Landfill Gas Investigation and Characterization Study San Antonio Landfill

Prepared for City of Albuquerque
Albuquerque, New Mexico

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Acronyms and Technical Terms

AEHD	Albuquerque Environmental Health Department
AP-42	1995 EPA publication entitled *Compilation of Air Pollutant Emission Factors,* which provides default values for k and L_0.
bgs	below ground surface
Campbell 21X	self-contained datalogger
cf/lb-yr	cubic feet per pound per year
cfm	cubic feet per minute
CH_4	methane
City	City of Albuquerque
CO_2	carbon dioxide
DBS&A	Daniel B. Stephens & Associates, Inc.
EPA	U.S. Environmental Protection Agency
ft^3/ton	cubic feet per ton
GasTech monitor	gas monitor with built-in datalogging capability that allows for short-term, stand alone monitoring
GPS	global positioning system
H_2O	water
H_2S	hydrogen sulfide
Hg	mercury
IDLH	immediately dangerous to life and health
k	methane generation rate constant (estimated fraction of waste that decays annually and produces methane to project annual landfill gas generation at 50 percent methane equivalent)
LandGEM	U.S. Environmental Protection Agency Landfill Gas Emissions Model
Landtec GA™-90	portable datalogging field analyzer designed to monitor methane, carbon dioxide, and oxygen
lbs/yd^3	pounds per cubic yard
LEL	lower explosive limit
LFG	landfill gas
LFG generation rate	rate at which a given landfill will produce landfill gas (influenced by the volume of waste, the percentage of degradable materials in the waste, the age of the waste, and the amount of moisture in the waste)

Acronyms and Technical Terms (continued)

L_0	ultimate methane generation rate (ultimate amount of methane which a ton of refuse produces over time)
Mcf	millions of cubic feet
Mg	megagrams
MSW	municipal solid waste
NIOSH	National Institute for Occupational Safety and Health
NSPS	New Source Performance Standards
PID	photoionization detector
ppm	parts per million
ppbv	parts per billion, volume
psi	pounds per square inch
PVC	polyvinyl chloride
QA/QC	quality control/quality assurance
RFP	request for proposal
ROI	radius of influence
scfm	standard cubic feet per minute
SCS	SCS Engineers
Summa canister	1-liter stainless steel vessel with chemically inert internal surfaces
TO-14	EPA-approved method for determining VOCs in ambient air using a Summa canister for sampling and gas chromatography or gas chromatography/mass spectroscopy
Usft.	U.S. survey foot (equals 0.3048006096 meters)
VOC	volatile organic compound

Executive Summary

Executive Summary – San Antonio Landfill
Landfill Gas Investigation and Characterization Study

This report presents the findings of a study conducted for the City of Albuquerque Environmental Health Department (City) by the engineering firms of Daniel B. Stephens & Associates, Inc. and SCS Engineers (study team) between July 2001 and March 2002. The study assessed whether landfill gas is present in seven closed landfills formerly owned and/or operated by the City. The study is part of the City's effort to prevent current and future risks related to landfill gas.

The study was conducted with the primary goal of providing new information to assist future land use plans regarding properties in close proximity to the former landfills. The City has established *Interim Guidelines for Development Within 1,000 Feet of Landfills* (Interim Guidelines), which provides for City review of development plans to ensure protection of public health and safety.

The former City owned and/or operated landfills covered by this report are:

- Atrisco Landfill
- Coronado Landfill
- Eubank Landfill
- Nazareth Landfill
- Sacramento Landfill
- San Antonio Landfill
- Yale Landfill

This Executive Summary provides (1) an overview of the investigation methods used in the landfill gas study and (2) presents the results and recommendations specific to the San Antonio Landfill.

1. Overview of the Study

1.1 Landfill Gas Characteristics

Landfills have the potential to emit gases as a result of natural decomposition of the materials they contain. Landfill gas is typically composed of methane (about 50 to 60 percent) and carbon dioxide (about 40 to 50 percent). Neither methane nor carbon dioxide is toxic to humans in small amounts. However, methane concentrations between 5 and 15 percent (of the total gas in air) can create a risk of explosion. The minimum concentration that can be explosive (5 percent) is called the lower explosive limit.

Landfill gas may also contain trace amounts of toxic substances such as volatile organic compounds (VOCs), some of which are classified by the U.S. Environmental Protection Agency (EPA) as carcinogens. Hydrogen sulfide, an inorganic gas that is toxic at relatively low concentrations, can be produced in landfills from the degradation of gypsum wallboard.

The rate of landfill gas generation is influenced by the percentage of degradable materials in the waste (i.e. food, paper, lawn clippings, textiles, wood, etc.) and the amount of moisture in the waste (increased moisture causes more rapid degradation). Larger landfills with more waste have a greater potential to generate gas and present a more significant likelihood of landfill gas migrating off-site.

The study team measured gas concentrations underground at the seven former landfills to identify the potential for present and future problems. Landfill gas detected underground may never reach the surface and pose a public health threat. However, landfill gas can migrate underground, through soils or along utility corridors, and therefore can present a concern for nearby properties.

1.2 Study Methods

The study team reviewed existing documents and records about each landfill, then performed field investigations to determine landfill gas concentrations and waste characteristics. Using the data obtained, modeling was performed for each landfill to estimate current and future landfill gas generation rates.

Site History and Access

Site histories were compiled that summarize the types of materials that may have been disposed of at each landfill and the time periods during which disposal occurred. General background information was also collected on landfill boundaries, site hydrogeology, and existing development in the area.

The landfill properties have numerous public and private owners. The study team obtained formal access agreements with property owners at each site for permission to conduct field investigations.

Field Investigations

Several methods were used to determine the current and future behavior of landfill gas at each of the seven landfills studied. These methods include:

1) Landfill gas surveys using underground sampling with field and laboratory gas testing
2) Waste characterization to sample and describe waste types
3) Landfill gas pumping tests to establish site-specific gas generation rate parameters
4) Gas generation modeling to estimate the long-term gas generation potential.

The study was performed according to customary engineering practices and industry standards.

- *Landfill gas survey.* The study team performed a landfill gas survey at each site between September 10 and October 5, 2001 to establish concentrations of landfill gas. Boreholes were driven 10 feet below ground surface to collect gas samples in the underlying waste. Temporary and/or permanent monitoring probes were drilled on a grid pattern across the surface of each landfill.

  Landfill gas samples were tested in the field for methane, carbon dioxide, oxygen, and hydrogen sulfide using portable instruments. Gas samples were also submitted to a laboratory for additional testing of volatile organic compounds. A total of 163 gas sampling points were field tested during the study, and samples for laboratory testing were collected at approximately half of these sampling points. All samples were carefully collected, labeled, and transported to the laboratory for testing following established procedures.

- *Waste characterization.* A bucket auger drill rig or a backhoe was used to sample landfill materials at 12 locations. The study team maintained logs of waste composition and samples were collected for moisture content testing. Waste material decomposition rates were categorized as follows:

- Rapidly degradable – food waste
- Moderately degradable – green waste, paper, and cardboard
- Slowly degradable – wood and textiles
- Inert/inorganic – rubber, glass, metal, plastics, concrete, and construction debris
- Fines/unknown – soil and fines

- *Landfill gas pumping tests.* Multi-day landfill gas pumping tests were conducted at the two largest landfills studied (Eubank and Yale Landfills) where the gas surveys indicated relatively high landfill gas concentrations. These tests established site-specific data related to gas generation rates.

  Pumping tests indicate whether accumulated gases within a landfill consist of a limited reservoir of gas (i.e. one that can be extracted and depleted in a short time), or if gas is continually generated at a sustainable rate. The gas generation rate affects the likelihood of potential gas migration and provides information for the design of venting or containment systems, if needed.

- *Landfill gas generation modeling.* The study team estimated how much gas may be generated at each site using the EPA's LandGEM computer model. The model used various input parameters based on industry standards and site-specific data from the field investigation. Model calculations consider the volume and age of waste at each landfill as key factors in potential gas generation.

2. San Antonio Landfill Study Results and Recommendations

2.1 Landfill History

The San Antonio Landfill is located in northeast Albuquerque, east of I-25, west of Louisiana Boulevard, north of the Pino Arroyo, and south of westbound San Antonio Boulevard. San Antonio Boulevard overlies the landfill and splits the site in half. A significant amount of development has taken place along the landfill perimeter; several commercial businesses and a mobile home park are located to the north, while many residential homes and a health care facility have been built across the arroyo to the south. A Cracker Barrel Restaurant was built on the westernmost portion of the landfill in 1995. Restaurant construction required excavation of waste under the building.

The site was originally an arroyo used as a landfill by the City from 1968 to 1970. The site is unlined and covers approximately 42.5 acres, with a waste depth of about 20 feet.

2.2 Landfill Gas Survey

The landfill gas survey at the San Antonio Landfill, consisted of (1) installing 48 temporary gas sampling probes across the landfill, (2) testing gas samples for methane, carbon dioxide, oxygen, and hydrogen sulfide using field instruments, and (3) conducting laboratory analysis of 24 samples for 35 volatile organic compounds commonly found in landfill gas. The findings of this investigation included the following:

- *Methane concentrations ranged from 0 to 15.2 percent*. Elevated concentrations of methane occurred mainly in the central portion of the landfill. Other sample locations near the east and west ends of the landfill showed no measurable methane, but had elevated levels of carbon dioxide and depressed levels of oxygen indicating ongoing waste degradation.

- *Low levels of 25 volatile organic compounds* were detected in landfill gas samples taken beneath the ground surface. This volatile organic compound data will be used in further studies.

2.3 Waste Characterization

A waste characterization study was conducted at the San Antonio Landfill, which included (1) drilling one boring with a large-diameter bucket auger to a depth of 16.5 feet, and (2) collecting and analyzing the waste samples to establish their composition, percentage of degradable material, and moisture content. Results of the waste characterization study included:

- *Waste was encountered from 4 to 15 feet below the ground surface.* Most of the waste found at the site consisted wood, green waste, and construction debris. The degradable portion of the waste decomposes at a moderate rate.

- *Moisture content ranged from 10.2 to 13.7 percent by weight.* This level of moisture indicates slow waste decomposition and low gas generation rates.

2.4 Landfill Gas Generation Modeling

The landfill gas generation rate at the San Antonio Landfill was estimated with the EPA computer model, LandGEM, using input values based on site-specific data from the study. A range of projections were modeled using a combination of site-calibrated and "typical" landfill values. The modeling results indicate that:

- The peak year for landfill gas generation was 1971, which was one year after the landfill closed. The model indicates that landfill gas generation will continue to steadily decline as long as conditions do not change.

- The projected landfill gas generation rate in 2002 ranges from 36 to 65 standard cubic feet per minute. This is a moderate methane generation rate from this relatively large landfill and suggests there is a moderate potential for off-site landfill gas migration.

2.5 Recommendations

This report makes a number of recommendations as to actions that should be taken by the City. These recommendations are worded in terms of actions that should be taken by the City because the City is the party that requested recommendations. It is the City that has taken the lead in dealing with landfill gas problems. This report takes no position on whether it is properly the City's role or responsibility to deal with the concerns raised by these recommendations.

Reduce the Buffer Zone in the City's Interim Guidelines

The City could reduce the buffer zone in the Interim Guidelines to 500 feet, provided a landfill gas monitoring plan is implemented (see recommendation below) and methane is not found above specified limits after two years of monitoring on-site and perimeter wells, and selected underground utilities. Maintaining a minimum 500-foot setback is recommended because the landfill is expected to continue to generate gas and pose a potential risk for the long term.

Develop a Comprehensive Landfill Management Plan

The City should consider developing a landfill management plan for the San Antonio Landfill to include:

- *Implement a landfill gas monitoring plan.* This monitoring plan should include the installation of perimeter monitoring probes spaced approximately 250 feet apart to verify the limits of gas migration. Methane should be monitored quarterly for at least two consecutive years at probes and selected underground utilities. If methane is not detected above safe limits for two years, the monitoring period can be extended to every six months. If elevated levels are detected, the monitoring frequency should be increased. If impervious surfaces (e.g., pavement or structures) are developed on the landfill, increased monitoring may be necessary.

- *Maintain positive drainage* across the landfill to minimize water infiltration into the waste. The existing landfill cover has depressions that collect storm water. A site drainage study is recommended to identify improvements that may minimize methane generation.

- *Continue to require design, monitoring, and/or landfill gas abatement* as stated in the Interim Guidelines, such as directing storm water away from the landfill, sealing off underground utilities, installing venting systems beneath structures, and/or installing interior monitors in buildings.

- *Implement a landfill gas control plan* if sustained, elevated methane levels are found. Install passive or active gas control systems capable of reducing methane to safe levels.

For further detail on study methods, findings, and recommendations, please refer to the full report.

