Conf-9204110--2

Prioritization to Limit Sampling and Drilling in Site Investigations

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ANL/CP--74721

DE92 010513

ABSTRACT

Analytical work and drilling are two of the most expensive and intrusive activities undertaken in preremedial site characterization programs. These activities often begin with little information on the site. In a rush to generate analytical data and with little thought for the geologic setting and site history, geophysical programs often begin early in a program and use only one method. However, site characteristics generated from overlapping, integrated data sets obtained by multiple methods can be used with greater confidence.

For the New Mexico Bureau of Land Management, Argonne National Laboratory recently completed preremedial site characterization programs for landfills thought to contain hazardous wastes. The purpose of the programs was not only to conduct the investigations but also to establish a sound technical framework for future site investigations in that geologic setting. The emphasis was on identifying initial characterization procedures that would decrease the need for sampling and drilling on a random grid. This strategy is similar to that successfully used in exploration programs for petroleum and minerals, in which existing geology and surface geophysical techniques are used to prioritize sites.

The first step in the programs was the generation of sound geological and site history models that guided the selection of appropriate geophysical techniques. Geological features that influenced the selection of geophysical

techniques included the potential presence of bedrock near the surface and of thick clay lenses in the subsurface.

Significant results of the programs include the following: (1) Previously unmapped trenches and pits were located. (2) The principal controls on the subsurface migration pathways for contaminants were delimited, and critical sampling locations were identified. (3) The identification of confined and unconfined aquifers within the landfill significantly reduced the size of the sampling target. (4) The use of multiple geophysical techniques allowed the accurate prediction of water table levels and geologic features such as faults and confining clays. (5) Five monitoring wells were installed, in contrast to previous estimates of 11.

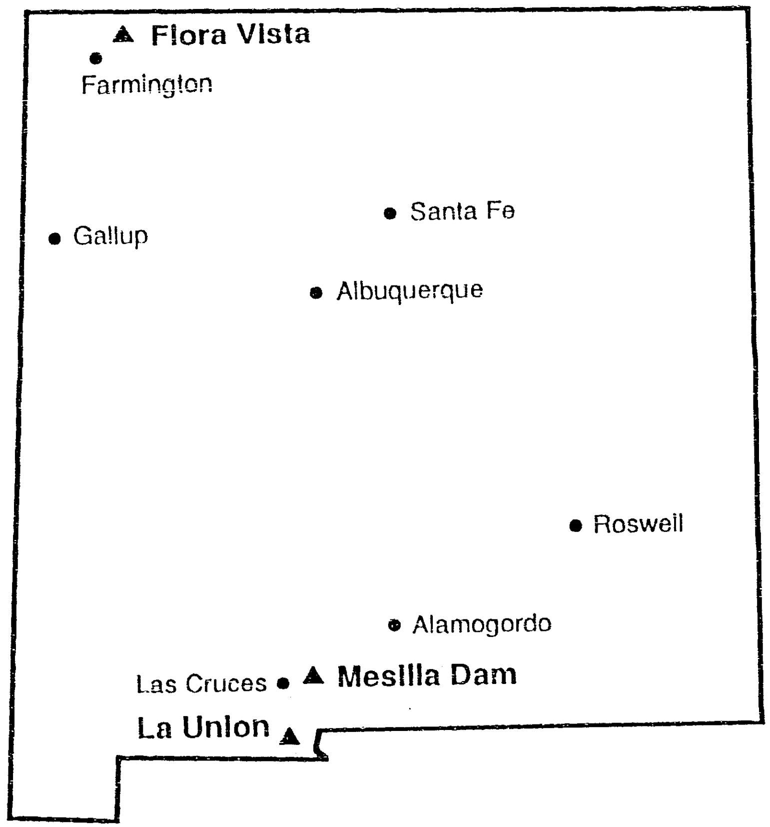
INTRODUCTION

One of the major goals of the Environmental Research Division of Argonne National Laboratory is to develop and provide governmental agencies with technically sound, cost-effective frameworks for environmental site characterization and remedial programs. An example of the development of such a framework for preremedial site characterization is presented in this paper. Specifically, this paper presents portions of an expanded site investigation program developed for landfills suspected of containing hazardous waste. The work was sponsored by the New Mexico State Office of the U.S. Department of Interior's Bureau of Land Management (BLM).

The emphasis of the BLM program was on identifying initial characterization procedures that would decrease the need for sampling and drilling on a random grid. Little written documentation was available on the placement of trenches and pits or the disposal history of the landfills. Therefore, an approach was required that would yield maximum information on the sites via nonintrusive technologies before any type of drilling began. The strategy used in the development of the BLM program is similar to that successfully used in exploration programs for petroleum and minerals, in which existing geology and surface geophysical techniques are used to prioritize drill sites. Multiple surface geophysical techniques in combination with geological interpretations based on regional geological data were used to provide maximal information on different aspects of the site as well as integrated proofs of specific features. For example, if three techniques rather than one indicate that groundwater is at 150 ft beneath the surface at the site or that a clay unit is present at 30 ft, greater confidence can be given to that prediction.

In addition to using this multidisciplinary, integrated approach to data gathering, experienced technical staff were present in the field to analyze data in real time and to alter and redirect the field program as needed to maximize its effectiveness. The importance of deploying technically qualified teams during the field program cannot be overemphasized. The capability to alter and switch emphases and even methodologies during a field program saves both cost and time. Because geophysical and geological data were interpreted in the field during the initial phases of the program, Argonne staff could proceed to the next phase of the program (e.g., selection of various sampling locations) almost immediately, with little down time. For example, soil gas sampling locations for the landfills were chosen, and probes were installed as the first phase of the sampling program within two to three days of completion of the surface geophysical investigations.

The locations of the three BLM landfills investigated by Argonne are shown in Figure 1. This paper will specifically illustrate how the geophysical and known regional geological data were integrated to prioritize


Flora Vista
Farmington
Gallup
Santa Fe
Albuquerque
Roswell
Alamogordo
Las Cruces
Mesilla Dam
La Union

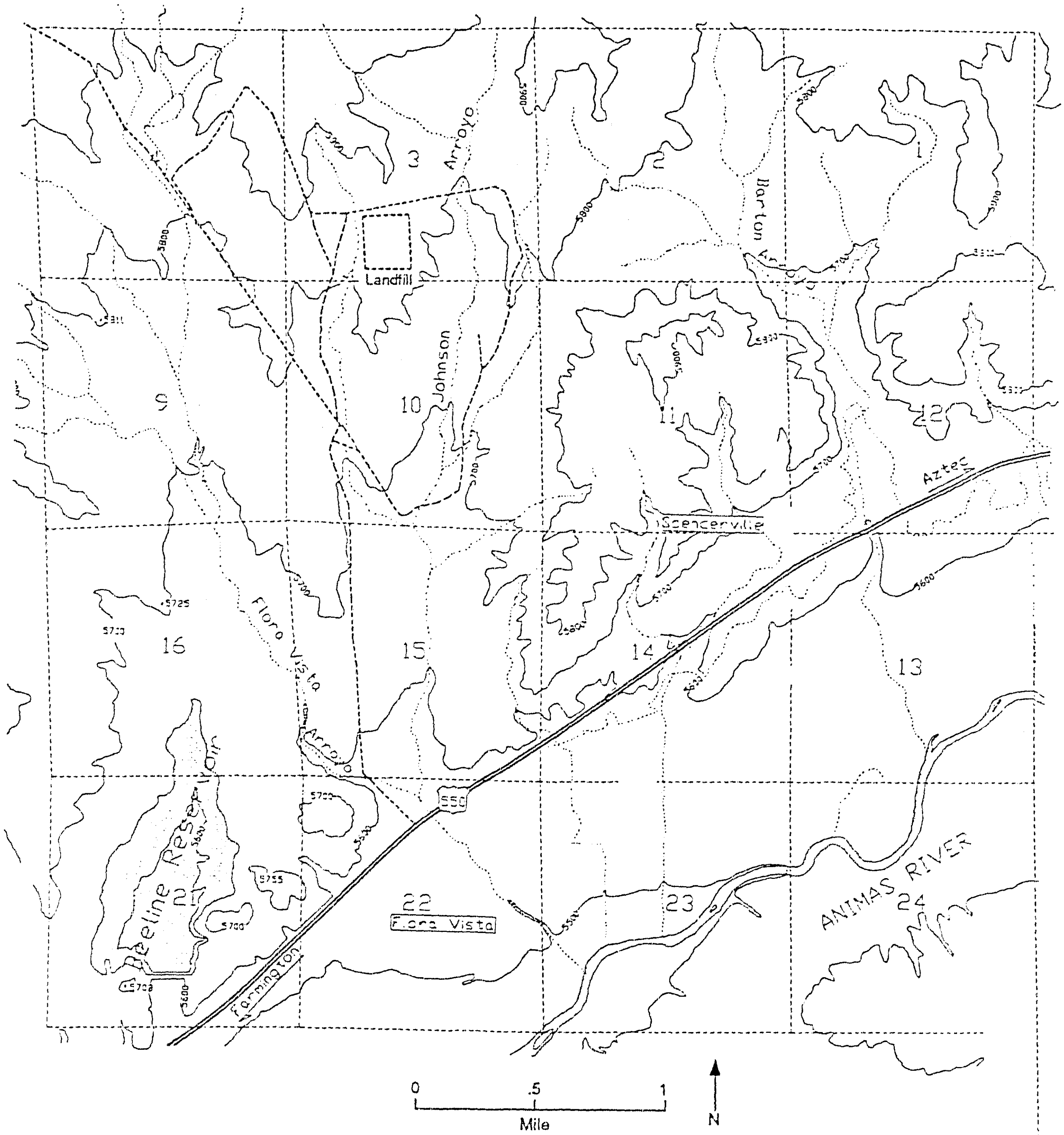
sampling and drilling sites for the Flora Vista and Mesilla Dam Landfills. In addition, data from Mesilla Dam yielded information on optimal techniques for mapping different aquifer types in that particular geologic setting.

LANDFILL SETTINGS AND HISTORIES

Flora Vista Landfill

The Flora Vista Landfill is an inactive landfill located approximately 5 miles west of Aztec and approximately 6 miles northeast of Farmington in San Juan County, New Mexico (Figure 2). Spencerville subdivision is approximately 1.8 miles southeast of the site, and the nearest residence is 1.2 miles south of the landfill. The Animas River is approximately 1.8 miles southeast of the site. The landfill covers 13 acres and is a modified sanitary (not covered daily) landfill that was leased and used by San Juan County from July 1978 through 1989. The State of New Mexico Environmental Improvement Division (NM EID) alleged in 1986 that large quantities of petroleum, industrial, or other hazardous waste had been deposited at Flora Vista Landfill between the 1970s and August 1985. These wastes were supposedly deposited in septage waste pits at the site without BLM authorization.

