential future site users, the grounds keeper would spend the most time onsite, day in and day out. The future post-closure maintenance worker represents the second highest exposure, based on the exposure frequency (i.e., how many times a week he would be onsite), exposure time, and the expected inhalation rate of the maintenance worker.

The future recreational user has a slightly longer exposure duration than the two other site-specific scenarios and the Industrial PRG scenario (i.e., 30 years versus 21.9 years and 25 years, respectively) and a higher soil ingestion rate (i.e., 120 milligrams per day versus 100). However, the future recreational user has the lowest potential exposure because its exposure time is significantly less than for the other exposure scenarios (i.e., 2 hours per day versus 4 and 8), and it uses the lowest skin factor, adherence rate and inhalation rate. The exposure assumptions presented for the future site recreational user are straight from the risk evaluation presented in the EE/CA. The exposure assumptions presented in the EE/CA for the future site recreational user combine child and adult exposures and assume that an individual would access the site for 30 years, starting from an early age (i.e., less than 6 years old).

Also note that the site-specific exposure assumptions used for the golf course grounds keeper and post closure maintenance worker are based on the guidelines provided by EPA in 1997, which modified and updated the 1991 risk assessment guidelines used in setting the EPA Region 9 PRGs. These exposure scenario assumptions relate to the expected exposures that would occur to a typical adult worker over a 20 to 25 year period.

When comparing the Industrial PRG exposure scenario assumptions to the future golf course grounds keeper (which allows for the comparison between the suggested clean soil criteria and the highest exposure onsite in the future), it can be seen that the Industrial PRGs are more conservative in assumptions regarding duration of exposure and inhalation rate. The Industrial PRGs assume an exposure duration of 25 years whereas the EPA guidelines

TABLE 2-1
Comparison of Exposure Scenario Assumptions for Industrial PRGs versus Site-specific Future Users

		Non-Site-specific Exposure Assumptions	**Site-specific Exposure Assumptions (in order from highest to lowest potential risk)**		
Parameter	**Unit**	**Region 9 Industrial PRGs**	**Future Golf Course Grounds Keeper or Maintenance Worker**	**Future Post-Closure Maintenance Worker**	**EE/CA Defined Future Site Recreational User[b]**
Body Weight	Kilograms	70	70	70	**58**
Average Time –Cancer	Days	25,550	25,550	25,550	**27,375**
Exposure Frequency	Days/year	250	250	**50**	**104**
Exposure Duration	Years	25	**21.9[c]**	**21.9 [c]**	**30**
Exposure Time	Hours/day	8[a]	8	**4**	**2**
Soil Ingestion Rate	Milligrams/day	100	100	100	**120**
Conversion Factor	Milligrams/kilograms	1,000,000	1,000,000	1,000,000	1,000,000
Skin Area	Square centimeter	3,300	3,300	3,300	**880**
Adherence Factor	Milligrams/square centimeter	0.2	0.2	0.2	**0.11**
Inhalation Rate	Cubic meters/hour	2.5[a]	**1.3[d]**	**1.3 [d]**	**1.5**
	Cubic meters/day	20	**10.4**	**5.2**	**3.0**

[a] estimated for comparative purposes.

[b] as presented in the EE/CA using conservative assumptions combining a child and adult user.

[c] Shorter exposure duration factor (21.9 versus 25 years) reflects change in EPA's policy from 1991 (EPA 1997).

[d] Lower inhalation rate factor (1.3 versus 2.5) reflects change in EPA's policy from 1991 to 1997.

assume an exposure of 21.9 years. Similarly, the Industrial PRGs assume an inhalation rate of 20 cubic meters per day, whereas the EPA guidelines assume an inhalation rate of 10.4 cubic meters per day. In both cases, the difference in exposure assumptions relates to changes in EPA guidelines between 1991 and 1997. Since the Industrial PRGs are based on the 1991 risk assessment guidelines, they are more conservative than any site-specific PRGs that would be developed utilizing the 1997 Exposure Factors Handbook.

Given the differences between the EPA guidelines available in 1991 versus 1997, and the fact that Region 9 purposefully uses a more conservative set of exposure assumptions in developing the Industrial PRGs than would be used for the worst-case onsite exposure scenario (i.e., the future golf course maintenance worker), the Industrial PRGs are more conservative than what would be calculated for site-specific PRGs.

2.3 Consideration of Other Health-Based Risk Issues

The Industrial PRGs do not account for the potential synergistic effects of co-located contaminants, or for non-carcinogenic effects. For the Henderson Landfill site, however, these potential limitations to the use of the Industrial PRGs as clean soil criteria were not considered to be significant because:

- With respect to synergistic effects:
  - Previous risk evaluations conducted in the EE/CA (CDM, 2001) considered synergistic effects of co-located contaminants without identifying unacceptable levels of risk.
  - SRADI related sampling did not identify situations where multiple contaminants were co-located at levels that approached the Industrial PRGs with two exceptions, both of which will be excavated and consolidated under the landfill cap.
- With respect to non-carcinogenic effects:
  - Previous risk evaluations conducted in the EE/CA (CDM, 2001) considered non-carcinogenic (systemic) effects of the contaminants of potential concern (COPCs) at the Landfill. These analyses indicated that for those COPCs that exist on-site, including various metals (e.g., iron, antimony); the non-carcinogenic effects are acceptable (i.e., meaning that the hazard quotient is less than 1).

2.4 Recommendations

The discussion above demonstrates that the Industrial PRGs are conservative *de facto* site-specific standards, and therefore appropriate for defining the clean soil criteria for those analytes and compounds present at the Landfill. To this point, the Industrial PRGs will be used to identify native soils that may be left in place, without further action, after removal and consolidation of surface debris and interred waste in accordance with implementation of the selected response action, and for defining the quality of soil that must be used for the upper 18 inches of the final cover system or for engineered earth fill.

The only exceptions to the use of the Industrial PRGs as clean soil criteria for analytes and compounds detected onsite, as will be discussed in the following sections, are for dioxin and dioxin-like compounds, and arsenic. In addition, TPH will be managed in accordance with NAC Section 445A.2272.1.b.

3 ATSDR Interim Policy Guideline

3.1 Purpose of Section

This section presents the following reasons for use of the ATSDR Interim Policy Guideline for dioxin and dioxin like compounds as clean soil criteria for the Henderson Landfill site:

1. The state of the science indicates that the PRGs do not adequately account for background contributions of dioxin and dioxin-like compounds in estimating reasonable future exposure scenarios.
2. Research has been developed by ATSDR and supported by EPA that define defensible levels for soil “evaluation” and “action” levels for dioxin and dioxin-like compounds.
3. NDEP, and therefore the local community, have accepted the use of this research (i.e., the Interim Policy Guideline) to define soil action levels for use in developing site-specific clean up standards at other sites in the Las Vegas Valley.

3.2 Background of the Interim Policy Guideline

EPA recognizes that "Dioxin-like compounds are widely distributed in the environment as a result of a number of physical and biological processes" (EPA, 2004). Moreover, EPA has determined that reference doses used to estimate carcinogenic and non-carcinogenic risks are inappropriate for dioxin and furans because background exposures are significant (EPA, 1994). This point was further highlighted in the Draft Dioxin Reassessment (EPA, 2000) which suggests that background exposures to dioxin and dioxin-like compounds have been previously under estimated. EPA's 2004 revised Draft Dioxin Reassessment corroborates this point, estimating that urban background dioxin levels range from 2 to 21 parts per trillion (ppt), with an average of 9.3 ± 10.2 ppt, well above the Region 9 Residential PRG of 3.9 and approaching or surpassing the Region 9 Industrial PRG of 16 ppt. Under such circumstances, the use of unmodified PRGs, which are not adjusted to account for background contributions to contaminant exposures, is not necessarily appropriate for dioxin and dioxin-like compounds.

As an alternative, the Agency for Toxic Substances and Disease Registry (ATSDR) has developed a decision framework, entitled the Interim Policy Guideline, for use by ATSDR and state-based health assessors, relevant federal, state and local health and environmental entities, and community groups (ATSDR, 1997). The Interim Policy Guideline is based on an understanding of the toxicology and epidemiology associated with TCDD and its congeners (including 2,3,7,8 TCDD, chlorinated dibenzofurans (CDFs), and other structurally related groups of chemicals from the family of halogenated aromatic hydrocarbons) and on exposure potential when soil is the primary media of interest (ATSDR, 1997). The guidance prepared by ATSDR is unique because it considers the potency of TCDD itself and the total potency of all dioxin and dioxin-like compounds in assessing current and future risk to users of the site.

The Interim Policy Guideline was developed for residential soils based on expected residential exposure pathways, and as such may overstate the risks associated with industrial or recreational use pathways. The evaluation and action levels specified in the Interim Policy Guideline (as indicated in the subsection that follows) are therefore deemed conservative and appropriate for application at the Henderson Landfill site because future uses of the site will not include exposures as substantial as would be typical for residential uses.