Part 1

General Section

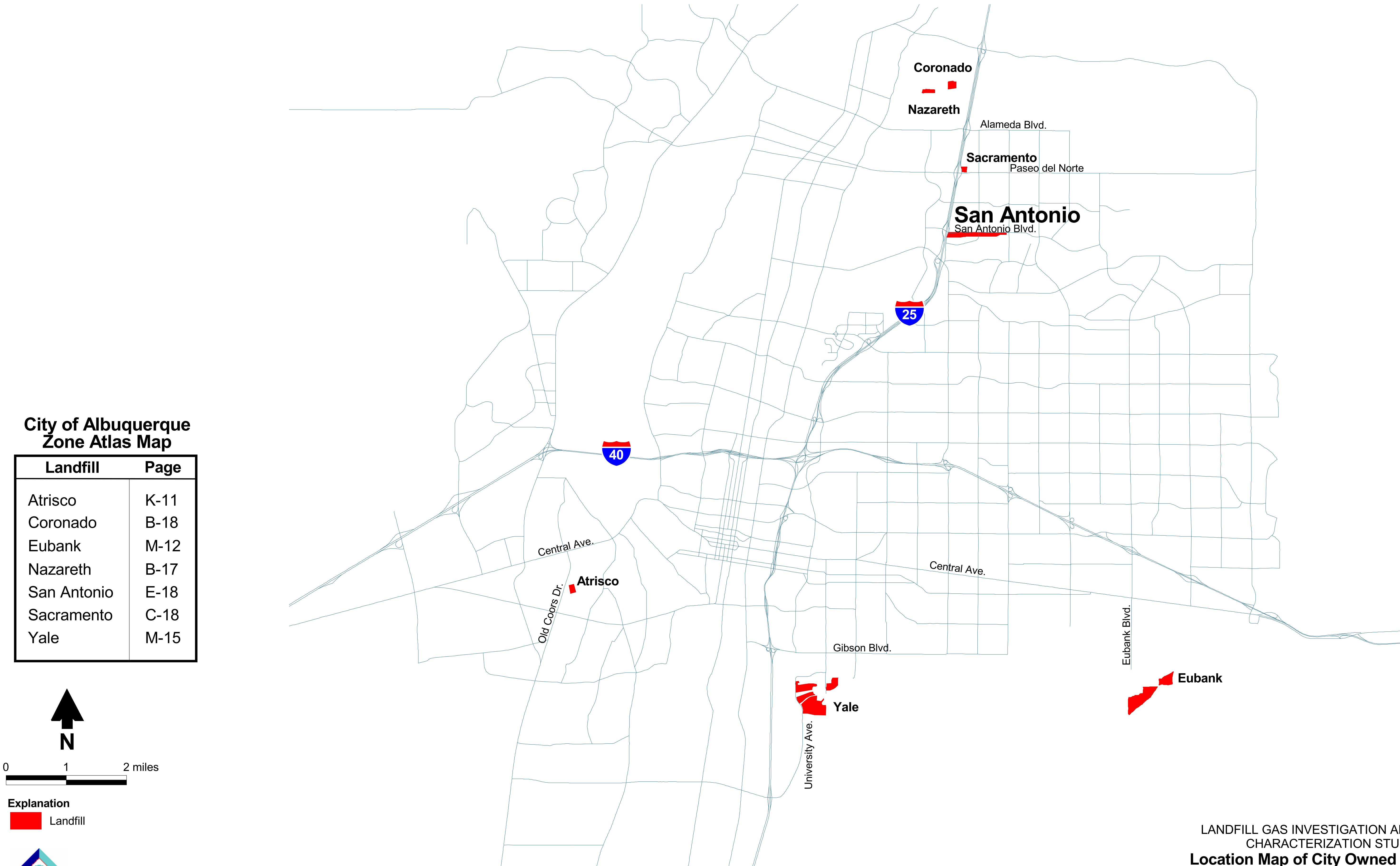
1. Introduction

This report details the approach used to perform a landfill gas (LFG) investigation to characterize the gas generation potential of former City of Albuquerque (City) owned and/or operated landfills being studied as part of the City's Landfill Gas Investigation and Characterization study. The study is being conducted under the direction of the Albuquerque Environmental Health Department (AEHD) by Daniel B. Stephens & Associates, Inc. (DBS&A) and SCS Engineers (SCS). The purpose of the study is to determine if LFG currently exists or could be generated at former City owned and/or operated landfill sites and how LFG might impact development and the public.

The City of Albuquerque currently has issued *Interim Guidelines for Development within 1,000 feet of Landfills*. The City's guidelines provide for review of development plans for public and private properties on or within a 1,000-foot buffer around former landfills. This includes not only City owned and/or operated landfills, but also permitted private landfills. This review is intended to ensure that appropriate landfill gas abatement measures are taken, based on the site-specific LFG conditions for a particular development. This LFG investigation and characterization study, as well as future studies, will assist the City in revising these Interim Guidelines, if needed, for each individual former City owned and/or operated landfill, and will provide planning and development guidance for future and existing development on and/or near the former City owned and/or operated landfills.

Part 1 of this report, which contains the first two sections, presents information on the overall Landfill Gas Investigation and Characterization study, which includes seven former City owned and/or operated landfill sites located within the City and Bernalillo County (Figure 1). These seven sites include:

- Atrisco Landfill
- Coronado Landfill (north cell only)
- Eubank Landfill
- Nazareth Landfill
- Sacramento Landfill



City of Albuquerque Zone Atlas Map

Landfill	Page
Atrisco	K-11
Coronado	B-18
Eubank	M-12
Nazareth	B-17
San Antonio	E-18
Sacramento	C-18
Yale	M-15

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Location Map of City Owned or Operated Landfills Studied

Figure 1

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T:\VDR\PROJECTS\9398\AlbLF_Landfill Locations- all-sites.apr (Layout = L4 - San Antonio Landfill Location Map, B-size, 1:96,000)

- San Antonio Landfill
- Yale Landfill

Components of the investigation include a LFG survey, waste characterization study, and LFG gas pump tests. Part 2 of this report presents the landfill-specific field investigation methods and results for the San Antonio Landfill. Results from individual landfill investigations were combined with modeling results and formed the basis for the conclusions and recommendations presented at the end of this report.

1.1 Composition and Measurement of Landfill Gas

LFG is composed primarily of methane (CH_4) and carbon dioxide (CO_2), naturally occurring byproducts of waste degradation that are not considered toxic to humans. Waste degradation occurs when organic landfill materials are exposed to moisture. The amount of methane generated by waste degradation depends on a number of factors, but primarily on the amount of water exposed to the organic waste under anaerobic (no oxygen) conditions.

Methane is a concern because concentrated accumulations of methane can be explosive and can displace oxygen, which may lead to asphyxiation. LFG can also carry trace concentrations of other gases with potential toxicity concerns. The most significant trace gases carried by LFG are volatile organic compounds (VOCs), some of which are classified by the U.S. Environmental Protection Agency (EPA) and other national public health organizations as carcinogens. In addition, LFG may include hydrogen sulfide (H_2S), an inorganic gas that can be toxic at relatively low concentrations, and is produced in landfills primarily from the degradation of gypsum wallboard.

Pure LFG within waste disposal cells typically contains approximately 50 to 60 percent methane and 40 to 50 percent carbon dioxide. LFG may also be diluted with air in the subsurface, which reduces methane and carbon dioxide concentrations and adds oxygen and nitrogen. Natural atmospheric barometric pressure changes, otherwise known as barometric pumping, mix air into the soil, and closed landfills that are covered with relatively permeable soil may have significant gas exchange with the atmosphere. This barometric pumping both dilutes the LFG deeper in the subsurface and oxygenates the soil gas. Through this process, methane breaks down in the subsurface and is prevented from reaching the shallow soils or the atmosphere.

Methane gas concentrations are measured using one of two reporting scales: (1) as a percentage of methane gas in the total gas or simply “percent”, or (2) as a percentage of the lower explosive limit (LEL). The LEL for methane is equivalent to 5 percent methane gas in atmospheric air, which contains approximately 20 percent oxygen. The upper explosive limit is 15 percent methane in air. Methane is explosive only in the range of 5 to 15 percent and is not explosive if methane concentrations exceed 15 percent or if oxygen is depleted. In this report, methane and other gas constituents are reported as percent of total gas, and the methane concentration is referred to as being above or below the LEL, depending upon whether the methane concentration exceeds 5 percent total gas. A methane concentration of 100 percent of the LEL is the lower range of methane that will explode.

1.2 Landfill Gas Standards

Standards for allowable levels of LFG have been established to avoid explosion hazards. LFG can accumulate in enclosed structures and migrate away from the landfill through soils and along subsurface utility corridors. The rate of LFG generation is influenced by the percentage of degradable materials in the waste (i.e. food, paper, lawn clippings, textiles, wood, etc.) and the amount of moisture in the waste. Larger landfills with more waste have a greater potential to produce LFG and present a more significant likelihood of off-site LFG migration. The City of Albuquerque Fire Marshall’s standard requires that methane concentrations must not exceed 10 percent of the LEL (0.5 percent) in an occupied structure.

Additional standards address the potential toxic hazard associated with VOCs and H_2S that may be present in LFG. Relatively low concentrations of certain gases, in the parts per million (ppm) range, may be a concern for human exposure. Allowable exposure limits for workers are published in a guide sponsored the National Institute for Occupational Safety and Health (NIOSH). These standards are not intended to protect non-workers against short- or long-term exposure, but may be used as an available guideline to evaluate potential hazards posed by trace gases in LFG.

The NIOSH guide provides standards for exposure limits to many VOCs that can be present in LFG. The NIOSH guide indicates a long-term permissible exposure limit for hydrogen sulfide of 10 ppm for workers. The guide also indicates that a hydrogen sulfide concentration of 300 ppm is immediately dangerous to life and health (IDLH). These NIOSH standards may be used as a guide to consider the relative toxicity of various trace gases that can be carried with LFG.

The results of the VOC sampling at each of the landfills indicate whether or not these trace gases exist below the ground surface of the landfills. However, the results obtained do not provide a basis to determine whether these values are toxic to the public, since it is unknown how these gases will migrate to the surface or how they may degrade and become diluted as they migrate up to the surface.

1.3 Future Land Use Considerations

Final land use plans are an integral part of landfill closures, and considerable work has been done across the country to complete landfill closures in a manner that provides for safe development of closed landfill sites. Development of closed landfills has included parks, industrial development, golf courses, and open space. The solid waste management industry in the United States has devised technologies to develop closed landfill sites in a manner that is protective of human health and safety and the environment.

Many of the significant issues concerning the development of a closed landfill are related to structures and facilities that are built directly on the closed landfill disposal cells. The following issues are generally addressed in developing a closed landfill:

- *LFG accumulation in enclosed structures*. LFG consists primarily of methane and carbon dioxide. If allowed to accumulate within a confined area in the presence of an ignition source, methane can explode if the concentration exceeds 100 percent of the LEL (5 percent). Development must prevent the potential for accumulation of explosive methane concentrations within buildings and smaller enclosures such as light poles, fence posts, and utility corridors and vaults.

- *Settlement of waste that affects structures built on the landfill*. Permanent structures and utilities must be designed in a manner to account for differential settlement that occurs as landfill waste degrades and consolidates over many years.

- *Infiltration of water into the landfill as a result of precipitation and irrigation*. The infiltration of water into a landfill from irrigation or precipitation must be minimized to prevent generation of leachate that can contribute to groundwater contamination. An increase in moisture content of the waste can also cause accelerated generation of LFG. Synthetic membranes or earthen covers are often used to cover landfills to prevent infiltration of precipitation/irrigation water into the waste. Landfill covers should also be graded to maintain positive drainage at all times.

By ensuring that these issues are addressed, development has been completed safely at many closed landfill sites.

2. Technical Approach

The technical approach for the landfill gas investigation and characterization project is described in this section. Several tasks were conducted including:

- Review of records on site history
- Obtaining permission for site access to landfill property
- LFG survey using push-probe sampling with field and laboratory gas testing
- Drilling waste characterization borings to characterize waste types
- LFG pumping tests to establish site-specific gas generation rate parameters
- LFG generation modeling to estimate the long-term gas generation potential

This section presents the methodology used for these tasks. Field investigation methods to implement the technical approach are provided in Section 4, and results are provided in Section 5.

2.1 Site History Records Review

The site history of each former landfill was obtained through a review of available records related to the landfill's operating history and previously completed investigations. Sources of data for this section were compiled by AEHD and include reports and files prepared by various organizations. A primary source of data was a report entitled *Past and Present Solid Waste Landfills in Bernalillo County, New Mexico* (Nelson, 1997), which focused on all seven landfills covered in the present study, as well as other private landfills not owned or operated by the City. Nelson's report provided details on the general backgrounds of the landfills including site history, landfill operational data, and site hydrogeology. Most importantly, Nelson (1997) carefully considered the landfill boundaries using past records such as aerial photographs and more recent on-site observations. These boundaries were used in the current investigation and are presented in the site maps included in this report.

2.2 Site Access

The seven former landfills being investigated have numerous landowners, and most are subdivided into several parcels under different ownership. The majority of properties are privately owned, with some public owners including the City of Albuquerque and the New Mexico State Land Office. The first task in arranging the LFG survey was to establish formal access agreements with property owners at each landfill to ensure access for field investigation.

Site access activities were initiated by obtaining zone atlas pages and identifying lots within the boundaries of the seven landfills. Property owners were identified using the Bernalillo County Tax Assessor's website in conjunction with the City of Albuquerque website. Information gathered from these websites was confirmed at the Bernalillo County Tax Assessor's office because the websites are updated only on an annual basis. Therefore, any changes in property ownership that had occurred during 2001 could be found only in the tax assessor's database at the County Assessor's office.

Once ownership was determined, formal access agreements were requested from property owners at each landfill to allow access for field investigation. Information gathered from the tax assessor's records was entered into a database and written access agreements were sent to each property owner for signature.