The BLM authorized both a preliminary assessment (PA) in 1986 and a site investigation (SI) in 1987 by private contractors. Both contractors generated maps of previously covered trenches and pits. However, these maps yielded conflicting results that Argonne could not readily explain because of the paucity of written records for the landfill. Surface and subsurface soil samples were collected during the PA and SI programs. Analytical results from both the PA and SI sampling indicated the presence of some hazardous compounds (tetrachloroethylene, toluene, benzene, acetone, 4-methylphenol, 1,1,1-trichloroethane, etc.) in one septage pit area of the landfill. In



Landfill
Arroyo
Johnson
Barton Arroyo
Aztec
Spencerville
Flora Vista Arroyo
Beeline Reservoir
Farmington
550
Flora Vista
ANIMAS RIVER
1
2
3
9
10
11
12
13
14
15
16
21
22
23
24
5900
5800
5700
5600
5725
5755
0
.5
1
Mile
N

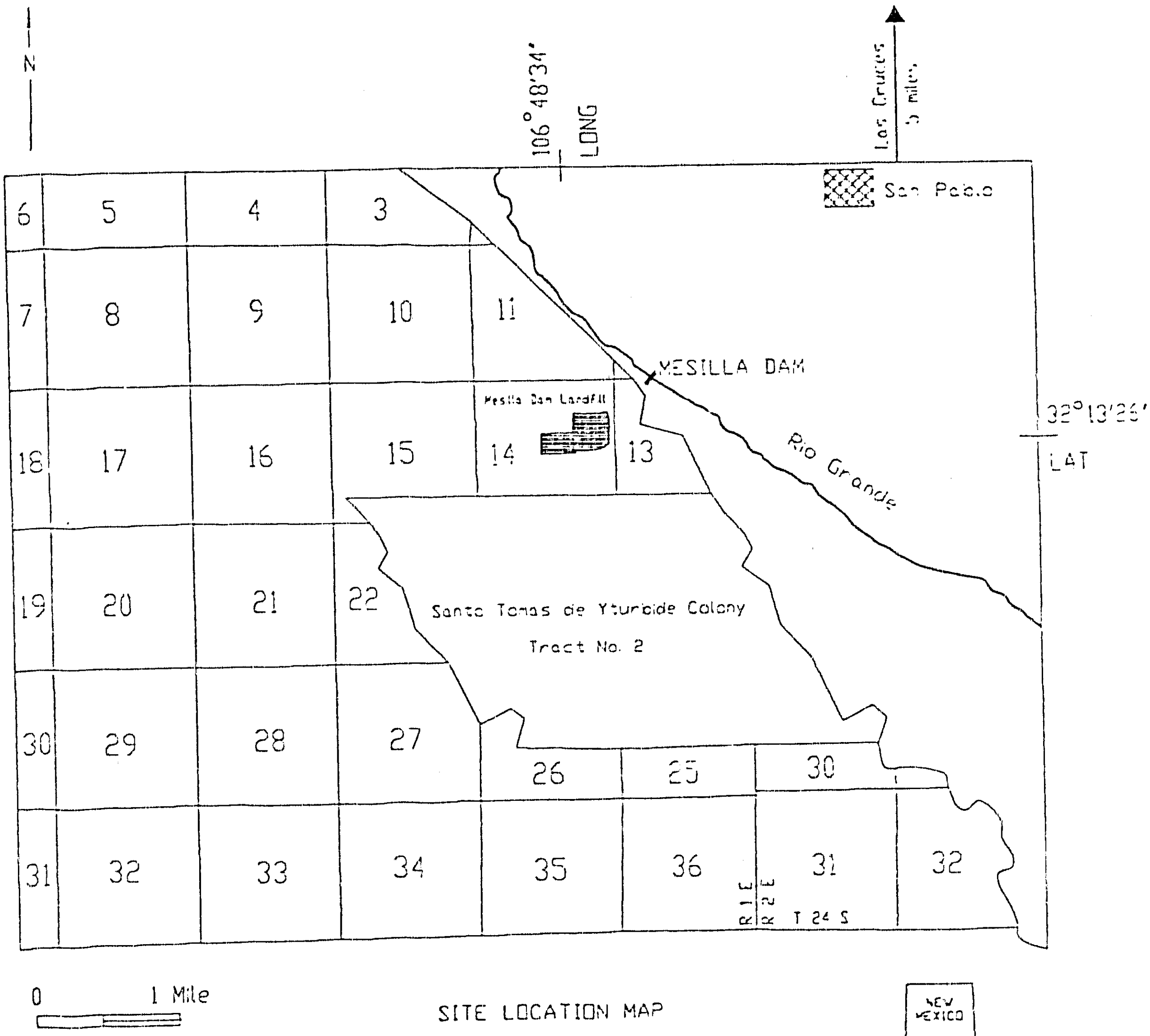
Figure 2

addition, the site investigation results were interpreted by the contractor as indicating possible lateral ·d vertical migration from this pit. Recommendations of the SI included the drilling of five monitoring wells at the site. On the basis of the results of the PA and SI, operation of the landfill was suspended, and the landfill was covered with approximately 2 ft of sandy soil. Argonne was then asked to initiate an expanded site investigation to determine if remediation of the landfill was required.

Mesilla Dam Landfill

The Mesilla Dam Landfill is an inactive landfill located approximately 8 miles southwest of Las Cruces, New Mexico, and approximately 0.5 miles southwest of the Mesilla Dam on the Rio Grande (Figure 3). The landfill is approximately 80 acres in size. The Mesilla Dam Landfill was operated by the Dona Ana County Board of County Commissioners from 1963 to 1988. The primary materials dumped at the landfill were agricultural and municipal wastes including excess agriculture crops (onions, peppers, chiles) (verbal communication, NM EID). Pits were dug in some areas of the landfill for septage wastes and waste water from grease racks, wash racks, etc. However, just as for the Flora Vista Landfill, written records of the disposal history at the site were very limited, and the exact locations of most of the pits were not recorded.

Because of suspected unauthorized dumping of industrial waste at other nearby BLM landfills, both a PA (1988) and an SI (1989) were conducted for the BLM by a private contractor at the Mesilla Dam site. Soil samples from the landfill and water samples from private wells in the vicinity of the landfill were collected for analysis during the PA and SI investigations. Although concentrations of compounds and elements did not exceed New Mexico water



SITE LOCATION MAP

MESILLA DAM LANDFILL

MESILLA, NEW MEXICO

Figure 3

quality standards for the well samples analyzed, elevated concentrations of lead, zinc, chromium, and arsenic were found in soil samples from one septage pit. Toluene, bis(2-ethylhexyl)phthalate, 1,1-dichloroethene, bromodichloromethane, and trichloroethene were found in other soil samples. No conclusions about contaminant migration patterns from the landfill could be generated from the data. Because of the proximity of the Mesilla Dam Landfill to a major river and the presence at the site of some hazardous elements and compounds, the BLM asked Argonne to include the site in the expanded site investigation program to determine if any remedial actions were required.

INVESTIGATION METHODOLOGY AND TECHNIQUE DESCRIPTIONS

The expanded site investigation was designed as a three-phase program. The first phase consisted of geological and geophysical investigations to identify source areas (previously unmapped trench and pit areas, contaminant plumes) and migration pathways (subsurface-bedrock, groundwater levels, aquitards; surface-arroyos, topographic relief). This information was then used to select sampling locations for the second phase of the program, testing for migration from source areas. The third phase incorporated data from the first two phases to locate monitoring wells as necessary for each site.

Only the results of the first phase of the program for the Flora Vista and Mesilla Dam Landfills are presented in this paper. In addition to using all available data for geological and site history reconstructions, four surface geophysical investigations were conducted. Seismic refraction, magnetics, electromagnetics, and resistivity surveys were conducted at all sites. The types of information targeted by each technique are the following:

- Seismic refraction -- delineate subsurface lithologies and water table

- Electromagnetics (frequency and time domain) -- define buried trench and pit boundaries; map conductive plumes; delineate subsurface lithologic features; define water table
- Magnetics -- map buried trenches
- Resistivity -- establish lithologic characteristics and water table

Seismic Refraction

Reversed seismic profiles were shot at 62 locations at the Flora Vista Landfill with an EG&G Geometrics 1225, 12-channel seismograph. Three cables with geophone takeout spacings of 50 ft, 16.2 ft (5 m), and 10 ft were used to extract information on velocities and depths from the surface to approximately 160 ft. Energy sources included 500-mg shotgun shells triggered with an electric blaster for the 650-ft spreads and 16-lb sledge hammer blows for the two shorter spreads. First-break times were hand-picked off the monitor screen, and times were then entered into the EG&G Geometrics software code "Seisview." The seismic refraction survey at the Mesilla Dam Landfill followed similar procedures to those used at Flora Vista with the following exceptions. Reversed seismic refraction profiles were shot at 39 locations. Two cables with geophone takeout spacings of 50 ft (650 ft from forward to reversed shot) and 16.2 ft (213.2 ft from forward to reversed shot) were used to obtain information on seismic velocities and depths from the surface to the top of the zone of saturation. Energy sources used included dynamite, electric blasting caps, shotgun shells, and 16-lb sledge hammer blows.

Electromagnetics

Frequency domain instruments used included the Geonics EM 31 and EM 34. Measurements with the EM 31 were taken at 10-ft station intervals along selected grid lines at both the Flora Vista and Mesilla Dam Landfills. The effective exploration depth of the EM 31 in this setting is approximately 15 ft. The EM 34 measurements were taken at 25-ft station intervals along selected grid lines for both landfills. Measurements were taken at a 20-m coil spacing with the coils in a vertical, coplanar orientation. The exploration depth of the EM 34 with this coil spacing is approximately 50 ft.

The time domain instrument used in the program was the Geonics EM 37/47. The EM 37/47 measurements were made at both landfills by using 100-ft by 100-ft transmitter loops. The EM 37/47 soundings were made at base frequencies of 30 Hz and 300 Hz, with a receiver coil with an effective area of 31.4 m^2. In the center of the transmitter loops, the electromotive force (emf) due to the changing vertical magnetic field was measured, at several amplifier gains, at two receiver polarities, and at two base frequencies. All data were stored in the field on a DAS-54 solid state memory logger. Stored EM 37/47 data were transferred at the end of each field day to a computer. The first step in data processing was construction of a decay curve of emf by combining the averaging transients collected at different gains and base frequencies. The resulting decay curve was subsequently entered into an Automatic Ridge Regressional Transient Inversion (ATTRI) program.

