Landfill Gas Investigation and Characterization Study Coronado and Nazareth Landfills

Prepared for **City of Albuquerque**
Albuquerque, New Mexico

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DBS&A engineering hydrology geoscience

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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
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/min	cubic feet per minute
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_2S	hydrogen sulfide
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/ft^3	pounds per cubic feet
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)
m^3	cubic meters
Mcf	millions of cubic feet
Mg	megagrams
MSW	municipal solid waste
NIOSH	National Institute for Occupational Safety and Health
NSPS	New Source Performance Standards
PCE	tetrachloroethene
PID	photoionization detector
ppm	parts per million
ppbv	parts per billion by volume
psi	pounds per square inch
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RFP	request for proposal
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 – Coronado and Nazareth Landfills
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 Coronado and Nazareth Landfills.

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, soil, and construction debris
  - Fines/unknown – 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. Coronado and Nazareth Landfill Study Results and Recommendations

2.1 Landfill Histories

The Coronado Landfill is located in northeast Albuquerque and includes separate northern and southern fill areas. This report describes only the northern fill area, since the southern fill area has been addressed in previous studies. The Coronado Landfill is located east of San Mateo Boulevard, north of Beverly Hills Avenue, south of Venice Avenue, and about 1,000 feet west of I-25. Currently, there is a moderate amount of development around the landfill perimeter, including several commercial businesses to the north and west.

The Coronado landfill was originally an arroyo that was filled in as a City-operated landfill from 1963 to 1965. The landfill is unlined and covers about 11 acres, with a waste depth ranging from about 15 to 35 feet.

The Nazareth Landfill is located in northeast Albuquerque, and is in the eastern part of the Balloon Fiesta Park, west of San Mateo Boulevard and north of San Diego Avenue. Currently, there is a small amount of development around the perimeter. The closest building is the Sumitomo plant approximately 200 feet east. The western portion is used as recreational vehicle (RV) parking during the Balloon Fiesta.

The Nazareth Landfill was originally an arroyo that was filled in as a City-operated landfill in 1971 and 1972. It is unlined and covers approximately 8 acres, with a waste depth up to about 30 feet.

2.2 Landfill Gas Survey

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

- *Methane was not detected* in any of the 12 gas probes installed at Coronado Landfill.

- *Methane was detected at relatively low concentrations* at the Nazareth Landfill. Low methane concentrations ranging from 0 to 0.5 percent were measured in seven gas probes. A probe in the central portion measured 7.9 percent, which slightly exceeds the explosive limit. These methane levels are generally low and create low potential for off-site migration.

- *Low levels of 7 volatile organic compounds* were detected at the Coronado Landfill and higher levels of 26 volatile organic compounds were detected at the Nazareth Landfill in landfill gas samples taken beneath the ground surface. The volatile organic compound data will be used in further studies.

2.3 Waste Characterization

A waste characterization study was conducted at the Coronado Landfill, which included (1) drilling three borings with a large-diameter bucket auger to depths of 12 to 15 feet, and (2) collecting and analyzing the waste samples to establish their composition and percentage of degradable material. Waste characterization was not performed at the Nazareth Landfill, because the City's ownership and control of land use reduces concerns of future gas generation. Results of the Coronado waste characterization study included:

- *Waste was encountered in only one boring.* Two borings did not contain waste and encountered only soil. In the boring containing waste, only a small amount of waste was found and this boring too, contained mainly soil.
- *Little gas generation is expected* at the Coronado Landfill based on the absence of degradable waste.

2.4 Landfill Gas Generation Modeling

The landfill gas generation rate at the Coronado and Nazareth Landfills 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 1966 at the Coronado Landfill, and 1973 at the Nazareth Landfill. 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 from Coronado Landfill ranges from 0.6 to 11.3 standard cubic feet per minute and for the Nazareth Landfill ranges from 23 to 25 standard cubic feet per minute. These are relatively low gas generation rates and suggest a low potential for off-site 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 provided a landfill gas monitoring plan is implemented (see recommendation below). The buffer zone can be reduced to 250 feet at the Coronado Landfill, since no methane was found; and to 500 feet at the Nazareth Landfill, because low levels of methane were found. Maintaining these minimum setback distances is recommended, because the landfills are 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 landfill management plans for the Coronado and Nazareth Landfills to include:

- *Implement landfill gas monitoring plans*. These monitoring plans should include the installation of perimeter monitoring probes to verify the limits of gas migration. Probes should be at approximately 250-foot spacings around the Coronado Landfill and along the east and south sides and a portion of the north side of the Nazareth Landfill. Perimeter monitoring on the west side and a portion of the north side of the Nazareth Landfill is contingent on use of this City property. Quarterly methane monitoring should be maintained for at least two consecutive years at probes and selected underground utilities. If methane is not detected for two years, monitoring periods 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 landfills to minimize water infiltration into the waste. The Coronado Landfill is potentially subject to seepage from storm water flow in arroyos or erosion damage. A site drainage study is recommended for each landfill 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 landfills, 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

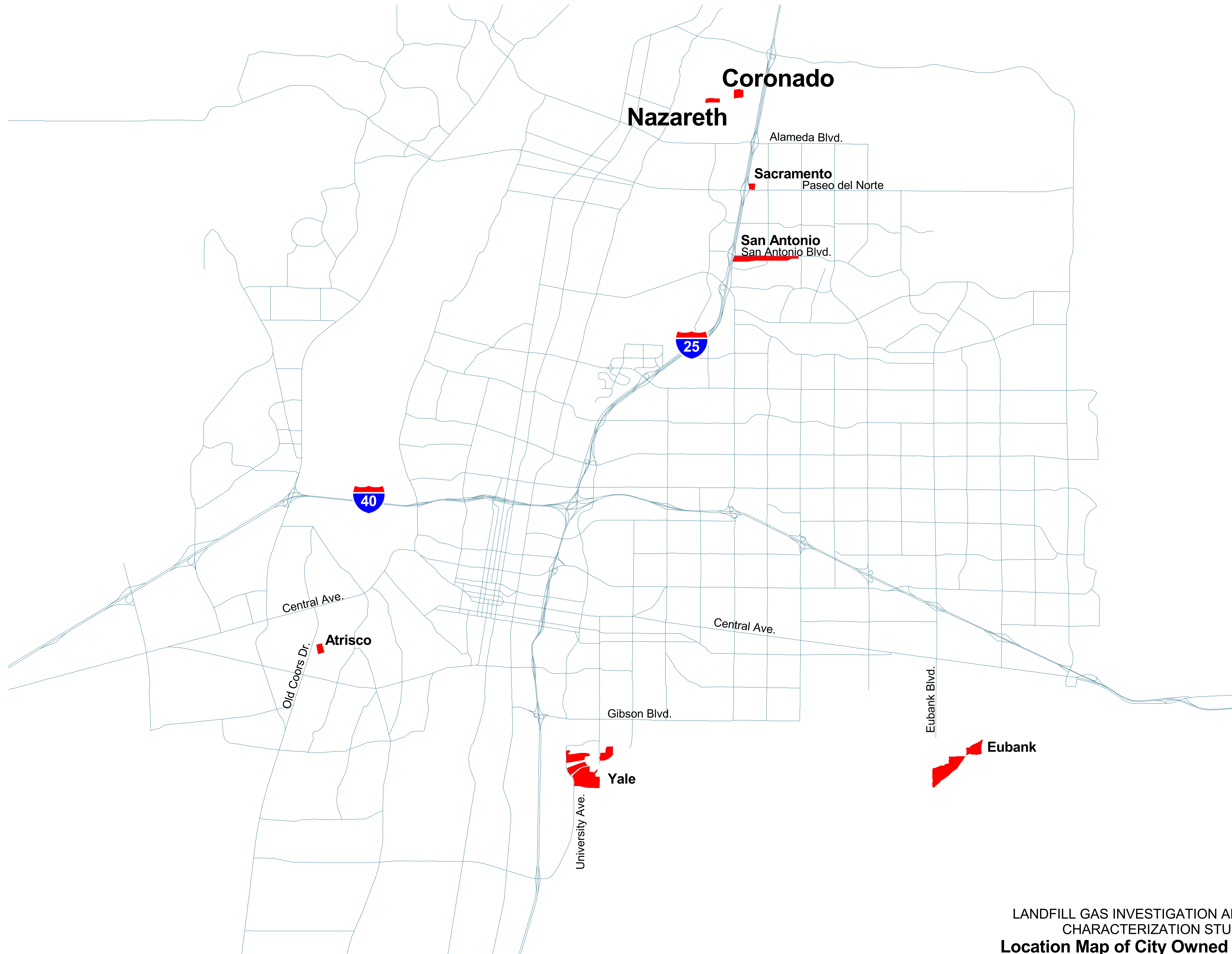
1. Introduction

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

N

0 1 2 miles

Explanation

Landfill

T:\VDR\PROJECTS\9398\AlbLF_Landfill Locations- all-sites.apr (Layout = L2 - Coronado-Nazareth Landfill Location Map, B-size, 1:96,000)

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Location Map of City Owned or Operated Landfills Studied