2.3 Landfill Gas Survey

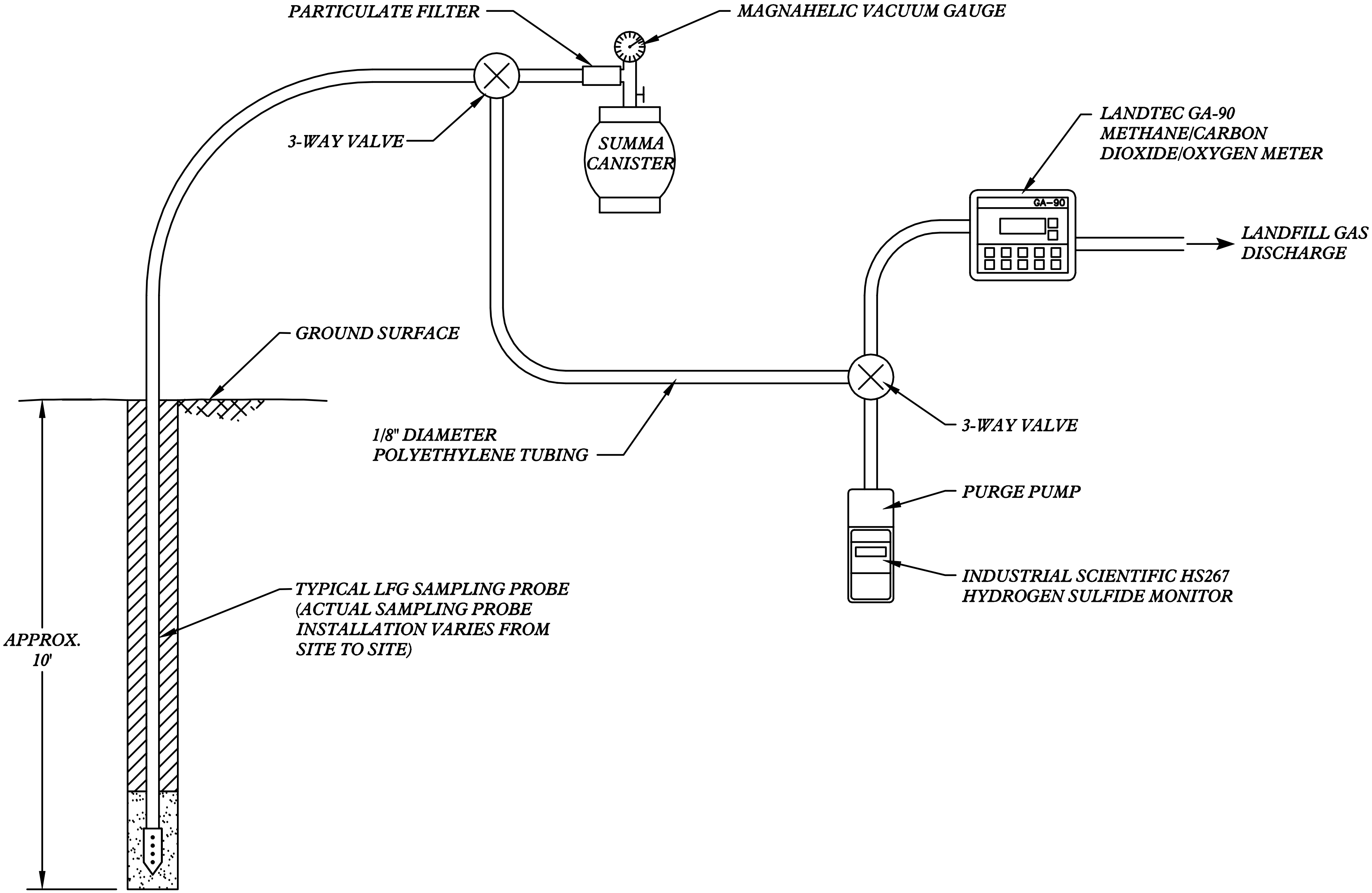
A LFG survey was performed to establish the existing concentration of LFG at each of the seven former landfills. The survey fieldwork was conducted during September 10 to October 5, 2001. The LFG survey involved collection of LFG samples using a probe driven 10 feet below ground surface (bgs), through the landfill cover and into the underlying waste. The survey was performed using temporary and/or permanent probe installations distributed across each landfill and in selected off-site locations. LFG samples were tested in the field using portable instruments, and samples were also collected and submitted to a laboratory for additional testing.

Sampling was performed on a grid pattern submitted to and approved by the City prior to sampling. Sampling locations were staked/marked using global positioning system (GPS) survey equipment. This survey method allowed for efficient sampling point identification during the LFG survey and provided the ability to make adjustments in the field. The sampling grids at the landfills were based on the following general spacing and adjusted to fit the landfill configuration.

• Atrisco Landfill	200 x 200-foot grid
• Coronado Landfill	200 x 200-foot grid
• Eubank Landfill	400 x 400-foot grid
• Nazareth Landfill	200 x 200-foot grid
• Sacramento Landfill	200 x 200-foot grid
• San Antonio Landfill	200 x 200-foot grid
• Yale Landfill (northern, central, and hotel areas)	200 x 200-foot grid
(southern area)	400 x 400-foot grid

LFG samples were collected at each landfill location using a hydraulically driven, truck-mounted geoprobe. ESN Rocky Mountain, of Golden, Colorado was retained by DBS&A to perform the gas probe drilling at all of the landfills. In addition, Geo-Test, Inc. of Albuquerque was retained to provide a four-wheel drive drill rig to access steep terrain at the Yale Landfill for installation of seven gas probes. Temporary gas probe installations used a small-diameter drive probe to penetrate the landfill cover and allow LFG extraction and sampling from the underlying waste. At certain locations, where the City intends to conduct additional monitoring, permanent monitoring probes were installed. Details of the gas probe installation methods are provided in Section 4.3.

At each probe installation, several field instruments were connected in a sampling train to test for LFG constituents. The sampling train (Figure 2) consisted of a Landtec GA™-90 infrared gas analyzer, a hydrogen sulfide meter, and a Summa canister connection valve to facilitate the collection of VOC samples for laboratory analysis. The Landtec GA™-90 was used to measure concentrations of methane, carbon dioxide, and oxygen as well as LFG pressure and



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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Landfill Gas Survey Sampling Train Detail

Daniel B. Stephens & Associates, Inc.

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Figure 2

atmospheric pressure. Calibration of field instruments was performed daily during the survey, using bottled calibration gas with standard gas concentrations.

The LFG static pressure is measured relative to atmospheric pressure; negative readings indicate a pressure lower than atmospheric and positive readings indicate a pressure greater than atmospheric. These pressure measurements show the influence of barometric pumping (Section 1.1). At the time a given sample is collected, negative LFG pressure indicates that atmospheric air has a tendency to move downward through the landfill cover. Positive LFG pressure indicates that LFG has a tendency to move upward through the landfill cover. LFG static pressures tend to be negative in the morning hours when atmospheric pressure is rising and neutral or positive in the mid to late afternoon when atmospheric pressure is falling.

LFG samples were collected for laboratory analysis in accordance with AEHD's guidance regarding the number, and for some landfills, the location of sampling sites. Samples for VOC analysis were collected from all seven landfills studied. Additional samples were collected for laboratory analysis of methane, carbon dioxide, oxygen, and nitrogen for quality assurance/quality control (QA/QC) purposes. These QA/QC samples were collected in duplicate on 5 percent of the samples tested with field instruments.

Samples for laboratory analysis were collected by attaching a Summa canister to the sampling train ahead of the field instruments (Figure 2). The entire sampling train was then purged while the field parameters were measured. Once the purge was complete and stable readings were measured, the valve on the Summa canister was opened, allowing the canister to fill with LFG. Samples were sent to Air Toxics Ltd. in Folsom, California, where they were analyzed for 35 of the most commonly found LFG constituents using a modified version of the standard test for toxic organics at ambient air temperature (TO-14 test). Samples for QA/QC purposes were analyzed by U.S. EPA Method 3C. Chain-of-custody forms provided by the laboratory were filled out and signed by DBS&A's field technician and submitted with the samples.

2.4 Waste Characterization Analysis

A waste characterization program was implemented to determine whether the former landfills contain decomposable materials that may continue to produce LFG in the future. Waste characterization describes the type of waste present, its current state of decomposition, and its moisture content. These waste characteristics identify both the degree of degradation that has occurred since waste deposition and the potential for further waste degradation.

2.4.1 Waste Sampling, Testing, and Monitoring

Waste characterization exploration was conducted by drilling with a large-diameter bucket auger or excavating a test pit with a backhoe. Koda Drilling, Inc., of Grapevine, Texas, was retained by DBS&A to drill bucket auger borings at four of the landfills in the study (Coronado, Eubank, San Antonio, and Yale). Rodgers Environmental, Inc., of Albuquerque, was retained to excavate a test pit at the Atrisco Landfill. Waste characterization was not performed at the Nazareth Landfill, which is under City ownership, or at the Sacramento Landfill, which is the smallest landfill in the study.

Key elements conducted during the waste sampling task were:

- Documentation of drilling and excavation
- Preparation of waste logs
- Gas monitoring for health and safety
- Collection of waste samples for moisture content analysis
- Characterization of waste into waste types and degradability categories

All sampling activities were observed and logs were prepared that contained specific waste data such as odor, color, temperature (when available), organic content, and general material description of the waste samples. The temperature of the debris retrieved from the borehole was recorded by inserting either a standard thermometer or a probe-mounted thermocouple connected to a Campbell 21X datalogger. Temperature measurements, odor, color, and organic content of the waste are included in the boring logs (Appendix A).

A GasTech gas monitor (Model 90) was used to monitor levels of hydrogen sulfide and methane for health and safety purposes of the drill crew and field staff. All air monitoring results were below the short-term health and safety thresholds of 15 ppm for hydrogen sulfide and 5 percent for methane. A photoionization detector (PID) was also used to monitor for the presence of VOCs. All readings were collected from the breathing zone.

2.4.2 Degradation Rates

Waste material from each waste characterization boring was observed, categorized, and percentages assigned. Examples of the waste categories used include:

- Food waste
- Wood
- Metal
- Green waste
- Rubber
- Plastics
- Paper
- Textiles
- Concrete
- Cardboard
- Glass
- Soil

Percentages were assigned to each waste category by volume, according to what was observed during the removal of the waste from the borehole or excavation pit. The percent volume was then converted to percent weight using the average densities provided by Peavy, et al. (1985) (Appendix B). After the weight percentages were calculated, decomposability ratings were estimated. The waste types listed above were divided into the following subjective categories:

- Rapidly degradable – food waste
- Moderately degradable – green waste, paper, and cardboard
- Slowly degradable – wood and textiles
- Inert/inorganic – rubber, glass, metal, plastics, concrete, and construction debris
- Fines/unknown – soil and fines

2.4.3 Moisture Content Analysis

Samples were collected for moisture content testing from the waste characterization borings that recovered substantial waste (Yale, Eubank, Atrisco, and San Antonio). Soil and other inert materials such as concrete encountered during drilling were not sampled for moisture content. Moisture content samples were collected only from the degradable portion of waste, since this is the only component of the waste stream that will have the potential to generate landfill gas.

Samples were selected at varying depths in the upper, middle, and bottom of each waste boring. The samples were placed in 5-gallon buckets with sealed lids and transported to the DBS&A Hydrologic Testing Laboratory in Albuquerque for moisture content analysis. The samples were labeled with a unique identification number indicating the date, time, and depth of each sample. Chain-of-custody was maintained and documented from the time of sample collection to completion of analyses.

2.5 Landfill Gas Pumping Tests

The purpose of pumping tests is to indicate whether the accumulated LFG within a landfill is a limited reservoir of gas (i.e., one that can be extracted and depleted in a short time) or whether high rates of gas generation will continue to replenish the gas extracted by pumping. The gas generation rate affects the likelihood of off-site LFG migration. During the multi-day pumping test, the rate of gas generation was estimated by observing whether LFG concentrations and flow rates were sustained during long-term extraction or whether LFG concentrations declined substantially after the initial reservoir of accumulated LFG was removed.

As part of this study, LFG pumping tests were conducted only at the two largest landfills studied (Yale and Eubank), in portions of the landfills where the LFG survey indicated relatively high LFG concentrations. For the Yale Landfill, the pump test was conducted from December 27, 2001 through December 30, 2002. For the Eubank Landfill, the pump test was conducted from January 4, 2002 through January 8, 2002. These tests were conducted to establish site-specific data pertaining to LFG generation for these two Albuquerque landfills. The data was used as a check on the validity of the LFG generation model used to estimate LFG generation for all seven landfills studied.

The LFG pumping tests were conducted by installing a LFG extraction well and three pressure monitoring probes at both the Eubank and Yale Landfills. Koda Drilling, Inc., of Grapevine, Texas, installed the extraction wells at the Eubank and Yale Landfills within one of the bucket auger borings drilled for waste characterization sampling. Rodgers Environmental, Inc. was retained by DBS&A to drill and construct three monitoring probes at each landfill using a hollow-stem auger drill rig.

LFG was pumped from the extraction well with a blower powered by an electric generator. Vacuum was measured in the three pressure probes installed at distances of 50, 100, and 200 feet from the extraction well. By monitoring the pressure drop resulting from LFG pumping, the radius of influence of the pumping well can be determined. Based on the LFG extraction rate and radius of influence, site-calibrated LFG generation input parameters were calculated for use in modeling LFG generation rates, as discussed in Section 2.6.

2.6 Landfill Gas Generation Modeling

Landfill gas generation projections were performed for each landfill evaluated in this study. Several input variables were assessed and used in the LFG generation estimations. The volume of in place waste at each landfill is a primary input variable and varying this number greatly influences the projected LFG generation rate. Another key factor in the estimation of LFG generation is the age of the in-place waste. Numerous information sources were used to determine the modeling input parameters, to provide for valid estimates of the expected range of LFG generation rates. Landfill gas generation projections were performed up to year 2020. Beyond 2020, the accuracy of the model declines without more recent site-specific data. The site-specific LFG generation model input and results are described in Section 5.

LFG generation was estimated using SCS's spreadsheet version of the EPA's Landfill Gas Emissions Model (LandGEM). LandGEM is a first-order decay model required by the EPA to be used for New Source Performance Standards (NSPS) evaluations, Title V permitting, and other

Clean Air Act permitting projects. This model is the industry recognized standard for predicting LFG generation rates. SCS has converted the LandGEM model to an Excel spreadsheet format for ease of use. LandGEM uses (1) annual waste disposal rates, (2) the ultimate amount of methane which a ton of refuse produces over time (ultimate methane generation rate or "L_0" value), and (3) the estimated fraction of waste that decays annually and produces methane (the methane generation rate constant or "k" value) to project annual LFG generation at 50 percent methane equivalent.

