(2)

INSTALLATION RESTORATION PROGRAM
STAGE 2

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

FOR

BOMARC MISSILE ACCIDENT SITE
MCGUIRE AIR FORCE BASE
NEW JERSEY

HEADQUARTERS MILITARY AIRLIFT COMMAND
SCOTT AIR FORCE BASE, ILLINOIS

MAY 1992

PREPARED BY

THE EARTH TECHNOLOGY CORPORATION
300 NORTH WASHINGTON STREET
SUITE 700
ALEXANDRIA, VIRGINIA 22314

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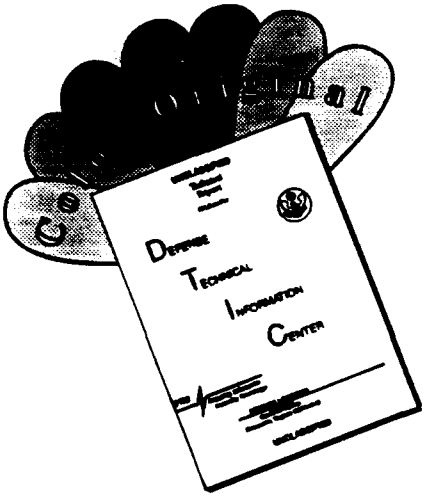

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EXECUTIVE SUMMARY

This report presents the findings of the Remedial Investigation/Feasibility Study (RI/FS) for the Boeing Michigan Aeronautical Research Center (BOMARC) Missile Site, McGuire Air Force Base (AFB), New Jersey. Specific tasks completed, findings, and recommendations are summarized below.

I. Site Description and Location

The BOMARC Missile Site occupies approximately 218 acres just east of Ocean County Highway 539 in Plumsted Township, Ocean County, New Jersey (Figure ES-1). It lies about 11 road miles east of McGuire AFB and is contained within the Fort Dix Military Reservation on land leased to the Air Force (Figure ES-2).

Rows of shelters built to house nuclear warhead-equipped BOMARC missiles were constructed at this facility during the late 1950s and early 1960s (Figure ES-3). The facility was deactivated in 1972, with all missiles removed from the shelters. Although the facility has been deactivated, it remains under Air Force lease and jurisdiction.

On June 7, 1960, an explosion and a fire occurred in BOMARC Missile Shelter 204. The force of the explosion destroyed portions of the shelter roof, caused flames to rise to 20 feet, and caused black smoke to blanket the area. At the time of the fire, a north-northeast wind of two to eight knots blew the smoke into the surrounding areas. Some of the plutonium released by the fire may have been carried aloft by the northeasterly wind, and dispersed from the BOMARC Missile Site.

The Air Force radiation surveys indicate that a substantial amount of plutonium was exhausted from Shelter 204 during the incident. The wall contamination results clearly show that uncontaminated air entered the shell of the structure from the north and northeast as these wall areas were uncontaminated. The air traveled southward towards the fire, and was exhausted in the southwest quadrant. Some contaminated exhaust was circulated around the lower level of the structure shell, and contaminated the lower walls on the east and west sides. The contaminated exhaust appears to have exited the building at the north half of the west wall and at the midline of the east wall. Substantial amounts of contamination were also detected on the upper surfaces of an "I" beam, which supports the roof structure, upwind from the source of plutonium.

The fire burned uninhibited for about 30 minutes. As part of the fire fighting activity, the area was sprayed with water from the fire hoses for approximately 15 hours. As a result, plutonium-contaminated water flowed under the front door of the Missile Shelter 204, down the asphalt apron and street, and into the drainage ditch leading outside the site boundary. An earthen dam was constructed across the ditch to contain the contaminated water. The drainage ditch runs in a southerly direction from Shelter 204, and parallels the site boundary fence for several hundred feet before it enters an underground culvert and crosses underneath Ocean County Route 539.

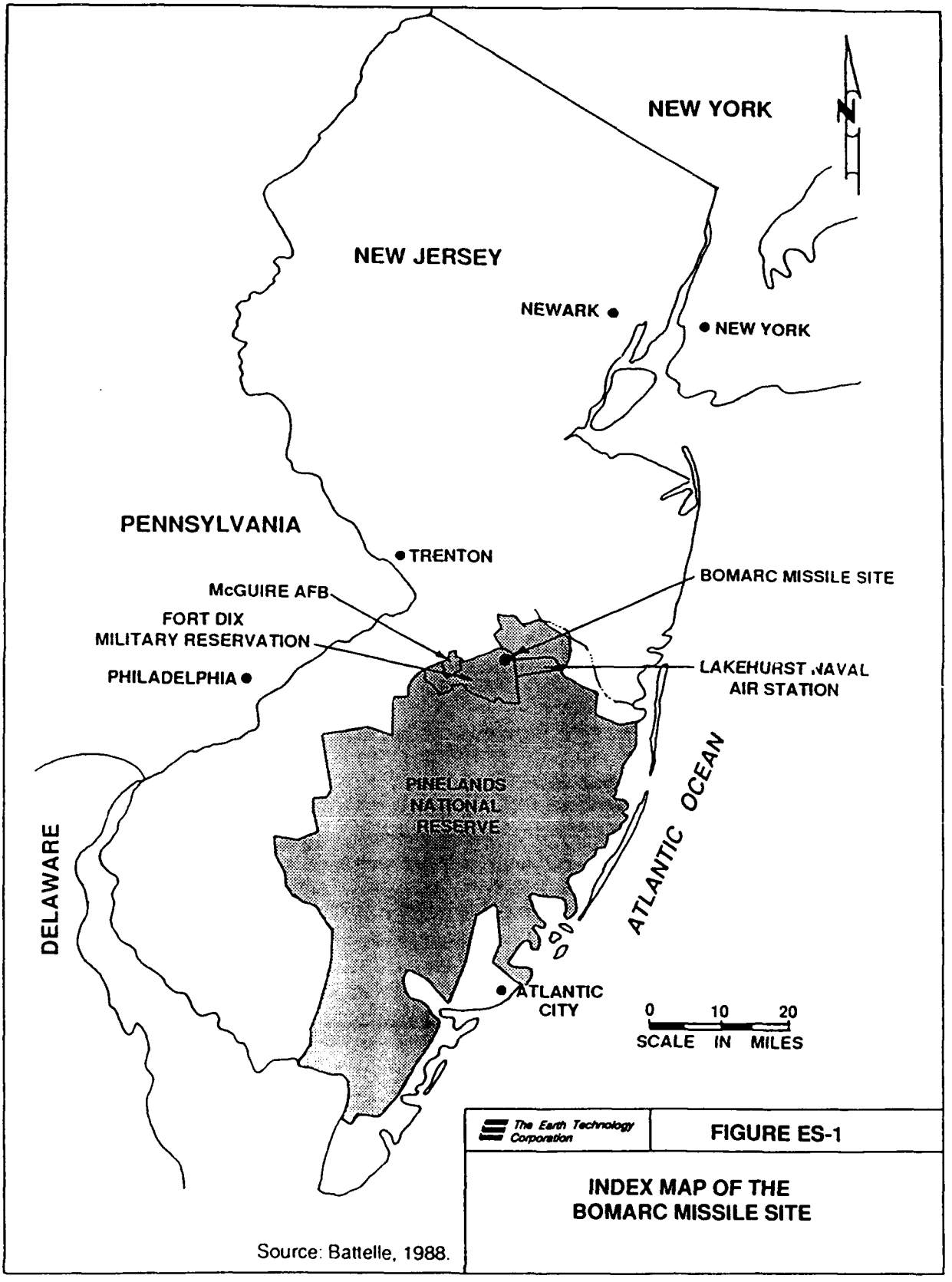
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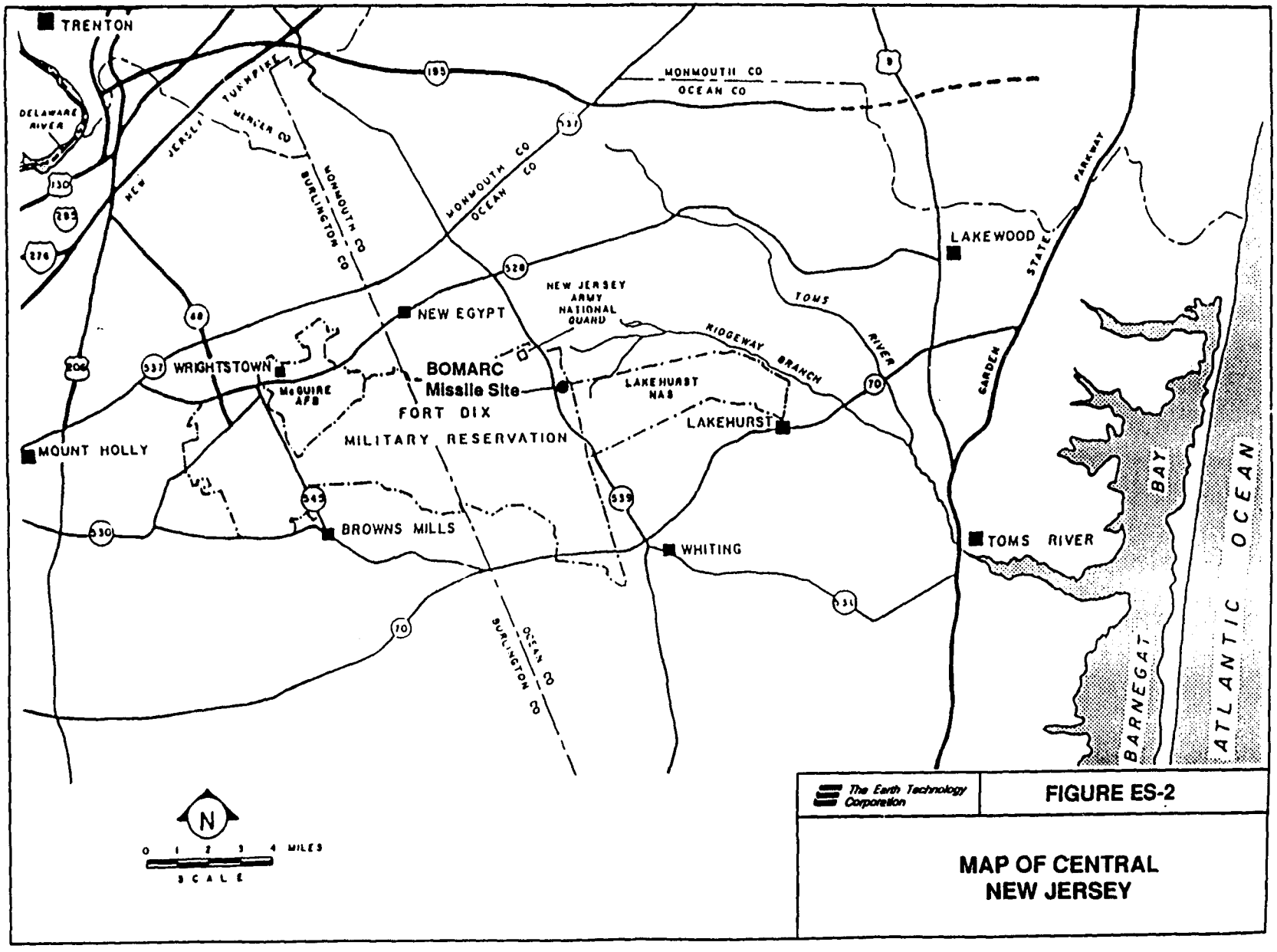
FIGURE ES-1
INDEX MAP OF THE
BOMARC MISSILE SITE
Source: Battelle, 1988.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LAKEWOOD
GARDEN STATE PARKWAY
NEW EGYPT
NEW JERSEY ARMY NATIONAL GUARD
TOMS RIVER
RIDGEWAY BRANCH
WRIGHTSTOWN
McGUIRE AFB
BOMARC Missile Site
FORT DIX
MILITARY RESERVATION
LAKEHURST NAS
LAKEHURST
MOUNT HOLLY
BROWNS MILLS
WHITING
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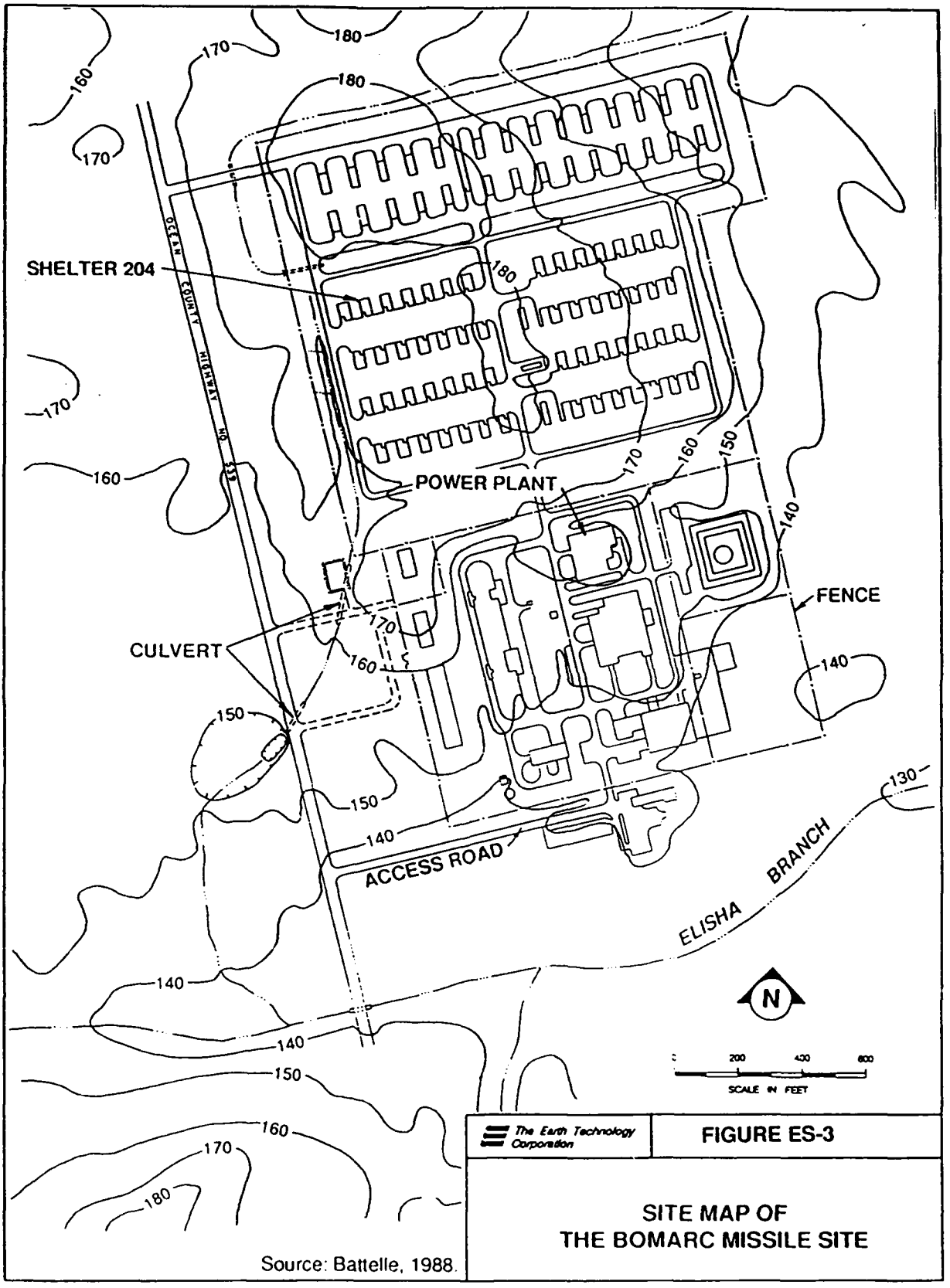
FIGURE ES-2
MAP OF CENTRAL NEW JERSEY



Source: Battelle, 1988.

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FIGURE ES-3

SITE MAP OF THE BOMARC MISSILE SITE

From this point, the culvert opens into a sandy ditch that eventually flattens into a wooded area.

Although no nuclear explosion took place, the nuclear warhead, which contained bottled tritium and plutonium, was burned and partially melted. The missile was destroyed, and the missile shelter was badly damaged. The oxidizer tank was displaced yet remained intact. The residue from the burning warhead contaminated the concrete floor. In addition to the severely damaged roof, the floor and concrete walls were pitted by flying fragments of the helium and fuel tanks. The steel roof beams were also deformed, and the shelter walls received heat damage.

The tritium bottle was found to be in good condition. The valve of the tritium bottle was removed, and both the valve and the bottle were sent to the Los Alamos National Laboratory in New Mexico. The remains of the warhead and all residue from the floor were placed in plastic bags, and then placed into sealed cans for disposal. The nuclear material was separated by grade. Shortly after the 1960 missile accident, seven containers of plutonium were recovered by explosive ordnance disposal personnel. Initially the containers were sent to Medina Base, San Antonio, Texas. The containers remained at the Medina Base until approximately 1965 when they were transferred to the Department of Energy (DOE) Pantex facility. The containers remained at Pantex until sometime in 1979 to 1982. The DOE conducted measurements of the recovered material during that period. The amount of plutonium in the warhead remains classified. However, DOE and Air Force scientists prepared an unclassified account of the disposition of the recovered material during that period. The account is provided as Volume 2, Appendix 2-5 of this EIS. The account indicates that the estimate of the upper limit of the plutonium that could have been left on-site is 300 grams.

The missile launcher is believed to have been removed from Shelter 204 shortly after the accident. However, its whereabouts remain unknown and no verified records indicating the manner or location of its disposal are known to exist. Air Force procedures in effect at the time of the accident would have included removal of contaminated debris from the shelter for disposal as waste. Existing records indicate disposal of additional radioactive waste from the site at the Idaho National Engineering Laboratory. Records also indicate containment measures were applied to the missile shelter and the asphalt apron but are silent as to the launcher.

In June 1960, air samplers were placed downwind of the accident site. The area was checked, and monitoring equipment was installed. During the fire, tar had melted and spread in a thin layer on sections of the floor of Shelter 204. Several sections of the floor containing tar showed radiation readings of over two million counts per minute (cpm). The level in the center of the road outside the shelter was also two million cpm.

The entire area was again washed down with water and then allowed to dry. Presumably, the wash water drained into the drainage ditch. Also in June of 1960, after the area was completely dry, the inside of the shelter was spray painted in order to shield alpha radiation emissions. The outside area was also painted. A total of 110 gallons of paint was used. After the paint had dried enough to walk on, radioactivity readings were again taken. Areas that had previously

shown two million cpm then showed zero due to the shielding effect of the paint layer on alpha radiation emitted by the plutonium. Some of the fringe areas showed readings of 50 to 500 cpm.

Later in the month of June 1960, 4 inches of reinforced concrete were poured over the asphalt apron in front of Shelter 204 in an effort to fix the plutonium contamination under a protective overburden. In addition to this, two inches of asphalt were placed along the bottom of the drainage ditch located inside the site boundary fence. An additional 2 inches of concrete was added to a small portion of the shelter apron area in 1967, covering the manhole access to the communication and power pits, proximate to Shelter 204. The pit area inside Shelter 204 was filled with soil excavated from the rear of the shelter.

II. Time Sequence of Work Performed

The RI/FS was authorized in January 1989. Planning documents were finalized between January and May 1989. Field Work, which consisted of field sampling and analysis of environmental samples, geophysical surveys, and mapping, was largely completed between June and November 1989.

Data reduction, analysis, and interpretation were ongoing and this RI/FS report was completed in May 1992.

III. Investigative Procedures and Summary of Field Program

The remedial investigation of the BOMARC Missile Site was conducted in order to determine the distribution and concentrations of plutonium and its decay product americium in site soils, surface water, ground water, air and structural materials. This was done through a combination of background research on site characteristics and history, sampling/analysis of soil, surface water, ground water, air, and structural materials onsite, and various other surveys as described below.

Two geophysical techniques, magnetic profiling and ground-penetrating radar (GPR) profiling, were used to search for the potentially contaminated missile launcher from Shelter 204 and containerized wastes which were possibly buried onsite. The Air Force standard operating procedure would have been to decontaminate any contaminated hardware, including the launcher and missile shelter doors, prior to disposal or removal from the site. This procedure would have been consistent with decontamination/containment measures taken on contaminated structures, such as the missile shelter and asphalt apron, soon after the accident. There is no available information that indicates that the launcher or missile shelter doors were contaminated, however, the Air Force conservatively assumes that these items could have become contaminated as a result of the accident, and could have been disposed of onsite. Magnetic surveying was the most appropriate method for locating the launcher and drums because their prominent physical property is magnetic susceptibility. The increased susceptibility of the ferrous metal relative to the surrounding soils causes localized perturbations (anomalies) in the earth's magnetic field.

GPR profiling was also an appropriate method for finding these objects because the metal forms a large dielectric contrast relative to the soil.

Surveys were completed at four areas; three are north to northeast of Shelter 204 (Figure ES-3) and one is just south of the site perimeter at a suspected dump site. The surveys located several anomalies representing buried ferrous objects (possibly the missile launcher and drums).

Field sampling performed at the BOMARC Missile Site involved the collection and analysis of ground water, surface water, concrete/asphalt core, soil, sediment, wipe, and ambient air samples. In addition, three separate in-situ gamma ray surveys were performed using both a hyper-pure germanium (HPG) detector and a field instrument to detect low energy radiation (FIDLER).

Ground water and soil samples were originally collected for plutonium analysis. Chemical analysis for both ground water and soil was added as a modification to the original project Statement of Work. The purpose of this modification was to identify chemical contaminants that may affect remedial alternatives considered. Non-radioactive chemical contaminants in ground water are being addressed under a separate ongoing base-wide RI/FS program. Non-radioactive chemical contaminants were detected in soils at levels below applicable regulatory action levels, and below levels that would affect remedial alternatives under consideration.

Subsurface soil sampling was conducted at the BOMARC Missile Site in order to determine the vertical extent of radionuclide migration in the soil column. Soil borings were installed primarily in areas of highest known radioactivity (exclusive of the concrete apron area) in order to ensure measurement of worst-case vertical contaminant migration. Borehole locations were selected by scanning areas of highest radioactivity (areas surrounding shelter 204, drainage pathway, and others) with a FIDLER probe. "Hot-spots" were pin-pointed by lowering the probe close to the ground. A two-inch diameter soil core was then obtained to a depth of six inches below the surface. This soil core was rescanned with the FIDLER to ensure its radioactivity. This sample then became the uppermost soil sample from each borehole sent for laboratory radioanalysis. Boreholes were drilled directly on the location of the surface sample, so that analytical results for subsurface samples could be compared to those for the radioactive surficial sample. All soil samples were scanned onsite using the FIDLER, and three samples from each borehole underwent laboratory analysis for plutonium. Most soil borings were terminated at depths of 10 feet or less. In addition, shallow (<2 ft.) soil corings were installed on the centerline of the asphalt drainage ditch using hand tools. Shallow soil coring samples collected from the ditch underwent analysis for plutonium and chemical contaminants. A total of 26 boreholes and four shallow soil corings were installed.

During borehole drilling at the BOMARC Missile Site, field observations were made by a qualified geologist and recorded in logbooks and on borehole log sheets. Soil lithology, sample recovery, hammer blow counts, radiation readings, and any pertinent data were recorded during drilling.

Continuous soil cores were scanned using a FIDLER probe. Soil cores were laid on a table, and the site health physicist scanned each core. A Bicron Model G5 FIDLER probe was used. Data were processed using an Eberline ESP-2 pulse height analyzer in rate-meter mode. Data were read directly from the analyzer as counts per minute.

Both filtered and unfiltered ground water samples were collected from the ten existing monitoring wells immediately surrounding Shelter 204. These 20 samples underwent gross alpha and gross beta analyses. Duplicates of the eight samples showing the highest activity underwent plutonium analysis by alpha spectroscopy. Two of the wells showing the highest levels of gross alpha activity were resampled in January 1992. Both filtered and unfiltered samples were collected. In addition, four ground water samples were collected for chemical analysis [Environmental Protection Agency (EPA) Target Compound List (TCL) and Target Analyte Lists (TAL) parameters]. Appropriate quality control samples (duplicates, equipment blanks) were also obtained and analyzed.

Thirty surface water samples were collected. Most of these were obtained as rainwater runoff, and were taken: (1) from the concrete apron just south of Shelter 204; (2) along the asphalt-lined ditch; (3) along the unlined portion of the ditch on either side of Highway 539; (4) along the drainage to the northwest of Shelter 204; and (5) from a drain culvert outside the perimeter fence, east of Shelter 204. Surface water was also collected from standing water in the forest near the headwaters of the Elisha Branch near the southeast corner of the site. Both filtered and unfiltered samples were obtained from the runoff and Elisha Branch samples. These samples underwent gross alpha and gross beta analyses. Two unfiltered water samples were collected, one each from the power and communication bunkers in front of Shelter 204. These two samples underwent plutonium analysis by alpha spectroscopy.

Concrete and/or asphalt coreholes were drilled at 18 locations along the concrete apron south of Shelter 204 and at three locations inside Shelter 204. The thickest concrete drilled was approximately 18 inches, inside Shelter 204. Concrete and asphalt cores were scanned onsite using the HPG detector.

Shallow soil samples were collected through the concrete cores at three discrete depths; 0-6, 6-12, and 12-18 inches below ground surface (bgs) using a slide-hammer coring device. Soil samples for chemical analysis were collected from three of the concrete coring sites and two background locations. Soil samples for plutonium analysis by alpha spectroscopy were collected from all of the concrete coring sites.

Six depth profile sampling stations were established for soil collection. At five of the six stations, soil samples were collected at the following intervals: 0-1, 1-2, 2-3, 3-6, and 6-12 inches bgs. At a sixth sampling station, the first sampling interval was from 0-6 inches bgs. This interval was composited since it was suspected to be primarily fill material. The remaining sampling intervals at station six were: 6-7, 7-8, 8-9, 9-12, and 12-18 inches bgs. Each of the samples collected for the depth profiles were sieved into two size fractions: greater than 20

microns and less than 20 microns. Each size fraction was then analyzed for plutonium by alpha spectroscopy.

Sediment samples were collected from the floor of the communications bunker located just south of shelter 204. The maximum thickness of sediment found in this bunker was approximately eight inches. Six samples were screened using the HPG and FIDLER detectors, and one sample underwent plutonium analysis by alpha spectroscopy.

A total of 619 wipe samples were collected from accessible surfaces inside and outside each of 21 missile shelters. The majority of the shelters sampled were in the vicinity of Shelter 204. Shelter 210 was established as a sampling model, with 44 sample locations defined and sampled. The surfaces sampled included the shelter floor, light fixtures, support beams, and the missile launcher. The outside surfaces sampled included structural beams and the "seams" where the two halves of the shelter roof met. With the exception of Shelter 204, 25 samples were collected from each of the other shelters. Shelter 204 was more thoroughly sampled, with 100 wipe samples collected from surfaces inside and outside of the structure. Most samples were analyzed onsite for alpha activity, but ten samples and one ambient condition blank underwent laboratory alpha spectroscopy analysis.

Ambient air samples were collected from three sampling stations, each equipped with a high-volume air sampler positioned in a triangular pattern around Shelter 204. Air samples were collected both before and during field operations to screen for suspended radioactive particles. Those samples collected prior to field operations underwent gross alpha and gross beta analyses. The samples collected during field operations were scanned onsite. One blank and one duplicate were also analyzed.

Three in-situ surveys were performed on the BOMARC Missile Site. The first was conducted using an HPG detector and involved an intensive in-situ survey of low-level gamma radiation (specifically Am-241). These measurements were collected in a grid pattern surrounding Shelter 204 and extending to the southwest following the main drainage along areas of known historical contamination. The second survey was conducted using a FIDLER along the concrete and asphalt south of Shelter 204 to identify areas showing relatively high levels of low-energy gamma radiation. A total of 330 points were sampled, and the information derived was used to select soil sampling locations. The third survey was also conducted using a FIDLER; 147 readings were taken both on and off site in c der to investigate depositional patterns predicted by a surface deposition modeling effort. The modeling effort was used to predict depositional patterns for radionuclides potentially dispersed in the smoke plume from the missile fire. Areas of predicted deposition were surveyed in order to ensure that all potentially contaminated areas were surveyed. Areas surveyed were also sampled; laboratory analysis of soil samples was used to confirm field survey data.

IV. Significance of Findings

No concentrations of radionuclides attributable to the missile accident were detected in ground water, surface water, or air at the site. Contaminants attributable to the missile accident (Pu-239, Am-241) were detected in shallow soils, sediments, and structural materials including the concrete/asphalt apron, Shelter 204, and the underground utility bunkers adjacent to Shelter 204. Distribution of contaminants was found to be consistent with that observed in previous studies, indicating little active transport of contaminants. The current distribution of contaminants is primarily the result of dispersion caused by the 1960 accident and subsequent fire-fighting efforts rather than active environmental transport of contaminants.

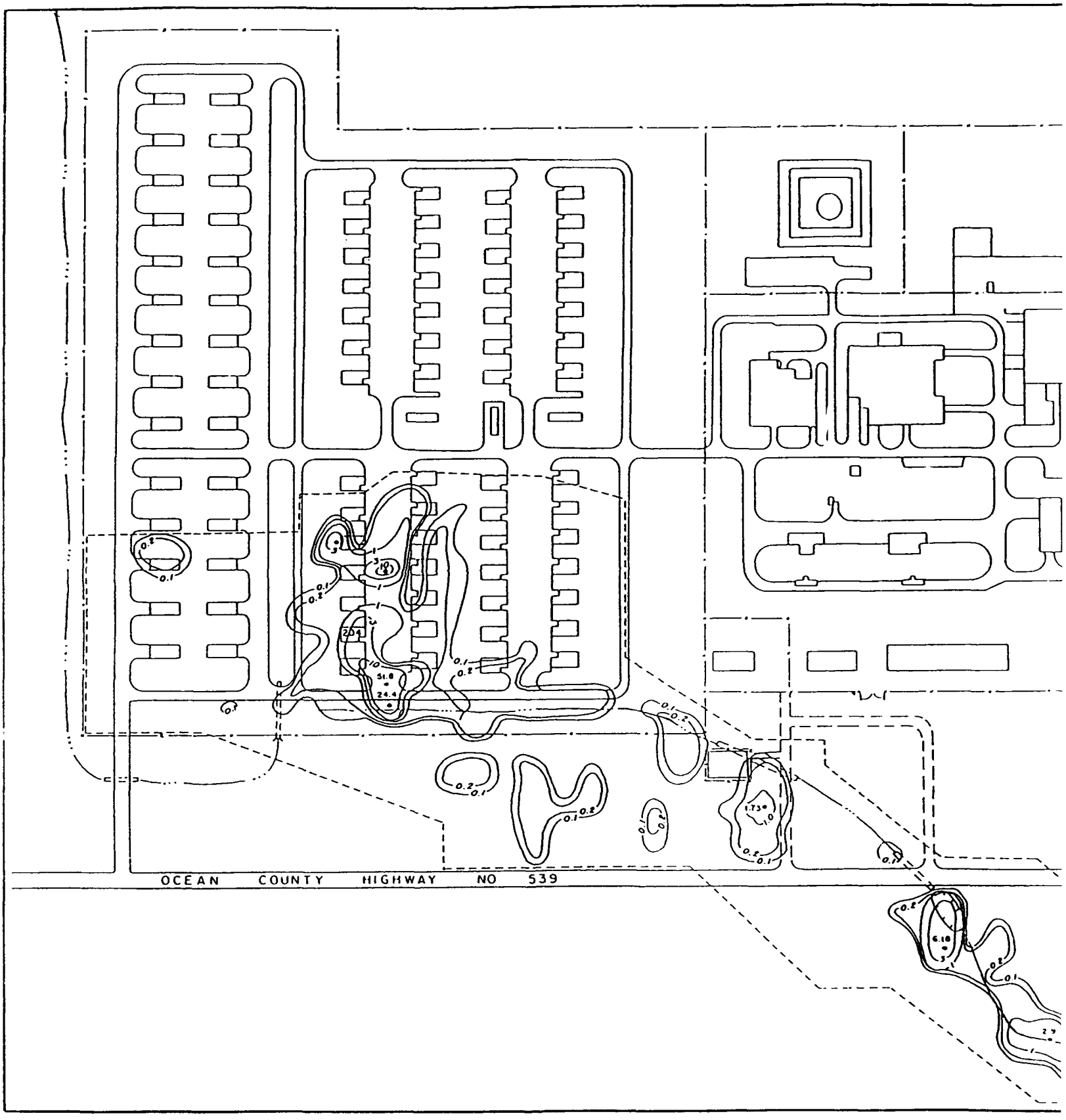
The general distribution of contaminants is shown on Figure ES-4, which is a map of in-situ radiological survey results obtained using the HPG detector. This map shows the areal extent of contamination. The vertical extent of soil contamination was determined using depth-discreet borehole soil sampling. Sample analysis indicated that for most of the site, radionuclides were confined to the top foot of the soil column. In a few areas, most notably the area just west of Shelter 204 and the area just west of the concrete apron, radionuclides were detected as deep as ten feet below the ground surface.

A baseline risk assessment (Baseline Radiological Hazard Assessment) was conducted in order to quantify risks to human health and the environment posed by the site. Risks were estimated for both offsite populations and for a hypothetical maximally exposed individual (MEI) residing *onsite*. Risks to offsite populations were determined to be insignificant. Risks to the hypothetical MEI were greater than those for offsite populations. Carcinogenic risks to the hypothetical MEI were estimated at 1.3×10^{-3} or 1.3 excess cancers per thousand persons.

The MEI exposure scenario used in the baseline risk assessment is a worst-case scenario that is considered extremely unlikely. This scenario is based on the conservative assumptions that the Air Force would drop access controls currently in place, that engineered containment structures currently in place (concrete and asphalt coverings) would be neglected and would provide no containment, and that the hypothetical MEI would establish residence in the most highly contaminated portions of the site. The MEI scenario was used to obtain the upper bound estimate of risk, and is not considered a likely or reasonable exposure scenario. Using the upper bound estimates obtained, risks to human health are raised above levels considered acceptable.

Based on these risk estimates, site remediation or control is warranted. Site remediation would be appropriate if the site were to be released for unrestricted access to the public. Site control, including institutional and access controls, would also be effective at reducing risks by eliminating the only exposure scenario (MEI) that presents unacceptable risk.

A Feasibility Study (FS) was conducted in order to develop and evaluate potential remedial alternatives for the site. The FS was conducted in a three-phase sequential process, in accordance with Version 2.0 of the Air Force Occupational Environmental Health Laboratory (OEHL) Handbook ("Handbook"). Guidance presented in the Handbook is designed to be in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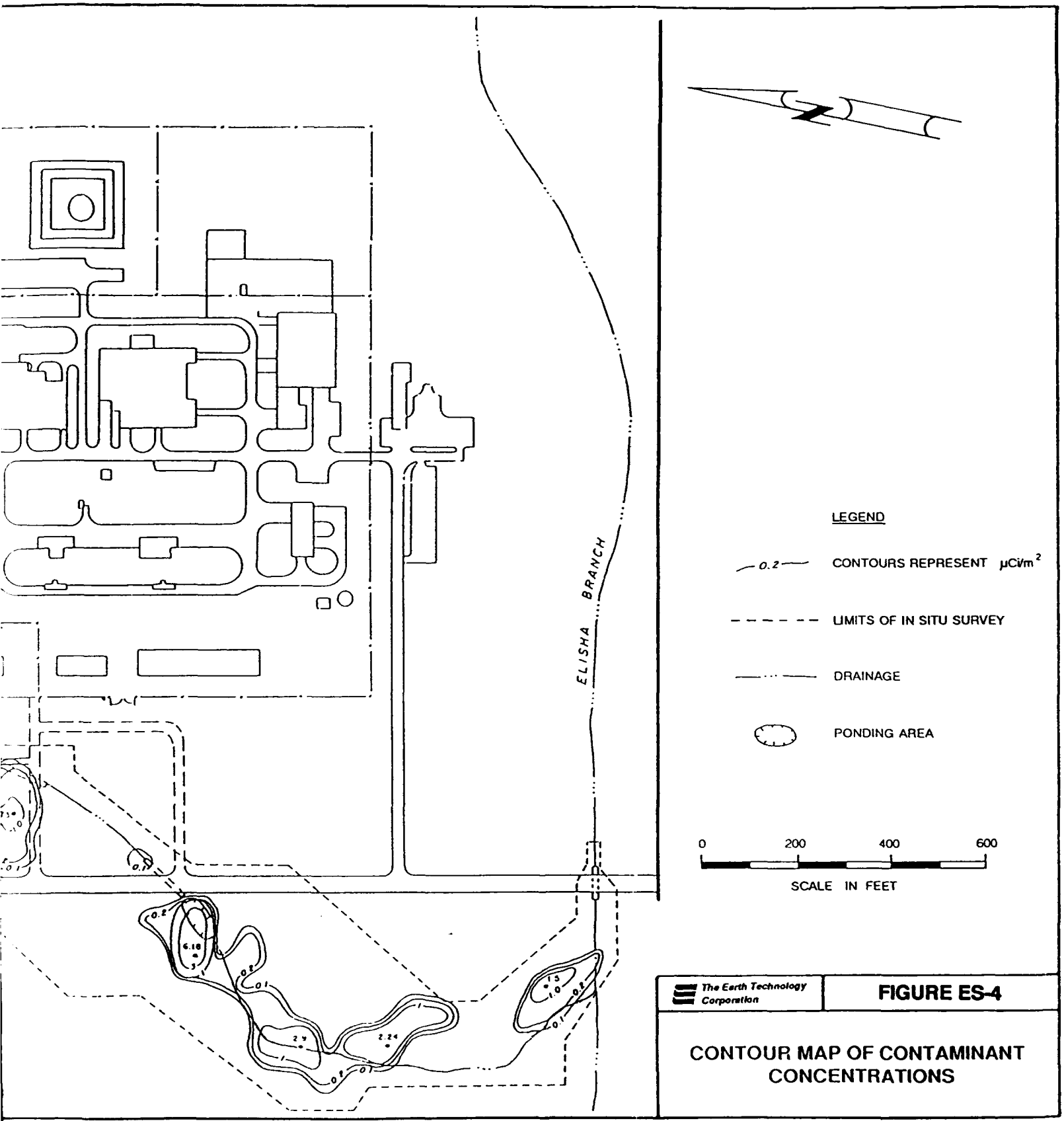

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FIGURE ES-4

CONTOUR MAP OF CONTAMINANT CONCENTRATIONS

conformance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund" law), the Superfund Amendments and Reauthorization Act (SARA), and the National Contingency Plan (NCP).

The FS was conducted using a three-phase approach, as outlined in the Handbook. In Phase I of the FS, the FS process and structure are introduced. Remedial objectives are identified, including health- and regulatory-based quantitative cleanup criteria as well as other chemical-, action-, and location-specific requirements. Volumes and types of contaminated materials are given, and general response actions selected to comply with NCP requirements are discussed.

Also in Phase I of the FS, an array of remedial technologies potentially applicable to the BOMARC site are identified and described. These technologies are then screened to eliminate those that are clearly infeasible due to waste characteristics, site conditions, or technical requirements. Technologies remaining after this preliminary screening are then assembled into alternatives for addressing contaminants onsite.

Six remedial alternatives are developed, including the following:

- An **Unrestricted Access** alternative that serves as the functional "no action" alternative in accordance with the NCP and provides a basis against which other approaches may be compared/contrasted;

- An **Existing Conditions** alternative that minimizes or eliminates onsite exposures using existing access and institutional controls;

- A **Limited Action** alternative that minimizes or eliminates onsite exposures using existing access controls, institutional controls, and removal and offsite disposal of a limited amount of the most highly contaminated wastes onsite;

- An **Onsite Containment** alternative designed to reduce or eliminate waste accessibility and migration of site contaminants through wind dispersion, erosion, and runoff;

- An **Onsite Treatment** alternative that employs a waste volume reduction strategy followed by secure offsite disposal of the plutonium/americium fraction; and

- An **Offsite Disposal** alternative that involves source removal and placement in an approved offsite disposal facility.

These alternatives represent a broad range of waste management options for the BOMARC Missile Site and incorporate unrestricted access, existing conditions, limited action, containment, treatment, and disposal strategies for existing radioactive sources at the facility.

In Phase II of the FS, the six alternatives are screened according to three criteria:

- Public health/environmental impacts;
- Technical feasibility; and

- Cost.

Alternatives that are not protective of public health and the environment, are not technically feasible, or have costs greatly exceeding those of equally effective alternatives are eliminated from further consideration.

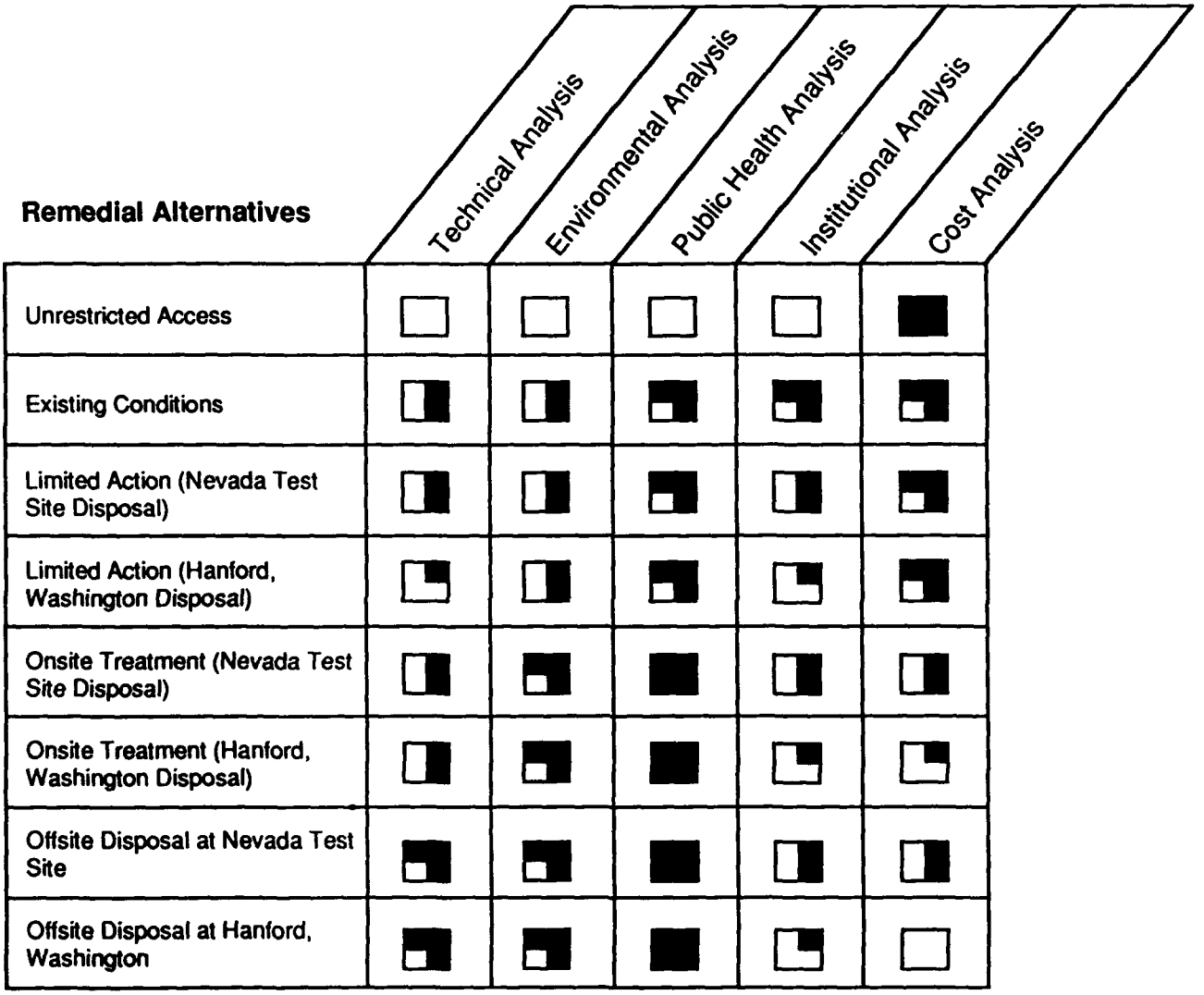
As a result of Phase II screening, the onsite containment alternative is eliminated from consideration due to lack of technical feasibility. Existing Federal and State of New Jersey institutional requirements effectively prohibit this particular alternative. The other five alternatives are carried forward for detailed analysis in the FS Phase III.

In Phase III of the FS, the five remedial alternatives carried forward from Phase II are evaluated in detail. Detailed analysis includes evaluation of technical feasibility, environmental effects, public health effects, institutional requirements, cost, and state/public acceptance. Alternatives are evaluated individually and in contrast with each other.

Figure ES-5 gives a summary of the comparative analysis of alternatives. In the technical analysis of alternatives, performance, reliability, implementability, and safety are evaluated. For the technical analysis criteria, the Onsite Treatment and Offsite Disposal alternatives are rated most favorably, followed closely by the Limited Action and Existing Conditions alternatives; the Unrestricted Access alternative is rated least favorably. Onsite Treatment and Offsite Disposal both achieve health-based and regulatory-based cleanup goals. Onsite Treatment fulfills the statutory preference stated in SARA for reduction in waste mobility, toxicity, or volume through treatment, whereas the Offsite Disposal alternative does not. However, this is balanced by the fact that Offsite Disposal is more reliable and easier to implement than the proposed Onsite Treatment process. Both alternatives would allow the site to be released for unrestricted access, which is an advantage over the Existing Conditions and Limited Action Alternatives, which require access restrictions in perpetuity. Although neither the Existing Conditions alternative nor the Limited Action alternative achieve health-based or regulatory-based cleanup goals, these goals apply to the site only if unrestricted access is allowed, and are therefore inapplicable under these alternatives. Both alternatives effectively mitigate site risks through access controls, which eliminate the only exposure scenario exhibiting significant risk (onsite exposure). The Limited Action alternative has a slight advantage over the Existing Conditions alternative in that it eliminates uncertainties associated with the potentially contaminated missile launcher from Shelter 204. The Unrestricted Access alternative does not achieve cleanup goals or reduce risk by any other means.

In the environmental analysis of alternatives, the beneficial and adverse effects of alternatives on the environment and human health are evaluated, and the ability of alternatives to address contaminant migration pathways is taken into account. The Onsite Treatment and Offsite Disposal alternatives are rated most favorably, followed by Limited Action and Existing Conditions; the Unrestricted Access alternative is rated least favorably. Onsite Treatment and Offsite Disposal both eliminate migration potential and benefit human health and the environment by removing contaminants from the site. Both alternatives have the potential for adverse effects associated with disturbance and possibly dispersion of wastes from the site, however, potential adverse effects can be mitigated through proper engineering controls and are outweighed by the benefits of permanent source removal. Neither the Existing Conditions nor the Limited Action

Figure ES-5
Summary of Comparative Analysis of Remedial Alternatives



alternatives act on migration pathways, however, RI results show that offsite migration of contaminants is minimal so this is not a major concern. Both alternatives protect human health through access restrictions, effectively preventing onsite exposure. The Unrestricted Access alternative does not protect human health and the environment or address contaminant migration.

In the Public Health analysis, alternatives are assessed in terms of effectiveness in mitigating long-term public exposure to contaminants. The Onsite Treatment and Offsite Disposal alternatives are rated most favorably, followed closely by the Existing Conditions and Limited Action alternatives; the Unrestricted Access alternative is rated least favorably. Both the Onsite Treatment and Offsite Disposal alternatives eliminate exposure to contaminants through source removal. The Existing Conditions and Limited Action alternatives prevent exposure in a slightly less effective manner, i.e., through access controls. The Unrestricted Access alternative does not prevent exposure through any means.

The institutional analysis evaluates the effects of federal, state, and local standards and other requirements on the feasibility of an alternative. The Existing Conditions and Onsite Treatment alternatives are rated most favorably, followed by Offsite Disposal and Limited Action. Unrestricted Access is rated least favorably.