Figure 1

- 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 Coronado and Nazareth Landfills. 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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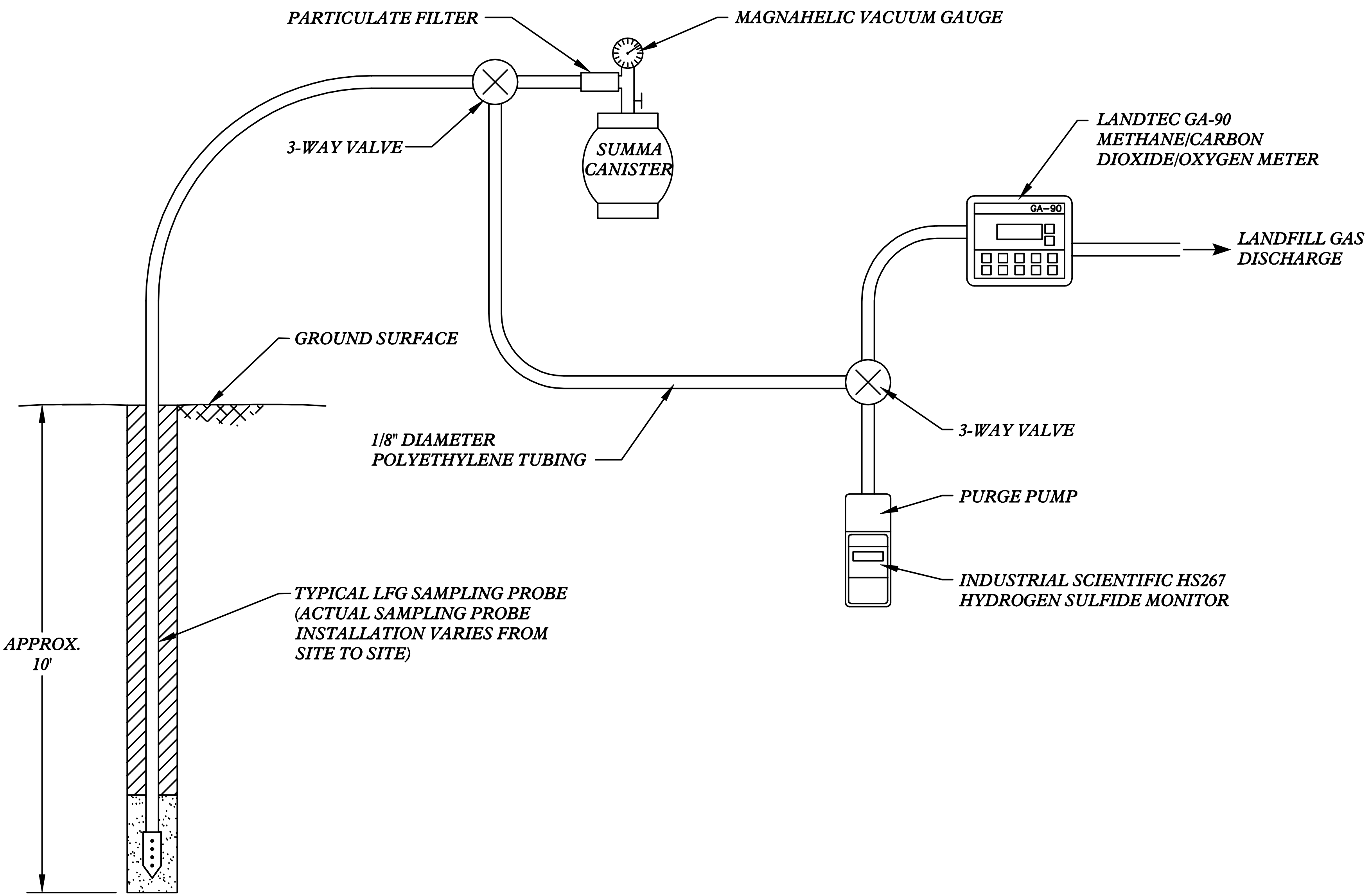

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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Landfill Gas Survey Sampling Train Detail

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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

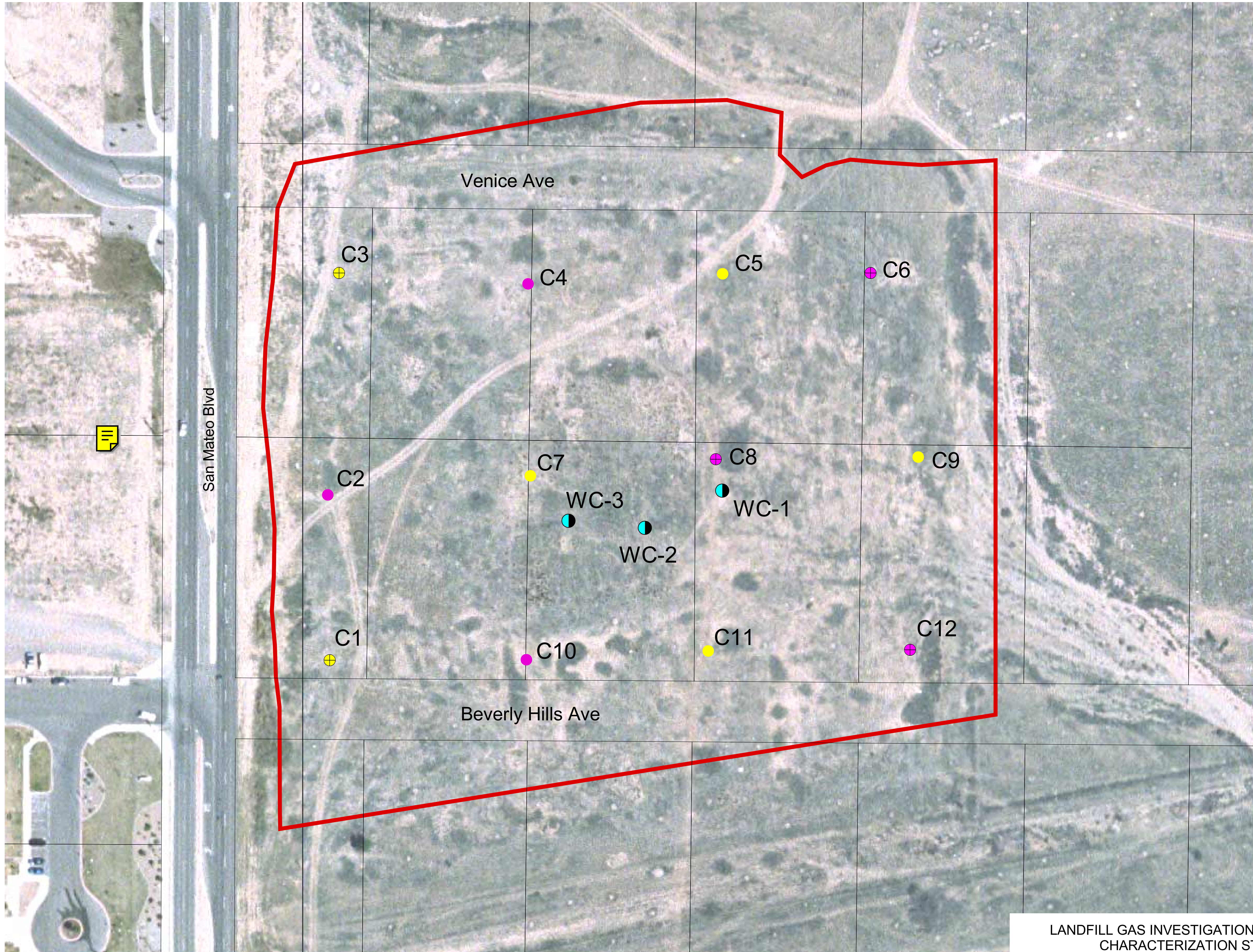
This section presents background information on the Coronado and Nazareth Landfills' operating histories and on previous investigations that have been conducted at these landfills. The two landfills are addressed together in this report because of their proximity (approximately 1,000 feet apart) and similar size and age.

3.1 Coronado Landfill

The Coronado Landfill is located in northeast Albuquerque in Zone B-18 (Figure 1). The Coronado Landfill includes separate northern and southern fill areas. The southern fill area is on property owned by Philips Semiconductor, and is not included in this study. This report describes only the Coronado Landfill northern fill area, which is located east of San Mateo Boulevard, north of Beverly Hills Avenue, south of Venice Avenue, and approximately 1,000 feet west of I-25 (Figure 3). Currently, there is a moderate amount of development around the perimeter of the landfill, including several commercial businesses to the north and west of the landfill. Most of the businesses to the north of the landfill have been constructed recently, as development of new commercial buildings continues to occur around the landfill.

The landfill was originally an arroyo that was filled in as a City-operated landfill from approximately 1963 to 1965. The landfill is unlined and covers approximately 11 acres, with a waste depth in the range of approximately 15 to 35 feet. Reportedly, material placed at the landfill was mainly residential and commercial waste. This was confirmed during excavation of waste in other portions of the Coronado Landfill south of the section covered in this investigation (Nelson, 1997).

The existing landfill cover is approximately 2 to 6 feet thick and consists of local porous soils composed of silty sands with some gravel. The cover is sparsely to moderately vegetated. The landfill cover is slightly mounded in the center, which promotes moderate positive drainage over most of the site. Several areas of the cover possess depressions due to waste settlement that are capable of ponding water. In addition, an arroyo flows into the landfill area at the southeastern corner of the landfill, and seepage from this arroyo may contribute moisture to



Source:
1999 Aerial photograph provided by Bernalillo County

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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

Coronado Landfill Test Locations

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Figure 3

(T:\VDR0-VDR-PROJECTS\9398 (PROJECT = albf_coronado.apr) (VIEW EXTENTS = Temp) (VIEW NAME = V5-Coro) (LAYOUT = L5-Coro) waste in the subsurface. The site area is open to access by the public on minor, unimproved dirt roads.