2.6.1 LFG Model Inputs: Annual Waste Disposal Rates

Information used to establish the waste disposal history needed as input for LFG models was obtained from the following sources:

- Information provided by the City of Albuquerque in Appendix C of the Request for Proposals (RFP) for the current project, including site acreage, refuse depths, and years that the landfill was open for disposal.

- Historical documents provided by the City of Albuquerque, which include reports documenting the results of field investigations and other prior studies with information relevant to waste disposal at the landfills.

- The present study, including drawings that define landfill areas, and field investigations to determine the locations, composition, and moisture content of refuse.

Based on data from previous studies and this field investigation, certain assumptions were made regarding the size, average soil cover thickness, average refuse thickness, and estimated volume and weight of refuse at the landfill.

Some of the landfills studied contain more than one disposal cell. In particular, the Yale Landfill is divided into four cells and the Eubank Landfill is divided into two cells. Other landfills may be divided into individual cells, although the configuration of cells is unknown. Detailed information on the age, acreage, and depth of the waste in individual waste cells is unavailable for the landfills studied. As a result, each landfill was modeled to estimate the total LFG production from the entire waste mass.

2.6.2 LFG Model Inputs: Ultimate Methane Generation Rate (L_0)

The L_0 value is estimated based on information from the following sources:

- U.S. EPA's estimated default (AP-42) L_0 value for dry landfills (EPA, 1995).

- The SCS default L_0 value, which is based on the SCS LFG database. This database includes actual LFG recovery data from over 100 U.S. landfills, representing over 300 years of flow data. The data indicate that the L_0 value is influenced by moisture and provide a correlation between average annual precipitation and the L_0 value.

- Waste characterization data, which include information on degradability categories (percentage of waste that is rapidly degradable, moderately degradable, etc.) and moisture content. The characteristics of wastes at each landfill were compared to the typical waste characteristics of landfills in the U.S. to estimate the likely effects of any deviation from average landfill conditions on the L_0 value.

Waste characterization data were generated for the landfills where waste borings and test pits were excavated (Atrisco, Coronado, Eubank, San Antonio, and Yale Landfills). At the Nazareth and Sacramento Landfills, where waste characterization was not studied, only default values were available.

2.6.3 LFG Model Inputs: Methane Generation Rate Constant (k)

The k value was estimated based on the following information sources:

- U.S. EPA's estimated default (AP-42) k value for dry landfills (EPA, 1995).

- The SCS default k value, which is based on the SCS LFG database. Data in this database indicate that the k value is strongly influenced by moisture, and provide a correlation between average annual precipitation and the k value.

- Results of the field evaluation of the moisture content of waste samples from the landfill under investigation. The moisture content of the sampled waste was compared to the moisture content of typical U.S. waste to estimate the likely effects of a significant variation from average refuse moisture content on the k value.

Waste moisture content data were generated from waste characterization sampling at the Atrisco, Eubank, San Antonio, and Yale Landfills. At the Coronado, Nazareth, and Sacramento Landfills, waste moisture was not studied through field testing, and only default values were available.

2.6.4 LFG Generation Projections

Multiple LFG model runs and resulting LFG generation projections were prepared for each landfill to cover the range of possible LFG generation rates. These included projections to delineate potential minimum and maximum LFG generation, and to estimate the effect of increasing moisture at selected landfills. The LFG generation projections used the following variables:

- EPA default (AP-42) projection using the default values for L_0 and k (EPA, 1995).

- The SCS default projection using the SCS precipitation-based values for L_0 and k.

- Site-calibrated projection(s) using the L_0 and/or k values derived from analyses of field data.

- Modified site-specific projection that uses the L_0 and k values derived from analyses of field data, but also shows the potential effects of adding moisture on LFG generation.

LandGEM simulates increased LFG generation rates when the waste moisture is increased. A projection with added moisture was modeled for the larger landfills in the study (Yale, Eubank, and San Antonio), where relatively high overall LFG generation rates are expected because of the large amounts of solid waste. A projection with added moisture was also modeled for the Sacramento Landfill, because this landfill has very poor drainage and is at a low topographic level that collects storm water runoff from surrounding areas. The added moisture scenario was not examined for the smaller landfills with positive drainage and/or no detection of methane during the LFG survey (Atrisco, Coronado, and Nazareth), because the added moisture would simulate a relatively small change in LFG generation.

LFG generation rates are adjusted to 50 percent methane content (standard normalization procedure) to reflect the typical methane content of LFG as it is generated.

2.6.5 Model Validation

Model validation of LandGEM is provided by the results of the LFG pumping tests conducted at the Eubank and Yale Landfills. These tests provided site-calibrated k values based on actual measurements of LFG production. The calibrated k values for Eubank and Yale were found to be consistent with k input parameters assigned through default values for the Albuquerque region. The consistency between pumping test results and regional default values for these two Albuquerque landfills support the application of the model to other landfills investigated in this study where no pumping tests were conducted. Adjusting LandGEM input parameters to reflect site-specific conditions for the remainder of the landfills should then provide reasonable estimates of the LFG generation rate.

The pumping test results for Eubank and Yale indicated the range of k values appropriate for the Albuquerque region and guided the adjustment to the k values made for these landfills based on waste moisture content. At the Atrisco and San Antonio Landfills, where no pumping tests were conducted, site-calibrated k values were assigned based on site-specific testing for the waste moisture content. At the Sacramento Landfill, which is characterized by storm water ponding and poor site drainage, a modeling scenario was analyzed using a k value adjusted upward from the default value to reflect a probable elevated waste moisture. For Coronado and

Nazareth Landfills, where neither pumping test nor waste moisture content results were obtained, the default k input values are expected to provide for reasonable estimates of the LFG generation rate using LandGEM.

Site-calibrated L_0 values were assigned by adjusting the regional default L_0 based on the percentage of degradable waste determined from waste characterization studies (Atrisco, Coronado, Eubank, San Antonio, and Yale). At the Nazareth and Sacramento Landfills, where waste characterization was not conducted, the default L_0 values were used to provide reasonable estimates of the LFG generation rate using LandGEM.

Part 2

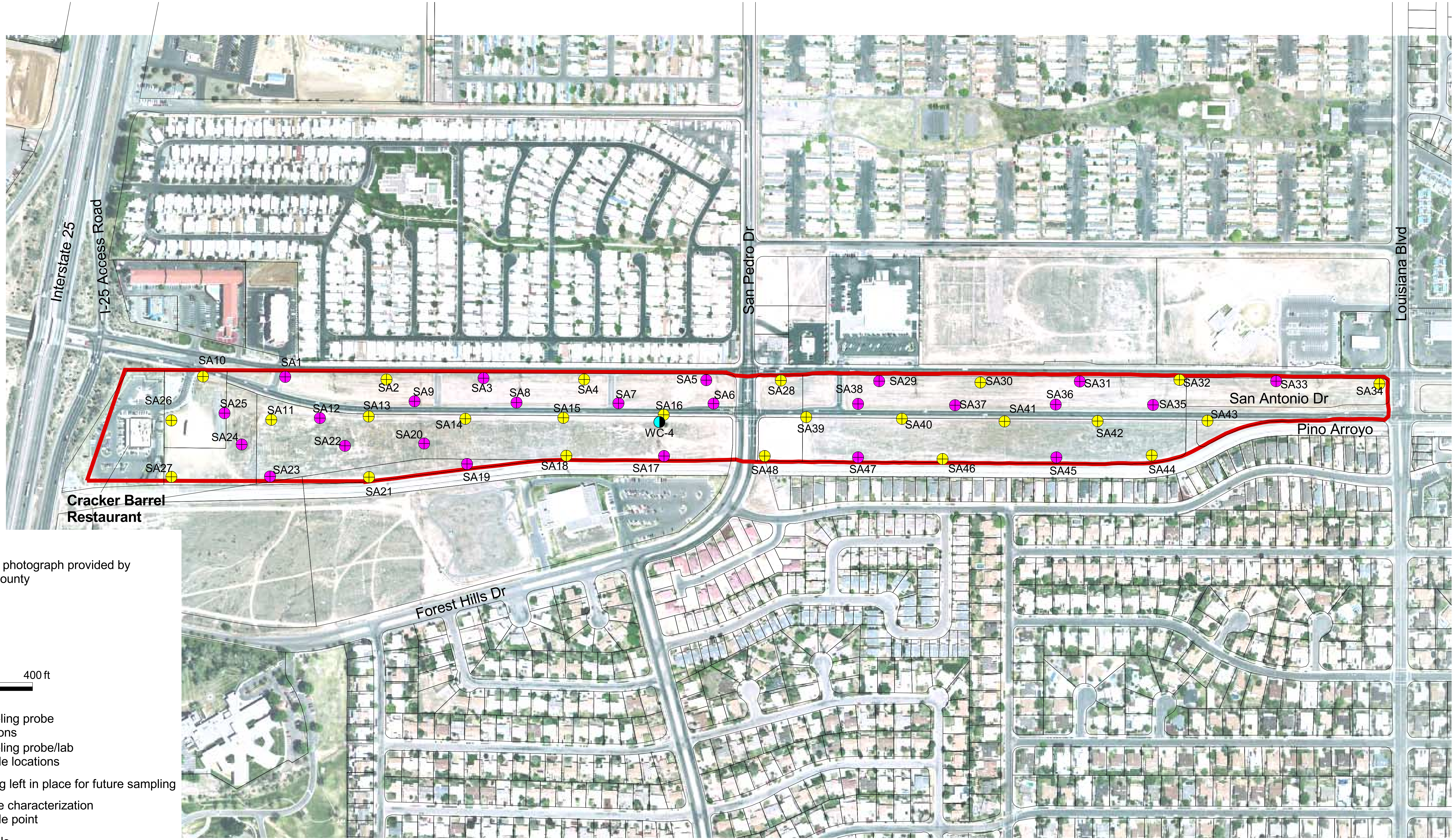
Landfill-Specific Section

3. Site Background and Previous Investigations

The San Antonio Landfill is located in northeast Albuquerque in Zone E-18, east of I-25, west of Louisiana Boulevard, north of Pino Arroyo, and south of westbound San Antonio Boulevard (Figure 1). San Antonio Boulevard is divided by a wide median, and eastbound San Antonio overlies the landfill and splits the site in half. Currently, there is a substantial amount of development around the perimeter of the landfill, although a few vacant lots also surround the landfill. Several commercial businesses and mobile homes are located to the north of the landfill, while many residential homes and a health care facility have been built across the arroyo to the south of the landfill. A Cracker Barrel Restaurant was built on the westernmost portion of the landfill in 1995 (Figure 3). Construction of the restaurant required excavation of a significant portion of the waste under the location of the building and the parking lot (Nelson, 1997).

The site was originally an arroyo used as a landfill by the City and private residents from 1968 to 1970 (EPA, 1982). The site is unlined and covers approximately 42.5 acres, with a waste depth in the range of approximately 10 to 20 feet. The arroyo was approximately 25 feet deep, but was shallower toward the east end of the site. Reportedly, material placed in the landfill was mainly residential and construction/demolition waste. This is consistent with observations during inspection of the waste excavated for construction of the Cracker Barrel Restaurant.

Currently, most of the landfill has a soil cover with moderate to sparse vegetation. Most of the landfill is open space, with portions overlain by San Antonio Boulevard and San Pedro Drive. San Antonio Boulevard is a divided road, with a median that also serves as a corridor for a major overhead power line running east-west over the northern half of the landfill. In general, the landfill has a slight grade, which promotes positive drainage of the landfill cover. However, many small depressions also exist on the landfill cover, which capture storm water. These depressions, as well as depressions in roadways, appear to be due to differential waste settlement. During the construction of San Antonio Boulevard, the New Mexico State Highway and Transportation Department consolidated the landfill materials using dynamic compaction (COA, 2002b).



Source:

1999 Aerial photograph provided by Bernalillo County

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0 400 ft

Explanation

- Sampling probe locations
- Sampling probe/lab sample locations
- Tubing left in place for future sampling
- Waste characterization sample point
- Parcels
- Landfill boundary

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

San Antonio Landfill Test Locations

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Figure 3

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An AEHD investigation of the hydrogeology at the San Antonio Landfill revealed the presence of alluvial fill deposits from the Rio Grande consisting of medium- to fine-grained sands underlain by a thick sequence of river sediments that grade from fine-grained sand to coarse gravel and boulders (Nelson, 1997). Limited geotechnical borings in the area of the landfill have shown a predominance of clean to silty or clayey sands in and around the landfill. Depth to groundwater is approximately 310 to 360 feet bgs, and the groundwater flow direction is primarily south-southeast (COA, 2002a).

To date, monitoring at the San Antonio Landfill has indicated varying levels of methane, with some measurements exceeding the LEL (COA, 2000). AEHD has conducted limited methane monitoring activities at this site. Other investigations performed by private consultants also have encountered low concentrations of methane at the San Antonio Landfill. In 1986, Fox & Associates of New Mexico, Inc. undertook a methane investigation as part of a development study for a proposed motel. No methane gas was detected during this investigation (Fox, 1986). The most recent study was performed by Geo-Test, Inc. on the western portion of the San Antonio Landfill, and was also related to a motel development project. Field measurements detected only slight methane readings up to 0.3 percent of total gas (Geo-Test, 2001).

4. Field Investigation Methods

The field investigation methods used at the San Antonio Landfill are described in this section. The field investigation tasks included:

- Obtaining permission for site access to landfill property
- Clearing underground utilities prior to subsurface investigation activities
- LFG survey using push-probe sampling with field and laboratory gas testing
- Waste characterization boring to sample and categorize waste composition

Sections 4.1 through 4.4 present the detailed methodology used for these tasks at the San Antonio Landfill.