For radioactive waste remediation, there are a number of criteria to consider in terms of institutional issues. The ability of an alternative to achieve health-based and risk-based cleanup criteria must be considered, as well as the ability of an alternative to satisfy statutory preferences stated in CERCLA/SARA. In addition, laws and regulations governing radioactive waste disposal, specifically the types of wastes and geographic origin of wastes that can be accepted by a given waste site must be considered. Currently, no radioactive waste disposal sites can accept wastes containing plutonium if the wastes exceed 100 nanoCuries/gram (nCi/g) in radioactivity. In addition, when the Low-Level Radioactive Waste Amendments Policy Act of 1980 takes effect in January 1993, radioactive wastes from New Jersey may be barred from available commercial disposal facilities, limiting disposal options to U.S. Department of Energy (DOE) disposal sites, including the Nevada Test Site. All alternatives that include offsite disposal of wastes as a component (Limited Action, Onsite Treatment, Offsite Disposal) have the potential to be negatively impacted by the institutional issues discussed above, which is a disadvantage in comparison to the Existing Conditions and Unrestricted Access alternatives, which do not involve offsite disposal.

In terms of the ability of alternatives to achieve health-based and regulatory-based cleanup goals and satisfy statutory preferences stated in CERCLA/SARA, the Onsite Treatment alternative does both, while the Offsite Disposal alternative achieves the cleanup criteria but does not satisfy the preference under CERCLA/SARA for remedies that reduce the mobility, toxicity, or volume of wastes. The Existing Conditions and Limited Action alternatives do not achieve cleanup criteria, but the criteria do not apply for sites with access restrictions and both alternatives effectively mitigate risks through access controls. The Unrestricted Access alternative does not achieve cleanup goals or mitigate risks through any other means.

Cost analysis compares overall estimated costs for each alternative. The Unrestricted Access alternative has no costs, and is therefore most favorable, followed closely by the Existing Conditions and Limited Action alternatives. For the Onsite Treatment and Offsite Disposal

alternatives, the difference in cost between disposal at a commercial facility (Hanford, Washington) and the U.S. DOE Nevada Test Site is substantial. Onsite Treatment and Offsite Disposal using the Nevada Test Site are most favorable, followed by Onsite Treatment with disposal at the Hanford, Washington site; Offsite Disposal at the Hanford, Washington site is least favorable.

State and public acceptance is not actually addressed within this RI/FS report, but will be addressed within the Responsiveness Summary contained in the Record of Decision (ROD) for the site. The ROD will be completed after the Final RI/FS report is issued. The ROD serves as a decision document for selection of a remedial alternative, and gives the rationale for alternative selection.

All of the five remedial alternatives evaluated in detail in the FS Phase III are also further evaluated for environmental impacts in an Environmental Impact Statement (EIS), which is a companion document to this RI/FS. In the companion EIS, the Existing Conditions alternative is referred to as the National Environmental Policy Act (NEPA) No Action Alternative. This is because as defined by NEPA, No Action consists of maintaining existing conditions.

NOTICE

This report has been prepared for the United States Air Force by The Earth Technology Corporation for the purpose of aiding in the implementation of a final remedial action plan under the Air Force Installation Restoration Program (IRP). As the report relates to actual or possible releases of potentially hazardous substances, its release prior to an Air Force final decision on remedial action may be in the public's interest. The limited objectives of this report and the ongoing nature of the IRP, along with the evolving knowledge of site conditions and chemical effects on the environment and health, must be considered when evaluating this report, since subsequent facts may become known which may make this report premature or inaccurate. Acceptance of this report in performance of the contract under which it is prepared does not mean that the United States Air Force adopts the conclusions, recommendations or other views expressed herein, which are those of the contractor only and do not necessarily reflect the official position of the United States Air Force.

PREFACE

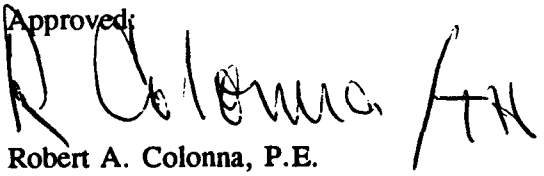
This Remedial Investigation/Feasibility Study was completed in accordance with the Department of Defense Installation Restoration Program. The objectives of this study were to determine the magnitude and extent of radioactive contamination at the BOMARC Missile Site, McGuire Air Force Base, New Jersey, to quantify risks to human health and the environment, and to use this information in conducting a Feasibility Study of remedial alternatives.

This project was performed under United States Air Force Human Systems Division Contract Number F33615-85-D-4533/0010. The project was authorized in January of 1989. The field program, which consisted of sampling and field testing of air, ground water, surface water, soil, and structural materials, was largely completed during the time period June 1989 through November 1989. Documentation of the field work, analysis and interpretation of the data, and evaluation of remedial alternatives were completed in July, 1991. Major John M. Clegg, Jr., P.E., U.S. Air Force Center for Environmental Excellence, was the Technical Monitor.

Phillip Watts, R.G., was The Earth Technology Corporation's Project Manager for this project. Other Earth Technology scientists and engineers included Franco Godoy, Melvin Tyree, Janet Robinson, D. Jay Wilburn, Sarah Hokanson, David Naleid, Lisa Goldberg, Richard Bizub, Edward Sciulli, Kerry Hennon, and John Lassiter. Science Applications International Corporation (SAIC) was a major subcontractor for this project, providing field sampling, radioanalytical, and risk assessment services. Key SAIC personnel included Dr. Robert Kennedy, Neil Botts, Donna Collins, Dr. Mark Otis, Michael McKenzie-Carter, Gregory DiGregorio, Mark Byrnes, Catherine Olsen, Scott Hay, and Dr. Reginald Gotchy.

Special thanks to Dana Bowers, Pamela Anderson, and Jill Langston of The Earth Technology Corporation, who did the word processing and graphics for this document.

Approved:



Robert A. Colonna, P.E.
Senior Vice President, Program Director

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APPENDICES

1.0 INTRODUCTION

The Earth Technology Corporation and Science Applications International Corporation have prepared this Remedial Investigation/Feasibility Study (RI/FS) Report in conjunction with the Air Force Installation Restoration Program (IRP) of environmental study and remediation. This report summarizes the results of studies on the Boeing Michigan Aeronautical Research Center (BOMARC) Missile Site at McGuire Air Force Base (AFB), New Jersey (Figure 1-1) under the Installation Restoration Program and incorporates data from other studies as appropriate. This report presents and summarizes data on the extent of radioactive contamination at the site, quantifies risks to potentially exposed populations, and evaluates appropriate remedial alternatives.

1.1 Purpose of the Installation Restoration Program

The Air Force IRP is designed to identify, confirm/quantify, and remediate problems caused by past management of hazardous wastes at Air Force facilities. It is the basis for assessment and response actions on Air Force installations under the provisions of Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA).

1.1.1 Program Origins

The Defense Environmental Restoration Program (DERP) was established in 1984 to promote and coordinate efforts for the evaluation and cleanup of contamination at Department of Defense (DoD) installations. The program currently consists of two major elements:

- The IRP, where potential contamination at DoD installations and formerly used properties is investigated and, as necessary, site cleanups are conducted.

- Other Hazardous Waste (OHW) Operations, through which research, development, and demonstration programs aimed at reducing DoD hazardous waste generation rates are conducted.

DERP is managed centrally by the Office of the Secretary of Defense. Policy direction and oversight of DERP is the responsibility of the Deputy Assistance Secretary of Defense (Environment). Each military service and the Defense Logistics Agency (DLA) are responsible for program implementation at their installations.

The Superfund Amendments and Reauthorization Act of 1986 (SARA) provide continuing authority for the Secretary of Defense to carry out this program in consultation with the U.S. Environmental Protection Agency (EPA). Executive Order 12580 on Superfund Implementation, signed by the President on January 23, 1987, assigned responsibility to the Secretary of Defense for carrying out the Department's Environmental Restoration Program within the overall framework of SARA and the CERCLA. The Defense Appropriations Act provides funding for DERP.

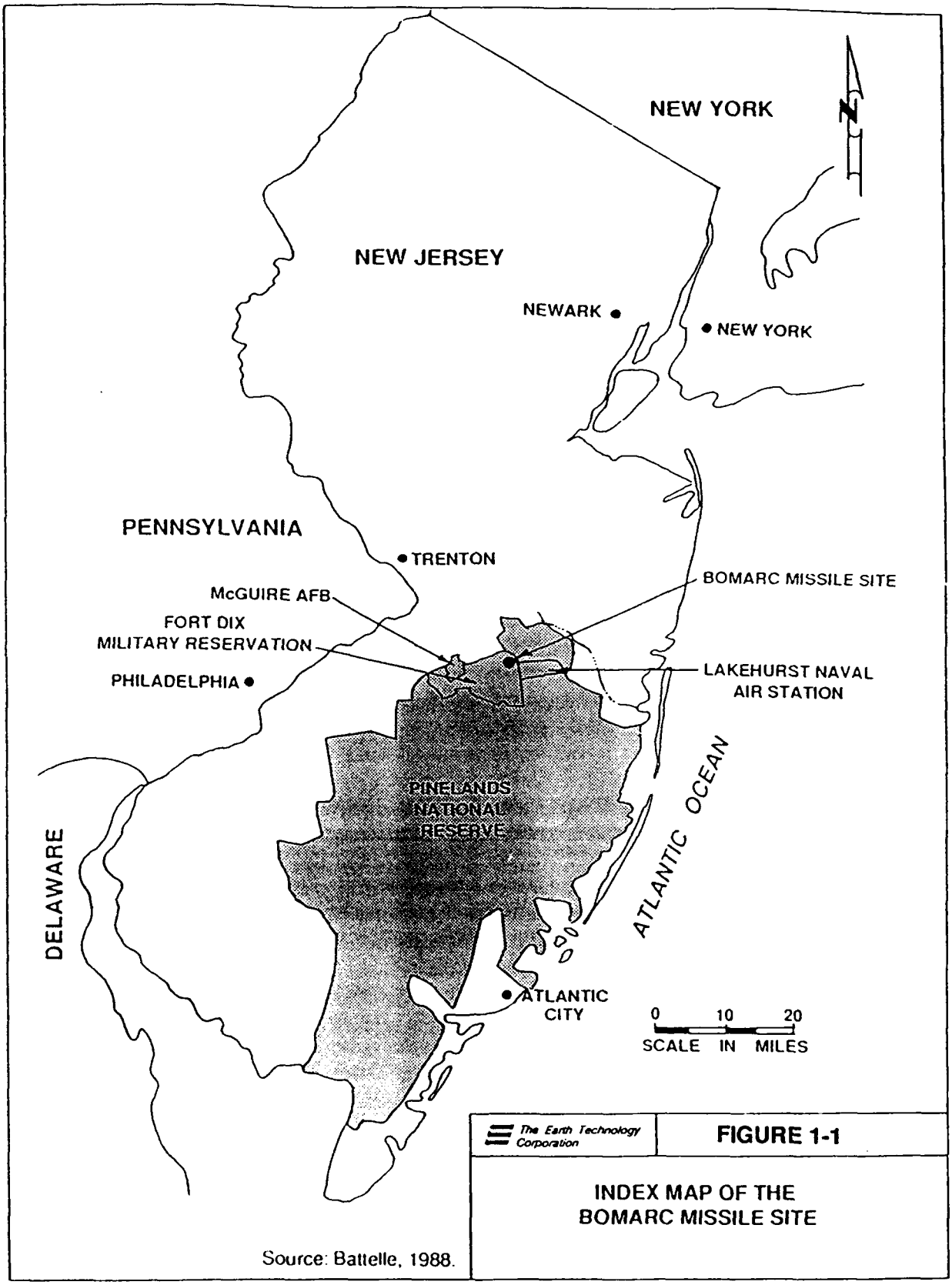

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FIGURE 1-1

INDEX MAP OF THE BOMARC MISSILE SITE

Source: Battelle, 1988.

1.1.2 Program Objectives

The objectives of the Air Force IRP are to assess past hazardous waste disposal and spill sites on Air Force installations, and to develop remedial actions consistent with the National Contingency Plan (NCP) for those sites which pose a threat to human health and welfare, or to the environment.

In order to meet this overall objective, specific program objectives must be met:

1. A reliable database must be developed through good field practice and rigorous analytical procedures.

2. A Quality Assurance/Quality Control (QA/QC) program must be developed and implemented to assure the production of meaningful and defensible data.

3. A site Health and Safety plan must be developed and followed to protect personnel and to prevent the release of, or exposure to, any contaminants.

4. A rigorous procedure must be utilized to characterize wastes and waste sources, evaluate potential pathways for contaminant migration, and identify human and environmental targets in order to compare remedial alternatives and select an appropriate remedy.

5. Data gaps must be identified, and appropriate additional or supplemental studies must be recommended and executed during the course of performing the program. This includes additional field and/or analytical data collection as well as the evaluation of candidate technologies.

6. The program must be conducted in compliance with appropriate Federal, State, and local regulations and available guidance.

7. The public and regulatory agencies must be informed regarding the nature of the contamination, the effects upon the community, the progress of the program, and the preferred remedial alternative and its impacts.

1.1.3 Program Organization

The IRP conforms to the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan. EPA guidelines are applied in conducting investigation and remediation work in the program. The initial stage, a Preliminary Assessment or PA, is an installation-wide study to determine if sites are present that may pose hazards to public health or the environment. Available information is collected on the source, nature, extent, and magnitude of actual and potential hazardous substance releases at sites on the installation. The next step, a Site Inspection (SI), consists of sampling and analysis to determine the existence of actual site contamination. The information gathered is used to evaluate the site and determine the response action needed. Uncontaminated sites do not proceed to later stages of the IRP process.

Contaminated sites are fully investigated in the Remedial Investigation/Feasibility Study or RI/FS. The RI may include a variety of site investigative, sampling, and analytical activities to determine the nature, extent, and significance of contamination. The focus of the evaluation is to determine the risk to the general population posed by the contamination. Concurrent with these investigations, the FS is conducted to evaluate remedial action alternatives for the site.

The RI/FS is intended to systematically:

1. Identify and prioritize contamination sources with respect to hazards,

2. Determine the nature and extent of contamination, or conclude that no significant adverse impact exists,

3. Determine the pathways and risks of the identified contamination to various human and environmental receptors,

4. Plan and conduct field activities that will support the selection and eventual design of appropriate remedial actions, and

5. Develop appropriate remedial alternatives.

The RI/FS program involves a sampling and analysis effort leading to the development of alternatives. The RI/FS of the IRP encompasses several key elements necessary to select an appropriate remedial action. These include:

1. Determination of the Federal, State, and local Applicable or Relevant and Appropriate Requirements (ARARs).

2. Development of the Data Quality Objectives (DQOs) necessary to be consistent with the ARARs and achievable with acceptable field and analytical procedures.

3. Performance of a field investigation in one or more stages, to collect sufficient information to assess contamination movement and pathways, and to support development of potential alternatives. This phase is described in CERCLA and NCP as the RI.

4. Determination of the hazards by quantifiably considering the impact on receptors through the pathways of surface water, ground water, biota, and air. Incorporation of the exposure and risk assessment as required under CERCLA, NCP, and SARA, and as defined in the Superfund Public Health Evaluation Manual.

5. Determination of those sites where the results of the field investigation and risk assessment indicate no significant threat to human health or welfare, or to the environment, and preparation of a decision document identifying any necessary control measures, or declining the need for further action.

6. Development of a set of potential alternatives, consisting of appropriate technologies that can remove the contamination or control its migration. These alternatives should provide a range of reduction of the mobility, toxicity, or volume associated with the contamination and should meet or exceed the ARARs.

Initial screening of alternatives is conducted using criteria of effectiveness, implementability, and cost. If necessary, additional studies are performed to support selection of technologies. A detailed analysis is then conducted to evaluate the alternatives. The set of criteria used includes: protectiveness; compliance with ARARs; reduction of waste mobility, toxicity, and volume; schedule; reliability; capital, operation, and maintenance cost; and state/public acceptance.

After agreement is reached with appropriate EPA and/or state regulatory authorities on how the site will be cleaned up, Remedial Design/Remedial Action or RD/RA work begins. During this phase, detailed design plans for the cleanup are prepared and implemented.

The notable exception to this sequence involves Removal Actions and Interim Remedial Actions (IRAs). These actions may be conducted at any time during the IRP to protect public health or control contaminant releases to the environment. Such measures may include providing alternate water supplies to local residents, removing concentrated sources of contaminants, or constructing structures to prevent the spread of contamination.

1.2 Time Period and Duration of Work Performed

The field program for the Stage 2 investigation of the BOMARC Missile Site involved field screening, sampling, and analysis of soils, sediments, surface water, ground water, air, and structural materials. Notice to proceed was given in January 1989. Field work began in June 1989 and was largely completed by the end of November 1989. Sporadic work involving surveying of data points and removal of investigation-derived wastes continued through January 1991. Many previous studies have been done for the site, and the dates of these are summarized in Section 1.4.

1.3 History of Base Activities

In 1937, the facility that was to become McGuire AFB was a dirt-strip runway called Rudd Field. It was developed as an adjunct to the U.S. Army Training Center at Fort Dix and was operated by the U.S. Army Air Corps under command headquarters located at New Castle Air Base, Delaware. Between 1940 and 1942, extensive improvements, including expanded aircraft pavements and landing strips, were made to the field by the U.S. Army Air Corps to accommodate World War II transitional training activities. The airfield remained under Army control until 1948.

In 1948, the Fort Dix Airfield and all existing facilities were transferred to the U.S. Air Force, and the installation was officially designated Thomas B. McGuire, Jr. AFB. The installation was assigned to the Strategic Air Command (SAC) until September 1949, when it was transferred to the Continental Air Command (CAC). In 1952, a major program of development was initiated to provide a port of aerial embarkation for Atlantic Division, Military Air Transport Service (MATS).

In July 1954, the Base was officially assigned to MATS, with Air Defense Command (ADC) and the New Jersey Air National Guard (NJANG) as major tenant organizations. The NJANG consolidated its activities on the west side of the Base, supported by a major construction program. Subsequently, SAC and CAC tenant units were assigned to McGuire AFB. In January 1966, MATS became the Military Airlift Command (MAC) with headquarters at Scott AFB, Illinois. Eastern Transport Air Force became the 21st Air Force with headquarters at McGuire AFB, and the 1611th Air Transport Wing became the 438th Military Airlift Wing. The SAC Tanker Squadron left McGuire AFB in 1965 and its facilities were occupied by the 170th Air Transport Group NJANG.

In 1958, the 46th Air Defense Missile Squadron (ADMS) from McGuire AFB was authorized use of approximately 220 acres of land on Fort Dix property for the construction of a missile facility. The facility ultimately housed two models of BOMARC missiles, the liquid-fueled Model A and the solid-fueled Model B.

The BOMARC interceptor missile Model A, IM-99A, with a Mk-40 nuclear warhead was a supersonic United States ground-to-air weapon designed to destroy attacking aircraft and airborne missiles. The missile was 45 feet long, with a wing-span of over 18 feet. It was a liquid-fueled rocket, using JP-X (jet fuel plus hydrazine) and an oxidizer [inhibited red fuming nitric acid (IRFNA)]. Helium was maintained under extreme high pressure in ready storage missiles to pressurize the fuel tanks and ensure constant fuel flow to the booster rocket during the boost-climb stage of missile flight. The nuclear warhead contained tritium and plutonium. The missile had a range of about 200 miles, giving a defensive coverage of more than 125,000 square miles. The BOMARC IM-99A was phased out of operation during 1964.

The BOMARC Model B, IM-99B, was similar except that it incorporated a solid-fueled rocket engine, enabling more space to be given to ramjet engine fuel and allowing the missile more range than the IM-99A.

The missiles were housed in individual, above-ground launcher shelters on a constant combat-ready basis. Upon receiving the alert signal, the shelter roof slid back and the BOMARC was raised on its erector arm to its vertical launching position. The erector then descended and the missile was fired. The entire process was carried out automatically in 30 seconds.

The missiles were retired from active service and McGuire's BOMARC facility was closed in 1972. The missiles and warheads were removed from the shelters prior to closing.

The present host organization at McGuire AFB is the 438th Military Airlift Wing. Its primary mission is to provide quick reacting, concentrated, massive airlift to place DoD forces into combat situations in a fighting posture, and then furnish them with the materials they need to operate efficiently. The Wing is also responsible for operating McGuire AFB and for providing adequate support to a large number of tenant units.

1.3.1 Description of Installation

McGuire AFB occupies 3,536 acres in south-central New Jersey, 18 miles southeast of Trenton, NJ (Figure 1-1). It borders the community of Wrightstown (to the north) in Burlington County

(Figure 1-2). The eastern, southern, and western boundaries of McGuire AFB border the U.S. Army Fort Dix installation. McGuire AFB also leases the BOMARC Missile Site land from Fort Dix. This site is detach' from McGuire AFB and lies approximately 11 miles east of the Base (Figures 1-1 and 1-2).

Separate studies and reports have been prepared for other hazardous waste investigations on McGuire AFB proper and are not repeated within this report. This study deals specifically with the radioactive contamination from the explosion and fire in the launcher shelter area of the BOMARC Missile Site, described below.

1.4 BOMARC Missile Site Description

The BOMARC Missile Site occupies approximately 218 acres just east of Ocean County Highway 539 in Plumsted Township, Ocean County, New Jersey. It lies about 11 road miles east of McGuire AFB, and is contained within the Fort Dix Military Reservation on land leased to the Air Force (Figure 1-2).

The focus of this investigation is the BOMARC Missile Site, located on land leased to the Air Force by the Fort Dix Military Reservation. Rows of shelters housing launchers and BOMARC missiles were built at this facility during the late 1950s and early 1960s (Figure 1-3). The facility was deactivated in 1972, with all missiles removed from the launcher shelters, and the shelters themselves locked. Although the site has been deactivated, it remains under Air Force lease and jurisdiction. Figure 1-4 shows the BOMARC Missile Site and surrounding area, including wetlands and drainage pathways.

1.4.1 Accident History

On June 7, 1960, an explosion and fire occurred in the BOMARC Missile Shelter 204. The fire burned uninhibited for about 30 minutes. The force of the explosion destroyed portions of the shelter roof, flames rose to 20 feet, and black smoke blanketed the area. At the time of the fire a north-northeast wind of 2 to 8 knots blew the smoke into surrounding areas. Some of the plutonium may have been carried aloft on the northeasterly wind and dispersed from the BOMARC Missile Site, as indicated by Air Force environmental sampling data.

As part of the fire-fighting activity, the area was sprayed with water from fire hoses for approximately 15 hours. As a result, plutonium-contaminated water flowed under the front door, down the asphalt apron and street, and into the drainage ditch leading outside the site boundary. An earthen dam was constructed across the ditch to contain the contaminated water. Despite extensive research efforts, the nature and location of the eastern dam (both during and after fire-fighting activities) is unknown. The drainage ditch runs southerly from Shelter 204, paralleling the site boundary fence for several hundred feet before entering an underground culvert and crossing underneath Ocean County Highway 539. From this point the culvert opens into a sandy ditch that eventually flattens into a wooded area (Figure 1-3).

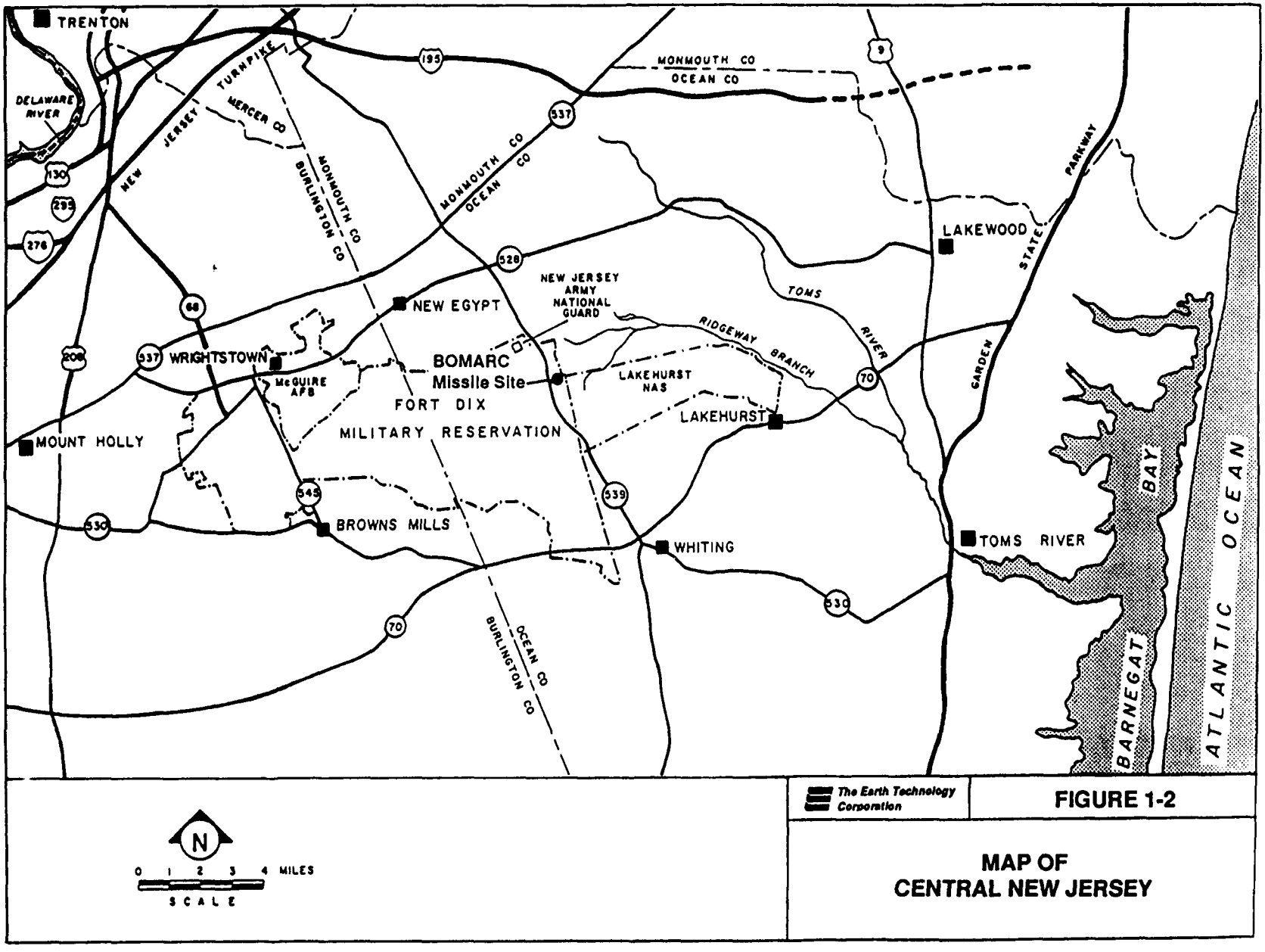

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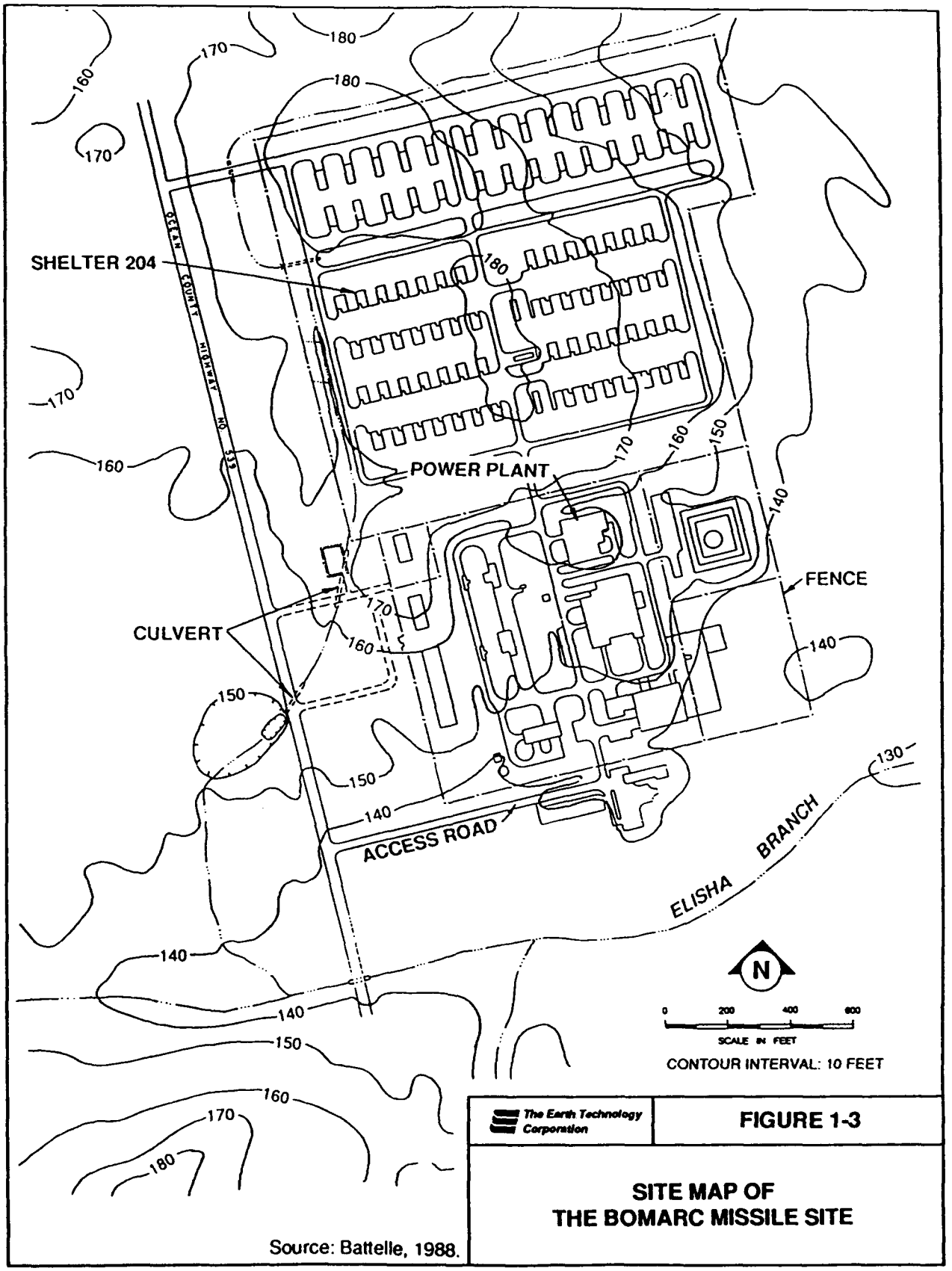
FIGURE 1-2

MAP OF CENTRAL NEW JERSEY



Source: Battelle, 1988.

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FIGURE 1-3

SITE MAP OF THE BOMARC MISSILE SITE

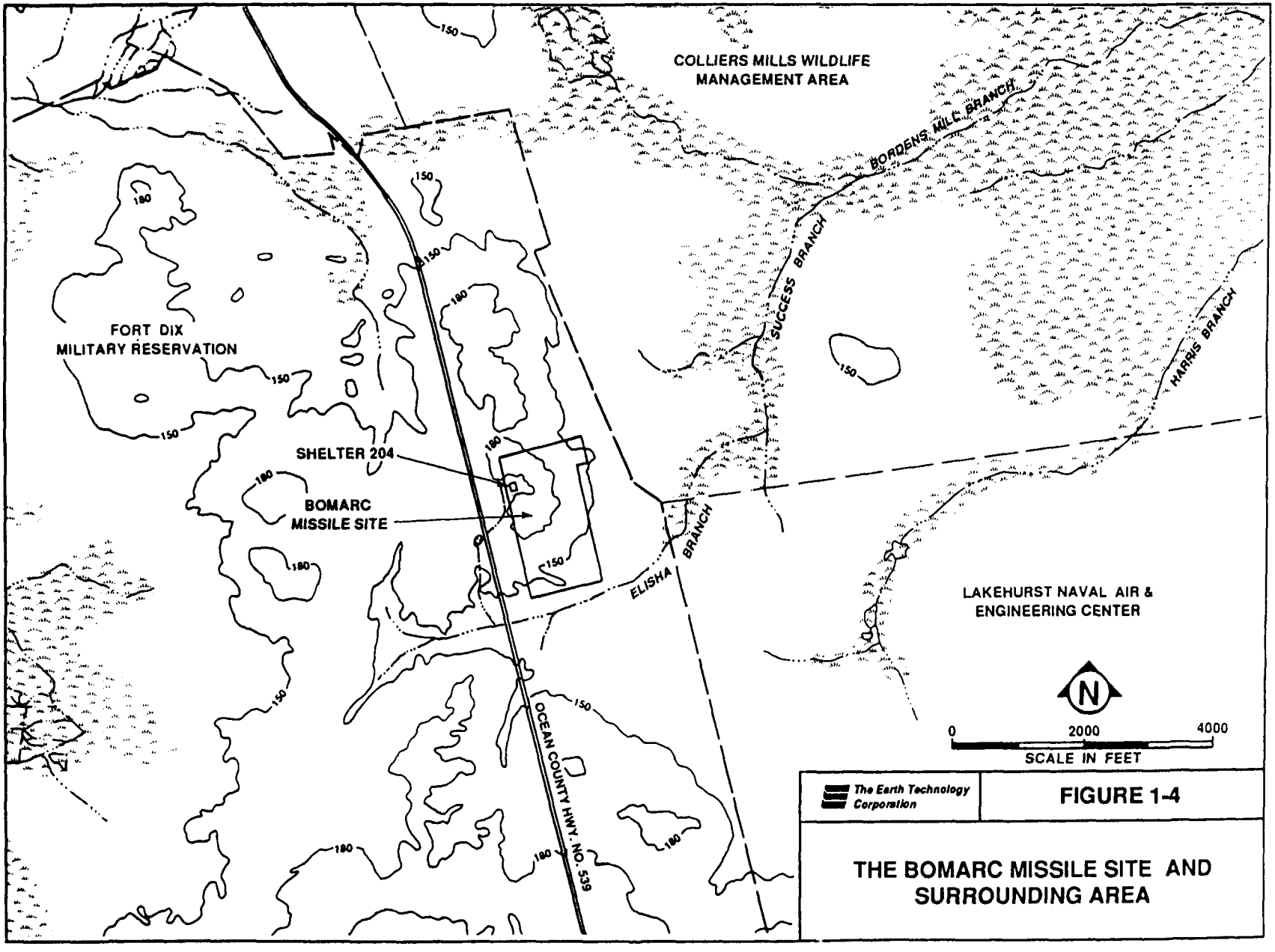

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FIGURE 1-4

THE BOMARC MISSILE SITE AND SURROUNDING AREA

Although no nuclear explosion took place, the nuclear warhead was burned and melted, the missile was destroyed, and the launcher shelter was badly damaged. The oxidizer tank was displaced but intact. In addition to the severely damaged roof, the floor and concrete walls were pitted by flying fragments of the helium and fuel tanks, steel roof beams were deformed, and the shelter walls received heat damage. The residue of the burning warhead contaminated the concrete floor.

The tritium bottle was in good condition. The valve of the tritium bottle was removed and both the valve and the bottle were sent to Los Alamos Scientific Laboratory in Albuquerque, New Mexico. The remains of the warhead and all residue from the floor were placed in plastic bags and then into sealed cans for disposal. The nuclear material was separated by grade, and the high-grade nuclear material was shipped to the Medina Base in San Antonio, Texas, and then to the Pantex facility in Amarillo, Texas. The containers remained at Pantex until sometime in 1979 to 1982. The DOE conducted measurements of the recovered material during that period. The amount of plutonium in the warhead remains classified. However, DOE and Air Force scientists prepared an unclassified account of the disposition of the material removed from the site. The account is provided as Appendix Q. The account indicates that the estimate of the upper limit of the plutonium that could have been left onsite is 300 grams.

1.4.2 Decontamination and Containment

Decontamination was initiated on June 8, 1960, with placement of air samplers downwind of the accident site. On June 10, the area was checked and monitoring equipment installed. During the fire, tar had melted and spread in a thin layer on sections of the floor of Shelter 204. Several sections of the floor containing tar showed radiation readings of over two million counts per minute (CPM). The levels in the center of the road outside the shelter were also two million CPM. The entire area was again washed down and allowed to dry; the levels in the center of the road in front of the shelter were still elevated.

On June 11, 1960, after the area was completely dry, the inside of the shelter was spray painted. The outside area was also painted, with brooms used to spread the paint on the asphalt. A total of 110 gallons of paint was used. After the paint had dried enough to walk on, readings were again taken. Areas that had previously shown two million CPM read zero due to the shielding effect of the paint on alpha emissions of the plutonium underneath. Some of the fringe areas showed readings of 50 to 500 CPM.

In June 1960, four inches of reinforced concrete were poured over the asphalt apron in front of Shelter 204 in an effort to fix the plutonium contamination under a protective overburden. In addition to this, two inches of asphalt were placed along the bottom of the drainage ditch located inside the site boundary fence. Additional concrete (two inches), was added to the shelter apron area in 1967, covering the manhole access to the communication and power pits proximate to Shelter 204. The pit area inside Shelter 204 was filled with soil excavated from the rear of the shelter.

1.4.3 Monitoring

Since 1960, many radiation surveys have been conducted around the BOMARC Missile Site. The Air Force Radiological Health Laboratory (now USAFOEHL), Brooks AFB, Texas has conducted surveys since 1960 and, in 1973, was directed by the Department of the Air Force to initiate an annual survey program. Surveys have also been conducted by the Army Environmental Hygiene Agency, the U.S. Army Radiation Team, Ballistics Research Laboratory, EG&G Inc., and others in recent years.

Confirmed radiological surveys occurred on or about the following dates:

- June 8, 10, 11, 16, 24-28, 1960
- November 21-24, 1966
- October 1970
- August 22-27, 1971
- October 16-20, 1972
- March 19-23, 1973
- November 13-14, 1973 (ARMS)
- May 20-29, 1975
- April 29, 1976 (Soils)
- May 17-20, 1976
- September-December, 1976 (Installation Assessment)
- June 1978
- October 1979
- 1981 (IRP)
- 1982 (IRP)
- 1983 (IRP)
- 1984 (IRP)
- September 15-21, 1985
- October/November, 1985 (ground water and air dispersion modeling)
- October 1986
- September 1987.

There are indications from radiation surveys that a substantial amount of plutonium was exhausted from the building during the incident. The wall contamination results show clearly that uncontaminated air entered the shell of the structure from the north and northeast. These areas were uncontaminated. The air traveled southward to the fire and was exhausted in the southwest quadrant. Some contaminated exhaust was circulated around the lower level of the structure shell and contaminated the lower walls on the east and west sides. The contaminated exhaust appears to have exited the building at the north half of the west wall and at the midline of the east wall. Substantial amounts of contamination were also detected on the upper surfaces of the "I" beam upwind from the source of plutonium.

1.5 Identification and Characterization of Contaminants

The radiological waste at the BOMARC accident site consists of weapons grade plutonium (WGP). The primary isotope in WGP is Pu-239, but small quantities of Pu-238, Pu-240, Pu-

241, and Am-241 (from beta decay of Pu-241) may be found. These contaminants are found in or on soil, concrete, asphalt, and steel. The radioactive contamination is not distributed uniformly over the site, but occurs in discrete "hot spots", which in several instances have been found to be a single particle, presumably containing plutonium oxide. Thus, radiation measurements within a small area can vary somewhat. This variation is seen in samples that have been drawn from the same location but at different times. Generally, however, the samples indicate that the levels of contamination have remained stable over the intervening years since the accident.

1.6 Identification of Field Team

The field work for the phase II, stage 2 activities at the BOMARC Missile Site was completed from June 1989 to January 1991. Ground water, surface water, concrete/asphalt core, soil, sediment, wipe, and ambient air samples were collected during field activities at the BOMARC Missile Site.

Field teams from both The Earth Technology Corporation and SAIC were present during field activities. Field teams from The Earth Technology Corporation consisted of Phillip Watts, Project Manager; D. Jay Wilburn, Geologist; Melvin Tyree, Geologist/Biologist; Janet Robinson, Environmental Scientist; Lisa Goldberg, Environmental Scientist; Richard Bizub, Geologist; David Naleid, Engineer; and Ed Sciulli, Geophysicist.

Field teams for SAIC consisted of Neil Botts, Project Manager; Donna Collins, Field Manager; Mark Byrnes, Geologist; Greg DiGregorio, Geologist; Catherine Olsen, Geologist; Charles Marcinkiewicz, Health Physicist; Scott Hay, Environmental Scientist; and Reg Gotchy, Health Physicist. Additional field health physicist support was given by Phil Gianutsos, Stanley Waligora, and Mark Roberts.

2.0 ENVIRONMENTAL SETTING

2.1 Geographic Setting

The BOMARC Missile Site, located in Ocean County, New Jersey, is in a heavily wooded semi-rural part of east-central New Jersey (Figure 1-1). It lies inland from the coast near the northern boundary of the New Jersey Pinelands (Pine Barrens).

The BOMARC facility is on the Fort Dix Military Reservation property, leased to McGuire AFB. Fort Dix extends tc the west of the BOMARC facility (Figure 1-2). The New Jersey Wildlife Game Refuge lies northeast of the BOMARC facility and the Lakehurst Naval Air Station (NAS) lies to the southeast.

2.1.1 Physiography (Physical Geography)

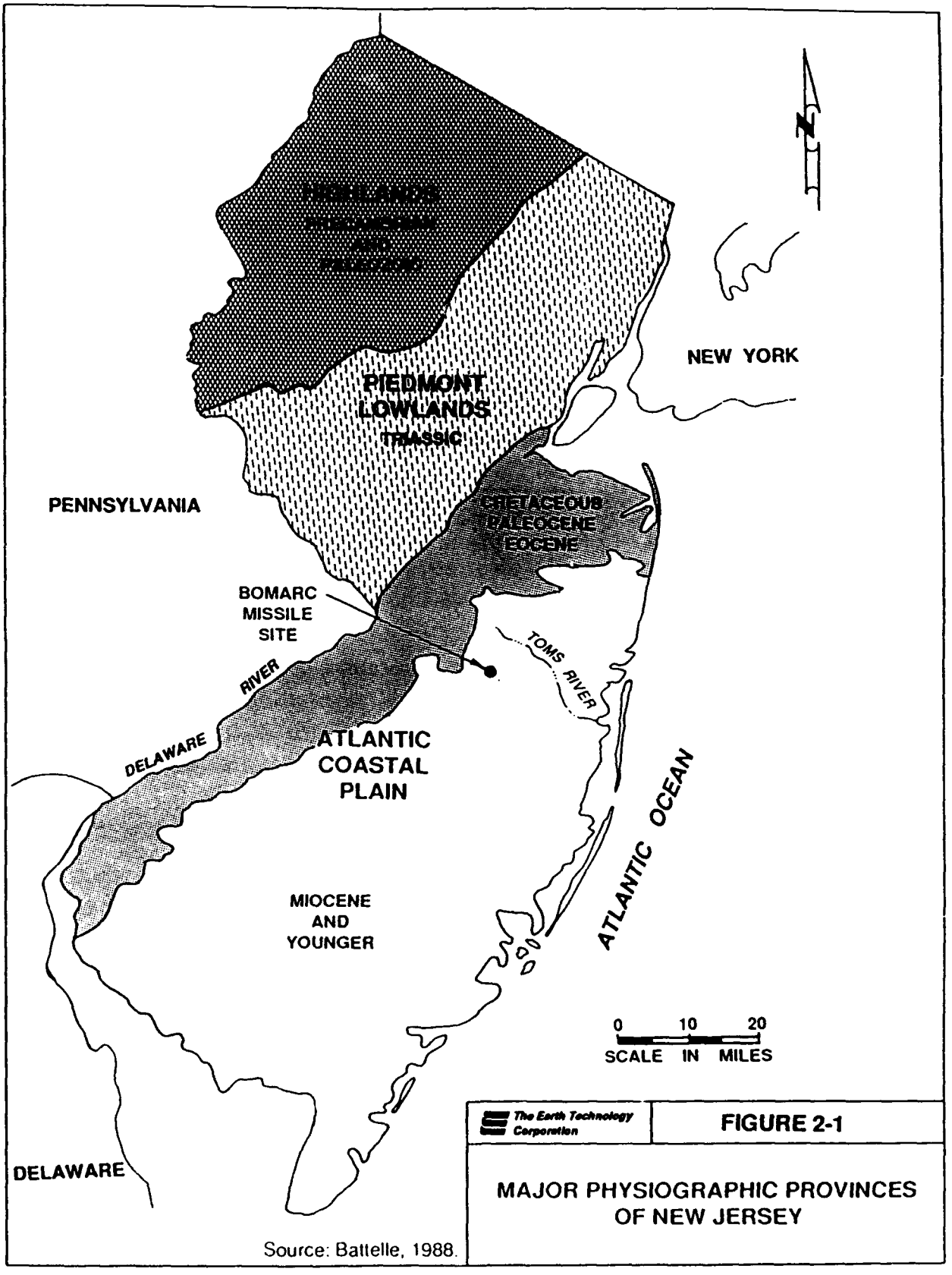
The BOMARC Missile Site is located along the northern boundary of the outer coastal plain section of the Atlantic Coastal Plain Physiographic Province (Figure 2-1). Coastal plain topography is gently rolling with elevations ranging between 60 and 180 feet above mean sea level (msl). It is generally low-lying, with poor drainage, many swamps, and slow-flowing streams. Maximum elevation at the BOMARC Missile Site is about 180 feet above msl near Shelter 204 and decreases to about 130 feet above msl at the southeastern perimeter of the facility (Figure 1-3).

A major drainage divide separates the inner coastal plain from the outer coastal plain. The inner coastal plain drains into the Delaware River Basin, while the outer coastal plain drains directly to the Atlantic Ocean. The BOMARC Missile Site lies in the outer coastal plain, just east of the drainage divide. Streams in the outer coastal plain generally flow to the southeast. The nearest and only natural drainageway in the vicinity of the site is the northeast-trending Elisha Branch of the southeast-trending Toms River, located to the south of the site.

2.1.2 Cultural Geography

The BOMARC Missile Site lies within the bounds of the New Jersey Pinelands, a region of dense vegetation dominated by pitch pine and characterized by boggy lowland areas used to cultivate cranberries.

The area is generally semi-rural, with nearby small towns of New Egypt (6 miles), Wrightstown (10 miles), Whiting (5 miles), Lakehurst (6 miles), and Browns Mills (9 miles). Populations for the nearby areas (1980 census) are given in Table 2-1. There are no private residences within a one-mile radius of the missile site. The nearest private residence lies just over a mile north-northwest of the facility fence. The only land use within several miles of the BOMARC Missile Site is military, but the sections of the two military reservations immediately adjoining the BOMARC Missile Site are not often used for active military operations. A New Jersey Army National Guard post located about one mile west-northwest of the BOMARC facility is used for heavy land vehicle (tanks, etc.) training.



The Earth Technology Corporation

FIGURE 2-1

MAJOR PHYSIOGRAPHIC PROVINCES OF NEW JERSEY

Source: Battelle, 1988.

Table 2-1

Populations Near the BOMARC Missile Site

Municipality	Population (1980 census)
Plumsted Township (includes New Egypt)	4,674
Manchester Township (includes Whiting)	27,987
Lakehurst Township (includes Lakehurst)	2,908
New Hanover Township (includes Wrightstown)	14,258
Pemberton Township (includes Browns Mills)	29,720
Jackson Township	25,644
North Hanover Township	9,050
Upper Freehold Township	2,750

2.2 Geology

The following sections discuss the geology of the BOMARC Missile Site.

2.2.1 Geologic Setting

The Atlantic Coastal Plain (Figure 2-1) is a gently seaward-sloping surface characterized by a series of poorly consolidated, marginal marine sediments that thicken to the southeast and range in age from Recent to Cretaceous (Figure 2-2). Underlying those sediments are consolidated, metamorphosed Precambrian crystalline rocks ("basement rocks").