3.3 Interim Policy Guideline Evaluation and Action Levels

The Interim Policy Guideline establishes both evaluation and action levels of dioxin for residential areas. Evaluation levels are those levels at which site-specific factors and evaluations should be considered in a deliberate process to assess the nature and extent of contamination and its impact on the community (ATSDR, 1997). Based on the human exposure to direct ingestion of soils contaminated with dioxin and dioxin-like compounds in residential areas, ATSDR recommends using 50 ppt as the evaluation level for total dioxin (expressed as a toxicity equivalency (TEQ) using toxicity equivalency factors (EPA, 1992)). Above 50 ppt, ATSDR recommends developing site-specific analyses of the contamination, including, but not limited to, bioavailability, ingestion rates, pathway analyses, soil cover, climate, other contaminants, demographics, and background components. Such an evaluation may or may not prompt further assessment at the next level where actions are considered.

Action levels, on the other hand, are concentrations of chemicals at which consideration of action to interdict exposures occurs (ATSDR, 1997). Based on the results of Kimbrough et. al. (1984), ATSDR established a 1,000 ppt, or 1 part per billion (ppb), concentration of TCDD in residential soil as a level of concern, constituting a "reasonable level to begin consideration of action to limit exposure." This 1 ppb action level is also consistent with EPA national guidance issued in 1997 which suggested that "EPA should generally use [1 ppb] as a starting point for residential soil cleanup levels for CERCLA non-time critical removal sites (time permitting, for emergency and time critical sites) and as a PRG for remedial sites" (EPA 1998). Notably, EPA's guidance goes on to acknowledge that the Agency's historical dioxin soil standards for industrial and commercial uses were even higher, ranging from 5,000 to 2,000 ppt (EPA 1998).

To the extent that NDEP seeks a standard for determining when remedial activity should be required during the Henderson Landfill cleanup process, the ATSDR Action Levels of 1 ppb, designed to trigger specific remedial activity, would constitute a logical choice. Notwithstanding this fact, Henderson proposes to use the more conservative residential screening standard of 50 ppt which is consistent with the soil action level that the NDEP has approved for use at two non-residential sites along Lake Mead Boulevard – the Levy Trust Parcel and the Interchange Parcel. Both of these locations are within the City of Henderson.

3.4 Recommendation

The ATSDR Interim Policy Guideline evaluation level of 50 ppt for the TEQ of dioxin and dioxin-like compounds is relevant as clean soil criteria to the Henderson Landfill site since:

- It defines a numerical level for dioxin and dioxin-like compounds in soil that can be used as an action level;
- Has been previously accepted by NDEP for use at other non-residential sites within proximity to the City of Henderson as a soil action level; and
- Provides a conservative and protective standard based on sound science.

4 Arsenic

4.1 Purpose of Section

Based on the data and discussions presented herein, it will be demonstrated that the arsenic as found at the Henderson Landfill site occurs as the result of native rocks and minerals, and not as a result of past municipal solid waste disposal activities. It is therefore proposed that no single arsenic value be assigned to define background and that no future remedial actions or activities be required as a result of the arsenic sampling and associated analytical results.

4.2 Introduction

Arsenic is a ubiquitous, naturally occurring element that is known to be present at elevated levels in the Western United States and Nevada, in particular. Based on the geologic makeup of the Henderson Landfill site and surrounding areas, and data collected from various sources characterizing arsenic-soil concentrations in Southern Nevada and onsite, evidence indicates that the concentrations of arsenic in soil in and around the Henderson Landfill result from naturally-occurring sources rather than past municipal solid waste disposal activities. The "background concentrations" of arsenic, while well above Industrial PRGs across a substantial portion of the site, result from naturally-occurring arsenic native to the area geological material, and therefore should not trigger any specific cleanup or action level under federal or state law.

To support this argument, this Section presents the following information:

- A discussion of the regional and local geologic setting;
- A presentation of arsenic data collected by other investigators, regionally and locally;
- A presentation of the arsenic data collected onsite during past and current investigations; and
- A discussion of these data and information, as a means to identify trends and make observations regarding the nature of arsenic found onsite.

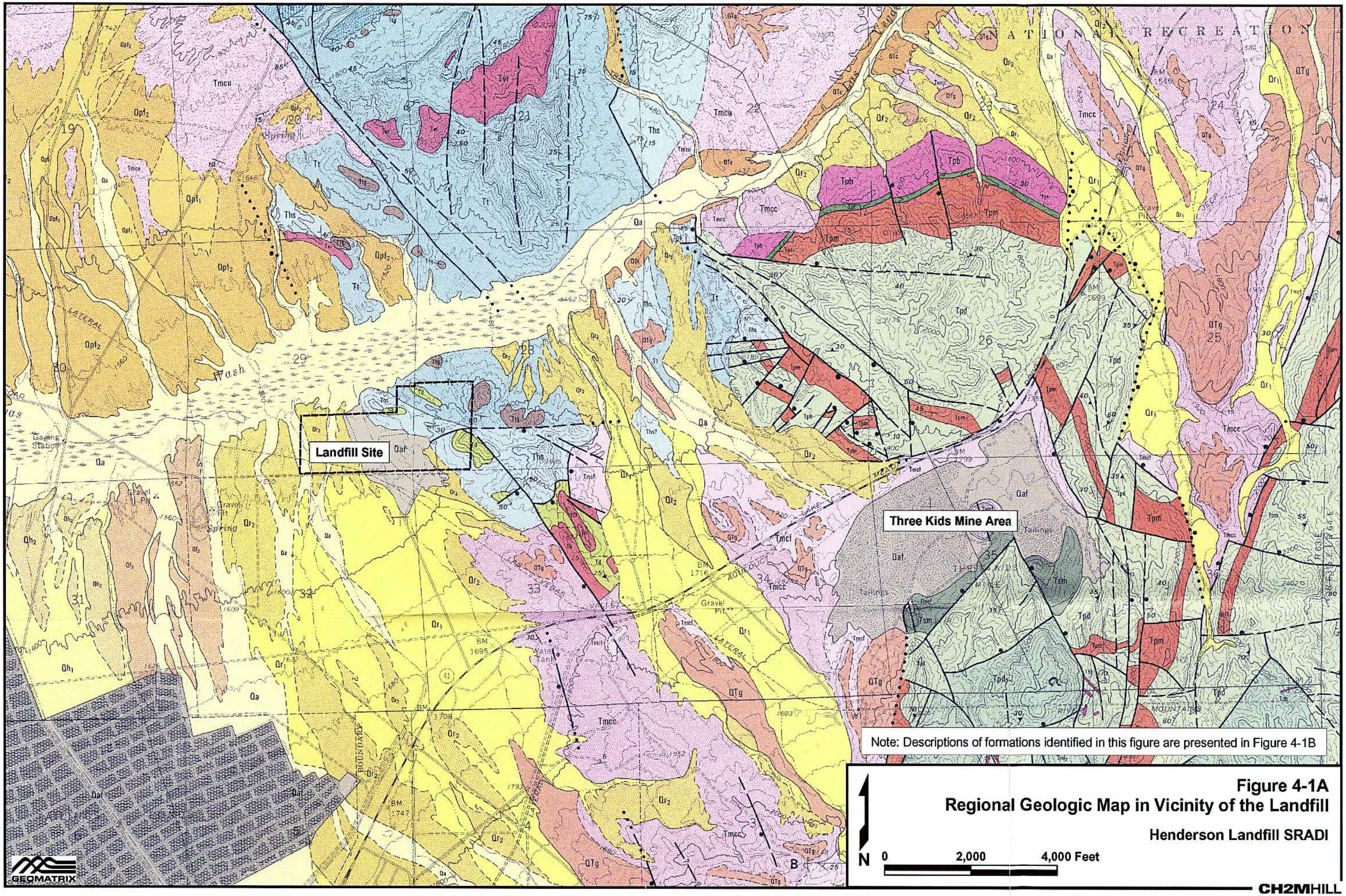
4.3 Regional and Local Geologic Setting

The Henderson Landfill site is located in the physiographic feature of the province known as the Las Vegas Valley, or the Las Vegas Basin. The valley is bounded on the west by the Spring Mountains, to the north by the Desert, Sheep, and Las Vegas Ranges, on the east by the River Mountains, and on the south by the McCullough Range.

The site itself lies on the south side of the Las Vegas Wash, abutting the western-most portions of the River Mountains, locally characterized as the Horse Springs and Thumbs Formations of the River Mountains. These formations, which are carbonate, continental red-bed and limestone deposits contain volcanic intrusions that are known to contain elevated concentrations of naturally occurring arsenic (Bevans, et. al., 1998).

Surficial deposits around the site, especially to the south and west, are predominantly quaternary in age, consisting of alluvial, poorly sorted, silty to gravelly sediments eroded from volcanic rocks of the McCullough Range to the southwest. In the central and eastern portions of the site, however, the quaternary deposits are derived from the tertiary and volcanic outcrops of the River Mountains that are composed chiefly of the Horse Springs and Thumbs Formations and the volcanic intrusions into these formations that exist along the eastern and northeastern borders of the site (see Figures 4-1A and 4-1B).

Volcanic rocks intrude into the Horse Springs and Thumbs Formations onsite at three specific locations (Figure 4-1A); one is located in the hillock in the north central portion of the site, one tends northwest to southeast in the northeastern portion of the site, and one outcrops at the top of the hill along the eastern boundary of the site.