4.1 Site Access

Based on records from the City of Albuquerque and the Bernalillo County Tax Assessor's Office, property owners were identified and access agreements were obtained to provide site access for the field investigation. Property along the southern half of the landfill (on the south side of San Antonio Boulevard) is privately owned. Property along the northern half of the landfill (along the San Antonio Boulevard corridor) is owned by the City of Albuquerque and needed no formal access agreement.

4.2 Utility Survey

Before the investigation commenced, New Mexico One Call was contacted to ensure that no utilities would be encountered during subsurface work. Few utilities were found to exist across most of the landfill, and utilities near roadways were easily avoided during the sampling activities. A major overhead electric line is located in the median of San Antonio Boulevard. The overhead lines did not affect this project, but could limit access for large drill rigs in future work.

4.3 Landfill Gas Survey

LFG sampling locations at the San Antonio Landfill are shown in Figure 3. The sampling grid at San Antonio Landfill was established at approximately 200 x 200-foot spacings with adjustments made to fit the specific configuration of the landfill. Forty-eight sampling locations were established across the landfill surface.

At the San Antonio Landfill, a geoprobe drill rig was used to drive a 1-inch-diameter drive probe to a depth of 10 feet bgs (see photographs, Appendix C) and install sacrificial stainless steel, screened sampling points (⅜-inch diameter by 2.5-inch length, perforated with eight 0.1-inch-diameter holes). Once the sampling tip was in place, 10-20 silica sand was poured into the lower 1 to 2 feet of the borehole, around the tip, to provide for landfill gas transmission. The remainder of the borehole was sealed with a slurry of hydrated bentonite. Polyethylene tubing (⅛-inch diameter) connected to the sampling point was left protruding from the ground surface with a cap on the end. After installation of the tubing, a LFG sample was obtained and analyzed as discussed in Section 2.3.

4.4 Waste Characterization Analysis

At the San Antonio Landfill, one waste characterization boring was drilled through the waste to allow for examination of the waste characteristics (Figure 3). The waste boring was drilled with a 30-inch-diameter bucket auger to collect samples of waste materials and soil, as shown in photographs provided in Appendix C. The boring location was selected based on the results of the LFG survey, and the recommended location was submitted to AEHD for approval prior to drilling.

5. Results

Results of the LFG investigation and characterization study of the San Antonio Landfill are presented in this section. The results include the following:

- LFG survey results for methane, carbon dioxide, oxygen, VOCs, and hydrogen sulfide
- Waste characterization results that categorize the waste composition from borings
- LFG generation modeling results

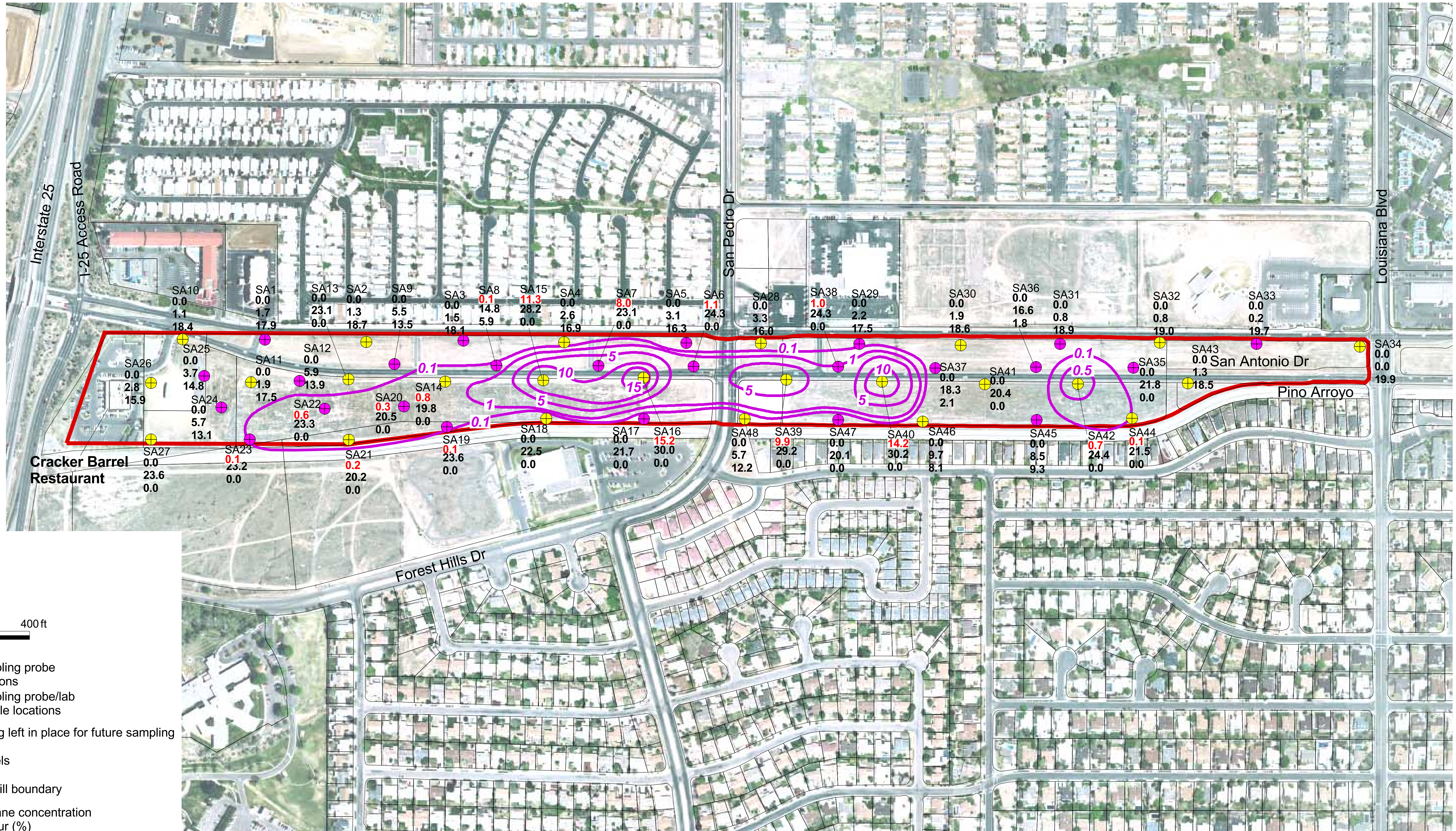
These items are addressed in Sections 5.1 through 5.4.

5.1 LFG Survey Field Analysis Results

A methane concentration map is presented in Figure 4 to graphically show the LFG concentrations at the San Antonio Landfill. The map displays numeric results for methane, carbon dioxide, and oxygen concentrations. Results of the LFG survey of San Antonio Landfill are also summarized in Table 1.

Methane concentrations at the San Antonio Landfill ranged from 0 to 15.2 percent (Figure 4). Elevated concentrations of methane occurred mainly in the central portion of the landfill, along the north and south shoulders of San Antonio Drive on either side of San Pedro Drive. Many sampling locations with no measurable methane showed elevated levels of carbon dioxide and depressed levels of oxygen. However, several probes along the northern edge of the landfill exhibited LFG concentrations indicative of atmospheric conditions. These results indicate the variable nature of LFG production, most likely due to local variations in the types of waste deposits.

Hydrogen sulfide concentrations at the San Antonio Landfill ranged from 0 to 21 ppm (Table 1). These relatively low concentrations suggest that hydrogen sulfide is being generated only at low rates in the landfill and that hydrogen sulfide is not likely to present significant adverse impacts.



Explanation

- Sampling probe locations
- Sampling probe/lab sample locations
- Tubing left in place for future sampling
- Parcels
- Landfill boundary
- -10- Methane concentration contour (%)
- 15.2 Methane (%)
- 30.0 Carbon dioxide (%)
- 0.0 Oxygen (%)

Note:

Methane concentrations of 0.0 are shown in black text

Source:

1999 Aerial photograph provided by Bernalillo County

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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

San Antonio Landfill Gas Survey Results

Figure 4

Table 1. Landfill Gas Survey Results
San Antonio Landfill
Page 1 of 3

Sampling Point	Date	Time	Methane Concentration (%)	Carbon Dioxide Concentration (%)	Oxygen Concentration (%)	Hydrogen Sulfide Concentration (ppm)	Landfill Gas Temperature (°F)	Landfill Gas Static Pressure [a] (inches H_2O)	Atmospheric Pressure [a] (inches Hg)	Lab Sample Collected (Y or N)	Approximate Cover Thickness [b] (feet)
SA1	09/15/01	4:40 PM	0.0	1.7	17.9	0.0	79.5	0.00	24.6	N	3.5
SA2	09/15/01	4:30 PM	0.0	1.3	18.7	0.0	82.9	0.00	24.6	Y	3.5
SA3	09/15/01	10:18 AM	0.0	1.5	18.1	1.0	76.3	0.00	24.6	N	2.5
SA4	09/15/01	9:56 AM	0.0	2.6	16.9	1.0	75.5	0.00	24.7	Y	2.0
SA5	09/15/01	9:26 AM	0.0	3.1	16.3	1.0	77.0	0.00	24.7	N	1.5
SA6	09/15/01	9:35 AM	1.1	24.3	0.0	2.0	74.1	–0.10	24.7	N	1.5
SA7	09/15/01	9:45 AM	8.0	23.1	0.0	1.0	75.0	–0.10	24.7	N	2.5
SA8	09/15/01	10:12 AM	0.1	14.8	5.9	2.0	76.2	0.00	24.6	N	2.5
SA9	09/15/01	10:28 AM	0.0	5.5	13.5	0.0	83.7	0.00	24.6	N	3.5
SA10	09/15/01	5:05 PM	0.0	1.1	18.4	0.0	77.6	0.00	24.6	Y	3.0
SA11	09/14/01	9:50 AM	0.0	1.9	17.5	0.0	81.0	0.00	24.7	Y	1.0
SA12	09/14/01	9:42 AM	0.0	5.9	13.9	0.0	75.9	0.00	24.7	N	2.0
SA13	09/15/01	4:49 PM	0.0	23.1	0.0	0.0	88.3	0.00	24.6	Y	1.5
SA14	09/14/01	10:45 AM	0.8	19.8	0.0	0.0	86.3	0.00	24.7	Y	1.5
SA15	09/14/01	11:05 AM	11.3	28.2	0.0	8.0	86.1	0.00	24.7	Y	1.0
SA16	09/14/01	11:22 AM	15.2	30.0	0.0	21.0	91.0	0.00	24.7	Y	1.5
SA17	09/14/01	11:51 AM	0.0	21.7	0.0	0.0	88.5	0.00	24.6	N	1.0

[a] Landfill gas static pressure and atmospheric pressure measurement was provided by the Landtec GA™-90.
[b] Approximate cover thickness is based on driller’s "feel" of breakthrough from cover soil to waste; this data may be subjective and is not a scientific measurement.
[c] Broken landfill gas temperature probe.

ppm = Parts per million
°F = Degrees Fahrenheit
H_2O = Water
Hg = Mercury
NM = Not measured
U = Unknown, could not be determined by the driller

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Table 1. Landfill Gas Survey Results
San Antonio Landfill
Page 2 of 3

Sampling Point	Date	Time	Methane Concentration (%)	Carbon Dioxide Concentration (%)	Oxygen Concentration (%)	Hydrogen Sulfide Concentration (ppm)	Landfill Gas Temperature (°F)	Landfill Gas Static Pressure [a] (inches H_2O)	Atmospheric Pressure [a] (inches Hg)	Lab Sample Collected (Y or N)	Approximate Cover Thickness [b] (feet)
SA18	09/14/01	12:00 PM	0.0	22.5	0.0	0.0	85.2	0.00	24.6	Y	1.0
SA19	09/14/01	10:32 AM	0.1	23.6	0.0	0.0	86.3	–0.10	24.7	N	2.0
SA20	09/14/01	10:20 AM	0.3	20.5	0.0	0.0	88.7	–0.10	24.7	N	1.5
SA21	09/14/01	9:20 AM	0.2	20.2	0.0	0.0	77.0	0.00	24.7	Y	1.5
SA22	09/14/01	9:32 AM	0.6	23.3	0.0	2.0	76.7	–0.10	24.7	N	2.0
SA23	09/14/01	9:03 AM	0.1	23.2	0.0	0.0	76.8	–0.40	24.8	N	1.0-1.5
SA24	09/13/01	3:49 PM	0.0	5.7	13.1	0.0	NM [c]	0.10	24.6	N	2.0
SA25	09/13/01	3:38 PM	0.0	3.7	14.8	0.0	NM [c]	0.10	24.6	N	2.0
SA26	09/13/01	3:06 PM	0.0	2.8	15.9	0.0	NM [c]	–0.40	24.7	Y	2.0
SA27	09/13/01	3:22 PM	0.0	23.6	0.0	0.0	NM [c]	0.10	24.7	Y	2.0
SA28	09/15/01	9:14 AM	0.0	3.3	16.0	0.0	75.6	–0.10	24.7	Y	2.0
SA29	09/15/01	9:06 AM	0.0	2.2	17.5	0.0	74.9	0.00	24.7	N	2.0
SA30	09/15/01	8:30 AM	0.0	1.9	18.6	0.0	61.7	–0.40	24.8	Y	1.0
SA31	09/14/01	4:20 PM	0.0	0.8	18.9	0.0	95.8	0.00	24.4	N	0.5
SA32	09/14/01	3:44 PM	0.0	0.8	19.0	0.0	96.3	0.00	24.4	Y	1.5
SA33	09/14/01	3:29 PM	0.0	0.2	19.7	1.0	NM	0.00	24.5	N	U
SA34	09/14/01	3:15 PM	0.0	0.0	19.9	1.0	85.5	0.00	24.5	Y	0.5