The basement rocks were formed during the Precambrian Era and then were uplifted into mountains during the Paleozoic Era. By the Triassic Period, the mountains were being eroded, with the resultant sediments deposited in basins flanking the mountainous highlands. These sediments were composed of large amounts of sand and similar materials and have since been eroded into lowlands called the Piedmont Lowland Province. The Piedmont Lowlands formed on the edges of the steeply upturned and altered rocks that were originally part of the Appalachian mountain system. As erosion continued, younger sedimentary deposits covered these older rocks so that the southeastern edge of the Appalachian system is no longer visible. During prolonged erosion of the mountain mass, thick sequences of Cretaceous sediments formed, covering what is now known as the Atlantic Coastal Plain. The break between the Piedmont and the Coastal Plain is known as the Fall Line. The Coastal Plain sediments are mixed marine and nonmarine. At the time these Cretaceous formations were deposited, the Atlantic Ocean had essentially its present form. Additional sediments were deposited during the Tertiary Period. Subsidence of the entire area to the southeast during both Cretaceous and Tertiary deposition formed a thick wedge of sediments that thickens to the southeast. A final thin, discontinuous veneer of Quaternary sediments covers parts of the area.

2.2.2 Bedrock Geology

Geologic units ranging in age from Cretaceous to Quaternary have been identified in the Atlantic Coastal Plain Province (Figure 2-3). These units are typically unconsolidated materials consisting of gravel, sand, silt, clay, glauconite, marl, and organics, resting unconformably on a Precambrian crystalline basement complex.

2.2.2.1 Stratigraphy

The stratigraphy of the BOMARC Missile Site (Figure 2-3) is dominated by interbedded continental and marine sands and clays. Surficial materials consist of a relatively thin expression (40 feet or less) of the Cohansey Sand, underlain by an unknown thickness of the Kirkwood Formation. The descriptions given in Figure 2-3 are for the formations (from youngest to oldest) known to underlie the Atlantic Coastal Plain (Lyttle and Epstein, 1987). Thicknesses given are usually ranges. In most cases, the thickness of a particular formation in the vicinity of the BOMARC Missile Site will be nearer the lower end of the range because of the general formational thinning toward the Fall Line on the northwest.

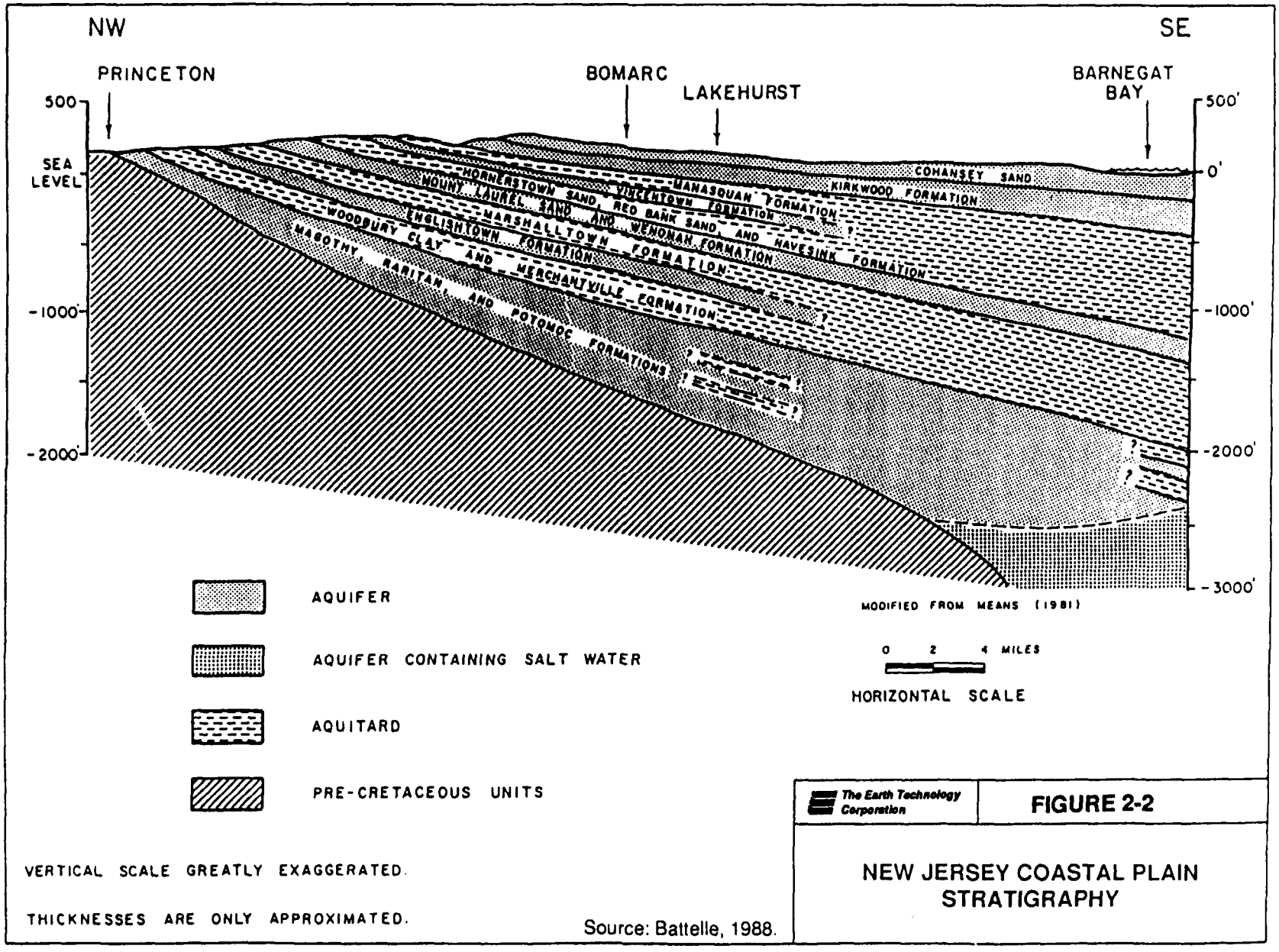
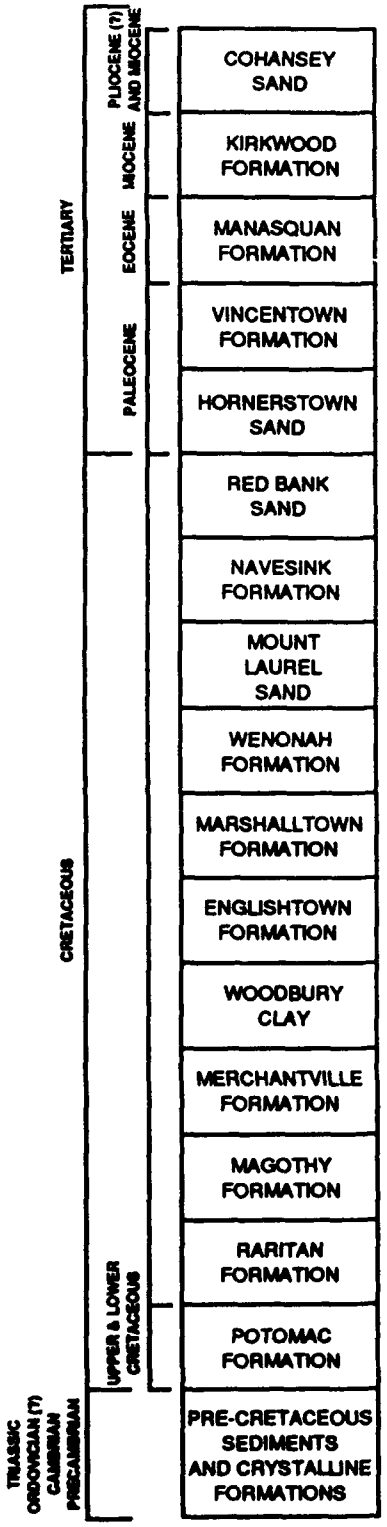

NW
SE
PRINCETON
BOMARC
LAKEHURST
BARNEGAT BAY
500
SEA LEVEL
-1000'
-2000'
500'
0'
-1000'
-2000'
-3000'
COHANSEY SAND
KIRKWOOD FORMATION
MANASQUAN FORMATION
VINCENTOWN FORMATION
HORNERSTOWN SAND, RED BANK SAND, AND HAVESINK FORMATION
MOUNT LAUREL SAND AND WENONAH FORMATION
ENGLISHTOWN FORMATION
MARSHALLTOWN FORMATION
WOODBURY CLAY AND MERCHANTVILLE FORMATION
MAGOTHY, RARITAN, AND POTOMAC FORMATIONS
BASEMENT
MODIFIED FROM MEANS (1981)
0 2 4 MILES
HORIZONTAL SCALE
AQUIFER
AQUIFER CONTAINING SALT WATER
AQUITARD
PRE-CRETACEOUS UNITS
VERTICAL SCALE GREATLY EXAGGERATED.
THICKNESSES ARE ONLY APPROXIMATED.
Source: Battelle, 1988.
The Earth Technology Corporation
FIGURE 2-2
NEW JERSEY COASTAL PLAIN STRATIGRAPHY

FIGURE 2-3
GENERALIZED STRATIGRAPHY FOR THE ATLANTIC COASTAL PLAIN
(Modified from Lyttle, P.T. and Epstein, J.B.)



COHANSEY SAND — Well-sorted, crossbedded, medium-grained, partly arkosic quartz sand; some dark, massive carbonaceous, kaolinitic, and illitic silty clay; crossbedded gravel in channels with pebbles of quartz and quartzite; and minor metamorphic rock fragments which are less than 5 cm (2 in) in diameter. As much as 46 m (150 ft) thick, thinning toward the Fall Line in the northwest. Aquifer.

KIRKWOOD FORMATION — Moderately well sorted, fine-grained, micaceous quartz sand, locally clayey or silty with local thick beds of clayey silt and fine-pebble gravel. Lower contact unconformable. 30-76 m (100-250 ft) thick. Aquifer.

MANASQUAN FORMATION — Thick-bedded to massive, silty and clayey glauconitic and quartzose sand; interbedded silty clay and clayey silt. Apatite pellets and siderite fragments locally abundant. 15-61 m (50-195 ft) thick. Aquitard.

VINCENTOWN FORMATION — Partly clayey, glauconitic quartz sand. 15-30 m (50-100 ft) thick. Aquifer.

HORNERSTOWN SAND — Massive, poorly sorted, fine to medium-grained, locally very silty and clayey glauconite and quartz sand with some phosphate pellets and bone fragments. Lower contact unconformable. About 6 m (20 ft) thick. Aquitard.

RED BANK SAND — Very thick bedded, medium to coarse-grained, fairly indurated, quartz, feldspar, and glauconite sand and fossiliferous sandy silt. As much as 37 m (120 ft) thick. Aquitard.

NAVESINK FORMATION — Dark-gray, thick bedded, clayey and silty, glauconite sand, with organic matter, pyrite, and local thick shell beds. As much as 14 m (45 ft) thick. Aquitard.

MOUNT LAUREL SAND — Medium-grained, poorly to moderately sorted, feldspathic quartz sand. Abundant borings filled with glauconite sand and thin-bedded, dark, micaceous and carbonaceous silt and clay alternating wit medium-bedded, light-colored, micaceous, glauconitic quartz snad with discontinuous layers of gray siderite concretions. As much as 15 m (50 ft) thick. Aquifer.

WENONAH FORMATION — Generally dark, thick-bedded, fine to medium-grained, poorly to moderately sorted, carbonaceous, pyritic, very silty and clayey, quartzose glauconitic sand. 21-30 m (70-100 ft) thick. Aquifer.

MARSHALLTOWN FORMATION — Dark, fine-grained, massive, fossiliferous, very silty and clayey, quartzose glauconite sand with common mica, feldspar, pyrite, and carbonaceous matter. 5-6 m (15-20 ft) thick. Aquitard.

ENGLISHTOWN FORMATION — Light-colored, well-sorted, fine to medium-grained, crossbedded, glauconitic, feldspathic, and micaceous quartz sand, and interbedded clayey silt and sand with numerous siderite concretions. 6-46 m (20-150 ft) thick. Aquifer.

WOODBURY CLAY — Dark-gray, massive to crudely laminated, carbonaceous, pyritic, partly glauconitic, micaceous, very clayey (dominantly illitic) silt. As much as 30 m (100 ft) thick. Aquitard.

MERCHANTVILLE FORMATION — Dark, clayey, micaceous, quartzose, carbonaceous silt and interbedded gravel containing reworked siderite concretions; thick-bedded glauconite and quartz sand. 6-30 m (20-100 ft) thick. Aquitard.

MAGOTHY FORMATION — Dark, micaceous, pyritic, kaolinitic, clayey silt and light-colored quartz sand with large lignitized logs. Lower contact is unconformable, but is buried by surficial deposits. 3-61 m (10-200 ft) thick. Aquifer.

RARITAN FORMATION — Massive crossbedded quartz sand; thick-bedded clayey silt; laminated clay and silt; and minor gravel. About 61 m (200 ft) thick. Aquifer.

POTOMAC FORMATION — Moderately well sorted, crossbedded, quartzose sand; gravelly sand with quartz and quartzite pebbles as much as 13 cm (5 in) long; and black, red, white, and yellow, massive, kaolinitic and illitic, crudely stratified, lenticular clay. 76-244 m (250-800 ft) thick. Lower contact unconformable. Aquifer.

PRE-CRETACEOUS SEDIMENTS AND CRYSTALLINE FORMATIONS

COASTAL PLAIN

The coastal Plain is a gently seaward-sloping surface on poorly consolidated sediments of Tertiary and Cretaceous age. These rocks form a southeastward-thickening, gently tilted prism of strata which exceeds 755 m (2,480 ft) in thickness along the coast, and thins to a feather edge along the Fall Line where they unconformably overlap the Sothern Piedmont and Newark Basin. Whereas the oldest Cretaceous clastic sediments are mostly nonmarine, the overlaying units are mostly marginal marine in origin.

The Cohansey Sand [Pliocene (?) and Miocene] is a light gray to yellowish-brown, well-sorted, cross-bedded, pebbly, fine- to coarse-grained, ilmenitic, partly arkosic quartz sand, often cemented locally with iron oxide (limonite). Small seams of dark, massive, carbonaceous, kaolinitic and illitic silty clays are interbedded in the sands. Crossbedded gravels are found in channels with pebbles of quartz and quartzite. At the BOMARC Missile Site the Cohansey Sand is a fine- to coarse-grained quartzose sand with lenses of gravel that are usually one foot or less in thickness. Limonite staining produces a generally yellowish sand, but shades of red, brown, gray, and white are also found. Near the coast, the Cohansey Sand can reach thicknesses of as much as 150 feet, but the unit near the BOMARC Missile Site probably closer to 50 feet thick. This formation forms the surface or near-surface aquifer in much of the region.

The Kirkwood Formation (Miocene) consists of light gray to yellowish-brown, moderately well-sorted, pebbly, lignitic, micaceous, fine- to very-fine-grained quartz sand. It often contains kaolinitic clay or silt, with local thick beds of clayey silt and fine-pebble gravel. There is a basal unit of pebbly, fine quartz sand or medium gray to dark brown, lignitic quartz silt and sand. Thicknesses range from 50 to 250 feet. This formation is hydraulically connected to the Cohansey Sand, and combined, these formations form the surface or near-surface aquifer in the area.

The Manasquan Formation (Eocene) is a thick-bedded to massive, silty and clayey glauconitic and quartzose sand, interbedded with silty clay and clayey silt. Apatite pellets and siderite fragments may be locally abundant. Thicknesses range from 20 to 195 feet. This formation is the first aquitard below the surface.

Sediments penetrated by wells drilled at the BOMARC Missile Site are reported to consist of four general units presented in order of decreasing abundance (Weston, 1988):

- Medium-to-fine quartz sand
- Coarse-to-medium quartz sand
- Coarse-to-fine quartz gravel
- Clay, silt, and peat.

Weston (1988) reports the following conditions:

> Medium-to-Fine Sand - This unit consists of well-sorted medium-to-fine quartz sand containing minor amounts of gravel, coarse sand, silt, and clay. Color ranges from light gray to brownish-yellow, and color laminations and mottling are common. Rusty-orange layers of iron oxide enrichment were noted often occurring just above clay- and silt-rich layers. Hard, brittle indurated iron-rich layers were occasionally encountered, and thin horizons rich in heavy mineral grains were also noted. Medium-to-fine sand units appear to be laterally extensive throughout the BOMARC Missile Site and range from less than 5 to more than 40 feet in thickness.
>
> Coarse-to-Medium Sand - This unit consists of well-sorted coarse-to-medium quartz sand with minor amounts of gravel, fine sand, and silt. These sediments are predominantly yellowish-brown with lesser amounts of light gray and red-

brown. Color laminations and mottling were common, and indurated iron-rich layers were occasionally encountered. Coarse-to-medium sand units occur both as localized lenses and as laterally extensive units up to nearly 30 feet thick beneath the BOMARC Missile Site. The coarse-to-medium and medium-to-fine sand units interact as a single hydrogeologic unit.

Coarse-to-Fine Gravel - This was observed as a distinct unit only at the MW-BMC-1 well location, from a depth of 18.5 feet to the bottom of the boring at 29 feet. The gravel is brownish-yellow and occurs in a matrix of silty medium sand. The bed pinches out and was not observed at adjacent wells MW-43 and MW-BMC-3. The gravel lens also interacts with the medium-to-fine sand unit as a single hydrogeologic unit. Elsewhere, gravel occurs either as a constituent in a sandy matrix or as localized thin lenses generally less than one foot thick.

Clay, Silt, and Peat - Clay and silt occur both as minor constituents (less than 30 percent) in the matrices of the coarse-to-medium and medium-to-fine sand units and as very thin, distinct laminations usually one inch or less in thickness.

Mappable clay- and silt-rich lenses occur beneath the vicinity of the western portion of the BOMARC Missile Site. These lenses were encountered in wells PU-1, PU-2, PU-4, and MW-47 at approximately the same elevations (161.64 $\pm$ 2.75 feet). The components of the lenses vary and include massive gray clay and fine sand (PU-1), laminated fine sand and clay (PU-2), gray clay (PU-4), highly plastic gray clay (MW-47), and very thinly laminated clay (PU-3). Whether or not these lenses extend laterally to form a single lens is unknown. The soil directly above the lenses in each well was observed to be damp, and a perched water condition was present above the clay lens in monitor well PU-4. Whether as one single lens or several distinct lenses, the occurrence of clay beneath the western part of the BOMARC Missile Site has only a localized effect on the hydrogeology.

Additionally, minor occurrences of dark brown to black peat and organic silt were observed in monitor wells PU-4 (54 to 61.9 feet), MW-16, MW-17, and MW-47 (43.5 to 48.4 feet).

In summary, the subsurface conditions beneath the BOMARC Missile Site consist of a series of interfingering lenses of predominantly medium-to-fine and coarse-to-medium sands with minor amounts of gravel, clay, silt, and peat. These conditions are characteristic of the Cohansey Sand.

2.2.2.2 Structural Geology

The Coastal Plain sediments form a relatively smooth-surfaced wedge (Figure 2-2) that both dips and thickens to the southeast (seaward). The average unit dip ranges from 10 feet per mile (Cohansey unit) to 45 feet per mile (Hornerstown unit). Cretaceous formations have a fairly uniform dip of 35 feet per mile. The strike (the direction or trend taken by the structural surface) of the Tertiary units is generally to the east, while the Cretaceous formations strike

generally northeast (Table 2-2). No folds, faults, or fractures have been mapped in the area near the BOMARC Missile Site.

2.2.2.3 Geotechnical and Engineering Properties

The engineering characteristics of the formations in this area are summarized in Table 2-3.

2.2.3 Surficial Geology

The following sections discuss the surficial geology at the BOMARC Missile Site.

2.2.3.1 Unconsolidated Rock Deposits

The Pinelands region is overlain by a discontinuous veneer of Quaternary sand, gravel, and clay.

2.2.3.2 Soils

Natural Soils. The Lakewood Series (Soil Conservation Service) is the predominant natural soil series at the BOMARC Missile Site. The Lakewood soils consist of 7 to 10 inches of gray sand overlying 20 to 25 inches of dark brown to yellowish-brown sand to a depth of about 60 inches. These soils are characterized as excessively drained; they are coarse, conducive to rapid water percolation, and have low soil moisture retention and low nutrient content. Permeabilities range from 0.2 to 6.3 inches per hour.

The Lakewood Series is a true podsol, which is "a group of zonal soils having an organic mat and a very thin organic-mineral layer overlying a gray, leached A2 horizon and a dark brown, alluvial B horizon enriched in iron oxide, alumina, and organic matter. It develops under coniferous or mixed forests or under heath, in a cool to temperate moist climate" (Bates and Jackson, 1980). In the Lakewood Series, the sodium, calcium, and magnesium have been dissolved, and the less soluble iron, aluminum, and titanium are partially leached and precipitated into the subsoil.

Urban Land Unit(s). As a consequence of Base development/construction activities, the predominant category of soil on the site proper is mapped as "sandy urban land". Urban land map units are generally so variable that their properties are not characterized by the Soil Conservation Service. Use constraints are probably severe due to the great permeability in the unit(s).

2.3 Hydrogeology

The Cohansey Sand and the Kirkwood Formation are the formations of principal hydrogeologic interest. These two formations are probably hydraulically connected locally and are found at the ground surface at the BOMARC Missile Site. Ground water occurs at shallow depths in these units; at the BOMARC facility, underlain by the highly permeable Cohansey Sand, ground water is present between 12 and 55 feet below grade under water table conditions. Water table elevations in the vicinity of the missile shelters range from approximately 127.8 to 129.5 feet msl and are highest to the west of the missile shelters. There is a ground water divide to the

Table 2-2

Attitudes of the Formations,
Calculated on the Basal Beds of the Formations

Age	Formation	Average Strike (Degrees)	Average Dip (feet/mile)
Tertiary	Cohansey	N72E	SE 10
Tertiary	Kirkwood	N70E	SE 18
Tertiary	Manasquan	N62E	SE 25
Tertiary	Vincentown	N56E	SE 30
Tertiary	Hornerstown	N53E	SE 45
Cretaceous	Red Bank	N47E	SE 35
Cretaceous	Navesink	N47E	SE 35
Cretaceous	Mount Laurel	N47E	SE 35
Cretaceous	Wenonah	N46E	SE 35
Cretaceous	Marshalltown	N46E	SE 35

(Modified from Minard and Owens, 1962)

Table 2-3

Some Engineering Characteristics of the Formations Near the BOMARC Missile Site

Formation	Slope Stability	Internal Drainage	Foundation Support	Pavement Support	Use
Cohansey	Poor[1]	Excellent	Good	Good	Mortar sand[2], concrete aggregate, retaining walls[3], borrow[4]
Kirkwood	Poor[5]	Good	Good	Good	Retaining walls[3], borrow[4], fill[6], molding sand[7]
Manasquan	Fair	Fair	Fair	Poor to Fair	Fill[8], source of glauconite
Vincentown	Poor[9]	Good	Good	Good	Borrow[4], asphalt, sand[9]
Hornerstown	Good	Fair	Good	Fair	Fill[8], source of glauconite
Red Bank (upper member)	Poor	Good	Good	Good	Borrow[4]
Red Bank (lower member)	Good	Poor	Good	Fair	Fill[8], source of glauconite
Navesink	Good	Poor to Fair	Good	Fair	Fill[8], source of glauconite
Mount Laurel	Good[10]	Good	Good	Good	Borrow[4], asphalt, sand[9]
Wenonah	Poor to Fair	Fair to Good	Good	Good	Fill[8], molding sand[7]
Marshalltown	Poor to Fair	Poor to Fair	Fair	Fair	Fill[8]

(Modified from Minard and Owens, 1962).

Footnotes:

1. Except in weathered upper 3 to 6 feet or where cemented by iron oxide.
2. Clean loose sand and gravel below surface 3 to 6 feet.
3. Sandstone slabs and blocks exposed in pits between Jacobstown and Arneytown (Kirkwood), on Stony Hill (Kirkwood), and on Taylors Mountain (Cohansey).
4. Borrow indicates good quality material acceptable to bring road beds up to grade.
5. Except where cemented by iron oxide.
6. Fill purposes only. Not good enough quality to use to bring road beds up to grade.
7. Essentially unweathered, silty and clayey, fine- to very fine-grained quartz sand from basal part of Kirkwood Formation and from the Wenonah Formation, probably is acceptable as molding sand.
8. Except where limestone ledges are present in outcrop.
9. Presence of available potassium in the glauconite and the softness of the glauconite makes the sand undesirable for mortar sand. Acceptable as sand in asphalt mix.
10. Good slope stability in most outcrops because of partial cementing by iron oxide.

west of the missile shelters; consequently, it is difficult to determine whether ground water flow in this area is to one side of the divide or the other. Ground water flow for the rest of the area is predominantly to the northeast.

2.3.1 Ground Water

The Coastal Plain is underlain by a succession of aquifers and aquitards. The principal aquifers of the Pinelands are the shallower Cohansey/Kirkwood and the deeper Potomac/Raritan/ Magothy.

Public water supplies in Ocean County are obtained entirely from ground water sources. Water use in the region is predominantly from the Potomac/Raritan/Magothy aquifer system. While the Cohansey/Kirkwood system is not currently in wide use for potable water, the system is under consideration for supplementary supplies for several large metropolitan areas. Usable standing water reserves in the Cohansey alone are estimated at 10.8×10^{12} gallons (Rhodehamel, 1970).

2.3.1.1 Occurrence and Movement

The BOMARC Missile Site lies just east of a major drainage divide between the outer and inner Atlantic Coastal Basins. This surface divide is also reflected in the ground water flow.

The Cohansey Sand and the Kirkwood Formation (estimated thickness about 100 feet) form the surface aquifer for much of the Pinelands region, including the BOMARC Missile Site. These formations are generally under unconfined (water table) conditions, although confined conditions may occur locally. New Jersey uses an aquifer classification system, under which the BOMARC Missile Site is classified as having a GW-2 aquifer. Class GW-2 ground water has a Total Dissolved Solids (TDS) of 500 milligrams per liter (mg/l) or less and is suitable for potable, industrial, or agricultural water supply, after conventional water treatment. Recharge of this Cohansey/Kirkwood aquifer occurs primarily through precipitation falling on the exposed portions of the formation(s). The BOMARC Missile Site lies within the recharge area. Recharge to the Kirkwood Formation is both from outcrop recharge and from leakage by the overlying water table aquifers. Specific yield of the Cohansey Sand averages 21 percent.

Two major flow systems have been identified in the Cohansey/Kirkwood: a surficial system and an intermediate system. A 1980 study by the New Jersey Pinelands Commission estimated that 85 percent of infiltrated precipitation enters the surficial system and is discharged to a surface water body as base flow. About 10 percent of the infiltrated precipitation enters the intermediate system. The surficial system exhibits a fairly short flow path, estimated by the New Jersey Pinelands Commission at about 1.5 miles. Under normal climatic conditions and typical hydraulic gradients, the flow rate is estimated to be on the order of four feet per day. If the travel distance is 1.5 miles, water retention time for the Cohansey/Kirkwood is expected to be less than 5 years. Travel time for the intermediate system may be ten times slower (less than 50 years).

Water level fluctuations are greater in water table wells tapping the Kirkwood Formation than water table wells tapping the Cohansey Sand because the fine sands of the Kirkwood Formation are less permeable and have lower specific yields than sands and gravels of the Cohansey.

Water levels in the local surficial aquifer generally decline during the growing season due to increased evapotranspiration. There may be a several month lag in water level changes, so that effects of pumping or precipitation do not immediately become apparent. Especially where the water table is deep, it reflects general seasonal and climatic changes rather than single rainfall events. At a number of ground water well sites, water levels were higher in wells screened at greater depths than in those adjacent wells screened at shallower depths, indicating a net upward flow.

The deep hydrologic unit is the regionally important Potomac/Raritan/Magothy aquifer system. This unit consists of three geologic formations in hydraulic communication that together comprise the primary source of potable water in the region. The base of the Potomac/Raritan/ Magothy aquifer is defined by the crystalline basement rock which the formations unconformably overlie.

The primary source of recharge to the Potomac/Raritan/Magothy system consists of rainfall or surface water flow contacting the outcrop area: a narrow band beginning in Delaware and trending northeast along the Delaware Valley and across New Jersey to Perth Amboy. Water in the deep system typically occurs under artesian conditions. Secondary recharge may occur as leakage from overlying units down-dip of the outcrop zone.

2.3.1.2 Ground Water Quality

Local aquifers contain water that is of generally good quality but with high iron, manganese, and TDS, as well as hardness problems, variations in pH, and disagreeable odors (often hydrogen sulfide, "rotten eggs"). In addition, overpumpage of some of the aquifers in certain areas has led to a lowering of the ground water table, occasionally accompanied by salt water intrusion.

Precipitation plays a major role in ground water chemistry in the Pinelands because precipitation enters the aquifer essentially unchanged. The soils are thin and poorly developed, and the quartz sands and gravels of the Cohansey are chemically unreactive and permeable. Ion exchange and adsorption capacities are exceptionally low. Precipitation in the area has an average pH of 4.4. Ground water similarly has a low pH, partly because of this contribution from precipitation, and partly because of the addition of carbon dioxide from plant respiration and decay, plus the added natural organic acids from swamplands.

Ground water in the Pinelands is generally low in TDS, averaging 15 to 30 parts per million (ppm). There is also more silicon dioxide, iron, and organic carbon in the ground water than in nearby surface water. Ground water quality observed during this investigation is discussed in Section 4.

2.3.1.3 Ground Water Uses

All public supplies in Ocean County are from ground water. Total county ground water pumpage in 1969 was about 23 million gallons per day (mgd). The BOMARC Missile Site lies within the area served by the Lakehurst NAS Water System. Lakehurst NAS is permitted to pump a maximum of 27.85 million gallons per month. Quantities recently pumped were well below this limit (11,122,000 gallons in October 1991; 14,501,000 gallons in November 1991, and 13,956,000 gallons in December 1991). Lakehurst NAS operates 25 wells finished in the Cohansey/Kirkwood aquifer and 1 well completed in the Raritan aquifer. Water use at Lakehurst NAS includes irrigation, drinking water, and industrial purposes (Telephone conversation with B. Panebianco, McGuire AFB, February 18, 1992).

The significant industrial water users in the county (1969) are the Toms River Chemical Company at Toms River and the Glidden Company at Lakehurst.

The irrigated land area in Ocean County is small and, as of 1969, was decreasing. Cranberries are grown where the ground water table intersects the land surface, creating bog conditions.

2.3.1.4 Well and Pump Maintenance

The water supply wells on the BOMARC facility are not currently being used for any purpose. Information on the maintenance of these wells or any problems with them is not available.

2.3.1.5 Well Inventory

On site, there are two shallow (100 feet) inactive water supply wells near the southwest quadrant of the facility (Table 2-4 and Figure 2-4). Each is six inches in diameter, approximately 100 feet deep, and apparently screened into the Kirkwood Formation. In 1957, water levels in these wells stood at about 125 feet msl. A third well, completed to about 100 feet, was reportedly used as a disposal well for various fluids (unconfirmed types, may include nitric acid, JP-X [60% JP-4 and 40% hydrazine], and soap solutions) during the time the Base was active (U.S. Army, 1977). The presence, use, depth, and disposition of this disposal well has been disputed. Interviews of BOMARC facility senior personnel and searches of records, facility drawings, and as-builts have not been able to verify the existence of that well. Persons knowledgeable of the missile facility indicated that they believed the reference was to an acid neutralization pit located in the support section of the facility. That pit and the issue of possible contamination from it is being addressed in a separate on-going RI/FS being conducted at the site.

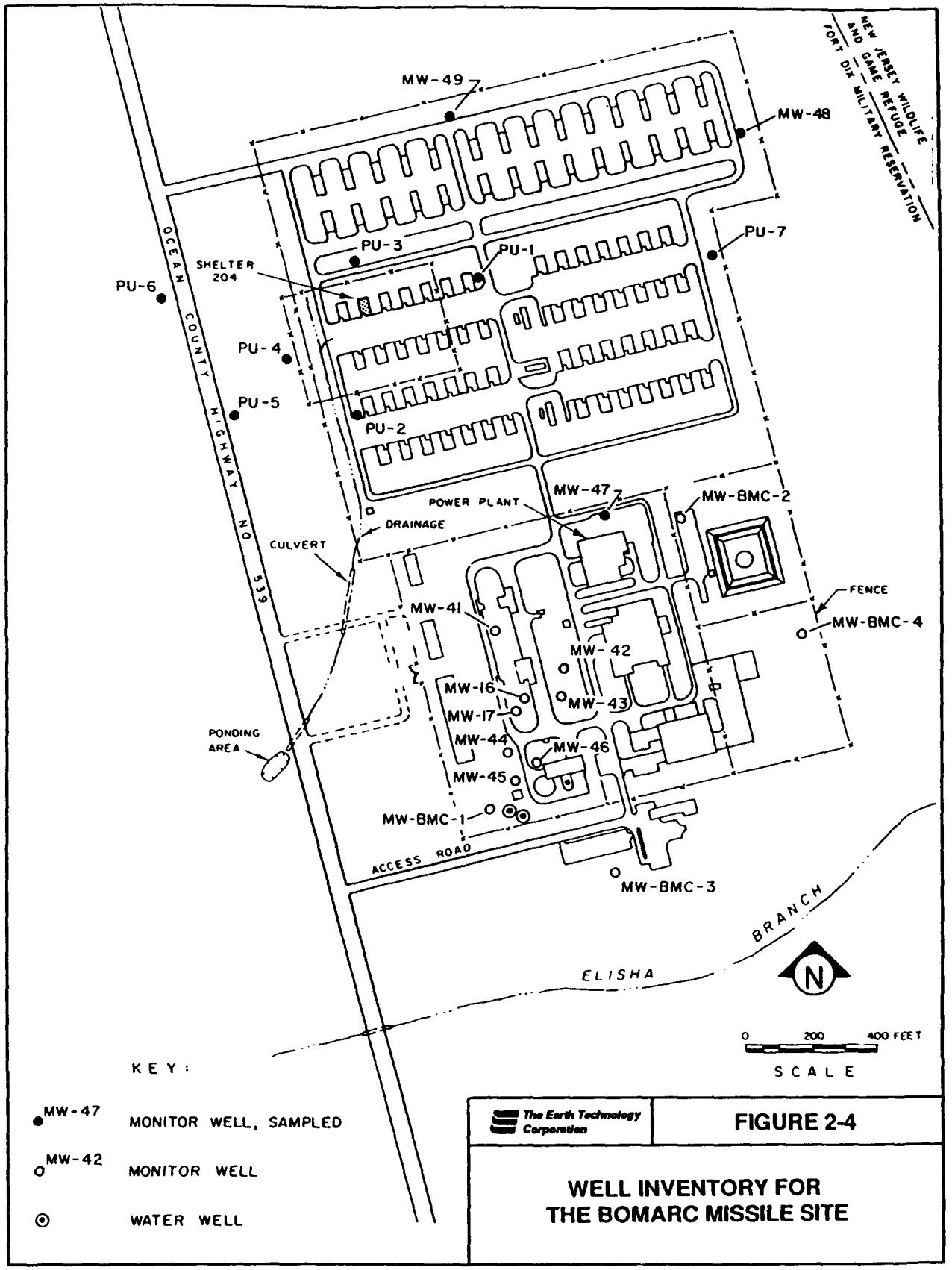
Twenty-two additional monitoring wells were installed on the facility during IRP Phase II efforts in 1983 and 1986-87 (Figure 2-4). Depth and water level information is summarized in Table 2-4.

Private or individually owned wells in the general central New Jersey area are usually screened into the deeper and more dependable aquifers (Potomac/Raritan/Magothy), although local exceptions may occur. Consumptive-use permitting of ground water withdrawals is not required for those installations pumping less than 100,000 gallons per day (gpd). In addition, individuals possessing "grandfather" rights (users diverting ground water resources prior to adoption of

Table 2-4
Well Data for the BOMARC Missile Accident Site
McGuire Air Force Base

Well No.	Date Drilled	Casing (inches)	Total Depth (feet)	Elevations of Tops of Casings* (feet, MSL)	Depth to Water, Feet Below Top of Casing* Most Recent (Mo/Year)	Water Table Elevations in Feet Above MSL (Mo/Year)
1	1957	6	101	148.5**	23***	---
2	1957	6	100	147.5**	22***	---
PU-1	12/15/86	2	67	182.89	54.80 (8/87)	128.09 (8/87)
PU-2	12/12/86	2	57	174.31	45.50 (8/87)	128.81 (8/87)
PU-3	12/10/86	2	62	177.06	48.52 (8/87)	128.54 (8/87)
PU-4	01/16/87	2	62	177.67	48.03 (8/87)	129.64 (8/87)
PU-5	01/20/87	2	52	169.01	40.00 (8/87)	129.01 (8/87)
PU-6	12/17/86	2	54	168.27	39.40 (8/87)	128.87 (8/87)
PU-7	01/12/87	2	37	152.30	24.10 (8/87)	128.20 (8/87)
MW-16	10/20/83	6	36	155.92	26.54 (3/87)	129.38 (3/87)
MW-17	10/19/83	6	29	153.66	24.10 (3/87)	129.56 (3/87)
MW-41	11/25/86	2	42	159.87	30.46 (3/87)	129.41 (3/87)
MW-42	11/26/86	2	37	156.69	27.90 (3/87)	128.79 (3/87)
MW-43	12/05/86	2	42	155.47	26.62 (3/87)	128.85 (3.87)
MW-44	12/18/86	2	37	152.01	22.83 (3/87)	129.18 (3/87)
MW-45	12/19/86	2	37	150.54	21.40 (3/87)	129.14 (3/87)
MW-46	12/22/86	2	35	149.93	20.86 (3/87)	129.07 (3/87)
MW-47	12/23/86	2	54	169.62	40.60 (3/87)	129.02 (3/87)
MW-48	01/09/87	2	34	145.73	18.24 (3/87)	127.49 (3/87)
MW-49	01/14/87	2	52	167.10	38.33 (3/87)	128.77 (3/87)
BMC-1	01/06/87	2	29	144.73	15.47 (3/87)	129.26 (3/87)
BMC-2	01/08/87	2	35	153.74	25.43 (3/87)	128.31 (3/87)
BMC-3	01/05/87	2	26	143.14	14.26 (3/87)	128.88 (3/87)
BMC-4	01/07/87	2	26	140.08	12.14 (3/87)	127.94 (3/87)

* Refers to PVC inner casing.
** Land surface elevations.
*** Feet below ground surface, depth at installation.


NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
MW-49
MW-48
PU-7
PU-3
PU-1
SHELTER 204
PU-6
PU-4
PU-5
PU-2
OCEAN COUNTY HIGHWAY NO 539
POWER PLANT
MW-47
MW-BMC-2
DRAINAGE
CULVERT
FENCE
MW-41
MW-BMC-4
MW-42
MW-16
MW-43
MW-17
PONDING AREA
MW-44
MW-46
MW-45
MW-BMC-1
ACCESS ROAD
MW-BMC-3
BRANCH
ELISHA
N
0 200 400 FEET
SCALE
KEY:
MW-47 MONITOR WELL, SAMPLED
MW-42 MONITOR WELL
WATER WELL
The Earth Technology Corporation
FIGURE 2-4
WELL INVENTORY FOR THE BOMARC MISSILE SITE

legislation and now, by virtue of chronology, exempt from permitting requirements) are not subject to ground water use regulations (Pinelands Commission, 1980). Because of these two situations, it is difficult to determine the number, depth, and location of individually owned domestic and irrigation wells installed near the BOMARC Missile Site.

Detailed information on wells from the New Jersey Department of Environmental Protection (Joseph Malazinsky, personal communication) indicates that there are no known public or private water wells within a one-mile radius.

2.3.2 Surface Water

The BOMARC facility lies within the Atlantic Coastal drainage basin, near the headwaters of the Toms River drainage system (494 km^2, 191 mi^2). There is no surface water flow on the site except during precipitation events. The nearest stream is the Elisha Branch of Toms River, just southeast of the BOMARC facility.

During precipitation events, water falling in the vicinity of the BOMARC Missile Site flows off of the concrete pads and into the asphalted drainage ditch, where flow is directed to the southwest, off of the Base facility. The water passes through ditches and culverts until it flows under Highway 539, where highway maintenance has created a ponding area on the west side of the road. Any surface water entering that ponding area would either evaporate, percolate downward to the water table, or flow in a southerly direction until it reached the drainage of the *Elisha Branch of Toms River.*

2.3.2.1 Occurrence and Flow

All surface drainage trends generally southeast to the Atlantic Ocean. The county is drained by east- and southeast-flowing consequent streams. The BOMARC facility lies just east of the divide that separates the inner coastal plain from the outer coastal plain within the Toms River drainage system.

The Toms River drainage system is the second largest in the Pinelands area. The river has numerous upstream branches, including the Elisha Branch, which is intermittent near the BOMARC Missile Site. The Elisha Branch joins the Success Branch, and progressively larger branches until they all join Toms River, eventually reaching the Atlantic Ocean. The Toms River average long-term discharge rate is 214 CFS, with a discharge/unit area of 1.73 CFSM.

The surface water in this region is derived primarily (85% - 89%) from ground water. Average annual precipitation in the area ranges between 42 and 46 inches, with an average evapotranspiration of 42 percent, yielding about 26 inches of water to infiltrate to ground water or run off through surface pathways. Because the soils are so porous, most of the precipitation enters the aquifer systems. Surface water temperatures in the Pinelands region range from about 1.0° to 23°C, depending on the time of year.

2.3.2.2 Surface Water Quality

Surface water quality information for the BOMARC facility is nonexistent because no streams drain the site. The only natural stream, the Elisha Branch of the Toms River, is south of the site and during storm events flows easterly into (successively) the Success Branch, the Bordens Mill Branch, and the Ridgeway Branch. There are no ponds, lakes, or bogs within the BOMARC facility boundaries, and no streams lie upgradient of the facility.

Surface water chemical compositions are largely controlled by precipitation. Surface waters within the Pinelands are generally acidic (average pH 4.5), tea-colored, and have an average TDS content of 20 ppm. Table 2-5 summarizes the average river water chemical composition.

Table 2-5
Average River Composition in the Pinelands (Means et al., 1981)

Na^+ (ppm)	K^+ (ppm)	Mg^{2+} (ppm)	Ca^{2+} (ppm)	Cl (ppm)	SO_4^{2-} (ppm)	PO_4^{3-} (ppm)	SiO_2 (ppm)
2.58	0.63	0.57	1.05	4.72	6.16	0.037	4.32

2.4 Air Quality

2.4.1 Ambient Quality

Concentrations observed at eight particulate monitor sites in the Pinelands National Reserve from 1973 to 1978 indicate that total suspended particulate levels in the Pinelands are low relative to the secondary standard of 60 micrograms per square meter ($\mu g/m^2$) (Pinelands Commission, 1980). The levels of lead, sulfur dioxide, carbon monoxide, and nitrogen dioxide, are all generally below national air quality standards. Ozone readings at Ancora Psychiatric Hospital in the Pinelands and at McGuire AFB show maximum one-hour concentrations that are well above the national air quality standard of 0.12 ppm. Observed average levels for the 1973-1978 period range from 0.147 to 0.216 ppm.

2.4.2 Pollution Characterization

The concept of local air basins is generally not relevant for air pollution dispersion in the Atlantic Coastal Region. For this reason, the BOMARC facility and surrounding Pinelands cannot be isolated from air pollution generated in the urban areas surrounding them. The Pinelands may be receiving a pollution burden from metropolitan areas to the west (i.e., Philadelphia) when prevailing winds are from the west from the New York metropolitan area when prevailing winds are from the northeast or from the Atlantic City area when sea breezes carry pollution from the southeast.

Air pollution sources may include point sources such as fossil-fuel burning power plants and industrial operations, area sources such as forest fires, unpaved roads, or fuel combustion, and line sources -- primarily traffic on highways.

2.5 Natural Resources

The following sections discuss the natural resources at the BOMARC Missile Site.

2.5.1 Mineral Resources

The only recorded mineral resources of Ocean County include gravel pits, generally mining industrial sand, or construction sand and gravel. However, southern New Jersey was the focus of an iron mining industry during the early 1700s through the mid 1850s. Bog iron (unconsolidated to massive limonite in sands and gravels) mined from the Cohansey Sand and Kirkwood Formation provided the raw material for furnaces and forges. More economical deposits in other parts of the country and the world in general ended that industry. Glauconite is mined from the Navesink, Red Bank, Hornerstown, and Manasquan Formations in other parts of the state for use as a fertilizer.

There are no known, naturally occurring, radioactive mineral ore deposits anywhere in Ocean County or surrounding areas. There are also no known, naturally occurring, radioactive ore deposits in either the Cohansey Sand or the Kirkwood Formation anywhere in New Jersey (Bell, 1983).

2.5.2 Environmental Resources

Water is one of the prime resources of this region, with as much as 17 trillion gallons of good quality water stored in the formations underlying the area. Other primary environmental resources include those contained within the New Jersey Pinelands, such as cranberry bogs and blueberry harvesting.

2.6 Cultural Resources

Cultural resources are defined as those things that may be used or studied to further the understanding of the human species of itself. Cultural resources include areas of archaeological, sociological (human resources), or historical interest.

2.6.1 Archaeology

There is archaeological evidence that the New Jersey Pinelands have been occupied by humans for at least the last 12,000 years (Pinelands Commission, 1980). Three distinct pre-historical cultures have been identified: Paleo-Indians (10,000 - 8,000 BC), Archaic Tradition (8,000 - 1,000 BC), and Woodland Tradition (1,000 BC - AD 1,700). The earliest people were hunter-gatherers, but the subsequent cultures also practiced farming in addition to utilizing the food resources of the rivers and forests.

Approximately 1,146 archaeological sites in the Pinelands region have been identified and mapped (Pinelands Commission, 1980). Archaeological sites usually consist of concentrations of stone flakes, although pottery shards and other artifacts have been discovered. The presently known archaeological sites tend to cluster around the major rivers and their tributaries, but this clustering may reflect a lack of systematic archaeological investigation of the forest upland areas

which are more difficult to access and study. Although there are known archaeological sites approximately 5 miles to the east of the BOMARC Missile Site, it is unknown if the BOMARC area has been specifically studied.

2.6.2 Human Resources

The Pinelands, by its great tracts of open, undeveloped land, has fostered the opportunity for residents to maintain traditional subsistence lifestyles and for visitors to enjoy recreational activities.

Historically, the Pinelands have afforded refuge-seeking ethnic groups a haven from persecution. Ethnic communities were established in the southern forests of the Pinelands, including those of English, Irish, Italian, and Jewish origins in the 18th and 19th centuries, and Russians, Blacks, and various urbanites in the 20th century. Agriculture has been the primary focus of these communities.

The northern forests of the Pinelands, known as the "Pine Barrens", have supported a traditional, rural lifestyle similar to that of the last century. The "Pineys," as the residents are called, have a history of self-sufficiency supported by hunting, fishing, gathering, farming, and berry growing. The maintenance of this life style is dependent on the existence of large, contiguous tracts of open land. The extensiveness of the Pinelands, uniquely located next to major metropolitan areas, provides this environment.

The Pinelands also provide a unique recreational resource to the population of the northeast metropolitan area. Hunting, trapping, and fishing are major recreational pursuits that depend upon the maintenance of the openness of the land. The area is of aesthetic interest as well, and several rivers have been nominated for inclusion in the New Jersey Wild and Scenic Rivers System.

2.6.3 Historical Resources

Historical resources in the Pinelands region include homes, commercial buildings, crossroad communities, etc. of historical interest.