Magnetics

An EDA total field magnetometer was used to acquire 900 total-field-intensity data points within the landfill at Flora Vista and 1,726 total-field-intensity data points at Mesilla Dam. At Flora Vista, magnetic stations were occupied at 10-ft intervals along east-west traverses and three north-south tie lines. Traverses were 100 ft apart on the east-west lines and 200 ft apart on the north-south lines. Because of its size, the Mesilla Dam Landfill could not be surveyed on as tight a grid as Flora Vista. North-south magnetic profiles were run 100 ft apart inside the area known to contain a septage pit at Mesilla Dam, whereas north-south lines were spaced 350 ft apart outside the fence. Several east-west tie lines were established outside the fence as well. Diurnal variations were established for each site. Total magnetic field data for each site were contoured with Golden Software "SURF." Station density and line spacing were such that the continuity of anomalies, particularly with the tie line date, was easily seen in the contour trends.

Resistivity

Electrical depth soundings at both landfills were made with an ABEM Terrameter and booster. The expanding-electrode Schlumberger configuration was used at both sites. Three locations immediately outside the Flora Vista Landfill were surveyed, as were 11 locations in and around the Mesilla Dam Landfill. Data were interpreted by using two software techniques, one by the U.S. Geological Survey (Zohdy, 1973) and one by INTERPEX (RESIX PLUS, 1988).