[a] Landfill gas static pressure and atmospheric pressure measurement was provided by the Landtec GA™-90.
[b] Approximate cover thickness is based on driller's "feel" of breakthrough from cover soil to waste; this data may be subjective and is not a scientific measurement.
[c] Broken landfill gas temperature probe.

ppm = Parts per million
°F = Degrees Fahrenheit
H_20 = Water
Hg = Mercury
NM = Not measured
U = Unknown, could not be determined by the driller

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Table 1. Landfill Gas Survey Results
San Antonio Landfill
Page 3 of 3

Sampling Point	Date	Time	Methane Concentration (%)	Carbon Dioxide Concentration (%)	Oxygen Concentration (%)	Hydrogen Sulfide Concentration (ppm)	Landfill Gas Temperature (°F)	Landfill Gas Static Pressure [a] (inches H_2O)	Atmospheric Pressure [a] (inches Hg)	Lab Sample Collected (Y or N)	Approximate Cover Thickness [b] (feet)
SA35	09/14/01	3:55 PM	0.0	21.8	0.0	0.0	94.2	0.00	24.4	N	0.5
SA36	09/14/01	4:01 PM	0.0	16.6	1.8	0.0	92.0	0.10	24.4	N	0.5
SA37	09/15/01	8:42 AM	0.0	18.3	2.1	0.0	62.0	–0.10	24.7	N	1.0
SA38	09/15/01	8:51 AM	1.0	24.3	0.0	0.0	76.6	–0.10	24.7	N	1.0
SA39	09/14/01	1:00 PM	9.9	29.2	0.0	4.0	94.5	0.10	24.6	Y	2.0
SA40	09/14/01	1:17 PM	14.2	30.2	0.0	11.0	91.0	0.00	24.6	Y	1.5
SA41	09/14/01	2:05 PM	0.0	20.4	0.0	0.0	NM	0.00	24.5	Y	U
SA42	09/14/01	2:17 PM	0.7	24.4	0.0	16.0	94.5	0.00	24.5	Y	0.5
SA43	09/14/01	2:33 PM	0.0	1.3	18.5	0.0	93[illegible]	0.10	24.5	Y	0.5
SA44	09/14/01	2:48 PM	0.1	21.5	0.0	0.0	97.3	0.00	24.5	Y	2.0
SA45	09/14/01	2:58 PM	0.0	8.5	9.3	0.0	96.0	0.00	24.5	N	0.5
SA46	09/14/01	1:49 PM	0.0	9.7	8.1	0.0	93.0	0.00	24.5	Y	1.0
SA47	09/14/01	1:29 PM	0.0	20.1	0.0	0.0	92.3	0.10	24.6	N	2.0
SA48	09/14/01	12:33 PM	0.0	5.7	12.2	0.0	92.7	0.00	24.6	Y	2.0

[a] Landfill gas static pressure and atmospheric pressure measurement was provided by the Landtec GA™-90.

[b] Approximate cover thickness is based on driller's "feel" of breakthrough from cover soil to waste; this data may be subjective and is not a scientific measurement.

[c] Broken landfill gas temperature probe.

ppm = Parts per million
°F = Degrees Fahrenheit
H_20 = Water
Hg = Mercury
NM = Not measured
U = Unknown, could not be determined by the driller

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5.2 LFG Survey Laboratory Results

During the LFG survey (described in Section 2.3), 24 LFG samples were collected at the San Antonio Landfill for laboratory analysis of VOCs. Each sample was analyzed using a modified version of Method TO-14, which analyzes for the VOCs most commonly occurring in LFG. The laboratory also analyzed two samples (SA13 and SA43) as duplicates to provide laboratory QA/QC. In addition, one sample (SA16) was tested for quality control purposes by EPA Method 3C for methane, carbon dioxide, oxygen, and nitrogen. The results of the quality control laboratory analysis shows good agreement with the field measurements for methane, carbon dioxide, and oxygen.

Results of the laboratory analyses are summarized in Table 2. San Antonio Landfill VOC maps illustrating the concentrations measured for selected VOCs are included in Appendix D. The VOCs shown were specified by AEHD based on review of the VOC data to determine the significant parameters detected. Full laboratory reports and chain-of-custody forms are provided in Volume II.

5.3 Waste Characterization Analysis

One waste characterization boring (designated WC-4) was drilled at the San Antonio Landfill (Figure 3). The depth of WC-4 was 16.5 feet, and waste was encountered from approximately 4 to 15 feet bgs. Slight odors were observed from WC-4, although methane and hydrogen sulfide gas were not detected by the field monitoring equipment in the breathing zone during monitoring for worker health and safety purposes. The soil encountered at the waste characterization at the San Antonio Landfill (WC-4) generally consisted of dry, reddish-brown, sandy clay with some gravel. A summary of the waste composition encountered in this boring is provided in Table 3, and additional details for each waste sample are provided in the boring logs in Appendix A and field notes in Volume II.

The primary types of waste encountered at WC-4 (along with the estimated percentage by weight) included construction debris (43.2 percent), wood (21.6 percent), and green waste (16.5 percent). In addition, minor quantities of metal (2.2 percent), plastic (1.5 percent), rubber (1.2 percent), and cardboard (1.1 percent) were encountered.

Table 2. Laboratory Results, San Antonio Landfill

Compound Name	SA2	SA4	SA10	SA11	SA13	SA13 (dup)	SA14	SA15	SA16	SA18	SA21	SA26	SA27	SA28	SA30	SA32	SA34	SA39	SA40	SA41	SA42	SA43	SA43 (dup)	SA44	SA46	SA48
Modified Method TO-14[a] (ppbv)																										
1,1,1-Trichloroethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,1,2-Trichloroethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethane	---	---	---	---	---	---	---	60	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,2,4-Trimethylbenzene	---	73	20	45	59	65	400	1,100	520	56	---	---	13	---	---	28	33	850	1,800	88	130	44	51	55	120	41
1,2-Dichlorobenzene	---	---	---	---	---	---	---	---	30	---	---	---	---	---	---	---	---	---	100	---	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	410	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,2-Dichloropropane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	63	---	---	---	---	---	---	---	---
1,3,5-Trimethylbenzene	---	31	---	---	37	45	170	530	220	15	---	---	---	---	---	---	14	490	940	32	37	20	24	23	64	15
1,3-Dichlorobenzene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,4-Dichlorobenzene	---	---	---	---	---	---	---	30	---	---	---	---	51	---	---	---	---	---	16	---	---	---	---	---	---	---
2-Propanol	---	83	---	---	---	---	580	2,600	1,200	---	---	---	---	---	---	---	---	1,600	1,200	---	320	---	---	39	19	---
Benzene	---	---	---	---	---	---	37	610	160	---	---	---	---	---	---	---	---	170	140	---	---	---	---	---	---	---
Bromomethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Carbon tetrachloride	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Chlorobenzene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	31	---	---	---	---	---	---	---
Chloroethane	---	---	---	---	---	---	---	300	35	---	---	---	---	---	---	---	---	---	29	---	---	---	---	---	---	---
Chloroform	---	---	---	---	---	---	34	---	---	42	---	---	26	---	---	---	---	---	---	27	---	---	---	---	---	---
Chloromethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
cis-1,2-Dichloroethene	---	---	---	---	---	---	500	1,800	520	---	---	---	---	---	---	---	---	6,000	2,000	---	---	---	---	---	---	---
Ethylbenzene	---	25	---	---	---	---	150	1,500	330	16	---	---	---	---	---	---	---	840	2,200	22	25	18	19	20	45	---
Ethylene dibromide	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Freon 11	---	---	---	---	30	37	45	80	---	2400	---	---	---	---	---	---	---	29	---	52	---	---	---	36	---	---
Freon 113	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Freon 114	---	---	---	---	---	---	35	33	66	40	---	---	---	---	---	---	---	---	38	---	---	---	---	---	---	---
Freon 12	180	180	32	82	270	320	330	2,000	690	740	58	23	60	180	16	---	14	740	540	83	400	---	---	12	---	23
m,p-Xylene	---	84	---	25	37	41	290	3,800	560	40	---	28	---	---	---	15	20	2,900	3,600	67	38	39	37	29	110	32
Methyl tertiary-butyl ether	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Methylene chloride	---	---	---	---	---	---	82	220	69	---	---	---	---	---	---	---	---	70	410	---	---	---	---	---	---	---
o-Xylene	---	37	---	---	---	---	140	1,400	310	14	---	---	---	---	---	---	---	1,300	1,900	38	22	17	16	17	53	---
Tetrachloroethene	170	93	81	300	560	650	350	1,200	180	550	53	30	---	170	---	---	---	780	74	53	---	21	17	---	14	22
Toluene	---	48	---	27	---	---	270	5,800	850	25	---	---	---	---	---	14	---	3,700	1,800	43	47	16	16	24	35	24
trans-1,2-Dichloroethene	---	---	---	---	---	---	---	22	18	---	---	---	---	---	---	---	---	59	---	---	---	---	---	---	---	---
Trichloroethene	---	27	---	---	21	21	57	360	200	---	---	---	---	---	---	---	---	170	260	---	---	---	---	---	---	---
Vinyl chloride	---	---	---	---	---	---	25	230	170	---	---	---	---	---	---	---	---	130	230	---	---	---	---	---	---	---
Method 3C[b] (% volume)																										
Carbon dioxide	NS	NS	NS	NS	NS	NS	NS	NS	26	NS	NS	NS	NS	NS	NS	NS	NS	NS	27	NS	NS	NS	NS	NS	NS	NS
Methane	NS	NS	NS	NS	NS	NS	NS	NS	11	NS	NS	NS	NS	NS	NS	NS	NS	NS	11	NS	NS	NS	NS	NS	NS	NS
Nitrogen	NS	NS	NS	NS	NS	NS	NS	NS	52	NS	NS	NS	NS	NS	NS	NS	NS	NS	55	NS	NS	NS	NS	NS	NS	NS
Oxygen	NS	NS	NS	NS	NS	NS	NS	NS	0.91	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.99	NS	NS	NS	NS	NS	NS	NS

[a] Detection limit for method is 5 ppbv; reporting limits vary depending on dilution factor (see laboratory results, Volume II).
[b] Detection limit for method is 0.10 percent of volume for all analytes.

--- = Not detected
NS = Not sampled
pppv = Parts per billion by volume

Table 3. Waste Characterization Boring Summary
San Antonio Landfill

Boring Number	Depth of Boring (feet)	Boring Location [a]	Depth Interval of Waste/Debris	Weight Percentages and Nature of Waste/Debris	Decomposability Rating
WC-4	16.5	• N 1513434 Usft. • E 1542148 Usft.	4 to 15 feet bgs	• 16.5% Green waste [b] • 1.9% Paper [b] • 1.1% Cardboard [b] • 1.2% Rubber • 2.2% Metal • 1.5% Plastic • 10.8% Concrete • 21.6% Wood [b] • 43.2% Other construction debris	Degradable fraction • 0% Rapid • 19.5% Moderate • 21.6% Slow Non-degradable fraction • 58.9% Inert

[a] New Mexico Planes Central Zone (NAD 83).
[b] Compose degradable fraction (see Table 6).

Usft. = U.S. survey foot (equals 0.3048006096 meters)
feet bgs = Feet below ground surface

NA = Not applicable

Three samples of waste materials were collected and analyzed for moisture content. The samples were obtained from 6 to 7 feet, 10 to 11 feet, and 14 to 15 feet bgs. The moisture content determined in the laboratory for the three waste samples ranged from 10.2 to 13.7 percent by weight. A summary of moisture content data is included in Table 4. Complete laboratory moisture content results are contained in Appendix E.

Table 4. Waste Moisture Content Laboratory Results
San Antonio Landfill

Location	Depth (feet)	Sample Number	Moisture Content (%, g/g)
Boring WC-4	6-7	6-7	13.7
	10-11	10-11	10.2
	14-15	14-15	12.2

g/g = Gram per gram

5.4 Landfill Gas Generation Modeling Results

This section presents the model inputs used to estimate LFG generation at the San Antonio Landfill and summarizes the model results.

5.4.1 Input Parameters

As described in Section 2.6, LFG generation modeling requires setting model input parameters for (1) waste disposal history, (2) L_0 value, and (3) k value. The selected average waste volumes used as input to the LFG generation model are provided in Table 5. Information was gathered from field investigations, laboratory analyses of waste samples, historical documents, and the RFP. Numerous information sources were used to provide for reliable estimates of the expected range LFG generation rates. The following model input parameters were chosen:

Table 5. Available Information on Waste Disposal History and Volumes San Antonio Landfill

Source of Information	Dates of Operation	Size (acres)	Average Soil Cover Thickness (feet)	Average Refuse Thickness (feet)	Estimated Refuse Volume [a] (cubic yards)	Estimated Waste in Place [b] (tons)	Notes
City of Albuquerque RFP for this project	1968-1970	42.52	---	9.5	651,644	325,822	Reports a range of refuse depths of 10 to 20 feet. Subtracts an estimated cover soil depth of 5.5 feet (calculated below).
Field investigation (present study)	---	42.88	4.0	11.0	760,998	380,499	Soil cover and refuse thickness from WC-4. Acreage from drawing.
Geo-Test, 2001	---	---	5.0	21.3	1,475,875	737,937	Soil cover thickness is average of 5 borings that found waste (there were 12 borings in total). Refuse thickness is an average of 3 of these borings (the other 2 borings that encountered waste were only 5 feet deep).
Geo-Test, 1989	---	---	7.5	12.5	864,770	432,385	Cover and refuse thickness are the average of 3 boreholes where trash was found (the other 2 borings that encountered waste were only 5 feet deep).
Values used for present study	1968-1970	42.88	5.5	13.6	940,870	470,435	Acreage is from present study. Cover thickness is average of field-derived values and historical reported values. Refuse thickness is average of RFP reported value, field-derived value, and historical reported values.