Use of the Pinelands by Europeans began in the early 1700s. The first use of the area was by the woodcutting industry, which harvested lumber, pitch, tar, and turpentine for the shipbuilding industry. From the mid-1700s to the mid-1850s, bog iron ore production sustained a good-sized population in the Pinelands. Remains of that industry include furnaces and forges, small water dams, sites of charcoal production, and related structures. After the bog iron industry collapsed in the 1850s, cotton mills, sawmills, paper mills, glass factories, and brick and tile factories used the original iron industry sites; some of these remain. After the Civil War, commercial cranberry production was a mainstay of the Pinelands population until the mid-1900s. Remains of settlements which were associated with this industry can still be found. Commercial blueberry production was also practiced in the late 1800s and early 1900s. Hunting, gathering, trapping, and fishing in the Pinelands have been important throughout its history, and hunting lodges built during the last 200 years are preserved. Since the 18th century, the Pinelands have

provided a refuge for European immigrants, and artifacts of these ethnic communities are preserved.

Although sites that may have historical significance have been identified near the BOMARC Missile Site, few have been placed on a Federal or State registry of historical sites (Pinelands Commission, 1980).

2.7 Biology and Ecology

The BOMARC Missile Site is located within the Pinelands or the Pine Barrens, and its flora and fauna are typical of the region. The vegetation of the region is primarily coniferous forest, composed largely of pitch pine that is seldom more than 50 feet in height, along with stands of blackjack oak and post oak. It is a region of sand and gravel, with few hard rock outcrops, and a low rolling topography. Soils are well drained (porous) and allow rapid percolation of water from the surface. Streams in the area are slow moving, shallow, tea-colored, acidic, and low in nutrients.

The vascular flora of the area numbers about 800 species (Pinelands Commission, 1980; Means et al., 1981), varieties, and forms and is unique with respect to the many plants that reach northern and southern range limits in this region. Fourteen (14) northern plants reach their extreme southern range limits in the Pine Barrens. These comprise about 1.8 percent of the total flora. At least 109 southern plants reach their extreme northern range limits in the Pine Barrens. These comprise about 13.5 percent of the total flora.

The Pine Barrens' fauna is characterized by generally having few species (about 400 animal species, Means et al., 1981; Pinelands Commission, 1980) with many individuals per species. The fauna is also of interest because few animal species are restricted to the Pine Barrens, but many southern species reach the limits of their northern range here.

The Pine Barrens' herpetofauna comprises 53 species: 10 salamanders (3 are extremely rare), 13 frogs and toads, 9 turtles, 3 lizards, and 18 snakes. The most common herpetofauna representative in upland sites (the BOMARC Missile Site is upland) are the fence lizard, box turtle, and pine snake.

Fish in Pine Barrens' waters are represented by only 24 species. This is largely due to the shallow, warm, slow moving, acid waters of the region and to the fact that all streams originate within the region, with no through-flowing streams crossing the Pine Barrens. Small sunfish, catfish, and pickerel are common.

The Pine Barrens apparently lack the diversity of habitats to support high numbers of bird species, resulting in an avifauna comprised of few species with large numbers of individuals. Upland representatives include grouse, crossbills, pine and prairie warblers, brown thrasher, and titmice.

The most conspicuous mammal is the white-tailed deer. The herbivorous deer have no natural predators in the modern-day Pine Barrens, although large numbers are harvested annually by hunters. The most common carnivores are bats and shrews. Moles and pine and white-footed

mice are common in upland areas. Thirty-four mammal species are present in the Pine Barrens' fauna.

2.7.1 Communities and Habitats

The Pinelands region is broken into uplands and lowlands. The uplands are generally arid because the sandy soils allow rapid percolation of water down to the water table. Fire has played a large part in the shaping of the types of vegetation found in the upland areas because the types that are either fire-resistant (blackjack and post oak) or require fire to complete their life-cycle process (pitch pine) are dominant.

The lowlands are characterized by a ground water table that often intersects the land surface, forming bogs. These bogs are cultivated for cranberries, which form one of the most predominant crops in the region.

2.7.2 Environmentally Sensitive Areas

The Pinelands has been designated as a National Reserve, and as such, is subject to severe restrictions on development and use. No surface water discharge, hazardous waste, or degradation is allowed within its bounds. A Comprehensive Management Plan has been established to define and regulate Pinelands uses (Pinelands Commission, 1980).

2.7.3 Endangered Species

Two species on the national list of endangered and threatened species, the bald eagle and the peregrine falcon, are found in the Pinelands. The Pine Barrens treefrog, already on the endangered list for Florida, is under consideration for the Pinelands area. The New Jersey state list of endangered, threatened, or otherwise jeopardized species includes the bald eagle, peregrine falcon, and osprey.

Numerous habitats and other natural features within the Pinelands have been designated as threatened, endangered, or jeopardized (Pinelands Commission, 1980).

2.7.4 Economic Species

Cranberries are grown in the bogs found in the Pineland lowlands.

2.8 Climatology/Meteorology

The following sections discuss climatology/meteorology at the BOMARC Missile Site.

2.8.1 Precipitation (Seasonal Variation)

McGuire AFB meteorological records (Table 2-6) for the period 1948 through 1981 (33 years) indicate that the mean annual total precipitation is 43.5 inches. Mean annual maxima and minima over this same period were 62.8 inches and 27.2 inches, respectively. The 24-hour maximum precipitation event was 9.61 inches in the month of August. Mean annual

Table 2-6
McGuire Air Force Base Climatic Conditions

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
TEMPERATURE													
Average Maximum	40	42	49	62	71	80	84	83	76	66	54	43	63
Average Minimum	24	26	32	41	51	60	66	64	57	47	37	28	44
Days ≥ 80°F	0	0	--	2	6	17	25	22	11	2	--	0	85
Days ≤ 32°F	25	22	16	4	--	0	0	0	0	1	10	22	100
Record Maximum	7	74	85	93	94	97	102	100	100	88	82	75	102
Record Minimum	-4	-4	8	19	31	42	50	42	35	24	15	0	-4
PRECIPITATION (All Forms)													
Average Inches	3.0	3.0	3.9	3.5	3.2	3.3	4.2	5.0	3.6	3.3	3.4	4.1	43.5
Greatest Inches	9.19	5.73	6.02	6.54	6.50	8.34	10.2	15.0	8.58	7.22	8.83	12.4	62.8
Least Inches	.31	.72	1.14	1.17	.23	.05	.71	.78	.82	.08	.24	.16	27.2
24-Hour Maximum	2.23	2.41	2.29	2.59	2.91	4.06	4.15	9.61	3.76	3.32	3.40	6.74	9.61
PRECIPITATION (As Snow)													
No. Days Precipitation	11	10	11	11	11	10	9	9	8	7	10	10	117
No. Days Snow	3	4	3	--	0	0	0	0	0	--	--	2	12
Average Inches	6.2	5.2	4.7	.5	T	0	0	0	0	T	.75	3.8	21.7
24-Hour Maximum	14.5	18.1	20.1	5.8	7	0	0	0	0	7	8.6	7.1	20.1

T = Trace
Source: Detachment 10, 15th Weather Squadron, McGuire AFB.
Period of Record: 1948-1981

precipitation as snow is 21.7 inches for the 33-year period of record. Mean monthly total precipitation ranges from 3.0 inches in January and February to 5.0 inches in August. Precipitation, in some form, occurs on the average about 117 days each year.

2.8.2 Temperature (Seasonal Variation)

Temperature maxima and minima (annual average) for the 33-year period of record (Table 2-6) are 63°F and 44°F, with July being the hottest month (average 66° to 84°F) and January the coolest (average 24° to 40°F). The average number of frost-free days per year is about 265.

The first killing frost in this area usually arrives at the end of October, and the last killing frost typically occurs during the last week of April. The area has a generally moderate climate.

2.8.3 Wind

Prevailing winds are generally from the northeast. Typical storm paths in the summer derive from the west or west-northwest. In the winter, storms generally come from the southwest. Although the storm paths usually derive from westerly directions, the coastal winds are strong enough to create a general prevailing wind for the region from the east or northeast.

2.8.4 Evapotranspiration (Seasonal Variation)

Average annual precipitation in the area ranges between 42 and 46 inches. Average evapotranspiration for the Pinelands is about 42 percent. This means that about 19 inches of precipitation is lost to evaporation and transpiration (that water taken into the roots of plants and eventually transpired to the atmosphere), leaving about 26 inches to infiltrate to ground water or run off through surface pathways.

In general, from May to October, evapotranspiration is high, while from November to April there is very little evapotranspiration. Ground water recharge occurs primarily between November and April, when precipitation percolates downward to the aquifer rather than being evaporated or transpired.

3.0 FIELD INVESTIGATION PROGRAM

3.1 Organization and Development of the Field Program

The following sections discuss the organization and development of the BOMARC Missile Site field program. The Stage 2 investigation of the BOMARC Missile Site included a RI, baseline risk assessment, and FS, the results of which are contained in this document.

The RI, baseline risk assessment, and FS contained in this document are used collectively to determine the extent of radioactive contamination at the site, resulting risks to human health and the environment, and the need for and extent of remedial actions. The organization of each element is discussed in the following sections.

3.1.1 Remedial Investigation

The remedial investigation of the BOMARC Missile Site was conducted in order to determine the distribution and magnitude of plutonium and americium contamination in site soils, surface water, ground water, air and structural materials. This was done through a combination of background research on site characteristics and history, and sampling/analysis of soil, surface water, ground water, air and structural materials onsite.

General information on the Air Force IRP program, site history, site description including contaminants of concern, and identification of the field team can be found in Chapter 1 of this report.

Chapter 2 contains information on the site environmental setting, including site geography, geology, hydrogeology, surface water, air quality, natural resources, cultural resources, biology/ecology, and climatology/meteorology.

Chapter 3 give specific details on the field investigation program, including organization, data quality objectives, summary of field work performed, investigation methods, drilling and borehole program, sampling program for air, water, soil, structures, and sediment, and laboratory program.

Chapter 4 gives results and significance of findings including analytical data and extent of contamination in all media sampled. Chapter 4 also presents the baseline risk assessment, which is discussed in detail below.

3.1.2 Baseline Risk Assessment

A baseline risk assessment (Baseline Radiological Hazard Assessment) was performed for the BOMARC site to evaluate the potential threat to human health and the environment in the absence of any remedial action. The baseline risk assessment is used to quantify risks to human health and the environment in the absence of remediation, and to determine the need for remediation.

The risk assessment process can be divided into four components:

1. Contaminant Identification - Contaminant identification screens the information that is available on hazardous substances or wastes present at the site and identifies contaminants of concern in order to focus subsequent efforts in the risk assessment process.

2. Exposure Assessment - An exposure assessment identifies actual or potential exposure pathways, characterizes the potentially exposed populations, and determines the extent of the exposure.

3. Toxicity Assessment - Toxicity assessment considers: (1) the types of adverse health or environmental effects associated with individual and multiple chemical exposures; (2) the relationship between magnitude of exposures and adverse effects; and (3) related uncertainties such as the weight of evidence for a chemical's potential carcinogenicity in humans.

4. Risk Characterization - In the final component of the risk assessment process, a characterization of the potential risks of adverse health or environmental effects for each of the exposure scenarios derived in the exposure assessment is developed and summarized. Estimates of risks are obtained by integrating information developed during the exposure and toxicity assessments to characterize the potential or actual risk, including carcinogenic risks, noncarcinogenic risks, and environmental risks.

The results of the Baseline Risk Assessment are presented in Section 4.1.5.3 of this report.

3.1.3 Feasibility Study (FS)

An FS was performed for the BOMARC Missile Site in order to identify appropriate remedial technologies and response actions for the site. The FS is presented in Section 5.0 of this report.

Remedial technologies and alternatives are identified and developed, screened, and analyzed using a three-stage sequential process. The three stages of this process correspond to sections 5.1, 5.2 and 5.3 of this report, which are described below.

In Section 5.1, remedial response actions and technologies appropriate for source control of the contaminated soils and structures are developed. Remedial action objectives are presented, and waste types and volumes are given. Remedial technologies and available process options are identified, and those technologies that are technically infeasible due to waste types or site conditions are eliminated from further consideration. Remaining technologies are then assembled into remedial alternatives.

In Section 5.2, remedial alternatives are reviewed according to their public health/environmental impacts, technical feasibility, and cost. Six remedial alternatives are considered in Section 5.2. These alternatives include an unrestricted access alternative, an existing conditions alternative, a limited action alternative, an onsite containment alternative, an onsite treatment alternative, and an offsite disposal alternative. Section 5.2 outlines the screening of the remedial alternatives and summarizes the rationale for retaining or eliminating alternatives.

In Section 5.3, alternatives remaining after development and screening are evaluated in detail. Several different criteria are used to evaluate the alternatives, both individually and in contrast with one another.

3.2 Data Quality Objectives

DQOs are an integral part of the thought and planning processes of each phase of a given RI/FS. The intent of DQO's is to specify levels of precision, accuracy, representativeness, comparability and completeness (PARCC) required in measurements and analyses in successive stages of the RI/FS. Site characterization studies, for example, typically begin with low-precision measurements such as geophysical or soil gas surveys to locate areas of contamination, and proceed to more precise and accurate chemical analyses to identify and quantify contaminants.

DQOs are the result of the data collection planning and decision-making process and, as such, are incorporated into the sampling and analysis plan, the quality assurance project plan, and, in general, the work plan.

The development of DQOs for the BOMARC project were designed to ensure that the level and extent of sampling and analysis conducted during the field effort were consistent with the data requirements needed to produce: (1) a baseline risk assessment and (2) an adequate evaluation of remedial alternatives in the FS.

The logical process of selecting and implementing DQOs occurs in three stages (Figure 3-1). Completion of the three stages of the DQO process results in an orderly, logical progression from the identification of the types of decisions to be made throughout the RI/FS, to selection of data uses and needs, to the design of a comprehensive data collection program. The DQOs for this RI/FS are documented in the project Work Plan and Quality Assurance Plan.

3.3 Implementation of the Field Program and Summary of Field Work Performed

The following sections give details on the time sequence of work performed and the identification and role of subcontractors.

3.3.1 Time Sequence of Work Performed

The field program for the stage 2 investigation of the BOMARC Missile Site involved field screening and sampling and analysis of soils, sediments, surface water, ground water, air, and structural materials. Notice to proceed was given in January 1989. Field work began in June 1989, and was largely completed by the end of November 1989. Sporadic work involving surveying of data points and removal of investigation-derived wastes continued through January, 1991.

3.3.2 Identification and Role of Subcontractors

The Earth Technology Corporation was the prime contractor for this effort. Several subcontractors were also used. The main subcontractor used was Battelle Memorial Institute (Golden, Colorado Remediation Division). During the course of the program, and prior to

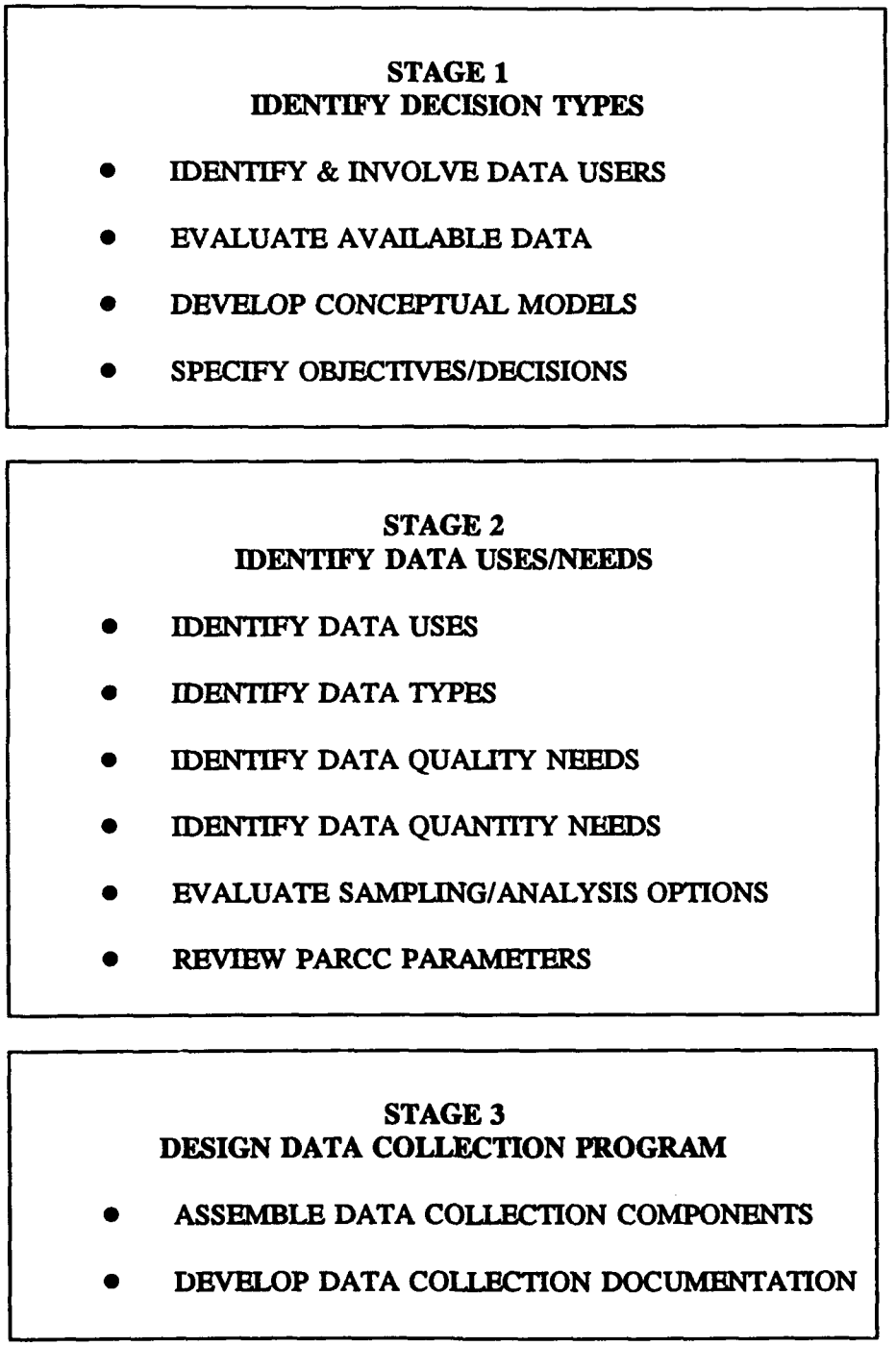


Figure 3-1 The Stages Involved in Selecting and Implementing Data Quality Objectives (EPA, 1987)

initiation of field work, the Golden Remediation Division of Battelle was acquired by Science Applications International Corporation (SAIC), which took over the subcontract. SAIC was responsible for conducting most of the field sampling program, with the exception of the geophysical investigation, soil boring program, site preparation, and surveying of sample locations.

SAIC arranged for, procured, and exercised quality assurance/quality control on all field and laboratory radioanalyses, and prepared those sections of the RI report dealing primarily with field sampling and analysis. SAIC also provided a certified health physicist for site health and safety oversight, and prepared the baseline risk assessment.

Drilling and construction services were provided by another subcontractor, John Mathes and Associates (JMA) of Winsor, New Jersey. JMA installed 26 shallow soil borings, constructed a containment structure for Shelter 204, and constructed roughly 2,500 linear feet of chain-link fence around the site.

Surveying services were provided by Robert D. Gilmore and Associates (RDGA) of New Britain, Pennsylvania. RDGA surveyed all soil boring, concrete coring and geophysical anomaly locations, as stipulated in the project scope of work, and placed concrete monuments at the locations of geophysical anomalies.

3.4 Investigation Methods and Surveys Conducted

The following sections discuss the investigation methods and surveys conducted at the BOMARC Missile Site.

3.4.1 Geophysical Investigation

Two geophysical techniques, magnetic and ground penetrating radar (GPR) profiling, were used to search for a missile launcher and containerized wastes which were thought to have possibly been buried onsite. Magnetic surveying was the most appropriate method for locating the launcher and drums because their prominent physical property is magnetic susceptibility. The increased susceptibility of the ferrous metal relative to the surrounding soils causes localized perturbations (anomalies) in the earth's magnetic field. GPR profiling is also an appropriate method for finding these objects because the metal forms a large dielectric contrast relative to the soil.

Surveys were completed at four areas; three are north to northeast of Shelter 204 and one is just south of the site perimeter at a suspected dump site. The four areas surveyed were selected based on a records search and available access for launcher burial at the time of the accident. Most interior areas are underlain by extensive utility corridors, and are not considered likely disposal areas. The surveys located several anomalies representing buried ferrous objects (possibly the missile launcher and drums).

3.4.1.2 Survey Grid Design and Layout

The survey grid was established at each of the four sites by constructing north-south baselines. Each baseline was marked at ten-foot intervals with either pin flags or spray paint. Data profiles were established by stretching a rope (marked at ten foot intervals), perpendicular to and between the baselines. Measurements were made at each mark (data station) along the rope. The rope was then moved to the next baseline mark and another data profile measured. The data grid and locations of cultural features are shown on the site base maps (Plates 3-1, 3-2, 3-3, and 3-4 for Sites 1,2,3,4, respectively).

At Site 1, (suspected dump site south of the base perimeter fence) three baselines were constructed. One was located approximately 10 feet east of the drainage pipe exposed at the site. The other two were located 130 feet and 280 feet, respectively, west of the first. The original grid was a 120 × 280 feet rectangle with the origin in the northwest corner. Profiles were numbered from 1001 at the origin, increasing southward to 1013. The stations were numbered from 101 at the origin, increasing eastward to station 129. The final survey grid was irregularly shaped because new stations were added to the south and east to better define magnetic anomalies measured in those areas.

At Site 2, (directly north of Shelter 204) four baselines were constructed. One was located approximately 15 feet east of the western most road on the base. The other three were constructed 220 feet, 440 feet, and 520 feet, respectively, east of the first. The final grid was a 180 × 520 feet rectangle with the origin located at the northwest corner. Profiles were numbered from 1001 at the origin, increasing southward to profile 1019 which is approximately 6 feet north of the shelters. The stations were numbered from 101 at the origin, increasing eastward to station 153.

At Site 3, (along the base eastern fence) three baselines were constructed. One was located along the asphalt/grass boundary on the site's west edge. The other two were located 80 feet and 140 feet, respectively, east of t[illegible]. The original grid was a 140 × 140 feet square excluding a 50 × 60 feet area in the southeast where the grid was truncated by the perimeter fence. The origin was located at the northwest corner of the site. Profiles were numbered from 1001 at the origin, increasing southward to profile 1015. The stations were numbered from 101 at the origin, increasing eastward to station 115. The final grid was a 140 × 160 feet rectangle because two profiles were added to the north to better define magnetic anomalies measured in that area.

At Site four, (north of the shelters) four baselines were constructed. One was located along the asphalt/grass boundary on the site's west edge. The other three were located 220 feet, 440 feet, and 660 feet, respectively, east of the first. The original grid was a 190 × 660 feet rectangle with the origin located in the southwest corner. Profiles were numbered from 1001 at the origin, increasing northward to profile 1020.

The stations were numbered from 101 at the origin, increasing eastward to station 167. The final grid was irregularly shaped because new stations were added to the north and west to better define magnetic anomalies measured at the northwest corner of the original grid.

The base maps show how cultural features within each study area relate to the data grid. Locations and descriptions of these features are used to interpret anomalies most likely to be caused by surface features. Also, areas of interest, as defined on the data contour maps, can be relocated in the field relative to the cultural features. The base maps also identify the location of the base station used for magnetic diurnal corrections. The base station at each site was remote from any cultural features that could have disturbed the base readings.

3.1.4.3 Magnetic Survey

The magnetic survey's objective was to search for suspected buried ferrous objects including a missile launcher and drums which might contain contaminants. A magnetometer measures the earth's magnetic field, which can be locally perturbed by the induced and remanent magnetization of ferrous objects. An object's induced magnetism depends on the strength of the earth's magnetic field and the concentration of magnetic compounds in the object. Remanence depends on the thermal, mechanical, and magnetic history of the material. Remanence is extremely variable, difficult to measure, and usually ignored when interpreting magnetic data (Breiner, 1973). Therefore, the strength of the perturbation (anomaly) caused by induced magnetization only is dependent on the ferrous object's weight and the distance between the object and the magnetometer.

Approximate launcher dimensions were measured at an open shelter north of Site 4. The launcher consisted of two massive steel components; a base plate (8×8 feet, 0.25 inches thick) and missile support (30×2×2.5 feet). The combined weight is estimated at two to three tons. Therefore, the launcher should produce a large amplitude, high-valued anomaly because of its large weight. The high-valued anomaly should have a corresponding low-valued envelope around it because the launcher is relatively thin and would resemble a magnetic dipole. The launcher would be located along the steepest gradient between the high/low-valued pair. The anomaly should be elongated about 30 feet along the launcher axis, if intact. However, the intense heat of the fire may have deformed the launcher. In contrast, a small cache of drums should produce a relatively small amplitude, high-valued anomaly because the weight of ferrous material is low. This anomaly would also be a high/low pair, but circular shaped.

Magnetic measurements were made at the grid stations with an EDA model OMNI IV, proton precession magnetometer/radiometer (S/N C088). It stores the total field and gradient data, profile/station numbers, and the time/date in solid-state memory. The instrument has a sensitivity of + - 1 gamma. Measurements were made with the sensor 5.7 feet above the ground at Sites 1,2,3 to reduce the amplitude of magnetic anomalies created by small metal objects on the surface. At Site 4, the sensor height was increased to 7.7 feet to further reduce the effect from surface sources. Both the earth's total field and the vertical gradient of the field were measured during the magnetic survey. Total field anomalies are used to estimate the

object's location, size, depth, and weight. The vertical gradient is used to resolve complex or overlapping anomalies and to enhance the identification of shallow targets (Breiner, 1973).

The data were electronically transferred to a portable computer for processing and display. Processing the total field data consisted of two steps. First, the drift rate within a base loop was determined from the successive base readings. A drift correction for each measurement within a loop was calculated by linear interpolation of the drift rate versus time. The average drift rate during this survey was 6 gammas per hour, which is relatively low. Second, an arbitrary constant value, 54,000 gammas was subtracted from all the drift-corrected readings to reduce the values from five to three digits. The gradient data do not require adjustment.

The magnetic data sets were gridded, using a minimum curvature program, and contoured. The total field and vertical gradient contour maps are shown in Plates 3-5 and 3-6 for Site 1, Plates 3-7 and 3-8 for Site 2, Plates 3-9 and 3-10 for Site 3, and Plates 3-11 and 3-12 for Site 4. All contour maps have the same scale and contour interval for direct comparison between sites. Anomalies were highlighted on the contour maps and the anomalies interpreted as being cultural features were labelled and removed from consideration. Anomalies supported by only one measurement point were also ignored. A large contour interval was required to make a legible display of the wide ranges of values at each site. Anomalies from small objects (on the order of a few 55 gallon drums) can not be resolved with contour intervals this large. The locations and characteristics of buried objects were estimated from the total field maps. The gradient maps were used to resolve overlapping anomalies into individual components.

3.4.1.4 Ground Penetrating Radar Survey

The GPR survey's objective was to help identify buried objects interpreted from the magnetic data. The GPR method can detect changes in dielectric properties of subsurface materials caused by buried metal objects and changes in soil types or ground water levels. The launcher should produce a distinct image on the GPR records with many reverberations appearing in later time because of the large cross sectional area and the large dielectric value of steel. The image should be repeated on several adjacent profiles because the launcher is about 30 feet long. In contrast, a small cache of drums should produce an image with at most a few reverberations because of the relatively small cross section and should appear as almost a point source.

Data were taken with a Geophysical Survey Systems, Inc., model SIR System 3 ground penetrating radar (S/N 128). The system consisted of a model PR-8304 Profiling Recorder with a model 3110 antenna (120 MHz). The system radiates repetitive, short-time duration (a few nanoseconds) electromagnetic pulses into the earth from a broad bandwidth antenna placed on the ground surface. The pulses are partially reflected back to the antenna by dielectric discontinuities in the subsurface. Continuous data are generated by towing the antenna along a profile and displaying the reflected signals on a graphic recorder. The 120 MHz antenna was used for this survey because maximum penetration depth was desired. (Higher frequencies provide higher resolution, but sacrifice penetration). The depth of penetration at the four

BOMARC sites is estimated at six to eight feet. The penetration was limited by moist surface conditions from recent rains.

The GPR data were collected over 19 magnetic anomalies. Data were recorded in two directions (usually north-south and east-west) along a grid covering each anomaly. As the antenna center passed by the station marks, a fiducial mark was electronically placed on the record. These marks were labelled with profile and station numbers and formed the basis for posting the locations of interpreted radar targets on the maps. The GPR data are shown in a real-time, graphic format that does not require any drift or other corrections. Figure 3-2 shows a data record at a location where subsurface conditions are relatively uniform (no anomaly). The horizontal axis shows distance along profile. The vertical axis shows round trip, pulse travel time from antenna to discontinuity and back to antenna. This axis is converted to depth by assuming 5 nanoseconds roughly equals 1 foot in depth. Figure 3-3 shows an anomaly (about 3 feet wide) recorded over a suspected pipe, as evidenced by the magnetic data, which runs east-west across Site 2. The record shows that GPR could detect buried metal objects at this site. Using the above conversion, interpreted depth to the pipe is approximately 3 to 4 feet, which is common for utilities. Figures 3-4 and 3-5 show interpreted buried metal objects (about 20 feet wide) thought to have caused the observed magnetic anomalies.

Anomalies were highlighted on the records, and those caused by known cultural features were labelled and removed from consideration. The GPR profiles and interpreted buried targets are shown in Plates 3-1, 3-2, 3-3, and 3-4 for Sites 1,2,3,4, respectively.

3.4.1.5 Results

The geophysical surveys covered over 300,000 square feet and identified 19 areas with magnetic anomalies that are not associated with obvious cultural features. These anomalies are highlighted and numbered on the total field contour maps and briefly discussed below. There are five anomalies (combined area totalling about 4% of study area) that could be caused by the buried missile launcher. The locations of these anomalies and the boundaries of the study areas are shown on Figure 3-6. These anomalies were ranked by considering the magnetic anomaly size and shape, GPR results, and surrounding cultural features that may have influenced the measurements. The most probable launcher locations are:

Site 1 Anomaly 2 (most probable)
Site 4 Anomaly 1
Site 4 Anomaly 2
Site 1 Anomaly 4
Site 1 Anomaly 1

The other 14 anomalies may represent containerized wastes, unmarked utilities, construction debris, or other ferrous objects. Table 3-1 lists the characteristics of the interpreted object producing the measured anomalies.

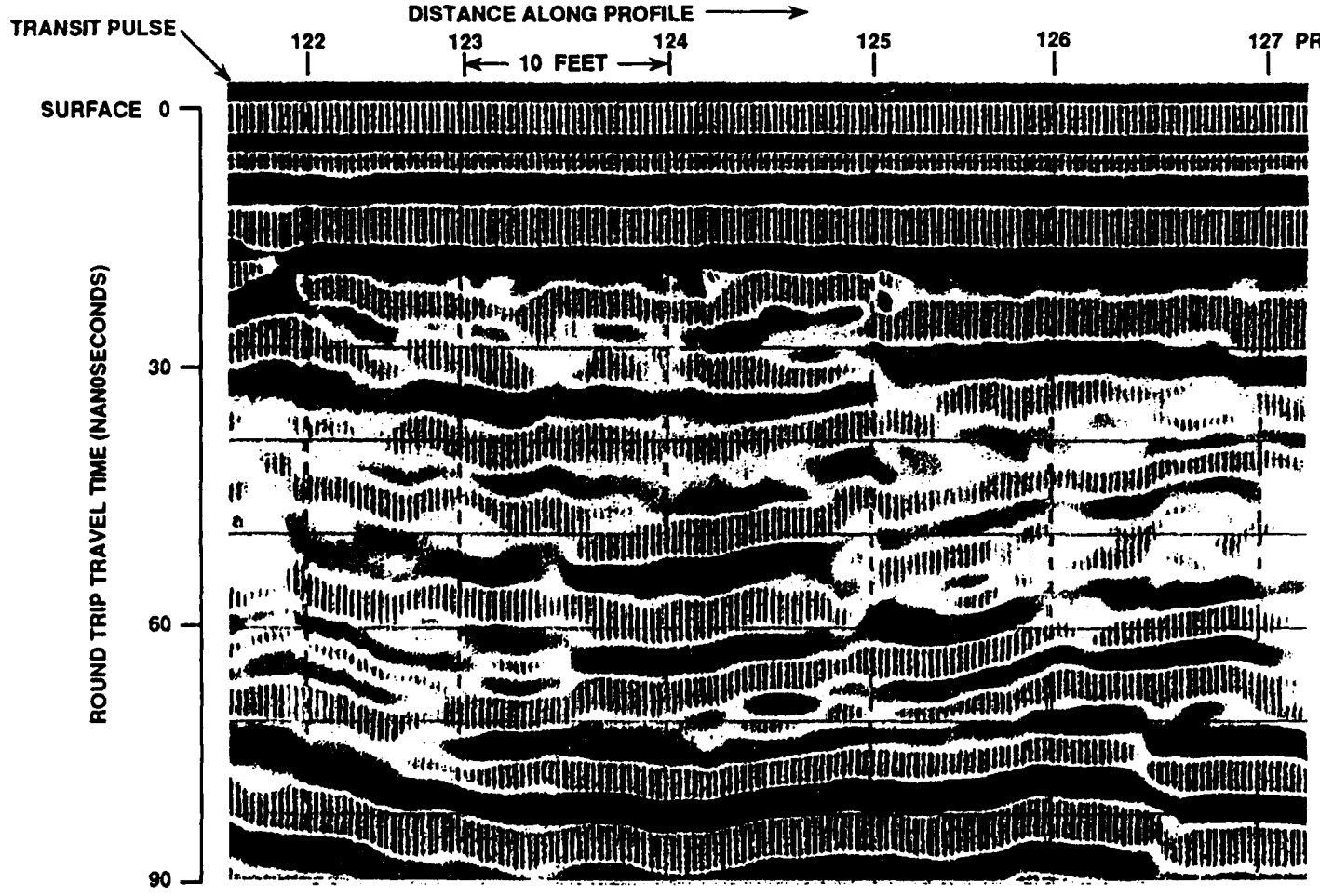


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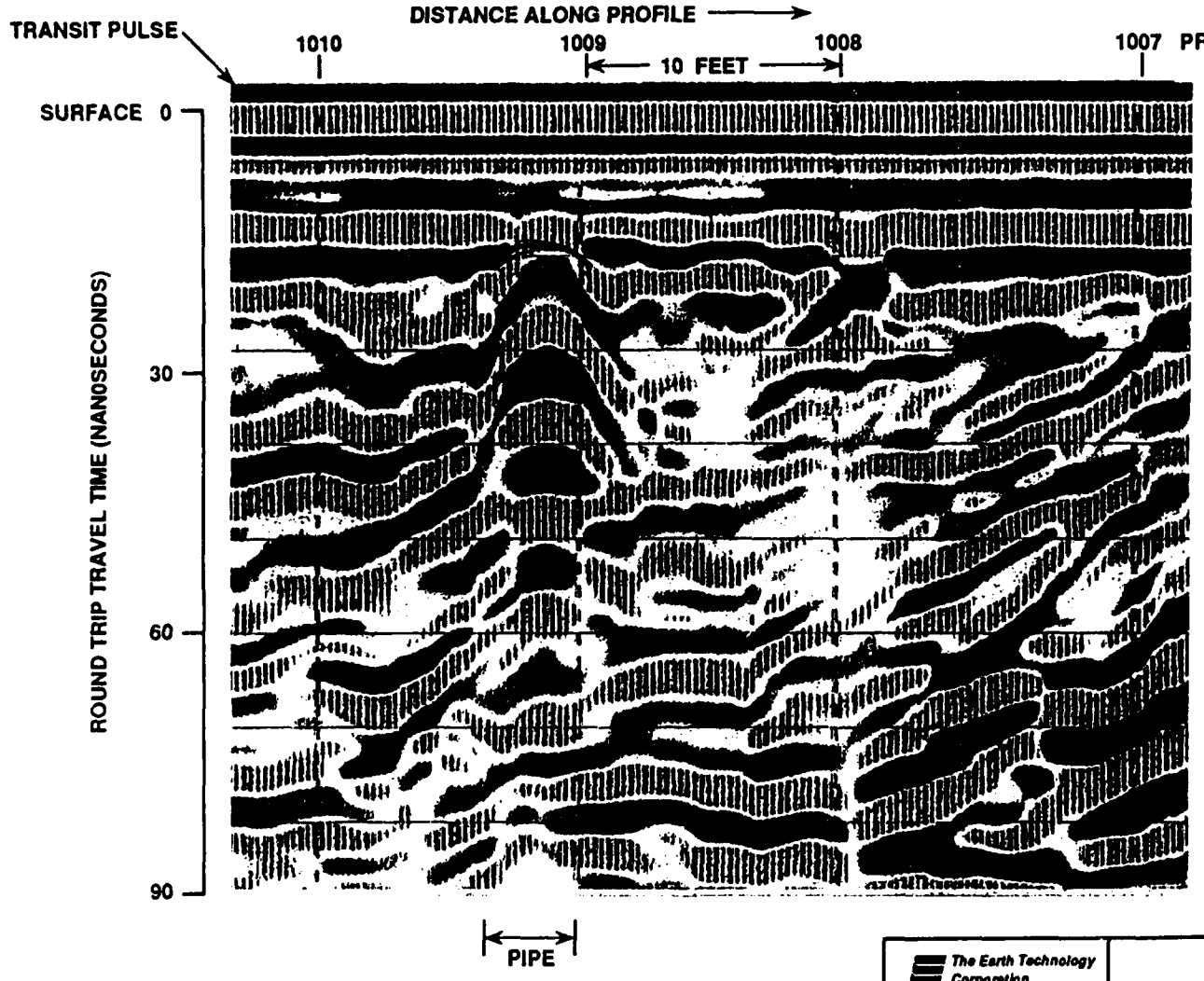
FIGURE 3-2

THE BOMARC MISSILE SITE
GPR PROFILE RECORD
SHOWING NO ANOMALY

NOTE: RECORD MADE WITH GSSI SIR 3 SYSTEM, MAGNETIC ANOMALY 5, SITE 2 ALONG PROFILE 1008, STATIONS 122 TO 127.



The Earth Technology Corporation

FIGURE 3-3

THE BOMARC MISSILE SITE GPR PROFILE RECORD SHOWING METAL PIPE

NOTE: RECORD MADE WITH GSSI SIR 3 SYSTEM, MAGNETIC ANOMALY 5, SITE 2 ALONG STATION 127, PROFILES 1010 TO 1007.

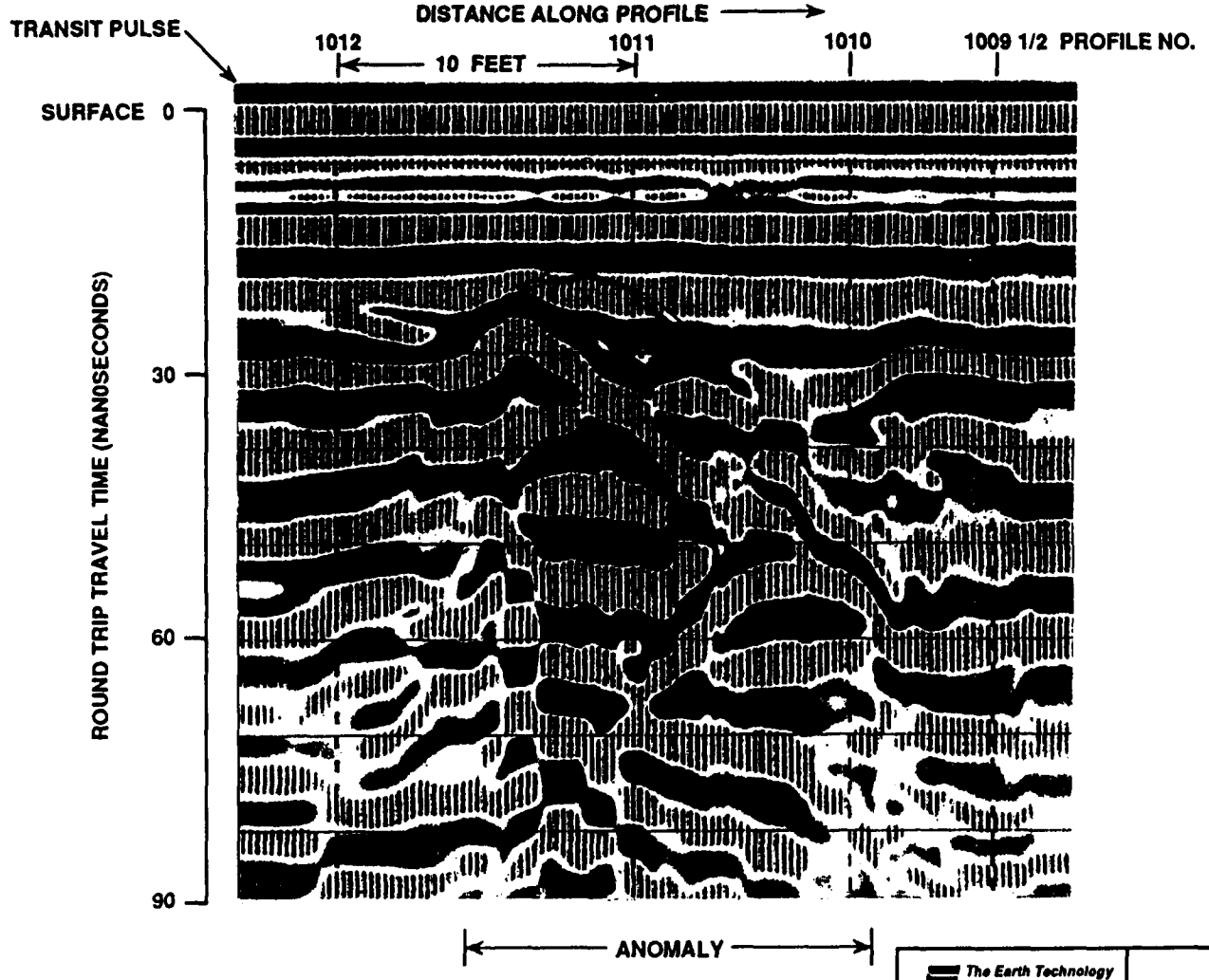


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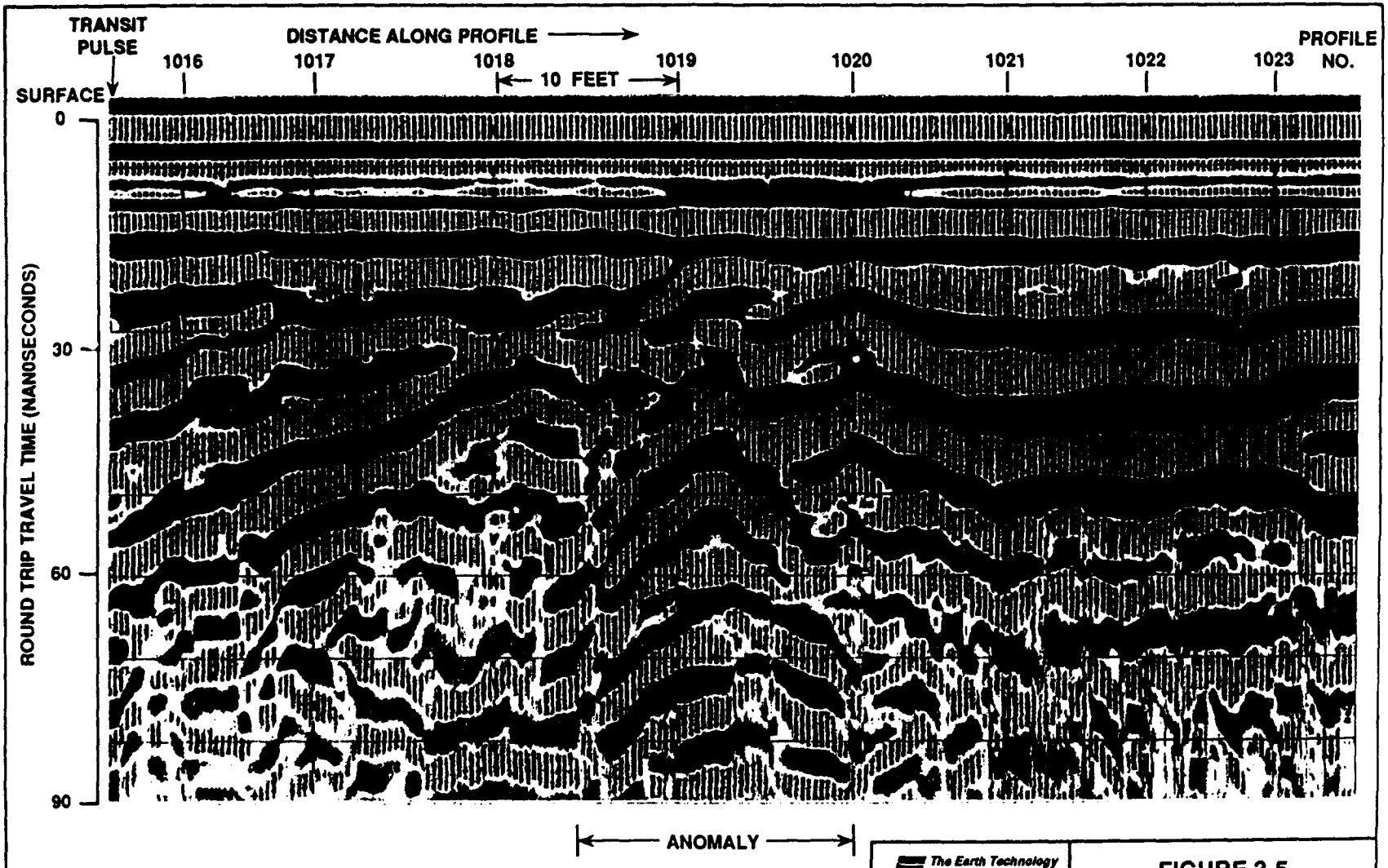
FIGURE 3-4

THE BOMARC MISSILE SITE
GPR PROFILE RECORD
SHOWING METAL ANOMALY

NOTE: RECORD MADE WITH GSSI SIR 3 SYSTEM, MAGNETIC ANOMALY 4, SITE 1 ALONG STATION 126, PROFILES 1009 1/2 TO 1012.