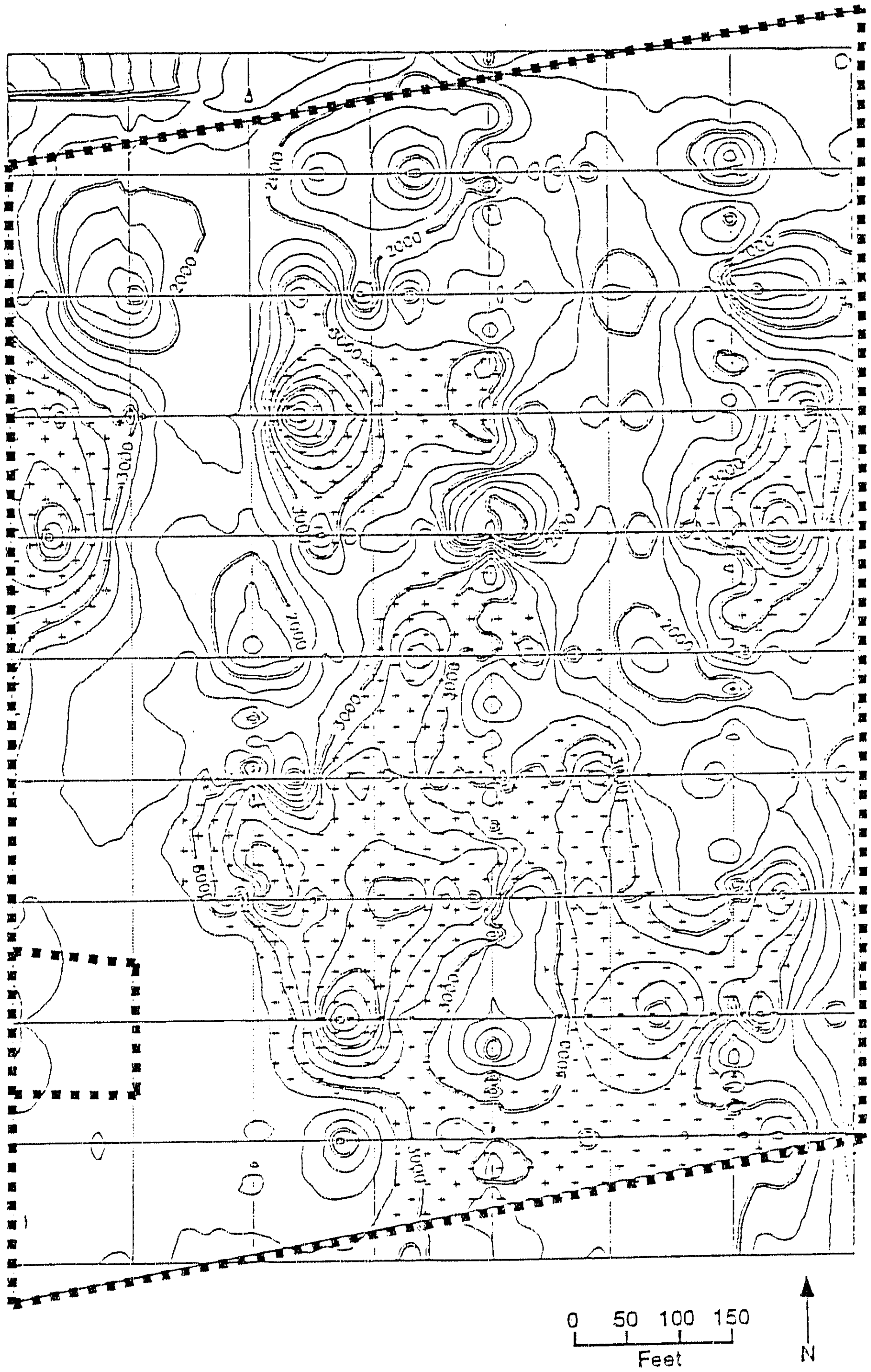
DATA INTEGRATION AND PRIORITIZATION OF SAMPLING AND DRILLING SITES

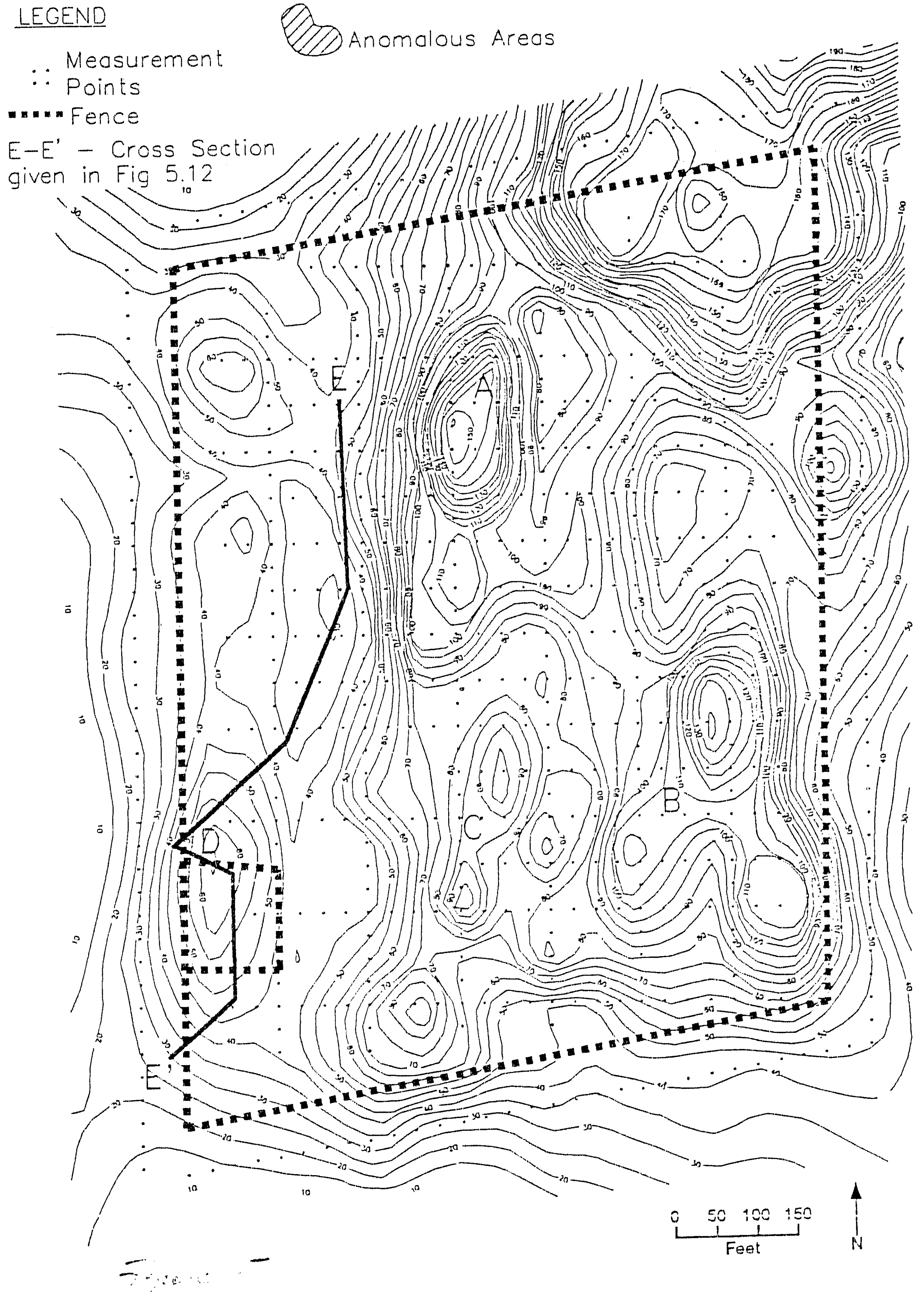
Flora Vista Landfill

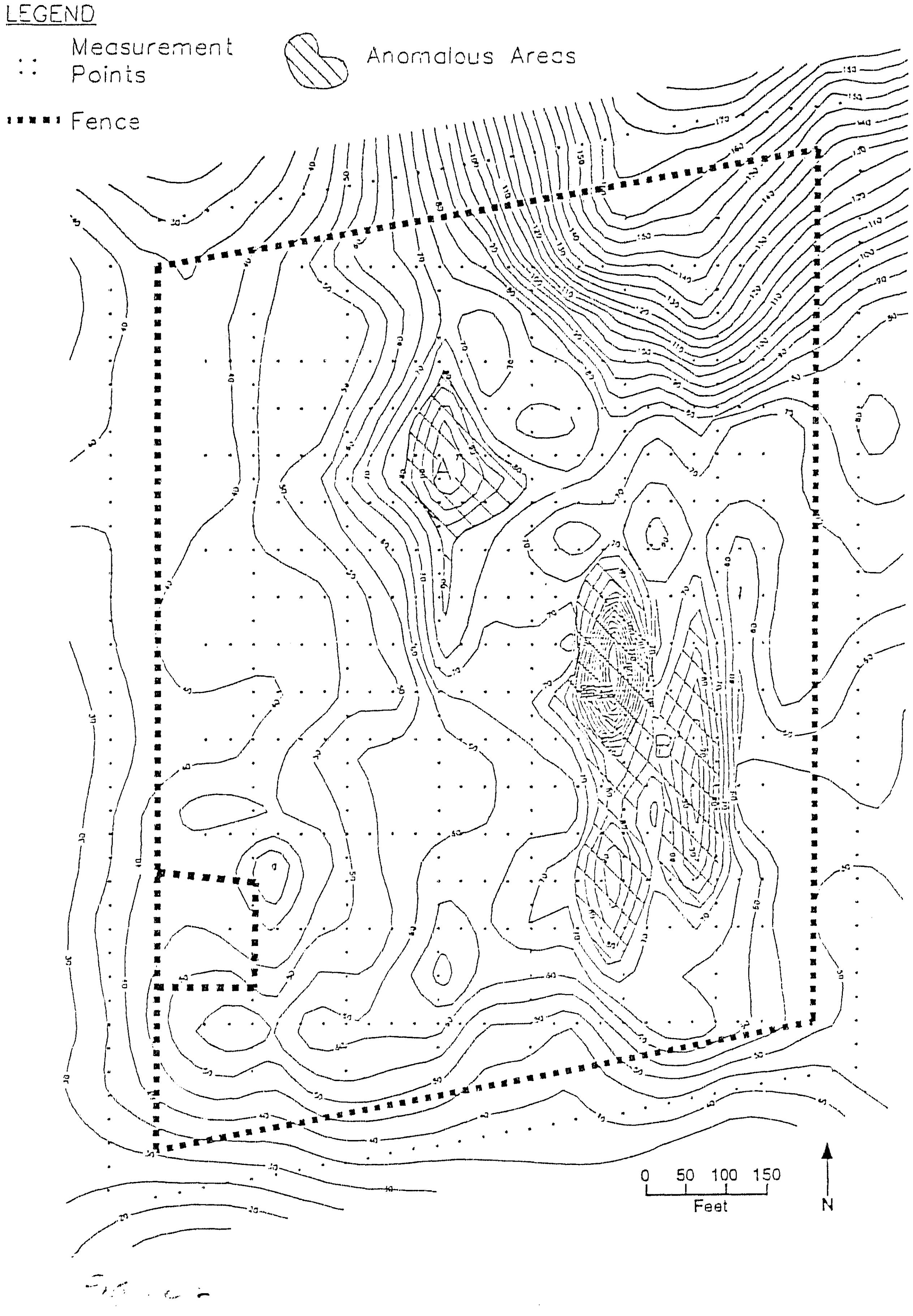
The existing data on the disposal history of the Flora Vista Landfill were extremely sparse at the beginning of the Argonne program, as discussed above. Before the site visit by Argonne staff, the landfill had been covered with 2 ft of sandy soil, fenced, and closed. In addition to the exterior fence, the county had fenced one interior area in the southwest corner of the landfill, where a septage pit was supposedly located. Except for this area, no records indicated the locations of additional pits or trenches, i.e., the principal source areas for contaminants at the landfill site. Therefore, the initial program was designed with two major objectives: (1) mapping now-buried source areas (trenches and pits) and (2) defining migration pathways for contaminant movement from these source areas (bedrock surfaces, clay lenses, surface drainage patterns, etc.). When the source and migration routes were delineated, an optimal sampling program could be designed to fully test migration from these sources.

Source Areas. The geophysical techniques for mapping trenches and pits included magnetometer, EM 31, and EM 34 surveys. The electromagnetic surveys were included for mapping pits because one of the chief fears was that oil field wastes might have been placed in the landfill trenches and pits. These materials are frequently conductive and should be detected by the electromagnetic equipment. The chief emphasis was on the EM 31 for pit and trench mapping because of the shallow depth and because no shallow clay layers were previously observed in the immediate vicinity of the landfill. The EM 34 depth of exploration (approx. 50 ft) is much deeper than for the EM 31 (approx. 15 ft). Regional geologic data indicated that clays could lie at this depth (30-50 ft). Therefore, the EM 34 measurements might indicate clay units rather than conductive fluids associated with landfilling activities. For our purposes, however, in the early stages of this program, we included anomalies from the EM 34 data in the trench mapping because we felt that in either case, clay versus fluid, we would want to test that particular area.

The results of the magnetometer, EM 31, and EM 34 surveys (Figures 4-6, respectively) show that several areas repeatedly appeared as anomalies with the different techniques. However, some areas yielded a response to only one


0 50 100 150
Feet
N

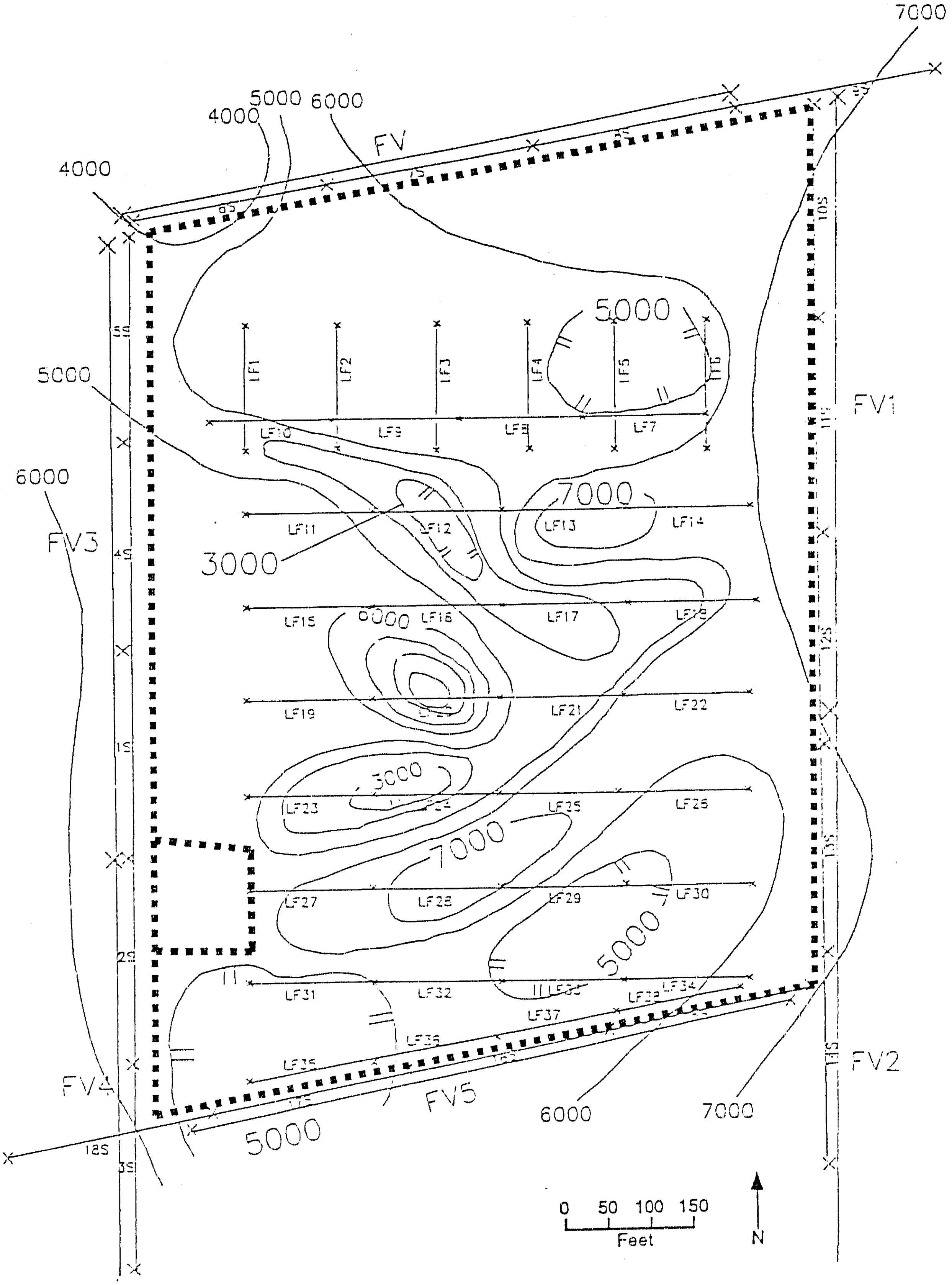

LEGEND
Anomalous Areas
Measurement Points
Fence
E–E' – Cross Section given in Fig 5.12
A
B
C
D
E
E'
0 50 100 150
Feet
N



LEGEND
Measurement Points
Anomalous Areas
Fence
A
B
0 50 100 150
Feet
N

technique, e.g., Area D in Figure 5 for the EM 31 survey. This location is of particular interest because it is the supposed septage pit area fenced by the county just before the landfill was closed. The fact that this area is responsive to the EM 31 and not the magnetometer or EM 34 indicates that it may well be a near-surface pit containing conductive materials. One feature to note is that the boundaries of the anomaly appear to extend well beyond the county's fence line. The anomalous areas identified by each survey were next overlain to generate a map of potential source areas (both pits and trenches) for the landfill. This process will be described after the migration pathways have been identified in the next section.

Migration Pathways. The next step in the program was to determine if any technique was generating data that would be useful in delineating information on migration pathways. After two days in the field, it was evident that the seismic refraction survey was mapping a bedrock surface at fairly shallow levels (15-45 ft) beneath the landfill surface. This relatively shallow bedrock surface had not been predicted by the regional geology data. However, inspection of several nearby outcrops indicated that the Tertiary Nacimiento Formation could be present as an erosional bedrock surface at the landfill site. The Nacimiento is a hard, lithified, fairly impermeable sandstone. Because it was felt that this surface might play an important role in unsaturated flow from the trenches and pits, the field program was altered to include a more comprehensive seismic refraction survey within and immediately around the landfill. Thirty-eight profiles with short spreads of 130-ft were acquired inside the fence (Figure 7). These data provided 76 depths to bedrock beneath shot points and were used to construct a bedrock topography map (Figure 8).