[a] Uses 42.88 acres for entire site (from present study) when site acreage not reported.
[b] Assumes an average in-place density equal to 1,000 pounds per cubic yard.

RFP = Request for proposal
--- = No data

- Waste disposal history: 470,435 tons of refuse were disposed between 1968 and 1970
- L_0 values ranging from 2,771 ft^3/ton to 3,550 ft^3/ton
- k values ranging from 0.010/yr to 0.025/yr

Development of the waste disposal history, L_0 values, and k values for LFG generation modeling for the San Antonio Landfill is described below.

5.4.1.1 Waste Disposal History

Annual waste volumes are a required input parameter for the LFG generation model. Since specific records do not exist for waste disposal at the San Antonio Landfill, three possible waste disposal histories were estimated for the San Antonio Landfill using the following data:

- Aerial extent of the landfill provided in the City's RFP for this project (42.5 acres) multiplied by the average waste thickness provided in the City's RFP (9.5 feet), which yields 651,644 cubic yards.

- Aerial extent of the site determined from drawings for this study (42.9 acres) multiplied by the average estimated refuse thickness based on information obtained from the waste characterization boring (11.0 feet), which yields 760,998 cubic yards.

- Aerial extent of the site determined from drawings for this study (42.9 acres) multiplied by the average refuse thickness derived from historical studies, including the following:

  - An average refuse thickness of 12.5 feet (Geo-Test, 1989), which yields 864,770 cubic yards.

  - An average refuse thickness of 21.3 feet (Geo-Test, 2001), which yields 1,475,875 cubic yards.

Additional assumptions used for the study include:

- The reported years of active disposal as provided in the RFP are 1968 to 1970.

- An estimated average refuse density of 1,000 lbs/yd^3.

Table 5 shows a range of in-place volume of waste based on the above information. For modeling the LFG generation for the San Antonio Landfill, a disposal volume of 940,870 cubic yards (470,435 tons) of refuse was used.

5.4.1.2 Ultimate Methane Generation Rate (L_0)

As outlined in Section 2.6.2, L_0 values used for LFG generation model runs for the San Antonio Landfill were assigned one of the following three values:

- EPA default value of 3,204 ft^3/ton, which is converted from the EPA (AP-42) value of 100 cubic meters (m^3) of methane per Mg of waste (EPA, 1995).

- SCS default value of 3,550 ft^3/ton based on the precipitation for the Albuquerque region, (8.7 inches per year according to the Desert Research Institute [www.wrcc.dri.edu]).

- Site-calibrated value of 2,771 ft^3/ton based on the amount of degradable refuse found. This value was compared to the expected fraction of degradable waste remaining for a "typical" U.S. waste stream that had degraded the same number of years as the waste at the San Antonio Landfill. The ratio of degradable waste measured in the field to the expected value was multiplied by the SCS default value to estimate the site-calibrated value.

Table 6 summarizes the waste composition data and L_0 adjustments used for developing the site-specific L_0 value for the San Antonio Landfill. Because the fraction of degradable refuse analyzed at San Antonio Landfill was lower than the typical value, the site specific L_0 was adjusted downward to 2,771 ft^3/ton.

Table 6. Derivation of a Site-Calibrated L_0 Value for San Antonio Landfill

Avg. Age of Landfill Refuse (years)	Typical MSW Degradable Fraction [a]	Site Sample Degradable Fraction [b]	Ratio of Site to Typical Degradable	SCS Default L_0 (ft^3/ton)	Site-Calibrated L_0 (Ratio x SCS L_0) (ft^3/ton)
32	52.7%	41.1%	0.78	3,550	2,771

[a] Derived from EPA's *Characterization of Waste in the United States: 1996 Update* (EPA, 1997) which shows that an average of 67.4 percent of MSW is decomposable as delivered to the landfill. Value shown is the expected fraction of decomposable refuse remaining as of the end of 2001 based on the age of waste in the landfill and the estimated rates of decomposition for waste components.
[b] Decomposable fraction of WC-4 (see Table 3).

MSW = Municipal solid waste L_0 = Ultimate methane generation rate ft^3/ton = Cubic feet per ton

5.4.1.3 Methane Generation Rate Constant (k)

As outlined in Section 2.6.3, k values used for the LFG generation model runs for the San Antonio Landfill were as follows:

- EPA (AP-42) default k value of 0.02 per year for landfills experiencing less than 25 inches per year of precipitation (EPA, 1995).
- SCS default k valu[illegible] 0.0[illegible]er year for[illegible] Albuquerque region.
- Site-calibrated k value of 0.010 per year based on refuse moisture content. The average refuse moisture derived from the field-testing program (12 percent) was compared to the moisture content for typical U.S. waste (20 percent) to estimate the likely effects of a significant variation from average refuse moisture content on the k value. Because refuse moisture at the San Antonio Landfill was significantly lower than average, the k value was adjusted downward from the SCS default value of 0.19.
- An elevated k value of 0.025 per year based on the estimated effect of adding moisture starting in 2002.

5.4.2 Model Validation Results

Validation of LandGEM's application to the San Antonio Landfill is provided by the site-calibrated k values, which are based on actual measurements of LFG production from pumping tests conducted at the Eubank and Yale Landfills. The calibrated k values of 0.01 and 0.023 for Eubank and Yale, respectively, provide a range of values that bracket the predicted k input parameters assigned through default values (0.019 and 0.020) used to model LFG generation at the San Antonio Landfill.

Use of site-calibrated k and L_0 values also supports the validity of LandGEM results. The site-calibrated k value of 0.010 (compared to default of 0.019) used at the San Antonio Landfill is based on a lower than typical waste moisture content of 12 percent (compared to the national average of 20 percent). The site-calibrated L_0 value of 2,771 ft^3/ton (compared to default of 3,550 ft^3/ton) is based on a lower than typical degradable waste content of 41.1 percent (compared to national average of 52.7 percent). Adjusting LandGEM input parameters in this manner to reflect site-specific conditions for the San Antonio Landfill should provide reasonable estimates of the LFG generation rate.

5.4.3 LFG Generation Model Results

Model results, provided in Table 7 and Figure 5, show estimated LFG generation through 2020 for the San Antonio Landfill for five different projection scenarios, including the effect of adding moisture to the refuse mass. Table 7 also provides the estimated disposal rates and the k and L_0 values used for each projection. All LFG generation rates shown are adjusted to 50 percent methane content (standard normalization procedure) to reflect the typical methane content of LFG as it is generated.

Except for the projection that shows the effects of adding moisture starting in 2002 (Projection 5), all projections show LFG generation reaching a peak in 1971, one year following landfill closure, and declining at a rate of 1 to 2 percent annually thereafter. LFG generation in 2002 is estimated to range between 36 and 65 scfm. The highest generation rates occur under Projection 2, the SCS default projection, which uses the highest L_0 value of any projection. The lowest generation rates occur under Projection 3, the site-calibrated projection, which uses a k value that has been adjusted downward from the SCS default of 0.019 to 0.01 due to the low moisture content of refuse at the site, and which uses a L_0 value (2,771 ft^3/ton) that has been discounted by approximately 22 percent from the SCS default L_0 based on the fraction of

Table 7. LFG Generation Projections
San Antonio Landfill
Page 1 of 3

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation: Projection 1 (EPA default values) scfm	Mcf/day	Projection 2 (SCS default values) scfm	Mcf/day	Projection 3 (site-calibrated values) scfm	Mcf/day	Projection 4 (site-calibrated k value; SCS default L_0 value) scfm	Mcf/day	Projection 5 (site-calibrated values with k adjustment for added moisture) scfm	Mcf/day
Methane content of LFG adjusted to:			*50*		*50*		*50*		*50*		*50*	
Methane generation rate constant (k):			*0.020*		*0.019*		*0.010*		*0.010*		*0.010 and 0.025* [a]	
Ultimate methane generation rate (L_0):			*3,204* [b]		*3,550* [b]		*2,771* [b]		*3,550* [b]		*2,771* [b]	
1968	156,812	156,812	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000
1969	156,812	313,623	37	0.054	39	0.057	16	0.024	21	0.030	16	0.024
1970	156,812	470,435	74	0.107	78	0.113	33	0.047	42	0.060	33	0.047
1971	0	470,435	110	0.159	116	0.167	49	0.070	62	0.090	49	0.070
1972	0	470,435	108	0.156	114	0.164	48	0.069	62	0.089	48	0.069
1973	0	470,435	106	0.153	112	0.161	48	0.069	61	0.088	48	0.069
1974	0	470,435	104	0.149	110	0.158	47	0.068	60	0.087	47	0.068
1975	0	470,435	102	0.147	108	0.155	47	0.067	60	0.086	47	0.067
1976	0	470,435	100	0.144	106	0.152	46	0.067	59	0.085	46	0.067
1977	0	470,435	98	0.141	104	0.149	46	0.066	59	0.084	46	0.066
1978	0	470,435	96	0.138	102	0.147	45	0.065	58	0.084	45	0.065
1979	0	470,435	94	0.135	100	0.144	45	0.065	58	0.083	45	0.065
1980	0	470,435	92	0.133	98	0.141	44	0.064	57	0.082	44	0.064
1981	0	470,435	90	0.130	96	0.138	44	0.063	56	0.081	44	0.063
1982	0	470,435	88	0.127	94	0.136	44	0.063	56	0.080	44	0.063
1983	0	470,435	87	0.125	93	0.133	43	0.062	55	0.080	43	0.062
1984	0	470,435	85	0.122	91	0.131	43	0.061	55	0.079	43	0.061
1985	0	470,435	83	0.120	89	0.128	42	0.061	54	0.078	42	0.061

[a] The k value changes from 0.010 to 0.025 after 2002 to reflect the addition of moisture.
[b] Cubic feet per ton.

scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day

Table 7. LFG Generation Projections
San Antonio Landfill

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation: Projection 1 (EPA default values) scfm	Projection 1 Mcf/day	Projection 2 (SCS default values) scfm	Projection 2 Mcf/day	Projection 3 (site-calibrated values) scfm	Projection 3 Mcf/day	Projection 4 (site-calibrated k value; SCS default L_0 value) scfm	Projection 4 Mcf/day	Projection 5 (site-calibrated values with k adjustment for added moisture) scfm	Projection 5 Mcf/day
Methane content of LFG adjusted to:			*50*		*50*		*50*		*50*		*50*	
Methane generation rate constant (k):			*0.020*		*0.019*		*0.010*		*0.010*		*0.010 and 0.025* [a]	
Ultimate methane generation rate (L_0):			*3,204* [b]		*3,550* [b]		*2,771* [b]		*3,550* [b]		*2,771* [b]	
1986	0	470,435	82	0.118	87	0.126	42	0.060	54	0.077	42	0.060
1987	0	470,435	80	0.115	86	0.124	41	0.060	53	0.076	41	0.060
1988	0	470,435	78	0.113	84	0.121	41	0.059	53	0.076	41	0.059
1989	0	470,435	77	0.111	83	0.119	41	0.058	52	0.075	41	0.058
1990	0	470,435	75	0.109	81	0.117	40	0.058	52	0.074	40	0.058
1991	0	470,435	74	0.106	80	0.114	40	0.057	51	0.073	40	0.057
1992	0	470,435	72	0.104	78	0.112	39	0.057	50	0.073	39	0.057
1993	0	470,435	71	0.102	77	0.110	39	0.056	50	0.072	39	0.056
1994	0	470,435	70	0.100	75	0.108	39	0.056	49	0.071	39	0.056
1995	0	470,435	68	0.098	74	0.106	38	0.055	49	0.071	38	0.055
1996	0	470,435	67	0.096	72	0.104	38	0.055	49	0.070	38	0.055
1997	0	470,435	66	0.094	71	0.102	37	0.054	48	0.069	37	0.054
1998	0	470,435	64	0.092	70	0.100	37	0.053	48	0.068	37	0.053
1999	0	470,435	63	0.091	68	0.098	37	0.053	47	0.068	37	0.053
2000	0	470,435	62	0.089	67	0.096	36	0.052	47	0.067	36	0.052
2001	0	470,435	60	0.087	66	0.095	36	0.052	46	0.066	36	0.052
2002	0	470,435	59	0.085	65	0.093	36	0.051	46	0.066	36	0.051
2003	0	470,435	58	0.084	63	0.091	35	0.051	45	0.065	86	0.123

[a] The k value changes from 0.010 to 0.025 after 2002 to reflect the addition of moisture.
[b] Cubic feet per ton.

scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day

Table 7. LFG Generation Projections
San Antonio Landfill
Page 3 of 3

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation: Projection 1 (EPA default values)		Projection 2 (SCS default values)		Projection 3 (site-calibrated values)		Projection 4 (site-calibrated k value; SCS default L_0 value)		Projection 5 (site-calibrated values with k adjustment for added moisture)	
			scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day
Methane content of LFG adjusted to:			*50*		*50*		*50*		*50*		*50*	
Methane generation rate constant (k):			*0.020*		*0.019*		*0.010*		*0.010*		*0.010 and 0.025* [a]	
Ultimate methane generation rate (L_0):			*3,204* [b]		*3,550* [b]		*2,771* [b]		*3,550* [b]		*2,771* [b]	
2004	0	470,435	57	0.082	62	0.089	35	0.050	45	0.064	83	0.120
2005	0	470,435	56	0.080	61	0.088	35	0.050	44	0.064	81	0.117
2006	0	470,435	55	0.079	60	0.086	34	0.049	44	0.063	79	0.114
2007	0	470,435	54	0.077	59	0.084	34	0.049	43	0.063	77	0.111
2008	0	470,435	53	0.076	58	0.083	34	0.048	43	0.062	75	0.109
2009	0	470,435	52	0.074	56	0.081	33	0.048	43	0.061	74	0.106
2010	0	470,435	51	0.073	55	0.080	33	0.047	42	0.061	72	0.103
2011	0	470,435	50	0.071	54	0.078	33	0.047	42	0.060	70	0.101
2012	0	470,435	49	0.070	53	0.077	32	0.046	41	0.060	68	0.098
2013	0	470,435	48	0.069	52	0.075	32	0.046	41	0.059	67	0.096
2014	0	470,435	47	0.067	51	0.074	32	0.046	41	0.058	65	0.094
2015	0	470,435	46	0.066	50	0.073	31	0.045	40	0.058	63	0.091
2016	0	470,435	45	0.065	49	0.071	31	0.045	40	0.057	62	0.089
2017	0	470,435	44	0.063	49	0.070	31	0.044	39	0.057	60	0.087
2018	0	470,435	43	0.062	48	0.069	30	0.044	39	0.056	59	0.085
2019	0	470,435	42	0.061	47	0.067	30	0.043	39	0.056	57	0.083
2020	0	470,435	41	0.060	46	0.066	30	0.043	38	0.055	56	0.081