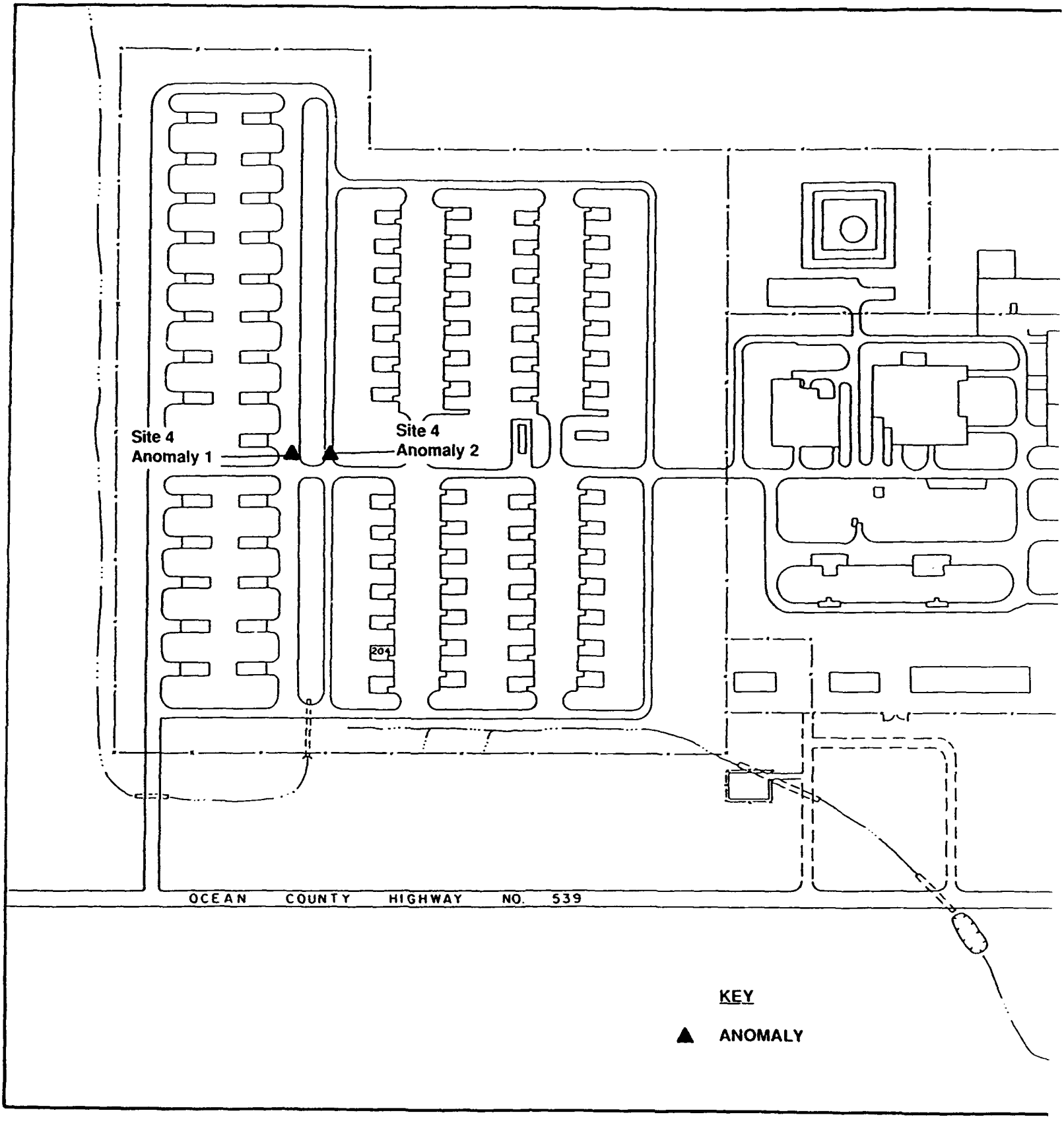


The Earth Technology Corporation

FIGURE 3-5

THE BOMARC MISSILE SITE
GPR PROFILE RECORD
SHOWING METAL ANOMALY

NOTE: RECORD MADE WITH GSSI SIR 3 SYSTEM, MAGNETIC ANOMALY 1, SITE 4 ALONG STATION 105, PROFILES 1016 TO 1023.


Site 4
Anomaly 1
Site 4
Anomaly 2
OCEAN COUNTY HIGHWAY NO. 539
KEY
ANOMALY

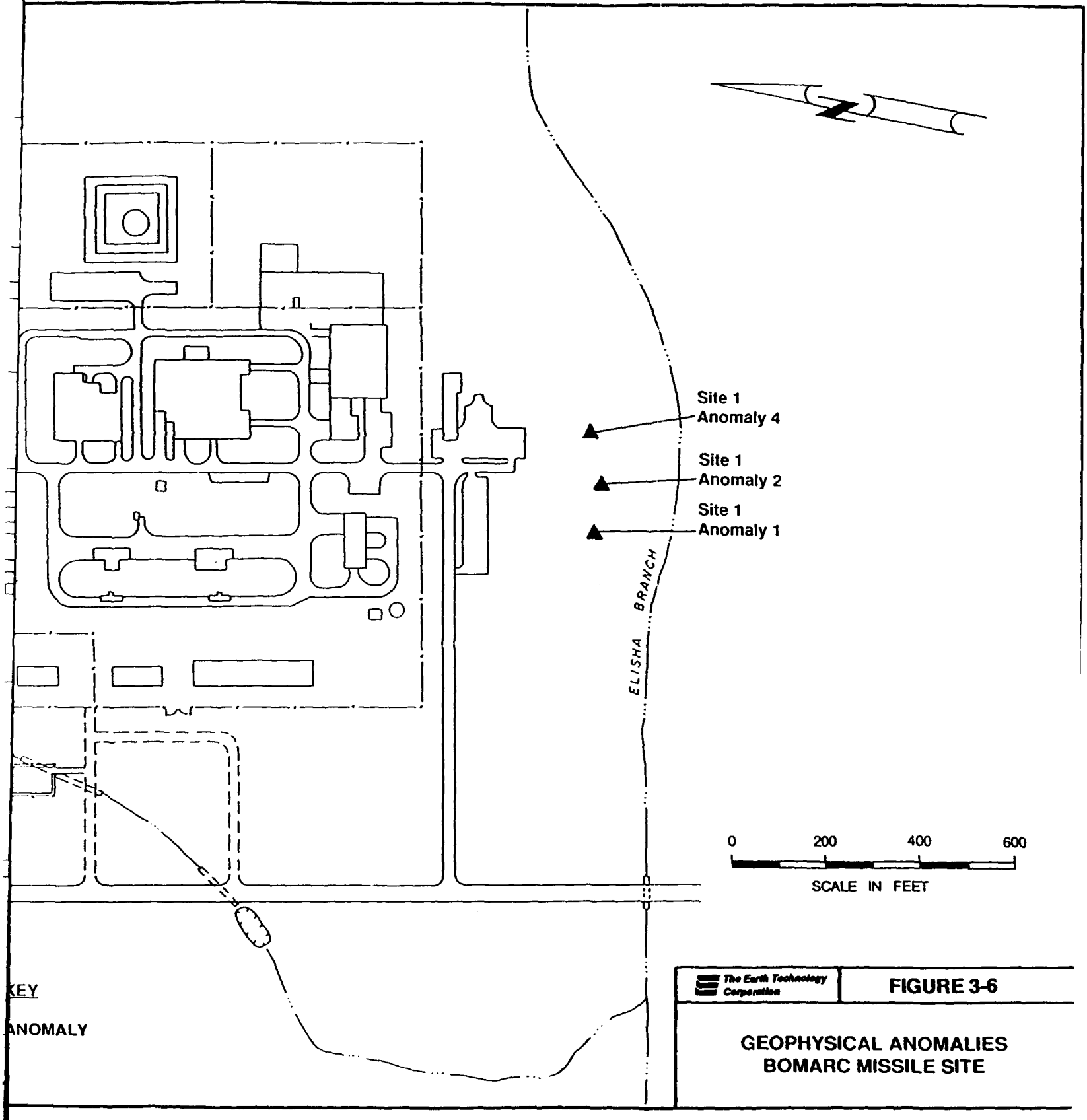


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FIGURE 3-6

GEOPHYSICAL ANOMALIES
BOMARC MISSILE SITE

Table 3-1
Description of Interpreted Subsurface Objects

Anomaly Identification	Magnetic Results: Anomaly Dimension (ft.)	Magnetic Results: Estimated Object Depth (ft)	Magnetic Results: Estimated Object Weight (lb)	GPR Results: Object Type	Cultural Description	Comments
Site 1						
#1	31NEx34NW	<5	1000-1500	Metal	None	Launcher?
#2	36Nx43E	5	>2000	No Data	None	Launcher?
#3	22Nx25E	1	<100	-	Tie Downs	Small
#4	32Nx40E	1	1000-1500	Metal	Pipe	Launcher?
#5	22Nx24E	<5	100-500	-	Iron Bar	Small
Site 2						
#1	31Nx66E	<5	1000-1500	-	Fence	Large
#2	30Nx20E	<5	1000-1500	Metal	Well	Heavy
#3	21Nx31E	1	100-500	Metal	None	Small
#4	26Nx50E	1	>2000	Metal	Fence	Large
#5	27Nx37E	5	500-1000	Metal	None	Small
Site 3						
#1	28Nx27E	5-10	1000-1500	Metal	None	Small
#2	29Nx23E	<5	1000-1500	-	Planter	Small
Site 4						
#1	53Nx60E	5-10	>6000	Metal	None	Launcher?
#2	76Nx50E	1	-	No Data	Manhole	Launcher?
#3	49NEx40NW	5-10	500-1000	No Data	None	Large
#4	45NEx37NW	1	500-1000	No Data	Steel	Large
#5	25Nx32E	-	-	No Data	None	Small
#6	31Nx37E	-	-	No Data	None	Small
#7	24NEx73NW	<5	100-500	No Data	None	Small

Maximum target depth calculated by the half width method (Breiner, 1973).

Site 1 Historical record search indicated this area may have been a dump site. The magnetic field at the site center is relatively featureless. Several cultural features (exposed pipe, manhole cover, and scrap metal pile) produce large amplitude anomalies. The remaining anomalies are high-valued, high/low pairs.

Anomaly 1 is large amplitude, elongated about 20 feet northwest and may be caused by more than one source. The anomaly's amplitude and dimensions are large enough to be caused by the launcher. GPR shows a metal target about 10 feet long and disturbed soil.

Anomaly 2 is the most probable launcher location detected by this survey. This large amplitude anomaly is elongated about 30 feet east and probably consists of only one source. There is no GPR data because trees limited the access.

Anomalies 3 and 5 are small amplitude, complex anomalies that are circular in shape. Anomalies may be caused by several closely spaced sources. Telephone pole tie downs may have caused Anomaly 3. The small metal object detected by GPR may have caused Anomaly 5.

Anomaly 4 may represent the launcher. This anomaly is elongated about 35 feet east, and probably consists of only one source. GPR data shows a 25 feet long metal object located near the steepest magnetic gradient and disturbed soil surrounding the metal object.

Site 2 The close proximity of this area to Shelter 204 makes it a likely burial site for the launcher but no magnetic anomaly characteristic of the launcher was measured. The magnetic field in the northern part of the site is relatively featureless. Several cultural features (row of shelters, concertina wire fence, and isolated manhole covers, steel poles, and fire hydrants) produce large amplitude magnetic anomalies. The remaining anomalies are high-valued, high/low pairs.

Anomalies 1 and 4 are complex, large amplitude, and probably caused by several closely spaced sources in addition to the concertina wire fence. GPR did not detect metal objects at Anomaly 1 but did locate a long, narrow, metal object (may be a pipeline) oriented parallel with the road at Anomaly 4.

Anomalies 2,3,5 are large amplitude, circular anomalies. Anomaly 2 is probably caused by a nearby well. The GPR data shows a long metal object (pipeline) oriented parallel with the road at each anomaly.

Site 3 No anomaly characteristic of the launcher was measured. The magnetic field at this site is dominated by cultural features (perimeter fence, and light posts) anomalies. The remaining anomalies are large amplitude, circular shaped, and are high-valued only, which represent magnetic monopoles (sources with long vertical axis relative to their width).

Anomaly 1 is probably caused by the small dimension metal object detected by the GPR survey.

Anomaly 2 is probably caused by several sources in addition to the perimeter fence and the planter.

Site 4 The magnetic field in the north central and northeast part of this site is featureless. Cultural features (row of shelters and isolated manhole covers, steel poles, and fire hydrants) produce many large amplitude anomalies. A GPR survey was completed only at Anomaly 1 because of project time constraints.

Anomaly 1 may represent the launcher. This anomaly is very large amplitude, circular shaped, and appears to be caused by a single source. The high/low pair is slightly elongated about 20 feet towards northwest. This anomaly is of large enough amplitude and dimensions to be the launcher, but its shape is more circular than linear. The low-valued closure on the southwest may be caused by the two manhole covers. If this low-closure is not associated with the high-valued closure, then this anomaly is caused by a monopole source and does not represent the launcher. GPR shows a multitude of metal objects and disturbed soil areas across the entire anomaly. This area may be a historical dump site or contain extensive underground utility corridors.

Anomaly 2 is similar to Anomaly 1 and could be caused by the launcher. The low-valued closure has larger amplitude and dimensions than the high-valued closure which means the source has remanent magnetism. The anomaly amplitude is too large to be solely caused by the manhole cover located within the low-valued closure. This anomaly may also be caused by an abandoned dump site or utility corridors.

Anomalies 3 and 4 are relatively low amplitude. Anomaly 3 is a high/low pair and Anomaly 4 is high-valued closure only. These anomalies are thought to be caused by several sources and may be associated with nearby Anomaly 2.

Anomalies 5,6,7 are small amplitude, complex anomalies that probably represent small dimension, buried objects.

3.5 Drilling and Borehole Program

Subsurface soil sampling was conducted at the BOMARC Missile Site in order to determine the vertical extent of radionuclide migration in the soil column. Soil borings were installed primarily in areas of highest known radioactivity (exclusive of the concrete apron area) in order to ensure measurement of worst-case vertical contaminant migration. Borehole locations were selected by scanning areas of highest radioactivity (areas surrounding shelter 204, drainage pathway,and others) with a Field Instrument to Detect Low Energy Radiation (FIDLER) probe. "Hot-spots" were pin-pointed by lowering the probe close to the ground. A two-inch diameter soil core was then obtained to a depth of six inches below the surface. This soil core was

rescanned with the FIDLER to ensure its radioactivity. This sample then became the uppermost soil sample from each borehole sent for laboratory radioanalysis. Boreholes were drilled directly on the location of the surface sample, so that analytical results for subsurface samples could be compared to those for the radioactive surficial sample. Most soil borings were terminated at depths of 10 feet or less.

In order to characterize the concrete apron and underlying soils, the concrete was cored at 22 locations (including one duplicate) with a diamond bit. The concrete and underlying asphalt and soil were analyzed for radioactivity. Concrete coring is discussed in Section 3.6.2.7. In addition, four shallow (<2 ft.) soil corings were installed on the centerline of the asphalt drainage ditch using hand tools. These shallow soil corings are discussed in section 3.6.2.6.1 of this report.

3.5.1 Number of Boreholes Drilled

Twenty-six boreholes were drilled at the BOMARC Missile site in October, 1989. The majority of these boreholes were drilled around shelter 204 and along the asphalt-lined drainage ditch. All boreholes were tremie-grouted upon completion and marked with wooden stakes and surveyed for elevation and location. The boreholes are numbered B1 through B26 and their locations can be seen on Figure 3-7.

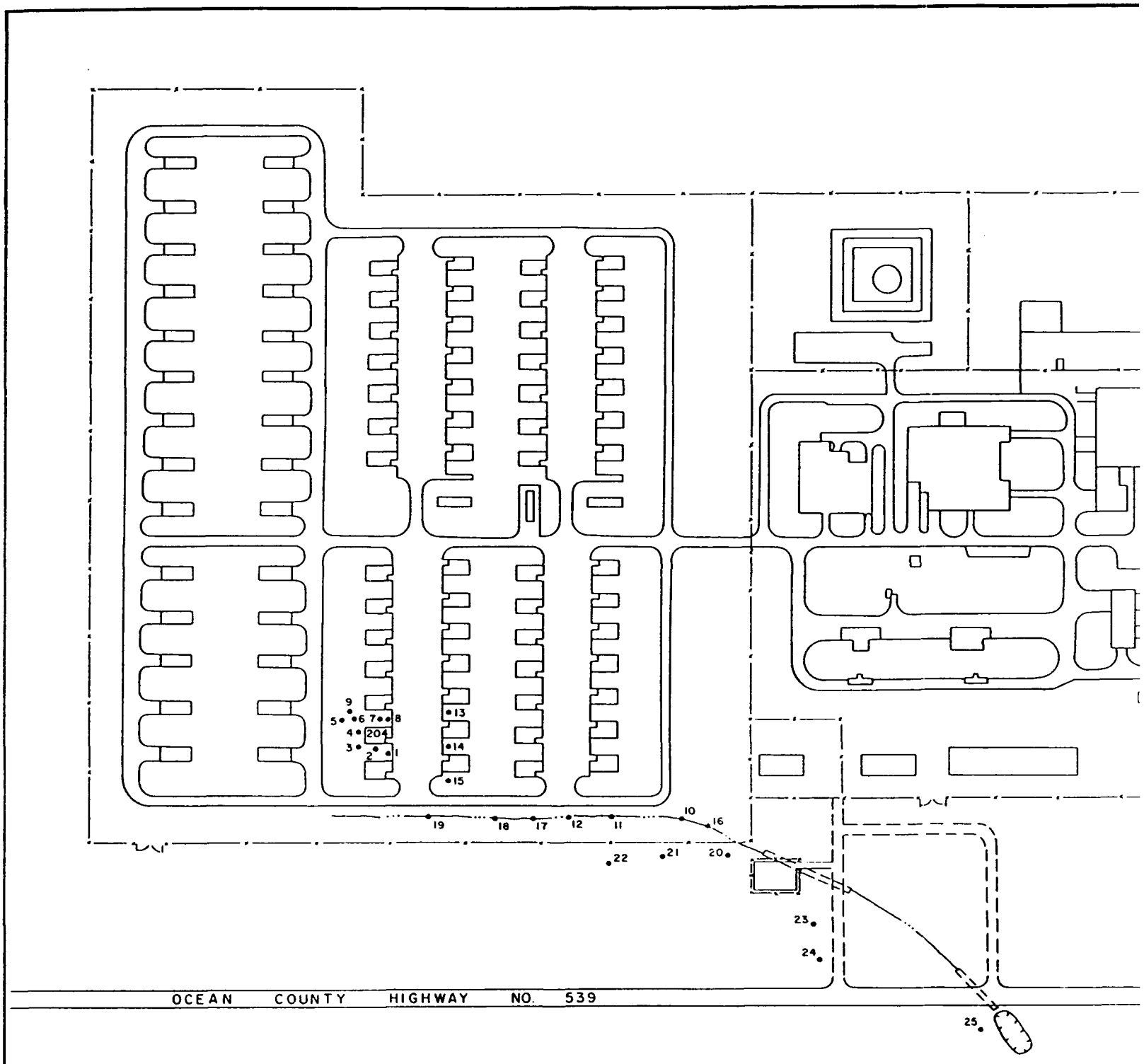
3.5.2 Footage Summary

Twenty-six boreholes were drilled for a total of 196 linear feet. Boreholes were drilled either to 6- or 10- foot depths below grade. Boreholes 1-4, 6-8, 10,12, and 16 were drilled to a depth of 10 feet below grade while boreholes 5, 9, 11, 13-15, and 17-26 were drilled to a depth of 6 feet below grade.

3.5.3 Drill Rig and Drilling Technique Used

All boreholes were drilled with a Diedrich D-50 hollow-stem auger rig. This drilling method does not require drilling fluids, therefore, no drilling fluids were introduced into any of the boreholes.

Using the hollow-stem auger rig, flights of augers were advanced using standard drilling techniques. The bottom of the lead auger was blocked with a plug while the auger advanced. When the desired sampling depth was reached, the plug was withdrawn and a sample was obtained from below the bottom of the augers using split spoon sampling techniques in accordance with American Society for Testing and Material (ASTM) Method D-1586. All borings were sampled continuously from the ground surface to the total depth. Auger drilling was performed to acquire soil samples for lithologic characterization, field analysis, and laboratory analysis. All borings were grouted to the surface upon completion of drilling and sample collection. Grout was mixed in accordance with the project statement of work.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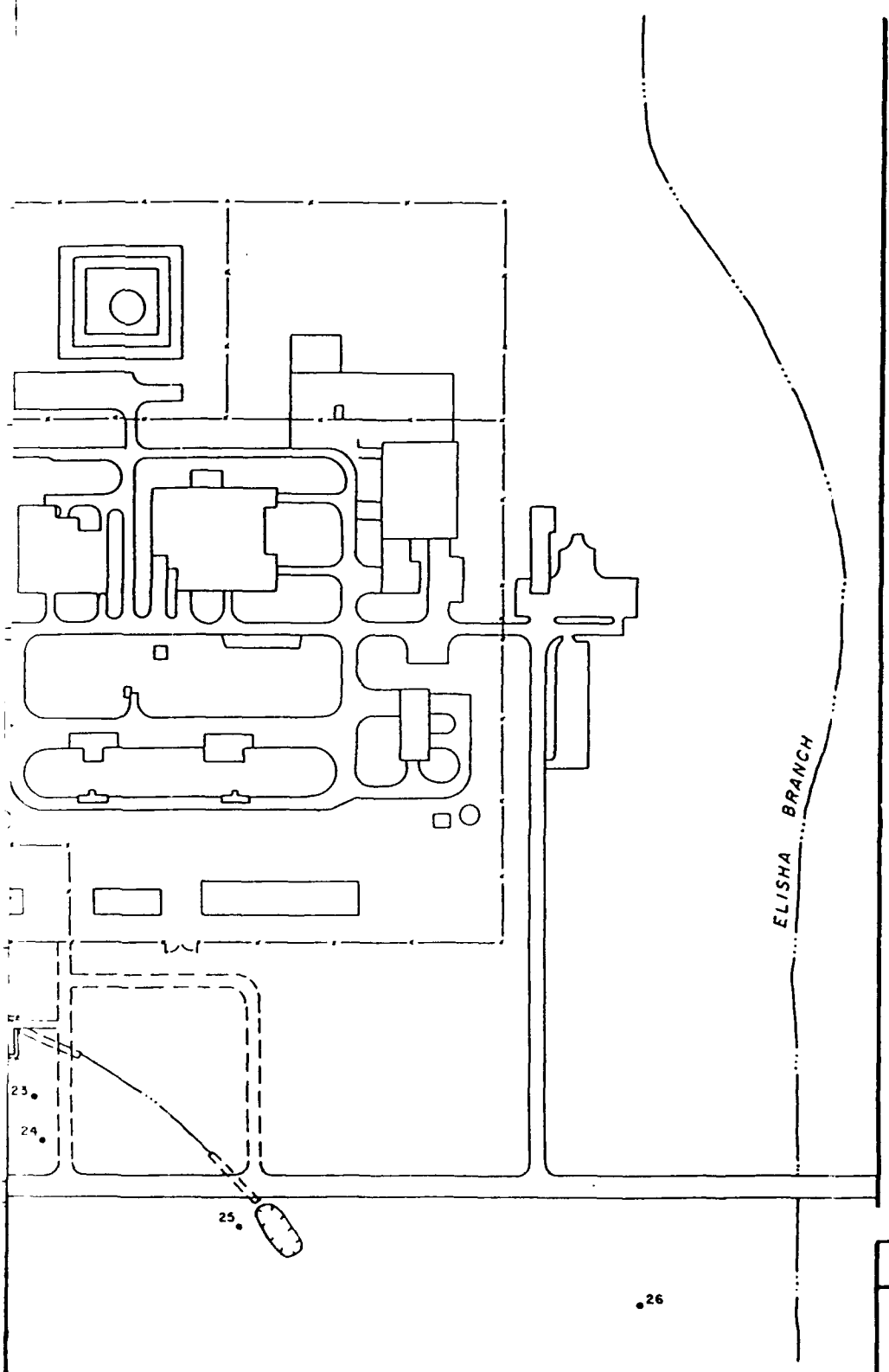
OCEAN COUNTY HIGHWAY NO. 539



EXPLANATION

•20 BOREHOLE LOCATION AND IDENTIFICATION NUMBER (B20)

DRAINAGE

PONDING AREA

CULVERT

NORTH

0 250 FEET

SCALE

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FIGURE 3-7

LOCATIONS OF SHALLOW SOIL BORINGS

3.5.4 Field Measurements and Data Acquisition

During borehole drilling at the BOMARC Missile site, field measurements were taken and recorded in logbooks and on borehole log sheets by an Earth Technology geologist. Soil lithology, sample recovery, hammer blow counts, radiation readings, and any pertinent data were recorded during drilling.

Continuous soil cores were scanned using a FIDLER probe. Soil cores were laid on a table, and the site health physicist scanned each core. A Bicron Model G5 FIDLER probe was used. Data were processed using an Eberline ESP-2 pulse height analyzer in rate-meter mode. Data were read directly from the analyzer as counts per minute. The FIDLER probe was optimized for measurement of 60 Kiloelectron volts (KeV) x-rays from americium 241. Background was established several times daily by taking readings in uncontaminated areas (on a concrete pad near the field trailer). FIDLER readings were recorded in project log-books, and are given on borehole logs contained in Appendix C.

3.6 Sampling Program for Air, Water, Soil, Sediment, and Biological Data

The following sections discuss the sampling program for air, water, soil, sediment, and biological data.

3.6.1 Types and Numbers of Samples Taken

The Stage 2 field work performed at the BOMARC Missile Site involved the collection and analysis of ground water, surface water, concrete/asphalt core, soil, sediment, wipe, and ambient air samples. In addition, three separate in-situ gamma ray surveys were performed using both a hyper-pure germanium detector and a field instrument to detect low energy radiation (FIDLER). Table 3-2 lists the types and number of samples collected, places of analysis, and type of analysis.

Ground water and soil samples were originally collected for plutonium analysis. Chemical analysis for both ground water and soil was added as a modification to the original project statement of work. The purpose of this modification was to identify chemical contaminants that may affect remedial alternatives considered. Non-radioactive chemical contaminants in ground water are being addressed under a separate ongoing base-wide RI/FS program.

Both filtered and unfiltered ground water samples were collected from the ten existing monitoring wells immediately surrounding Shelter 204. These 20 samples were sent to TMA Eberline for gross alpha and gross beta analyses. Duplicates of the eight samples showing the highest activity were sent to Teledyne Isotopes for plutonium analysis by alpha spectroscopy. In addition, 4 ground water samples were collected for chemical analysis (TCL and TAL parameters including volatile organics, semi-volatile organics, pesticides/PCBs, and metals) and sent to MetaTrace Laboratories. Appropriate quality control samples (duplicates, equipment blanks) were also obtained and analyzed.

Table 3-2
Types and Numbers of Samples Collected at the BOMARC Missile Site
McGuire AFB, New Jersey

Sample Type and Locality	No. of Samples Collected	Splits, Duplicates, Blanks	Laboratory	Analysis
Groundwater Samples				
Monitor Wells	20*	2	TMA Eberline	Gross Alpha, gross beta
Monitor Wells	8*		Teledyne Isotopes	Pu, alpha spectroscopy
Monitor Wells	8*		Metatrace	VOA, BNA, Pest/PCB, metals
Surface Water Samples				
Runoff	26*		TMA Eberline	Gross alpha, gross beta
Elisha Branch	2		TMA Eberline	Gross alpha, gross beta
Bunkers	2		Teledyne Isotopes	Pu, alpha spectroscopy
Concrete/Asphalt Coring				
Cores--Concrete/asphalt	21		Screened, not analyzed	AM-241, gamma activity
Cores--Soil	57		Teledyne Isotopes	Pu, alpha spectroscopy
Cores--Soil (Chemical)	3		Metatrace	VOA, BNA, Pest/PCB, metals

Table 3-2
Types and Numbers of Samples Collected at the BOMARC Missile Site
McGuire AFB, New Jersey (Continued)

Sample Type and Locality	No. of Samples Collected	Splits, Duplicates, Blanks	Laboratory	Analysis
Soil Samples				
Random Samples	30		Teledyne Isotopes	Pu, alpha spectroscopy
Depth Profile (boreholes)	78	9**		
			Teledyne Isotopes	Pu, alpha spectroscopy
Particle Sizing	62***		Teledyne Isotopes	Pu, alpha spectroscopy
Shallow--Drainage Ditch	8		Teledyne Isotopes	Pu, alpha spectroscopy
Boreholes (Chemical)	4		Metatrace	VOA, BNA, Pest/PCBs, metals
Background (Chemical)	2		Metatrace	Metals
Sediment Samples				
Communication Bunker	1		Teledyne Isotopes	Pu, alpha spectroscopy
Communication Bunker	5		Screened, not analyzed	Am-241, gamma activity

Table 3-2
Types and Numbers of Samples Collected at the BOMARC Missile Site
McGuire AFB, New Jersey (Continued)

Sample Type and Locality	No. of Samples Collected	Splits, Duplicates, Blanks	Laboratory	Analysis
Wipe Samples				
Launcher Shelters	619		On-site analysis	Alpha Count
Launcher Shelters	10****	1	Teledyne Isotopes	Pu, alpha Spectroscopy
Air Samples				
Baseline	13	1	Battelle, Columbus Division Laboratory	Gross alpha, gross beta
Ambient	4	2	SAIC, Rockville	Gross alpha
In-situ Surveys				
HPG--Areas of Known Contamination	409		On-site analysis	Am-241 gamma activity
FIDLER--Concrete Apron	330		On-site analysis	Am-241 gama activity
FIDLER--Air Model Validation	147		On-site analysis	Am-241 gamma activity

Table 3-2
Types and Numbers of Samples Collected at the BOMARC Missile Site
McGuire AFB, New Jersey (Continued)

*	=	Includes both filtered and unfiltered samples.
**	=	Samples retained by EPA/CDM for grinding, homogenizing and splitting; split to be returned to SAIC for analysis. EPA laboratory errors invalidated the samples, so splits were not obtained and analyses were not performed.
***	=	Each sample was sieved into 2 fractions, one greater than 20 microns and one less than 20 microns; this resulted in the 62 samples becoming 124 for analytical purposes.
****	=	These 11 samples were part of the 619 screened for alpha activity on site. After screening, they were sent to Teledyne Isotopes for alpha spectroscopy analysis.

Thirty surface water samples were collected. Most of these were obtained as rainwater runoff, and were taken: (1) from the concrete apron just south of Shelter 204; (2) along the asphalt-lined ditch; (3) along the unlined portion of the ditch on either side of Highway 539; (4) along the drainage to the northwest of Shelter 204; and (5) from a drain culvert outside of the perimeter fence, east of Shelter 204. Surface water was also collected from standing water in the forest near the headwaters of the Elisha Branch near the southeast corner of the site. Both filtered and unfiltered samples were obtained from the runoff and Elisha Branch samples. Two unfiltered water samples were collected, one each from the power and communication bunkers in front of Shelter 204. These two samples were sent to Teledyne Isotopes for plutonium analysis by alpha spectroscopy.

Concrete and/or asphalt coreholes were drilled at 18 locations along Lorin Street in front of Shelter 204 and at three locations inside Shelter 204. The thickest concrete drilled was approximately 18 inches, inside Shelter 204.

Shallow soil samples were collected through the concrete cores at three discrete depths; 0-6, 6-12, and 12-18 inches below ground surface (bgs) using a slide-hammer coring device. Shallow subsurface soils from the asphalt covered ditch were also collected at three depths; 0-6, 6-12, and 12-18 inches bgs along the drainage ditch and on the west side of Highway 539 using a hand auger and slide-hammer coring device.

Soil samples for chemical analysis were collected from eight of the shallow subsurface soil sample/concrete coring sites and two background locations. Sample analysis included TCL organics and TAL metals. Soil samples for plutonium analysis by alpha spectroscopy were collected from all of the shallow subsurface and concrete coring sites.

Six depth profile sampling stations were established for soil collection. At five of the six stations, soil samples were collected at the following intervals: 0-1, 1-2, 2-3, 3-6, and 6-12 inches bgs. At a sixth sampling station, the first sampling interval was from 0-6 inches bgs. This interval was composited since it was suspected to be primarily fill material. The remaining sampling intervals at station six were: 6-7, 7-8, 8-9, 9-12, and 12-18 inches bgs. Each of the samples collected for the depth profiles were sieved into two size fractions: greater than 20 microns and less than 20 microns. Each size fraction was then analyzed for plutonium by alpha spectroscopy.

Sediment samples were collected from the floor of the communications bunker. The maximum thickness of sediment found in this bunker was approximately eight inches. Six samples were screened for americium activity using the Hyper-pure Germanium Detector (HPG) and FIDLER detectors, and one sample was sent to Teledyne Isotopes for plutonium analysis by alpha spectroscopy.

A total of 619 wipe samples were collected from accessible surfaces inside and outside of each of the 21 shelters. The majority of the shelters sampled were in the vicinity of Shelter 204. Shelter 210 was established as a sampling model, with 44 sample locations defined and sampled.

The surfaces sampled included the shelter floor, light fixtures, support beams, and the missile launcher. The outside surfaces sampled included structural beams and the "seams" where the two halves of the shelter roof met. With the exception of Shelter 204, 25 samples were collected from each of the other shelters. Shelter 204 was more thoroughly sampled, with 100 wipe samples collected from surfaces inside and outside of the structure. Most samples were analyzed onsite for alpha activity, but ten samples and one ambient condition blank were sent to Teledyne Isotopes for alpha spectroscopy analysis.

Ambient air samples were collected from three sampling stations, each equipped with a high-volume air sampler, positioned in a triangular pattern around Shelter 204. Air samples were collected both before and during field operations to screen for suspended radioactive particles. Those samples collected prior to field operations were sent to Battelle Columbus Division Laboratory for gross alpha and gross beta analyses. The samples collected during field operations were scanned on site and sent to the SAIC Laboratory in Rockville, Maryland. One blank and one duplicate were also analyzed. Certain filters were scanned and sent to the SAIC Laboratory in Rockville, Maryland. One blank and one duplicate were also analyzed. Certain filters were scanned and stored on site in the event that analysis was determined to be necessary.

Three in-situ surveys were performed on the BOMARC Missile Site. The first was conducted using a hyper-pure germanium (HPG) detector and involved an intensive in-situ survey of low-level gamma radiation (specifically Am-241). These measurements were collected in a grid pattern surrounding Shelter 204 and extending to the southwest following the main drainage along areas of known historical contamination. The second survey was conducted using a FIDLER along the concrete and asphalt in front of Shelter 204 to identify areas showing relatively high levels of low-energy gamma radiation. A total of 330 points were sampled, and the information derived was used to select coring locations. The third survey was also conducted using a FIDLER; 147 readings were taken both on and off site in order to validate depositional patterns predicted by the surface deposition modeling effort.

Sample containers, preservation methods and holding times are addressed in Section 3.6.3. Contamination control and decontamination procedures are described in Section 3.6.2.10.

3.6.2 Sampling Methodology and Protocols

The following sections discuss the sampling methodology and protocols used at the BOMARC Missile Site.

3.6.2.1 Ground Water Sampling

Ground water samples from ten previously installed wells were collected and analyzed for gross alpha and gross beta activities. Those samples with readings above the MCL for the desired parameters were also analyzed for plutonium using alpha spectroscopy. The wells sampled included wells PU-1 through PU-7 and wells MW-47, MW-48, and MW-49 (Figure 3-8). Ground water samples from wells PU-1, PU-2, PU-5, and PU-7 were also analyzed for TCL

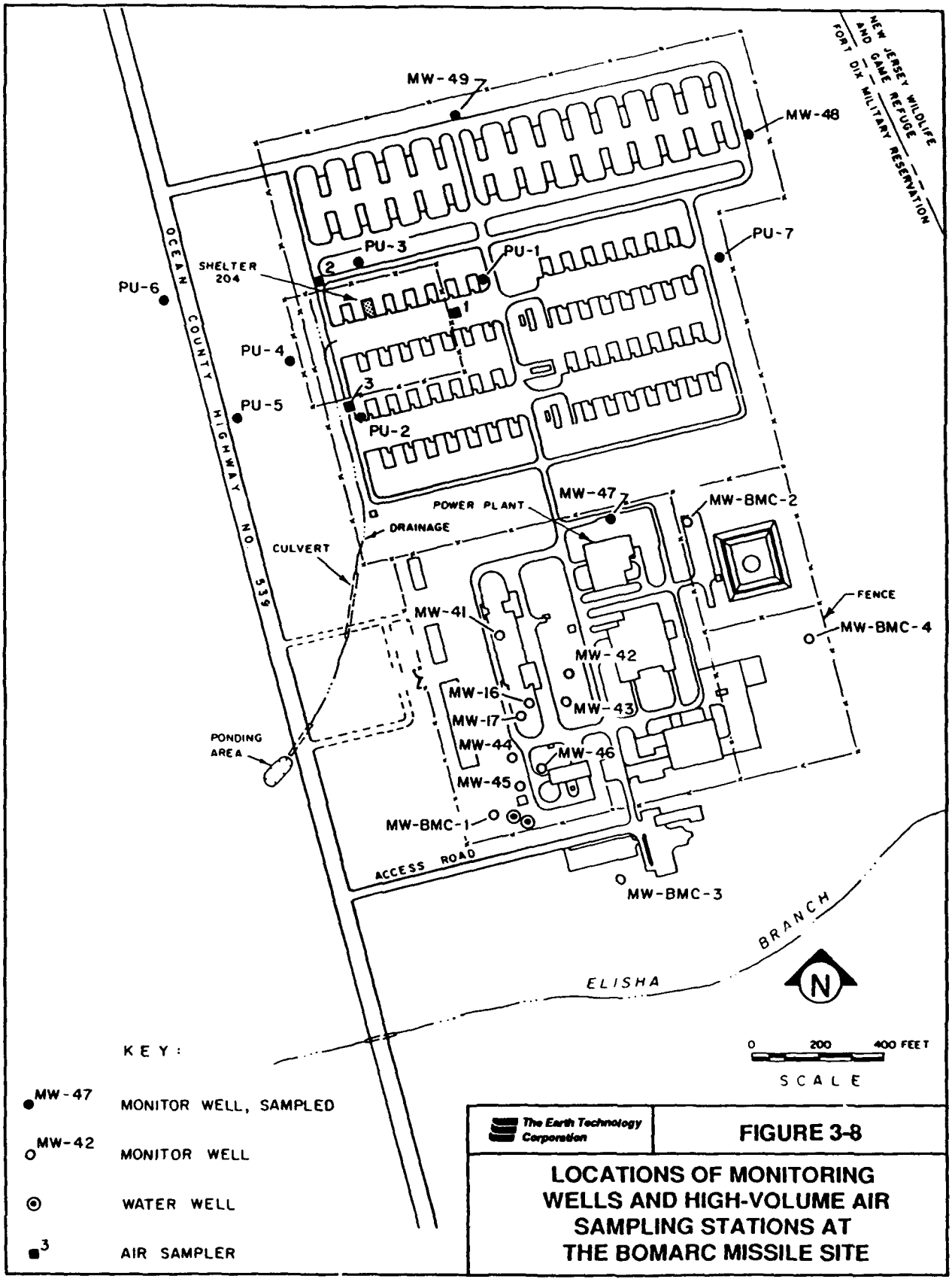
MW-49
MW-48
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
OCEAN COUNTY HIGHWAY NO. 539
PU-3
PU-1
PU-7
SHELTER 204
PU-6
PU-4
PU-5
PU-2
MW-47
POWER PLANT
MW-BMC-2
DRAINAGE
CULVERT
FENCE
MW-41
MW-BMC-4
MW-42
MW-16
MW-43
MW-17
MW-44
PONDING AREA
MW-46
MW-45
MW-BMC-1
ACCESS ROAD
MW-BMC-3
ELISHA BRANCH
N
0 200 400 FEET
SCALE
KEY:
MW-47 MONITOR WELL, SAMPLED
MW-42 MONITOR WELL
WATER WELL
3 AIR SAMPLER
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FIGURE 3-8
LOCATIONS OF MONITORING WELLS AND HIGH-VOLUME AIR SAMPLING STATIONS AT THE BOMARC MISSILE SITE

organics and TAL metals (Table 3-3). The ground water sampling procedure used in the sampling of the wells is discussed below.

A Foxboro Model 128GC flame ionization organic vapor analyzer (OVA) and/or an HNu photoionization detector (HNu), a Yellow Springs Instrument (YSI) Model 33 conductivity meter, and an Orion Research (OR) Model SA230 pH and temperature meter were used to field test each well. Each instrument was calibrated each morning prior to ground water sampling. The date and time that each instrument was calibrated were recorded in a logbook.

The Foxboro OVA was calibrated at a background location using methane (95.2 ppm) as the calibration gas. Prior to calibration, the OVA was allowed to warm up for approximately five minutes. The gas-select knob was unlocked, the range select switch was moved to the 10X position, and the adjust knob rotated until the instrument read zero. A Teflon™ calibration bag was then filled and purged three times with the methane calibration gas. The OVA probe was inserted into the bag the fourth time it was filled. The gas select knob was turned until the instrument read 95.2 ppm (equal to the methane concentration). The knob was then locked to prevent the loss of calibration.

The HNu meter was calibrated using isobutylene calibration gas at a concentration of 75 ppm in air. After allowing the instrument to warm up, the zeroing screw was adjusted to zero the instrument. The probe end of the HNu was connected to the calibration gas bottle via a piece of rubber tubing.

After the instrument's reading had stabilized, the span knob was adjusted until the reading on the instrument matched the isobutylene concentration in the bottle.

The YSI Model 33 conductivity meter was calibrated by zeroing and red-lining the instrument at the sampling site just prior to the commencement of well purging, in accordance with manufacturers instructions.

The OR Model SA230 pH and temperature meter was calibrated at the sampling site just prior to well purging, using a two-buffer standardization method. Because local ground water is acidic, the buffers chosen were pH 4 and pH 7, to "bracket" expected local conditions. With the mode switch set to record temperature, the temperature and pH probe were lowered into the pH 7 buffer solution, and a temperature reading was taken. The temperature/slope control was set to reflect this temperature. The mode switch was then switched to record pH. Once the pH reading stabilized, the calibration control knob was adjusted to the pH 7 buffer value. The pH electrode was rinsed with distilled water and placed in the pH 4 buffer solution. After the reading stabilized, the temperature/ slope control was adjusted until the correct pH of the second buffer was displayed.

Once the sampling instruments were properly calibrated, the steel well cover was unlocked and removed. The PVC well cap was then removed and either the OVA or the HNu probe was inserted several inches below the casing for approximately 30 seconds. The highest reading was

Table 3-3

Chemical Ground Water Samples and Analyses

Sample Number	VOA	BNA	Pesticide/PCB	Total Metals	Dissolved Metals
001-GW-PU1	*	*	*	*	*
001-GW-PU2	*	*	*	*	*
001-GW-PU5	*	*	*	*	*
001-GW-PU7	*	*	*	*	*
001-GW-PU10 (Dup. of PU-7)	*	*	*	*	*

*Parameters analyzed

recorded on a well purging/sampling form. The breathing zone was also screened to determine the level of protection against organic vapors needed for well sampling. A radiation instrument (Micro R) was also used to screen the well and breathing zone to ensure against the sampler receiving a radiation dose.

A decontaminated water level sounder was lowered into the well to measure the depth to static water and the depth to the bottom of the well. These measurements were used to calculate the number of gallons of water that comprise one well volume. This number was then multiplied by three to derive the minimum volume of water needed to be removed from the well for proper well purging.

A tripod and reel were positioned on the upwind side of the monitoring well to help minimize the sampler's exposure to any organic vapors or other harmful emissions. An 80-pound-test, monofilament fishing line was wound onto the reel to allow a two-inch stainless-steel bailer to be lowered into the well. The bailer was tied to the end of the monofilament line and was lowered into the well to a depth several feet below the static water level, but above the bottom of the well. The bailer was then retrieved.

As the full bailer reached the top of the casing, an OVA reading was taken just above the water surface. While the purging water was being poured into a five-gallon waste bucket, a sample of the water was collected in a 16-ounce glass jar for temperature, pH, and conductivity measurements. The bailer was lowered back down the hole to continue purging.

Samples for temperature, pH, and conductivity measurements were collected periodically to track well water stabilization. The well was considered to be stable when two consecutive samples met the following criteria: temperature, $\pm 0.5°C$; pH, ± 0.1 units; and conductivity, ± 10 μmhos/cm. Each time the five-gallon waste bucket was filled, the purging water was transferred into a 55-gallon drum. Using the calibrated waste bucket facilitated tracking the amount of water purged.

Immediately after the well stabilized, the stainless-steel bailer was removed from the well, and a second water level measurement was taken. This measurement was taken for specific capacity and transmissivity calculations. The well was then sampled.

For sampling, a decontaminated two-inch Teflon™ bailer was attached to the monofilament line and lowered into the well. Sampling water was collected from the center of the water column. For those wells where organic compounds were included in the chemical analyses, 40 milliliter Volatile Organic Analysis (VOA) vials were the first sample bottles to be filled. Both filtered and unfiltered samples were collected for radiation analysis. The filtered samples were prepared by pouring sample water from the Teflon™ bailer into an acrylic barrel filter. When the barrel was approximately two-thirds full, it was sealed and pressurized with a hand pump. As the sample water was forced through a filter paper with a 0.45 micrometer (μm) pore size, it was collected in a sample bottle. The same procedure was used to collect filtered samples for metals analysis.

Immediately after each bottle was filled with sample water, it was labeled, noting: the date and time of sampling, sample number, sampler, preservatives added, and parameters to be analyzed for. Samples to be analyzed for radioactivity were then taped closed. If the sample was to be analyzed for organic compounds, the bottle was placed in an ice-packed cooler. Samples were screened onsite for radioactivity using the HPG, and then shipped for analysis as outlined in the QAPP.

3.6.2.2 Surface Water Sampling

No surface water is present under normal conditions at the BOMARC Missile Site. Therefore, surface water samples were collected during heavy rainstorms. These created sufficient surface water runoff on the concrete apron and asphalt drainage ditch to allow for collection of samples.

A total of 30 surface water samples were collected for analysis at the BOMARC Missile Site (Figure 3-9). Twenty-six of those samples were collected from 13 locations as rainwater runoff, and two samples were obtained from the vicinity of the headwaters of the Elisha Branch. In addition, samples were collected from the power bunker and from the communication bunker (Figure 3-10) in front of Shelter 204. One sample from each bunker was sent for analysis.

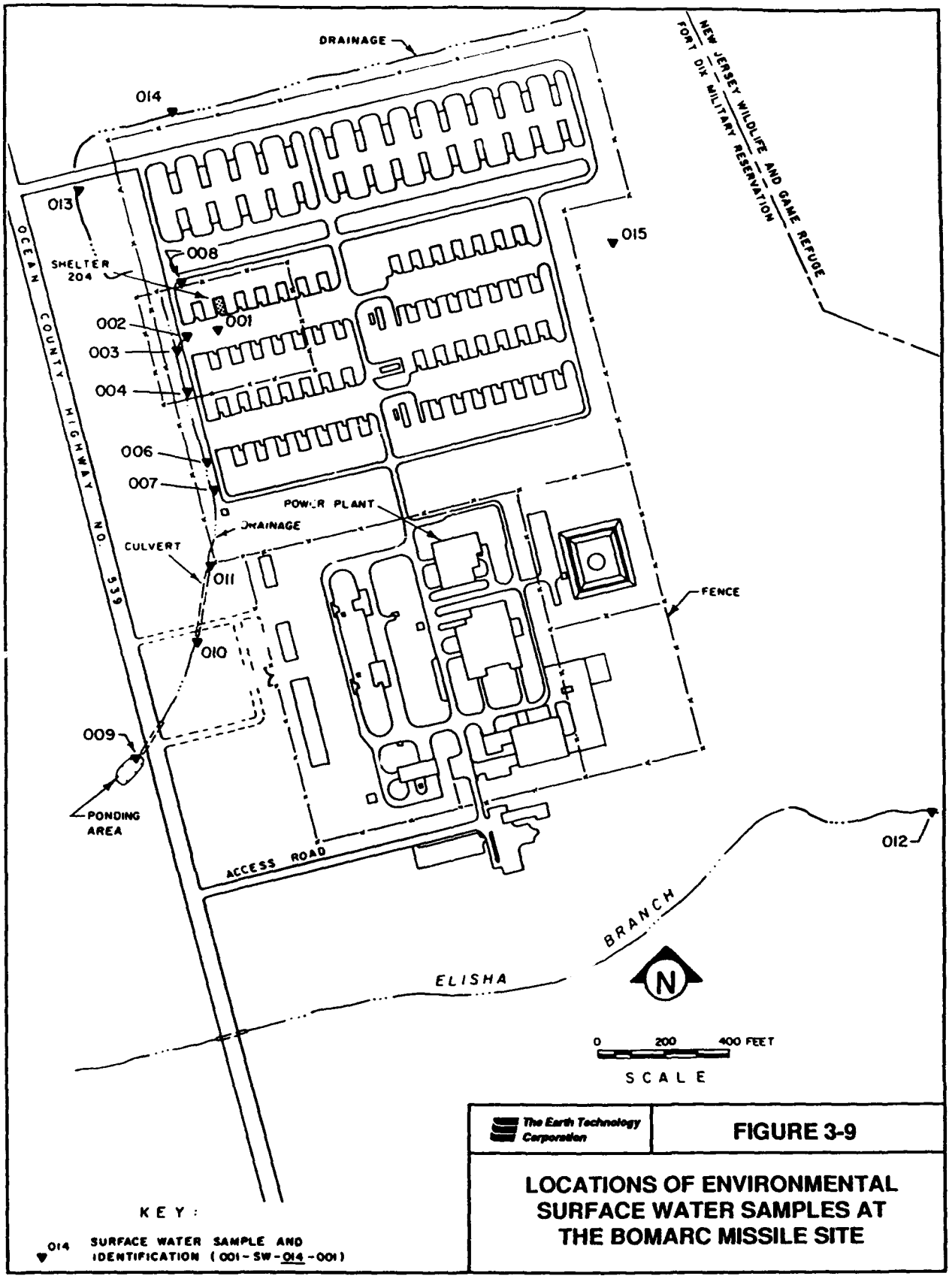
3.6.2.2.1 Runoff and Elisha Branch Samples

Of the 28 environmental surface water samples, 26 were from rainwater runoff (Figure 3-9). Four were collected from two locations on the concrete apron in front of Shelter 204, eight were taken from four locations along the asphalt-lined ditch west of Shelter 204, six came from three locations along the unlined portions of the ditch on either side of Highway 539, six were obtained from three locations in the drainage to the northwest of Shelter 204, and two were collected from the drain culvert outside of the perimeter fence, east of Shelter 204. Two samples were collected from the Elisha Branch in a swampy area near the stream headwaters (Figure 3-9). For each location, both a filtered and an unfiltered sample was collected.