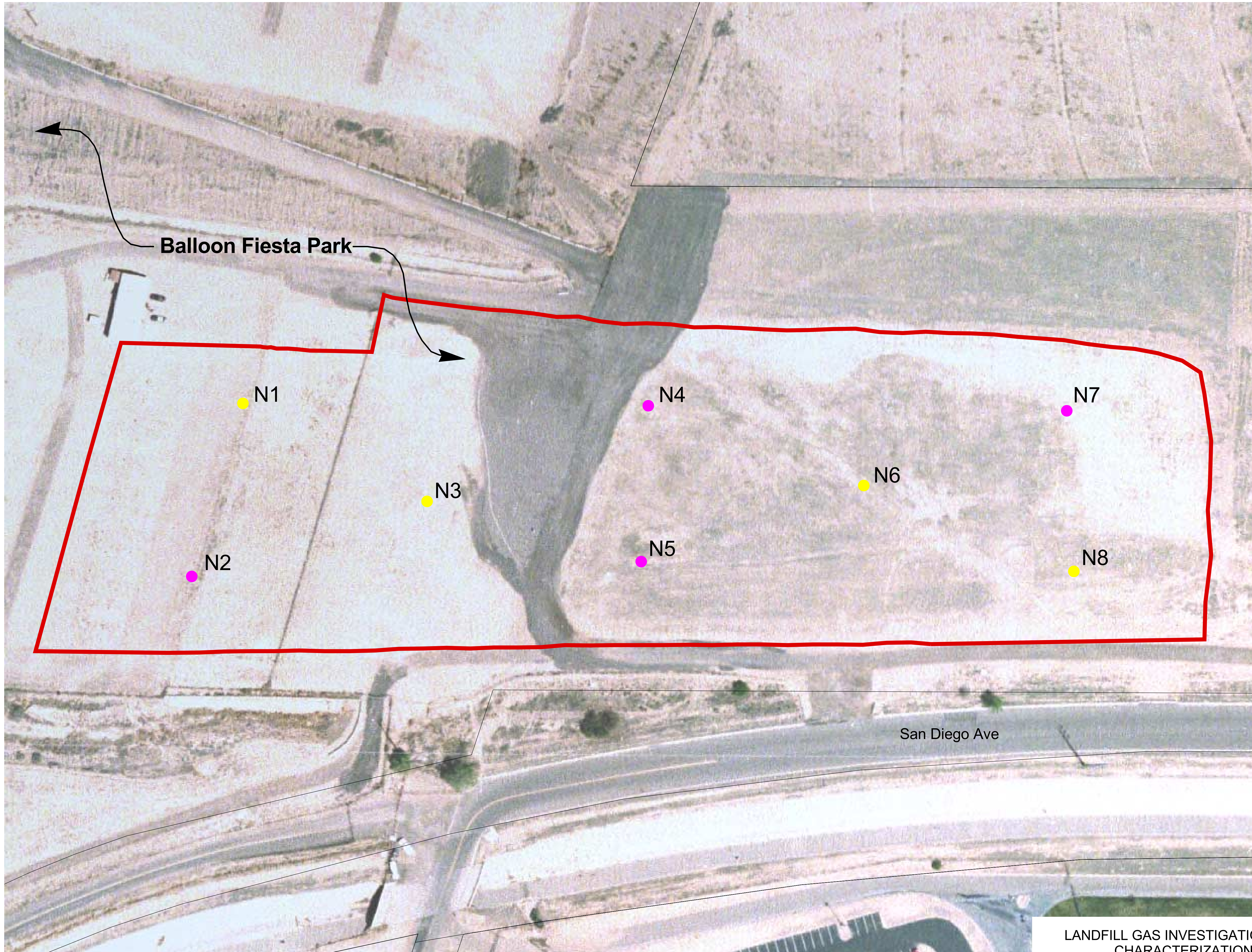
Surface sediments at the Coronado Landfill are dominated by the Edith Formation, which consists of gravels from the ancestral Rio Grande. The Edith Formation overlies poorly-sorted alluvial sediments eroded primarily from the Sandia Mountains. Depth to groundwater varies between approximately 170 and 240 feet bgs, and groundwater flow is primarily south to southeast (COA, 2002).

In December 1999, CH2M Hill conducted an extensive study of the Coronado Landfill for Philips Semiconductor. Twelve samples were collected from the northern area of the landfill being investigated as part of this study. Only low concentrations of methane were found (0 to 1.4 percent) at the landfill. Several VOCs including toluene, xylenes, tetrachloroethene (PCE), and ethylbenzene were also measured at the landfill, but only in low concentrations (0 to 4.26 parts per billion [ppb]) (CH2M Hill, 2000).

3.2 Nazareth Landfill

The Nazareth Landfill is located in northeast Albuquerque in Zone B-17, west of San Mateo Boulevard and north of San Diego Avenue (Figures 1 and 4). Currently, there is a small amount of development around the perimeter of the landfill. The closest building to the Nazareth Landfill is the Sumitomo plant approximately 200 feet east of the landfill. The landfill property is part of the Balloon Fiesta Park, and the western portion of the landfill is used as recreational vehicle (RV) parking during the Balloon Fiesta, with RV occupancy during late-September to mid-October each year. There are water and electrical service connections on this portion of the landfill to provide power and water to the RVs.

The site was originally an arroyo that was filled-in as a landfill by the City and private citizens (EPA, 1982) from 1971 to 1972. The landfill is unlined and covers approximately 8 acres, with a waste depth up to 30 feet. Before it was filled in, the arroyo was approximately 32 feet deep with shallower depths to the east. It is reported that material placed at the landfill was mainly municipal waste (Nelson, 1997).



Source:
1999 Aerial photograph provided by Bernalillo County

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Explanation

- Sampling probe locations
- Sampling probe/lab sample locations
- Parcels
- Landfill boundary

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY
Nazareth Landfill Test Locations

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Figure 4

The Nazareth Landfill has an existing soil cover that is smoothly graded and nearly flat, with a slight grade toward the west. The western portion of the landfill is covered with either gravel base-coarse or asphalt millings that have been placed on the surface for Balloon Fiesta RV parking. The eastern portion of the landfill is covered with silty sand soil and has sparse vegetation. The slight grade provides for positive drainage off of the site and little ponding appears to be occurring. The eastern portion of the landfill is open to public access, whereas the western portion is fenced with restricted access.

The geology at the Nazareth Landfill is dominated by deposits of the ancestral Rio Grande and is essentially the same as that at the Coronado Landfill. Depth to groundwater is approximately 140 to 160 feet bgs, and groundwater flow is primarily south to southeast (COA, 2002).

No known significant landfill gas monitoring activities occurred at the Nazareth Landfill before this study.

4. Field Investigation Methods

The field investigation methods used at the Coronado and Nazareth Landfills 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 borings to sample and categorize waste composition (Coronado Landfill only)

Sections 4.1 through 4.4 present the detailed methodology used for these tasks at the Coronado and Nazareth Landfills.

4.1 Site Access

Access agreements were established with the property owners at the Coronado Landfill, to provide site access for the field investigation. Property owners were identified at the Coronado Landfill, based on City of Albuquerque and Bernalillo County Tax Assessor's Office records. Access agreements for the LFG investigation and characterization study were established with property owners to provide access to the landfill area for investigation.

The Nazareth Landfill property is part of the Albuquerque Balloon Fiesta Park and is owned by the City; therefore, site access was granted without a separate 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. Meetings were arranged with some utility locators to explain precisely where sampling was to occur. Utility locations at the Nazareth Landfill were examined by directly contacting the City Parks and Recreation

Department. Buried water and electric lines exist on the western portion of the Nazareth Landfill for RV hook-ups used during the Balloon Fiesta.

4.3 Landfill Gas Survey

LFG sampling locations at the Coronado and Nazareth Landfills are shown in Figures 3 and 4, respectively. The sampling grid at each landfill was established at approximately 200 x 200-foot spacings, with adjustments made to fit the irregular shape of each landfill. At the Coronado Landfill, 12 sampling locations were established across the landfill surface, and at the Nazareth Landfill, 8 sampling locations were established.

At the Coronado and Nazareth Landfills, a geoprobe drill rig was used to drive a 1-inch-diameter, hollow drive probe to a depth of 10 feet bgs (see photographs, Appendix C). Probe installations involved driving a sacrificial tip to the specified depth, followed by retracting the probe a few inches. The upward pull allowed the sacrificial tip to drop off the probe and enabled gas to enter the end of the probe. The gas was then drawn into the sampling train through polyethylene tubing (⅛-inch diameter) attached to the end of the drive probe. LFG samples were collected and analyzed as discussed in Section 2.3.

4.4 Waste Characterization Analysis

A waste characterization program was implemented at the Coronado Landfill to determine whether the former landfill contains decomposable materials that may continue to produce LFG in the future. The type of waste present, the waste's current state of decomposition, and the waste moisture content provide information on the degree of degradation since waste deposition and the potential for further waste degradation. At the Coronado Landfill, three borings were drilled through waste to allow for examination of the waste characteristics. The waste characterization analysis was not extended to the Nazareth Landfill, because the City's ownership and control of land use reduces concerns of future LFG generation. However, the results from the waste characterization analyses completed at Coronado and four other landfills as part of this project provided useful data on the typical conditions at all the former landfills.

The three waste characterization borings at the Coronado Landfill were drilled with a 30-inch-diameter bucket auger to collect samples of waste materials and soil, as shown in photographs provided in Appendix C. Boring locations, shown in Figure 3, were selected based on the results of the LFG survey, and recommended locations were submitted to AEHD for approval prior to drilling.

