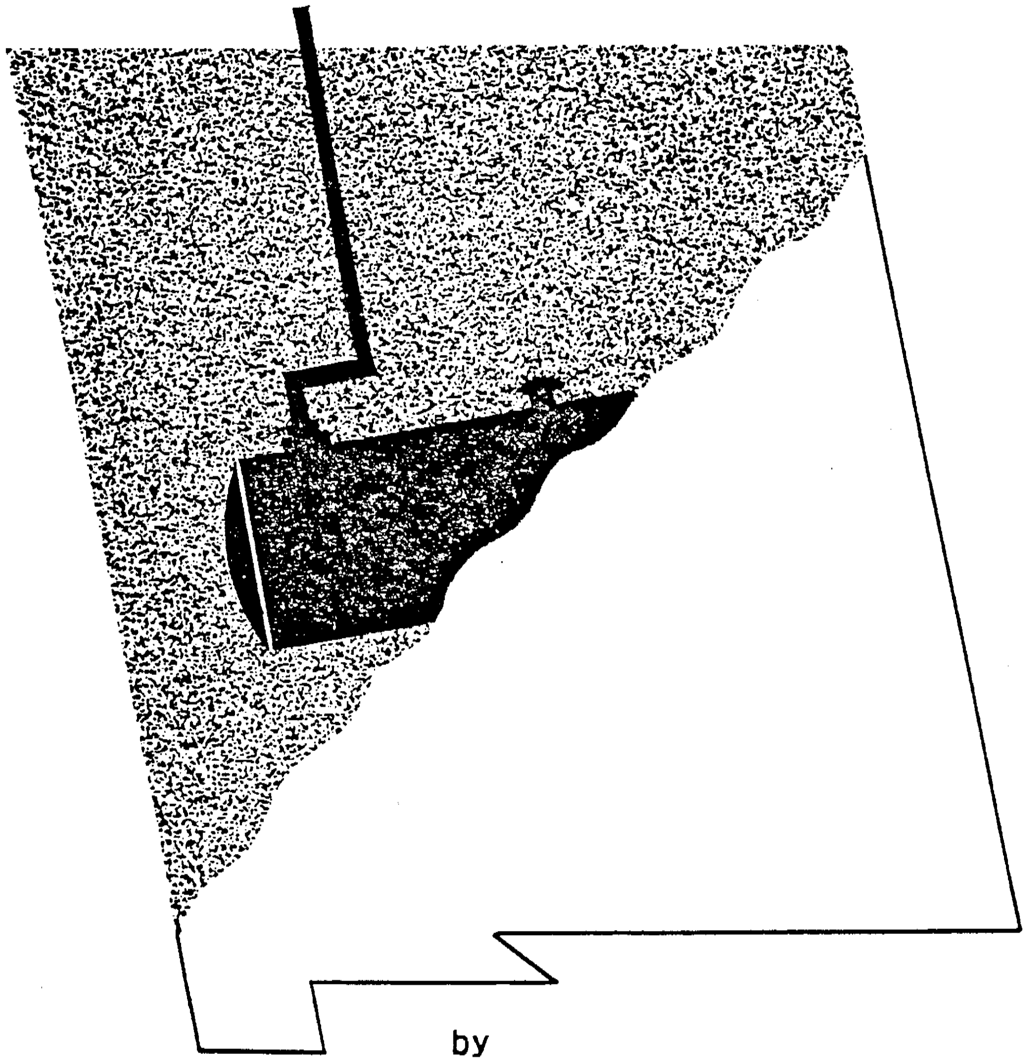
1990 Site Investigation and Benzene Hazard Assessment at the Bass Site in Albuquerque, New Mexico



by

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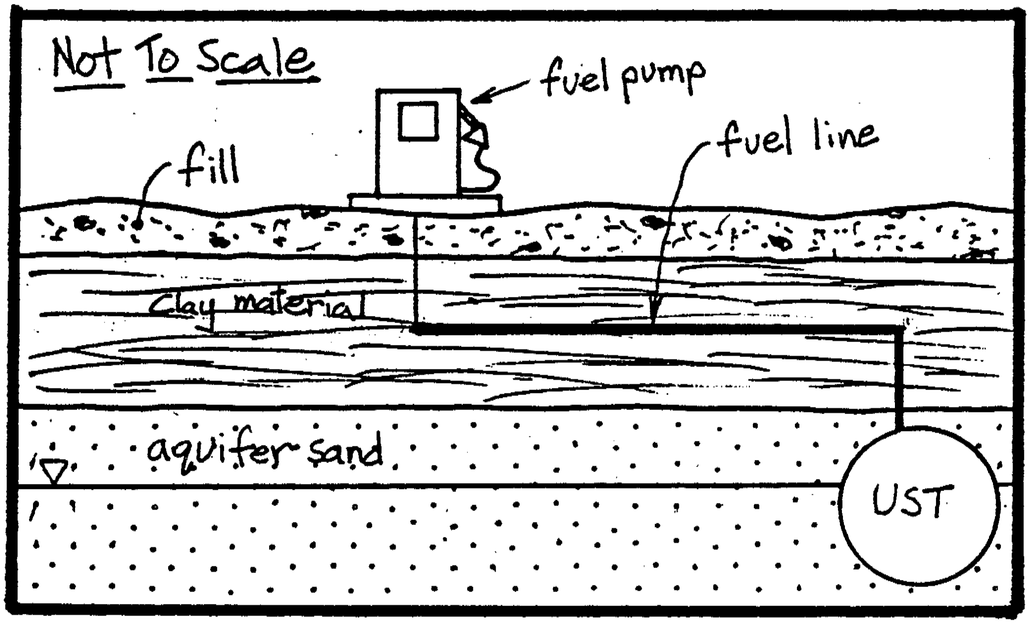
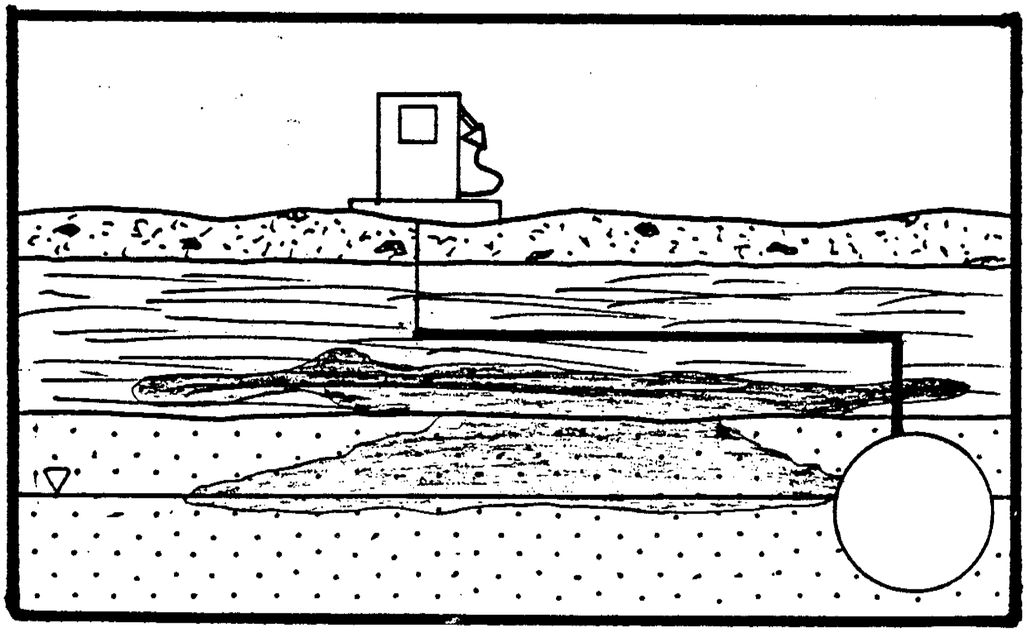
ABSTRACT

The Bass Site is a gasoline contamination site located in the south valley of Albuquerque, New Mexico. The spill was discovered during the installation of sewer lines in 1980 and a leaking underground storage tank was subsequently replaced. In 1983, a significant loss of product occurred as a result of a line leak. The New Mexico Health and Environment Department published a study of the site in 1984 and, in 1988, a settlement agreement was finally reached with the Site's operator to remediate the site. A pump and treat system consisting of an extraction well and air stripping tower was installed, but was shut down due to mechanical problems, odors, and other difficulties after less than one year of operation. In spite of this, the operator was able to meet the terms of the settlement agreement and the responsibility for the Site's cleanup was turned over to the Albuquerque Environmental Health Department (AEHD). Billings and Associates, Inc. (BAI), was retained as consultant on the project and, in 1990, a new site investigation consisting of a soil gas survey, augering, and ground water sampling was conducted in conjuction with AEHD. The investigation revealed that the bulk of the petroleum was bound to the clayey overbank materials which overlie the aquifer sands. Contaminants are slowly released from the clayey materials to the aquifer below and then diluted and/or biodegraded downgradient. Contour maps of benzene ground water contamination show that the shape and extent of the plume has changed little over time, indicating that a state of "dynamic equilibrium" exists at the Site. Based on this information, BAI installed a unique in-situ soil ventilation system which began remediating the Site in October, 1990. Final site cleanup should be complete in 1992. A risk assessment indicates that if no remedial action were undertaken, domestic drinking water wells may pose a health risk to area residents as far as 450 feet away from the Site.

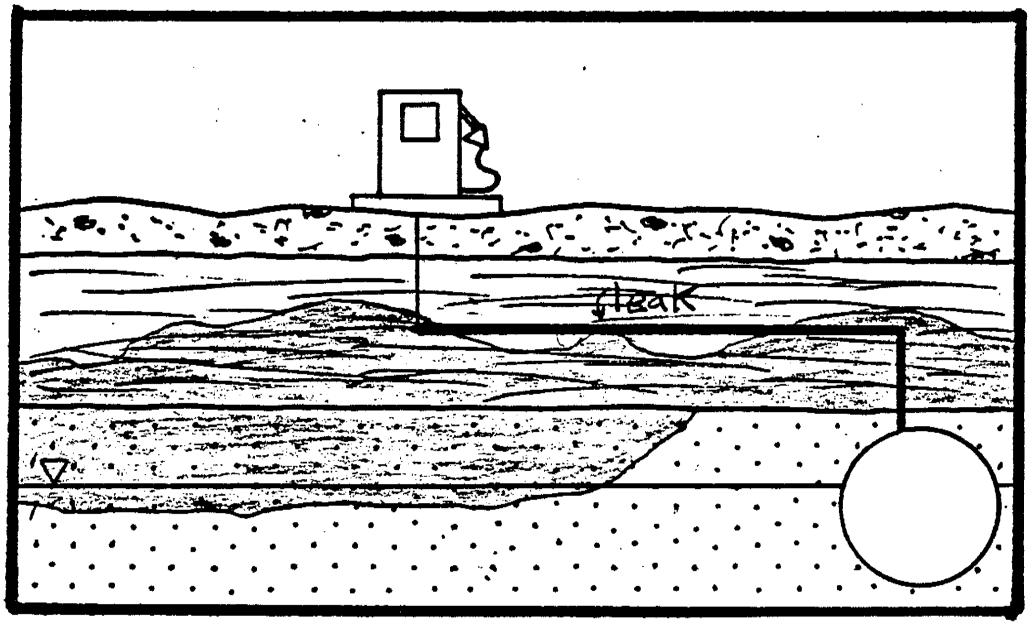
SCHEMATIC DEPICTION OF BASS SITE HISTORY



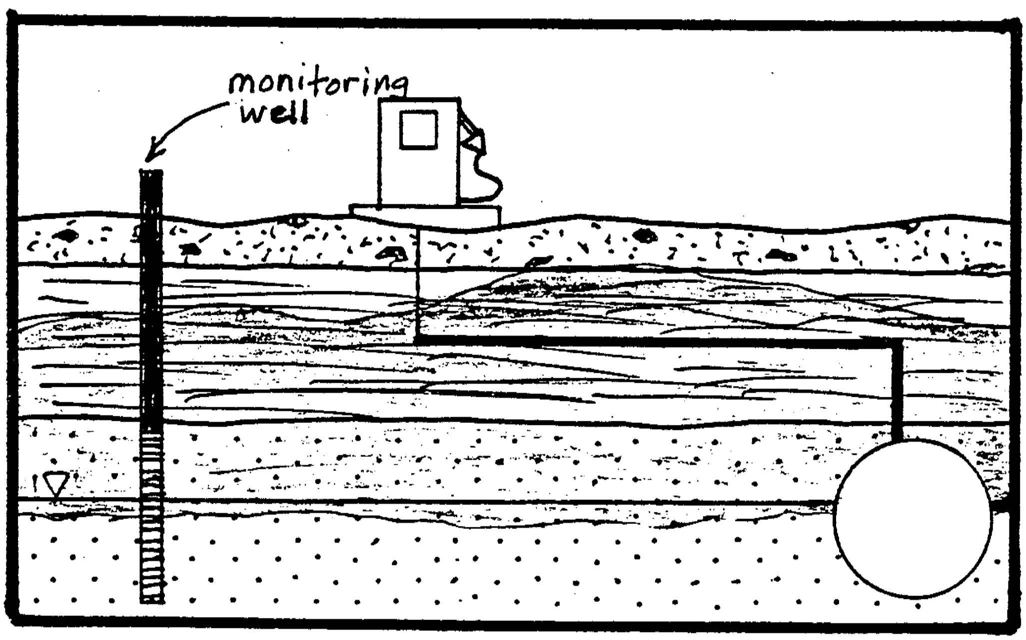
(1) Mid-1970's - Before UST leak.



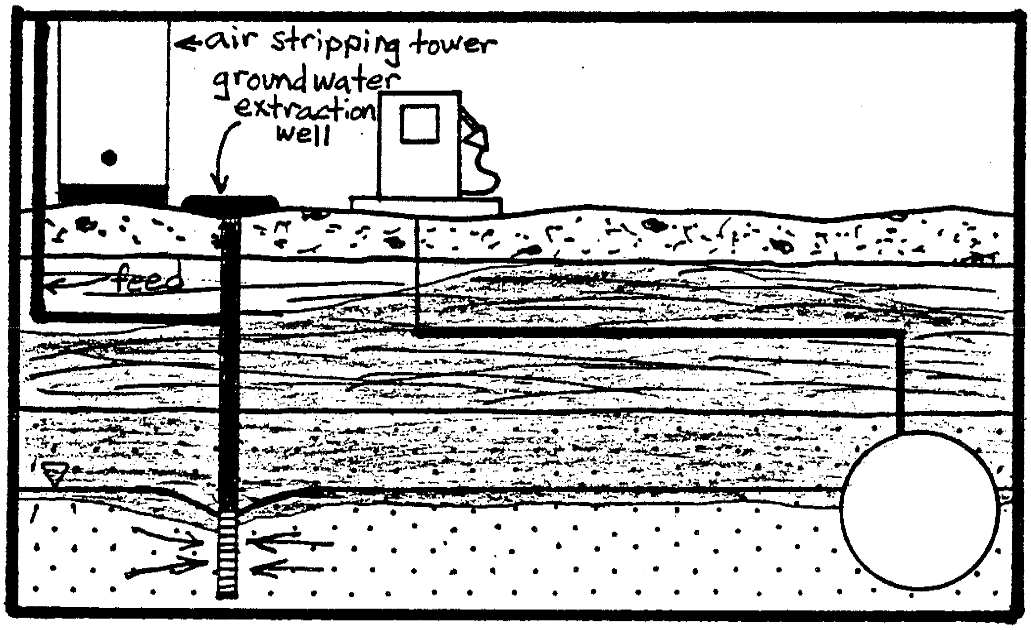
(2) Late 1970's? - UST leaks gasoline. Spill discovered in 1980 by workers installing sewer lines along Isleta Blvd. UST is replaced by order of NMHED.



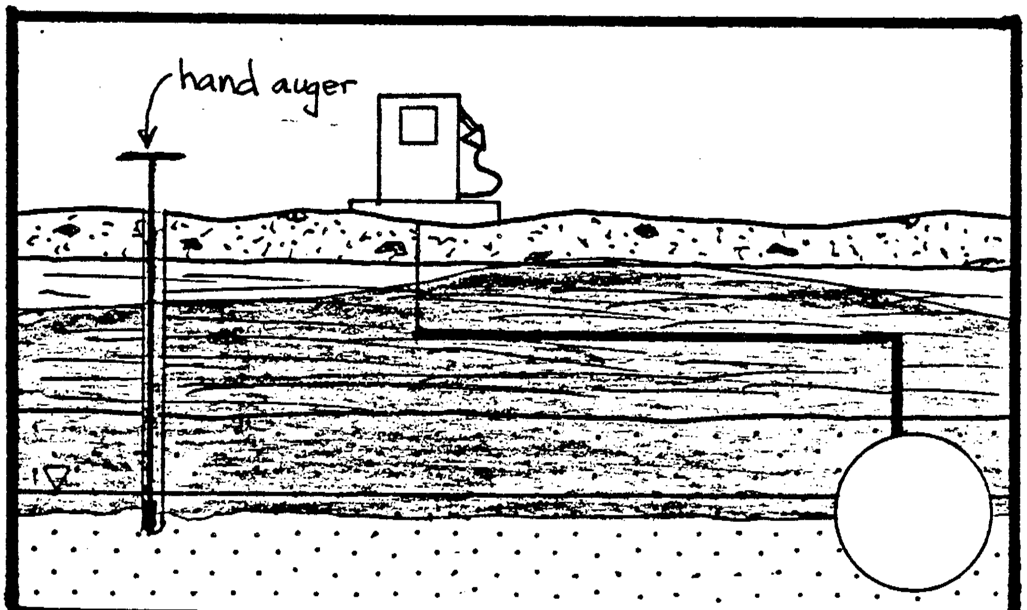
(3) 1983 - Pressurized line leak discovered after a large but unknown quantity of gasoline is released.



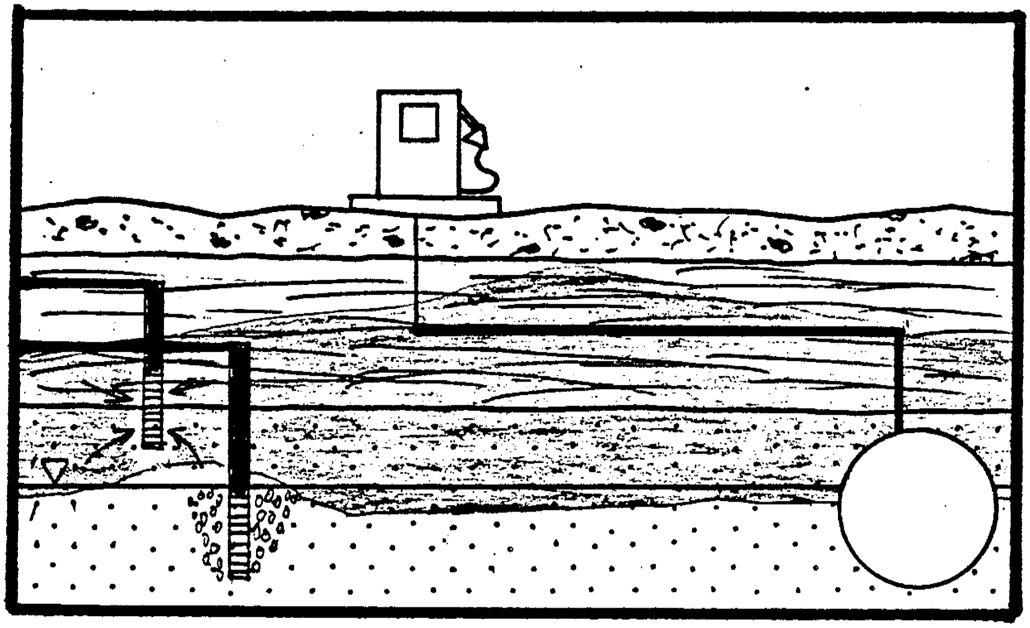
(4) 1983-84 - NMHED conducts a site investigation and installs four monitoring wells to study the problem. Additional monitoring wells are later installed by Contractor DEC in 1987-88.