Sample bottles and the barrel filter were rinsed with sample water prior to filling. All sample water was collected using a decontaminated stainless-steel pitcher. With the sampler facing upstream, the pitcher was lowered below the water surface, being careful not to disturb the ground or sediment below. Water was then poured directly from the pitcher into sample bottles for unfiltered samples, and into a barrel filter for those samples requiring filtration.

The barrel filter was pressurized to approximately 25 psi using a hand pump. This pressure was used to force sample water through a filter at the bottom of the barrel in order to remove suspended material greater than 0.45 μm in size. Bottles used for filtered samples were rinsed only with filtered water before being filled.

Immediately after each bottle was filled, it was capped and labeled. Each sample label noted the sample number, date and time of collection, sampler, chemical preservatives added, and parameters for analysis. Samples were preserved after all bottles for one sample had been filled,


DRAINAGE
014
013
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SHELTER 204
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NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
OCEAN COUNTY HIGHWAY NO. 539
POWER PLANT
DRAINAGE
CULVERT
011
FENCE
010
009
PONDING AREA
ACCESS ROAD
012
BRANCH
ELISHA
N
0 200 400 FEET
SCALE
KEY:
014 SURFACE WATER SAMPLE AND IDENTIFICATION (001-SW-014-001)
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FIGURE 3-9
LOCATIONS OF ENVIRONMENTAL SURFACE WATER SAMPLES AT THE BOMARC MISSILE SITE

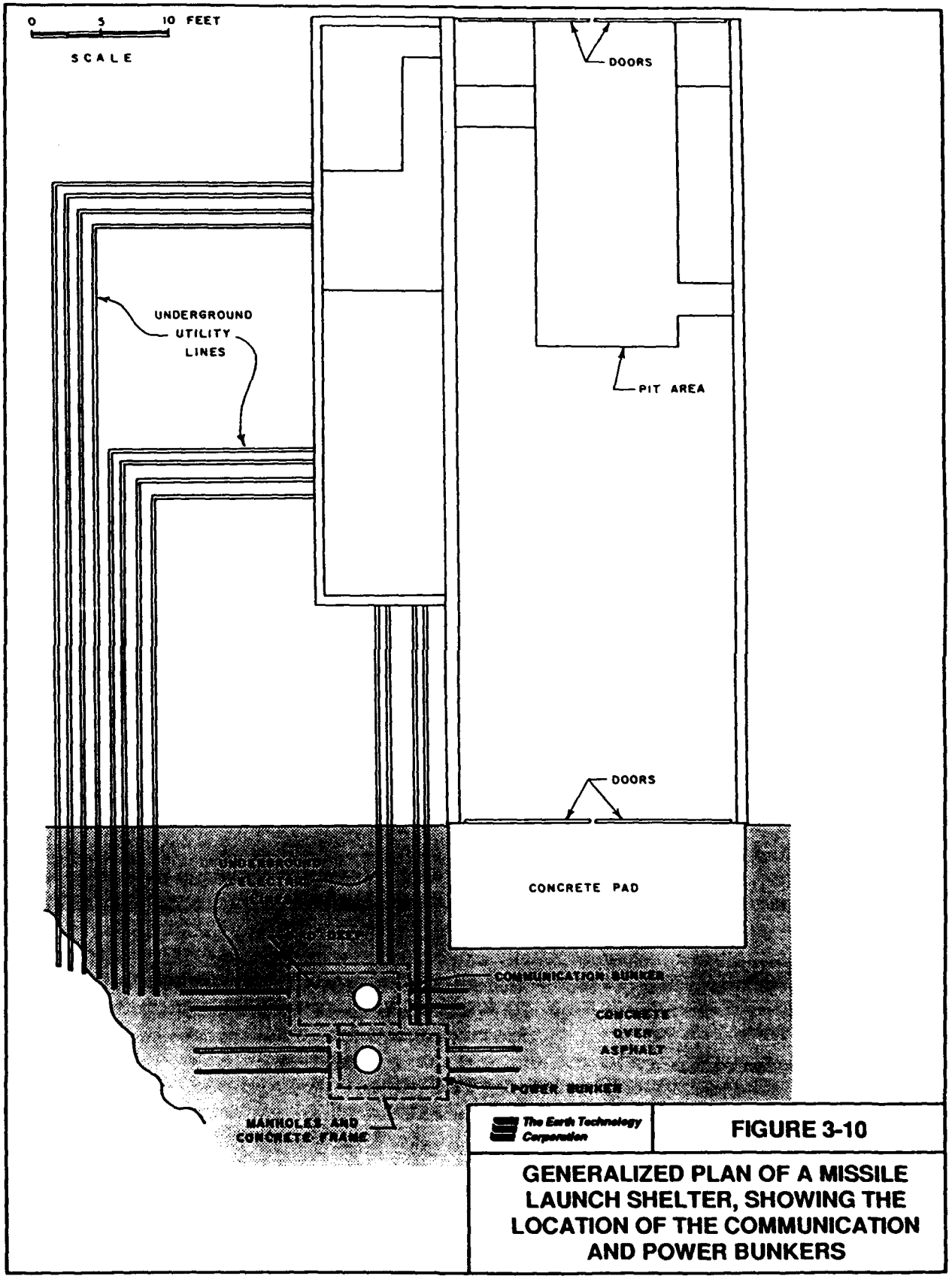

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FIGURE 3-10

GENERALIZED PLAN OF A MISSILE LAUNCH SHELTER, SHOWING THE LOCATION OF THE COMMUNICATION AND POWER BUNKERS

and then were screened for radioactivity using the HPG and shipped to the laboratory as outlined in the QAPP. All surface water samples were analyzed for gross alpha and gross beta emissions.

3.6.2.2.2 Bunker Samples

After the 1960 fire, the openings to the power and communication bunkers in front of Shelter 204 were sealed with concrete.

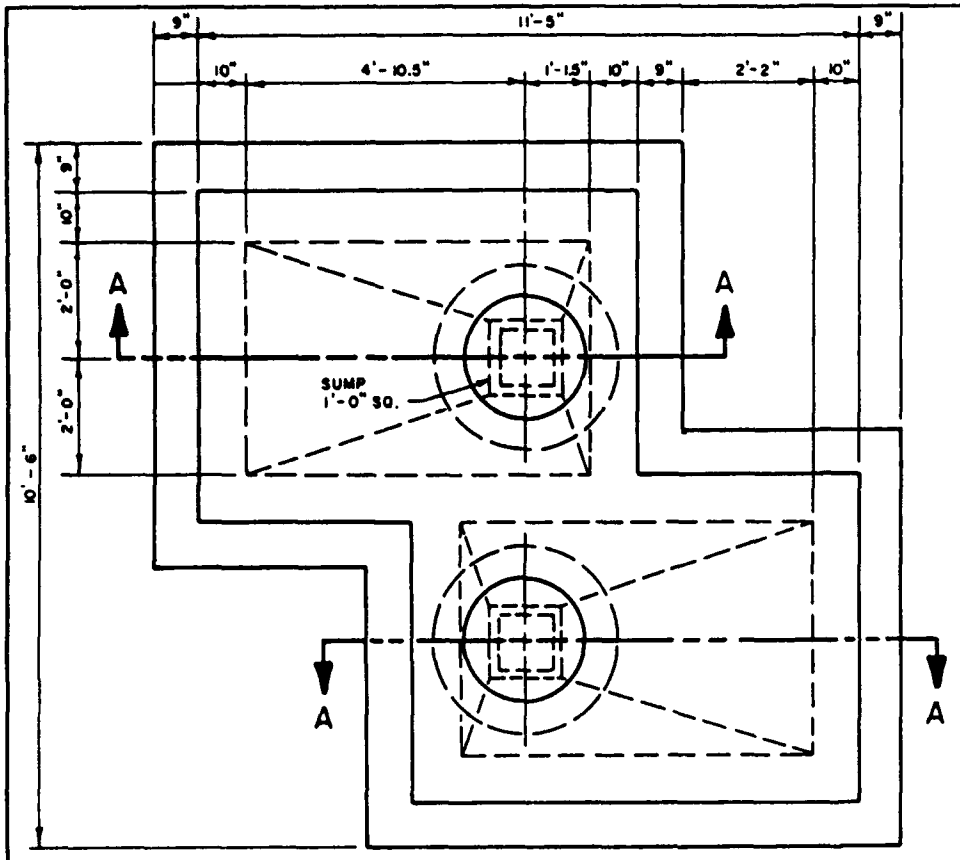
The communication bunker and power bunker for Shelter 204 are located approximately 18 feet and 24 feet, respectively, south of Shelter 204. These bunkers were opened during Stage 2 activities by removing the overlying concrete, manhole covers, and inner lids. These two bunkers are both approximately 6.5 feet long, six feet wide, and eight feet deep (Figure 3-11). The walls of the bunkers are made of concrete and are approximately 10 inches thick. The floor of each bunker is sloped towards a sump which is 1.25 feet deep. The manhole cover that allows entrance to each bunker is located directly over the sump. The power bunker was the first to be sampled.

Prior to commencing work at the power bunker, a 10-foot by 12-foot piece of plastic sheeting was placed on the ground to prevent the spread of contamination. A 22-pound, wedge-end crowbar and sledge hammer were used to chip away the two-inch layer of concrete that had been poured over the manhole cover soon after the accident. As the manhole cover was exposed, it was surveyed with the PAC-4G and/or PAC-1S alpha meters and the FIDLER gamma meter. All instrument readings were recorded into the field log.

The manhole cover was removed and placed into a heavy plastic bag marked for radioactive materials. The bag was folded under the cover in order to prevent any spread of contamination. Once this was complete, the inner lid was also surveyed and enclosed in plastic. An OVA was used to screen for organic vapors in the breathing zone surrounding the open bunker and for organic vapors within the bunker itself.

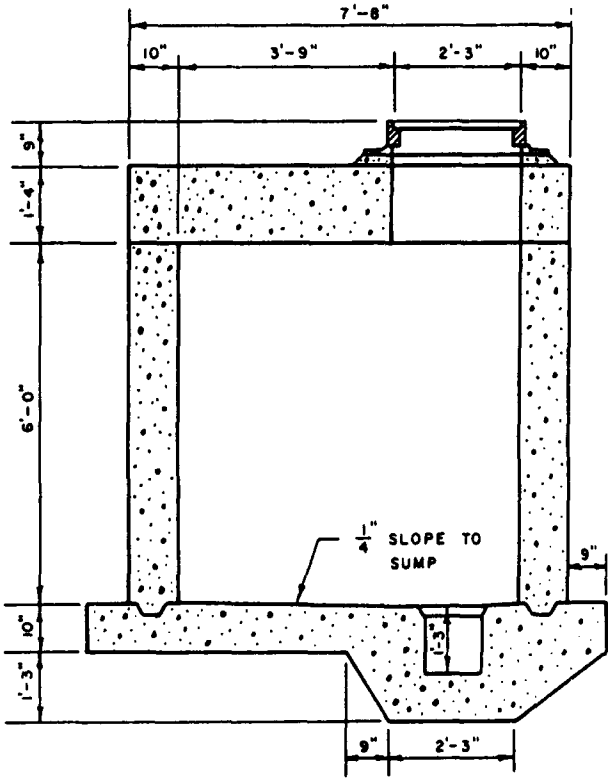
Six surface water samples were the first samples to be removed from the power bunker. Other types of samples collected (wipe, sediment, rust) are addressed in following sections of this report.

Due to a potential lack of oxygen, potentially high radiation, and other possible confined-space hazards, samplers did not enter the underground bunkers to perform the required sampling. A decontaminated sampling bowl was attached to an extension rod, which was then lowered into the bunker to collect the samples. Care was taken not to disturb underlying sediment as the bowl was submersed in the standing water. As the sample was removed from the bunker, sample water was poured directly into sample bottles.



WALL AND FOUNDATION PLAN

SCALE: $\frac{1}{2}$" = 1'-0"



SECTION A-A

SCALE: $\frac{1}{2}$" = 1'-0"

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FIGURE 3-11

DETAILED PLAN OF THE COMMUNICATION AND POWER BUNKERS

Sample bottle handling, preservation, and labeling were the same as for other surface water sampling. Two samples were shipped to the laboratory for alpha spectroscopy analysis, and the remaining four samples were stored onsite for potential future analyses.

The power bunker was then pumped dry using a sump pump. The water removed was containerized in 30- or 55-gallon drums, which were labeled, noting the location, time, and date of water sample collection.

3.6.2.3 Air Monitoring

The following sections discuss the air monitoring completed at the BOMARC Missile Site.

3.6.2.3.1 Baseline Environmental Air Monitoring

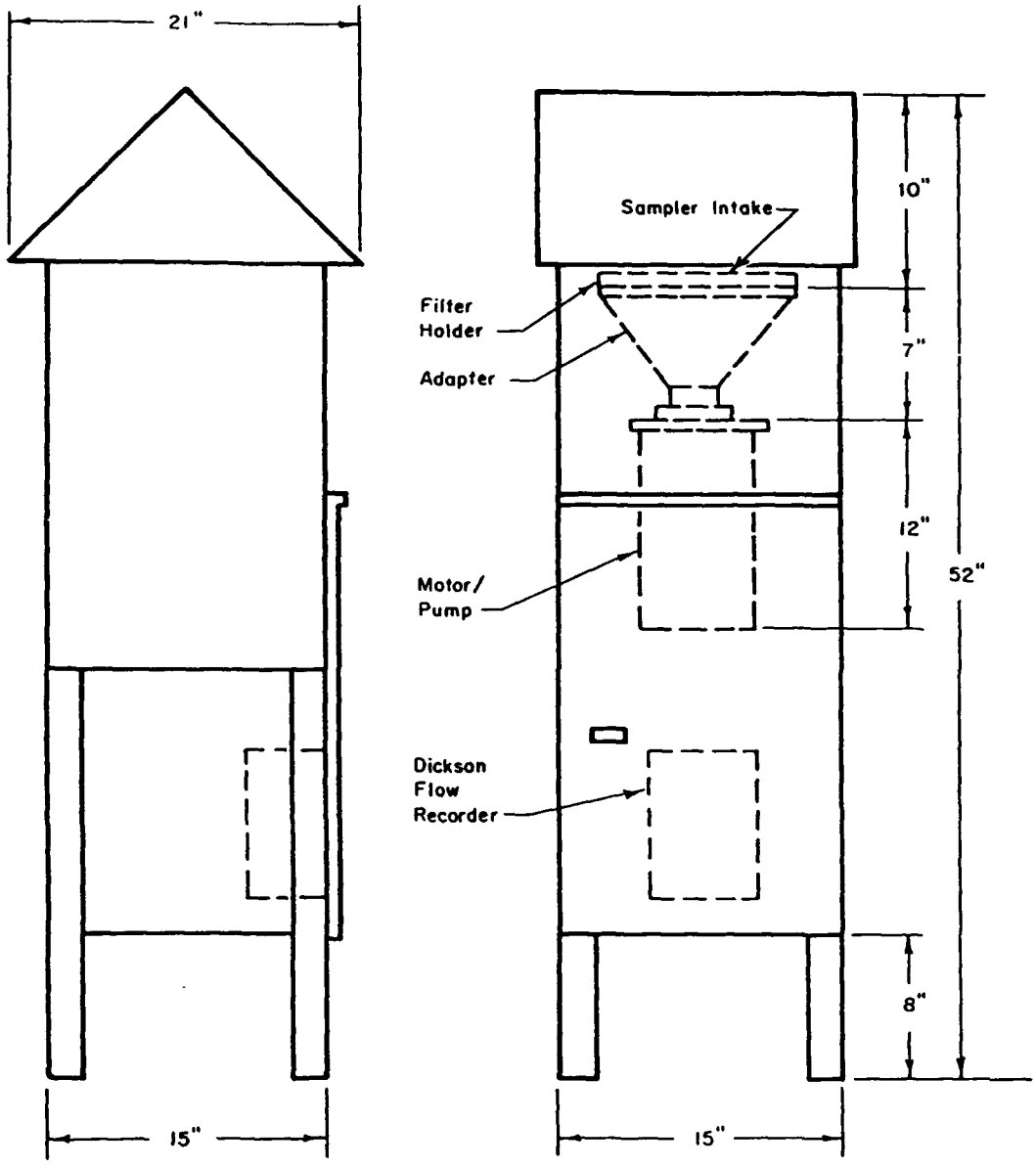
In order to determine the existing baseline concentration of airborne radioactive particulate matter around the BOMARC Missile Site, a total of 13 ambient air samples were collected almost continuously over a five-day period prior to any field activity. The results from the analysis of these samples were used as a baseline and to document the existing background for comparison during and after sampling in order to ensure the health and safety of both workers and the local public. The 13 samples were collected from three sampling stations situated in a triangular pattern around the perimeter of the study area (Figure 3-6). Samples were collected over periods as long as 27 hours. A meteorological station set up on the site continuously recorded all local weather data during the baseline environmental air monitoring. These samples, along with one ambient condition blank, were submitted to Battelle Columbus Division Laboratory for gross alpha and gross beta analyses.

Three Sierra Instruments high volume air sampling system samplers (Model GMWL-2000H) were used to collect the ambient air samples (Figure 3-12). These samplers were made of aluminum except for the filter holder, which was of stainless steel. Each sampler had a Dickson pressure-transducer flow-rate recorder and pen to provide a continuous flow rate recording. The 0.6 horsepower motor in each sampler was powered by a portable, gasoline-operated generator.

Recordings of flow rate and time were taken so that each analysis could be correlated with a specific volume of air. A five point calibration check was initially performed on each sampler to assure that the samplers met the sampling flow rate requirements outlined in the Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (Federal Register, 1982, p. 54913), as well as to check the accuracy of the chart recorders (Figure 3-12).

Following this initial calibration, one point calibration checks were performed periodically to confirm calibration.

The five point calibration procedure required the use of a manometer tube and five stainless-steel plates with increasing orifice sizes (plates #5, #7, #10, #13, #18). A manometer tube was connected to the pump at the base of the sample intake column with a rubber hose. The smallest



NOT TO SCALE

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FIGURE 3-12

SCHEMATIC DIAGRAM OF THE HIGH VOLUME AIR SAMPLING SYSTEM SAMPLERS

plate (Plate #5) was then attached to the sampler intake to restrict the volume of air flow. The sampler was turned on and a manometer reading was taken. The rubber hose from the pump was then attached to the Dickson flow recorder and a reading was taken. The two readings were entered into a logbook. After turning the sampler off, Plate #5 was replaced with Plate #7 which allowed a slightly larger volume of air to flow through the sampler. This procedure was repeated for each of the other plates. After manometer and chart recorder readings were recorded for each of the five plates, the manometer readings were compared to the factory calibration chart to give the actual flow rate. That rate was then compared against the flow rate recorded by the chart recorder to check its accuracy. As long as the sampling flow rate was found to fall within the range of 39 to 60 ft^3/min specified by the Federal Register (1982, p. 54913), it was considered acceptable.

The one point calibration check was accomplished by connecting the manometer to the rubber hose from the pump. After the sampler was turned on, the number of centimeters of fluid displacement recorded by the manometer was compared against the calibration curve for that instrument to arrive at the flow rate. This rate was then compared against the chart recorder to check its accuracy.

After each sampler was checked for calibration, a clean piece of filter paper was mounted to a decontaminated stainless-steel filter holder, which in turn was mounted in place over the sampler inlet. A clean disk was added to the chart recorder, and the starting position on the chart was initialed and marked with the date and time. The sampler pump was then turned on to begin sample collection. A sample logsheet was used to record sampling times and other pertinent information.

At the end of sampling, the sampler pump was turned off. The ending sampling time and date were recorded both on the chart recording disk and on the sample logsheet. The filter paper was carefully removed from the stainless-steel filter holder, folded in half, slid into a plastic Ziplock™ bag, and then sealed. The sample bag and sample logsheet were placed in a large manilla envelope and sealed. A chain-of-custody seal was placed across the envelope flap before shipping the sample to the laboratory for gross alpha and gross beta analysis.

The activity measurements were conducted by Battelle Columbus Division using a Tennelec Series III 5100 Automatic Alpha and Beta/Gamma Counting System both before and after weight measurements were performed, following a 24 hour exposure to controlled humidity and temperature conditions. This exposure allowed the moisture content of the filter to equilibrate with the room conditions. Without such exposure, the variation in moisture content of the filter would affect the accuracy of the particulate mass determination. Samples from the filters were prepared by cutting a circular section 4.45 cm in diameter from the sample filter. Each sample was counted for 40 minutes and the measured activity was scaled up to reflect the area of the entire filter.

3.6.2.3.2 Routine Environmental Air Monitoring

Ambient air samples were collected routinely during the following work activities: concrete and asphalt core drilling, soil core sampling, borehole installation and sampling, bunker sampling, and surface debris cleaning and sampling inside Shelter 204. The purpose of this sampling was to determine if the above-mentioned work activities had any effect on surrounding ambient air quality. These samples were collected from the same sampling locations as were the baseline ambient air samples (Figure 3-8). Section 3.6.2.3.1 provides details on sampling equipment, calibration procedures, sample handling, and record keeping. A meteorological station set up on the site recorded local meteorological conditions during all working hours.

Each morning prior to the activities described above, a new piece of filter paper was loaded into each sampler before being started. At the end of the day, sample filters were removed, folded, and sealed in a plastic Ziplock™ bag. Each bag was then labeled noting the date, time, and duration of sample collection, as well as the sampler's name. Those samples collected during the activities most likely to generate alpha particles were scanned on site for total alpha radiation using the PAC-4G and sent to the SAIC Laboratory in Rockville, Maryland. One blank and one duplicate filter were also analyzed. Certain filters were scanned with the PAC-4G and stored on site. Filter samples were stored for future analysis if any suspected fugitive emissions from work activities were released.

3.6.2.3.3 Breathing Zone Air Monitoring

During all intrusive sampling or work activities, instruments that monitor breathing zone air were operating. Two instruments used included an Eberline Alpha 3 Constant Air Monitor (CAM) with an Air Pump (RAP-1) and Staplex TF-1A with an Air Sampler (RAS) calibrated for use with a 10-foot tygon tube. A RADECO Selective Alpha Monitor (SAM) Model 442A with a high-flow air sampler was also available on site. Each instrument was set to react to a threshold, set on site, with an audible alarm and/or a recorded printout.

After Shelter 204 was enclosed in plastic for the cleanup and sampling work being performed, two of these instruments were set up: one inside the shelter and the other outside the shelter. This provided verification that the correct levels of worker respiratory protection were being maintained, and assured that fugitive emissions were not escaping from the containment structure.

3.6.2.4 In-situ Surveys

Three separate in-situ surveys were performed onsite. The first was a survey of the known areas of contamination using a hyper-pure germanium detector to determine the boundaries of contamination. The other two surveys used a field instrument to detect low-energy radiation (FIDLER) to assess contamination on the concrete apron south of Shelter 204 and to validate the surface disposition modeling. Following the in-situ surveys, surface soil samples were collected to delineate or confirm the extent of possible contamination.

3.6.2.4.1 Hyper-Pure Germanium Detector Survey

A hyper-pure germanium (HPG) detector was used to assist in defining the boundaries of the known plutonium contamination that resulted from the 1960 missile fire and subsequent fire fighting activities (Figure 3-13). This was done by measuring the x/gamma radiation emitted by the ^{241}americium isotope (Am-241, a plutonium daughter).

It should be noted that ^{239}plutonium (Pu-239) has a very low energy (17 KeV) gamma ray which is difficult to detect on any instrument. Since it has been 30 years since the accident, it is expected that much of the plutonium has migrated deep enough into the soil so that lower energies of both gamma and alpha radiation from the plutonium would be almost totally absorbed by the soil and, hence, would be undetectable. However, Am-241 is formed during the decay of Pu-239. It emits a higher-energy x/gamma ray (60 KeV) which is more easily measured.

The HPG was adjusted to focus on the 60 KeV energy peak of Am-241 because of its relatively high energy and penetrating power. To increase the counting efficiency of the HPG, two low-energy photon detectors with thin beryllium windows were used. These windows were designed specifically to measure x-ray and gamma radiation in the energy range of interest.

The HPG was powered by electricity generated by a portable, gas-powered generator. The electrical power was first run through a power conditioner to prevent variations in current and voltage from damaging the equipment. The high voltage power supply and amplifier for each detector were standard nuclear instrumentation modules (NIM) mounted in NIM bins. The signal was processed using an analog to digital converter (ADC) and a multichannel analyzer (MCA) connected to an IBM-compatible portable computer. The spectra were analyzed using commercially available software prepared by Nuclear Data Corporation.

The detector and a lead shield used as a collimator were mounted on a portable stand and suspended four feet above the ground surface at each sampling location (Figure 3-14). The collimator and detector height defined a circular sampling area (Figure 3-15) with a diameter of 4m (12.57 square meters).

The low energy photon detectors were calibrated using a National Institute of Standards and Technology (NIST)-traceable, mixed nuclide point source. As part of the calibration, the point source was measured at several locations around the detector to determine how the efficiency changed as the distance from the detector changed.

An experiment was performed before the commencement of field activities to confirm that the low energy photon detectors were sensitive enough to detect an 8μCi point source of Am-241. The results from this investigation revealed that when the point source was positioned 2 meters from the center of the sample area and 5cm below the ground surface, a sampling time of 3,000 seconds was needed to record the 8 microcurie (μCi, 10^{-6} curie) (Table 3-4). Based on the results from this experiment, it was determined that a 3,000-second count (50 minutes) would be sufficient for each in-situ measurement.

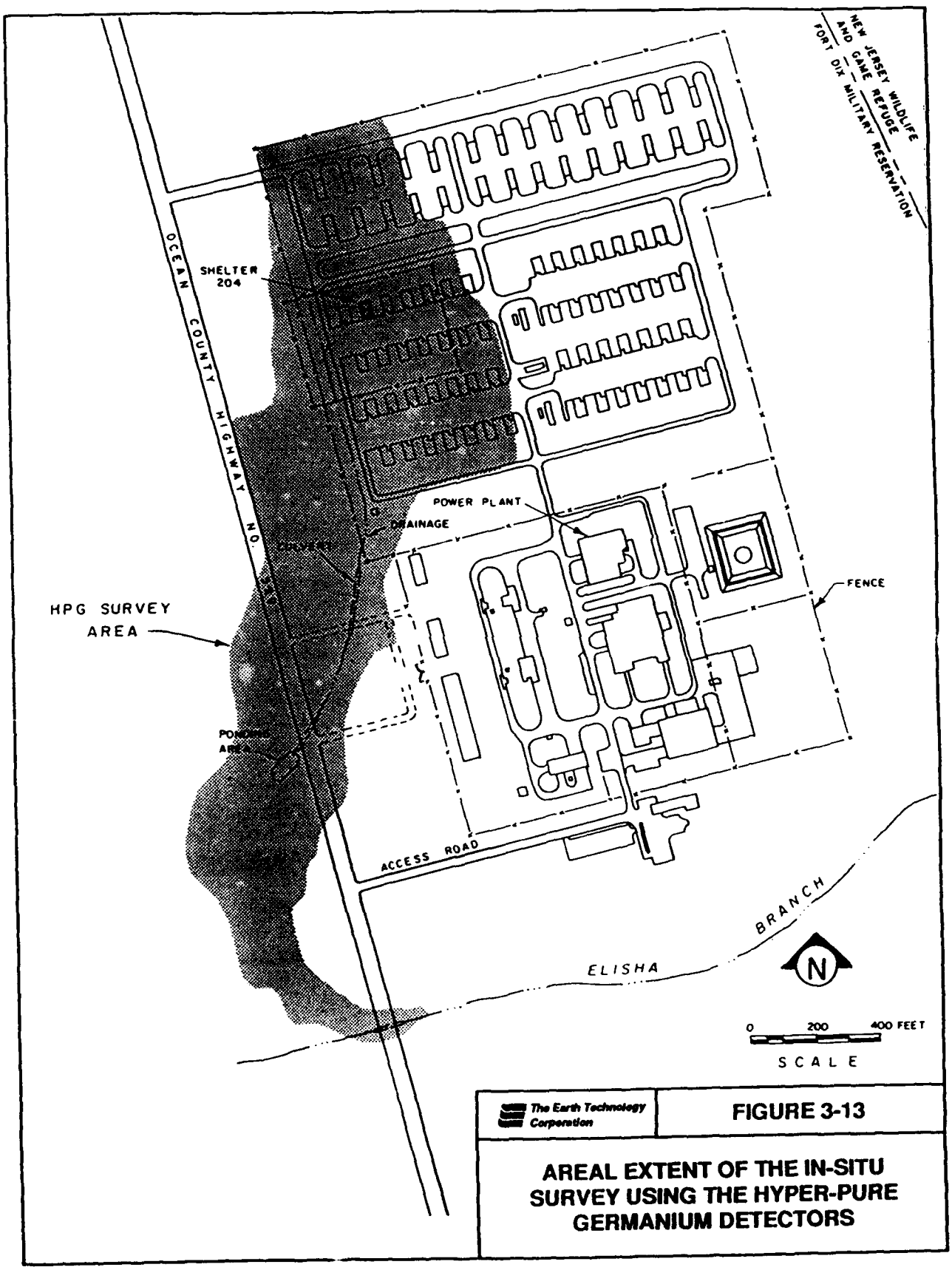

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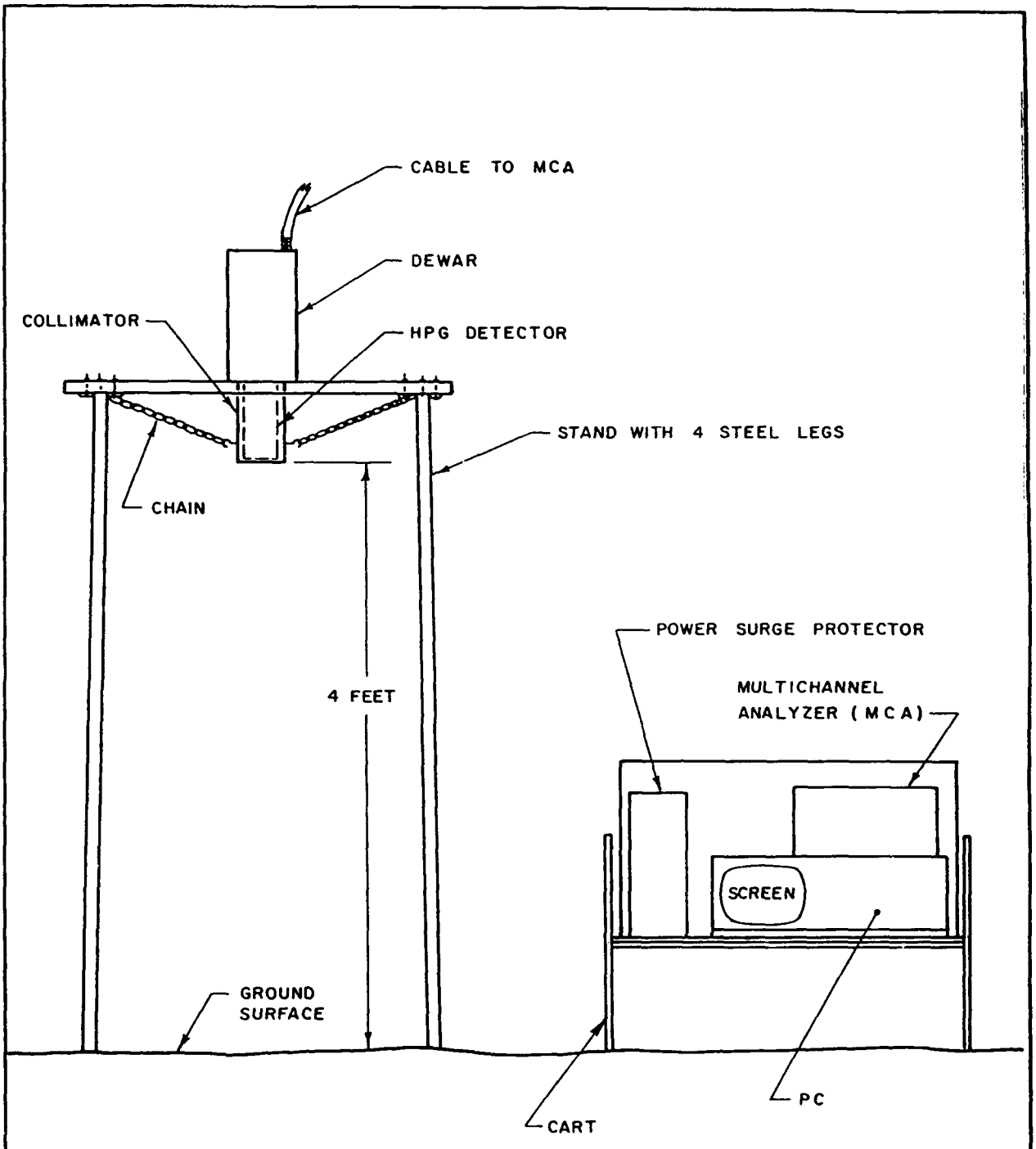
FIGURE 3-13

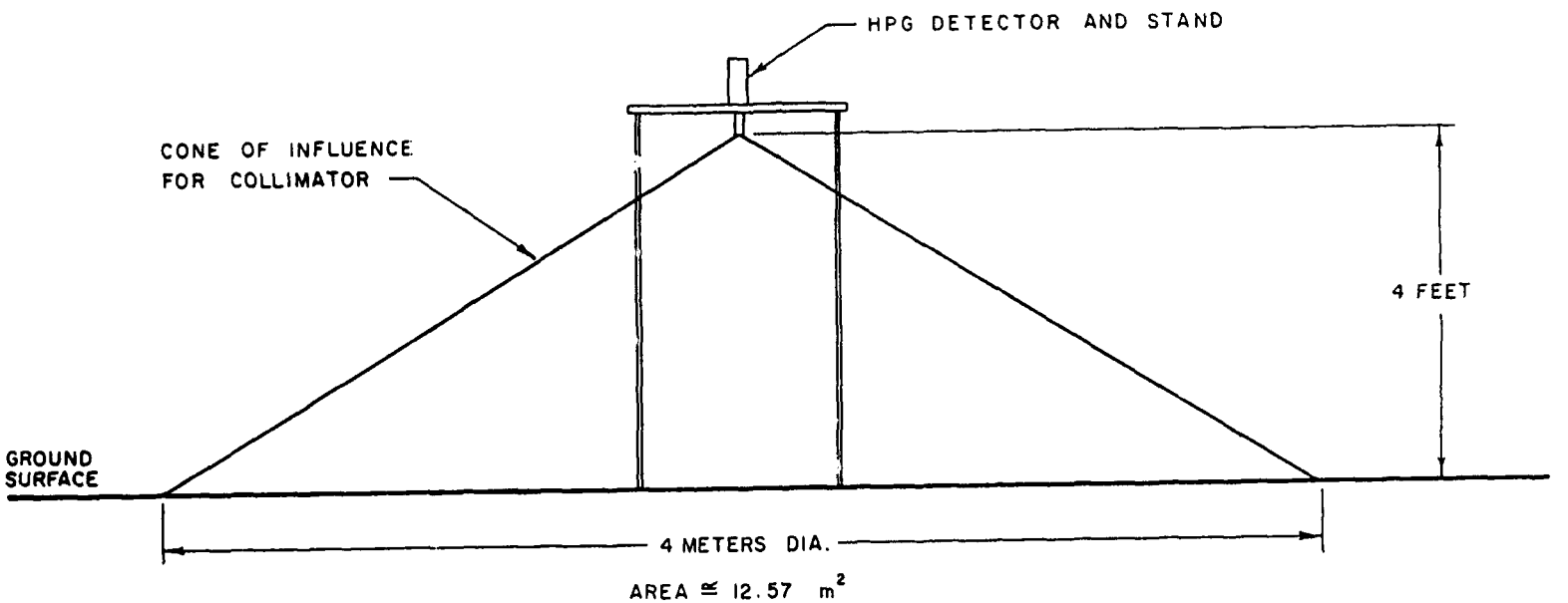
AREAL EXTENT OF THE IN-SITU SURVEY USING THE HYPER-PURE GERMANIUM DETECTORS



The Earth Technology Corporation

FIGURE 3-14

SCHEMATIC DIAGRAM OF THE SETUP FOR THE HYPER-PURE GERMANIUM DETECTOR INCLUDING THE MULTICHANNEL ANALYZER AND COMPUTER



SCALE : $\frac{1}{2}$" = 1'

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FIGURE 3-15

CONE OF INFLUENCE DEFINED BY THE HYPER-PURE GERMANIUM DETECTOR AND COLLIMATOR

Table 3-4
In-Situ Measurement Experiment Results
(Count Times Required to Detect 8 μCi of Am-241)

	Distance From Center of Sample Area		
Depth	0 meters	1 meter	2 meters
0.0 cm	100 sec.	100 sec.	100 sec.
2.5 cm	100 sec.	100 sec.	1,000 sec.
5.0 cm	300 sec.	1,000 sec.	3,000 sec.

Prior to beginning the HPG detector survey, a sampling grid with 60 feet spacings was laid out using a tape and compass. Inside of the BOMARC property fence, a 183-point grid was positioned around Shelter 204. Outside the property fence, a 222-point grid was extended to the southwest across Highway 539 and on to the headwaters of the Elisha Branch following the main drainage (Figure 3-13). Each sampling point was marked with either spray paint or a pin flag. The sampling stations within the facility fence were surveyed before those outside the fence.

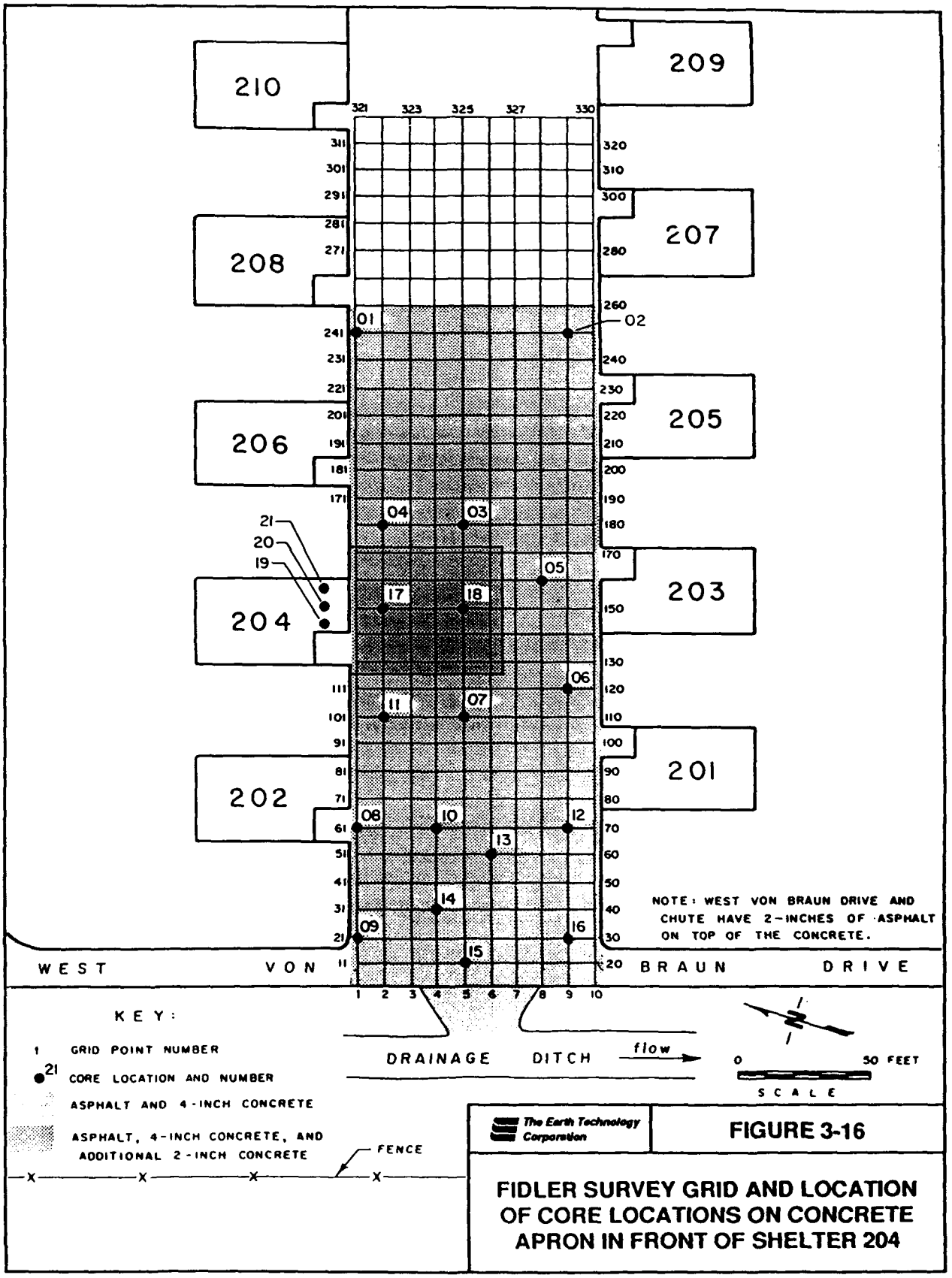
3.6.2.4.2 FIDLER Surveys

Two in-situ surveys were performed using a Field Instrument to Detect Low Energy Radiation (FIDLER). The instrument chosen was a Bicron Model G5. The first survey was used to determine the extent of contamination on the concrete apron south of Shelter 204. The second survey was performed to validate the surface deposition modeling predictions.

FIDLER Survey On Concrete/Asphalt Apron. A radiation survey was performed on the concrete/asphalt apron south of Shelter 204 to identify areas showing relatively high levels of low-energy x/gamma radiation. A Bicron Model G5 FIDLER set to detect low-energy x/gamma radiation from Pu-239 and/or Am-241 was used to perform a radiation survey over the top of the concrete and asphalt surface of Lorin Street, just south of Shelter 204.

The FIDLER is a sodium iodide (NaI) scintillation probe designed for field operation. This instrument contains a 5 inch-diameter by 0.063-inch-thick NaI crystal, a 0.01-inch thick low background beryllium radiation entrance window, and a 5-inch by 2-inch quartz optical light pipe. This instrument was calibrated daily by adjusting the single channel analyzer response to an Am-241 calibration source.

The FIDLER survey grid was laid out over the top of Lorin Street, south of Shelter 204, using 10-foot spacings. This grid was extended as far east as Shelter 210 and as far west as the asphalt-lined surface water drainage ditch (Figure 3-16). The probe end of the FIDLER meter was laid directly on top of the concrete or asphalt surface at each of 330 grid intersections. FIDLER readings were observed at each sampling point for approximately one minute, and the highest readings for each point were recorded in a field sampling logbook.


210
209
208
207
206
205
204
203
202
201
321
323
325
327
330
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
NOTE: WEST VON BRAUN DRIVE AND CHUTE HAVE 2-INCHES OF ASPHALT ON TOP OF THE CONCRETE.
WEST VON BRAUN DRIVE
DRAINAGE DITCH
flow
0 50 FEET
SCALE
KEY:
GRID POINT NUMBER
CORE LOCATION AND NUMBER
ASPHALT AND 4-INCH CONCRETE
ASPHALT, 4-INCH CONCRETE, AND ADDITIONAL 2-INCH CONCRETE
FENCE
The Earth Technology Corporation
FIGURE 3-16
FIDLER SURVEY GRID AND LOCATION OF CORE LOCATIONS ON CONCRETE APRON IN FRONT OF SHELTER 204

At the completion of the FIDLER survey, the results from this investigation were plotted on a map and contoured, with core drilling locations chosen based on the highest readings.

FIDLER Survey to Investigate Surface Deposition Model Predictions. A reconnaissance in-situ FIDLER survey of the soil and land areas surrounding Shelter 204 was performed to delineate the extent of plutonium contamination and the information derived was used to investigate the depositional patterns predicted by the surface deposition modeling effort. This survey utilized a hand-held, 5-inch-diameter FIDLER probe coupled to a portable single-channel analyzer (SCA) using an estimated sensitivity of 0.5 $\mu Ci/m^2$. This type of instrument is sensitive to the low energy electromagnetic emissions (x- and gamma rays) emitted by Pu-239 (17 KeV) and its daughter product, Am-241 (60 KeV). Each day the FIDLER was calibrated using an Am-241 source.

This survey was performed in an organized manner using a meteorologically based transect grid (Figures 3-17 and 3-18) centered at Shelter 204. The outer boundaries of the grid were established through modeling and analysis of historical data. The grid focused on those areas downwind of Shelter 204 at the time of the accident and subsequently on those areas downwind of the shelter and drainage ditch that may have been "sources" for resuspension since the accident, but prior to the asphalt and concrete covering of these contamination sources.

Traverses were conducted according to radial transects determined from the surface deposition modeling data. At 43 locations along two of the transects ("A" and "B") and 25 locations at a third transect ("C"), a 15-minute in-situ FIDLER reading was taken at each location and the location was marked with a survey flag (Figure 3-18). Readings were taken every 100 feet for 0.5 miles, then every 300 feet thereafter for a total distance of approximately 1.0 mile. This yielded a total of 111 survey points along the three transects. Soil samples were collected along the transects at 30 locations (Figure 3-18). Soil sample locations were determined from the FIDLER survey at locations showing the highest readings.

During a second analysis of the surface deposition modeling, it was determined that the wind factors may have distributed $\leq$ 20 micron plutonium particles further downwind than originally projected. Therefore, 20 additional survey locations (Figure 3-17) were located south of the BOMARC Missile Site along highway 70 (Transect D).

Each location was spaced approximately 0.5 miles apart and scanned for 15 minutes using the FIDLER.

On November 17, 1989 permission was received from Lakehurst Naval Air Station to extend the "A" transect out to approximately 0.5 mile onto Lakehurst Navel Air Station property. Sixteen (16) locations were added to the survey and each location was scanned for 15 minutes using the FIDLER.

A total of 147 readings and 30 soil samples were taken both on and off site during the site characterization field effort.