5. Results

Results of the LFG investigation and characterization study of the Coronado and Nazareth Landfills 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 (Coronado Landfill only)
- LFG generation modeling results

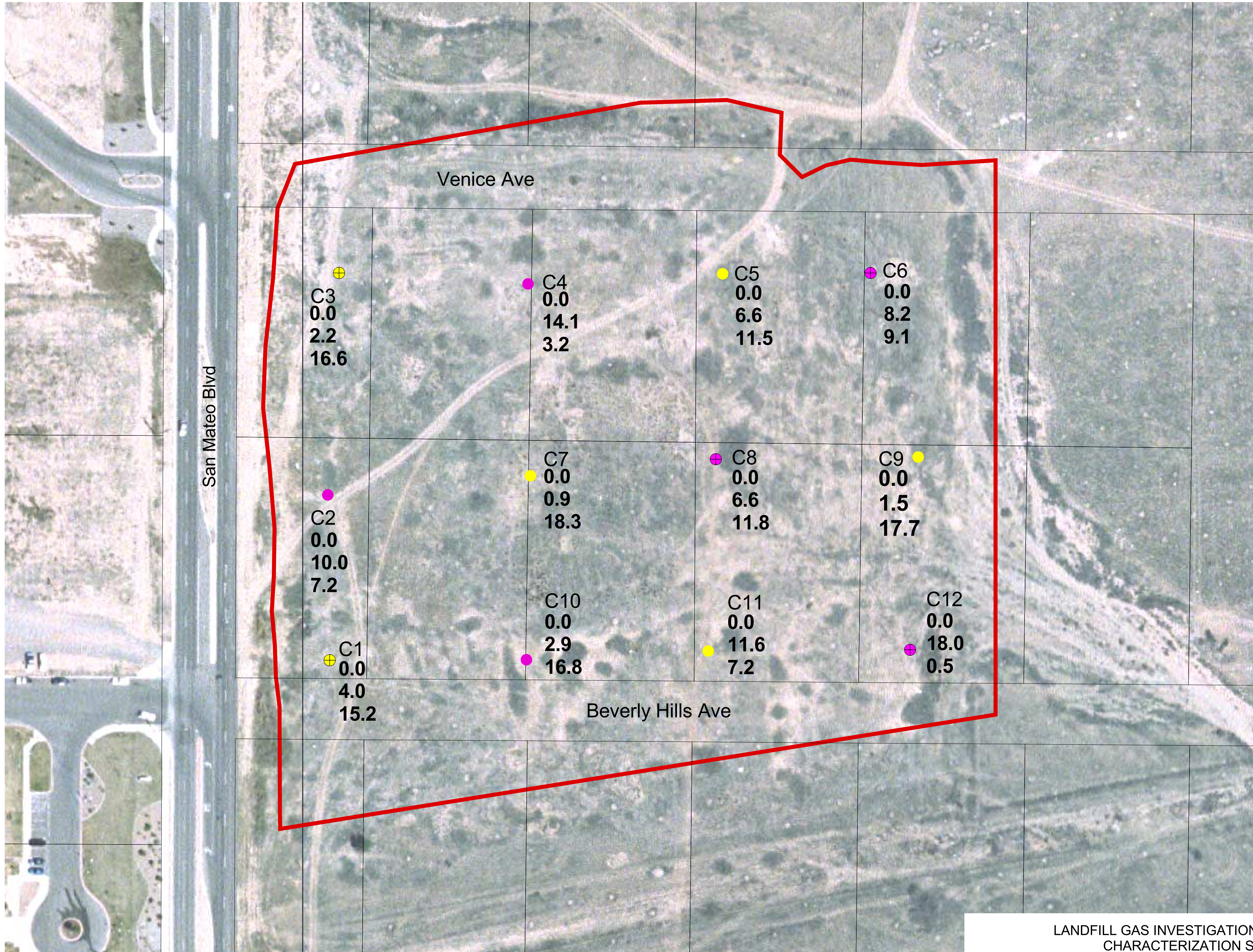
These items are addressed in Sections 5.1 through 5.4.

5.1 LFG Survey Field Analysis Results

Methane concentration maps are presented in Figures 5 and 6 to graphically show the LFG concentrations at the Coronado and Nazareth Landfills, respectively. The maps display numeric results for methane, carbon dioxide, and oxygen concentrations. Results of the LFG surveys of the Coronado and Nazareth Landfills are also summarized in Tables 1 and 2.

No methane was encountered at the Coronado Landfill and only moderate levels of carbon dioxide were found (Table 1, Figure 5). Most sampling locations also possessed significant amounts of oxygen, indicating the presence of atmospheric air. Several of the samples have such low levels of carbon dioxide and high levels of oxygen that it is likely they were not extracted from waste. Instead, these samples may have originated in soil layers between isolated waste trenches. Another possibility is that extent of waste at the landfill may not be as great as indicated by current site maps.

Methane concentrations at the Nazareth Landfill were relatively low, ranging from 0 to 7.9 percent (Table 2, Figure 6). All methane detected was in the central and western portions of the landfill. Only the highest methane reading (from N3) exceeded the LEL; the remaining methane detected was at concentrations well below the LEL, ranging from 0.2 to 0.5 percent.



Source:

1999 Aerial photograph provided by Bernalillo County

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Explanation

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

0.0	Methane (%)
4.0	Carbon dioxide (%)
15.2	Oxygen (%)

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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY
Coronado Landfill Gas Survey Results

Figure 5

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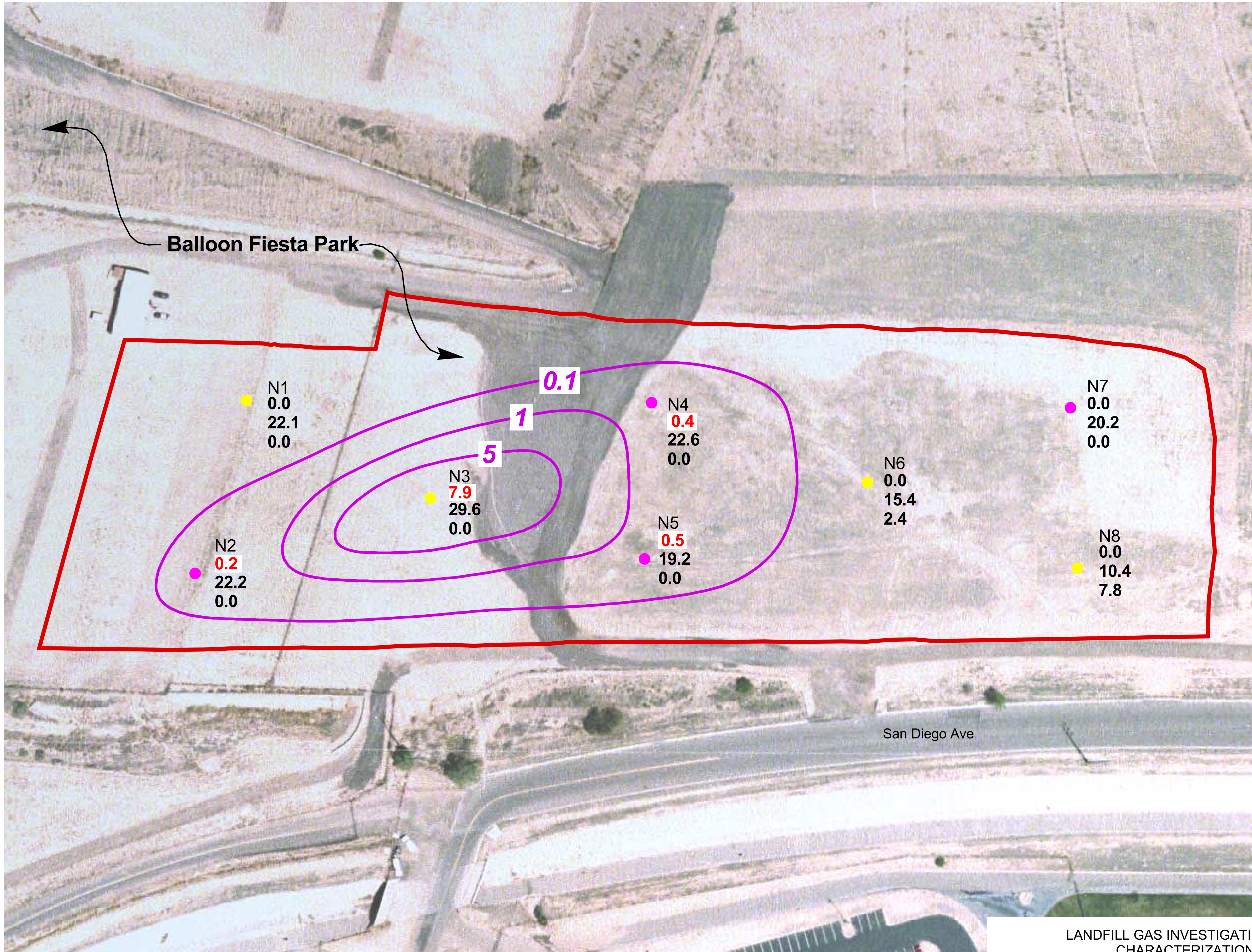

Source:

1999 Aerial photograph provided by Bernalillo County

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Explanation

Sampling probe locations

Sampling probe/lab sample locations

Parcels

Landfill boundary

5 Methane concentration contour (%)

7.9 Methane (%)
29.6 Carbon dioxide (%)
0.0 Oxygen (%)

Note:

Methane concentrations of 0.0 are shown in black text

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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Nazareth Landfill Gas Survey Results

Figure 6

Table 1. Landfill Gas Survey Results, Coronado Landfill

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)
C1	09/13/01	8:05 AM	0.0	4.0	15.2	0.0	76.6	–0.30	24.9	Y	3.0
C2	09/12/01	4:15 PM	0.0	10.0	7.2	0.0	90.3	–0.10	24.6	N	1.5
C3	09/11/01	1:53 PM	0.0	2.2	16.6	3.0	91.4	0.00	24.8	Y	6.0
C4	09/11/01	2:14 PM	0.0	14.1	3.2	2.0	88.3	0.00	24.7	N	6.0
C5	09/11/01	2:40 PM	0.0	6.6	11.5	3.0	85.5	0.00	24.7	Y	2.0
C6	09/11/01	3:10 PM	0.0	8.2	9.1	1.0	89.6	0.00	24.7	N	U
C7	09/11/01	4:45 PM	0.0	0.9	18.3	1.0	87.3	0.00	24.7	Y	S
C8	09/11/01	4:15 PM	0.0	6.6	11.8	1.0	85.5	0.00	24.7	N	S
C9	09/11/01	3:39 PM	0.0	1.5	17.7	2.0	NM [c]	0.00	24.7	Y	U
C10	09/13/01	7:35 AM	0.0	2.9	16.8	0.0	73.0	–0.10	24.8	N	1.5
C11	09/13/01	8:35 AM	0.0	11.6	7.2	0.0	78.6	–0.20	24.9	Y	0.5
C12	09/13/01	8:55 AM	0.0	18.0	0.[illegible]	0.0	79.7	–0.20	24.9	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.