Note: Descriptions of formations identified in this figure are presented in Figure 4-1B

Figure 4-1A
Regional Geologic Map in Vicinity of the Landfill

Henderson Landfill SRADI

CH2MHILL

LITHOLOGY

Sedimentary Rocks

QUATERNARY DEPOSITS

Qaf **Artificial fill.** Settling ponds of Basic Management, Inc. cover areas of Qh_1, Qr_2, Qf_2, and Qa; sanitary land fill covers Qr_1, Qr_2, and Ths; tailings from Three Kids Mine cover Qr_1, Qr_2, QTg, Tmcf, and Tsm.

Qa **Modern wash deposits.** Dominantly sandy pebble to cobble gravel; anastomosing bar and channel network; poorly to very poorly sorted, poorly to moderately stratified, non-indurated. Las Vegas Wash area contains mostly salt-rich silty sand, and has a deep knickpoint that is rapidly migrating upwash. No soil development. Deposits generally <3 m (10 ft) thick.

Qr_1 Qr_2 Qr_3 **Pediment and fan deposits of the River Mountains.** Silty, sandy pebble to cobble gravel; composed dominantly of dacite clasts with locally high concentrations of basalt, tuff, and sedimentary clasts, all derived from the River Mountains area; locally rich in reworked and pedogenic gypsum. Poorly to very poorly sorted, poorly to moderately stratified. **Qr_1**: Anastomosing network of undifferentiated Holocene alluvium, occurring in low wash terraces, and modern wash deposits (Qa); deposits are non-indurated; low terraces are characterized by bar and channel topography with incipient desert varnish and desert pavement. Soils under terraces have A–C profiles with incipient calcic horizons as much as 50 cm (20 in.) thick. Deposits generally 1–3 m (3–10 ft) thick. **Qr_2**: Slightly indurated deposits underlying broad, flat interfluvial surfaces; moderately to well-developed desert varnish and desert pavement. Soils have dark-brown to yellowish-brown cambic and argillic B horizons 30–45 cm (12–18 in.) thick and moderately to well-developed Cca horizons about 1 m (3 ft) thick; soils locally have gypsic horizons. Deposits generally 1–3 m (3–10 ft) thick. **Qr_3**: Deposits underlying well-dissected fan surfaces in the Interior Valley and probably underlying most Qr_1 and Qr_2 deposits. Surfaces are generally rounded linear ridges with moderately to well-developed desert varnish and desert pavement. Remnants of soil have hard, well-cemented petrocalcic horizons 1–2 m (3–6 ft) thick. Total thickness uncertain; exposed thickness in the Interior Valley is about 6 m (20 ft).

QUATERNARY-TERTIARY DEPOSITS

QTg **Older alluvial-fan deposits.** Sandy pebble to boulder gravel; in the River Mountains area, composed dominantly of dacite clasts and typically gypsiferous; in the Frenchman Mountain area, composed of granitic and gneissic clasts. Fan surfaces are well dissected and characteristically consist of rounded linear ridges; soils are preserved only as isolated petrocalcic remnants. Poorly to very poorly sorted; poorly to moderately stratified; moderately indurated. Deposits typically seen unconformably ovelying Tmcc and Tmcf. Deposits generally 1–10 m (3–33 ft) thick.

TERTIARY ROCKS

Tmcc Tmcf Tmcu **Muddy Creek Formation.** Extensive basin-fill sediments of lacustrine and subaerial origin (Longwell and others, 1965); mapped as unnamed formation by Brenner-Tourtelot (1979) and as QTcs by Bingler (1977). Formation unconformably overlies Ths and is generally gently dipping except where disrupted by faulting. Total thickness in quadrangle >100 m (325 ft). Formation is overlain by a basalt at Fortification Hill in the Lake Mead area, K-Ar dated at 5.88 ± 0.18 m.y. (Damon and others, 1978). **Tmcc**: Coarse-grained facies comprises upper and lower portions of the formation in this area and consists of yellowish- to reddish-brown fanglomerate; well-cemented coarse sandy, pebble to cobble gravel. Deposits locally contain interbedded gypsiferous siltstone, and in the area near North Shore Road, they consist of gypsiferous pebbly sand. Upper portion is well bedded (beds are 0.3–0.6 m [1–2 ft] thick) and consists dominantly of volcanic pebbles 1–2 cm (½–1 in.) in diameter. Lower portion is poorly to moderately bedded and consists of volcanic, sedimentary, gneissic and granitic clasts. **Tmcf**: Fine-grained facies; dominantly gypsiferous pink to red siltstone, sandy siltstone and claystone; upper portions contain massive beds of white to light-pink gypsum; locally manganese-rich; beds of whitish siltstone and claystone locally occur throughout. Deposits are thin bedded (shaly) to massive; the unit is a prominent badland and bluff former in Las Vegas Wash-Lake Mead area. **Tmcu**: Coarse- and fine-grained facies, undifferentiated. In the area along the western flank of Frenchman Mountain area, unit consists of pink gypsiferous pebbly sand and sandy gravel, containing clasts reworked from older sedimentary rocks, interbedded with pink to white siltstone.

Tsm **Manganiferous sedimentary rocks of the Three Kids Mine.** Gray to black manganese-rich tuff, tuffaceous sandstone and siltstone; moderately to well bedded. Dominantly of pyroclastic origin; variably reworked by water. Originally mapped as part of the Muddy Creek Formation (McKelvey and others, 1949; Longwell and others, 1965). Deposits underlie Tmcf; they are probably older than the Muddy Creek Formation and may be part of the volcanic rocks of Powerline Road.

Ths **Horse Spring Formation.** Carbonate rocks; dominantly light to pinkish gray; finely to medium crystalline limestone and siliceous limestone with interbedded white to yellow calcareous siltstone and shale. Deposits locally are dolomitic and lithium bearing (Brenner-Tourtelot, 1979). Limestones are generally thick bedded to massive, and commonly brecciated. Intruded by and interbedded with Tb, Td, and Tvr. K-Ar ages in the Muddy Mountain-Gale Hills area range from 13.2–21.3 m.y. (Anderson and others, 1972).

Tt Ttc Ttl Ttg **Thumb Formation.** Continental red-bed and limestone deposits. K-Ar ages on intrusive and interbedded volcanic rocks in Rainbow Gardens (Tvr) range from about 11–17 m.y. (Anderson and others, 1972). In the Muddy Mountains area the formation is mapped as the lower member of the Horse Spring Formation and is fission-track dated at about 13–17 m.y. (Bohannon, 1979a). **Tt**: Comprises major portion of Thumb Formation. Dominantly red to pink calcareous siltstone and sandstone, gypsiferous shale and claystone; contains undifferentiated beds of Ttc conglomerate, Ttl limestone and Tvr; locally contains massive beds of gypsum. Siltstone and sandstone are well bedded with beds commonly 2.5–15 cm (1–6 in.) thick. Contains several Tvr flow interbeds and dikes. **Ttc**: Gray to red calcareous pebble to cobble conglomerate; occurs as a basal facies and as interbeds throughout the lower half of the formation. Characteristically contains subrounded to well-rounded clasts of pre-Tertiary limestone, sandstone and quartzite in a well-cemented sandy matrix; contains no Ttg-type granitic or gneissic clasts. Beds are very resistant and are prominent ridge formers. **Ttl**: Dominantly pink to light-brown finely crystalline to clastic limestone (calcarenite to calcirudite); contains intercalated red siltstone and sandstone; may be locally conglomeratic. Unit occurs in lower half of formation. **Ttg**: Masses and beds of brecciated basement rock and breccia occurring within Tt; believed to be of massive landslide origin (Longwell, 1974). Basement rocks are presumed to be of Precambrian age and derived from the Gold Butte Granite, now exposed in the Gold Butte area, south of the Virgin Mountains (Anderson, 1973; Longwell, 1974). Rock types include: rapakivi granite, porphyritic microcline granite, gneissic garnetiferous granite, quartz monzonite, gneiss, and quartzo-feldspathic schist. Deposits form prominent resistant knobs and pinnacles within Tt.