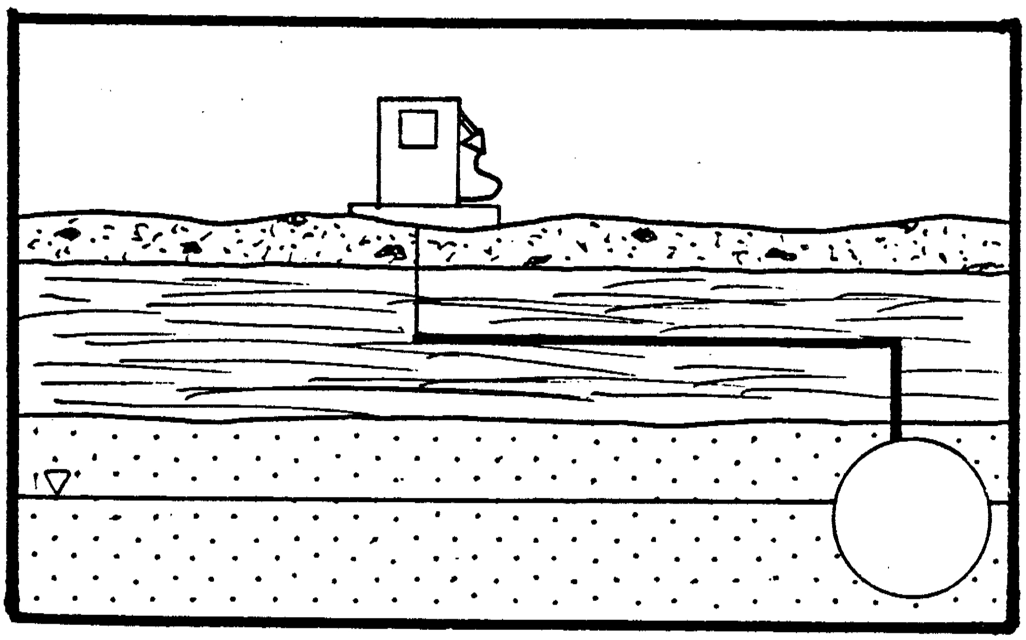
(5) 1988 - Settlement agreement reached between NMHED and Company ROC. Contractor DEC installs a pump and treat remediation system consisting of an extraction well and air stripping tower. After less than one year of operation, system is shut down due to mechanical problems, odors, and other difficulties.



(6) 1989-90 - Company ROC released of responsibility at the Site. Remediation of the Site is assigned to AEHD and BAI retained to implement remedial action. A new site investigation is initiated which includes a soil gas survey, augering, and ground water sampling.



(7) 1990 - SVVS remediation system installed at the Site by BAI.



(8) 1992 - Site remediation complete.

ACKNOWLEDGMENTS

I would like to thank Billings and Associates, Inc., for graciously allowing me to incorporate their figures, diagrams, and data into this paper. It was truly a pleasure to work with them in the field.

Curtis Verploegh, my boss and friend, provided me the job I needed to make it through graduate school. His support and willingness to share his experience with me was invaluable.

I would like to express gratitude to my friends Roy Anglada, Bill Bennett, Doug Earp, Rosemary Glenn, Gary Lasswell, Mary Lou Leonard, Milo Myers, and Rick Renn at the AEHD who made my internship with them a most valuable and rewarding experience. Special thanks to Cindy Ardito, also of AEHD, whose input, assistance, and guidance made this paper possible.

I am grateful to my advisor, Dr. Andrew Campbell, who understood that today's environmental problems not only require specialists, but workers with diverse educational backgrounds. Through his foresight, an innovative course of study was developed--one which, I believe, will become commonplace in the future.

Finally, my excursion to Socorro would not have been possible without the support of my parents, Connie and Randy.

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1990 SITE INVESTIGATION

Site History

The Bass Site is a gasoline contamination site located at the northwest corner of Isleta Blvd. and Lakeview Rd., in the south valley area of Albuquerque, New Mexico (Figure 1). Jercinovic (1984) describes the discovery and the initial efforts to characterize the nature and extent of the spill. The contamination was discovered during the excavation and dewatering activities associated with the installation of sewer lines along Isleta Blvd. in April, 1980. The Bernalillo County Fire Prevention Bureau (BCFPB) reported the spill to the State of New Mexico Environmental Improvement Division's Hazardous Waste Group (HWG) and ordered an inspection of the underground fuel storage tanks. A tank was found to be leaking and was replaced. In May, 1980, the HWG responded when gasoline odors were again detected during dewatering activities for the sewer line. Subsequently, the BCFPB requested the Bass facility to construct an unlined evaporation pond to dispose of the dewatering fluids.

In June, 1983, BCFPB contacted the Environmental Improvement Division's Ground Water Section (GWS) concerning the presence of explosive vapors in the storm sewer adjacent to the Bass facility. The Bass facility at this time was being leased to Company ROC. Their inventory records revealed that a significant loss of product was occurring which was later traced to a line leak near the pump islands (Ardito, personal communication, 1990). The GWS conducted a study of the ground water impact caused by the contamination and the results were compiled in Jercinovic's (1984) study. The conclusions reached in this study were:

1. The underground gasoline storage tank(s) had leaked for some time prior to the leak(s) being detected.
2. This facility is located in a relatively densely populated area.
3. The water table is quite shallow - approximately two to three meters below ground surface.
4. Homes adjacent to the site all have individual domestic supply wells and individual domestic waste disposal systems (i.e. septic tanks).

5. Domestic water supplies are obtained from the above mentioned shallow aquifer (wells are generally 6-45 meters deep).

6. The variety of other possible sources of hydrocarbon contamination, including other service stations and small auto repair facilities, makes study of the site more difficult.

7. The Pajarito Lateral, located east of the site, was not found to be in hydraulic contact with the aquifer. Other drains, however, appear to control the local configuration of the water table.

8. Ground water flow beneath the Bass Site is toward the west-southwest with a shallow gradient of just 0.002 (≈12 feet/mile). See Figure 2.

9. Ground water flow velocity is estimated to be in the range of 30 to 150 m/year.

10. An explosivity survey (Figure 3) indicated that contamination has migrated off of the site property boundaries.

11. Of the five monitoring wells installed for this investigation, only the upgradient well (MW2) did not show evidence of petroleum contamination (see Figure 1 for well locations). In addition, a sampling round in August, 1983, showed that three downgradient domestic wells had detectable concentrations (1.4-23.0 ppb BTEX) of the same contaminants found in the monitoring wells (see Table 5).

With exception of items #4, #6, and #8, the conclusions reached in Jercinovic's (1984) study appear to be still valid. In regard to item #4, homes on Isleta Blvd. were being hooked up to the City of Albuquerque's water supply starting in August, 1990. It is not known at this time whether this service will be available to homes on Lakeview Rd. With respect to item #6, there was no evidence found during the 1990 field study that sources other than the Bass facility contributed to the contamination at the Bass Site. Finally, there is evidence that suggests that the ground water may flow in directions other than those cited in #8. Studies by Kues (1986) and Peter (1987) indicate that the ground water may also flow to the south or southeast, perhaps as a result of seasonal pumping or inflow from the other drains referred to in #7 (see Figures 4 and 5).

In 1988, a settlement agreement for the remediation of the site was negotiated between the Owner of the station, Company ROC, and the New Mexico Health and Environment Department (NMHED). In early 1989, ROC hired Consultant DEC to remediate the site in accordance with the settlement agreement.

DEC installed a "pump and treat" system consisting of a single recovery well located roughly in the center of the contamination and an air stripping tower. Contaminated water is pumped to the top of the tower where it trickles down through a filter-packing material so that droplet size is diminished. A blower fan forces air upward, striking the droplets and volatilizing the hydrocarbons in the water and removing them with the air stream out of the stack into the atmosphere. The water continues to drop down the stripper where it collects into a drain and then discharged.

This remediation system has proved reasonably successful at many petroleum contamination sites throughout the U.S. In general, it has shown that it can be cost effective, relatively easy to maintain, and can remove volatile organics dissolved in water efficiently (Armstrong, 1988; Nyer, 1989; Fair and Dryden, 1990). At the Bass Site, however, several difficulties were encountered during the operation of this system which limited its effectiveness. Although access to the operational records was limited, it appears that there were mechanical difficulties which initially thwarted continuous system operation. When the system was operating, sulfurous odors and noise were generated which drew complaints from the residents in the area. DEC attempted to control odor production by treating the influent with sodium or potassium hydroxide (to raise the pH), and by use of hydrogen peroxide and sodium hypochlorite (to oxidize the sulfur compounds present). It appears that this treatment was not entirely successful and the system was completely shut down in the latter part of 1989.

Despite these operational difficulties, ROC was able to meet the terms of the settlement agreement. The terms of the settlement stated that ROC was responsible only for the cleanup of 1,2-dichloroethane (EDC), a lead scavenging additive to gasoline (Sax and Lewis, 1987). Presumably, unleaded gasoline would contain little EDC, hence, it is possible that ROC could have met the terms of the settlement by doing little or nothing in the way of remediation. If the bulk of the leakage were unleaded gasoline, EDC would likely be present in amounts below the limits of laboratory detection. Although difficult to prove, this appears to be the case.

In early 1990, it was clear that a significant petroleum contamination problem still existed at the Bass Site. The quarterly monitoring reports continued to show considerable BTEX (benzene, toluene, ethylbenzene, and xylene) contamination in many of the monitoring wells around the site. ROC acknowledged that there was still substantial petroleum contamination and offered to turn over custody of the stripping tower and its associated equipment to NMHED for a nominal fee. Given that the Owner of the property which the station is located was financially unable to continue the remediation, NMHED accepted this offer. Funds to remediate the Bass Site were made available through the State's Leaking Underground Storage Tank (LUST) Trust Fund. This Fund was developed in part to insure that petroleum contamination sites throughout the State are cleaned up when the Responsible Party(s) is unable (or unwilling) to pay for the remediation.

By mid-1990, NMHED assumed control of directing the remediation activities at the site. NMHED instructed the local LUST authority, the Albuquerque Environmental Health Department (AEHD), to restart the remediation. Subsequently, Billings & Associates, Inc. (BAI), was retained as the consultant on the project.

Soil Gas Survey

In July, 1990, a soil gas survey was performed at the site. Probes consisting of a drive point and two sections of 6" hollow slotted steel tubes screwed into a 2.5' hollow steel rod were driven into the ground using an electric hammer. The slotted tubes allow soil gas to pass through them when a vacuum is applied. Usually, the probes were driven so that the slots were about 2.5' below the ground surface. An electric vacuum pump with a Teflon flask mounted in line near the inlet was attached to the top of the probe, as shown in Figure 6. Soil gas was withdrawn for approximately 30 seconds and the pump turned off. The Teflon flask served as reservoir for the extracted soil gas into which the sample probe of a Foxboro Model 128GC Century Organic Vapor Analyzer (OVA) could be inserted and a reading obtained a few seconds later. The OVA was set in survey mode and is very sensitive to organic vapors in air in the 0-1,000 ppm range.

It was hoped that the soil gas survey could help define the plume of contamination in the ground water. Unfortunately, no clear trends in the soil gas data could be delineated (see Figure 7). A reading of 1,000+ ppm in one location could be followed by a reading of 0 ppm a short distance away. Later, after the augering activities were completed, the reason for this was clear--clay, silty clay, and sandy clay overbank deposits dominated the upper 4 feet of the stratigraphy at the site. As is discussed later in this report, the clayey materials acted like a "sponge" into which the petroleum contamination was irregularly dispersed, resulting in erratic soil gas data. Despite this problem, the soil gas data proved useful in the remediation system design stage by providing a qualitative indication of the extent of soil contamination.

Augering

Also in July, 1990, a soil augering survey was performed at the Bass Site. The goals of the augering program were:

1. To determine the subsurface geology and how it might impact the design of the proposed remediation system.

2. To determine the nature and extent of petroleum contamination in the vadose zone soils.

3. To determine if free product is "floating" on the water table.

Figure 8 shows the boring locations. The boring was carried out using a hand auger. Each 5 foot flight had convenient clips on each end so that the handle, buckets, or additional flights could be easily added or removed. Both sand and clay buckets were used, depending on the lithology encountered. Each borehole was logged and its location recorded in a field book.

The stratigraphy at the Bass Site was remarkably consistent. In cross section, clayey overbank materials dominated the upper 4 feet and were underlain by medium to coarse aquifer sands (Figures 9 and 10). Generally, the caving in of saturated aquifer sands limited borehole depth to 8-9 feet. Frequently, contaminated soils were coated with a black, tarry-looking substance, indicative of microbial action on petroleum products, and gave off a strong gasoline odor. While no augering was performed outside the Site's property boundaries, it is apparent that the contaminants have migrated off the Bass property boundaries to the east and south.

To gage the amount of soil contamination, samples were taken at depths of about 2, 4, 6, and 8 feet in each borehole. One quart mason jars were filled halfway with soil and covered with aluminum foil. A canning ring was screwed on to seal each jar and the jars were allowed to warm for 10-15 minutes. Then, the sample probe of the OVA was pushed through the foil into the container headspace and the result recorded. In this manner, it was hoped that the vertical and horizontal extent of contamination in the vadose zone could be relatively quantified.

The results of the soil headspace survey seemed to indicate that the relative amount of soil contamination increased with depth (Table 1). This may, in part, be due the increasing sand content with depth which allowed a greater proportion of adsorbed volatile components to be released when warmed in the jar. Horizontal trends were less clear. The data was highly variable, even over short distances, much like the soil gas data. The horizontal variability of the data may be the result of:

1) Variations in the amount of volatile hydrocarbons released into the jar headspace caused by differences in sample clay and moisture content.

2) Variations in the amount of petroleum absorbed from point to point at the same depth.

3) Unequal warming of the jars. For example, samples taken in the morning probably did not attain as high a temperature as those taken in the afternoon.

Despite the lack of clear trends in the headspace data, the data collected proved valuable when designing the remediation system by providing a semi-quantitative means by which to judge the amount of soil contamination present at different locations.

To see if free product was floating on the water table, a section of 2" slotted PVC well casing was placed in several of the boreholes and allowed to stand for about thirty minutes. Samples were withdrawn using a disposable bailer and inspected for free product. Free product was not found in any of the boreholes, although a surface sheen of petroleum was observed in each case. Up to 4" of free product was found, though, in MW-1 in mid-1985. Given the age of the spills, the free product probably become diluted or degraded over time and, hence, the lack of free product in the boreholes was not surprising.

Unsaturated clay can posess considerable hydraulic conductivity (Freeze and Cherry, 1979, p. 43). It is clear that the bulk of the contamination was absorbed into the clayey materials of the vadose zone and, for the most part, remains bound there. It appears, however, that small amounts of product are continually being released and contaminating the ground water, evidenced by the continuing presence of petroleum contamination in the monitoring wells. These contaminants are carried down gradient where they are diluted and/or biodegraded. A comparison of the benzene plumes (Figures 13-18) reveals that the shape and extent of the ground water contamination has changed relatively little over time. This suggests that these two processes are occurring at roughly the same rate and that a state of "dynamic equilibrium" exists at the Site (BAI As-Built Report, 1990). Left unchecked, this process could continue for many years until the petroleum in the clays is depleted.

The soil augering work provided some of the most useful information regarding the site. The quantitative and qualitative data collected proved useful in understanding the nature of the contamination problem and aided in the remediation system design.

Ground Water Sampling

The final action in the 1990 site investigation was the collection of ground water samples at the various monitoring wells around the site. Some 30 monitoring wells had been previously installed in and around the Bass Site by the NMHED and Contractor DEC (Figure 11). Unfortunately, some of the wells have been rendered unusable by acts of vandalism or by degradation of their annular spaces. Others simply could not be located due to dense vegetation.

The remaining monitoring wells were sampled in August, 1990. Most of the wells are approximately 15 feet deep and screened above and below the water table from 5 to 15 feet. All are finished above grade with 2" stainless or galvanized steel casings (Figure 12). The well construction details are available in the BAI Update Report (April, 1990).

Approximately 5 gallons was purged from each well before samples were collected. The wells were hand bailed using disposable PVC bailers. The samples were analyzed using gas chromatography for benzene, toluene, ethylbenzene, and xylene by the New Mexico State Laboratory Division (SLD). The sample results are tabulated in Table 2 and a benzene contour map of this data is shown in Figure 18. Historical well data is available in the BAI As-Built Report (November, 1990).

The August, 1990, data clearly show that a contamination problem still exists at the Bass Site. Of the 15 samples collected, 10 exceeded the New Mexico Water Quality Control Commission (1987) ground water quality standards for benzene (see Tables 2 and 3). The Maximum Concentration Levels (MCLs) were also exceeded for toluene, ethylbenzene, and total xylenes in almost half of the wells sampled at that time.

BAI prepared several benzene contour maps using data collected by other contractors (Figures 13-17). Comparing these maps to each other and to the one prepared using the August, 1990 (Figure 18), data reveals that the shape of the benzene plume has changed little over time. This consistency of shape, as noted earlier, is probably the result of a state of dynamic equilibrium between benzene supplied from the clayey materials to the ground water and the simultaneous dilution or biodegradation of this component down gradient. In the risk assessment discussed later, it is assumed that this process would provide a constant source of contamination if no remedial action is taken.

Section II:

INSTALLED REMEDIATION SYSTEM

The degradation of organic compounds is affected by a variety of chemical and biologic processes including hydrolysis, dehydrohalogenation, oxidation, and reduction. These processes, as well as volatilization and adsorption, also affect the extent to which organic compounds are transported in the subsurface environment. Olsen and Davis (1990, Parts 1 & 2) provide an excellent discussion of these processes and furnish the basis for the following discussion.

For non-halogenated aromatic compounds, including the BTEX components present at the Bass Site, oxidation is the most important degradation process. Reduction does occur, but at a much slower rate. Overall, chemical oxidation of organic compounds in ground water systems is extremely limited unless oxygen or oxidizing agents (e.g. peroxides) are added. Typically, such additions are not used to destroy the organic compounds directly, but to create an aerobic environment which increases microbial activity and, hence, the rate of biologic oxidation. Biologic or microbially mediated oxidation of aromatic compounds occurs by introduction of an oxygen molecule onto the ring structure by enzyme action where it is subsequently split. From here, a series of complex intermediate compounds are formed prior to final mineralization (i.e. the complete conversion of the organic compound to carbon dioxide and water).