ppm = Parts per million
°F = Degrees Fahrenheit
H_20 = Water
Hg = Mercury

NM = Not measured
U = Unknown, could not be determined by the driller
S = Surface, no significant amount of cover present

Table 2. Landfill Gas Survey Results, Nazareth Landfill

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)
N1	09/11/01	11:41 AM	0.0	22.1	0.0	0.0	85.3	0.00	24.8	Y	0.0-1.0
N2	09/11/01	12:14 PM	0.2	22.2	0.0	6.0	95.5	0.00	24.8	N	0.0-1.0
N3	09/11/01	11:08 AM	7.9	29.6	0.0	0.0	86.7	0.00	24.8	Y	0.0-1.5
N4	09/11/01	10:36 AM	0.4	22.6	0.0	2.0	87.6	0.00	24.9	N	2.0
N5	09/11/01	10:00 AM	0.5	19.2	0.0	2.0	85.1	–0.10	24.9	N	3.0-4.0
N6	09/11/01	9:22 AM	0.0	15.4	2.4	2.0	85.3	–0.30	24.9	Y	2.0-3.0
N7	09/11/01	8:45 AM	0.0	20.2	0.0	1.0	NM	0.00	24.9	N	2.0
N8	09/10/01	4:15 PM	0.0	10.4	7.8	0.0	85.0	NM	NM	Y	2.0-3.0

[a] Landfill gas static pressure and atmospheric pressure measurements were 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.

ppm = Parts per million
°F = Degrees Fahrenheit
H_20 = Water
Hg = Mercury
NM = Not measured

Hydrogen sulfide concentrations at the Coronado Landfill ranged from 0 to 3 ppm (Table 1), and at the Nazareth Landfill ranged from 0 to 6 ppm (Table 2). 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.

5.2 LFG Survey Laboratory Results

During the LFG survey (described in Section 2.4), six vapor samples were collected at the Coronado 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 found in LFG. In addition, one sample (C11) was tested for quality control purposes by Method 3C for carbon dioxide, methane, nitrogen, and oxygen.

Four vapor samples were collected at the Nazareth Landfill for laboratory analysis. Each sample was analyzed for VOCs using the modified version of Method TO-14. The laboratory also analyzed one sample (N3) as a duplicate to provide laboratory QA/QC. In addition, N3 was tested by Method 3C for carbon dioxide, methane, nitrogen, and oxygen.

Results of the laboratory analyses are summarized in Tables 3 and 4, for Coronado and Nazareth Landfills, respectively. Coronado and Nazareth 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 laboratory chain-of-custody forms are provided in Volume II.

5.3 Waste Characterization Analysis

Three waste characterization borings (WC-1, WC-2, and WC-3) were drilled at the Coronado Landfill (Figure 3). The depths of WC-1, WC-2, and WC-3 were 12, 15, and 15 feet bgs, respectively. Waste was not encountered at borings WC-2 and WC-3. At boring WC-1, only minimal amounts of waste were encountered (8.5 percent wood and 2.3 percent plastic, by weight). The remaining 89.2 percent of material recovered from WC-1 consisted of soil.

Table 3. Laboratory Results
Coronado Landfill

Compound Name	C1	C3	C5	C7	C9	C11
Modified Method TO-14 [a] (ppbv)						
1,1,1-Trichloroethane	---	---	---	---	---	---
1,1,2-Trichloroethane	---	---	---	---	---	---
1,1-Dichloroethane	---	---	---	---	---	---
1,1-Dichloroethene	---	---	---	---	---	---
1,2,4-Trimethylbenzene	---	160	---	14	15	---
1,2-Dichlorobenzene	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---
1,2-Dichloropropane	---	---	---	---	---	---
1,3,5-Trimethylbenzene	---	---	---	---	16	---
1,3-Dichlorobenzene	---	---	---	---	---	---
1,4-Dichlorobenzene	---	---	---	---	---	---
2-Propanol	---	---	---	---	---	---
Benzene	---	---	---	---	---	---
Bromomethane	---	---	---	---	---	---
Carbon tetrachloride	---	---	---	---	---	---
Chlorobenzene	---	---	---	---	---	---
Chloroethane	---	---	---	---	---	---
Chloroform	16	38	36	---	---	42
Chloromethane	---	---	---	---	---	---
cis-1,2-Dichloroethene	---	---	---	---	---	---
Ethylbenzene	---	---	---	---	---	---
Ethylene dibromide	---	---	---	---	---	---
Freon 11	---	---	---	---	---	---
Freon 113	---	---	---	---	---	---
Freon 114	---	---	---	---	---	---
Freon 12	12	16	---	16	---	15
m,p-Xylene	---	14	---	---	17	---
Methyl tertiary-butyl ether	---	---	---	---	---	---
Methylene chloride	---	---	---	---	---	---
o-Xylene	---	---	---	---	---	---
Tetrachloroethene	82	370	56	250	240	---
Toluene	---	19	---	---	---	---
trans-1,2-Dichloroethene	---	---	---	---	---	---
Trichloroethene	---	---	---	---	---	---
Vinyl chloride	---	---	---	---	---	---
Method 3C [b] (% volume)						
Carbon dioxide	NS	NS	NS	NS	NS	12
Methane	NS	NS	NS	NS	NS	---
Nitrogen	NS	NS	NS	NS	NS	76
Oxygen	NS	NS	NS	NS	NS	11

[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   ppbv = Parts per billion by volume

Table 4. Laboratory Results
Nazareth Landfill

Compound Name	N1	N3	N3 (dup)	N6	N8
Modified Method TO-14 [a] (ppbv)					
1,1,1-Trichloroethane	15	---	86	87	28
1,1,2-Trichloroethane	---	---	---	---	---
1,1-Dichloroethane	190	7,600	7,400	---	---
1,1-Dichloroethene	---	220	220	---	---
1,2,4-Trimethylbenzene	130	3,000	3,800	14	---
1,2-Dichlorobenzene	---	---	---	---	---
1,2-Dichloroethane	---	570	560	---	---
1,2-Dichloropropane	---	240	260	---	---
1,3,5-Trimethylbenzene	55	1,500	2,000	---	---
1,3-Dichlorobenzene	---	---	---	---	---
1,4-Dichlorobenzene	15	---	130	---	---
2-Propanol	---	43,000	45,000 [b]	---	---
Benzene	---	600	610	---	---
Bromomethane	---	---	---	---	---
Carbon tetrachloride	---	---	---	---	---
Chlorobenzene	---	---	---	---	---
Chloroethane	16	1,600	1,600	---	---
Chloroform	100	---	---	50	38
Chloromethane	---	---	---	---	---
cis-1,2-Dichloroethene	17	11,000	11,000	---	---
Ethylbenzene	28	3,500	3,600	---	---
Ethylene dibromide	---	---	---	---	---
Freon 11	170	---	---	140	120
Freon 113	17	---	120	---	---
Freon 114	22	220	230	26	25
Freon 12	880	11,000	11,000	580	650
m,p-Xylene	120	9,500	10,000	---	---
Methyl tertiary-butyl ether	---	---	---	---	---
Methylene chloride	110	3,000	3,000	---	14
o-Xylene	58	3,600	4,200	---	---
Tetrachloroethene	170	1,000	1,100	37	370
Toluene	160	26,000	25,000	17	---
trans-1,2-Dichloroethene	---	---	100	---	---
Trichloroethene	150	18,000	18,000	---	100
Vinyl chloride	---	620	650	---	---
Method 3C [c] (% volume)					
Carbon dioxide	NS	29	NS	NS	NS
Methane	NS	7.3	NS	NS	NS
Nitrogen	NS	60	NS	NS	NS
Oxygen	NS	1	NS	NS	NS

[a] Detection limit for method is 5 ppbv; reporting limits vary depending on dilution factor (see laboratory results, Volume II).
[b] Exceeds instrument calibration range.
[c] Detection limit for method is 0.10 percent of volume for all analytes.
--- = Not detected NS = Not sampled ppbv = Parts per billion by volume

Because of the limited waste encountered, a sample of waste was not collected for moisture content testing.

No odors were observed from the three borings, and 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 each boring consisted of dry, light-brown, coarse sandy silt with little gravel. The results of the waste characterization borings are provided in Table 5 and the boring logs are included in Appendix A.

5.4 Landfill Gas Generation Modeling Results

This section presents the model inputs used to estimate LFG generation at the Coronado and Nazareth landfills 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 for Coronado and Nazareth Landfills are provided in Tables 6 and 7, respectively. Information was gathered from field investigations, 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 for the Coronado Landfill were chosen:

- Waste disposal history: 90,780 tons of refuse were disposed between 1963 and 1965
- L_0 values ranging from 197 ft^3/ton to 3,550 ft^3/ton
- k values ranging from 0.019/yr to 0.020/yr

Based on information gathered from field investigations, historical documents, and information provided in the RFP, the following model input parameters for the Nazareth Landfill were chosen:

Table 5. Waste Characterization Boring Summary
Coronado Landfill

Boring Number	Depth (feet)	Boring Location [a]	Depth Interval of Waste/Debris	Weight Percentages and Nature of Waste/Debris	Decomposability Rating
WC-1	12	• N 1526515 Usft. • E 1540416 Usft.	Intermittent waste at 7 feet bgs	• 8.5% Wood [b] • 2.3% Plastic • 89.2% Sandy silt	Degradable fractions • 8.5% Slow Non-degradable fractions • 2.3% Inert • 89.2% Fines
WC-2	15	• N 1526478 Usft. • E 1540339 Usft.	No waste	NA	NA
WC-3	15	• N 1526485 Usft. • E 1540263 Usft.	No waste	NA	NA

[a] New Mexico Planes Central Zone (NAD 83).
[b] Composes degradable fraction (see Table 8).