Volcanic Rocks

MID-TERTIARY ROCKS

Tpd Tpd_2 Tpm Tpb Tpbr Tpt **Volcanic Rocks of Powerline Road. Tpd**: Numerous flows of texturally variable, plagioclase-, biotite-, and hornblende-bearing dacite. Interbedded with epiclastic sandstone, conglomerate and breccia, and thin pyroclastic units. Dacite lavas are commonly flow banded and display large amplitude flow folds. In the SE/4,S11,T22S,R63E flow banding is highly contorted; plunging flow folds have wavelengths of 30–60 m (100–200 ft) and amplitudes of about 60 m (200 ft). Flows vary in color from grayish red to grayish yellow green. Zeolitized flows are white. The upper and lower parts of many flows are brecciated, and basal (and less commonly upper) vitrophyre zones are present. Spherulitic dacite is the dominant rock type in the NE/4,S36,T21S,R63E to the east of the Three Kids Mine. Spherulites vary in size from <0.5 cm (0.2 in.) to >5 cm (2 in.). The resistant spherulites are easily plucked from a soft perlitic matrix and become a locally important component of wash deposits. Just to the south of the Three Kids Mine, dacite is very fine grained and contains xenoliths of porphyritic dacite and andesite. Tpd forms a broad lava shield. Flow direction studies indicate the source of most of the flows lies to the east of the quadrangle, however a probable source is in the NW/4,S25,T22S,R63E. Here the roots of a northwest-trending, fan-structured dome are exposed. A yellow-green pyroclastic unit containing abundant fragments of pumice up to 15 cm (6 in.) in size crops out to the north of Lake Mead Drive in S27,T21S,R63E. Tpd is equivalent to the rhyodacite unit (Trr) of Anderson (1977). **Tpd_2**: Grayish-red to red dacite flows with plagioclase, biotite and hornblende as phenocrysts. The unit varies in thickness from 45–60 m (150–200 ft), and contains numerous xenoliths of dark-gray andesite. Tpd_2 is an important marker horizon in the northern River Mountains. **Tpm**: Basalt and andesite flows. K-Ar dated at 11.8 ± 0.5 m.y. by Anderson and others (1972). Three varieties crop out in the map area: 1) Basalt with phenocrysts of augite (up to 1 cm [0.4 in.]) in size, and plagioclase set in a grayish-red-purple matrix. Many flows have vesicular and fine-grained tops, and coarsely porphyritic interiors. The basal parts of several flows have been enriched in augite phenocrysts due to gravitational settling. 2) Aphyric platy basalt containing microscopic crystals of plagioclase, augite and olivine. 3) Andesite with plagioclase, hornblende, and augite phenocrysts. Varieties 1 and 2 are interbedded with agglomerate and breccia. A thick agglomerate unit overlies Tpm along the eastern margin of the quadrangle in S6,T22S,R64E. This area probably is close to the source of the flows. **Tpb**: Dark-gray porphyritic olivine basalt flows crop out to the north of Lake Mead Drive. Olivine is subhedral to euhedral (up to 0.5 cm [0.2 in.] in size) and is set in a glassy matrix containing small plagioclase laths and subhedral augite crystals. The flows are interbedded with agglomerate and breccia. **Tpbr**: Thick section of poorly bedded, unsorted, monomictic breccia interstratified with Tpd. Clasts range in size from <1 cm (0.5 in.) to >2 m (6.5 ft). Fragments are completely surrounded by fine-grained matrix. Probably deposited by mud flows. **Tpt**: Volcaniclastic unit containing well-bedded white to very light-gray ash and pumice lapilli, and red to orange sandstone and conglomerate. The pumice is locally interbedded with two thin (>1 m [3.3 ft] thick) flows of basalt. The pyroclastic beds may be air-fall deposits; the sandstones and conglomerates are water deposited. Tpt crops out only to the north of Lake Mead Drive where it separates Tpm from Tpb.

Tb Td **Volcanic Rocks North of Lake Mead Drive. Tb**: Basalt flows containing phenocrysts of plagioclase and augite. Commonly brecciated. Tb may be equivalent to Tpm to the south of Lake Mead Drive. **Td**: Dacite flows and breccia. Flows contain phenocrysts of plagioclase, biotite and hornblende and are commonly flow banded. Td may be equivalent to Tpd to the south of Lake Mead Drive.

GEOMATRIX

Figure 4-1B
Regional Geologic Map Legend
Henderson Landfill SRADI

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4.4 Arsenic in Native Rock Based on Past Investigations

The volcanic intrusions that exist onsite are composed of basalt flows containing phenocrysts of plagioclase and augite that are commonly brecciated (Bell and Smith, 1980). These intrusions with flows containing phenocrysts of plagioclase, biotite and hornblends are commonly flow banded and may be equivalent to River Mountain formations found to the south of Lake Mead Drive bordering the Three Kids Mine (located between 2 ½ and 3 miles to the east southeast of the site) to the east, north and south (Bell and Smith, 1980). Sampling conducted by UNLV at and in the vicinity of the Three Kids Mine indicated that naturally-occurring arsenic may exist at concentrations ranging from below 70 to greater than 500 milligrams per kilogram (mg/kg) (Sims, 1997 and Naugle, 1997). (Although these data were not obtained from an EPA-approved laboratory; they are included in this document for informational purposes.) As a point of reference, the Industrial PRG for arsenic is 1.6 mg/kg.

In addition, Bevans, et. al. (1998), in their paper on water quality on the Las Vegas Valley and Carson and Truckee River Basins, Nevada and California, 1992-96, indicate that groundwater within the study areas had ultimately been impacted by arsenic contained in “volcanic rocks and sediment derived from volcanic rocks.” Finally, the regional investigations presented by Welch (1988) and Bevans, et. al. (1998) indicate that arsenic may occur naturally in native rock outcrops composed of volcanic materials similar to those found onsite in concentrations well over 100 mg/kg.

Based on these observations, it can be expected that arsenic concentrations onsite will be highest within the volcanic intrusions and neighboring soils with lower concentrations in the quaternary formations that are composed of various mixtures of the weathered volcanic rock. In addition, arsenic concentrations found near the bedrock outcrops in the north, northeast and eastern parts of the site can be expected to be substantially greater than the Industrial PRGs. The results of the onsite sampling bore out these predictions, as presented in the following section.

4.5 Results of Onsite Arsenic Sampling

Sampling of soil for arsenic has occurred numerous times over the last 6 years related to:

- The preparation for and construction of the Sunset Road road bed;
- Conducting the EE/CA; and
- Conducting the SRADI Phase field program which included three separate sampling events.

The results from each of these sampling efforts are presented as a means to characterize the onsite concentrations of arsenic. Note that only the SRADI Phase field program was successful in characterizing arsenic concentrations site wide. All other onsite sampling focused upon characterizing soils both above and adjacent to interred waste (as was the case with the Sunset Road sampling), or hydraulically down stream of the interred waste (as was the case of the EE/CA). Although the SRADI Phase sampling effort did include collection of soils from beneath and adjacent to interred waste, only the SRADI Phase sampling effort collected and analyzed soils from previously undisturbed areas onsite, as well. Therefore, the majority of the data presentation and analyses will focus on the results of the SRADI Phase field program.

4.5.1 Sunset Road Roadbed Construction

Sampling was conducted by various investigators during the planning and construction of the Sunset Road roadbed. Samples were collected for environmental assessment in 1992, 1993, 1994, 1998, and 1999. Although some of the samples were collected to test for the quality of potential fill material from offsite sources, most of the samples characterized onsite soils in and along the roadbed alignment. Based on data presented by Douglass (1998 and 1999), the onsite sampling produced arsenic concentrations that varied from less than 5 to 88 mg/kg.