Until recently, much attention has been focused on pump and treat remedial technologies, but this technique leaves substantial fuel residue in the capillary fringe or vadose zone (Hinchee and Miller, 1990). For a time, restarting the system installed by Consultant DEC was being considered, but for this reason and given the past operational difficulties, this alternative was rejected.

A relatively new technology, in-situ venting or aeration, was considered to be a much better alternative for the Bass Site. This technique, discussed by Hinchee and Miller (1990), involves actively extracting air out of or injecting air into the vadose zone to encourage microbial activity and/or volatilization through a well drilled near the center of the petroleum contamination. Typically, an extraction well or wells accompany an injection well so that an air flow pattern through the vadose zone is established. Sketches of both systems are presented in Figures 19 and 20. Reports indicating the successful employment of these methods are becoming common in the literature (e.g.

Hutton, 1990).

An innovative approach is being employed by BAI to remediate the Bass Site. While similar in some respects to the configuration shown in Figure 20, the Subsurface Volatilization and Ventilation System (SVVS, patent pending, 1989) contains several unique features. A well nest consisting of an air injection well screened below the water table and an extraction well screened above it in the vadose zone operate simultaneously. This creates an air flow pattern which introduces oxygen to the ground water and vadose zone and removes any volatile organics present in the soil gas (see Figure 21).

The SVVS employs a series of these injection/extraction well nests distributed over the areas of greatest petroleum contamination. The preliminary layout of the system is shown in Figure 22. This layout was changed, however, as a result of the soil gas and augering surveys. For example, these surveys revealed that the area around MW-9 showed reduced levels of contamination. As a result, the well nests were moved to an area of greater contamination to the northwest, as shown in Figure 23.

To gage the effectiveness of the SVVS, a variety of tests are being performed by BAI. Among these include:

- Soil microbial counts and total petroleum hydrocarbons.
- Ground water sampling for BTEX.
- Dissolved oxygen tests in monitoring wells.
- Tests for soil gas carbon dioxide and organic vapors.
- Saturated and unsaturated zone temperatures.
- Exhaust stack emissions monitoring as per the air quality permit.
- Well nest vacuum and pressure.

As stated in their As-Built Report (November, 1990), the BAI soil performance criteria for the Bass Site is to reduce the soil residual contamination to below 100 ppm total petroleum hydrocarbons. This criteria will be measured at the end of approximately 15 months of operation. The ground water performance criteria will be to reduce the dissolved benzene concentrations by an average of 90% throughout all the suitable monitoring wells at the Site. BAI's experience at similar sites has shown that these criteria have a high probability of being met.

Section III:

BENZENE HAZARD ASSESSMENT

Assumptions

Gasoline is a complex mixture of volatile hydrocarbons whose major components are branched-chain paraffins (alkanes), cycloparaffins (e.g. cyclohexane), and aromatics (e.g. benzene). A typical ground water sample at the Bass Site is analyzed for benzene, toluene, ethylbenzene, xylene, ethylene dichloride (EDC), ethylene dibromide (EDB), and Total Petroleum Hydrocarbons (TPH). Of these, benzene, ethylene dichloride, and ethylene dibromide are both toxic and carcinogenic at certain concentrations in different media. The other compounds are considered only to be toxic or possible human carcinogens. In this risk assessement, only the carcinogenic effects of benzene will be considered because:

1. Higher concentrations of a substance in a media are usually required for toxic effects to occur. Thus, any toxic effects would occur close to the source of contamination. Fortunately, no household drinking water wells are located in the zone of greatest ground water contamination at the Bass Site. Carcinogenic effects, however, can occur at much lower dose levels more distant from the source.

2. The data available on EDC and EDB is scattered and did not lend itself to statistical evaluation. In addition, the more recent monitoring well data excluded EDC and EDB from the analysis.

3. A large amount of data is available on the health effects of benzene.

4. Benzene is the most abundant of the known carcinogens found in gasoline.

This risk assessment investigates the hazard presented to residential wells down-gradient from the Bass Site <u>if no remedial action is taken</u> and <u>the dynamic equilibrium process continues to supply a constant source of benzene over time</u>. Although the Site would probably self-remediate within 30-40 years, a lifetime exposure to benzene is assumed. By taking this conservative approach, it is hoped that any synergistic or additive effects of benzene with other components of gasoline will be accounted for as well as avoid underestimating any health risks caused by the Site.

Potential Exposure Pathways

INGESTION OF DRINKING WATER. The ingestion of contaminated drinking water poses the largest health threat at the Bass Site. Some of the residential wells are less than ten meters deep--not much deeper than the monitoring wells. Deeper wells would presumably be less threatened, but information on the finishing details and screened intervals of these wells is generally not available. Therefore, it would be prudent to consider all residential wells to be equally at risk.

DERMAL EXPOSURE WHILE BATHING. Data were not found for the carcinogenicity of benzene administered by the dermal route, except for many skin painting studies in which benzene was used as a vehicle. These studies found benzene negative for carcinogenicity when applied in this manner (ATDSR, 1989). Therefore, it is unlikely that dermal contact with water contaminated with benzene presents a significant health risk.

INHALATION WHILE BATHING. Due to the volatility of benzene, it is possible that persons could be exposed to benzene while bathing. The exposure level associated with an individual lifetime upper-bound risk of 10^{-6} has been calculated to be 0.04 ppb (ATSDR, 1989). Fortunately, exposure by inhalation of benzene by this route would be of short duration and, when time-weighted over 8 or 24 hours, the exposure is likely to be insignificant. Therefore, exposure by inhalation of benzene will not be considered in the assessment of risk.

SOIL CONTAMINATION BY WATERING PLANTS. Again, due to its volatility, much of any dissolved benzene will be released to the atmosphere where it will become infinitely diluted. That which remains could leach into the soil, where it would be subject to aerobic digestion by microorganisms (Davis and Olsen, 1990). Unfortunately, the ATSDR (1989) profile does not make any reference to benzene uptake by plants and it will be assumed that this route of exposure can be ignored.

Exposure and Risk Assessment

As noted earlier, the horizontal direction of ground water flow is difficult to define precisely (Figure 24). Based on the flow direction data available and shapes of the benzene plumes shown in Figures 13-18, a risk "wedge" encompassing the possible flow directions was drawn with its apex at the recovery well used for the now-dismantled pump and treat remediation system (Figure 24). The selection of the recovery well as the apex of the risk wedge was somewhat a matter of convenience, although the benzene plume maps (Figures 13-18) consistently showed the recovery well at or near the center of the of the 10,000 ppb benzene contour. The nearest home upgradient (or outside the risk wedge) is greater than 600 feet to the north of the recovery well. As seen later in assessment, homes 600 feet away from the recovery well would appear to incur little risk from the Bass Site. The nearest home downgradient (or inside the risk wedge) is less than 200 feet. For the purposes of this risk assessment, homes upgradient from the recovery well will not be considered because their wells are presumably at less risk than downgradient wells. In addition, there is comparatively little upgradient data, making any study of that area more difficult.

The benzene data within the risk wedge are summarized in Table 4. As a conservative measure, a value of one-half the detection limit was assigned to samples in which benzene was not detected. This action is justified based on the fact that there is evidence that some of the residential wells in the area have been impacted by contamination in the past (Table 5).

The mean of the historical well data was plotted against distance from the recovery well (Figure 25). Using the linear regression program in an HP-11C calculator, a "best fit" line for the data was determined. The data had a correlation coefficient of r = -0.90. From the regression analysis, an equation approximating the benzene concentration with distance was developed:

$$[\text{benzene}] = \frac{98.628}{10^{0.0113x}} \qquad (1)$$

where [benzene] is the concentration of benzene in ppm or mg/L and x is the distance from the recovery well in feet. From (1), the expected daily dose for benzene in drinking water can be calculated by:

$$\text{dose} = [\text{benzene}] \times \frac{(\text{ingestion})}{(\text{avg. body weight})} \qquad (2)$$

where dose is in mg/kg-day and [benzene] in mg/L. Ingestion is assumed to be 2 liters of water per day and the average body weight of an adult is approximately 70 kg (USEPA, 1985). Using (2), the dose vs. distance from the recovery well can be defined by:

$$\text{dose (mg/kg/day)} = \frac{2.818}{10^{0.0113x}} \qquad (3)$$

From data presented in the ATSDR (1989) profile, a dose vs. cancer risk plot for the ingestion of benzene was prepared (Figure 26). From Figure 26, the cancer risk can be defined by:

$$\text{risk} = \frac{\text{dose}}{36} \qquad (4)$$

where dose is in mg/kg-day. The cancer risk number represents the probability of developing cancer as a direct result of the exposure to benzene. For example, a cancer risk of 10^{-4} means that exposure to a specified concentration of benzene throughout a lifetime (assumed to be 70 years) may be associated with a 1 in 10,000 chance of developing cancer as a result of exposure. The unit risks used find equation (4) are the upper 95% confidence limits on the maximum likelihood estimate of the line relating exposure and dose. Because the unit risks used are upper bounds, the actual risk with a given exposure is unlikely to be higher but may be much lower than the predicted risk.

By combining Equations (3) and (4), the following risk vs. distance from the recovery well equations can be derived:

$$\text{risk} = \frac{0.0783}{10^{0.0113x}} \qquad (5)$$

$$x = \frac{-\log(\text{risk}) - 1.11}{0.0113} \qquad (6)$$

These equations are plotted on Figure 27.

Using the EPA standard risk of 10^{-6}, persons using drinking water wells within about 450 feet of the recovery well at the Bass Site may be subject to a 1 in 1,000,000 chance of developing cancer as a result of benzene ingestion. Accordingly, within at least 450 feet, it would be prudent to assume that benzene poses a health risk and appropriate protective actions should be initiated.

Uncertainty Analysis

The above analysis is by no means comprehensive. It is, at best, a reasonable "first cut" estimation of the risks presented by the Bass Site. Among the uncertainties are:

1. Synergistic and/or additive effects of benzene with other components of gasoline were not accounted for. A comprehensive risk analysis would include the toxic and carcinogenic effects of some of the other compounds found in gasoline. However, by utilizing a lifetime risk for benzene, it is hoped that some component of synergistic and additive effects will be accounted for.

2. A lifetime dose may not be a valid assumption. Given time, say 30-40 years, the site should completely remediate itself through chemical and biological action. Data are lacking, however, to substantiate such a claim. Nonetheless, it is safe to say that a number of the residential wells in the area would be impacted at some point if no remedial action was undertaken. Fortunately, a new and likely more effective remediation system (i.e. the SVVS) has been installed and is now operating at the site.

3. Biodegradation of the contamination in the ground water was not taken into account. The action of microorganisms would reduce the concentration of benzene and other organic compounds down-gradient, potentially reducing the risk.

4. Most of the residential wells are believed to be significantly deeper than the monitoring wells. Since petroleum products are less dense than water, wells screened at a greater depth are presumably at less risk than those screened nearer to the surface. In addition, most of the monitoring wells at the Bass Site are only 15 feet deep and screened above and below the water table. As a result, contamination levels at depth and vertical flow components could not be evaluated.

5. Any future changes in ground water depth and flow direction have not been accounted for. For example, the installation or decomissioning of irrigation wells, abandonment of drains, and the continued pumping of the aquifer by the City and County could affect the contaminant migration patterns and render the assessment invalid.

Risk Conclusion

Based on this simple risk analysis, it appears that the Bass Site may pose a threat to residential wells within the risk "wedge". Although many conservative assumptions were built into the assessment, it is suggested that residential wells within approximately 450 feet down-gradient of the recovery well not be used for drinking water purposes until remediation at the site is complete.

DISCUSSION AND CONCLUSIONS

The Bass Site is just one of nearly 100 active leaking underground storage tank sites being handled by the AEHD in Bernalillo County. A majority of these sites, including Bass, are located near the Rio Grande, where the depth to ground water is less than 100 feet. Because of the potential for aquifer contamination, these sites tend to be given a high priority for remedial action. The Bass Site exhibited a continuing high level of contamination off site and there existed evidence that domestic wells had been impacted--two items which will boost a site's ranking. Once the responsibility for the Bass Site was turned over in late July, 1990, the State and the AEHD acted quickly to get a remedial system in place. By October, 1990, BAI had the SVVS system installed and operational.

The Bass Site is somewhat unique in that there is data extending back nearly seven years. In addition, BAI will continue to collect in the future a variety of soil and ground water data to gage the effectiveness of the SVVS system in remediating the Site. This would appear to make the Bass Site an ideal candidate for a combined study of the vadose zone/ground water contamination and the effects of microbial degradation on petroleum hydrocarbons. It seems possible that such a study could lead to the development of a model or further refine existing models. The predictive powers of such a model could aid in the selection and design of remediation systems at other petroleum hydrocarbon sites as well as provide data for more accurate risk assessments.

The nature and extent of the soil contamination at the Bass Site presented a difficult problem--one which a pump and treat system would have been slow to remediate. Even if the pump and treat system initially installed at the Site was operated continuously, the pace of the cleanup would have been limited by the slow rate of contaminant release from the clayey overbank materials. By attacking the problem in-situ with an active aeration system, the cleanup should be significantly accelerated and make the stated goal of site cleanup by 1992 a reasonable objective.

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FIGURES

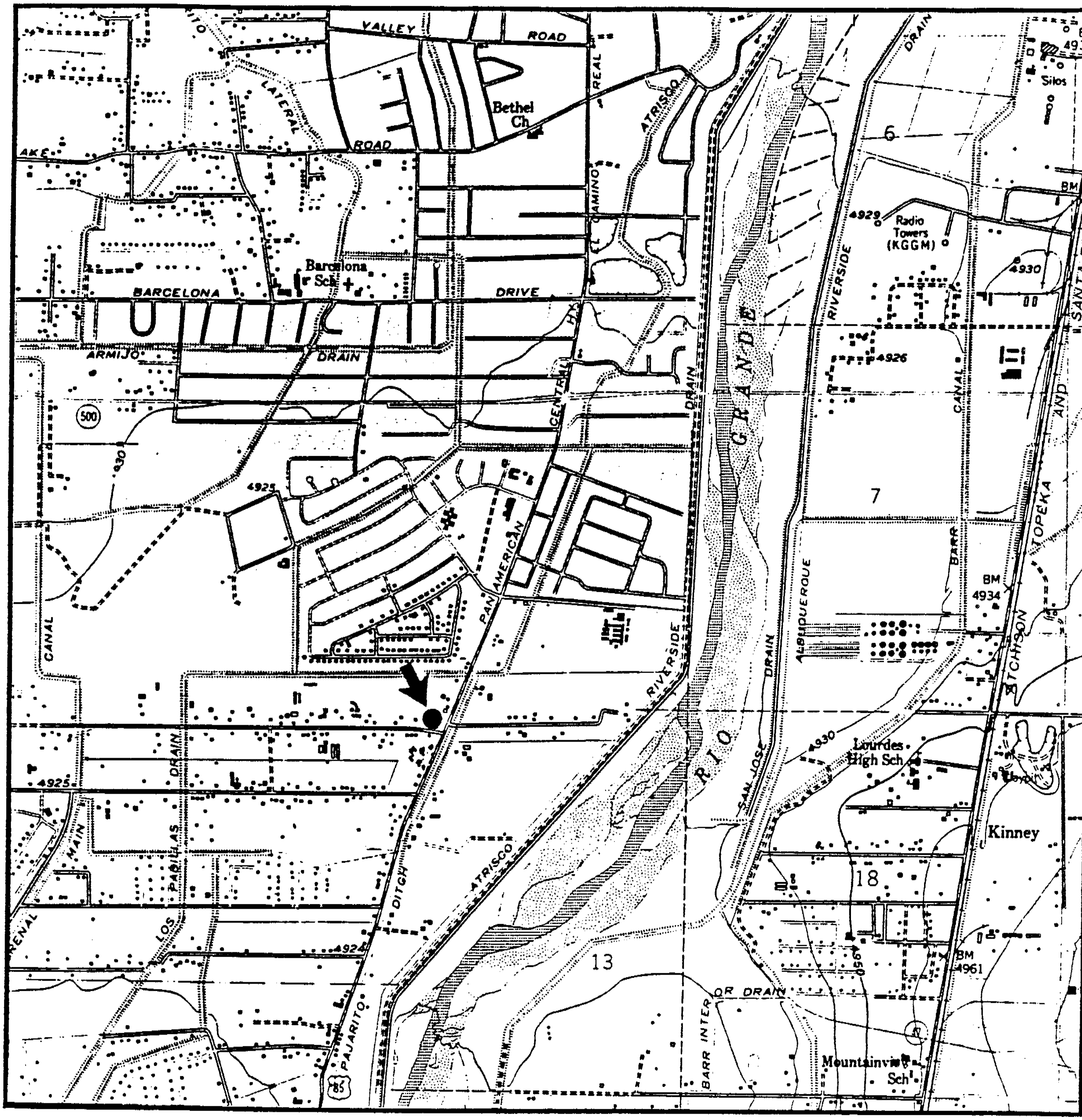


Figure 1

Location Map

Bass Site

Billings & Associates, Inc.
October, 1990

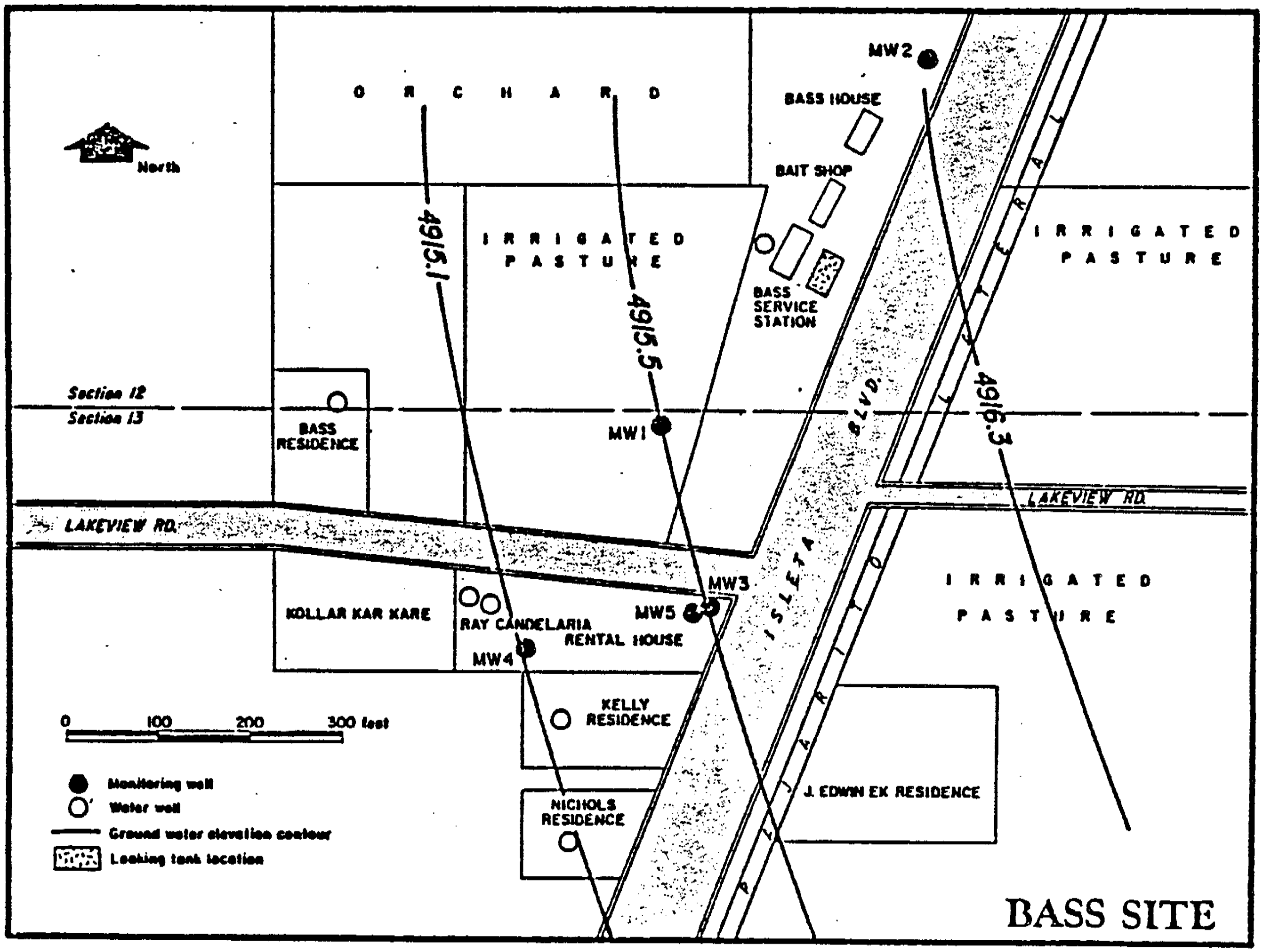


Figure 2. Water table contour map of the Bass Site (from Jercinovic, 1984).