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

NA = Not applicable

Table 6. Available Information on Waste Disposal History and Volumes Coronado 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
RFP information	1963-1965	---	---	20.7	---	---	Acreage appears to include landfill areas outside of study scope. Reports a range of refuse depths of 15 to 35 feet. Subtracts an estimated cover soil depth of 4.3 feet (Engineering Solutions and Design, Inc., 2000).
Field investigation (present study)	---	10.42	7.0	1.0	16,811	8,406	2 borings found no waste, 1 boring found intermittent waste at 7 feet below ground surface (ft bgs). Acreage from drawing.
Insite Architecture + Development, 2000	---	---	---	13	218,543	109,272	Refuse thickness is average of 3 borings. Uses current study acreage for volume estimate.
Engineering Solutions and Design, Inc., 2000	---	---	4.3	8.7	145,696	72,848	Cover and refuse thickness are the average for 3 boreholes where trash found (23 boreholes drilled in southern portion of site).
Values used for present study	1963-1965	10.42	4.3	10.8	181,559	90,780	Acreage is from present study. Cover thickness is from Engineering Solutions and Design, Inc., 2000. Refuse thickness is average of RFP reported value, field-derived value, and historical reported values.

[a] Uses 10.42 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

Table 7. Available Information on Waste Disposal History and Volumes Nazareth Landfill

Source of Information	Dates of Operation	Size (acres)	Average Soil Cover Thickness (feet)	Average Refuse Thickness (feet)	Estimated Refuse Volume (cubic yards)	Estimated Waste in Place [a] (tons)	Notes
RFP information	1971-1972	7.89	---	27.0	343,863	171,931	Reports a refuse depth of 30 feet. Subtracts an assumed cover soil depth of 3 feet.
Field investigation (present study)	---	7.90	---	---	344,088	172,044	No field investigation conducted at this site. Acreage from drawings provided. Refuse volume calculated using RFP refuse thickness.
Values used for present study	1971-1972	7.90	3.0	27.0	344,088	172,044	Acreage is from present study. Cover thickness is an assumed value (3 feet). Refuse thickness is RFP value.

[a] Assumes an average in-place density equal to 1,000 pounds per cubic yard.

RFP = Request for proposal
--- = No data

- Waste disposal history: 172,044 tons of refuse were disposed of between 1971 and 1972
- L_0 values ranging from 3,204 ft^3/ton to 3,550 ft^3/ton
- k values ranging from 0.019/yr to 0.020/yr

Development of the waste disposal history, L_0 values, and k values for LFG generation modeling for the Coronado and Nazareth landfills 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 Coronado and Nazareth Landfills, several possible historical waste disposal rates were calculated for the landfills using the following data:

Coronado Landfill

- Aerial extent of the landfill in the City's RFP for this project (20.6 acres) includes the northern and southern fill areas and does not provide the acreage for the northern area only. The average waste thickness is reported to be 20.7 feet.

- Aerial extent of the landfill (10.4 acres) multiplied by average estimated refuse thickness based on information obtained from the waste characterization borings (1 foot), which yields 16,811 cubic yards.

- Aerial extent of the landfill (10.4 acres) multiplied by the average thickness derived from a combination of field values from this investigation and historical studies (10.8 feet), which yields 181,559 cubic yards.

- Historical studies, which indicate the refuse thickness in the range of 8.7 feet (Engineering Solutions and Design, Inc., 2000) to 13 feet (Insite Architects + Development, 2000) and yield refuse volumes in the range of 145,696 cubic yards to 218,543 cubic yards.

Additional assumptions used for the study include:

- The years of disposal reported in the RFP (1963 to 1965)
- An estimated average refuse density of 1,000 lbs/yd^3

Nazareth Landfill

- Aerial extent of the landfill (7.89 acres) multiplied by the average waste thickness provided in the City's RFP for this project (27.0 feet), which yields 343,863 cubic yards.

- Aerial extent of the landfill (7.90 acres) from the present study multiplied by the average waste thickness provided in the City's RFP for this project (27.0 feet), which yields 344,088 cubic yards.

Additional assumptions used for the study include:

- The years of disposal reported in the RFP (1971 to 1972)
- An estimated average refuse density of 1,000 lbs/yd^3

Tables 6 and 7 show a range of in-place volume of waste based on the above information. For modeling the LFG generation for the Coronado and Nazareth Landfills, disposal volumes of 181,559 cubic yards (90,780 tons) of refuse, and 344,088 cubic yards (172,044 tons) of refuse were used, respectively.

5.4.1.2 Ultimate Methane Generation Rate (L_0)

As outlined in Section 2.7.2, L_0 values used for LFG generation model runs for these landfills were assigned one of the following 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]).

- For the Coronado Landfill only, a site-calibrated L_0 value of 197 ft^3/ton based on the amount of degradable refuse found in the waste characterization borings. This value was compared with 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 Coronado 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. Because the fraction of degradable refuse analyzed at Coronado Landfill was lower than the typical value, the site-calibrated L_0 was adjusted downward to 197 ft^3/ton. This adjustment is shown in Table 8.

The Nazareth Landfill was not included in the waste characterization study and waste sampling data are not available to indicate the percentage of degradable waste. Therefore, only default L_0 values were used as LandGEM input.

Table 8. Derivation of a Site-Calibrated L_0 Value for Coronado Landfill

Avg. Age of Landfill Refuse (years)	Typical MSW Degradable Fraction [a]	Site Average 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)
37	51%	2.83%	0.056	3,550	197

[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] Represents the average of samples from WC-1 (8.5% degradable waste), WC-2 (0% degradable waste), and WC-3 (0% degradable waste) (see Table 5).

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)

The methane generation rate constant (k) values used for the LFG generation model runs for the Coronado and Nazareth Landfills were one of the following:

- 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 value of 0.019 per year for the Albuquerque region.

5.4.2 Model Validation Results

Validation of LandGEM's application to the Coronado and Nazareth Landfills 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 Coronado and Nazareth Landfills.

Use of site-calibrated k and L_0 values also supports the validity of LandGEM results. The site-calibrated L_0 value of 197 ft^3/ton (compared to default of 3,550 ft^3/ton) is based on a much lower than typical degradable waste content of 2.8 percent (compared to national average of 51 percent). Adjusting LandGEM input parameters in this manner to reflect site-specific conditions for the Coronado Landfill should provide reasonable estimates of the LFG generation rate.

5.4.3 LFG Generation Model Results

5.4.3.1 Coronado Landfill

Model results are provided in Table 9 and Figure 7, which show estimated LFG generation through 2020 at the Coronado Landfill for three different scenarios. Table 9 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.

All projections show LFG generation reaching a peak in 1966, one year following landfill closure, and declining at a rate of approximately 2 percent annually thereafter. LFG generation in 2002 is estimated to range between 0.6 and 11.3 scfm. The highest generation rates occur under the

Table 9. LFG Generation Projections
Coronado Landfill
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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)	
			scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day
Methane content of LFG adjusted to:			*50%*		*50%*		*50%*	
Methane generation rate constant [illegible]			*[illegible]02*		*0.019*		*0.019*	
Ultimate methane generation rate (L_0):			*3,204* [a]		*3,550* [a]		*197* [a]	
1963	30,260	30,260	0.0	0.000	0.0	0.000	0.0	0.000
1964	30,260	60,520	7.2	0.010	7.6	0.011	0.4	0.001
1965	30,260	90,780	14.3	0.021	15.1	0.022	0.8	0.001
1966	0	90,780	21.3	0.031	22.4	0.032	1.2	0.002
1967	0	90,780	20.8	0.030	22.0	0.032	1.2	0.002
1968	0	90,780	20.4	0.029	21.6	0.031	1.2	0.002
1969	0	90,780	20.0	0.029	21.2	0.031	1.2	0.002
1970	0	90,780	19.6	0.028	20.8	0.030	1.2	0.002
1971	0	90,780	19.2	0.028	20.4	0.029	1.1	0.002
1972	0	90,780	18.9	0.027	20.0	0.029	1.1	0.002
1973	0	90,780	18.5	0.027	19.6	0.028	1.1	0.002
1974	0	90,780	18.1	0.026	19.3	0.028	1.1	0.002
1975	0	90,780	17.8	0.026	18.9	0.027	1.1	0.002
1976	0	90,780	17.4	0.025	18.6	0.027	1.0	0.001
1977	0	90,780	17.1	0.025	18.2	0.026	1.0	0.001
1978	0	90,780	16.7	0.024	17.9	0.026	1.0	0.001
1979	0	90,780	16.4	0.024	17.5	0.025	1.0	0.001
1980	0	90,780	16.1	0.023	17.2	0.025	1.0	0.001
1981	0	90,780	15.8	0.023	16.9	0.024	0.9	0.001
1982	0	90,780	15.4	0.022	16.6	0.024	0.9	0.001
1983	0	90,780	15.1	0.022	16.2	0.023	0.9	0.001
1984	0	90,780	14.8	0.021	15.9	0.023	0.9	0.001
1985	0	90,780	14.5	0.021	15.6	0.023	0.9	0.001
1986	0	90,780	14.3	0.021	15.3	0.022	0.9	0.001
1987	0	90,780	14.0	0.020	15.1	0.022	0.8	0.001
1988	0	90,780	13.7	0.020	14.8	0.021	0.8	0.001
1989	0	90,780	13.4	0.019	14.5	0.021	0.8	0.001
1990	0	90,780	13.2	0.019	14.2	0.020	0.8	0.001
1991	0	90,780	12.9	0.019	14.0	0.020	0.8	0.001
1992	0	90,780	12.6	0.018	13.7	0.020	0.8	0.001
1993	0	90,780	12.4	0.018	13.4	0.019	0.7	0.001

[a] Cubic feet per ton.