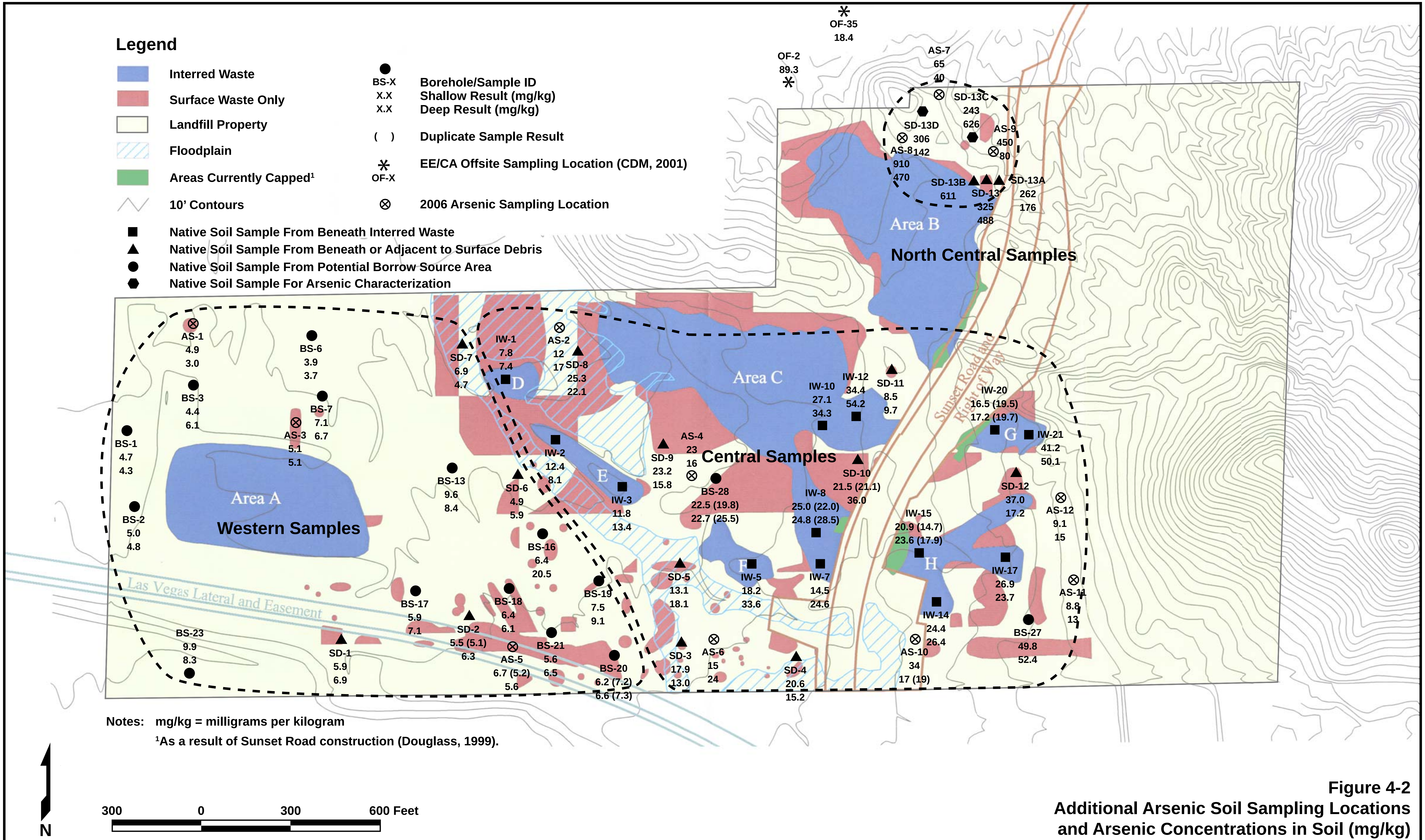
4.5.2 EE/CA

Sampling was conducted during performance of the EE/CA (CDM, 2001) to characterize environmental conditions of the onsite and offsite soils and sediment. Sampling results were obtained utilizing both field and fixed laboratory methods. Samples were generally collected well away from the native bedrock outcrops. This sample collection method is reflected in the relatively low arsenic concentrations detected in these samples. The only samples collected near the volcanic outcrops were at two offsite locations northeast of the site (see Figure 4-2). The range of arsenic concentrations found in three onsite samples (including surface and subsurface soils) was < 8.5 to 16.5 mg/kg, whereas the offsite concentrations for three sample locations north and northeast of the site ranged from 18.7 to 89.3 mg/kg.

4.5.3 SRADI

Sampling during the initial SRADI Phase field program, based on the SRADI Work Plan (CH2M Hill, 2003) was initially focused on characterizing the native soils in three areas—in areas that are candidates for use as borrow material, in areas that underlie surface debris and in areas that underlie interred waste. Supplemental sampling of previously undisturbed bedrock in the north central portion of the site in the vicinity of sample SD-13 (see Figure 4-2) was also conducted to verify and better characterize arsenic concentrations in native soils in this area. By combining the original and supplemental sampling, eighty-nine individual soil samples were collected from two separate depths (except at one location) from 45 different locations, not including field or lab QA/QC samples.

The initial SRADI Phase field program was amended to include additional supplemental site soil sampling, which was performed in February 2006 in response to the "Additional Arsenic Sampling Work Plan" (CH2M HILL, 2006) dated January 6, 2006 and approved by the Nevada Division of Environmental Protection (NDEP) and SNHD (known as Clark County Health District [CCHD] at that time). The supplemental site soil sampling included the collection of additional samples in the western, central and north central areas of the site to create appropriate sample populations within each of these three geologic-based areas (see below) for use in specific statistical evaluations. In particular, in the western and central areas of the site, the sampling was used to collect additional samples from beneath and immediately adjacent to surface debris and interred waste, and from previously undisturbed soils, respectively. The purpose of the additional arsenic sampling and the subsequent statistical analyses is to demonstrate that the arsenic found in the soils onsite is naturally occurring such that arsenic can be removed from the site's contaminants of potential concern (COPCs) listed in the Engineering Evaluation/Cost Analysis (EE/CA) and



Legend

🟦	Interred Waste
🟥	Surface Waste Only
☐	Landfill Property
▨	Floodplain
🟩	Areas Currently Capped[1]
╱╲	10' Contours

● BS-X X.X X.X	Borehole/Sample ID Shallow Result (mg/kg) Deep Result (mg/kg)
( )	Duplicate Sample Result
✳ OF-X	EE/CA Offsite Sampling Location (CDM, 2001)
⊗	2006 Arsenic Sampling Location

■	Native Soil Sample From Beneath Interred Waste
▲	Native Soil Sample From Beneath or Adjacent to Surface Debris
●	Native Soil Sample From Potential Borrow Source Area
⬢	Native Soil Sample For Arsenic Characterization

Notes: mg/kg = milligrams per kilogram

[1]As a result of Sunset Road construction (Douglass, 1999).

GEOMATRIX

Figure 4-2
Additional Arsenic Soil Sampling Locations and Arsenic Concentrations in Soil (mg/kg)

Henderson Landfill SRADI

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presented in the Action Memorandum and therefore no action level will be needed for arsenic to implement the selected response action.

The three geologic-based areas – the western, central and north central areas – were differentiated from one another based on the field observations and the geologic map of the Henderson quadrangle presented in Figure 4-1a. The geologic map shows that the site can be divided into these three areas as follows:

- North Central – relates to the Thumbs Formation and the volcanic rocks (i.e., basaltic flows) found north of Lake Mead Drive.
- Central – relates to the artificial fill area that covers the pediment and fan deposits of the River Mountains and further to the east the Horse Spring Formation.
- Western – relates to the uncovered areas of the pediment and fan deposits of the River Mountains and the modern wash deposits.

The additional site soil sampling for arsenic was used to obtain the following samples for the statistic analyses as indicated:

- **North Central Area** – collected an additional 6 samples from three locations at two different depths (i.e., from approximately six inches below ground surface and from 18 inches to three feet below ground surface) to create a total sample population of 15 samples to characterize this area of elevated naturally-occurring arsenic. Because no surface debris or interred waste was disposed of in this area of the site, no comparative statistical analyses were performed using this set of sampling results, however statistical parameters were calculated and a histogram of these data was prepared to further characterize the nature of the naturally-occurring arsenic found in this location.
- **Central Area**– collected an additional 12 samples from six locations at two different depths (i.e., from six to twelve inches below ground surface and from 18-inches to three-feet below ground surface) to create a total sample population of 14 samples representing undisturbed soils not previously covered with interred waste or surface debris. The results from these 14 samples were compared to those samples from this same area that were collected from beneath interred waste or surface debris using a parametric, two-sample two-sided t-test to determine if the mean of the sample populations are the same within the defined level of significance as indicated in the approved Additional Arsenic Sample Work Plan (i.e., $\alpha = 0.05$).
- **Western Area** - collected an additional 6 samples from three locations at two different depths (i.e., from six to twelve inches below ground surface and from three to five feet below ground surface) to create a total sample population of 14 samples representing soils previously covered with interred waste or surface debris. The results from these 14 samples were compared to those samples from this same area that were collected from previously undisturbed soils using a parametric, two-sample two-sided t-test to determine if the mean of the sample populations are the same within the defined level of significance as indicated in the approved Additional Arsenic Sample Work Plan (i.e., $\alpha = 0.05$).

Details related to the February site soil sampling efforts are included in Appendix A.

4.5.4 Data Analyses

The scope of additional arsenic sampling performed, as well as the statistical testing methods, were based on discussions with NDEP and NDEP's consultant (Neptune and Company, Inc. [Neptune]). The additional arsenic sampling sought to create (and successfully created) appropriate sample populations within each of the three geologic-based onsite "areas of interest" – the western, central and north central areas (see Figure 4-2) that were used to conduct specific statistical evaluations (described below). Appendix B presents a summary of the arsenic soil sample results from within each of these three areas, including all of the samples from previous SRADI related field activities and those collected in fulfillment of the Additional Arsenic Sampling Work Plan.

The proposed data analyses include statistical analyses that were used to compare samples within the same geologic unit(s) representing undisturbed soils and soils from beneath interred waste or surface debris using a parametric, two-sample two-sided t-test. This statistical test was used to test the null hypothesis that the mean of samples associated with landfill waste is equal to the mean for samples not associated with landfill waste (as represented by samples from undisturbed areas) within like geologic conditions (i.e., the Western and Central portions of the site).

In the North Central portion of the site, past sampling has already confirmed that naturally occurring arsenic exists at elevated concentrations. Comparative analyses are not necessary because it is clear that the elevated arsenic concentrations observed in this area are present in previously undisturbed soils and rock. Therefore, the sampling in the North Central portion of the site was used to better characterize the statistical distribution of naturally occurring arsenic in this area, using the calculated mean and standard deviation of this sample population.

Western Area

Forty individual soil samples were collected in the western area of the site, with 26 samples collected from previously undisturbed areas and 14 collected from beneath or immediately adjacent to waste materials (e.g., surface debris). Table 4-1 presents the arsenic data and the results of the two-sample two-sided t-test. The results of the two-sample two-sided t-test (i.e., p-value = 0.03 is less than α) indicates that there is a significant difference between the mean of samples associated with landfill waste and the mean for samples not associated with landfill waste (i.e., undisturbed soils). Noteworthy; however, is that the hypothesis of the subject means being equal was rejected because the mean of the samples associated with the waste (5.46 milligram per kilogram) is significantly less than the mean of the undisturbed samples (6.99 milligram per kilogram). Therefore, it is concluded that the there is no evidence to suggest that arsenic concentrations in the Western Area are elevated as a consequence of the landfill waste.