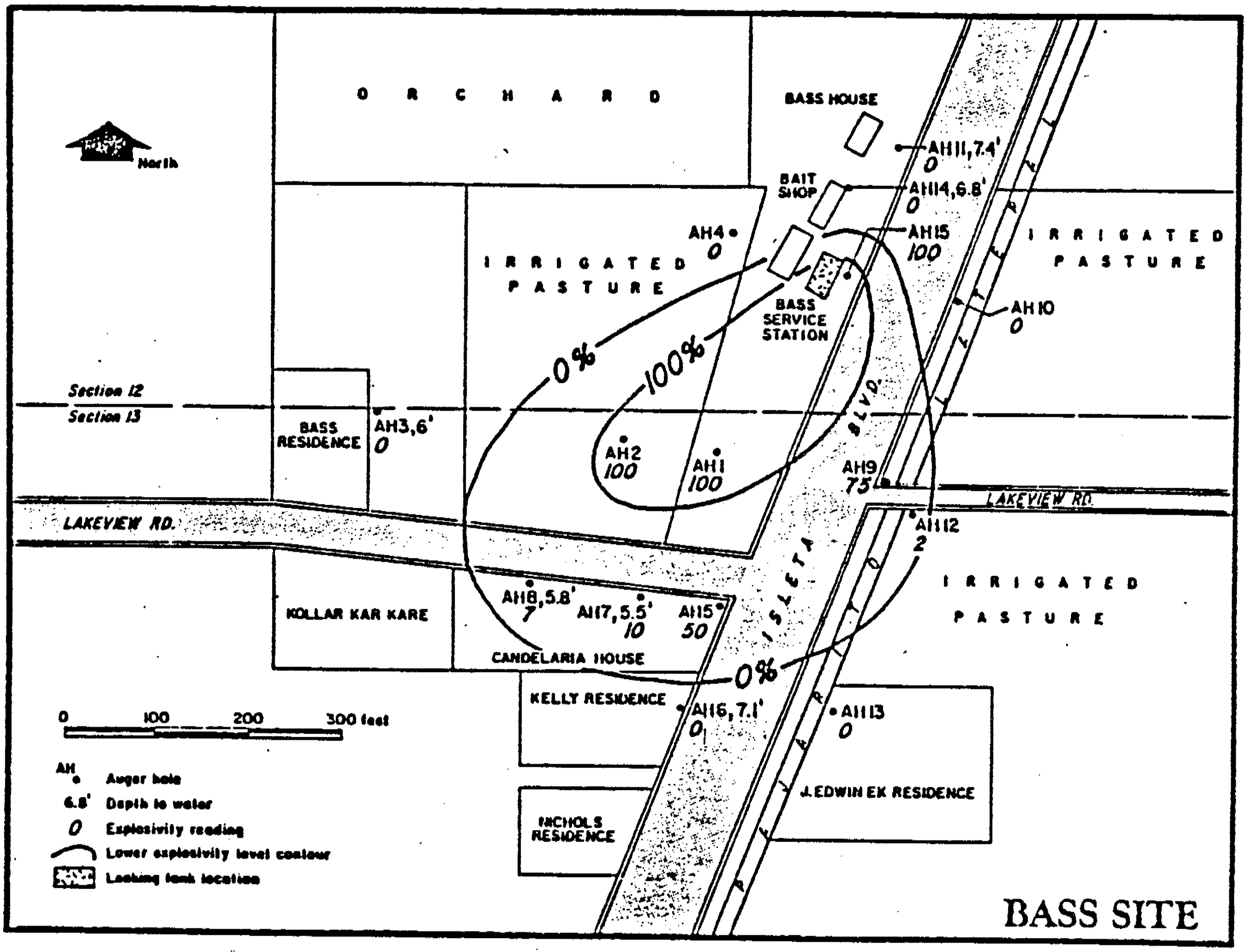
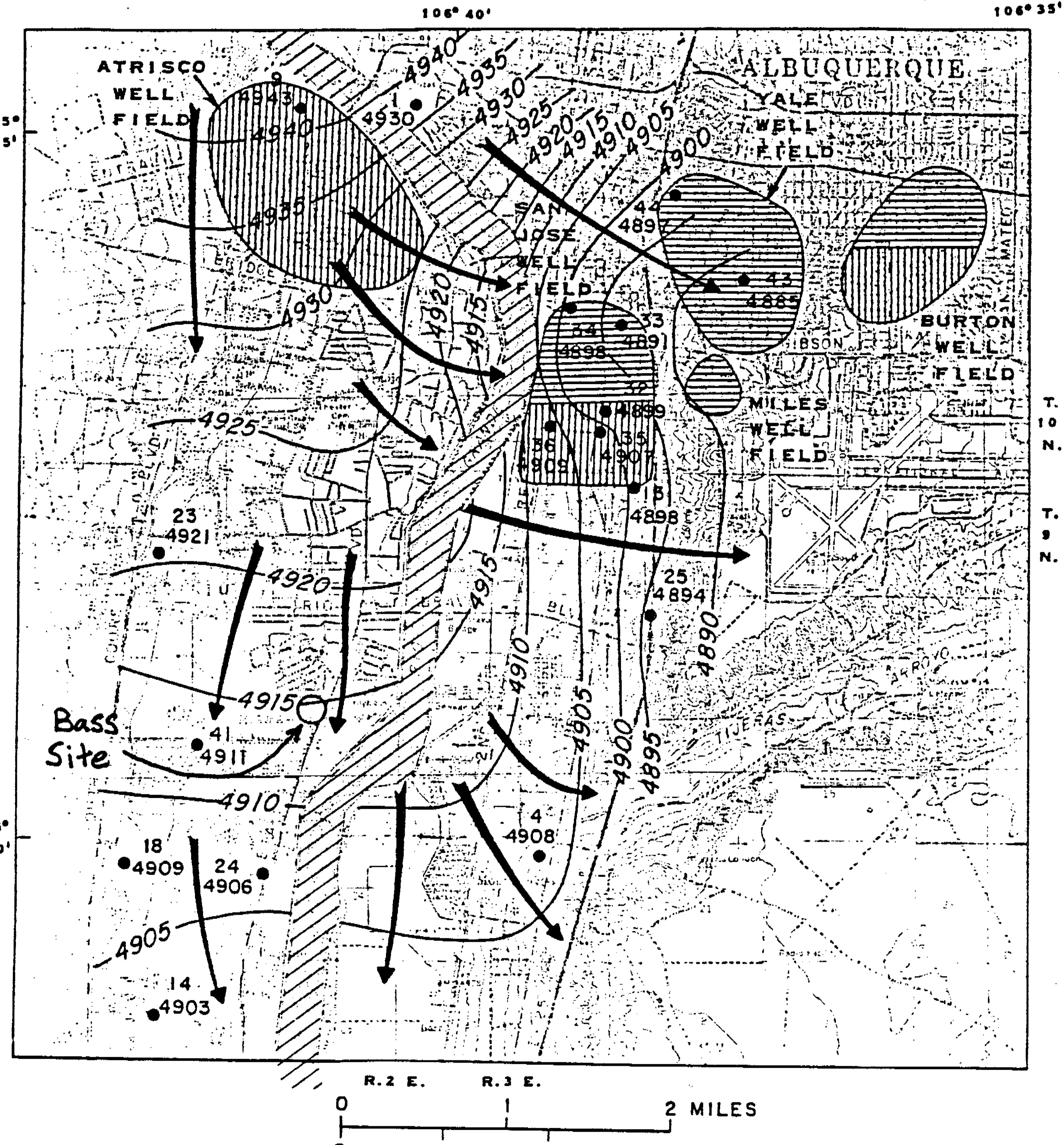


Figure 3. Explosivity contour map of the Bass Site (from Jercinovic, 1984).



EXPLANATION

FLOW LINE--Approximate direction of horizontal component of ground-water flow

MUNICIPAL WELL FIELD WITH WELLS PUMPED DURING 1983--Boundaries are approximate.

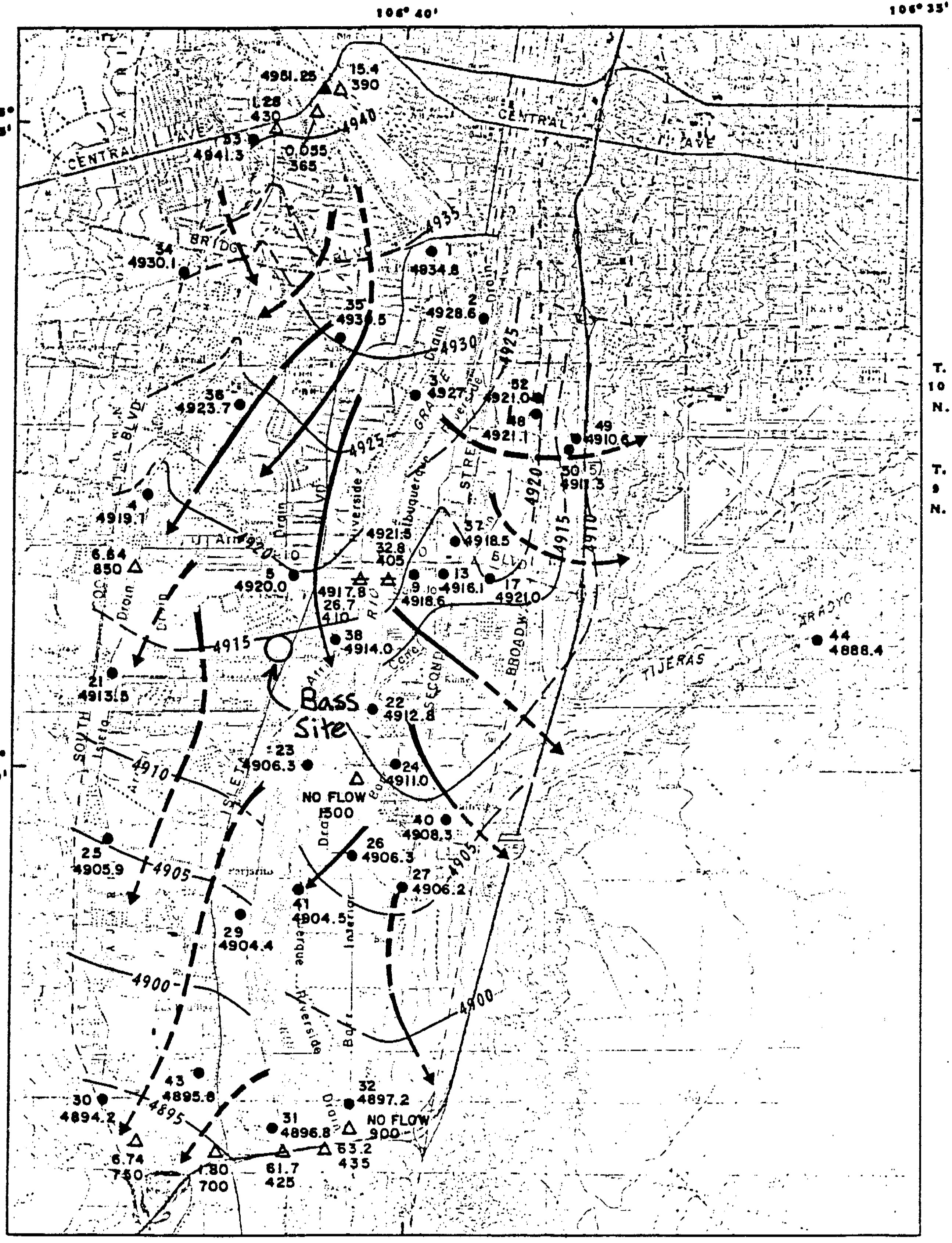
INACTIVE MUNICIPAL WELL FIELD--Boundaries are approximate.

AREA BETWEEN RIVERSIDE DRAINS

—— 4900 —— APPROXIMATE WATER-LEVEL CONTOUR--Shows altitude at which water would have stood in wells, July and August 1983. Contour interval 5 feet. Datum is sea level.

4
4908
● WELL--Upper number is well number in tables 1, 2, and 3. Lower number is water-level altitude, in feet above sea level.

Figure 4. Water levels for wells completed below 4,800 feet above sea level (from Kues, 1986).



Base from U.S. Geological Survey, Albuquerque, 1:100,000, 1978

0 1/2 1 2 MILES

0 1/2 1 2 KILOMETERS

Figure 5. Altitude of the water table on February 28, 1986 (from Peter, 1987).

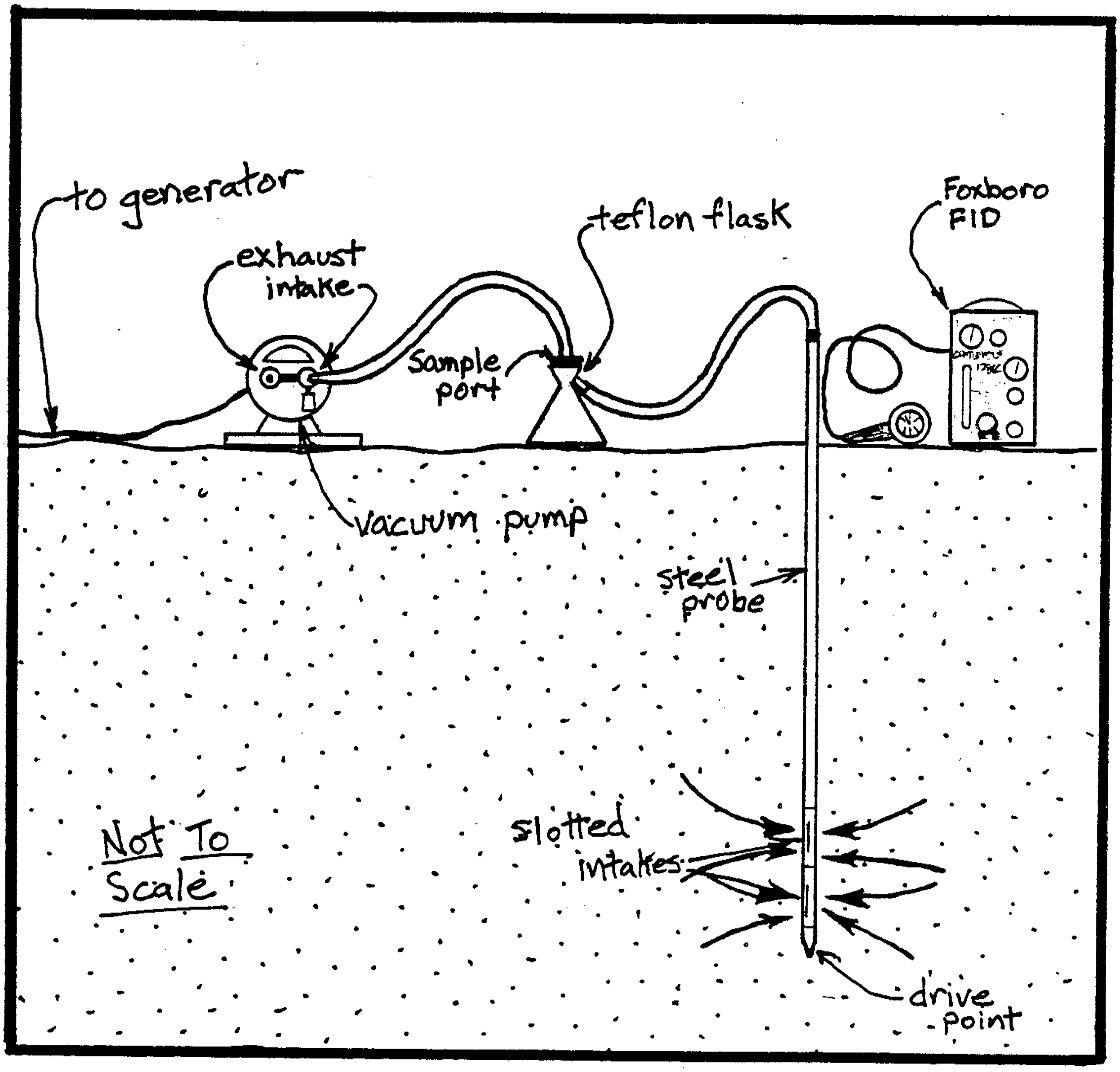
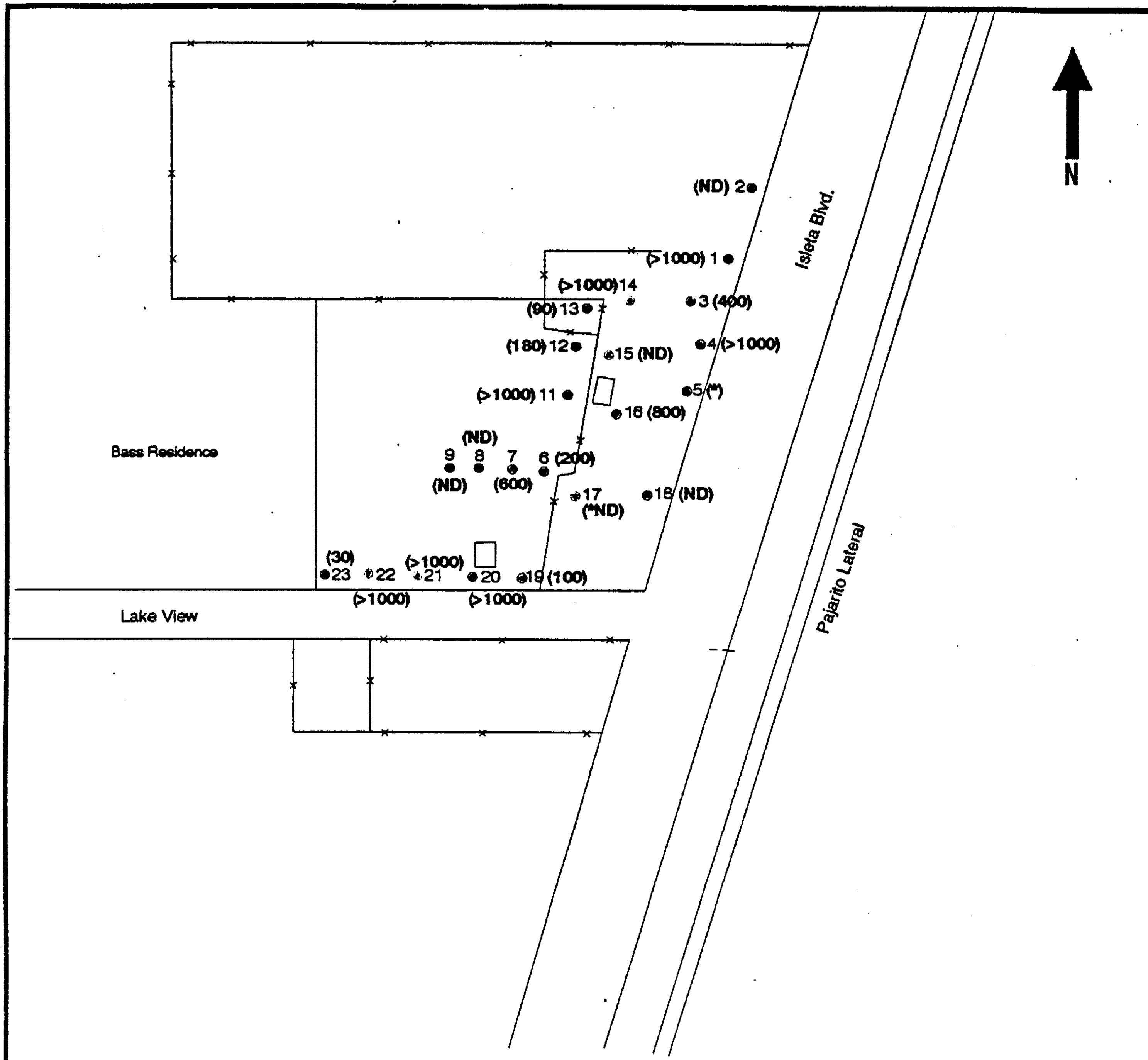


Figure 6. Soil gas survey equipment set up.