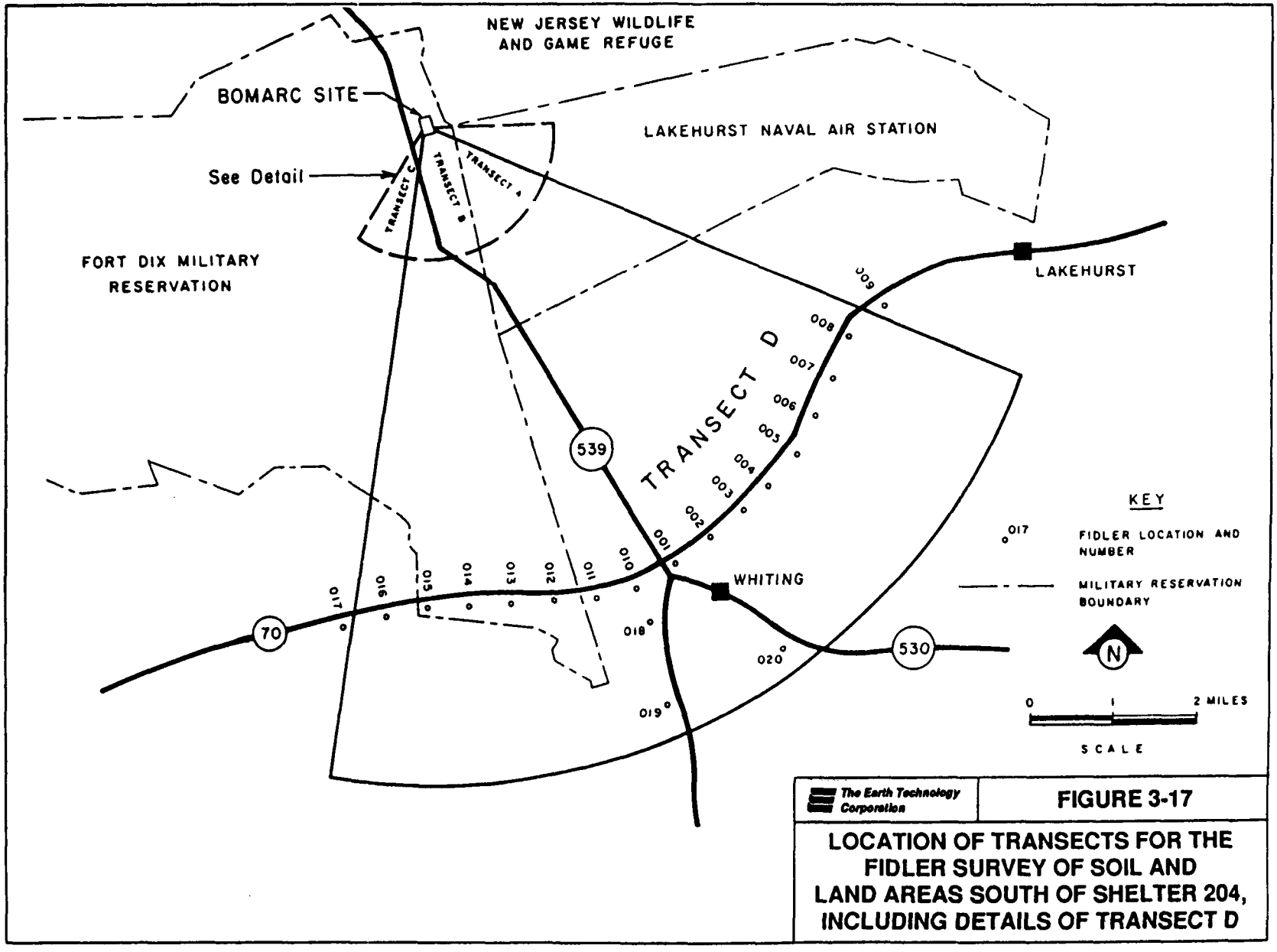


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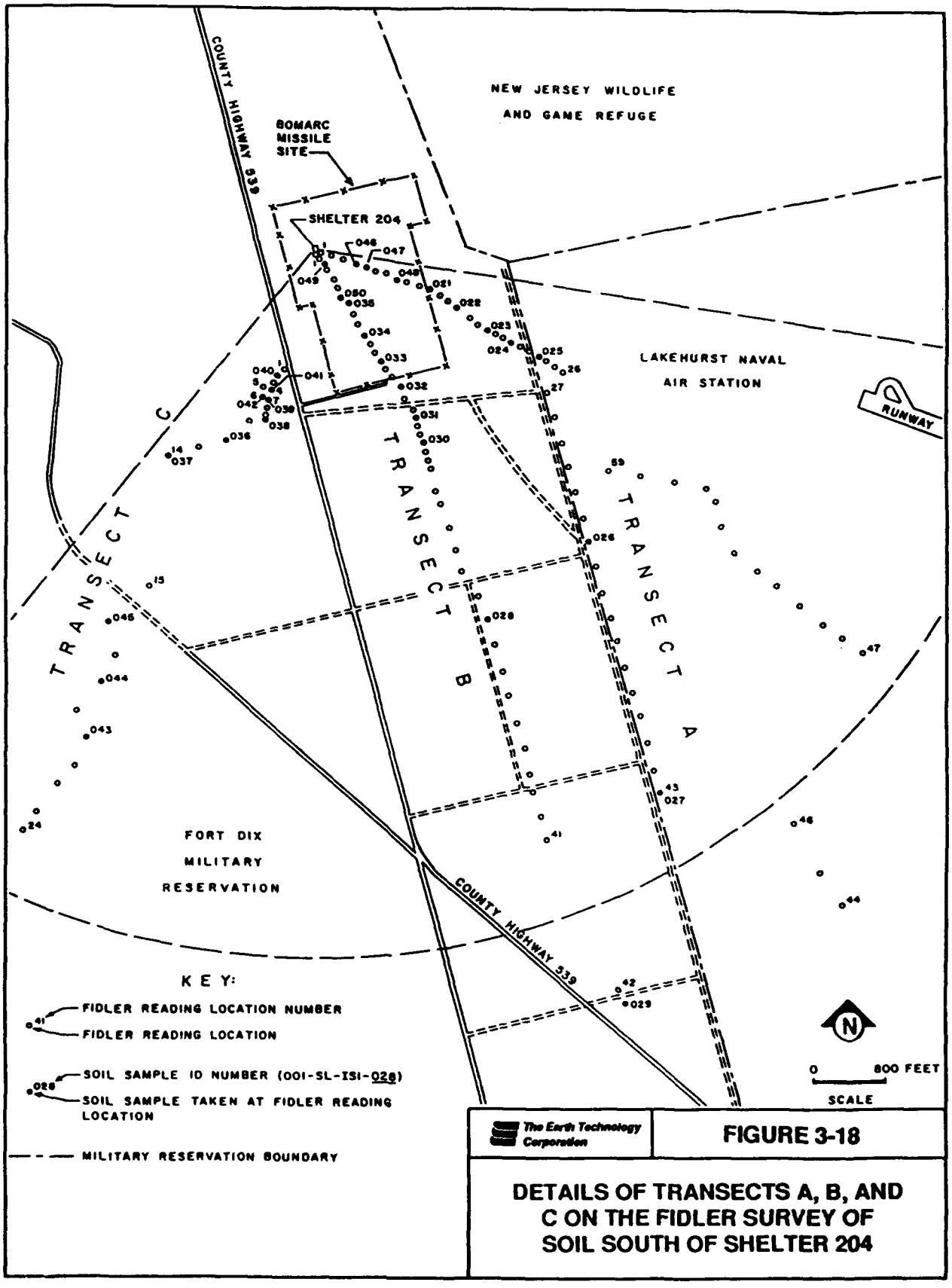
FIGURE 3-17

LOCATION OF TRANSECTS FOR THE FIDLER SURVEY OF SOIL AND LAND AREAS SOUTH OF SHELTER 204, INCLUDING DETAILS OF TRANSECT D


COUNTY HIGHWAY 539
NEW JERSEY WILDLIFE
AND GAME REFUGE
BOMARC
MISSILE
SITE
SHELTER 204
LAKEHURST NAVAL
AIR STATION
RUNWAY
TRANSECT C
TRANSECT B
TRANSECT A
FORT DIX
MILITARY
RESERVATION
COUNTY HIGHWAY 539
KEY:
FIDLER READING LOCATION NUMBER
FIDLER READING LOCATION
SOIL SAMPLE ID NUMBER (001-SL-ISI-028)
SOIL SAMPLE TAKEN AT FIDLER READING LOCATION
MILITARY RESERVATION BOUNDARY
N
0 800 FEET
SCALE
The Earth Technology Corporation
FIGURE 3-18
DETAILS OF TRANSECTS A, B, AND C ON THE FIDLER SURVEY OF SOIL SOUTH OF SHELTER 204

3.6.2.5 Wipe Sampling

In order to evaluate the surface contamination levels in and around Shelter 204, a total of 619 wipe samples were collected from accessible surfaces in 21 shelters (Figure 3-19). In addition, six wipe samples were collected from the power bunker south of Shelter 204. These samples were analyzed onsite for gross alpha activity.

Shelter 210 was the first shelter to be sampled. In this shelter, index sampling stations were established and a total of 44 wipe samples were collected (Figures 3-20, 3-21, 3-22, 3-23, 3-24, and 3-25). These particular stations were selected as positions where air particulate matter would be likely to accumulate. Sampling stations included numerous positions on the concrete floor, and horizontal surfaces of missile launchers, support beams, light fixtures, control panels, electrical control boxes, ventilation louvers, and pipes (Table 3-5). Each sampling point in this shelter was permanently marked with a station number (1 - 44) for future reference.

Samples were collected by placing a plastic 10 cm × 10 cm template over the top of each sampling point to outline the sample area. When practical, each sampling location was screened for alpha particles using a PAC-4G meter before sample collection. One dry Whatman filter paper (size #2) was then used to collect the sample by wiping inside that template area (Figure 3-26).

The wiping technique used the filter paper to initially pull any dust and dirt from the edges of the sampling area to the center (Figure 3-26). The filter paper was then laid flat in the center of the sampling area and moved in a circular motion until the bottom side of the paper was well coated with dust. The coated filter paper was then placed inside a labeled Ziplock™ bag and sealed. When all the samples had been collected from within a shelter, they were placed in one large Ziplock™ bag, sealed, and placed in a cooler until they were analyzed for alpha activity on site using a Ludlum Model 2000 scaler with alpha scintillation detector.

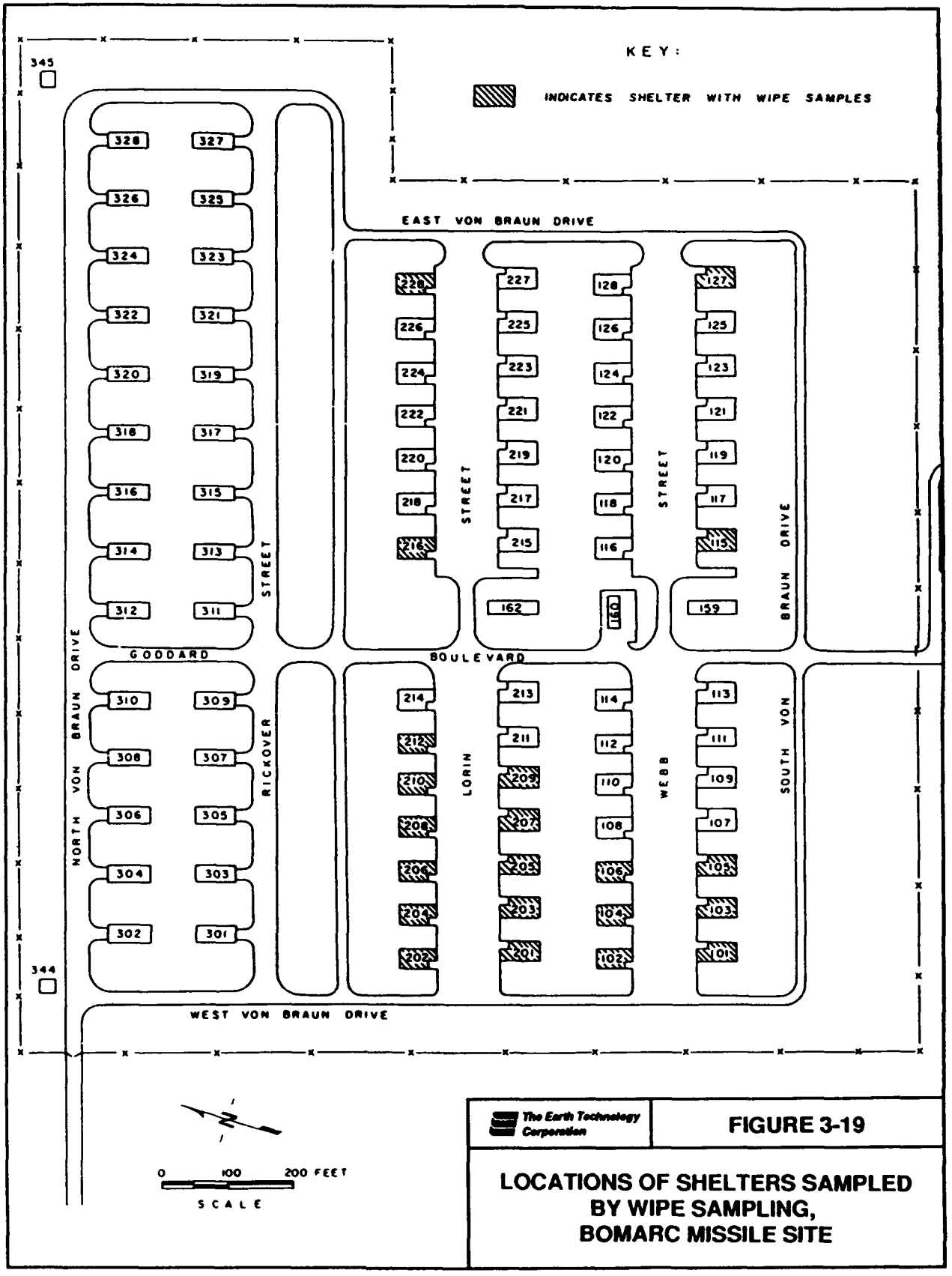
Ten samples and one blank sample were shipped to the laboratory for alpha spectroscopy analysis.

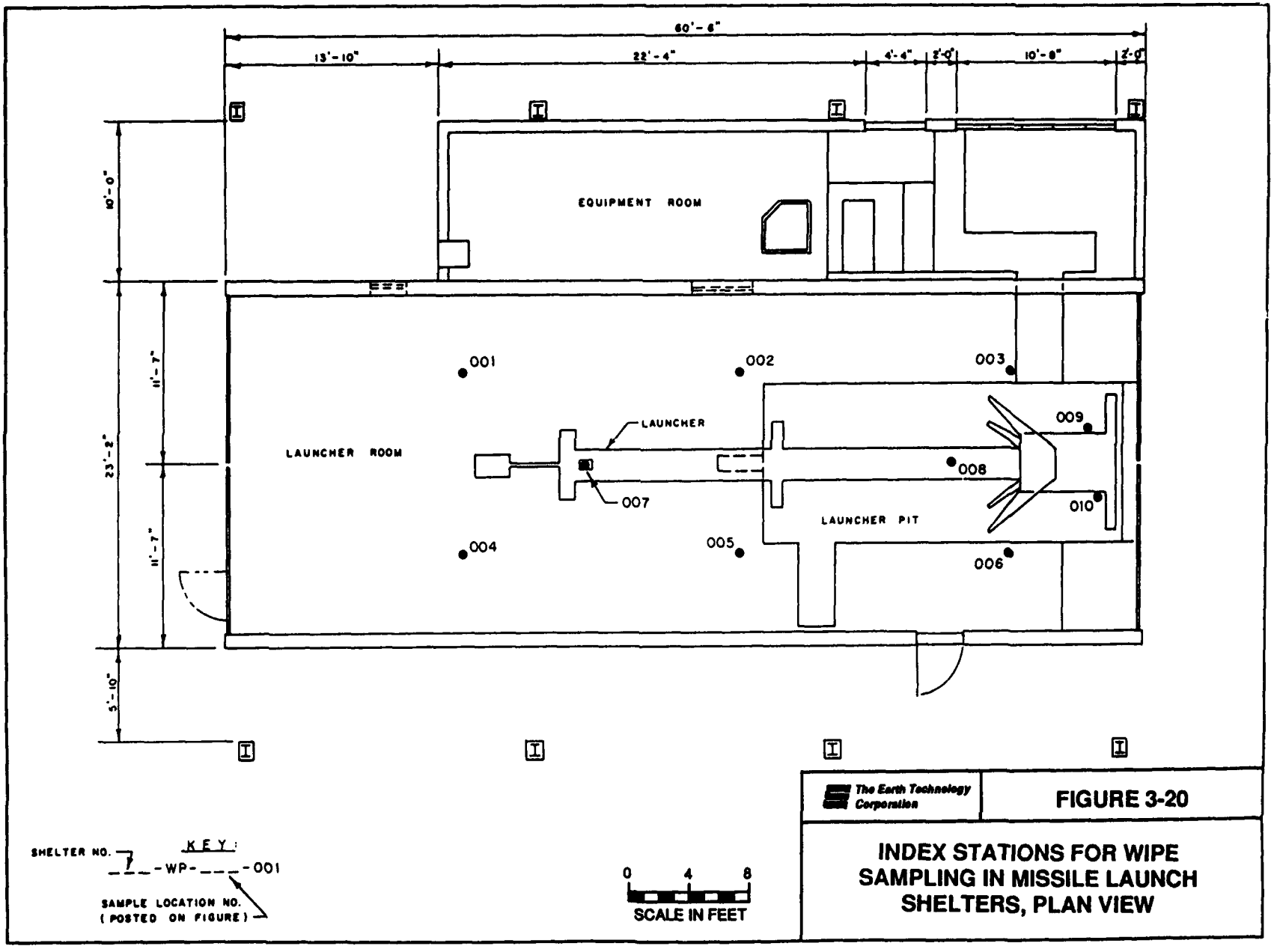
3.6.2.5.1 Launcher Shelter 204

A total of 100 wipe samples were collected from Shelter 204. Where possible, these samples were collected from the originally designated 44 sampling stations (Table 3-5 and Figures 3-21 through 3-25) as well as from additional locations unique to Shelter 204 (Table 3-6, Figures 3-27 through 3-32).

3.6.2.5.2 Other Launcher Shelters

A total of 25 wipe samples were collected from each of 19 additional shelters (Shelters 201, 202, 203, 205, 206, 207, 208, 209, 212, 101, 102, 103, 104, 105, 106, 115, 127, 216, and 228). The majority of these were in the immediate vicinity of Shelter 204 (Figure 3-19), but some


KEY:
INDICATES SHELTER WITH WIPE SAMPLES
345
344
EAST VON BRAUN DRIVE
WEST VON BRAUN DRIVE
NORTH VON BRAUN DRIVE
SOUTH VON BRAUN DRIVE
GODDARD BOULEVARD
STREET
RICKOVER STREET
LORIN STREET
WEBB STREET
328 327 326 325 324 323 322 321 320 319 318 317 316 315 314 313 312 311
310 309 308 307 306 305 304 303 302 301
228 226 224 222 220 218 216
227 225 223 221 219 217 215 162
128 126 124 122 120 118 116 160
127 125 123 121 119 117 115 159
214 212 210 208 206 204 202
213 211 209 207 205 203 201
114 112 110 108 106 104 102
113 111 109 107 105 103 101
0 100 200 FEET
SCALE
The Earth Technology Corporation
FIGURE 3-19
LOCATIONS OF SHELTERS SAMPLED BY WIPE SAMPLING, BOMARC MISSILE SITE


60'-6"
13'-10"
22'-4"
4'-4"
2'-0"
10'-8"
2'-0"
20'-0"
11'-7"
23'-2"
11'-7"
5'-10"
EQUIPMENT ROOM
LAUNCHER ROOM
LAUNCHER
LAUNCHER PIT
001
002
003
004
005
006
007
008
009
010
KEY:
SHELTER NO.
-WP-
-001
SAMPLE LOCATION NO.
(POSTED ON FIGURE)
0 4 8
SCALE IN FEET
The Earth Technology Corporation
FIGURE 3-20
INDEX STATIONS FOR WIPE SAMPLING IN MISSILE LAUNCH SHELTERS, PLAN VIEW

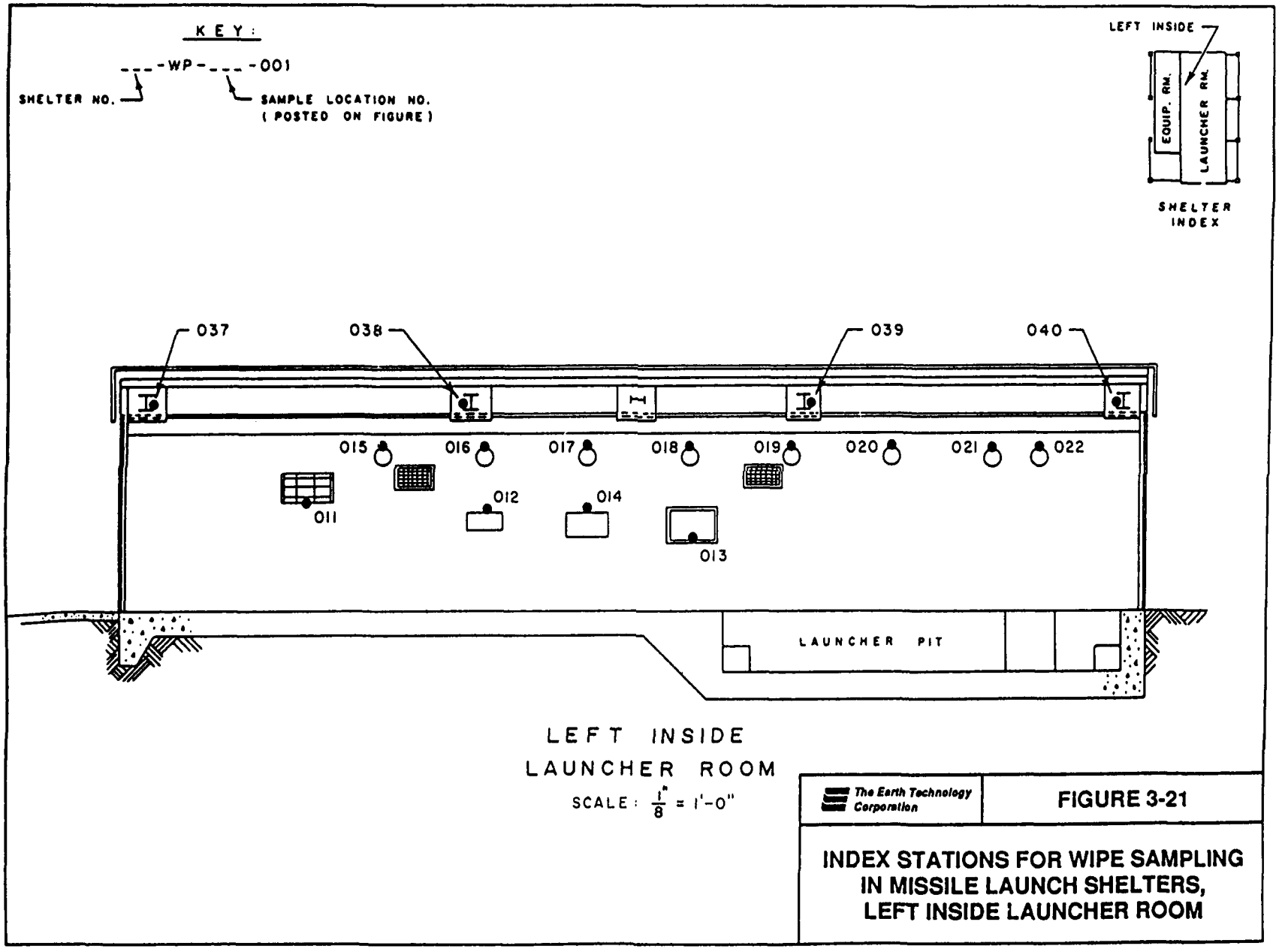


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FIGURE 3-21

INDEX STATIONS FOR WIPE SAMPLING IN MISSILE LAUNCH SHELTERS, LEFT INSIDE LAUNCHER ROOM

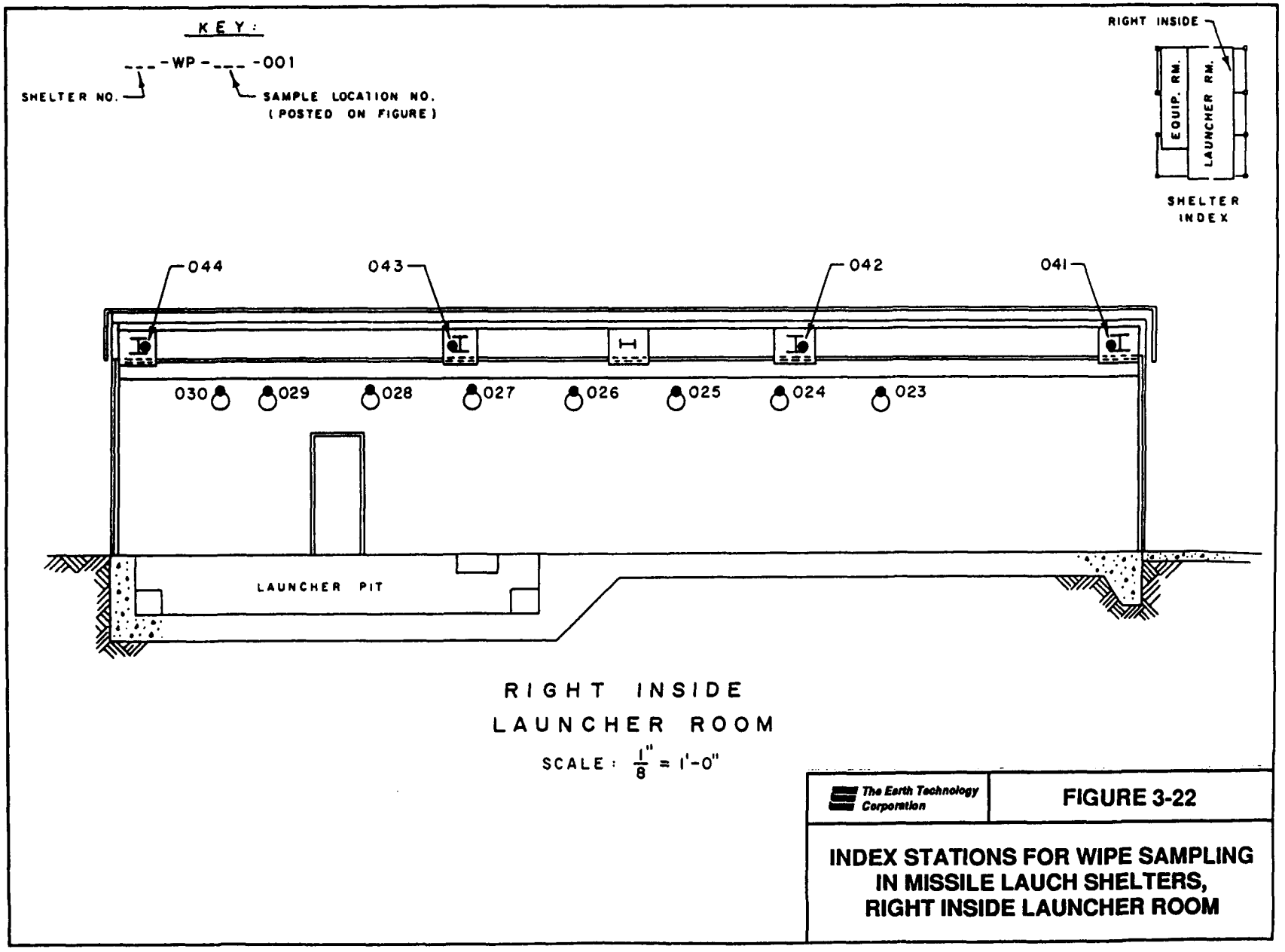

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FIGURE 3-22

INDEX STATIONS FOR WIPE SAMPLING IN MISSILE LAUCH SHELTERS, RIGHT INSIDE LAUNCHER ROOM

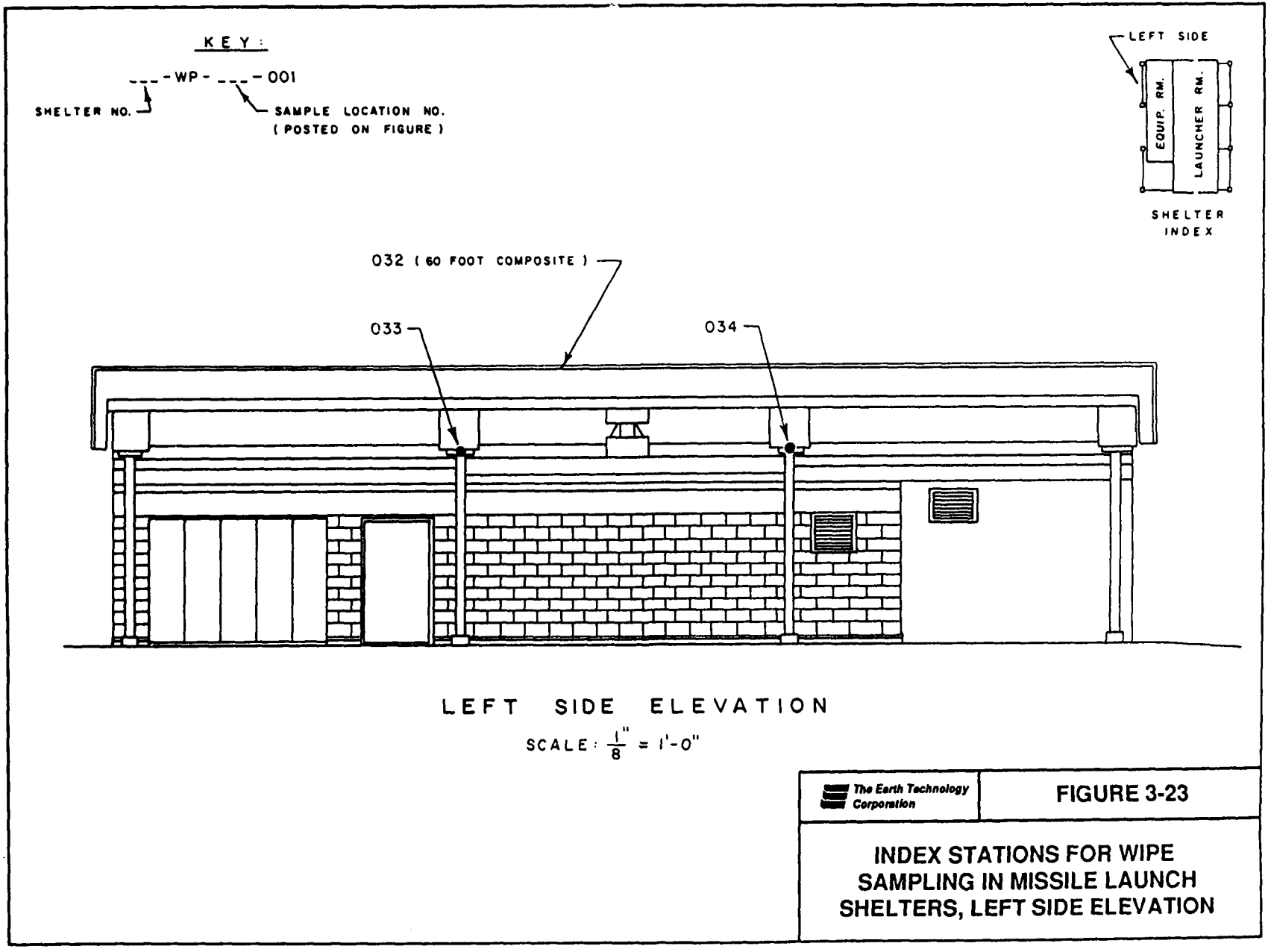

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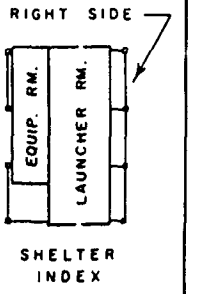
FIGURE 3-23

INDEX STATIONS FOR WIPE SAMPLING IN MISSILE LAUNCH SHELTERS, LEFT SIDE ELEVATION

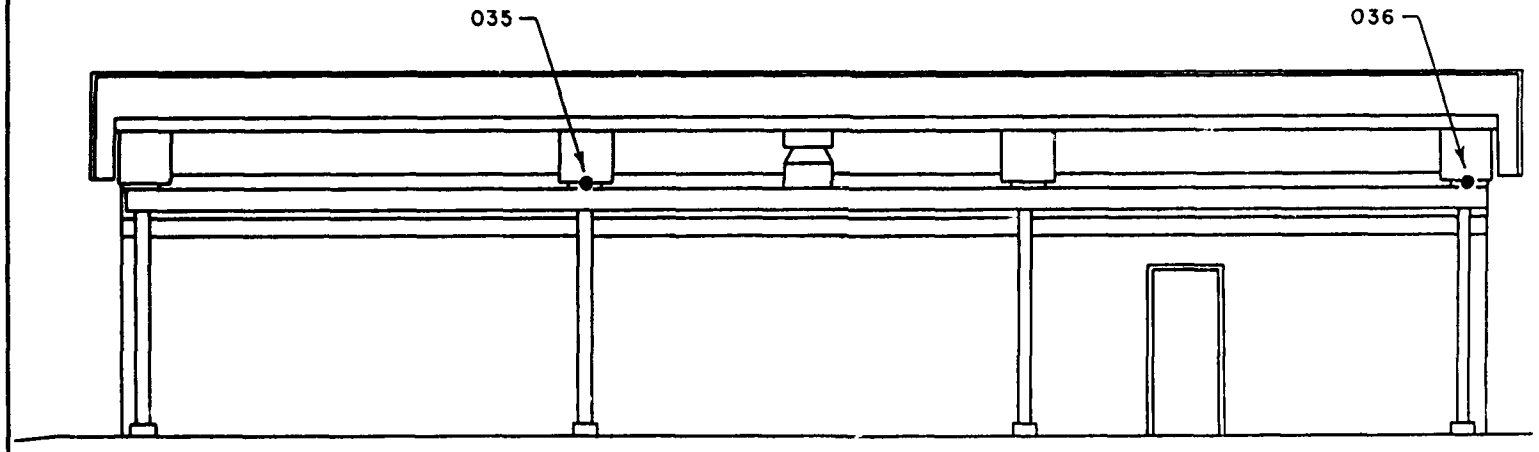
KEY:

---WP-----001

SHELTER NO. — SAMPLE LOCATION NO. (POSTED ON FIGURE)



SHELTER INDEX



RIGHT SIDE ELEVATION

SCALE: $\frac{1"}{8}$ = 1'-0"

The Earth Technology Corporation

FIGURE 3-24

INDEX STATIONS FOR WIPE SAMPLING IN MISSILE LAUNCH SHELTERS, RIGHT SIDE ELEVATION

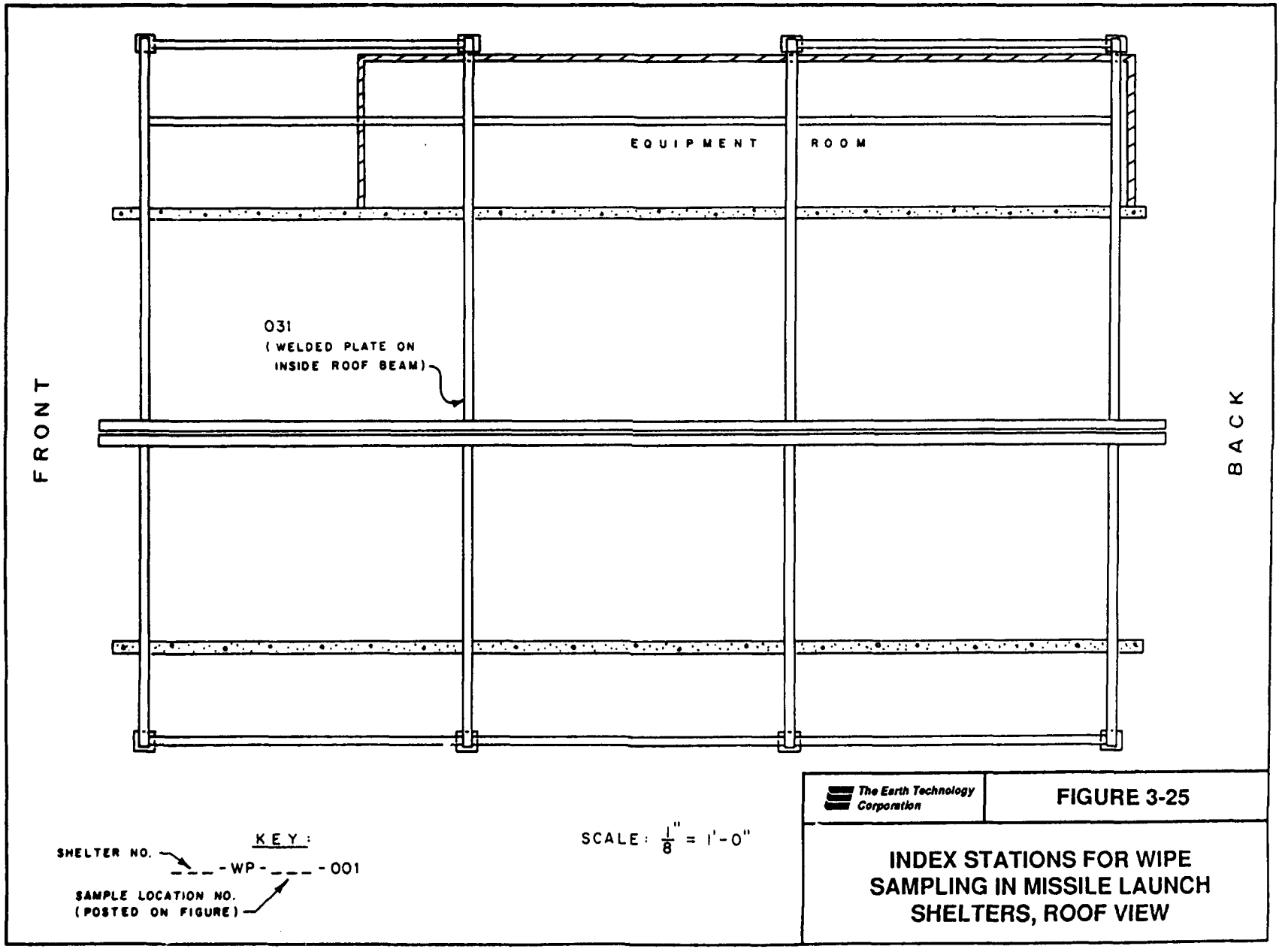


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FIGURE 3-25

INDEX STATIONS FOR WIPE SAMPLING IN MISSILE LAUNCH SHELTERS, ROOF VIEW

Table 3-5
Wipe Sampling Stations Established for Launcher Shelters

Shelter No.	Station No.	Station Description
		FLOOR WIPES
210 - WP - 001	- 001	Floor, direct line from 1st light (closest to big doors), left* side 5 ft. out from wall.
210 - WP - 002	- 001	Floor, direct line from 4th light (counted from main doors), left* side (facing back doors), 5 ft. out from wall.
210 - WP - 003	- 001	Floor, direct line from and perpendicular to 7th light, left* side, 5 ft. out from wall.
210 - WP - 004	- 001	Floor, direct line from 1st light, right* side, 5 ft. out from wall.
210 - WP - 005	- 001	Floor, direct line from 4th light, right* side, 5 ft. out from wall.
210 - WP - 006	- 001	Floor, direct line from 7th light, right* side, 5 ft. out from wall.
		LAUNCHER WIPES
210 - WP - 007	- 001	Forward part of launcher, center of electrical control box.
210 - WP - 008	- 001	Center rear of launcher, behind cable protection plate, between that plate and a tricorn-shaped bonnet.
210 - WP - 009	- 001	Horizontal ledge, rear, left side of launcher, on main part of launcher behind cables. Floor level.

Table 3-5 (continued)
Wipe Sampling Stations Established for Launcher Shelters

Shelter No.	Station No.	Station Description
210 - WP - 010 - 001		Horizontal corner ledge, rear right side of launcher on main part of launcher. About 2 ft. below floor level.
*		"Left" and "right" determined by standing at front of shelter (where nose of missile would have been) and looking to the rear (toward launcher mechanism and pits).
		ELECTRICAL CONNECTORS
210 - WP - 011 - 001		Ventilation louvers, left side of shelter, bottom ledge; left corner to 19 inches from that corner.
210 - WP - 012 - 001		Left side of shelter, Bottom of shelf in hole (13 3/4 x 5 7/8") in concrete wall leading to pneumatic control panel.
210 - WP - 013 - 001		Left side of shelter ledge on pass-through window from control room (3' wide x 17" high) Sampled center of ledge on edge closest to control room.
210 - WP - 014 - 001		Left side shelter, top of missile test conn. box; Dead center of top of box.
		LIGHT FIXTURES
210 - WP - 015 - 001		Top of light fixture box, left side, light no. 1 (counting in from front doors).
210 - WP - 016 - 001		Top of light no. 2, left side.
210 - WP - 017 - 001		Top of light no. 3, left.
210 - WP - 018 - 001		Top of light no. 4, left.

Table 3-5 (continued)
Wipe Sampling Stations Established for Launcher Shelters

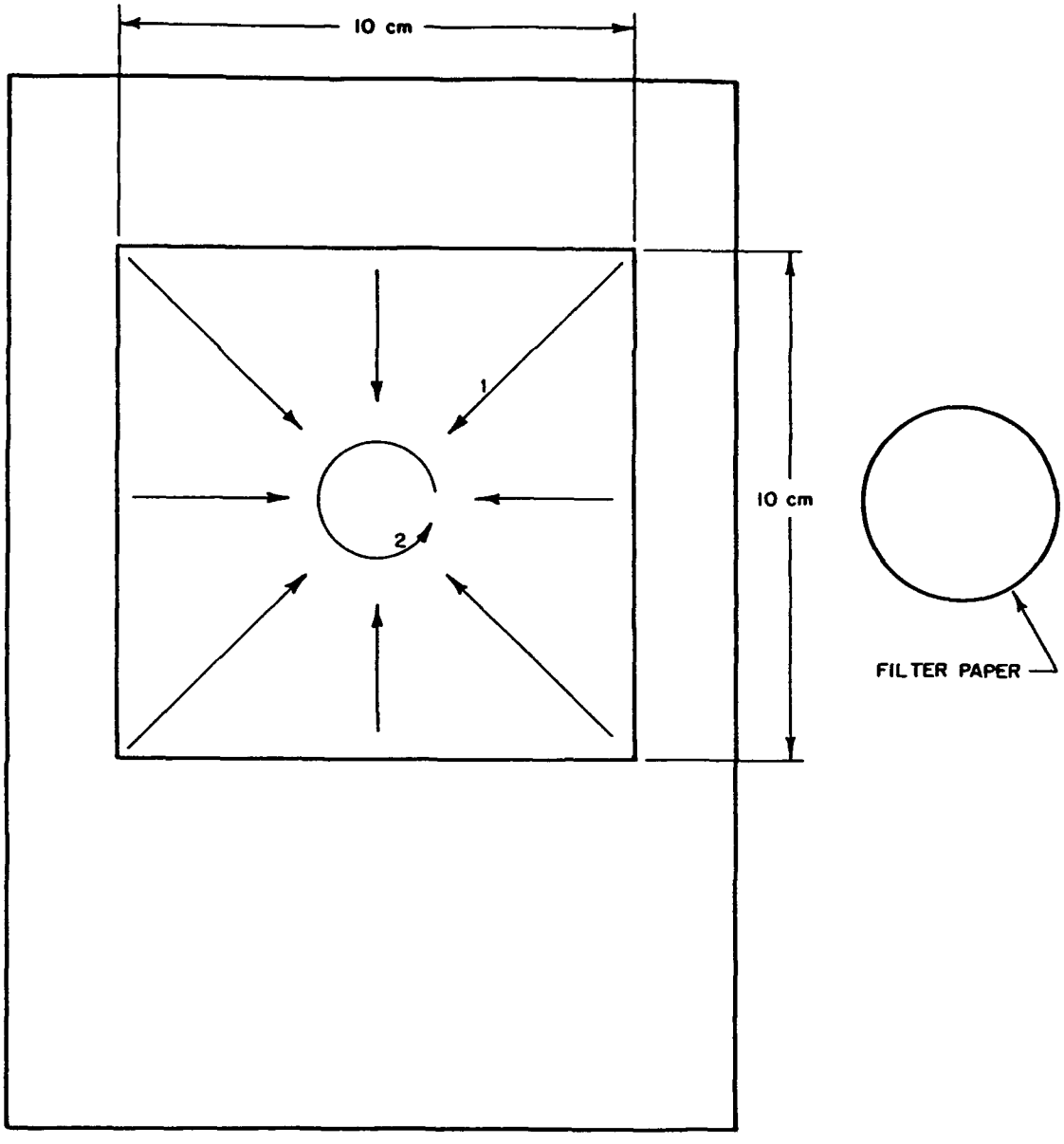
Shelter No.	Station No.	Station Description
210 - WP - 019 - 001		Top of light no. 5, left.
210 - WP - 020 - 001		Top of light no. 6, left.
210 - WP - 021 - 001		Top of light no. 7, left.
210 - WP - 022 - 001		Top of light no. 8, left.
210 - WP - 023 - 001		Top of light no. 1, right side of shelter.
210 - WP - 024 - 001		Top of light no. 2, right.
210 - WP - 025 - 001		Top of light no. 3, right.
210 - WP - 026 - 001		Top of light no. 4, right.
210 - WP - 027 - 001		Top of light no. 5, right.
210 - WP - 028 - 001		Top of light no. 6, right.
210 - WP - 029 - 001		Top of light no. 7, right.
210 - WP - 030 - 001		Top of light no. 8, right.
		INSIDE HIGH ROOF BEAM WIPES
210 - WP - 031 - 001		Horizontal roof plate, front left center of shelter - 18 ft. in from door top of plate.

Table 3-5 (continued)
Wipe Sampling Stations Established for Launcher Shelters

Shelter No.	Station No.	Station Description
		OUTSIDE WIPES
210 - WP - 032 - 001		60 ft composite swipe along the top of the roof beam (astragal). Composite will be of the total length of beam.
210 - WP - 033 - 001		4th cross I-beam from the front of the shelter - the vertical portion of the center of I-beam - on equipment room side of shelter.
210 - WP - 034 - 001		2nd cross I-beam from the front of the shelter - the vertical portion of the center of I-beam - on equipment room side of shelter.
210 - WP - 035 - 001		2nd cross I-beam from the front of the shelter - horizontal portion of center of beam - on the non-equipment side of the shelter.
210 - WP - 036 - 001		5th (last) cross I-beam from the front horizontal portion of center of beam; on the non-equipment side of the shelter.
		INSIDE SHELTER WIPES - ROOF BEAMS ABOVE CONCRETE WALLS
210 - WP - 037 - 001		Left front corner of shelter; top of main (first) I-beam directly above concrete wall.
210 - WP - 038 - 001		Left side, 2nd main I-beam (20 ft. from front of shelter); top of I-beam directly above concrete wall.
210 - WP - 039 - 001		Left side, 4th main I-beam (40 ft. from front of shelter), top of I-beam directly above concrete wall.

Table 3-5 (continued)
Wipe Sampling Stations Established for Launcher Shelters

Shelter No.	Station No.	Station Description
210 - WP - 040 - 001		Left side, last main I-beam by back doors, top of I-beam directly above concrete wall.
210 - WP - 041 - 001		Right side, front corner of shelter; top of main (first) I-beam, directly above concrete wall.
210 - WP - 042 - 001		Right side, 2nd main I-beam (20 ft. from front); top of I-beam, directly above concrete wall.
210 - WP - 043 - 001		Right side, 4th main I-beam (40 ft. from front); top of I-beam, directly above concrete wall.
210 - WP - 044 - 001		Right side, last main I-beam by back doors, top of I-beam directly above concrete wall.