Central Area

Fifty-six individual soil samples were collected in the central area of the site, with 14 samples collected from previously undisturbed areas and 42 collected from beneath or immediately adjacent to waste materials (e.g., surface debris). Table 4-2 presents the arsenic data and the results of the two-sample two-sided t-test. The results of the two-sample two-sided t-test (i.e., p-value = 0.08 is greater than α) indicates that there is not a significant difference between the mean of samples associated with landfill waste and the mean for

Table 4-1

Comparison of Western Area Soil Samples Using a Two-Sample, Two-Sided t-Test

Henderson Landfill SRADI

Soil Sampling Results

Below Waste		Undisturbed Areas	
Sample Location	Arsenic (mg/kg)	Arsenic (mg/kg)	Sample Location
SD-01	5.9	4.7	BS-01
SD-02	5.3	5	BS-02
SD-06	4.9	4.4	BS-03
SD-07	6.9	3.9	BS-06
AS-1-6	4.9	7.1	BS-07
AS-3-6	5.1	9.6	BS-13
AS-5-6	5.95	6.4	BS-16
SD-01	6.9	5.9	BS-17
SD-02	6.3	6.4	BS-18
SD-06	5.9	7.5	BS-19
SD-07	4.7	6.7	BS-20
AS-1-36	3	5.6	BS-21
AS-3-36	5.1	9.9	BS-23
AS-5-36	5.6	4.3	BS-01
		4.8	BS-02
		6.1	BS-03
		3.7	BS-06
		6.7	BS-07
		8.4	BS-13
		20.5	BS-16
		7.1	BS-17
		6.1	BS-18
		9.1	BS-19
		6.95	BS-20
		6.5	BS-21
		8.3	BS-23

t-Test: Two-Sample Assuming Unequal Variances

	Below Waste	*Undisturbed*
Mean	5.460714286	6.986538462
Variance	1.003145604	10.41471154
Observations	14	26
Hypothesized Mean Difference	0	
df	33	
t Stat	-2.220407695	
P(T<=t) one-tail	0.016685407	
t Critical one-tail	1.692360258	
P(T<=t) two-tail	0.033370813	
t Critical two-tail	2.034515287	

Table 4-2
Comparison of Central Area Soil Samples Using a Two-Sample, Two-Sided t-Test
Henderson Landfill SRADI

Soil Sampling Results			
Below Waste		Undisturbed Areas	
Sample Location	Arsenic (mg/kg)	Arsenic (mg/kg)	Sample Location
IW-01	7.8	21.15	BS-28
IW-02	12.4	12	AS-2-6
IW-03	11.8	23	AS-4-6
IW-05	18.2	15	AS-6-6
IW-07	14.5	34	AS-10-6
IW-08	23.5	8.8	AS-11-6
IW-10	27.1	9.1	AS-12-6
IW-12	34.4	24.1	BS-28
IW-14	24.4	17	AS-2-36
IW-15	17.8	16	AS-4-36
IW-17	26.9	24	AS-6-36
IW-20	18	18	AS-10-18
IW-21	41.2	13	AS-11-18
SD-03	17.9	15	AS-12-18
SD-04	20.6		
SD-05	13.1		
SD-08	25.3		
SD-09	23.2		
SD-10	23.1		
SD-11	8.5		
SD-12	37		
IW-01	7.4		
IW-02	8.1		
IW-03	13.4		
IW-05	33.6		
IW-07	24.6		
IW-08	26.65		
IW-10	34.3		
IW-12	54.2		
IW-14	26.4		
IW-15	20.75		
IW-17	23.7		
IW-20	18.45		
IW-21	50.1		
SD-03	13		
SD-04	15.2		
SD-05	18.1		
SD-08	22.1		
SD-09	15.8		
SD-10	36		
SD-11	9.7		
SD-12	17.2		

t-Test: Two-Sample Assuming Unequal Variances

	Below Waste	*Undisturbed*
Mean	22.27261905	17.86785714
Variance	117.24161	47.05677198
Observations	42	14
Hypothesized Mean Difference	0	
df	36	
t Stat	1.775786732	
P(T<=t) one-tail	0.042111071	
t Critical one-tail	1.688297694	
P(T<=t) two-tail	0.084222143	
t Critical two-tail	2.028093987	

samples not associated with landfill waste (i.e., undisturbed soils), albeit that the results are marginal.

An additional test was performed to further characterize the distribution of arsenic in Central Area soils. A two-sample two-sided t-test was used to test the null hypothesis that the mean of samples taken at a depth of 1-foot or less either below ground surface or below waste is equal to the mean for samples taken from 18-inches or deeper below either ground surface or below waste. If there were arsenic impacts to soil caused by the placement of landfill waste, they would be expected to attenuate with depth. This statistical test can be used to determine if said attenuation exists onsite. Table 4-3 presents the arsenic data and the results of the two-sample two-sided t-test for this comparative analysis. The results of the two-sample two-sided t-test (i.e., p-value = 0.55 is substantially greater than α) indicates that there is not a significant difference between the mean of samples taken at a depth of 1-foot or less and the mean for samples taken from 18-inches or deeper.

Therefore, it is concluded that arsenic concentrations in the Central Area not are elevated as a consequence of the landfill waste.

North Central Area

Arsenic found in the 15 samples of previously undisturbed soils in the North Central area of the site exhibit concentrations ranging from 40 to 910 mg/kg. The mean concentration and standard deviation of the 15 samples are 346 and 246, respectively. The logarithmic mean and standard deviation are 2.40 and 0.39, respectively.

A histogram of the north central arsenic results, shown in Figure 4-3, indicates that the arsenic data may be log normally distributed. A log normal distribution is consistent with what may be expected with natural occurring concentrations at very high levels.

Given the previously undisturbed nature of soils sampled in this area, there is no evidence that any of the arsenic found in the North Central area of the site is anything other than naturally occurring.

4.6 Summary of Observations

The foregoing discussion can be summarized as follows:

- Naturally occurring bedrock outcrops consisting of volcanic intrusions, along with other igneous and sedimentary rock, exist onsite, as well as along the majority of the southeastern margin of the Las Vegas Valley bordering the City of Henderson. These same rocks constitute the majority of the Three Kids Mine area. Past investigators have shown that regionally these rocks contain naturally occurring deposits of arsenic ranging from the 10s into the 100s of mg/kg.
- Local environmental sampling onsite and within a few miles of the site has detected arsenic at concentrations ranging from below detection limits to over 500 mg/kg.
- Onsite or near site sampling in areas proximate to the bedrock outcrops have produced arsenic concentrations from double digits to over 900 mg/kg.

Table 4-3
Comparison of Central Area Soil Samples By Depth Using a Two-Sample, Two-Sided t-Test

Henderson Landfill SRADI

Soil Sampling Results			
Shallow Samples		**Deep Samples**	
Sample Location	**Arsenic (mg/kg)**	**Arsenic (mg/kg)**	**Sample Location**
IW-01	7.8	7.4	IW-01
IW-02	12.4	8.1	IW-02
IW-03	11.8	13.4	IW-03
IW-05	18.2	33.6	IW-05
IW-07	14.5	24.6	IW-07
IW-08	23.5	26.65	IW-08
IW-10	27.1	34.3	IW-10
IW-12	34.4	54.2	IW-12
IW-14	24.4	26.4	IW-14
IW-15	17.8	20.75	IW-15
IW-17	26.9	23.7	IW-17
IW-20	18	18.45	IW-20
IW-21	41.2	50.1	IW-21
SD-03	17.9	13	SD-03
SD-04	20.6	15.2	SD-04
SD-05	13.1	18.1	SD-05
SD-08	25.3	22.1	SD-08
SD-09	23.2	15.8	SD-09
SD-10	23.1	36	SD-10
SD-11	8.5	9.7	SD-11
SD-12	37	17.2	SD-12
BS-28	21.15	24.1	BS-28
AS-2-6	12	17	AS-2-36
AS-4-6	23	16	AS-4-36
AS-6-6	15	24	AS-6-36
AS-10-6	34	18	AS-10-18
AS-11-6	8.8	13	AS-11-18
AS-12-6	9.1	15	AS-12-18