[a] The k value changes from 0.010 to 0.025 after 2002 to reflect the addition of moisture.
[b] Cubic feet per ton.

scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day

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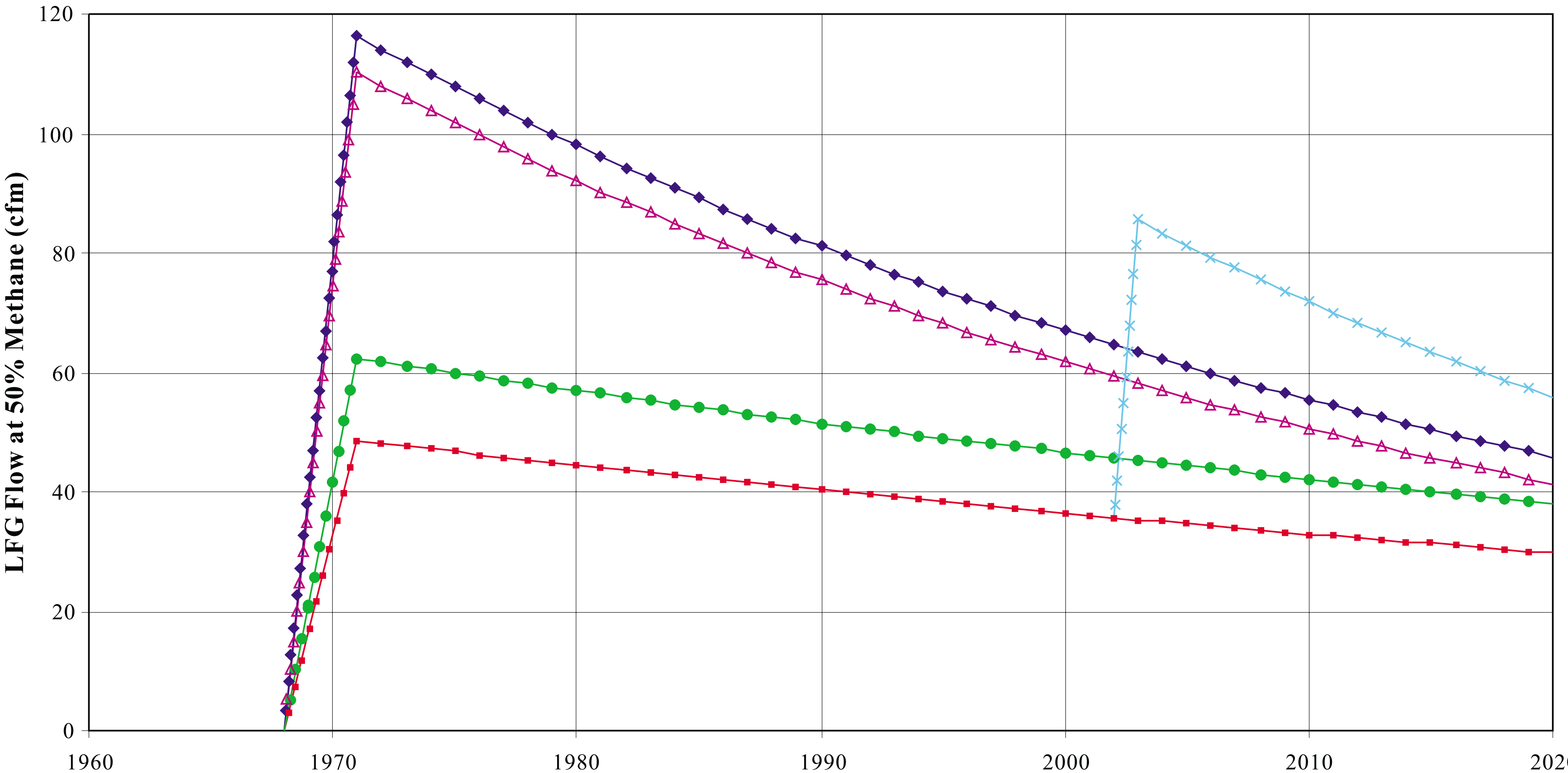

Explanation

- EPA (AP-42) Default Values k = 0.020 Lo = 3,204 cu.ft./ton
- SCS Default Values k= 0.019 Lo = 3,550 cu.ft./ton
- Site-Calibrated Values w/Added Moisture k = 0.025 Lo = 2,771 cu.ft./ton
- Site-Calibrated Values k = 0.010 Lo = 2,771 cu.ft./ton
- Site-Calibrated k Value w/SCS Default Lo Value k = 0.010 Lo = 3,550 cu.ft./ton

Source: SCS Engineers

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

San Antonio Landfill
LFG Generation Projection

Daniel B. Stephens & Associates, Inc.
3-28-02 JN 9398

Figure 5

degradable waste found in waste samples taken in the field. Projection 4 yields mid-range LFG generation rates from modifications to the site-calibrated projection model using the site-calibrated k value with the SCS default L_0 value.

Projection 5 is a modified (moisture added) site-calibrated projection that uses the site-calibrated k and L_0 values through 2002, but which increases the k value to 0.025 for generation after 2002 to reflect the effect of adding moisture to the refuse mass. This projection shows LFG generation increasing from 36 scfm in 2002 to 86 scfm in 2003, the first year that the effects of added moisture are reflected in the model results. LFG generation is projected to decline at 2.5 percent annually after 2003 under the added moisture scenario.

6. Conclusions and Recommendations

The landfill gas investigation and characterization study was conducted with the primary goal of providing new information to determine appropriate measures to address LFG issues related to the use of properties on and within close proximity to the former landfills. The following conclusions and recommendations related to the San Antonio Landfill have been made based on available information and the data collected during this investigation. Though it is impossible to precisely predict future LFG generation and migration, careful analysis of data can provide a tool for making an educated prediction of future LFG behavior. These assumptions of future LFG behavior combined with past LFG experience have allowed us to determine the possible effects of LFG on current and future development at and near the former landfills.

This report makes a number of recommendations as to actions that should be taken by the City. These recommendations are worded in terms of actions that should be taken by the City because the City is the party that requested recommendations. It is the City that has taken the lead in dealing with landfill gas problems. This report takes no position on whether it is properly the City's role or responsibility to deal with the concerns raised by these recommendations.

6.1 Conclusions

Based on the data and analysis discussed, the following conclusions can be made regarding LFG generation at the San Antonio Landfill:

- Based on the modeling results, the peak year for LFG generation at the San Antonio Landfill was 1971.

- The estimated LFG generation rate for the San Antonio Landfill indicates that the production of LFG is steadily declining in its current state. The projected LFG generation rate for 2002 for the San Antonio Landfill ranges from 36 to 65 scfm.

- Due to the LFG concentrations measured and the LFG generation rate predicted for the San Antonio Landfill, the potential for significant volumes of LFG to migrate off-site is moderate.

- VOCs were detected in LFG gas samples collected at the San Antonio Landfill; however, at this time insufficient data exist to form conclusions concerning potential impacts to public health.

6.2 Recommendations

Based on the data and analyses discussed, the following recommendations are provided to address LFG issues relevant to the San Antonio Landfill.

6.2.1 Buffer Zone Reduction

The basic requirements of the City's *Interim Guidelines for Development within 1,000 feet of Landfills* should remain in place; however, reductions in the buffer zone distance are recommended contingent on implementing a LFG monitoring plan, as described below.

- *LFG monitoring plan.* The City should consider developing a LFG monitoring plan for the San Antonio Landfill to assess potential offsite migration of LFG. The plan should address the following:

  – *Installation of perimeter LFG monitoring probes.* These probes should be installed outside the waste disposal areas to confirm the limits of LFG migration. The probes should extend at least 10 feet below the depth of waste, or to approximately 30 to 40 feet bgs (typical). The monitoring probes should be spaced at approximate 250-foot intervals to form a monitoring perimeter that verifies the limits of LFG migration. Suitable and accessible locations for the monitoring probes will need to be identified. The final number, spacing, and locations of monitoring probes will need to be determined during development of the LFG monitoring plan.

- *Quarterly monitoring*. The perimeter monitoring probes and selected subsurface utility vaults should be monitored for methane gas on a quarterly basis for at least two consecutive years. The utility investigation recommended in Section 6.2.2 should specify which subsurface utility vaults will be monitored on a regular basis. If methane gas is not detected during the two years of monitoring, the frequency may be reduced to once every six months.

- *Change in frequency of monitoring*. If methane gas is detected at any time exceeding 25 percent of the LEL in selected subsurface utility vaults or 50 percent of the LEL in perimeter LFG monitoring probes, the frequency of monitoring should be increased to monthly for at least six months. Subsequently, if the methane gas content stays below these limits for six months of monthly monitoring, the frequency can be decreased to quarterly.

- *Long-term monitoring and care.* Monitoring of perimeter probes and selected subsurface utility vaults should continue indefinitely, because LFG conditions in and around the landfill can change and may be affected by future development.

• *Development of property outside landfill perimeter.* Based on the results of the LFG investigation and characterization study, changes are recommended for the San Antonio Landfill in the City's Interim Guidelines.

  - *Reduction of setbacks.* Assuming monitoring of the perimeter probes and selected utility vaults continues to verify that no methane gas is present after the initial two-year period, the setback distance from the property boundary could be decreased to 500 feet for determination of applicability of the Interim Guidelines. The recommended setback reduction is contingent on the results of continued LFG monitoring. The detection of methane above 25 percent of the LEL in selected utility vaults or above 50 percent of the LEL in any perimeter monitoring probe, will result in this recommendation being rescinded and a return to a greater setback distance.

Maintaining a minimum 500-foot setback is recommended, because of the existing high methane concentrations and a predicted LFG generation rate that will remain elevated for many years. These conditions will continue to pose a potential risk, and the City may still consider some design, monitoring, and/or LFG abatement measures suitable under the Interim Guidelines. Examples of requirements that could be needed, even with a setback distance from the landfill, include directing storm water away from the landfill, sealing off subgrade utilities to prevent possible LFG migration, installation of subsurface venting systems beneath structures, and/or installing interior monitors in buildings (particularly in basements). Any requirements will depend on the site-specific development plans.

- *Monitoring conditions for reduction of setbacks.* The recommended setback distance reduction is contingent on the results of continued LFG monitoring. The detection of methane above 25 percent of the LEL in selected utility vaults or above 50 percent of LEL in any perimeter monitoring probe will result in this recommendation being rescinded and reinstatement of a setback distance of 1,000 feet (or other setback distance appropriate for the conditions observed).

6.2.2 Landfill Management Plan

The City should consider developing a comprehensive landfill management plan for the San Antonio Landfill, to address several items that play a significant role in reducing LFG generation and preventing adverse LFG impacts. The LFG monitoring plan, described above, is a component of the overall landfill management plan. The landfill management plan should include the recommended components described below.

- *LFG control plan.* If the methane content exceeds 25 percent of the LEL in selected subsurface utility vaults or 50 percent of the LEL in perimeter monitoring probes, the City should consider developing a LFG control plan. If the methane content exceeds the specified limits for three consecutive months, the City should immediately develop and implement a LFG control plan. The LFG control plan should consist of either passive or active LFG control systems capable of reducing the methane content to levels protective of public health and safety.

The San Antonio Landfill has existing development near waste disposal areas where methane levels were measured above 100 percent of the LEL. In response, a LFG control plan may be needed immediately, should implementation of the LFG monitoring plan reveal public health and safety threats due to elevated methane levels. Decisions on implementing a LFG control plan will need to consider the specific site conditions and potential threats to determine appropriate actions.

- *Utility investigation.* Selected subsurface utilities should be monitored for the presence of LFG and included with the quarterly monitoring program discussed above. Utilities should be investigated on and around the San Antonio Landfill to determine if existing utility corridors pose a risk by acting as conduits for the migration of LFG. Utility locations should be examined to the fullest extent possible, using all available records and possible on-site investigation. A utility monitoring plan should be developed to select utility monitoring locations where LFG may be detected and monitoring can minimize the risk for utility conduits to transmit LFG. As long as methane concentrations remain below 25 percent of LEL in selected subsurface utilities, no further utility investigation is needed. However, if methane concentrations increase above 25 percent of LEL, additional investigation of utilities should commence.

- *Development of landfill property*. If development occurs on the San Antonio Landfill, the developer should meet all applicable requirements of the City's Interim Guidelines. If development occurs on the landfill that may increase the potential for off-site LFG migration by sealing the landfill cover surface (e.g. buildings, paved parking areas, and densely vegetated areas), the perimeter probe monitoring frequency may need to be increased and/or additional monitoring probes added.

- *Drainage control.* The existing drainage at the San Antonio Landfill provides positive drainage over most of the site, but some low points exist that collect storm water runoff. This storm water may contribute to LFG generation that has caused the elevated methane concentrations observed. It is recommended that the City undertake a site drainage study to determine existing drainage patterns and identify possible improvements.

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