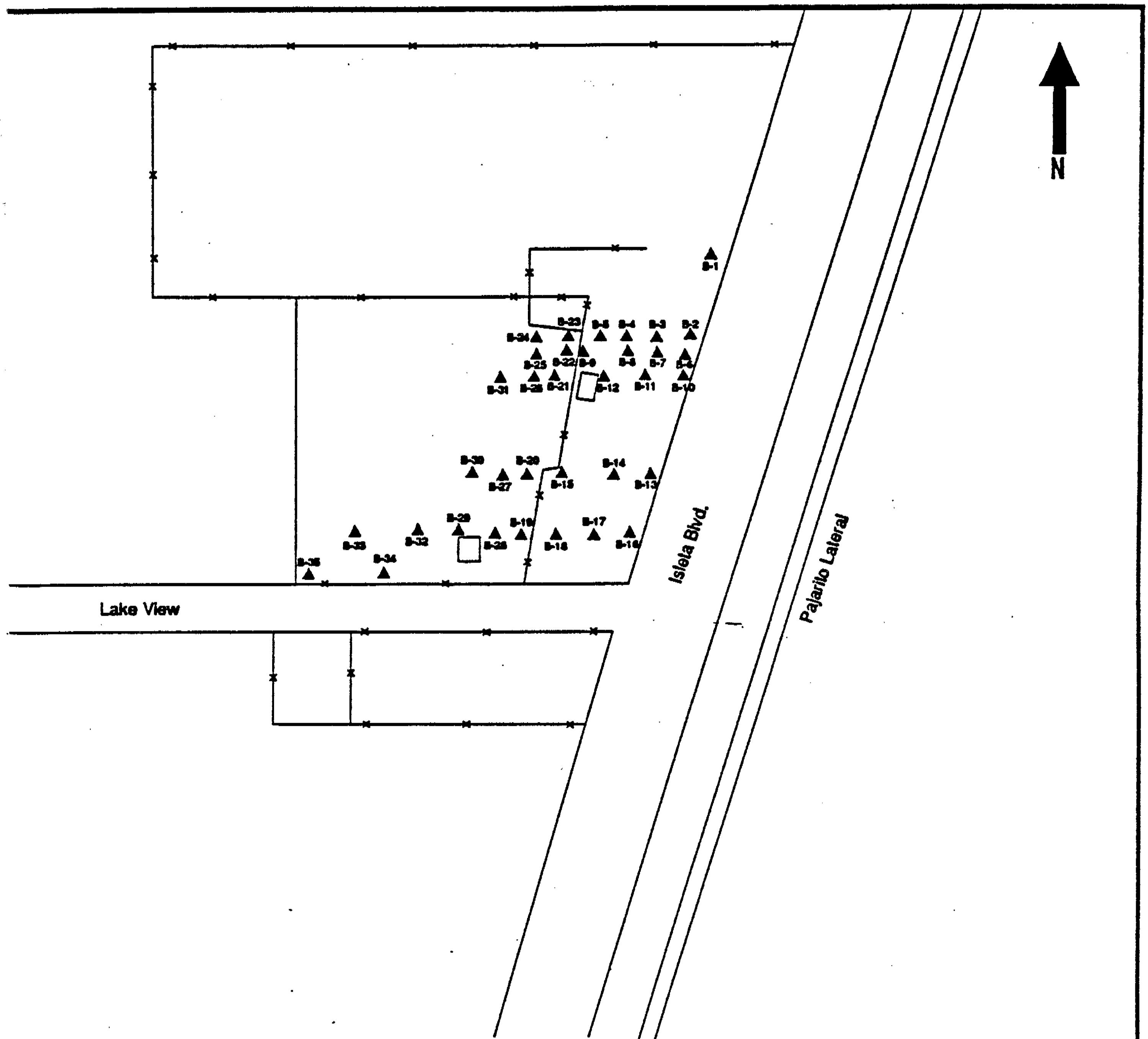
Scale (feet)

0 100 200

- soil gas survey (all probes driven from surface)
- (*) no reading-gasoline odor strong
- clay zone 2.5-3 feet
- fence

Figure 7

AEHD Soil Gas Survey 7-19-90 - 7-20-90
Bass Site
Billings & Associates, Inc. October, 1990



Scale (feet)

0 100 200

▲ boring location

—×—×— fence

Figure 8

Boring Locations
Bass Site
Billings & Associates, Inc. October, 1990

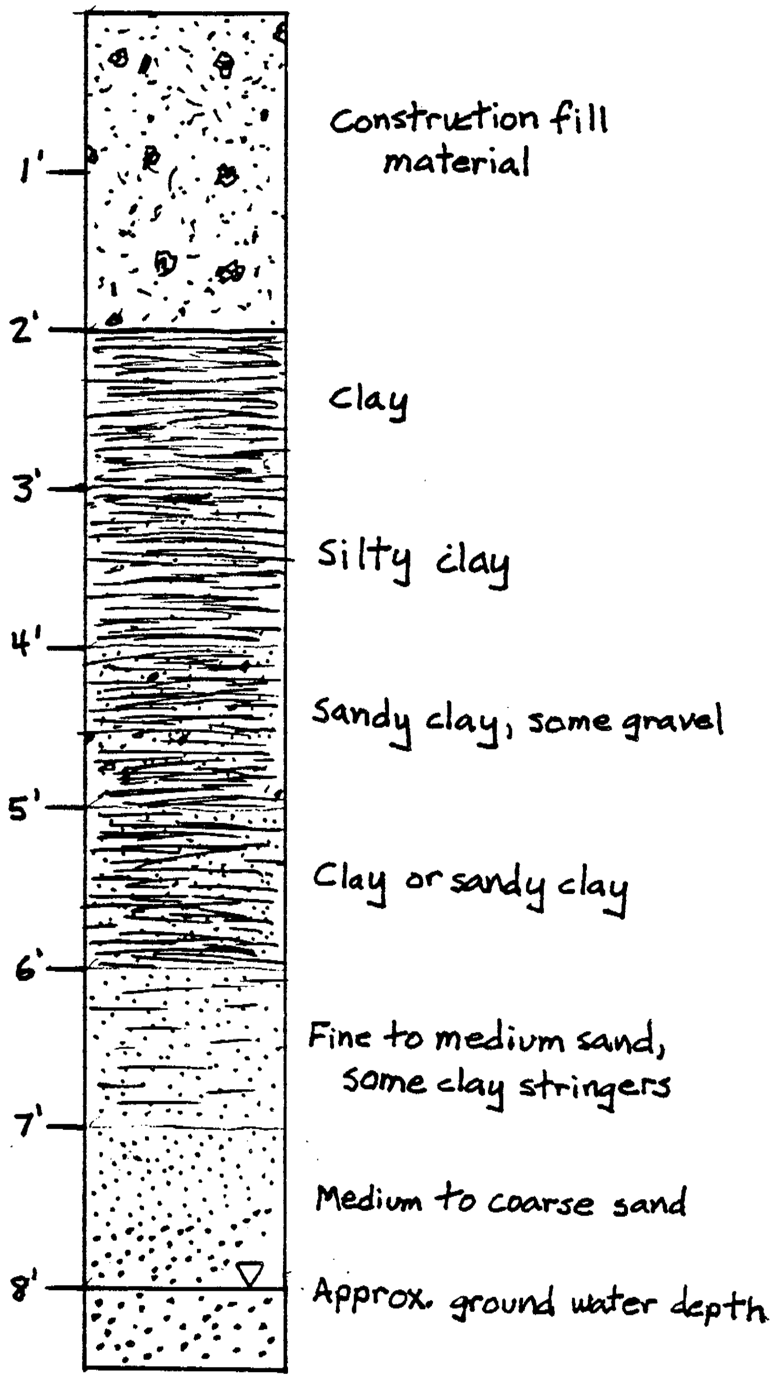


Figure 9. Representative stratigraphy at the Bass Site.

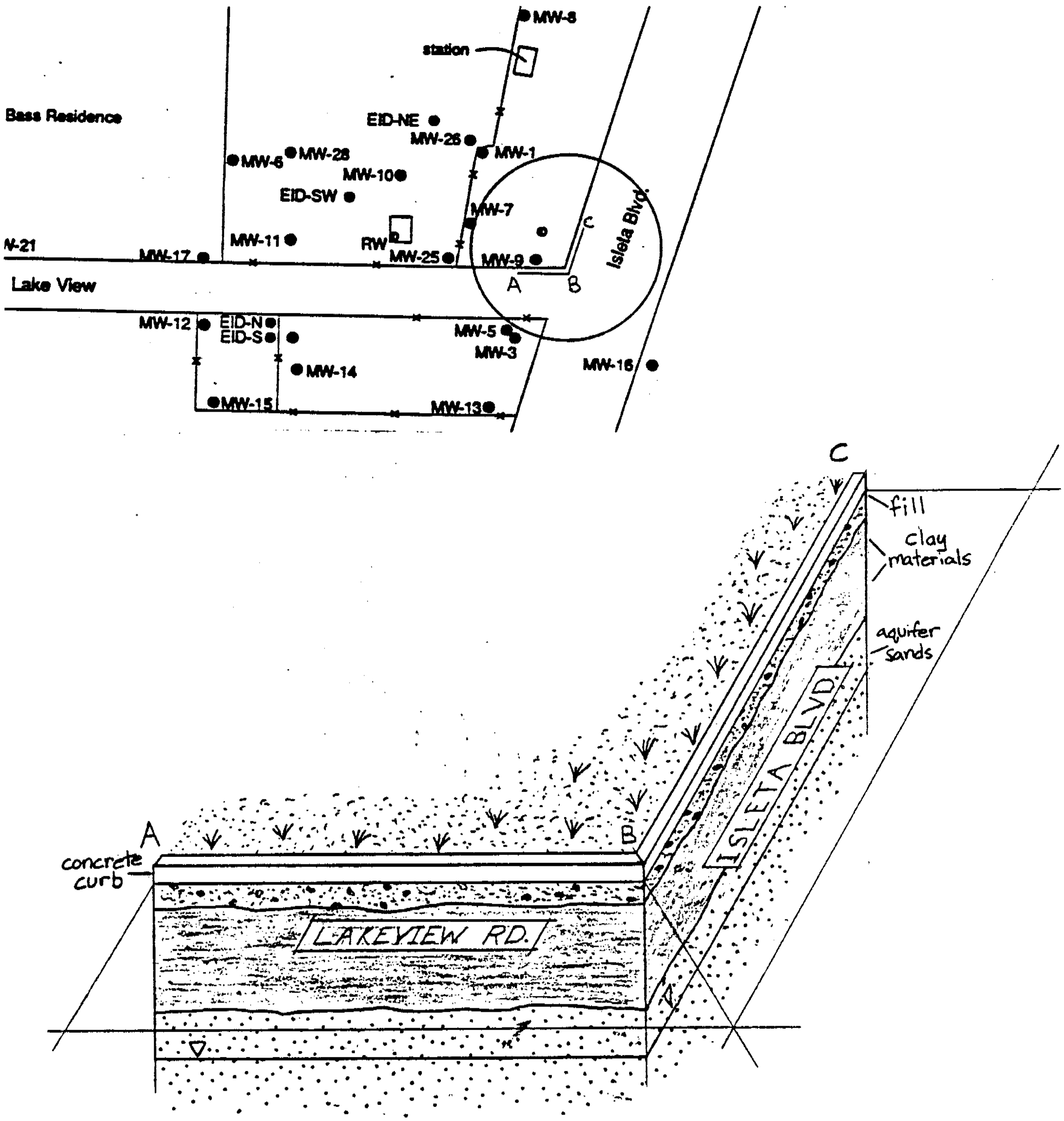


Figure 10. Three-dimensional sketch of Bass Site stratigraphy.

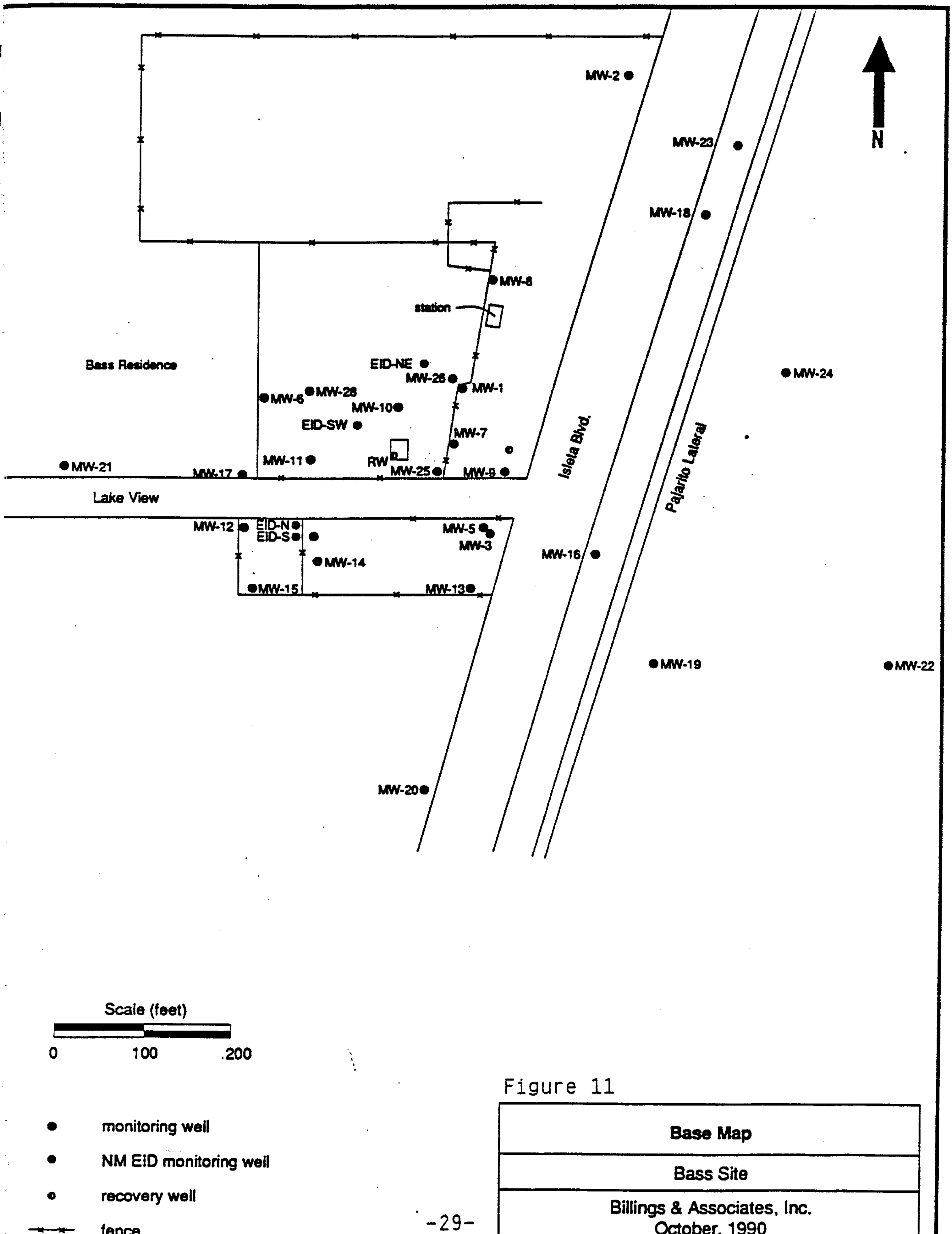


Figure 11

Base Map

Bass Site

Billings & Associates, Inc.
October, 1990

Well Statistics

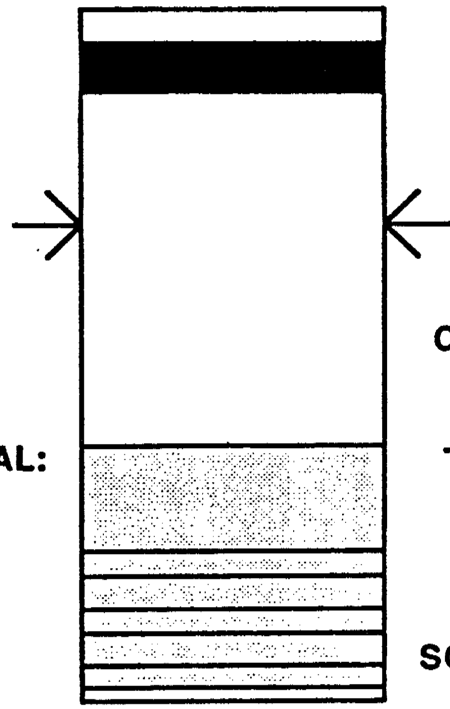
SITE: MW-14

COMPLETION: 2/22/88

TOTAL DEPTH BORING: 15'

SLOT: #20

TOP ELEVATION: 4924.4



DIAMETER: 2"

CEMENT/BENTONITE GROUT: 2' TO 0' BENTONITE

SAND INTERVAL:

SCREEN THICKNESS: 15' TO 5'

TOTAL DEPTH: 15'

REMARKS:

Figure 12. Typical finishing detail for Bass Site monitoring wells.