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

Table 9. LFG Generation Projections
Coronado Landfill
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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
Methane content of LFG adjusted to:			*50%*		*50%*		*50%*	
Methane generation rate constant (k):			*0.020*		*0.019*		*0.019*	
Ultimate methane generation rate (L_0):			*3,204* [a]		*3,550* [a]		*197* [a]	
1994	0	90,780	12.1	0.017	13.2	0.019	0.7	0.001
1995	0	90,780	11.9	0.017	12.9	0.019	0.7	0.001
1996	0	90,780	11.7	0.017	12.7	0.018	0.7	0.001
1997	0	90,780	11.4	0.016	12.4	0.018	0.7	0.001
1998	0	90,780	11.2	0.016	12.2	0.018	0.7	0.001
1999	0	90,780	11.0	0.016	12.0	0.017	0.7	0.001
2000	0	90,780	10.8	0.016	11.8	0.017	0.7	0.001
2001	0	90,780	10.6	0.015	11.5	0.017	0.6	0.001
2002	0	90,780	10.4	0.015	11.3	0.016	0.6	0.001
2003	0	90,780	10.1	0.015	11.1	0.016	0.6	0.001
2004	0	90,780	9.9	0.014	10.9	0.016	0.6	0.001
2005	0	90,780	9.8	0.014	10.7	0.015	0.6	0.001
2006	0	90,780	9.6	0.014	10.5	0.015	0.6	0.001
2007	0	90,780	9.4	0.013	10.3	0.015	0.6	0.001
2008	0	90,780	9.2	0.013	10.1	0.015	0.6	0.001
2009	0	90,780	9.0	0.013	9.9	0.014	0.6	0.001
2010	0	90,780	8.8	0.013	9.7	0.014	0.5	0.001
2011	0	90,780	8.6	0.012	9.5	0.014	0.5	0.001
2012	0	90,780	8.5	0.012	9.4	0.013	0.5	0.001
2013	0	90,780	8.3	0.012	9.2	0.013	0.5	0.001
2014	0	90,780	8.1	0.012	9.0	0.013	0.5	0.001
2015	0	90,780	8.0	0.011	8.8	0.013	0.5	0.001
2016	0	90,780	7.8	0.011	8.7	0.012	0.5	0.001
2017	0	90,780	7.7	0.011	8.5	0.012	0.5	0.001
2018	0	90,780	7.5	0.011	8.4	0.012	0.5	0.001
2019	0	90,780	7.4	0.011	8.2	0.012	0.5	0.001
2020	0	90,780	7.2	0.010	8.0	0.012	0.4	0.001

[a] Cubic feet per ton.

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

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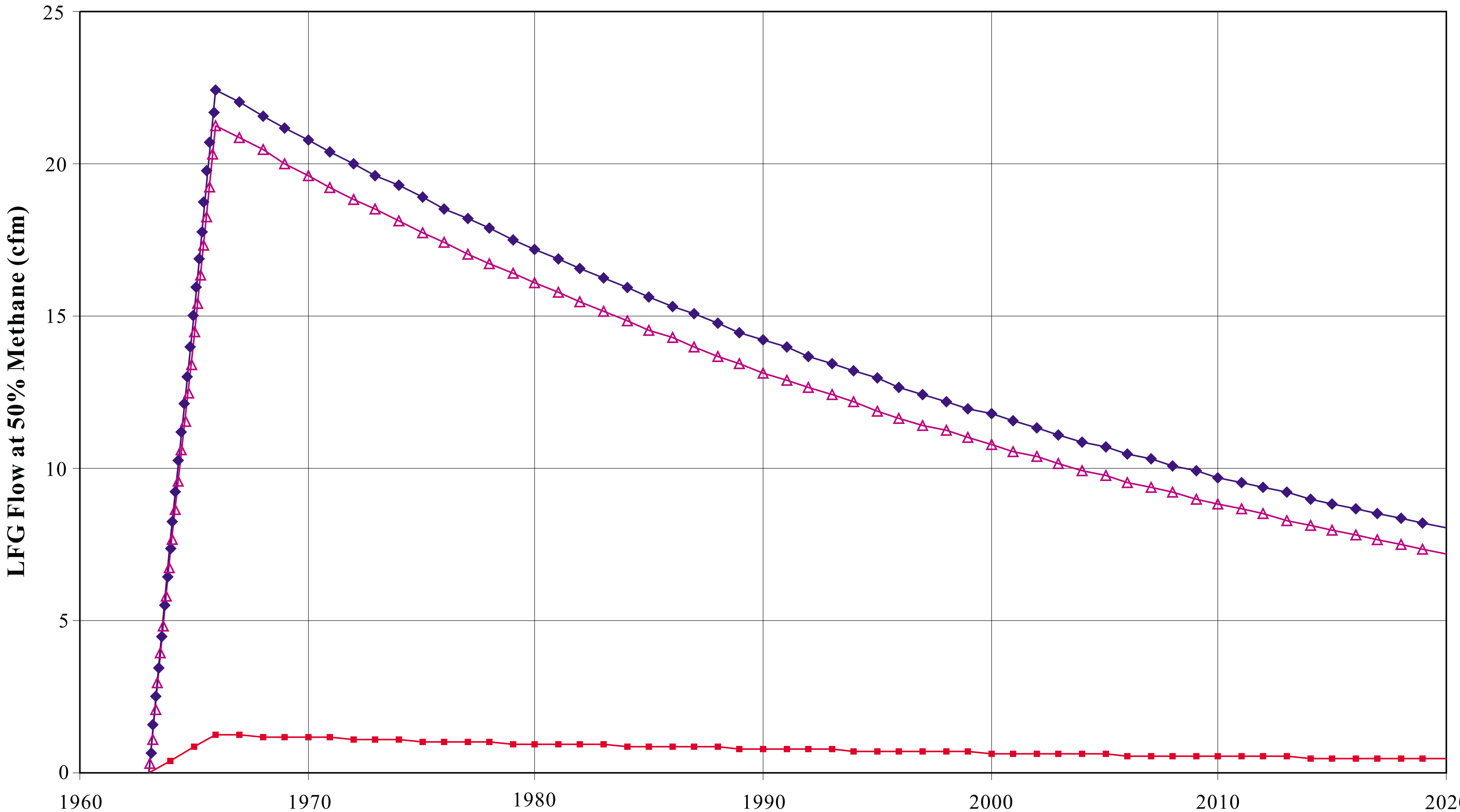

Explanation

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 k = 0.019 Lo = 197 cu.ft./ton

Source: SCS Engineers

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Coronado Landfill
LFG Generation Projection

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Figure 7

SCS default projection, which uses the highest L_0 value of any projection. The lowest generation rates occur under the site-calibrated projection, which uses a L_0 value (197 ft^3/ton) that has been discounted by approximately 94 percent from the SCS default L_0 based on the fraction of degradable waste found in waste samples taken in the field.

5.4.3.2 Nazareth Landfill

Model results are provided in Table 10 and Figure 8, which show estimated LFG generation through 2020 at the Nazareth Landfill for two different scenarios. Table 10 also provides the estimated disposal rates and the k and L_0 values used for each projection. No site-calibrated projection is provided since this study did not include field investigation at this landfill. 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.

Both projections show LFG generation reaching a peak in 1973, one year following landfill closure, and declining at a rate of approximately 2 percent annually thereafter. LFG generation in 2002 is estimated to lie between 23 and 25 scfm. The SCS default projection is slightly higher than the EPA (AP-42) default projection since it uses a higher L_0 value.

Table 10. LFG Generation Projections
Nazareth Landfill
Page 1 of 2

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation: Projection 1 (EPA default values) scfm	Projection 1 (EPA default values) Mcf/day	Projection 2 (SCS default values) scfm	Projection 2 (SCS default values) Mcf/day
Methane content of LFG adjusted to:			*50%*		*50%*	
Methane generation rate constant (k):			*0.020*		*0.019*	
Ultimate methane generation rate (L_0):			*3,204* [a]		*3,550* [a]	
1971	86,022	86,022	0	0.000	0	0.000
1972	86,022	172,044	21	0.030	22	0.031
1973	0	172,044	41	0.059	43	0.062
1974	0	172,044	40	0.057	42	0.061
1975	0	172,044	39	0.056	41	0.059
1976	0	172,044	38	0.055	41	0.058
1977	0	172,044	38	0.054	40	0.057
1978	0	172,044	37	0.053	39	0.056
1979	0	172,044	36	0.052	38	0.055
1980	0	172,044	35	0.051	38	0.054
1981	0	172,044	35	0.050	37	0.053
1982	0	172,044	34	0.049	36	0.052
1983	0	172,044	33	0.048	35	0.051
1984	0	172,044	33	0.047	35	0.050
1985	0	172,044	32	0.046	34	0.049
1986	0	172,044	31	0.045	34	0.048
1987	0	172,044	31	0.044	33	0.047
1988	0	172,044	30	0.043	32	0.046
1989	0	172,044	30	0.043	32	0.046
1990	0	172,044	29	0.042	31	0.045
1991	0	172,044	28	0.041	30	0.044
1992	0	172,044	28	0.040	30	0.043
1993	0	172,044	27	0.039	29	0.042
1994	0	172,044	27	0.039	29	0.041
1995	0	172,044	26	0.038	28	0.041
1996	0	172,044	26	0.037	28	0.040
1997	0	172,044	25	0.036	27	0.039
1998	0	172,044	25	0.036	27	0.038
1999	0	172,044	24	0.035	26	0.038
2000	0	172,044	24	0.034	26	0.037
2001	0	172,044	23	0.033	25	0.036

[a] Cubic feet per ton.