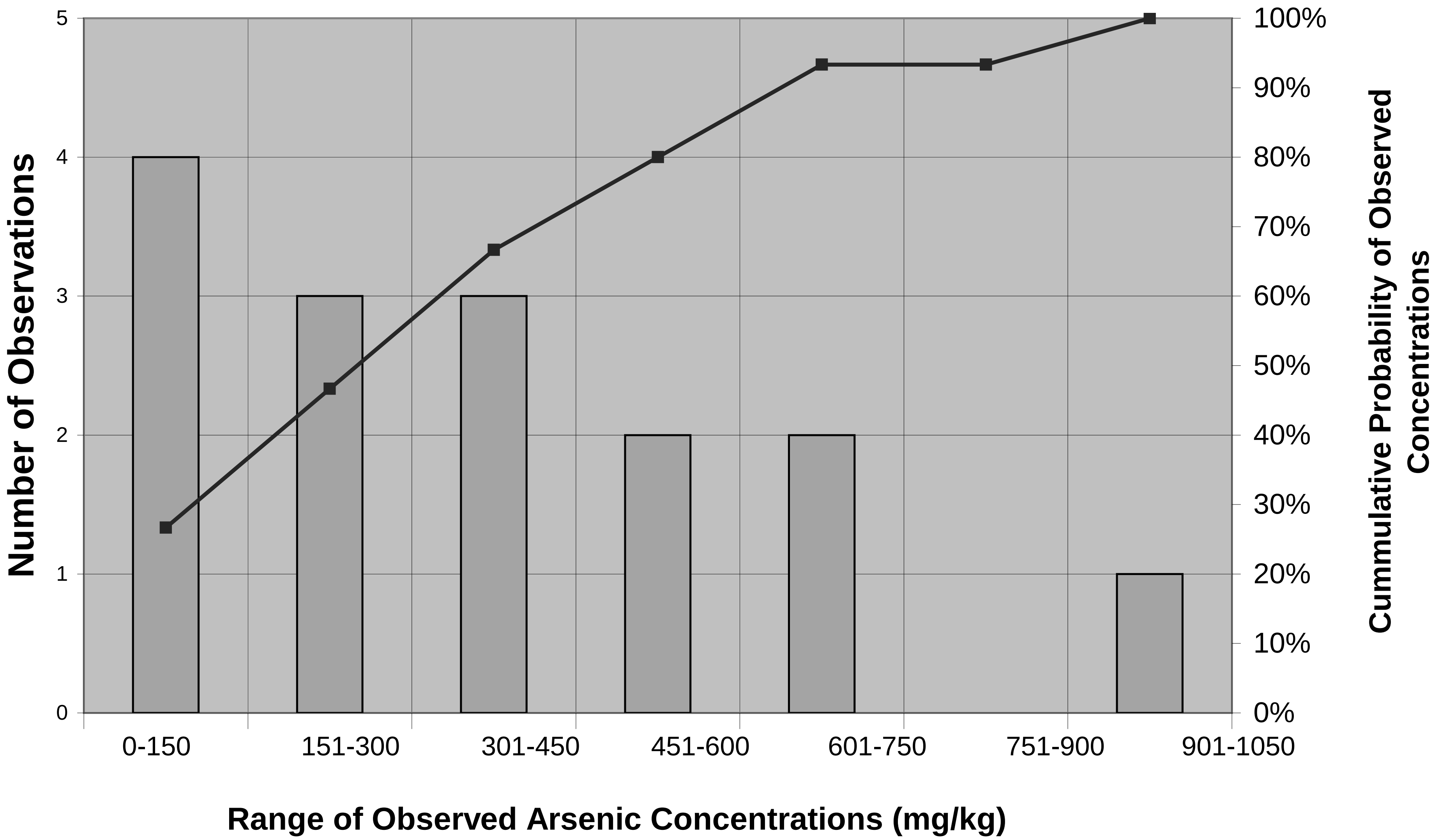
t-Test: Two-Sample Assuming Unequal Variances

	Shallow	*Deep*
Mean	20.34821429	21.99464286
Variance	80.01286706	126.8172851
Observations	28	28
Hypothesized Mean Difference	0	
df	51	
t Stat	-0.605780074	
P(T<=t) one-tail	0.273673738	
t Critical one-tail	1.675284951	
P(T<=t) two-tail	0.547347477	
t Critical two-tail	2.007583728	

Figure 4-3

Histogram of Observed Arsenic Concentrations in Samples from the North Central Portion of the Site

Henderson Landfill SRADI



The results of the SRADI Phase field sampling, including the most recent additional arsenic sampling efforts, which represents the most geographically diverse and uniformly distributed sampling of onsite soils completed to date, indicates a distribution of arsenic onsite that results from naturally occurring sources. This is evidenced by the statistical testing comparing analytical results from soil samples collected from previously undisturbed areas with those from samples collected beneath or immediately adjacent to waste materials. The results of the overall data analyses indicate that:

- Arsenic concentrations in the Central and Western Areas of the site are not elevated as a consequence of the landfill waste; and
- There is no evidence that any of the arsenic found in the North Central area of the site is anything other than naturally occurring.

4.7 Recommendations

Developing a numerical standard to define the background concentration of arsenic in the Las Vegas Valley area is challenged by the large volume and variability of naturally occurring arsenic in native rock outcrops and soils. At the Henderson Landfill site, the situation is no different. Bedrock outcrops co-exist with other types of weathered and eroded volcanic and sedimentary rock onsite creating natural, and variable, sources of arsenic that impact surface soils, sediment, and alluvial deposits. Concentrations of arsenic in these native deposits have been shown to exist to levels greater than 900 mg/kg.

In addition, no sampling onsite has identified or characterized any potential sources of arsenic beyond those that appear to be naturally occurring. Based on the data presented herein and the discussions presented above, it is clear that arsenic as found onsite occurs as the result of native rocks and minerals, and not because of past municipal solid waste disposal activities.

Therefore, arsenic should be removed from the list of contaminants of potential concern for the site and in doing so; no action level would be required for arsenic to implement the selected response action.

5 Summary of Recommendations

This section summarizes the recommendations presented in this TM.

5.1 Industrial PRGs

The EPA Region 9 Industrial PRGs are more conservative than PRGs that would be developed using site-specific criteria, and therefore are appropriate for defining the clean soil criteria for those analytes and compounds present at the Henderson Landfill. Therefore, the Industrial PRGs will be used to:

- Identify native soils that may be left in place, without further action, after removal and consolidation of surface debris and interred waste in accordance with implementation of the selected response action;

- Define the quality of soil that must be used for the upper 18 inches of the final cover system or for engineered earth fill; and
- Evaluate the results of post-closure verification sampling and analyses.

The only exceptions to the use of the Industrial PRGs as clean soil criteria for analytes and compounds detected onsite (as discussed below) are for TPH, dioxin and dioxin-like compounds, and arsenic.

5.2 TPH

TPH, which is not a specific analyte or compound, will be managed in accordance with NAC Section 445A.2272.1.b.

5.3 Dioxin and Dioxin-Like Compounds

The ATSDR Interim Policy Guideline evaluation level of 50 ppt for the TEQ of dioxin and dioxin-like compounds is relevant as the clean soil criteria for the Henderson Landfill site because:

- It defines a numerical level for dioxin and dioxin-like compounds in soil that can be used as an action level;
- Has been previously accepted by NDEP for use at other non-residential sites within the City of Henderson as a soil action level; and
- Provides a conservative and protective standard based on sound science.

5.4 Arsenic

Based on the data and discussions presented herein, it is clear that the entire range of arsenic concentrations found onsite represent naturally occurring levels that originate as the indigenous rocks and minerals, and not from past municipal solid waste disposal activities. It is therefore proposed that no single arsenic value be assigned to define background, that arsenic be removed from the COPC list contained in the EE/CA and the Action Memorandum, and that no future remedial actions or activities be required as a result of arsenic found onsite.

References

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APPENDIX A

Summary of the 2006 Additional Arsenic Sampling Field Activities

A-1 Sampling

Soil samples were collected on February 1, 2006 by a two-person field crew from the locations shown in Figure 1 using the methods described in the SRADI Work Plan dated October 27, 2003. Excavations were made in the ground at the selected soil sampling locations by hand using a clean shovel, pick, trowel and/or post-hole digger. Once the first target depth was reached at 6-inches below ground surface, the soil sample was obtained using a disposable trowel. The excavation then continued until the second sample depth was reached at which time the second soil sample was obtained from the material excavated out of the hole at that depth. Note that the second sample depth was selected based on the relative location of the sample. In the western and central areas west of Galleria Drive, where alluvium exists at ground surface, the second depth was 36-inches below ground surface. In the north central area and in the central area east of Galleria Drive, where bedrock materials outcrop, the second depth was 18-inches below ground surface.

Field quality control samples (i.e., co-located samples) were collected during the sampling program at two locations determined by the field geologist (locations 5 shallow and 10 deep). All retained samples were placed in glass sample jars and labeled in accordance with the protocols defined in the SRADI Work Plan. All samples were analyzed for arsenic using EPA Method 7060, per the SRADI Work Plan.

A-2 Sampling Methods and QA/QC Sampling

Decontamination of the field shovel, pick, trowel and/or post-hole digger was performed using decontamination techniques consistent with those defined in the SRADI Work Plan. All decontamination wastes were drummed and stored onsite in a manner consistent with previous investigations derived wastes.

For each day that the field team is collecting arsenic samples, a field log book was kept to record field conditions, sample locations, sampling issues and other relevant observations. The field team took pictures of all sampling locations after the samples had been collected to record site conditions and sample locations (attached).