EID BASS SITE
Billings & Associates, Inc.

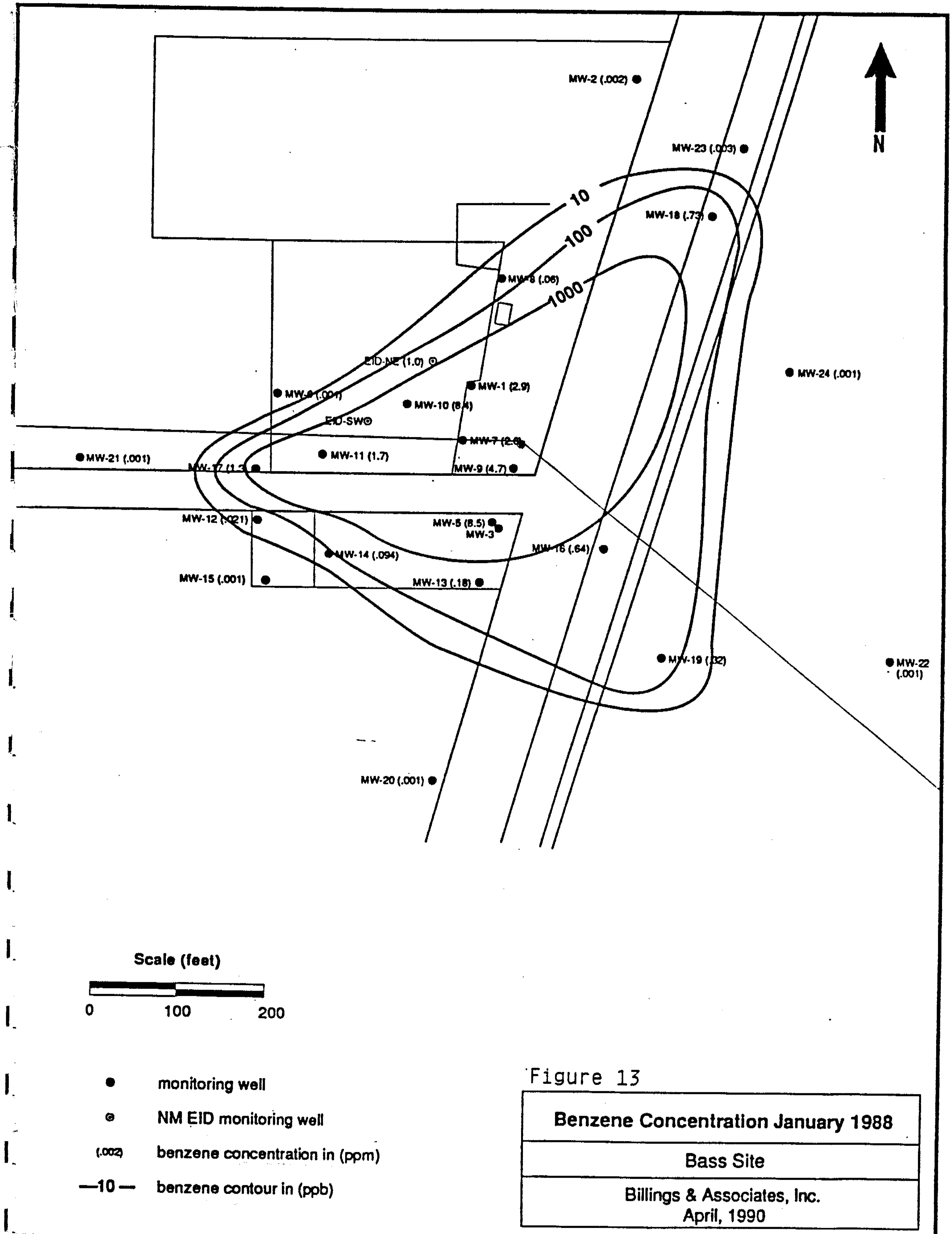
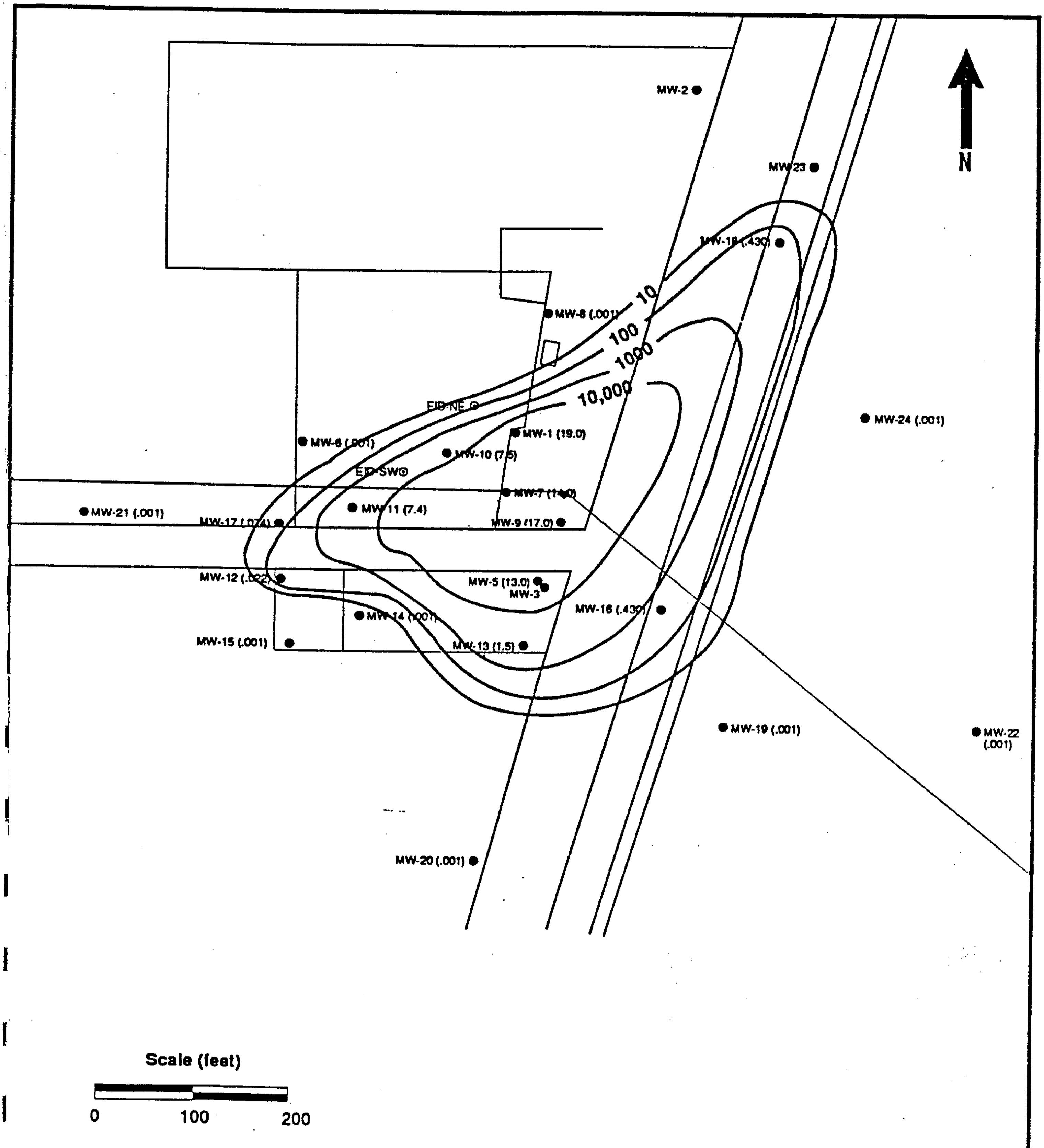


Figure 13

Benzene Concentration January 1988

Bass Site

Billings & Associates, Inc.
April, 1990



● monitoring well

⊙ NM EID monitoring well

(.002) benzene concentration in (ppm)

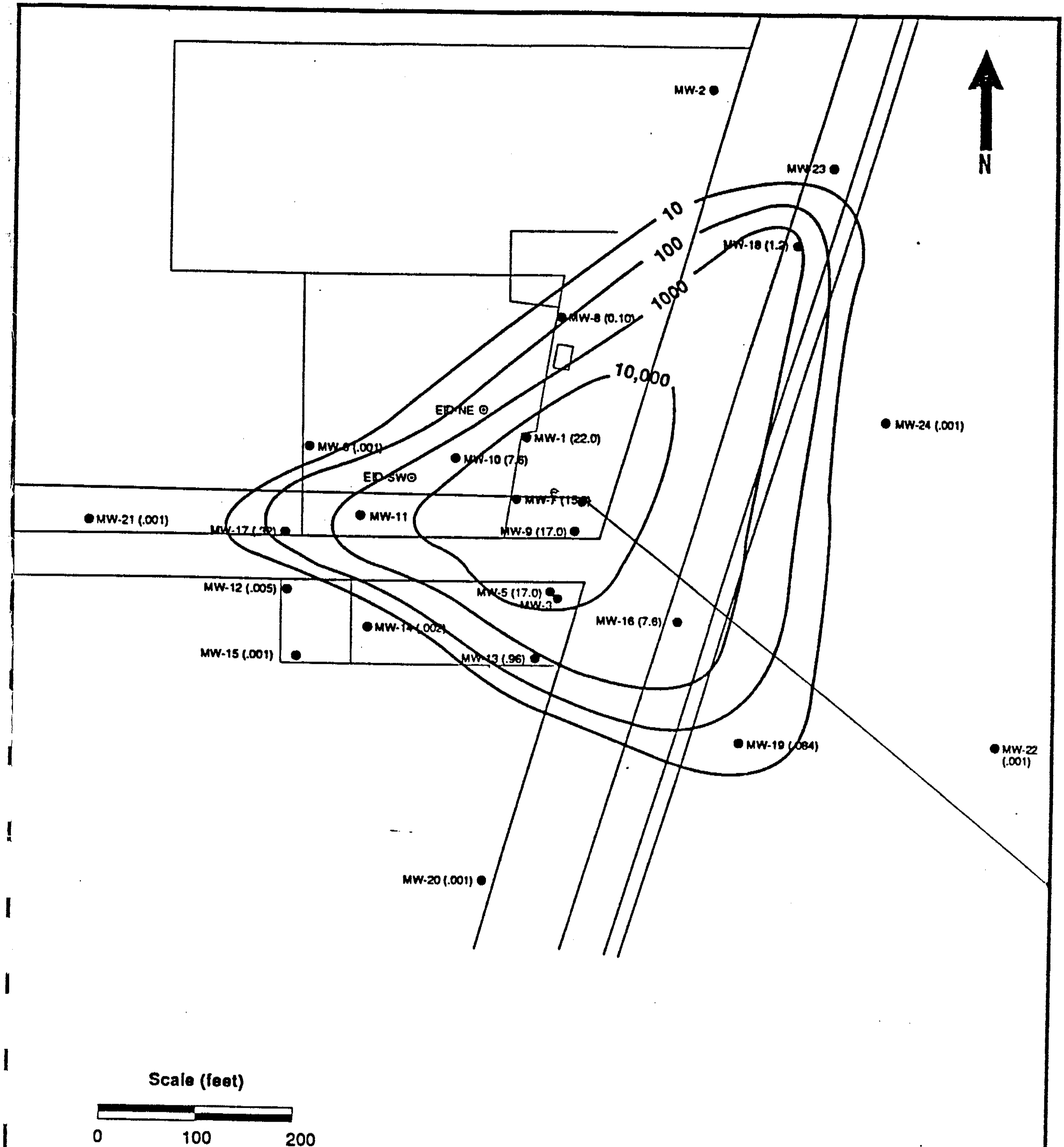
—10— benzene contour in (ppb)

Figure 15

Benzene Concentration February 1989

Bass Site

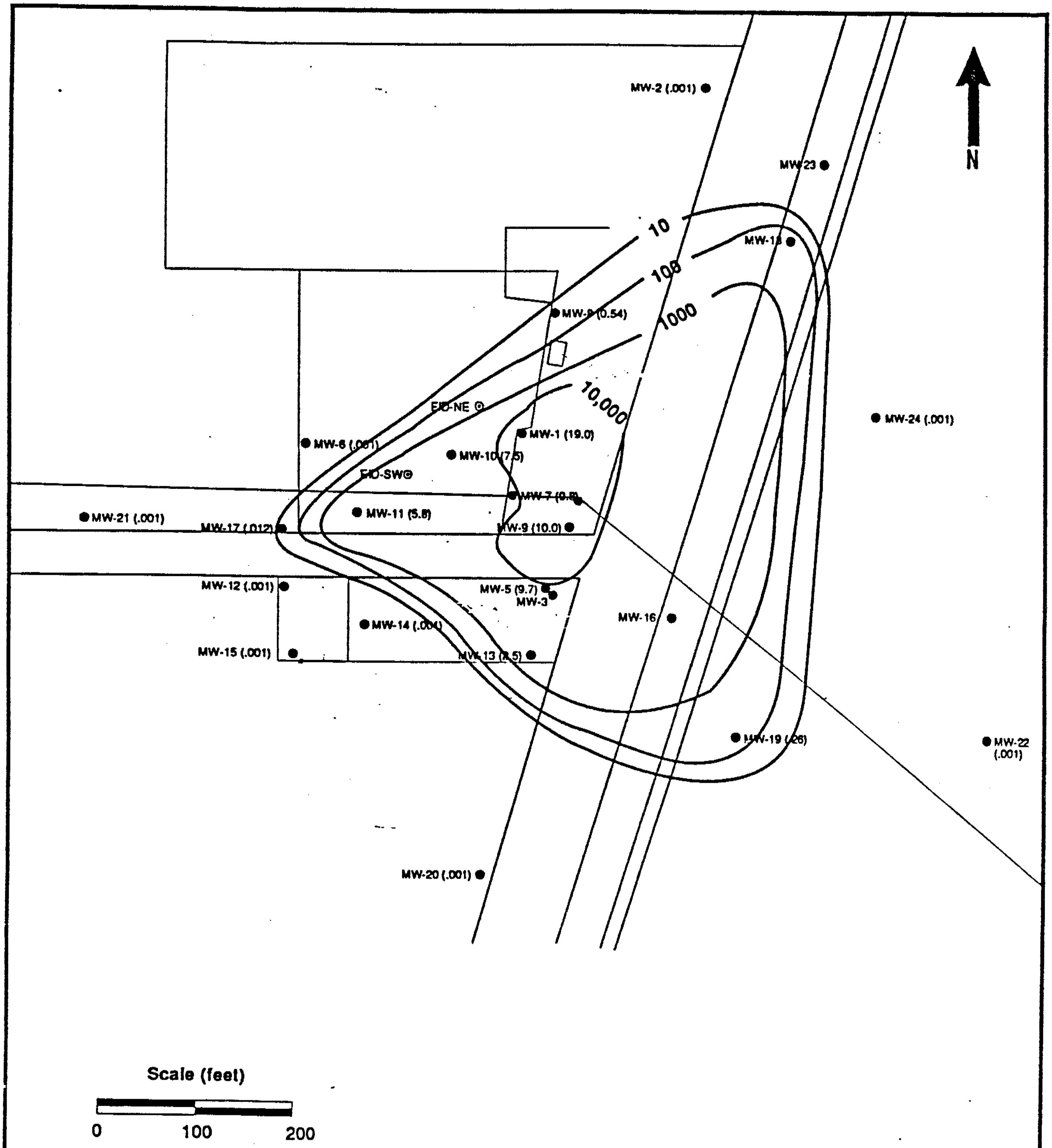
Billings & Associates, Inc.
April, 1990



- monitoring well
- NM EID monitoring well
- (.001) benzene concentration in (ppm)
- —10— benzene contour in (ppb)

Figure 16

Benzene Concentration April 1989
Bass Site
Billings & Associates, Inc. April, 1990



● monitoring well

⊙ NM EID monitoring well

(.001) benzene concentration in (ppm)

—10— benzene contour in (ppb)

Figure 17

Benzene Concentration July 1989
Bass Site
Billings & Associates, Inc. April, 1990