7000
4000
5000
6000
FV
4000
5000
5000
LF1
LF2
LF3
LF4
LF5
LF6
LF10
LF9
LF8
LF7
FV1
6000
7000
LF11
LF12
LF13
LF14
FV3
3000
LF15
LF16
LF17
LF18
LF19
LF21
LF22
3000
LF23
LF24
LF25
LF26
7000
LF27
LF28
LF29
LF30
5000
LF31
LF32
LF34
LF37
LF36
LF35
FV2
FV4
FV5
6000
7000
5000
0 50 100 150
Feet
N

Fig. 7

BEDROCK TOPOGRAPHY

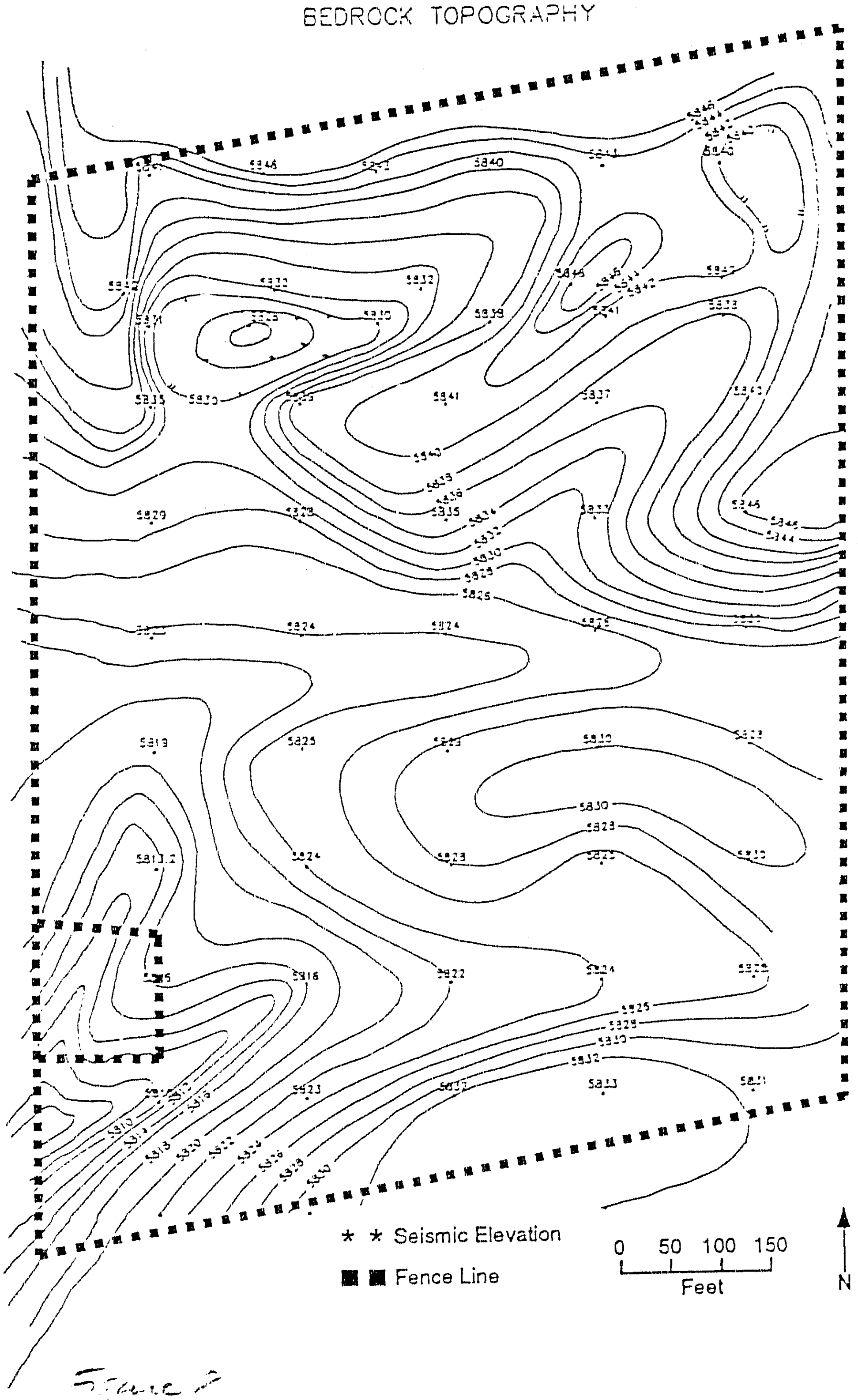


Figure 2

As Figure 8 shows, the bedrock surface is an erosional surface with valleys, depressions, and definite flow direction patterns. These drainage patterns are drawn on the bedrock surface in Figure 9. In addition to defining potential subsurface flow directions, a topographic map was constructed in the field for the landfill itself (Figure 10). This surface map was then used to define surface migration pathways from the landfill.

Integration of Data and Selection of Sampling Sites. The data on source areas and potential migration pathways were combined to prioritize sample locations for the site (Figure 11). Source areas were represented by integrating the magnetic, EM 31, and EM 34 contours taken from Figures 4-6. Principal subsurface migration pathways were represented by the thin lines from the bedrock mapping (Figure 9) and principal surface migration pathways by the thick lines from the surface topographic mapping (Figure 10). Sampling and soil boring locations could now be chosen to test for movement or leaching of materials from these source areas without drilling into a trench or pit in the first phase of the program. This restriction eliminated the possibility of introducing contamination into the subsurface by arbitrary drilling through potentially contaminated pits and trenches. Sampling and soil boring locations for testing the landfill are given in Figure 11. Inspection of the figure reveals that all major migration pathways were tested.

Results of Field Testing of Predictions. When soil borings were installed, the trench areas trending north-south in the landfill were found to be real. The accuracy of predictions of trench boundaries was within 5 ft. Predicted depths to bedrock were accurate within 10 ft, and the soil borings substantiated the general nature of the bedrock surface.

The only pit area actually drilled was the fenced area mapped by EM 31 in Figure 11. During the SI, the contractor had drilled two soil borings in