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

Table 10. LFG Generation Projections
Nazareth Landfill
Page 2 of 2

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation: Projection 1 (EPA default values) scfm	LFG Generation: Projection 1 (EPA default values) Mcf/day	LFG Generation: Projection 2 (SCS default values) scfm	LFG Generation: Projection 2 (SCS default values) Mcf/day
Methane content of LFG adjusted to:			*50%*		*50%*	
Methane generation rate constant (k):			*0.020*		*0.019*	
Ultimate methane generation rate (L_0):			*3,204* [a]		*3,550* [a]	
2002	0	172,044	23	0.033	25	0.036
2003	0	172,044	22	0.032	24	0.035
2004	0	172,044	22	0.032	24	0.034
2005	0	172,044	21	0.031	23	0.034
2006	0	172,044	21	0.030	23	0.033
2007	0	172,044	21	0.030	22	0.032
2008	0	172,044	20	0.029	22	0.032
2009	0	172,044	20	0.029	22	0.031
2010	0	172,044	19	0.028	21	0.031
2011	0	172,044	19	0.027	21	0.030
2012	0	172,044	19	0.027	20	0.029
2013	0	172,044	18	0.026	20	0.029
2014	0	172,044	18	0.026	20	0.028
2015	0	172,044	18	0.025	19	0.028
2016	0	172,044	17	0.025	19	0.027
2017	0	172,044	17	0.024	19	0.027
2018	0	172,044	17	0.024	18	0.026
2019	0	172,044	16	0.023	18	0.026
2020	0	172,044	16	0.023	18	0.025

[a] Cubic feet per ton.

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

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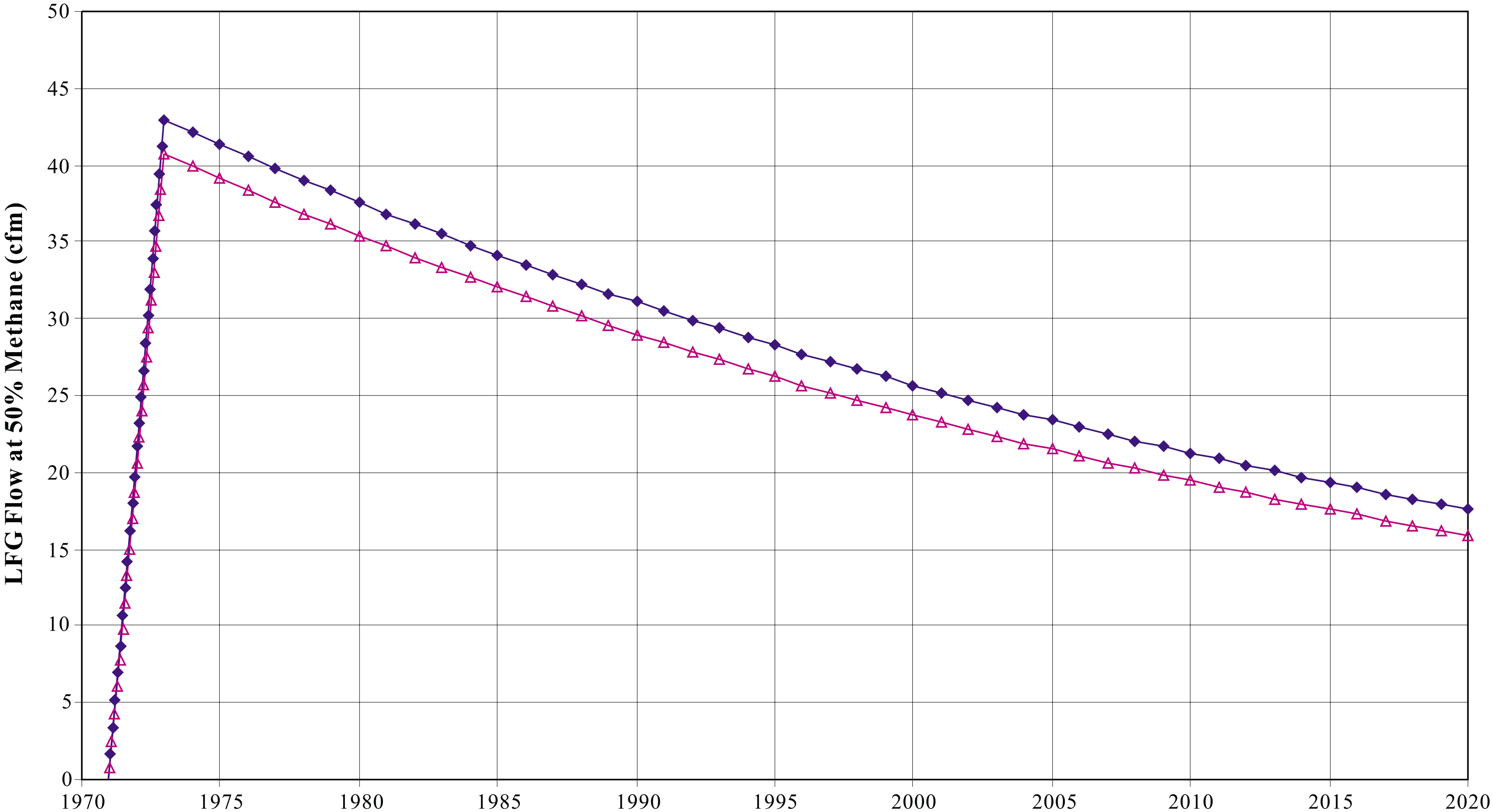

Explanation

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

Source: SCS Engineers

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Nazareth Landfill
LFG Generation Projection

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Figure 8

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 Coronado and Nazareth Landfills 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 Coronado and Nazareth Landfills:

- Based on the modeling results, the peak year for LFG generation at the Coronado Landfill was 1966 and at the Nazareth Landfill was 1973.

- The estimated LFG generation rate for the Coronado and Nazareth Landfills indicates that the production of LFG is steadily declining in its current state. The projected LFG generation rate for 2002 for the Coronado Landfill ranges from 0.6 to 11.3 scfm and for the Nazareth Landfill ranges from 23 to 25 scfm.

- Due to the small volumes of LFG predicted to be generated at both the Coronado and Nazareth Landfills, the potential for significant volumes of LFG to migrate off-site is low.

- The LFG survey did not detect measurable methane in any of the 12 gas probes installed at Coronado Landfill. Waste was encountered in only one of the three waste characterization borings drilled to depths of 12 to 15 feet bgs, and the only waste encountered contained a small fraction (5 percent by volume) of degradable material.

- The LFG survey detected relatively low methane concentrations at the Nazareth Landfill. Methane concentrations ranging from 0 to 0.5 percent were measured in seven gas probes. A higher methane concentration of 7.9 percent was measured in one gas probe, indicating a methane concentration exceeding 100 percent of the LEL in the central portion of the Nazareth Landfill.

- VOCs were detected in LFG gas samples collected at both the Coronado and Nazareth Landfills; however, at this time insufficient data exist to form conclusions concerning potential impacts to public health. VOC concentrations were much higher at Nazareth than at Coronado.

6.2 Recommendations

Based on the data and analyses discussed, the following recommendations are provided to address LFG issues relevant to the Coronado and Nazareth Landfills.

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 LFG monitoring plans, as described below.

- *LFG monitoring plan.* The City should consider developing LFG monitoring plans for the Coronado and Nazareth Landfills to assess potential offsite migration of LFG. The plans 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. The need for any monitoring on City property on the west side and a portion of the north side of the Nazareth Landfill should be considered based on the City's control of land use on this adjacent property. 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 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 both the Coronado and Nazareth Landfills in the City's *Interim Guidelines for Development near Landfills.*

  - *Reduction of setbacks.* It is recommended that the setback distance be reduced at both the Coronado and Nazareth Landfills. This recommendation is contingent on implementing the LFG monitoring plan described above. It is recommended that the setback distance be reduced to a provisional limit of 250 feet at the Coronado Landfill, based on the absence of methane during the LFG survey. It is recommended that the setback distance be reduced to a provisional limit of 500 feet at the Nazareth Landfill, based on the relatively low levels of methane found during the LFG survey. Since one gas probe had a methane concentration exceeding 100 percent of the LEL and projected LFG generation rates are higher at Nazareth, a greater setback distance is appropriate.

    Maintaining the minimum 250- or 500-foot setback distance is recommended because the landfills 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, installing 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 buffer zone reduction.* The recommended buffer zone 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 comprehensive landfill management plans for the Coronado and Nazareth Landfills. The landfill management plans should include 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 these limits for three consecutive months, the City should immediately develop and implement a LFG control plan. Since the City owns the property on the west side and a portion of the north side of the Nazareth Landfill, institutional control of the land use in these areas may constitute suitable LFG controls, even if LFG concentrations exceed the limits stated above. If institutional controls are not implemented, 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.

- *Utility investigation.* Selected subsurface utilities should be monitored for the presence of LFG and included with the quarterly monitoring program discussed above. Buried utilities exist over a portion of the Nazareth Landfill, some of which are used only for about one month each year during the Albuquerque Balloon Fiesta. Utilities should be investigated on and around the Coronado and Nazareth Landfills 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 Coronado or Nazareth Landfills, 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 landfill covers at both the Coronado and Nazareth Landfills provide reasonably good positive drainage. The Coronado Landfill has a potential for impacts from storm water flow in arroyos causing seepage into the waste or potential erosion damage, particularly along small drainages on the south side of the landfill. It is recommended that the City consider undertaking a site drainage study for both the Coronado and Nazareth Landfills to determine existing drainage patterns and identify needs for possible improvements.

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