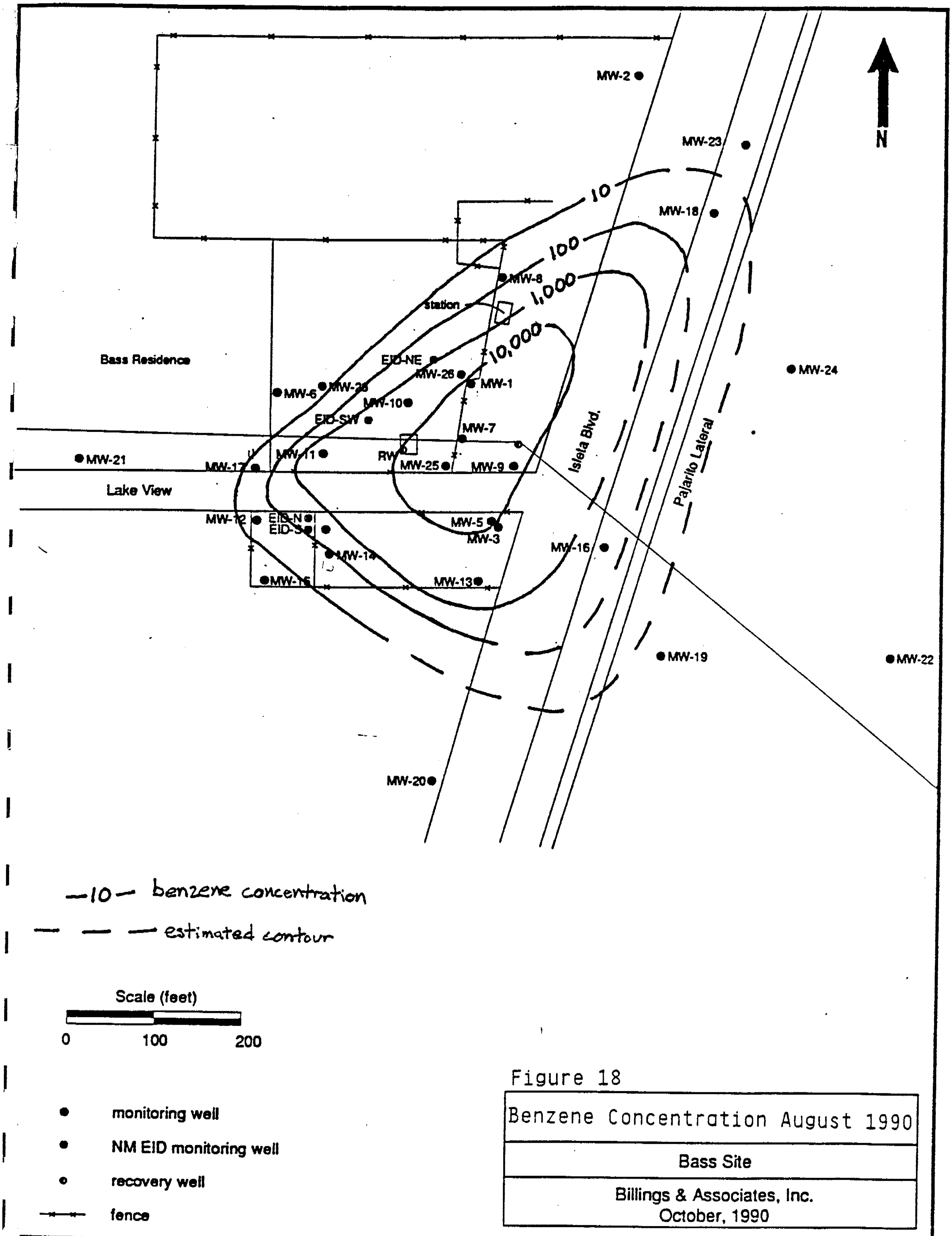


Figure 18

Benzene Concentration August 1990

Bass Site

Billings & Associates, Inc.
October, 1990

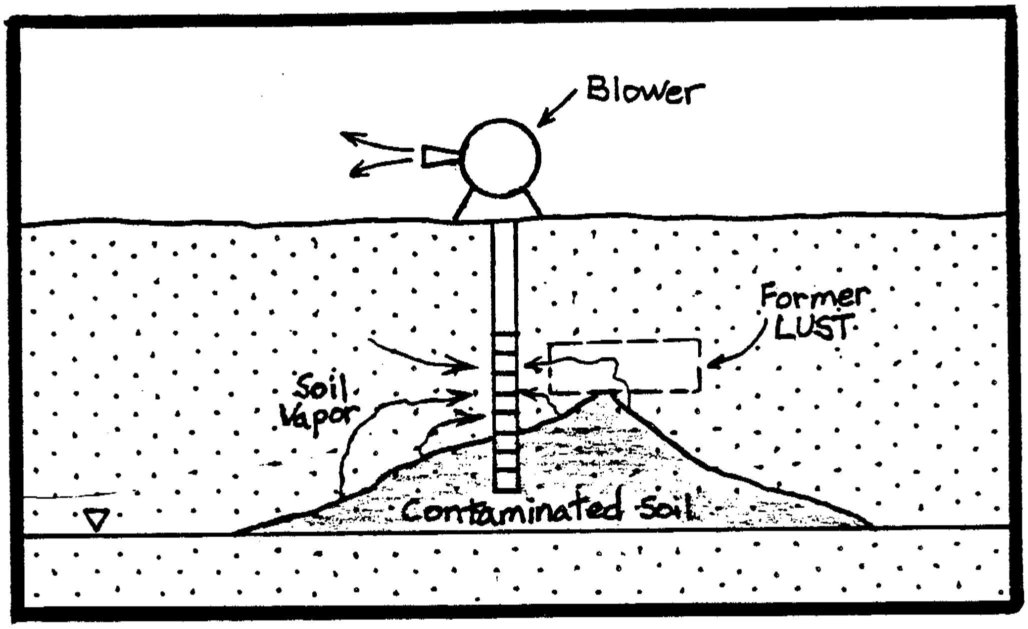


Figure 19. Possible configuration utilizing a single soil venting well (adapted from Hinchee and Miller, 1990).

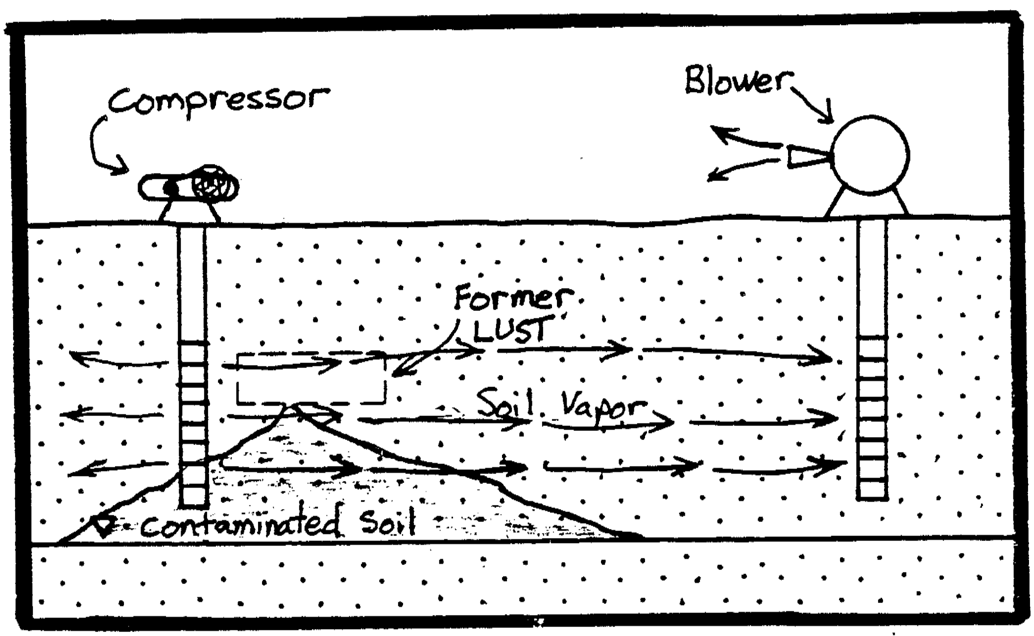


Figure 20. Possible configuration utilizing air injection and soil venting (adapted from Hinchee and Miller, 1990).

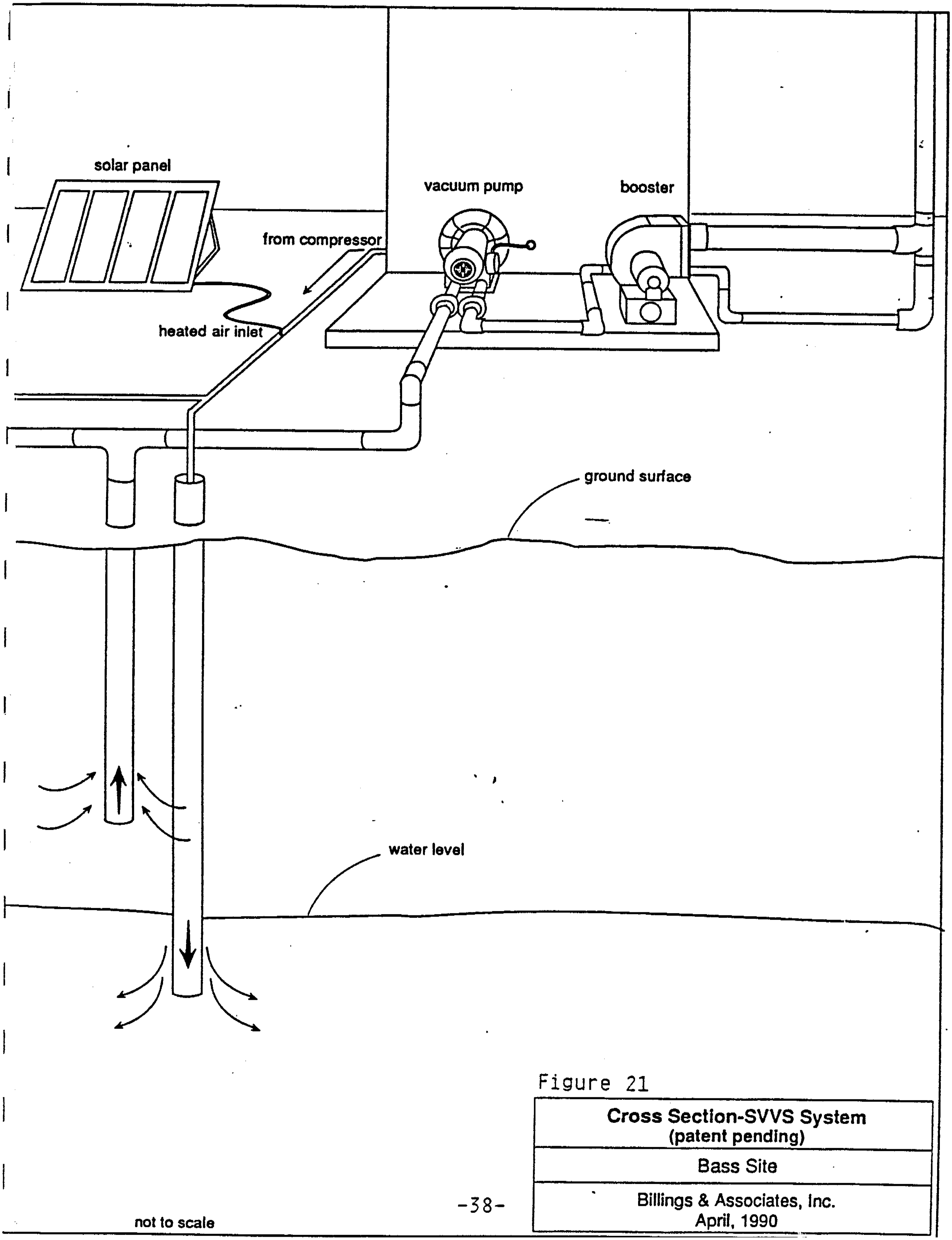


Figure 21

Cross Section-SVVS System (patent pending)
Bass Site
Billings & Associates, Inc. April, 1990

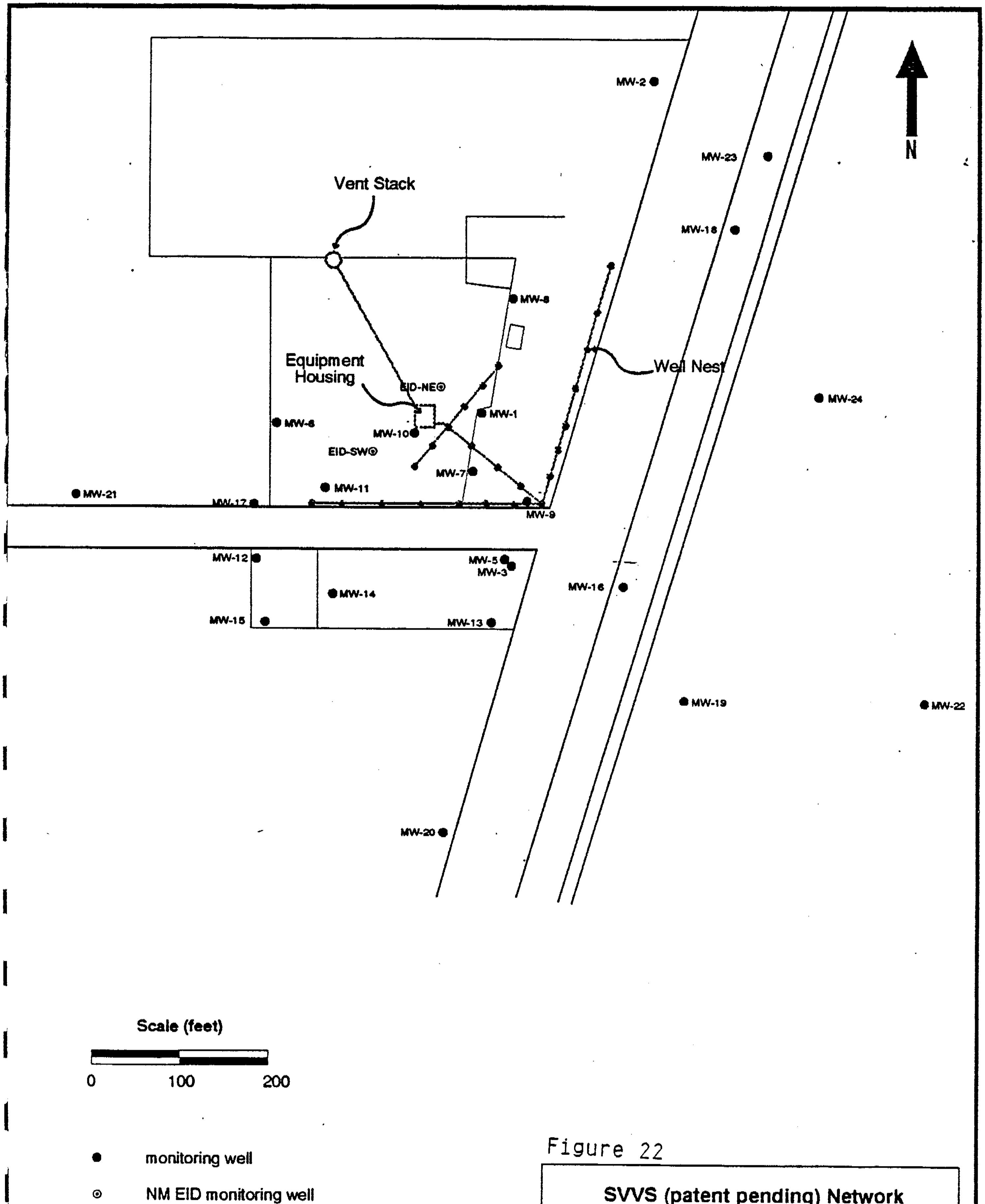


Figure 22

SVVS (patent pending) Network

Bass Site

Billings & Associates, Inc.
April, 1990

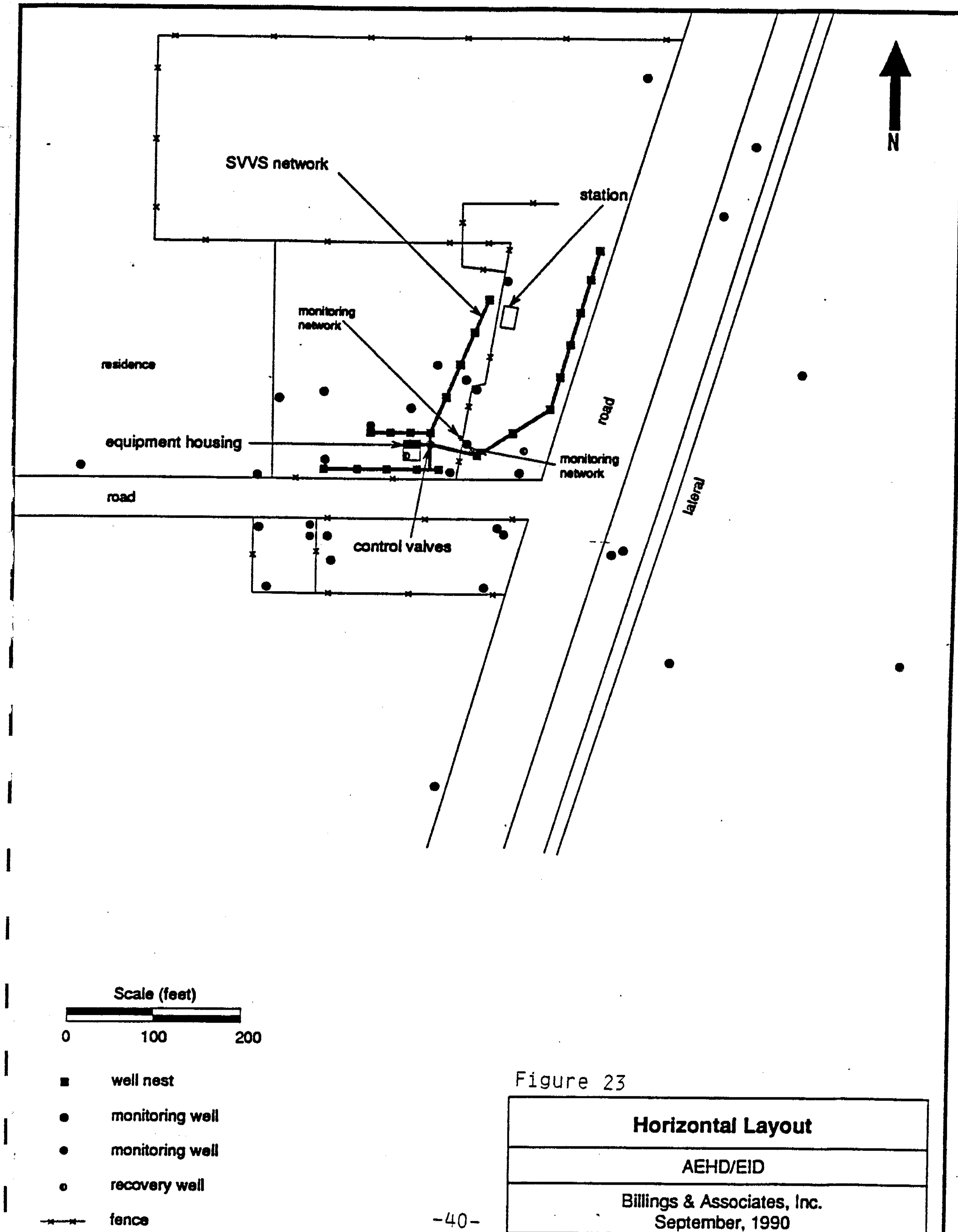


Figure 23

Horizontal Layout

AEHD/EID

Billings & Associates, Inc.
September, 1990

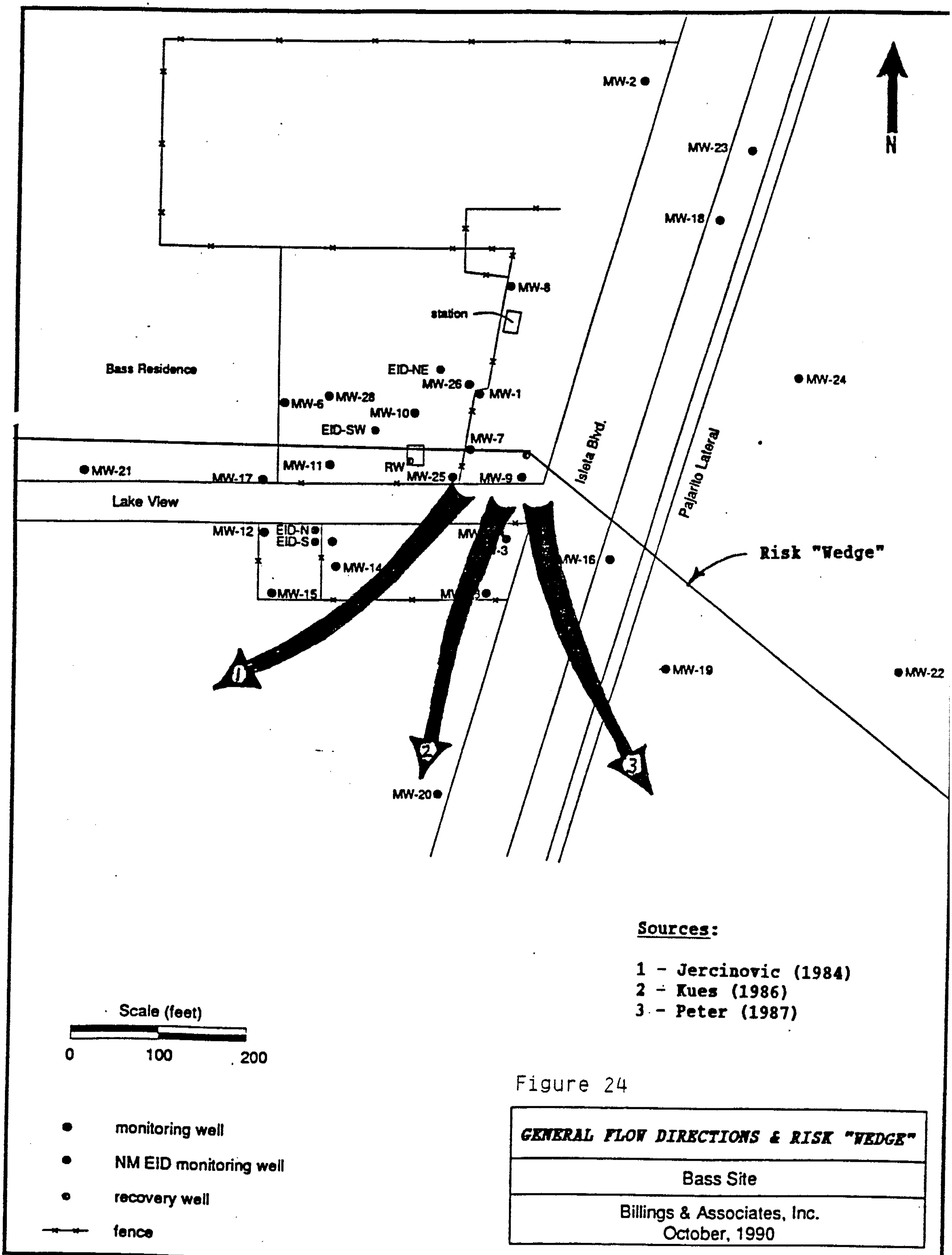


Figure 24

GENERAL FLOW DIRECTIONS & RISK "WEDGE"