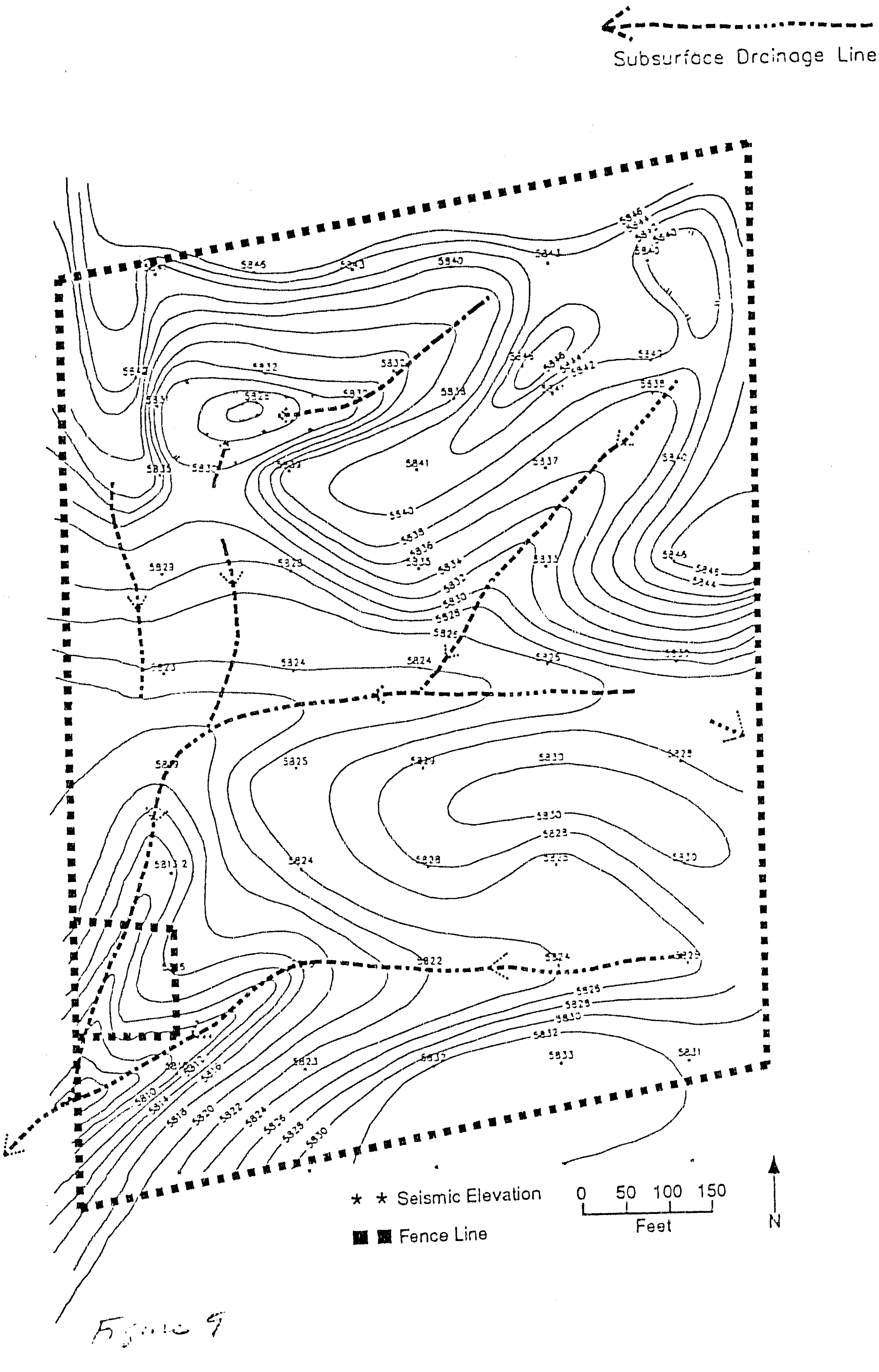

Subsurface Drainage Line
Seismic Elevation
Fence Line
0 50 100 150
Feet
N

Figure 9

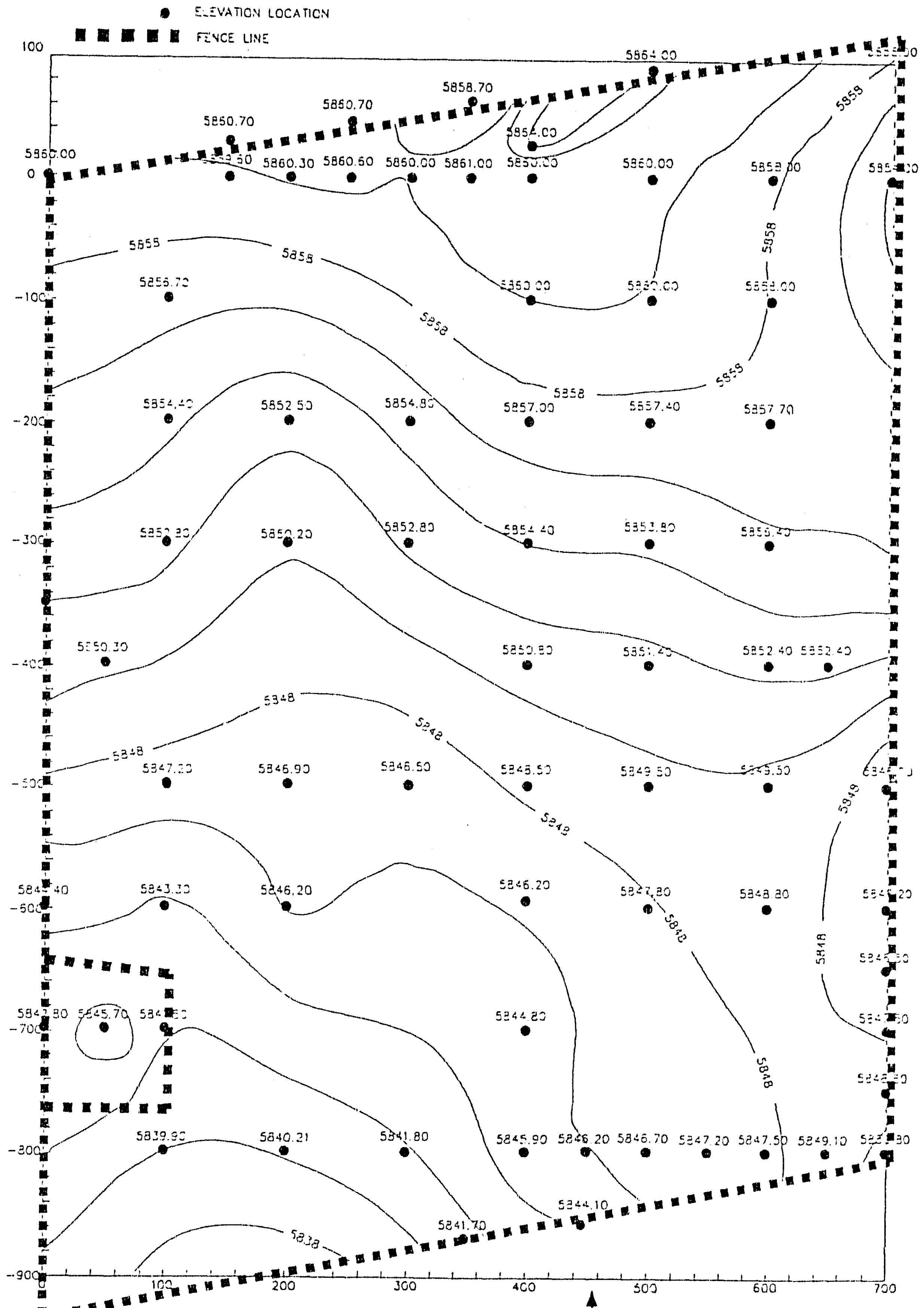
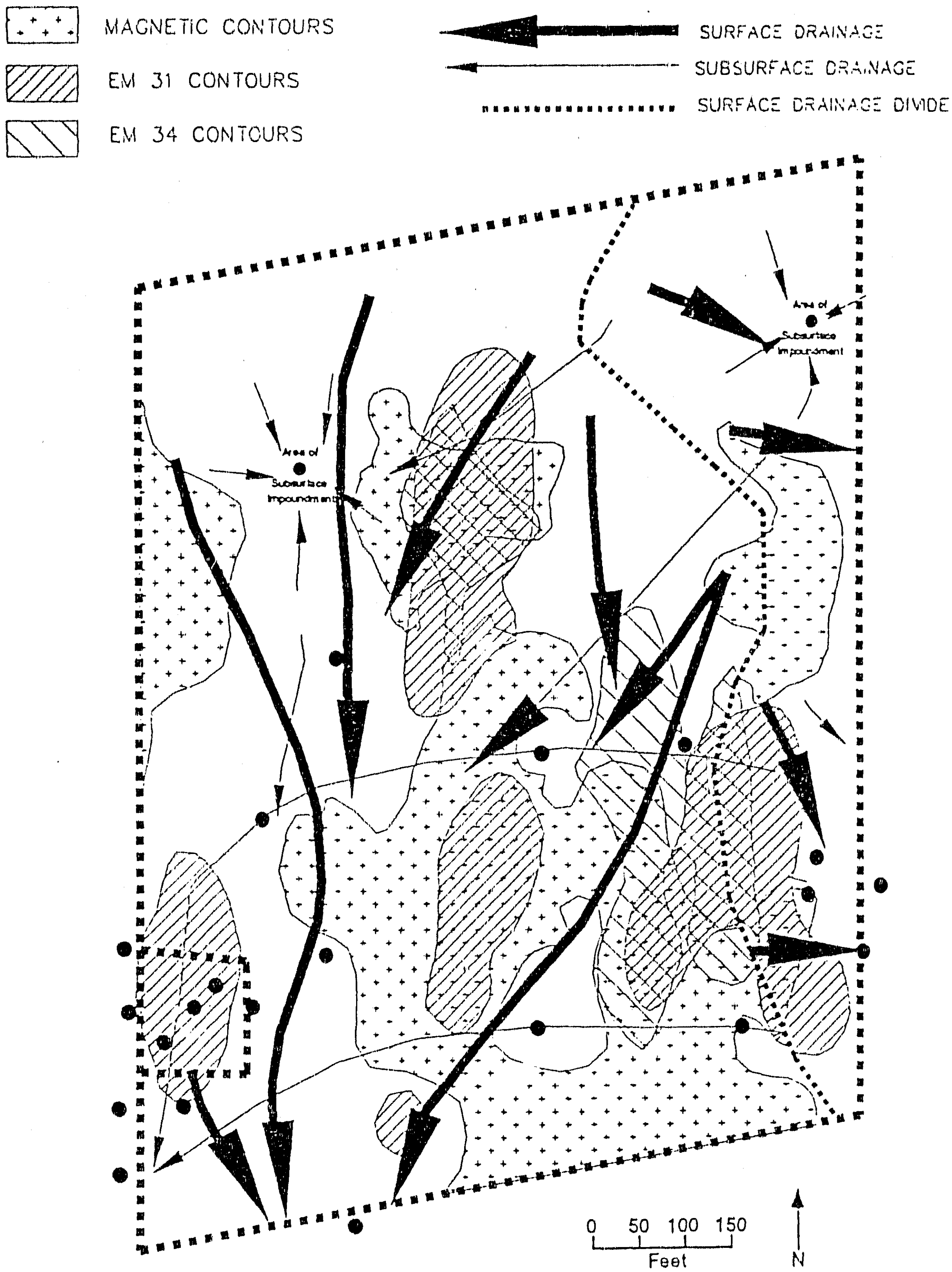


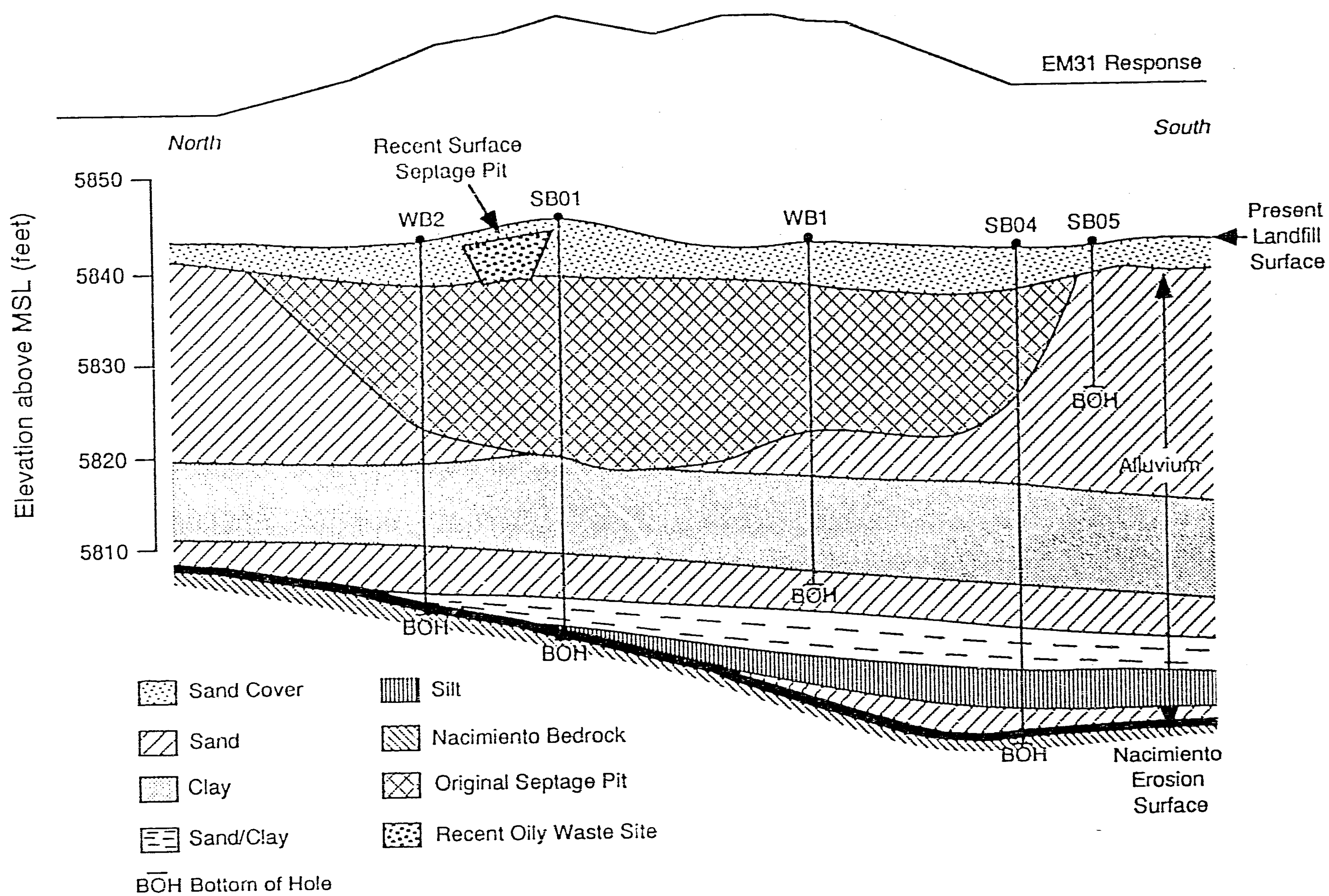
Figure [illegible]


MAGNETIC CONTOURS
EM 31 CONTOURS
EM 34 CONTOURS
SURFACE DRAINAGE
SUBSURFACE DRAINAGE
SURFACE DRAINAGE DIVIDE
Area of Subsurface Impoundment
Area of Subsurface Impoundment
0 50 100 150
Feet
N

this pit area, one inside the fenced area and one just south of the southern interior fence boundary. On the basis of the analytical results from this drilling, the contractor had proposed that lateral and vertical migration of contaminants had occurred from the pit area. The location of the contractor's two soil borings (WB1 and WB2) are shown in cross-sectional view in Figure 12 with Argonne's soil borings in this pit area and with the results of the EM 31 study superimposed. Argonne's soil borings, coupled with a reexamination of the contractor data and the EM 31 response, proved that this is actually one large septage pit and that no lateral or vertical migration has occurred from it. The interior fence is just an artificial boundary and is not at all representative of the extent of the pit. Without the EM 31 data, outlining the possible boundaries of the pit, and the seismic data, giving an idea of the location of the base of the pit, considerable time and money could have been wasted in drilling and attempting to understand this one area.