APPENDIX A.1

Sample Location Photographs

Location AS-1

Location AS-2

Location AS-3

Location AS-4

Location AS-5

Location AS-6

Location of AS-7

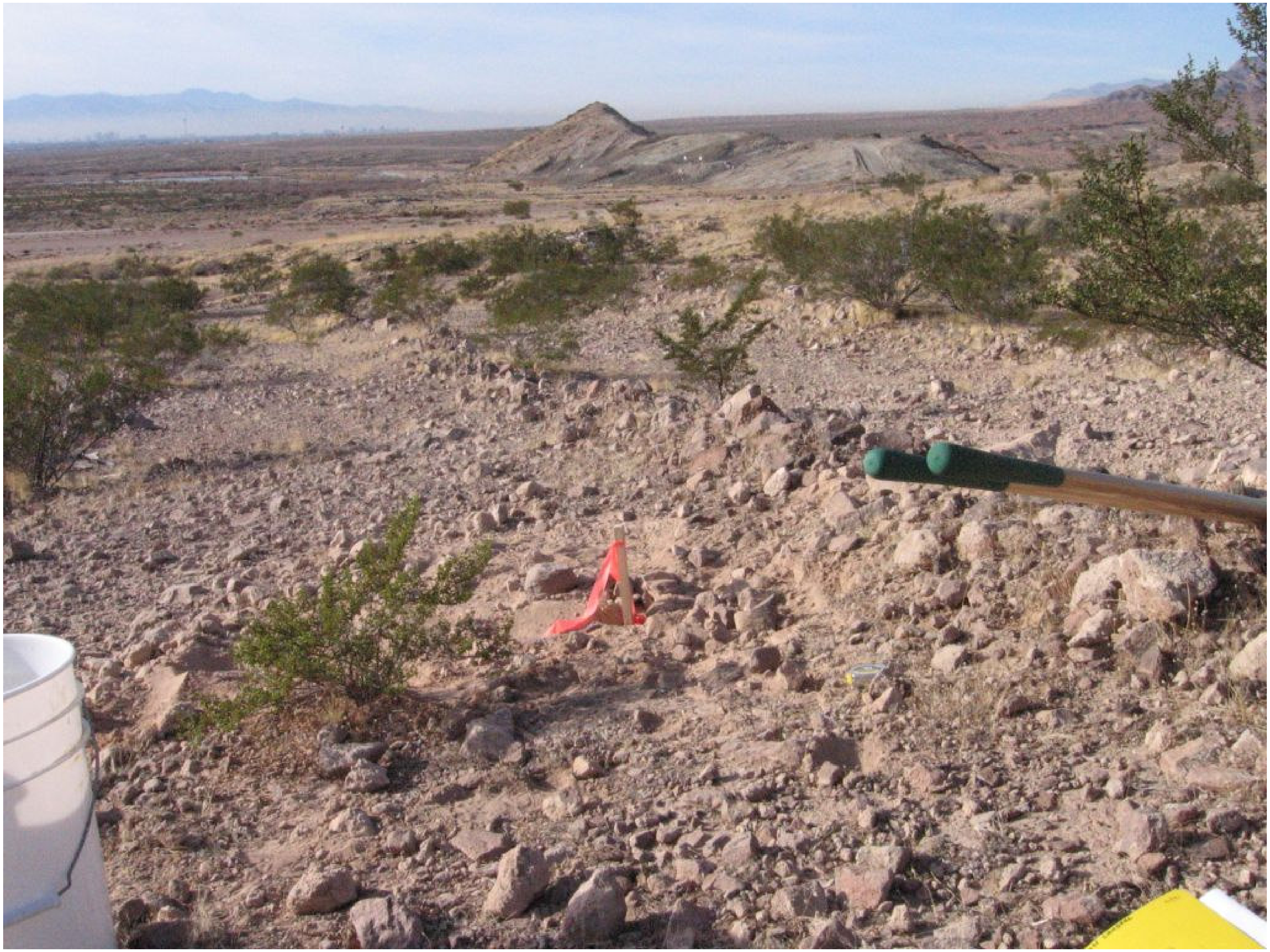
Location AS-8

Location AS-9

Location AS-10

Location AS-11

Location AS-12



APPENDIX B

SRADI Arsenic Soil Sampling Results

Table B-1
Summary of Arsenic Soils Analyses
Henderson Landfill SRADI

Western Area Soil Sampling Results

Below Waste			Undisturbed Areas		
Sample Location	Sample Depth (ft)	Arsenic (mg/kg)	Sample Location	Sample Depth (ft)	Arsenic (mg/kg)
SD-01	1.0	5.9	BS-01	0.5	4.7
SD-02	1.0	5.5	BS-02	0.5	5
SD-02 (col)	1.0	5.1	BS-03	0.5	4.4
SD-06	1.0	4.9	BS-06	0.5	3.9
SD-07	1.0	6.9	BS-07	0.5	7.1
AS-1-6	0.5	4.9	BS-13	0.5	9.6
AS-3-6	0.5	5.1	BS-16	0.5	6.4
AS-5-6	0.5	6.7	BS-17	0.5	5.9
AS-5-6 (col)	0.5	5.2	BS-18	0.5	6.4
SD-01	5.0	6.9	BS-19	0.5	7.5
SD-02	5.0	6.3	BS-20	0.5	6.2
SD-06	5.0	5.9	BS-20 (col)	0.5	7.2
SD-07	5.0	4.7	BS-21	0.5	5.6
AS-1-36	3.0	3	BS-23	0.5	9.9
AS-3-36	3.0	5.1	BS-01	3.5	4.3
AS-5-36	3.0	5.6	BS-02	3.5	4.8
			BS-03	3.5	6.1
			BS-06	3.5	3.7
			BS-07	3.5	6.7
			BS-13	3.5	8.4
			BS-16	3.5	20.5
			BS-17	3.5	7.1
			BS-18	3.5	6.1
			BS-19	3.5	9.1
			BS-20	3.5	6.6
			BS-20 (col)	3.5	7.3
			BS-21	3.5	6.5
			BS-23	3.5	8.3

col - co-located sample

Table B-1
Summary of Arsenic Soils Analyses
Henderson Landfill SRADI

Central Area Soil Sampling Results

Below Waste			Undisturbed Areas		
Sample Location	**Sample Depth (ft)**	**Arsenic (mg/kg)**	**Sample Location**	**Sample Depth (ft)**	**Arsenic (mg/kg)**
IW-01	1.0	7.8	BS-28	0.5	22.5
IW-02	1.0	12.4	BS-28 (col)	0.5	19.8
IW-03	1.0	11.8	AS-2-6	0.5	12
IW-05	1.0	18.2	AS-4-6	0.5	23
IW-07	1.0	14.5	AS-6-6	0.5	15
IW-08	1.0	23.5	AS-10-6	0.5	34
IW-10	1.0	27.1	AS-11-6	0.5	8.8
IW-12	1.0	34.4	AS-12-6	0.5	9.1
IW-14	1.0	24.4	BS-28	3.5	22.7
IW-15	1.0	20.9	BS-28 (col)	3.5	25.5
IW-15 (col)	1.0	14.7	AS-2-36	3.0	17
IW-17	1.0	26.9	AS-4-36	3.0	16
IW-20	1.0	16.5	AS-6-36	3.0	24
IW-20 (col)	1.0	19.5	AS-10-18	1.5	17
IW-21	1.0	41.2	AS-10-18 (col)	1.5	19
SD-03	1.0	17.9	AS-11-18	1.5	13
SD-04	1.0	20.6	AS-12-18	1.5	15
SD-05	1.0	13.1			
SD-08	1.0	25.3			
SD-09	1.0	23.2			
SD-10	1.0	23.1			
SD-11	1.0	8.5			
SD-12	1.0	37			
IW-01	5.0	7.4			
IW-02	5.0	8.1			
IW-03	5.0	13.4			
IW-05	5.0	33.6			
IW-07	5.0	24.6			
IW-08	5.0	24.8			
IW-08 (col)	5.0	28.5			
IW-10	5.0	34.3			
IW-12	5.0	54.2			
IW-14	5.0	26.4			
IW-15	5.0	23.6			
IW-15 (col)	5.0	17.9			
IW-17	5.0	23.7			
IW-20	5.0	17.2			
IW-20 (col)	5.0	19.7			
IW-21	5.0	50.1			
SD-03	5.0	13			
SD-04	5.0	15.2			
SD-05	5.0	18.1			
SD-08	5.0	22.1			
SD-09	5.0	15.8			
SD-10	5.0	36			
SD-11	5.0	9.7			
SD-12	5.0	17.2			

col - co-located sample

Table B-1
Summary of Arsenic Soils Analyses
Henderson Landfill SRADI

North Central Area Soil Sampling Results

Below Waste			Undisturbed Areas		
Sample Location	Sample Depth (ft)	Arsenic (mg/kg)	Sample Location	Sample Depth (ft)	Arsenic (mg/kg)
			SD-13	1.0	324
			SB-13A	1.0	262
			SD-13B	1.0	611
			SD-13C	1.0	243
			SD-13D	1.0	306
			AS-7-6	0.5	65
			AS-8-6	0.5	910
			AS-9-6	0.5	450
			SD-13	5.0	488
			SB-13A	3.5	176
			SD-13C	2.5	626
			SD-13D	2.5	142
			AS-7-18	1.5	40
			AS-8-18	1.5	470
			AS-9-18	1.5	80