Bass Site

Billings & Associates, Inc.
October, 1990

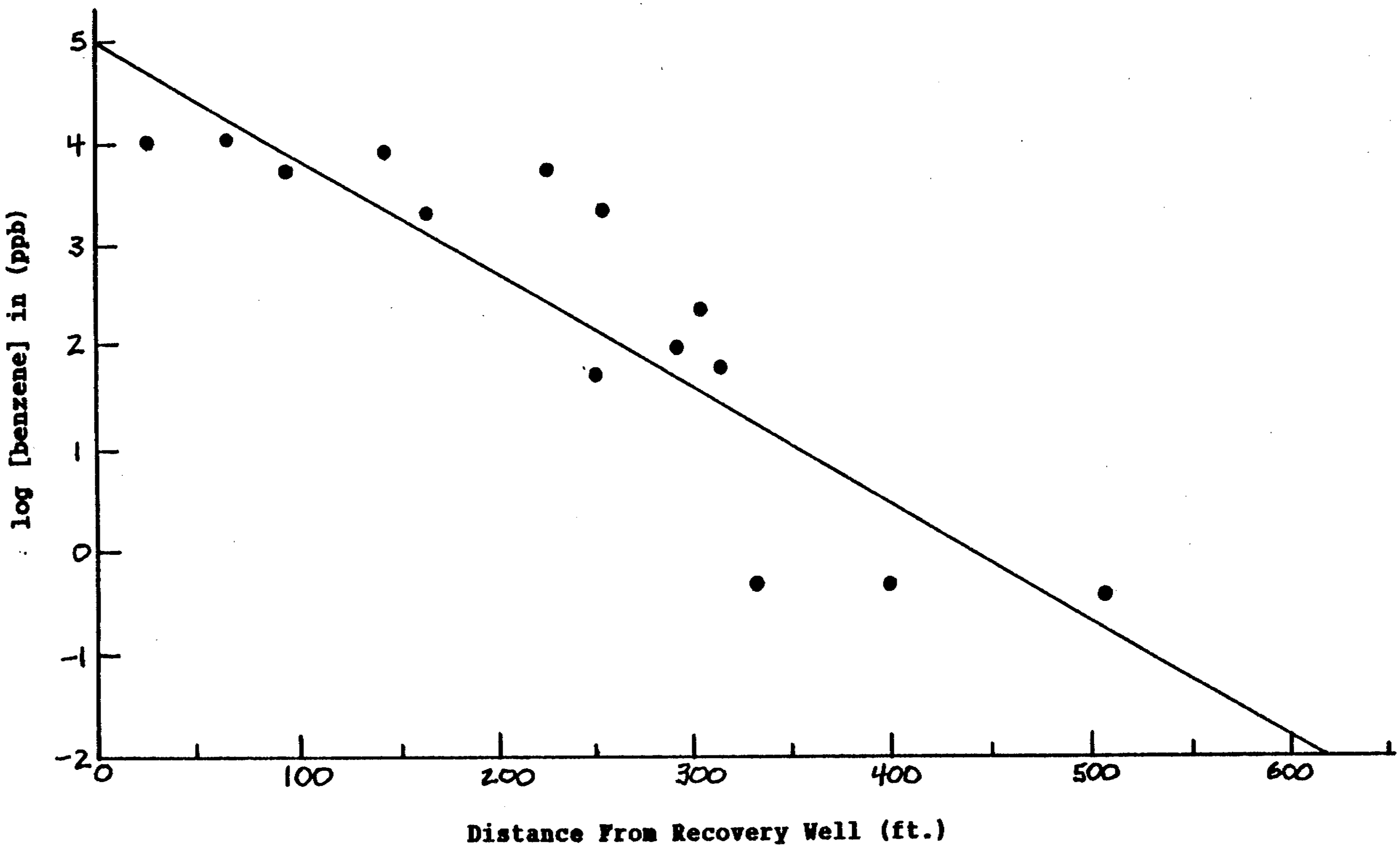


Figure 25. "Best fit" of benzene data vs. monitoring well distance from the recovery well.

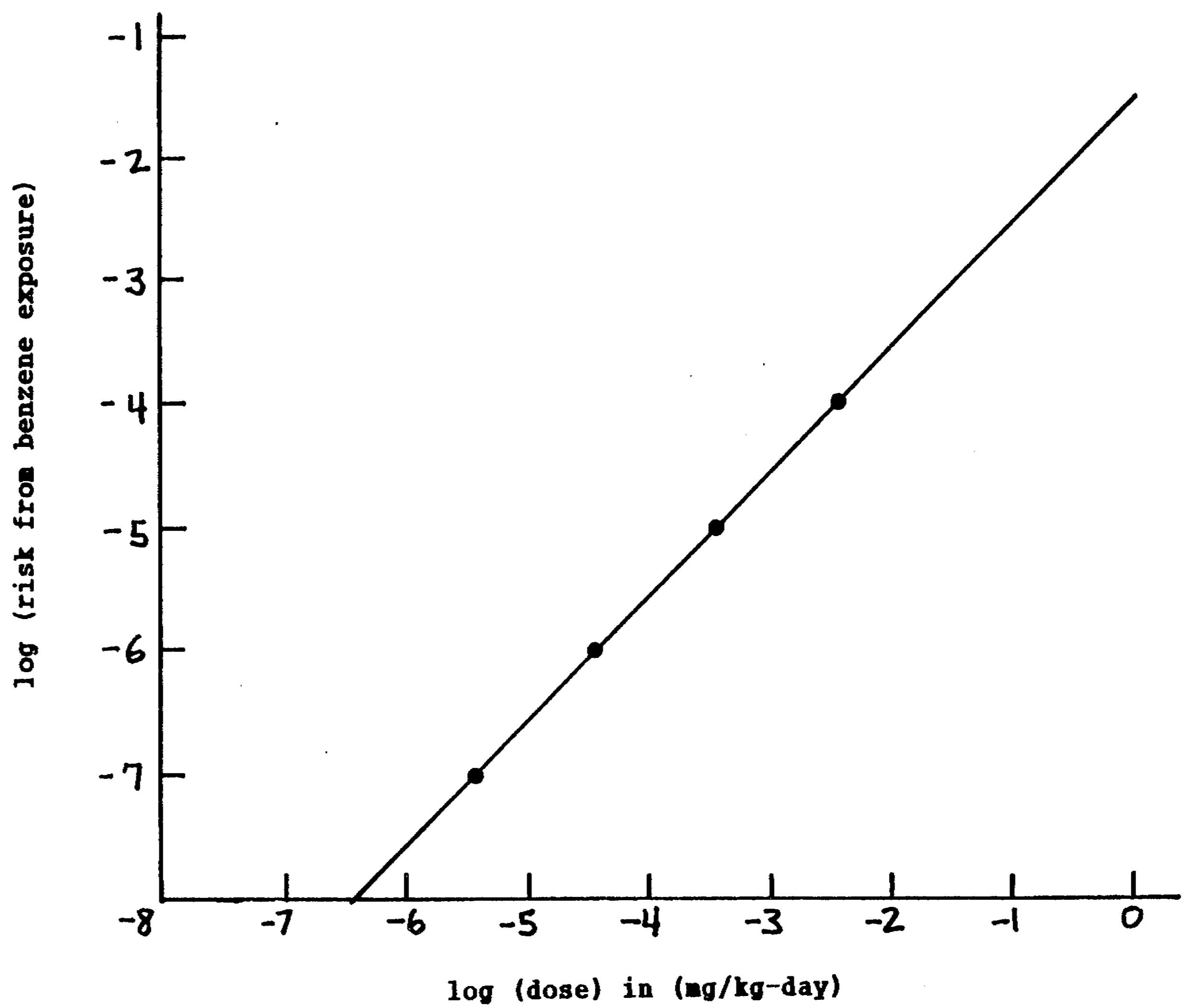


Figure 26. Plot of risk from benzene ingestion vs. dose (prepared using data from ATSDR, 1989).

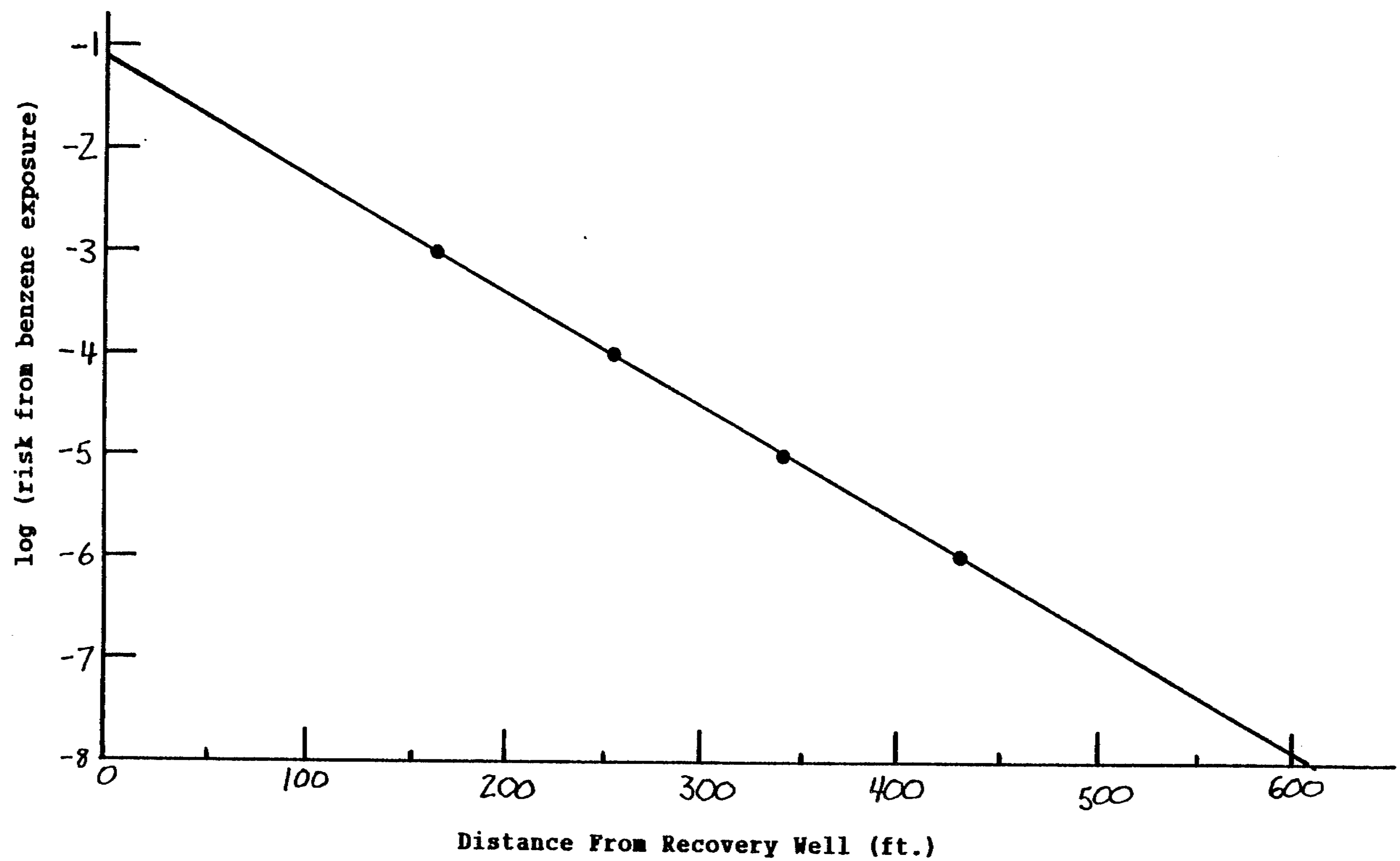


Figure 27. Plot of risk inside the risk wedge from benzene ingestion vs. distance from the recovery well.

TABLES

TABLE 1. Soil Boring Data from the Bass Site Augering Survey, July 28-31, 1990 (ppm)

Bore Hole	Depth	OVA Reading
B-1	3.5′	1000+
B-2	3.5′	1000+
B-4	2′	23.5
"	4′	112.9
"	6′	165.9
B-5	2′	5.8
"	4′	13.1
"	6′	7.9
B-6	2′	156.5
"	4′	206
"	6′	224
B-7	2′	105.4
"	4′	92.2
"	6′	91.7
B-8	2′	17.4
"	4′	124.1
"	6′	179.5
B-9	2′	18.5
"	4′	9.4
"	6′	9.4
B-10	2′	218
"	6′	687
"	8′	247
B-11	2′	134.7
"	6′	107.9
"	8′	180.1
B-12	2′	173.9
"	6′	208.9
"	8′	246.0
B-13	2′	22.7
"	6′	105.6
"	8′	147.2
B-14	2′	111.0
"	6′	156.7
"	8′	182
B-15	2′	39.2
"	6′	126.7
"	8′	165.6
B-16	2′	6.2
"	6′	48.7
"	8′	68.9
B-17	2′	88.4
"	6′	129.4
"	8′	214.6
B-18	2′	68.7
"	6′	96.4
"	8′	186.3
B-19	2′	26.6
"	5′	179.3
B-20	2′	28.7
"	5′	214.0
B-21	3′	88.7
"	5′	220.3
B-22	3′	20.2
"	5′	13.8
B-23	3′	11.2
"	5′	65.6
B-24	3′	16.1
"	6′	38.6
B-25	3′	9.7
"	6′	40.2
B-26	3′	28.9
"	6′	98.7
B-27	3′	181.1
"	6′	213.6
B-28	3′	175.6
"	6′	240.1
B-29	3′	79.2
"	6′	179.5
B-30	3′	131.1
"	6′	240.1
B-31	3′	2.8
"	6′	3.7
B-32	3′	9.3
"	6′	341
B-33	3′	8.6
"	6′	416
B-34	3′	15.6
"	6′	316
B-35	3′	7.7
"	6′	534

TABLE 2. Summary of the August, 1990, Ground Water Sampling Results at the Bass Site (ppm)[a]

Well	Date	Benzene	Toluene	Ethylbenzene	Total Xylenes
MW-1	8/8/90	17.00	33.10	2.46	9.60
MW-2	NS[b c]				
MW-3	8/9/90	8.31	8.80	16.00	17.60
MW-4	NS[b]				
MW-5	8/9/90	11.90	0.12	18.30	9.80
MW-6	8/10/90	<0.001	<0.001	<0.001	<0.001
MW-7	8/8/90	12.60	16.50	2.07	7.30
MW-8	NS[b]				
MW-9	8/8/90	10.30	18.20	1.58	7.95
MW-10	8/8/90	5.97	21.80	1.61	9.39
MW-11	8/8/90	3.27	17.90	1.73	11.61
MW-12	8/10/90	0.06	<0.001	<0.001	0.02
MW-13	8/9/90	5.30	<0.10	<0.10	0.39
MW-14	8/9/90	0.02	<0.001	<0.001	<0.001
MW-15	NS[c]				
MW-16	NS[b]				
MW-17	8/10/90	<0.005	<0.005	<0.005	0.12
MW-18	NS[b]				
MW-19	NS[b]				
MW-20	NS[c]				
MW-21	NS[c]				
MW-22	NS[c]				
MW-23	NS[b c]				
MW-24	NS[c]				
MW-25	8/8/90	<0.001	<0.001	0.002	0.003
MW-26	8/8/90	<0.001	<0.001	<0.001	<0.001
MW-27	NA[d]				
MW-28	8/10/90	<0.001	<0.001	<0.001	<0.001
MW-29	NS[b c]				
MW-30	NS[c]				

[a] All sample analysis performed by the State Laboratory Division.
[b] Not Sampled. Well was damaged or could not be located.
[c] Not Sampled. Well has shown no past history of contamination and was not sampled due to cost considerations.
[d] Not Available. No records for this well have been found.

TABLE 3. New Mexico Water Quality Control Commission Ground Water Quality Standards (1987) for Selected Constituents (ppm)

Constituent	Max. Concentration Level (or MCL)
Benzene	0.01
Toluene	0.75
Ethylbenzene	0.75
Total Xylenes	0.62

TABLE 4. Summary of Benzene Data in the Risk "Wedge" at the Bass Site

Well	No. of Samples	Range(ppm)	Mean(ppm)	Standard Deviation	Distance from Recovery Well
MW-3	7	0.67-10.0	5.5	3.5	93′
MW-5	11	0.43-17.0	8.3	4.9	143′
MW-7	9	2.6-15.0	11.6	4.7	64′
MW-9	9	4.7-20.0	11.5	5.4	25′
MW-11	8	1.7-13.0	5.8	3.7	225′
MW-12	8	ND[a] -0.22	0.062	0.090	314′
MW-13	9	0.18-5.3	2.1	1.9	164′
MW-14	8	ND-0.20	0.052	0.074	251′
MW-15	6	ND-ND	0.00043[b]	----	332′
MW-16	4	0.21-7.6	2.2	3.6	154′
MW-17	8	<0.005-1.3	0.24	0.44	304′
MW-19	7	ND-0.32	0.095	0.14	293′
MW-20	7	ND-ND	0.00039[b]	----	399′
MW-21	6	ND-ND	0.00037[b]	----	507′
MW-25[c]	2	ND-<0.001	----	----	86′

[a] In calculating the mean concentrations and standard deviation, a value of one-half the detection limit was assigned to samples in which benzene was not detected. This is considered unlikely to significantly over- or underestimate actual mean concentrations.
[b] Average taken by using one-half the detection limit of each sample.
[c] Insufficient data to include in analysis.

TABLE 5. Benzene Data from Various Residential Wells in the Risk "Wedge" at the Bass Site

Well	Date	Concentration (ppm)	Approx. Distance from Recovery Well
Bass Garage	8/24/83	0.006	400′
Bass House	6/13/83	ND	475′
Bass Resid.	6/13/83	ND	550′
Ek Resid.	10/6/83	ND	500′
Kelly Well	6/16/83	ND	300′
" "	8/24/83	0.0003	"
Candelaria	6/16/83	ND	150′
"	8/24/83	0.0022	"
"	10/6/83	ND	"