Mesilla Dam Landfill

The initial geologic and geophysical program for prioritizing sampling locations at the Mesilla Dam Landfill was similar to that conducted at the Flora Vista Landfill. Even though the Mesilla Dam Landfill is much larger than the Flora Vista site and surveys were done on a much larger grid, the combination of geophysical and geological surveys generated interpretations that greatly decreased the potential area of concern at the site. Seismic refraction and time domain electromagnetic surveys both indicated the presence of a northeast-southwest-trending depression in the saturated zone beneath the landfill (Figures 13 and 14, respectively). These data, in combination with geologic reconstructions and drill data, demonstrated that the anomalous responses were most likely due to a normal fault that divides the landfill



Note: This is a best fit of septage waste distribution with present borehole information.

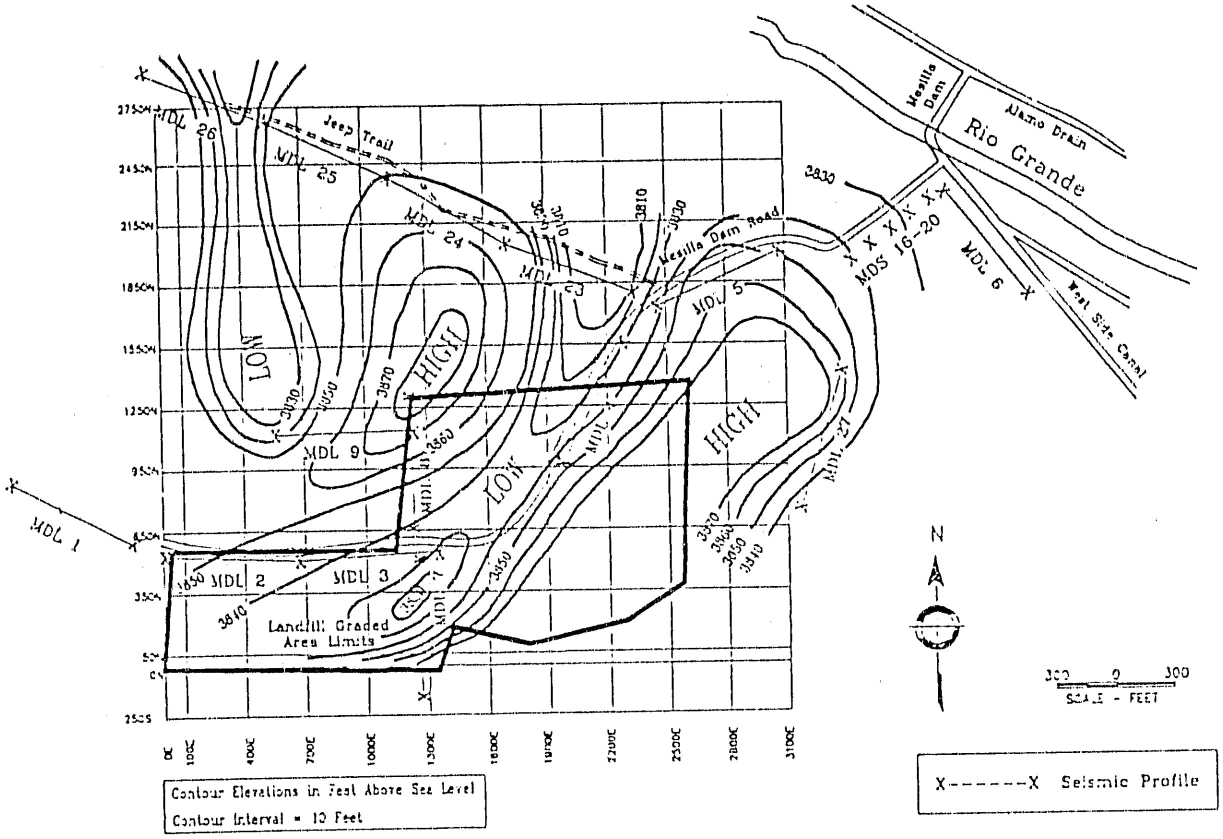
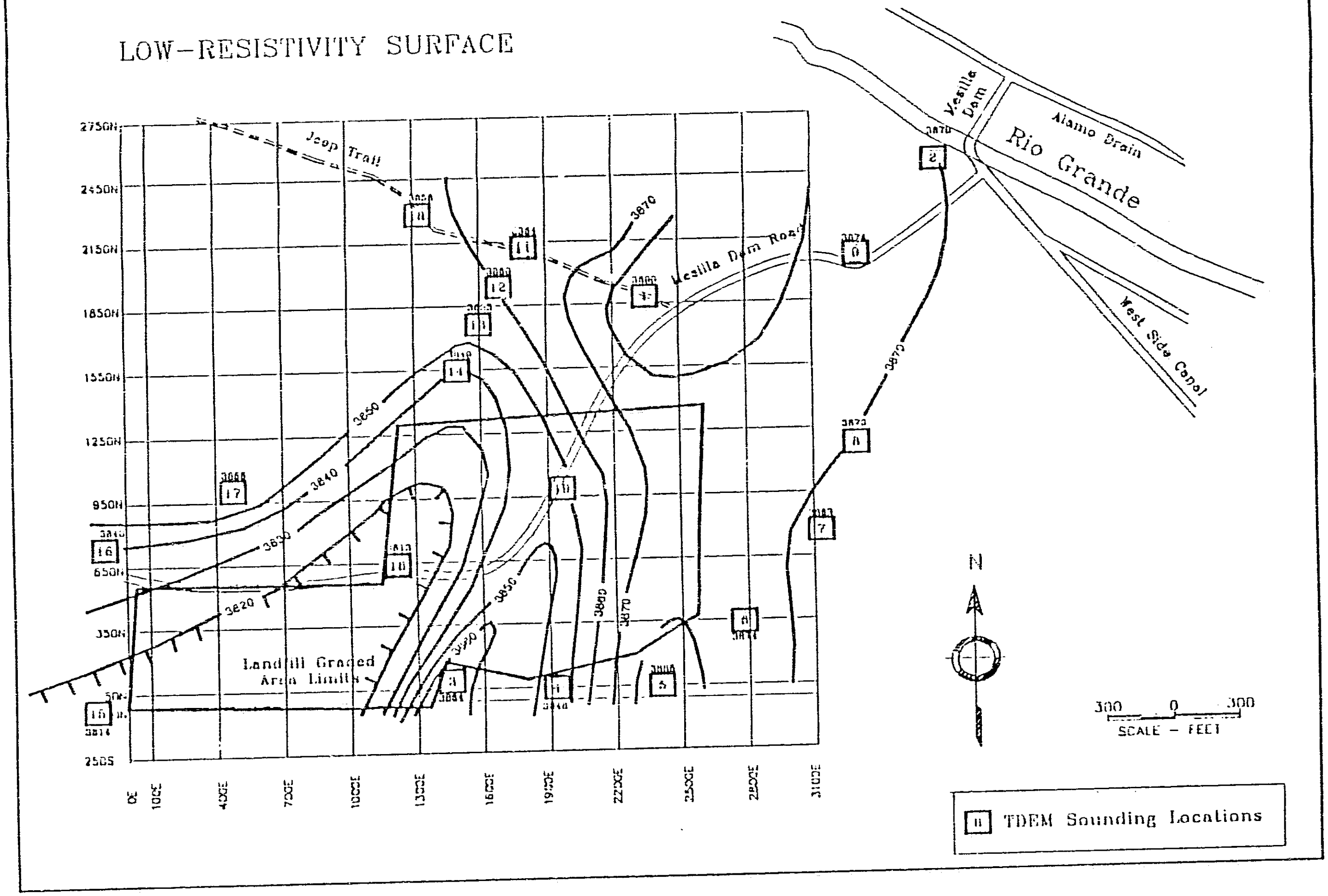

Jeep Trail
Mesilla Dam Road
Mesilla Dam
Alamo Drain
Rio Grande
West Side Canal
MDL 26
MDL 25
MDL 24
MDL 23
MDL 5
MDS 16-20
MDL 6
MDL 9
MDL 1
MDL 2
MDL 3
MDL 27
LOW
HIGH
Landfill Graded Area Limits
N
300 0 300
SCALE - FEET
Contour Elevations in Feet Above Sea Level
Contour Interval = 10 Feet
X------X Seismic Profile

Figure 13

MESILLA DAM – TDEM SOUNDINGS

LOW-RESISTIVITY SURFACE



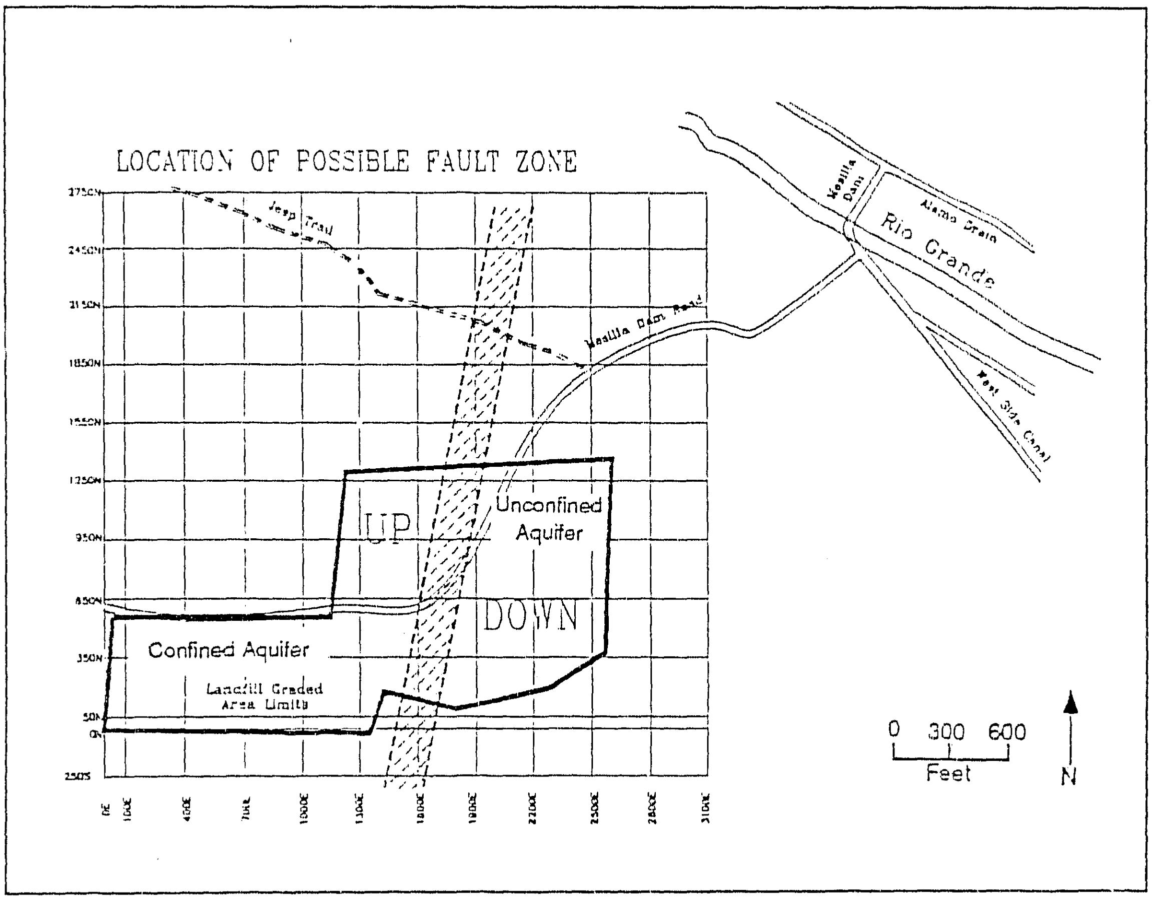
into two different hydrogeologic regimes (Figure 15). The area beneath the west side of the fault is underlain by a confined aquifer, with several feet of clay between the surface and the water table. The area beneath the east side is underlain by an unconfined aquifer. Because the groundwater on the west side of the fault is protected, the majority of effort could be focused on the east side.

Further examination of the geophysical data from the Mesilla Dam study generated a possible procedure for initial screening of hydrogeologic settings (e.g., confined versus unconfined aquifers) for landfills in this geologic regime. The major result of this approach is that when budgeted dollars are limited, landfills underlain by unconfined aquifers can be given a higher priority for investigation. The resistivity responses from the Mesilla Dam site are shown in Figure 16, in which the confined aquifer is distinguished by an erratic resistivity curve, whereas the unconfined aquifer is characterized by a smooth curve paralleling the water table. Therefore, an initial screening and prioritization of landfills for site investigation is possible with one fairly simple, relatively inexpensive geophysical survey.

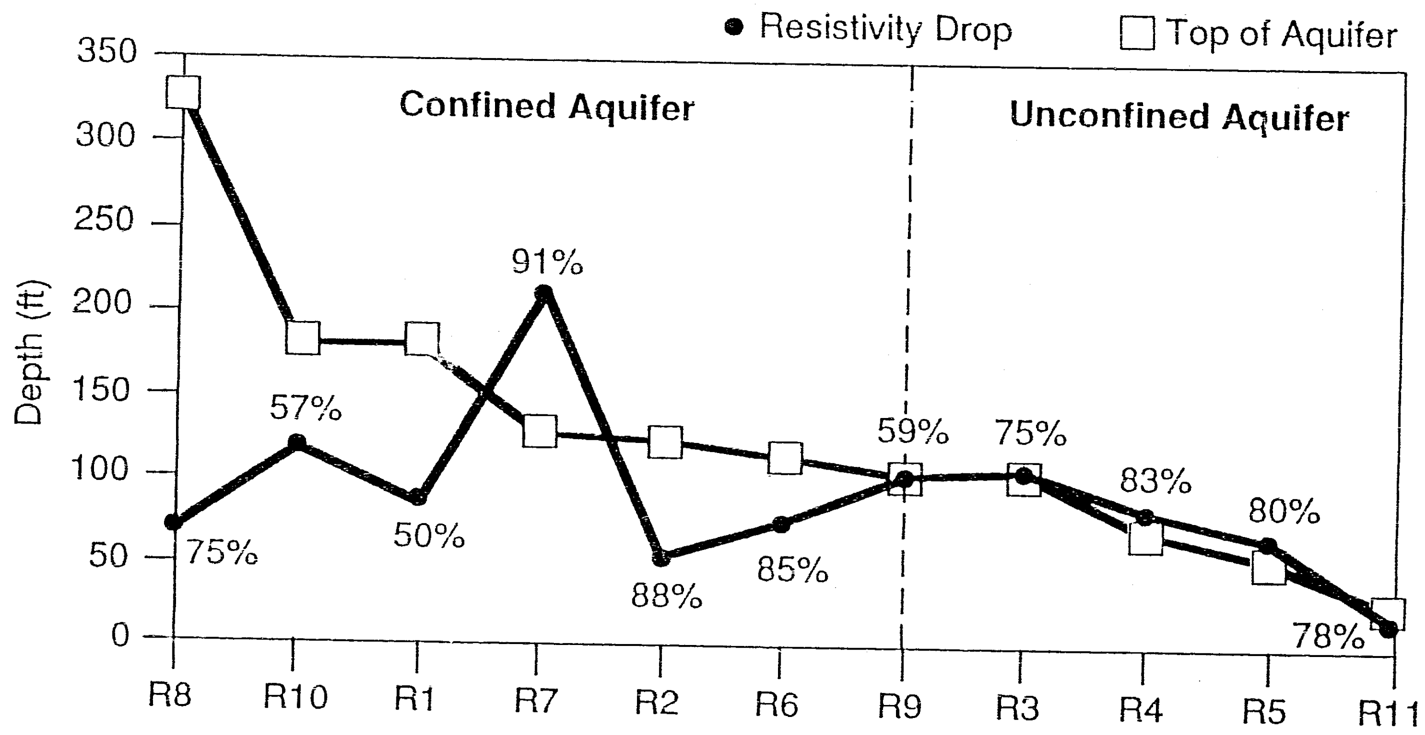
CONCLUSIONS

The following conclusions can be drawn from the results of this study:

- A dynamic, multidisciplinary field approach using experienced technical staff identified critical sample locations for testing contaminant migration from landfills in New Mexico.
- The use of multiple surface geophysical, remote-sensing techniques allowed accurate prediction of unmapped buried trenches and pits, the water table, and subsurface geological



LOCATION OF POSSIBLE FAULT ZONE
Jeep Trail
Mesilla Dam Road
Mesilla Dam
Alamo Drain
Rio Grande
West Side Canal
UP
DOWN
Unconfined Aquifer
Confined Aquifer
Landfill Graded Area Limits
0 300 600
Feet
N


Resistivity Drop
Top of Aquifer
Confined Aquifer
Unconfined Aquifer
Depth (ft)
350
300
250
200
150
100
50
0
75%
57%
50%
91%
88%
85%
59%
75%
83%
80%
78%
R8
R10
R1
R7
R2
R6
R9
R3
R4
R5
R11

features (bedrock erosional surfaces, faults, and confining clays) that contribute to controlling subsurface migration.

- The multidisciplinary approach cut the time, cost, and intrusive activities such as monitoring well installations for the program by maximizing data interpretation in the field and using multiple techniques to verify conclusions.

ACKNOWLEDGEMENTS

This work was supported by the Bureau of Land Management through interagency agreement YA651-1A9-340002 with the U.S. Department of Energy. This study involved Argonne staff from several different disciplines. In particular, the following individuals played key roles in making the program a success: Candace Rose, John Walker, Ted Jennings, Lyle McGinnis, and Bruce Hastings. In addition, the electromagnetic survey was conducted by Blackhawk Geosciences, Inc., of Golden, Colorado. Many thanks are also due to the State of New Mexico Bureau of Land Management staff for their assistance in the field and for critical review of documents.

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FIGURE CAPTIONS

Fig. 1. Locations of BLM Landfills in New Mexico Studied by Argonne

Fig. 2. General Location Map for Flora Vista.Landfill

Fig. 3. Site Location Map for Mesilla Dam Landfill

Fig. 4. Total Field Magnetic Contour Map for Flora Vista Landfill (Areas 200 gammas above background are marked with + symbol and represent potential solid waste trench locations.)

Fig. 5. EM 31 Contour Map for Flora Vista Landfill (Values are in millimhos per meter; anomalous Areas A-D are possible pit or trench areas.)

Fig. 6. EM 34 Contour Map for Flora Vista Landfill (Values are in millimhos per meter; anomalous Areas A' and B' are trench locations.)

Fig. 7. Bedrock Velocity Map of Flora Vista Landfill Derived from Seismic Refraction Data (Contour intervals are 1,000 ft/sec.)

Fig. 8. Bedrock Topography Map of Flora Vista Landfill, Based on Seismic Refraction Data (Contour intervals are 2 ft.)

Fig. 9. Bedrock Topography Map of Flora Vista Landfill Showing Subsurface Drainage Patterns

Fig. 10. Surface Topographic Map of Flora Vista Landfill

Fig. 11. Source Areas and Potential Surface and Subsurface Migration Pathways at Flora Vista Landfill as Defined by Geologic and Geophysical Surveys, with Soil and Soil Boring Sampling Points for Testing Contaminant Migration

Fig. 12. Drilling Confirmation of the One Waste Pit Predicted by the EM 31 Survey at Flora Vista Landfill

Fig. 13. Map of Saturated Zone from Seismic Refraction Data at Mesilla Dam Landfill

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