KEY:

→ WIPING MOTION

1 COLLECT DUST TO CENTER

2 CIRCULAR WIPING MOTION

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FIGURE 3-26

SCHEMATIC DIAGRAM OF THE WIPE SAMPLING TEMPLATE AND SAMPLE FILTER PAPER, WITH ARROWS ILLUSTRATING THE SAMPLING PROCEDURE

Table 3-6
Wipe Sampling Stations Established For Launcher Shelter 204

Sample No.	Station Description
	EQUIPMENT ROOM WIPES
204-WP-001-001	Right side of shelter, close to wall on the 1st beam.
204-WP-002-001	Right side of shelter, in the center of 2nd beam.
204-WP-003-001	Right side of shelter, in the center of 3rd beam.
204-WP-004-001	Right side of shelter, on the 4th beam.
204-WP-005-001	Right side of shelter, on the 5th beam.
204-WP-006-001	Right side of shelter, on the 6th beam.
204-WP-007-001	Right side of shelter, on the 7th beam.
204-WP-008-001	(Upper) control box between 6 and 7 on the right side of shelter.
204-WP-009-001	Support location under right side of 8th beam.
204-WP-010-001	Right side of shelter next to beam 9.
204-WP-011-001	Right side of shelter close to the 12th beam.
204-WP-012-001	Right side below the 9th beam.
204-WP-013-001	Right side of shelter on beam 10.
204-WP-014-001	Right side of shelter, on top of beam 11.

Table 3-6 (continued)
Wipe Sampling Stations Established For Launcher Shelter 204

Sample No.	Station Description
204-WP-015-001	Right side of shelter, bottom side of 12th beam.
204-WP-016-001	The gear guide adjacent to beam 12.
204-WP-017-001	Right side of shelter under the 13th beam.
204-WP-018-001	On the door hinge that's adjacent to beam 13.
204-WP-019-001	The underside of beam 14.
204-WP-020-001	Left side of shelter, 1st beam from front to back.
204-WP-021-001	Left side of shelter on 2nd beam.
204-WP-022-001	Left side of shelter top of 3rd beam.
204-WP-023-001	Top of gear guide, left side of shelter, below the 3rd beam.
204-WP-024-001	Left side of shelter on 4th beam.
204-WP-025-001	Left side of shelter on the 5th beam.
204-WP-026-001	Left side of shelter on the 6th beam.
204-WP-027-001	Left side of shelter on the 7th beam.

Table 3-6 (continued)
Wipe Sampling Stations Established For Launcher Shelter 204

Sample No.	Station Description
204-WP-028-001	Left side of shelter on the 8th beam.
204-WP-029-001	Left side of shelter on the 9th beam.
204-WP-030-001	Left of beam 10, on left side of gear guide box.
204-WP-031-001	Left side of shelter on beam 11.
204-WP-032-001	On door guide of left side of shelter.
204-WP-033-001	On door guide near beam 12 of left side.
204-WP-034-001	Left side of shelter of beam 13.
	LAUNCHER ROOM WIPES
204-WP-035-001	Right wall of building, 10 feet from front entrance and 5 feet above the floor.
204-WP-036-001	Right wall of building, 20 feet from front entrance and 5 feet above the floor.
204-WP-037-001	Right wall of shelter, 30 feet from front entrance and 5 feet above the floor.
204-WP-038-001	Right wall of shelter, 40 feet from front entrance and 5 feet above the floor.
204-WP-039-001	Right wall of shelter, 50 feet from front entrance and 5 feet above the floor.
204-WP-040-001	Right side of shelter, 60 feet from front entrance and 5 feet above the floor.

Table 3-6 (continued)
Wipe Sampling Stations Established For Launcher Shelter 204

Sample No.	Station Description
204-WP-041-001	Left side of wall, 10 feet from front entrance and 5 feet above the floor.
204-WP-042-001	Left side of shelter, 20 feet from front entrance and 5 feet above the floor.
204-WP-043-001	Left side of wall, 30 feet from front entrance and 5 feet above the floor.
204-WP-044-001	Left side of wall, 40 feet from front entrance and 5 feet above the floor.
204-WP-045-001	Left side of wall, 50 feet from front entrance and 5 feet above the floor.
204-WP-046-001	Left side of wall, 60 feet from front entrance and 5 feet above the floor.
204-WP-047-001	Left wall, 1st louver location.
204-WP-048-001	Top portion of louver on left wall side.
204-WP-049-001	Left side of louver on the left side.
204-WP-050-001	Left side of wall on the right side of louver.
204-WP-051-001	Left side of wall on the 1.2' x 2.3' bottom of duct.
204-WP-052-001	Left side of wall, close to light support on the pipe support below beam 5.

Table 3-6 (continued)
Wipe Sampling Stations Established For Launcher Shelter 204

Sample No.	Station Description
204-WP-053-001	Top of missile test connector box.
204-WP-054-001	On 3rd pipe of missile test connector box, 3' above the floor.
204-WP-055-001	Top of outlet 5' north of the missile test connector box.
204-WP-056-001	Mid-point of shelter, bottom of .6' x 1.2' of cutout.
204-WP-057-001	Mid-point of shelter, 5' up the electrical pipe.
204-WP-058-001	Bottom surface on louver opening to control room
204-WP-059-001	Left side wall of louver opening to control room.
204-WP-060-001	North of control room louver on bottom of 1.2' x 2.4' opening.
204-WP-061-001	On pipe 6" north of sample number 059-001
204-WP-062-001	On pipe 5' north of sample number 060-001 and 1" below.
204-WP-063-001	Horizontal pipe support below beam 12.
204-WP-064-001	Left Wall of shelter, on pipe 13' from front.

Table 3-6 (continued)
Wipe Sampling Stations Established For Launcher Shelter 204

Sample No.	Station Description
204-WP-065-001	Left wall on 2nd of 3 pipes up 2.5'.
204-WP-066-001	On the original top of lights 1 of 2.
204-WP-067-001	On the top of second light.
204-WP-068-001	Left wall north door, on the door jam 4.5' up.
204-WP-069-001	South door jam 4.5' up.
204-WP-070-001	South door on top of the door jam.
204-WP-071-001	Outside, back of shelter on top of support beam.
204-WP-072-001	Above left door on top exterior light.
204-WP-073-001	On top of middle door on left side.
204-WP-074-001	On left side from the back on 2nd support beam.
204-WP-075-001	Angled support beam outside on 2nd support.
204-WP-076-001	Left side of back of shelter on 3rd beam.
204-WP-077-001	Left side angle support beam 4th from back of shelter.
204-WP-078-001	Back of shelter on 4th support beam.
204-WP-079-001	Back of shelter on 5th support beam.

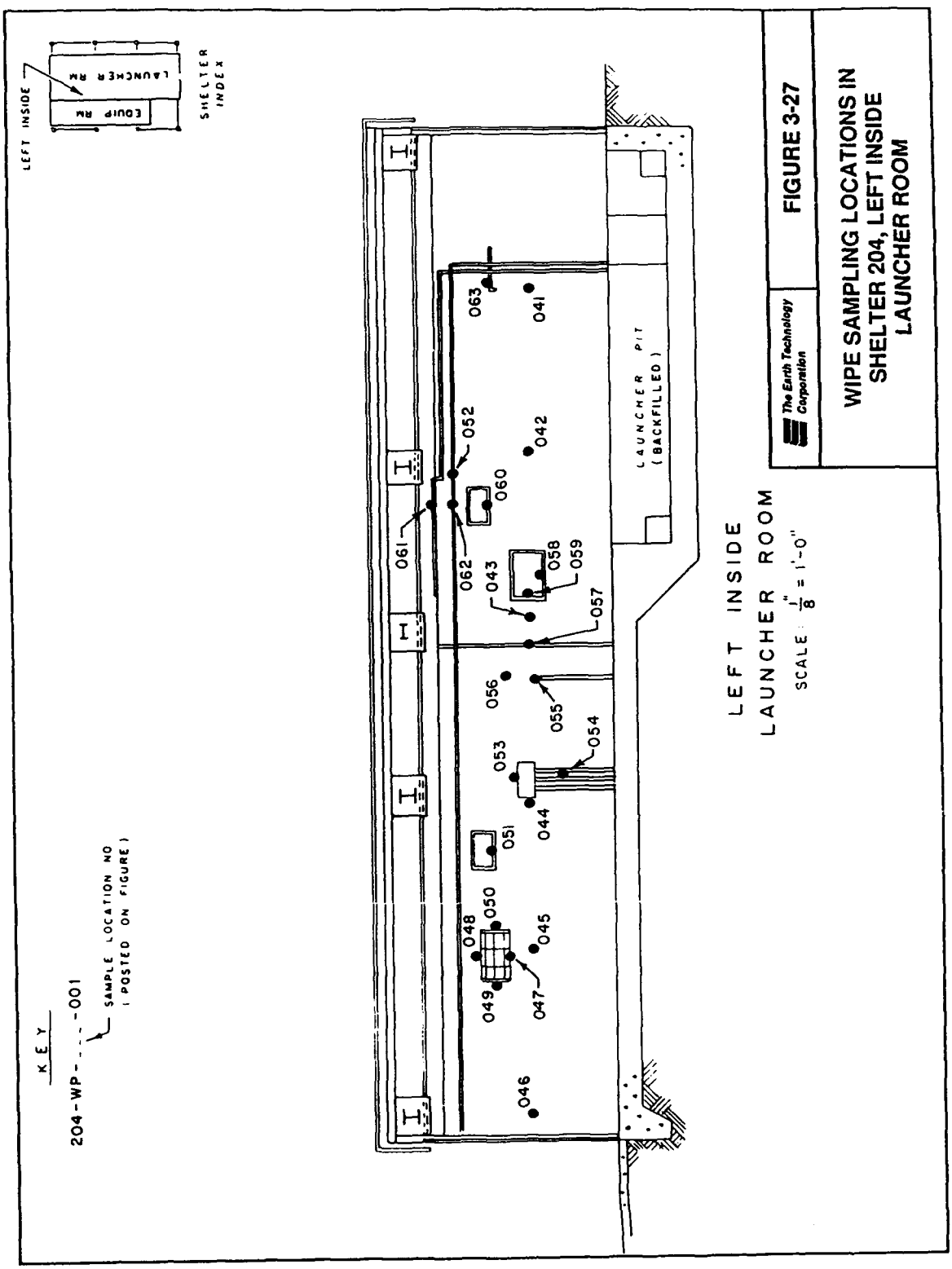
Table 3-6 (continued)
Wipe Sampling Stations Established For Launcher Shelter 204

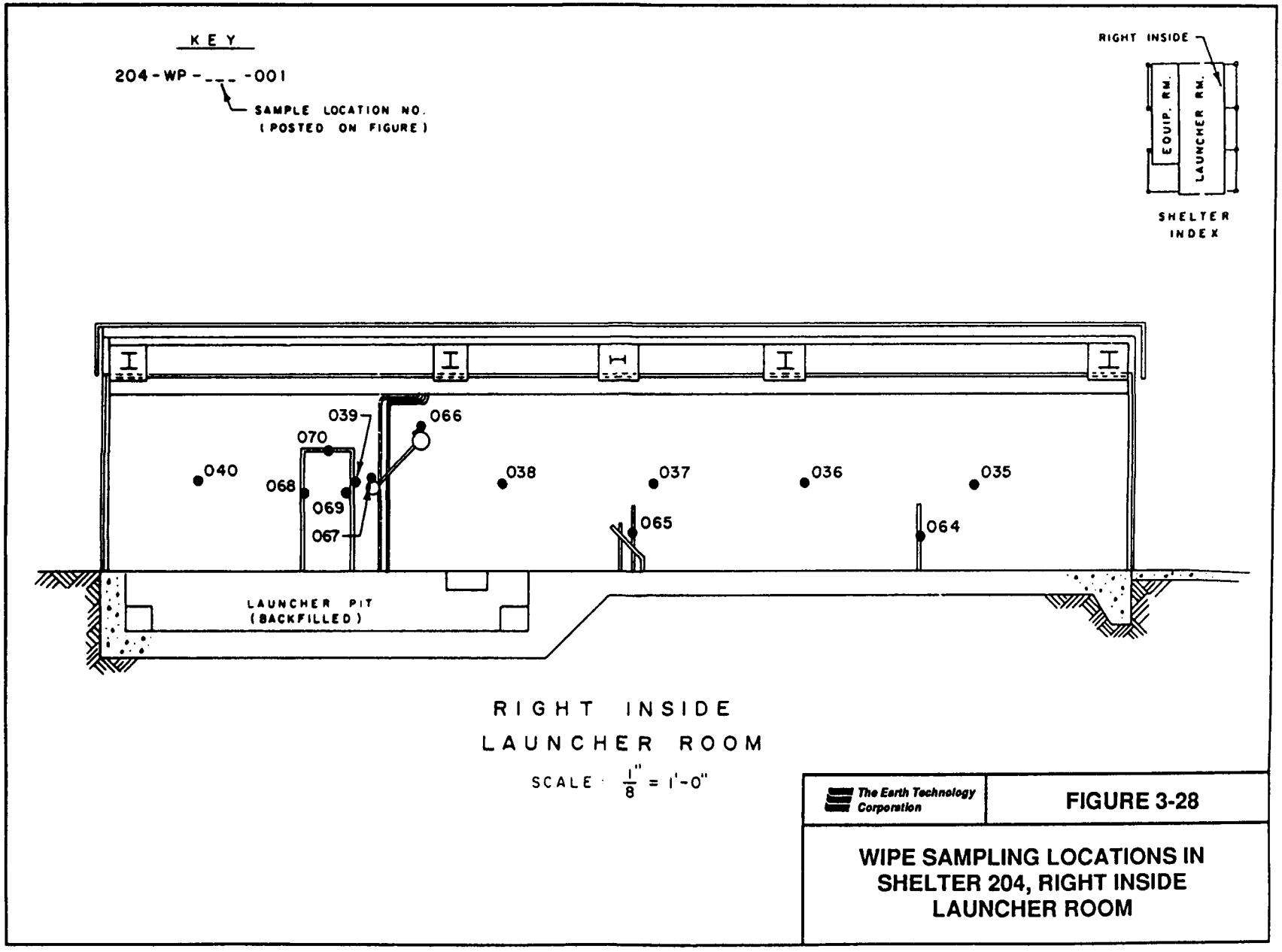
Sample No.	Station Description
204-WP-080-001	E-W trending from front of shelter on left side exterior of support 1.
204-WP-081-001	Right side of shelter, on support beam between wall and the 2nd beam.
204-WP-082-001	Right side exterior, 2nd beam outside near control room.
204-WP-083-001	Southwest side of shelter on southwest wall, top of control room.
204-WP-084-001	Exterior louver by right side of 1st louver.
204-WP-085-001	Interior of control room, inside right side of louvers.
204-WP-086-001	Front of shelter, on top of first light in control room.
204-WP-087-001	West shelter wall, in small opening inside control room.
204-WP-088-001	Inside control room on top of control panel.
204-WP-089-001	East side, on support bar that's protruding out of wall.
204-WP-090-001	West wall, small circuit box.
204-WP-091-001	Control room in middle of support beam.
204-WP-092-001	Control room on 5th light.

Table 3-6 (continued)
Wipe Sampling Stations Established For Launcher Shelter 204

Sample No.	Station Description
204-WP-093-001	Control room door on the interior side of door.
204-WP-094-001	Control room's last light in center on top of back of support beam.
204-WP-095-001	Back of control room 3' up on the 2" dia. pipe.
204-WP-096-001	Back on shelter wall in control room 14.9' from back and 5' up.
204-WP-097-001	9' from front of control room and 5' up.
204-WP-098-001	Horizontal west wall on wood panel.
204-WP-099-001	West wall of control room 1' above ground on 1st of the 4 pipes.
204-WP-100-001	West wall of control room on front of stainless steel box.

Note: * "Left" and "Right" determined by standing at front of shelter (where nose of missile would have been) and looking to the rear (toward launcher mechanism and pits).


WIPE SAMPLING LOCATIONS IN SHELTER 204, LEFT INSIDE LAUNCHER ROOM
FIGURE 3-27
The Earth Technology Corporation
LEFT INSIDE
LAUNCHER ROOM
SCALE: 1/8" = 1'-0"
LAUNCHER PIT (BACKFILLED)
KEY
204-WP-___-001
SAMPLE LOCATION NO (POSTED ON FIGURE)
LEFT INSIDE
SHELTER INDEX
EQUIP RM
LAUNCHER RM
041
042
043
044
045
046
047
048
049
050
051
052
053
054
055
056
057
058
059
060
061
062
063



The Earth Technology Corporation

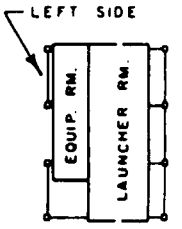
FIGURE 3-28

WIPE SAMPLING LOCATIONS IN SHELTER 204, RIGHT INSIDE LAUNCHER ROOM

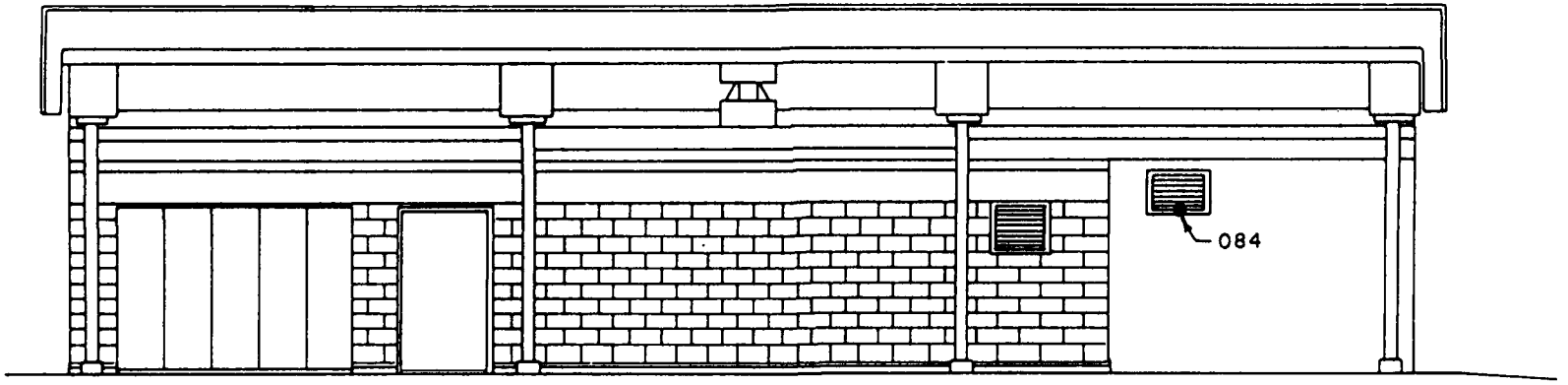
KEY

204 - WP - ___ - 001

SAMPLE LOCATION NO.
(POSTED ON FIGURE)



SHELTER
INDEX



LEFT SIDE ELEVATION

SCALE $\frac{1}{8}$" = 1'-0"

The Earth Technology Corporation

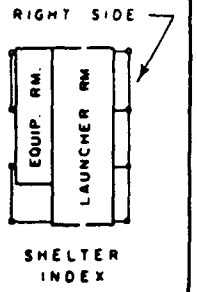
FIGURE 3-29

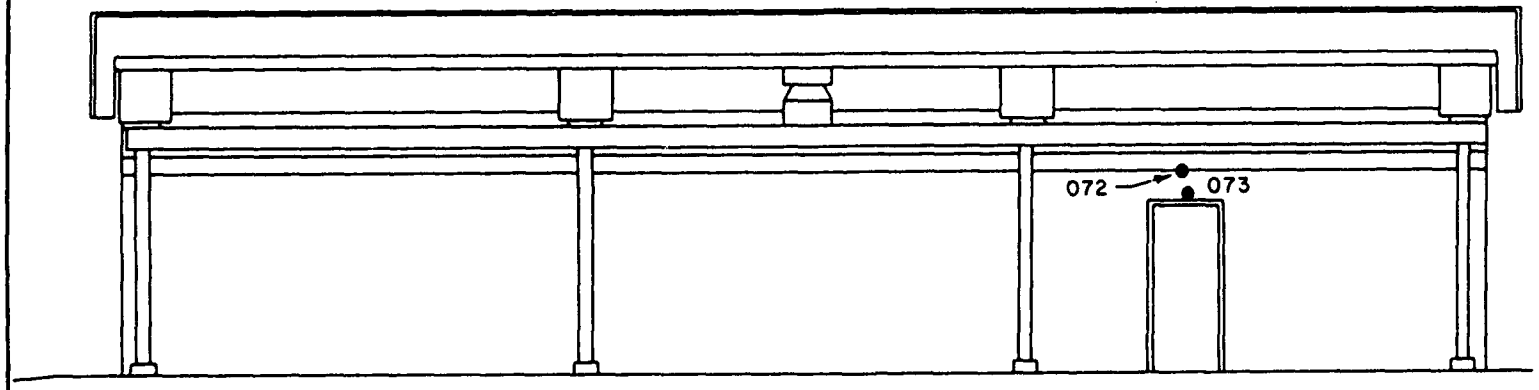
WIPE SAMPLING LOCATIONS IN SHELTER 204, LEFT SIDE ELEVATION

KEY:

204-WP-___-001

SAMPLE LOCATION NO (POSTED ON FIGURE)





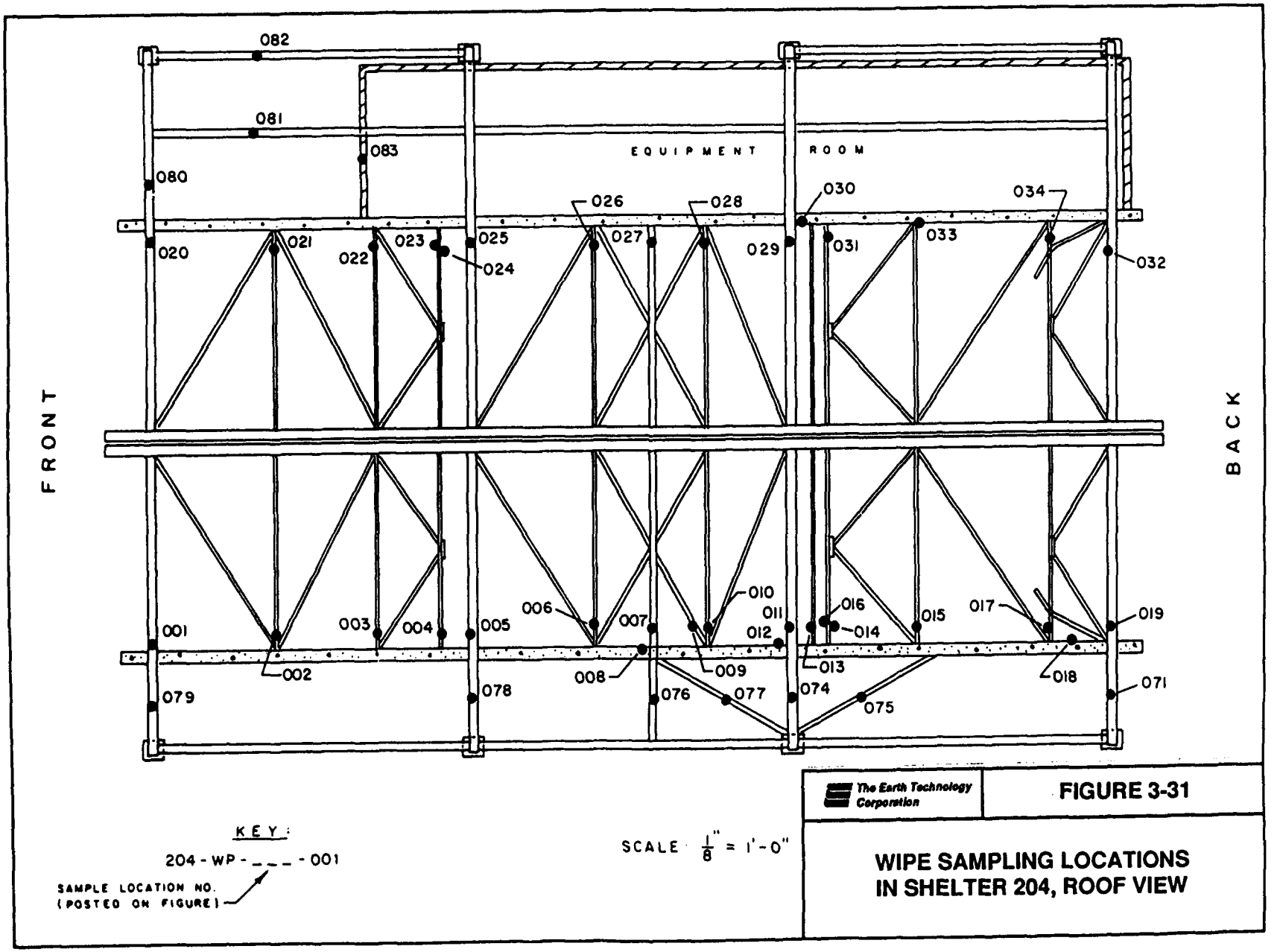
RIGHT SIDE ELEVATION

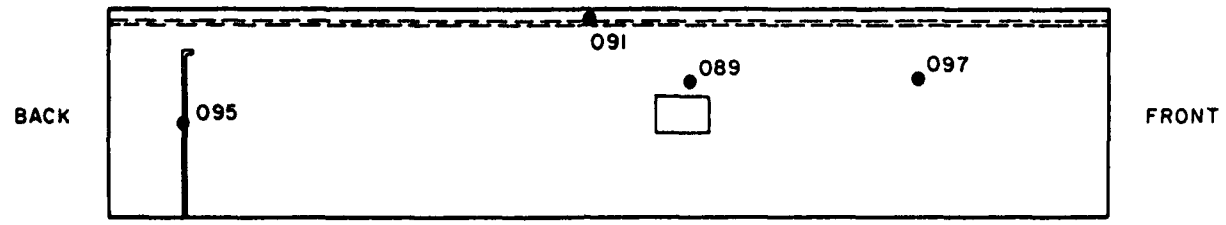
SCALE $\frac{1}{8}$" = 1'-0"

The Earth Technology Corporation

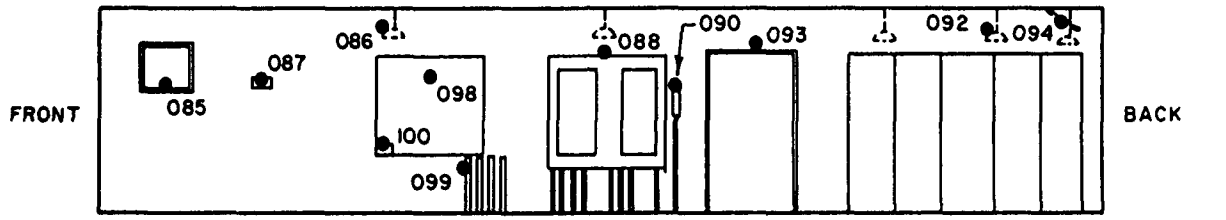
FIGURE 3-30

WIPE SAMPLING LOCATIONS IN SHELTER 204, RIGHT SIDE ELEVATION

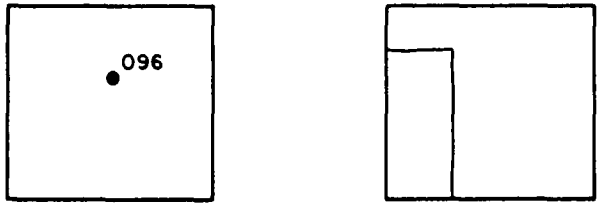

082
081
083
080
EQUIPMENT ROOM
026
028
030
034
020
021
022
023
025
024
027
029
031
033
032
FRONT
BACK
001
003
004
005
006
007
010
011
012
016
014
015
017
019
002
009
013
018
079
078
008
076
077
074
075
071
KEY:
204 - WP - ___ - 001
SAMPLE LOCATION NO. (POSTED ON FIGURE)
SCALE 1/8" = 1'-0"
The Earth Technology Corporation
FIGURE 3-31
WIPE SAMPLING LOCATIONS IN SHELTER 204, ROOF VIEW



RIGHT INSIDE
EQUIPMENT ROOM



LEFT INSIDE
EQUIPMENT ROOM



BACK INSIDE

FRONT INSIDE

EQUIPMENT ROOM

SCALE: $\frac{1}{8}$" = 1'-0"

KEY:

204 - WP - ___ - 001

SAMPLE LOCATION NO. (POSTED ON FIGURE)

The Earth Technology Corporation

FIGURE 3-32

WIPE SAMPLING LOCATIONS IN SHELTER 204, EQUIPMENT ROOM

were spaced at a distance. The stations sampled in each shelter were the same as those established in Shelter 210, (Figures 3-21 through 3-25) but alternated between odd and even numbers between successive shelters. Certain stations were sampled consistently in every shelter.

3.6.2.5.3 Power Bunker

There was not enough sediment in the power bunker to sample, so six wipe samples were collected in order to assess internal contamination. After the bunker was opened (see Section 3.6.2.2.2), the samples were collected from near the base of the south and west walls, from the top of a protective steel casing which houses a power line, and from the manhole itself (Figures 3-33 and 3-34). These samples were collected by attaching a clean piece of Whatman filter paper to a decontaminated sampling rod using duct tape.

The end of the sample rod was then lowered to one of the sampling points. The filter paper was firmly pressed against the wall and wiped over an area approximately 10 cm × 10 cm. Each sample was placed into a Ziplock™ storage bag, sealed, and labeled, noting the sampling location, date and time of collection, and the sampler. Samples were stored in a cooler until they were later analyzed on site using a Ludlum 2000 scaler with an alpha scintillation detector.

3.6.2.6 Soil Sampling

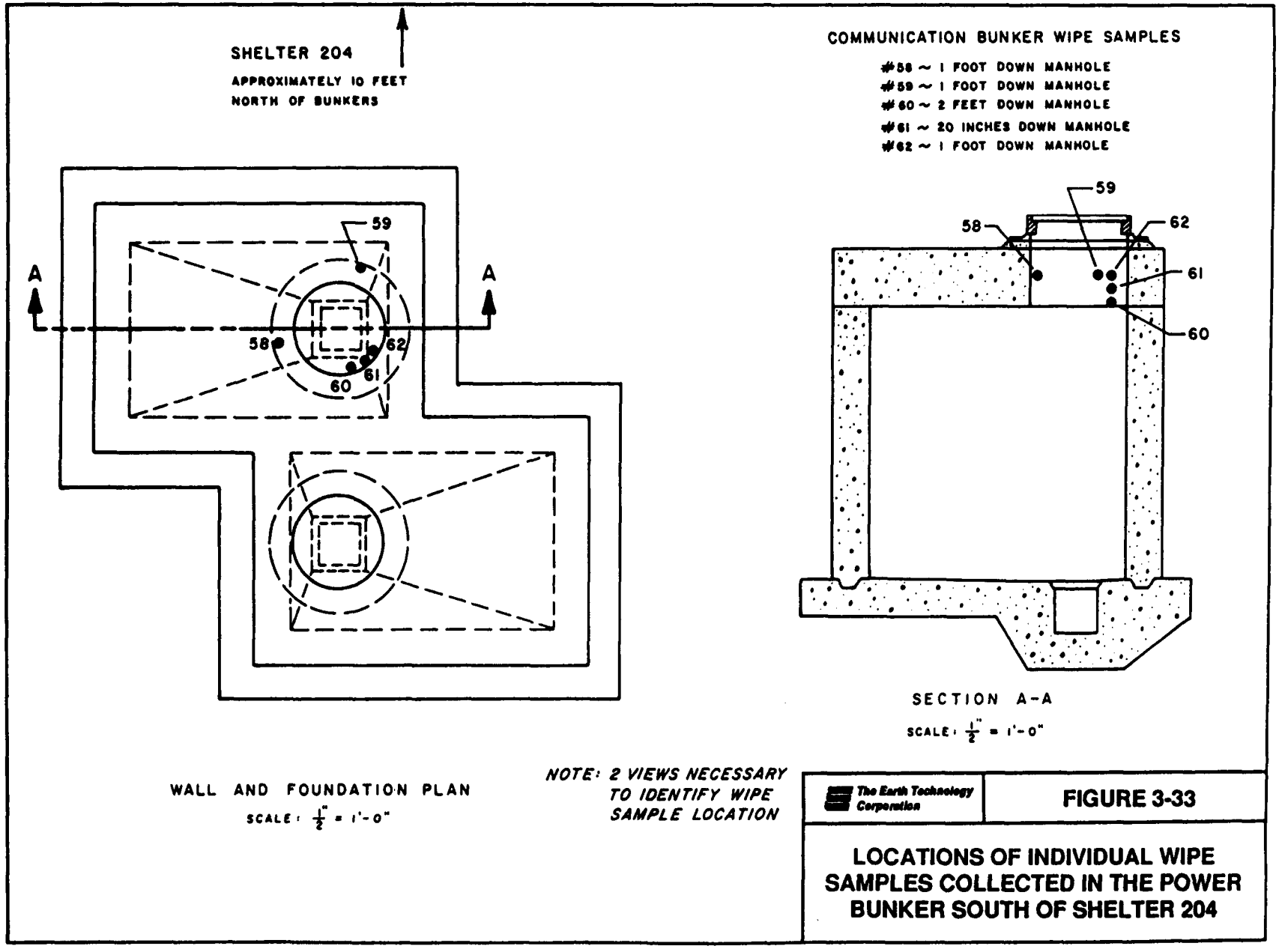
Soil samples were collected at various locations and depths in order to determine both the areal and vertical extent of contamination. In addition, soil samples were collected in order to determine particle size characteristics.

Following the in-situ surveys, surface soil samples were collected to delineate/confirm the extent of plutonium contamination. Surface soil sample types and locations were designed to optimally provide information that was relevant to the RI/FS investigation.

Chemical analyses were also completed on selected soil samples. Table 3-7 shows the sample identification and the chemical analyses completed.

3.6.2.6.1 Drainage Ditch Soil Sampling

A total of four soil samples were collected from the drainage ditch located to the southwest of Shelter 204 (Figure 3-35) and analyzed for radiological and chemical parameters. Three of these samples were collected from beneath the upper, asphalt-covered section of the drainage, and one sample was collected from the small ponding area on the west side of Highway 539. A 66-inch-long wedge and pointed-end crowbar was used to break through the 2-inch-thick layer of asphalt in the drainage. An Art's Manufacturing Supply soil auger was then used to collect soil samples from each of the four sampling sites.


SHELTER 204
APPROXIMATELY 10 FEET
NORTH OF BUNKERS
COMMUNICATION BUNKER WIPE SAMPLES
#58 ~ 1 FOOT DOWN MANHOLE
#59 ~ 1 FOOT DOWN MANHOLE
#60 ~ 2 FEET DOWN MANHOLE
#61 ~ 20 INCHES DOWN MANHOLE
#62 ~ 1 FOOT DOWN MANHOLE
A
A
59
58
62
61
60
WALL AND FOUNDATION PLAN
SCALE: 1/2" = 1'-0"
SECTION A-A
SCALE: 1/2" = 1'-0"
NOTE: 2 VIEWS NECESSARY TO IDENTIFY WIPE SAMPLE LOCATION
The Earth Technology Corporation
FIGURE 3-33
LOCATIONS OF INDIVIDUAL WIPE SAMPLES COLLECTED IN THE POWER BUNKER SOUTH OF SHELTER 204

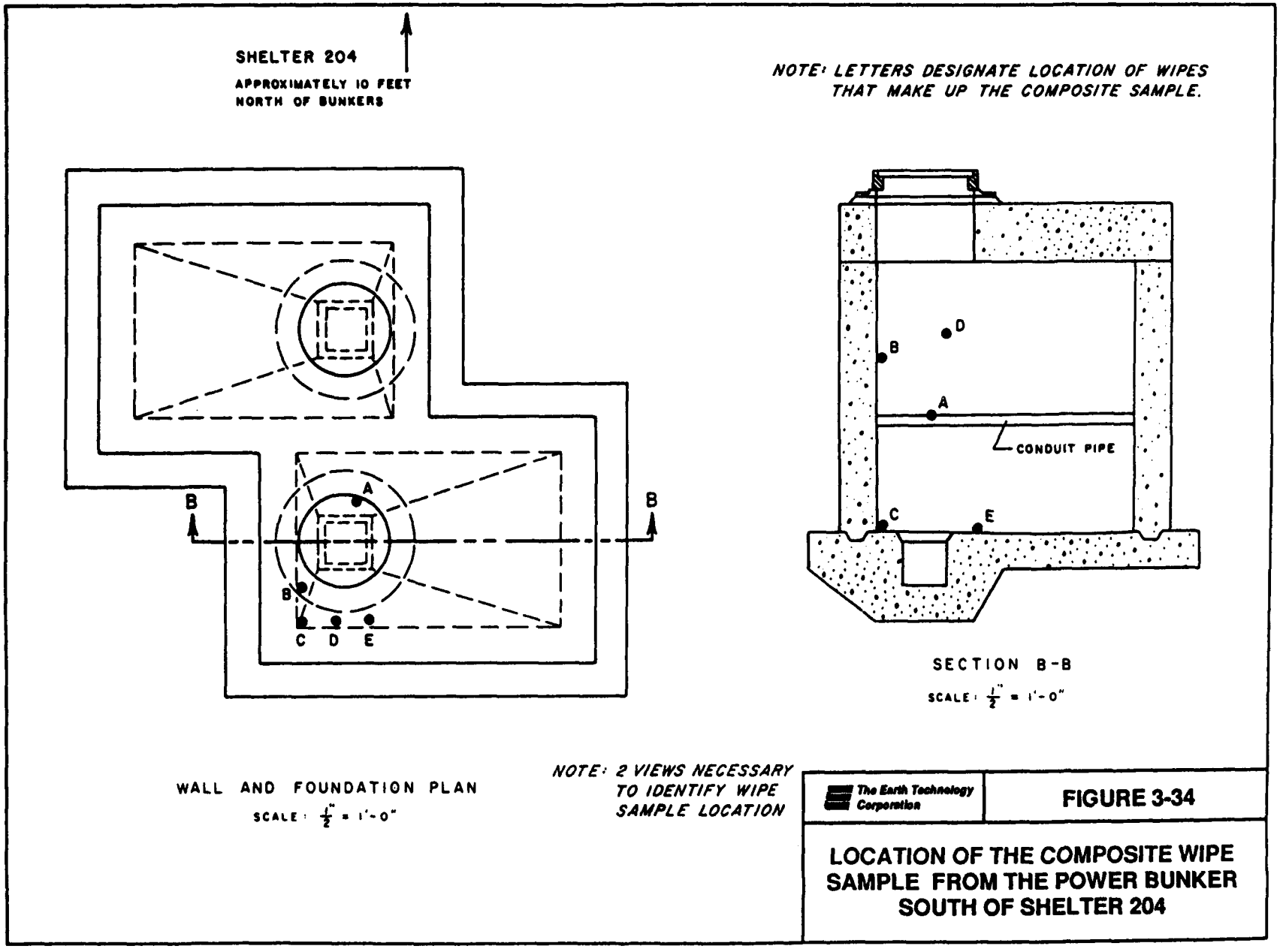
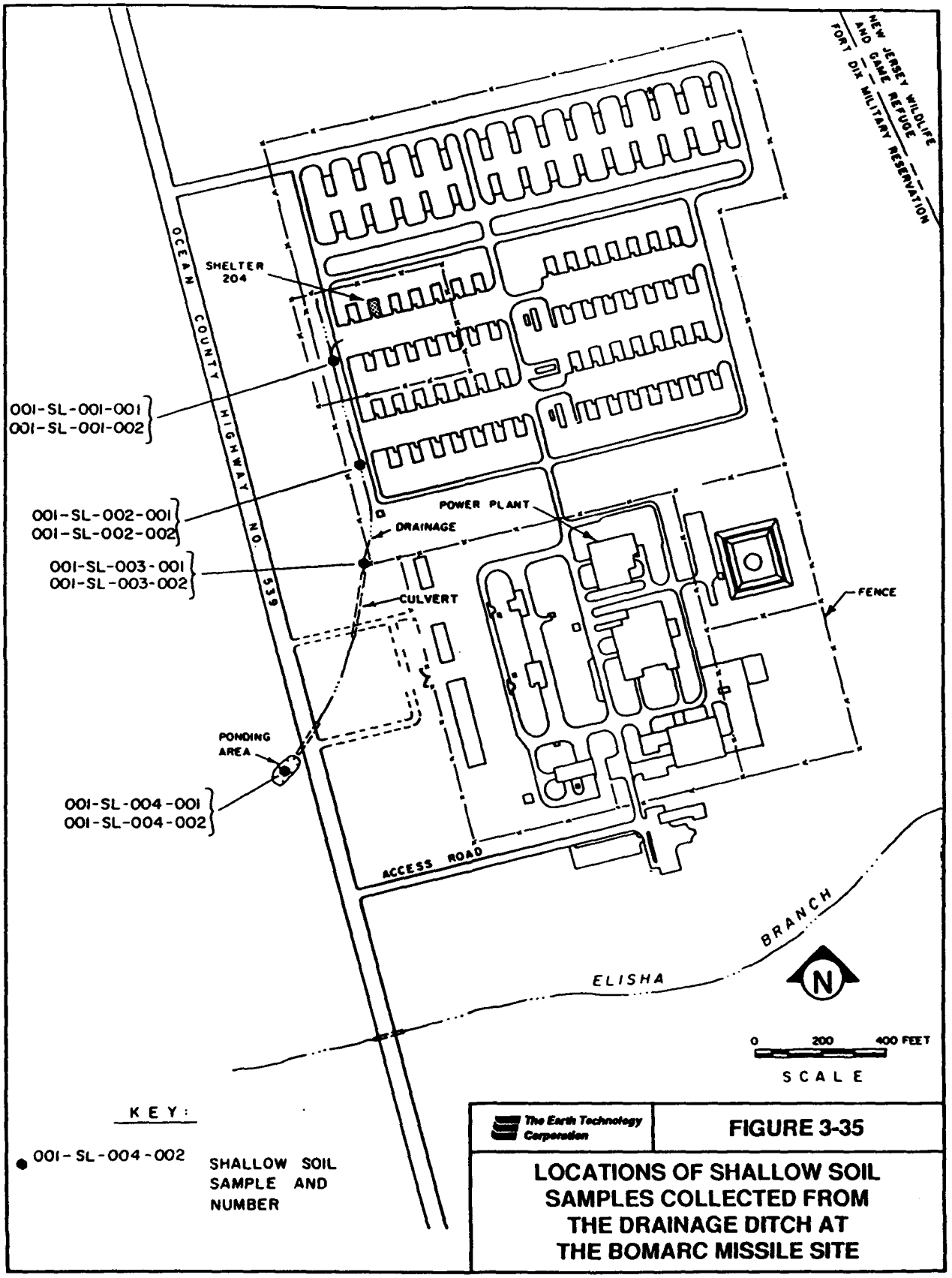

SHELTER 204
APPROXIMATELY 10 FEET
NORTH OF BUNKERS
NOTE: LETTERS DESIGNATE LOCATION OF WIPES THAT MAKE UP THE COMPOSITE SAMPLE.
A
B
B
B
C D E
WALL AND FOUNDATION PLAN
SCALE: 1/2" = 1'-0"
D
B
A
CONDUIT PIPE
C
E
SECTION B-B
SCALE: 1/2" = 1'-0"
NOTE: 2 VIEWS NECESSARY TO IDENTIFY WIPE SAMPLE LOCATION
The Earth Technology Corporation
FIGURE 3-34
LOCATION OF THE COMPOSITE WIPE SAMPLE FROM THE POWER BUNKER SOUTH OF SHELTER 204

Table 3-7
Chemical Soil Samples and Analyses

Sample Number	VOA	BNA	Pesticide/PCB	Metals
001-SL-AP1	*	*	*	*
001-SL-AP2	*	*	*	*
001-SL-AP3	*	*	*	*
001-SL-AP4	*	*	*	*
001-SL-C01	*	*	*	*
001-SL-C02	*	*	*	*
001-SL-C21	*	*		*
001-SL-BK1				*
001-SL-BK2				*

*Analyses performed


NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
OCEAN COUNTY HIGHWAY NO. 539
SHELTER 204
001-SL-001-001
001-SL-001-002
001-SL-002-001
001-SL-002-002
001-SL-003-001
001-SL-003-002
001-SL-004-001
001-SL-004-002
POWER PLANT
DRAINAGE
CULVERT
FENCE
PONDING AREA
ACCESS ROAD
ELISHA BRANCH
N
0 200 400 FEET
SCALE
KEY:
001-SL-004-002 SHALLOW SOIL SAMPLE AND NUMBER
The Earth Technology Corporation
FIGURE 3-35
LOCATIONS OF SHALLOW SOIL SAMPLES COLLECTED FROM THE DRAINAGE DITCH AT THE BOMARC MISSILE SITE

Chemical soil samples were taken from sample locations 001-SL-001, 001-SL-002, 001-SL-003, and 001-SL-004. These chemical samples from the drainage ditch were designated as 001-SL-AP-1, 001-SL-AP2, 001-SL-AP3, and 001-SL-AP4, respectively.

Two background samples were collected from locations north and west of the site. These samples were collected from 6-12 inches bgs and analyzed for metals. The background samples are identified as 001-SL-BK1, and 001-SL-BK2.

Three separate samples were collected for laboratory analysis of plutonium by alpha spectroscopy from discrete depths at each sampling location. These samples were collected from 0-6, 6-12, and 12-18 inches bgs. Samples collected from 6-12 inches bgs were also analyzed for TAL metals, pesticides/PCBs, and semi-volatile organics. Samples from 12-18 inches bgs were analyzed for TCL volatile organics.

As the soil was removed from the sample hole, the hole was screened for organic vapors using an HNu meter, and the results were recorded in the field log book. The soil from each sampling interval was transferred from the auger with a decontaminated stainless-steel spoon to glass sample jars. As each jar was filled, it was immediately sealed with a screw cap and labeled, noting the date and time of collection, sampler, sample number, sample interval, and parameters for which analyses were required.

The soil samples to be analyzed for chemical parameters were packaged and shipped to Metatrace using standard packaging and shipping procedures. The remaining samples to be analyzed for radionuclides were packaged and shipped in accordance with the procedures outlined in the QAPP. All samples were screened by the HPG detector prior to being shipped to the laboratories in order to comply with Department of Transportation (DOT) requirements and to inform the laboratory of the level of radioactivity in each sample.

3.6.2.6.2 Soil Core Sampling Beneath the Concrete Apron

The purpose of this soil core sampling was to determine if contaminants had migrated to soils beneath the concrete/asphalt apron. An AMS soil core sampler was used to collect 67 soil core samples through the 21 concrete coreholes drilled (Figure 3-16).

The soil core sampler, containing three 6-inch by 2-inch brass sample sleeves, was hammered 18 inches into the soil and then removed. As each of the three brass sleeves were removed from the sampler, they were screened with the FIDLER meter and then capped. Each sleeve was then marked as to vertical orientation and labeled, noting the sample number, sample time, date, sampler, and sampling interval. Each sample hole was then screened with an HNu or OVA and the readings were recorded. Samples were sealed in a Ziplock™ bag. Prior to shipping these samples, they were counted for the quantity and activity of Pu-239 as required by the DOT. However, in order to assure an exact reading by the HPG, the samples were transferred to 8-ounce plastic containers that were already calibrated for the HPG.

A total of three of the 67 samples were shipped to a separate laboratory for TCL organics and TAL metals analyses. Samples shipped for chemical analysis were obtained from core locations 1,2, and 21. Two samples were retained by EPA for grinding and splitting in order to perform QA duplicate analysis. The remaining 57 samples were sent for plutonium analysis by alpha spectroscopy.

3.6.2.6.3 Sediment Sampling in Bunkers

Sediment samples were to be collected from the floors of the communication and power bunkers (Figure 3-10 and Figure 3-11). Since no sediment was found within the power bunker, sediment samples were not collected from that structure. Samplers were instructed not to enter the bunkers to perform the sampling due to confined-space entry considerations, including the potential lack of oxygen and loose Pu-239 on the walls of the bunker.

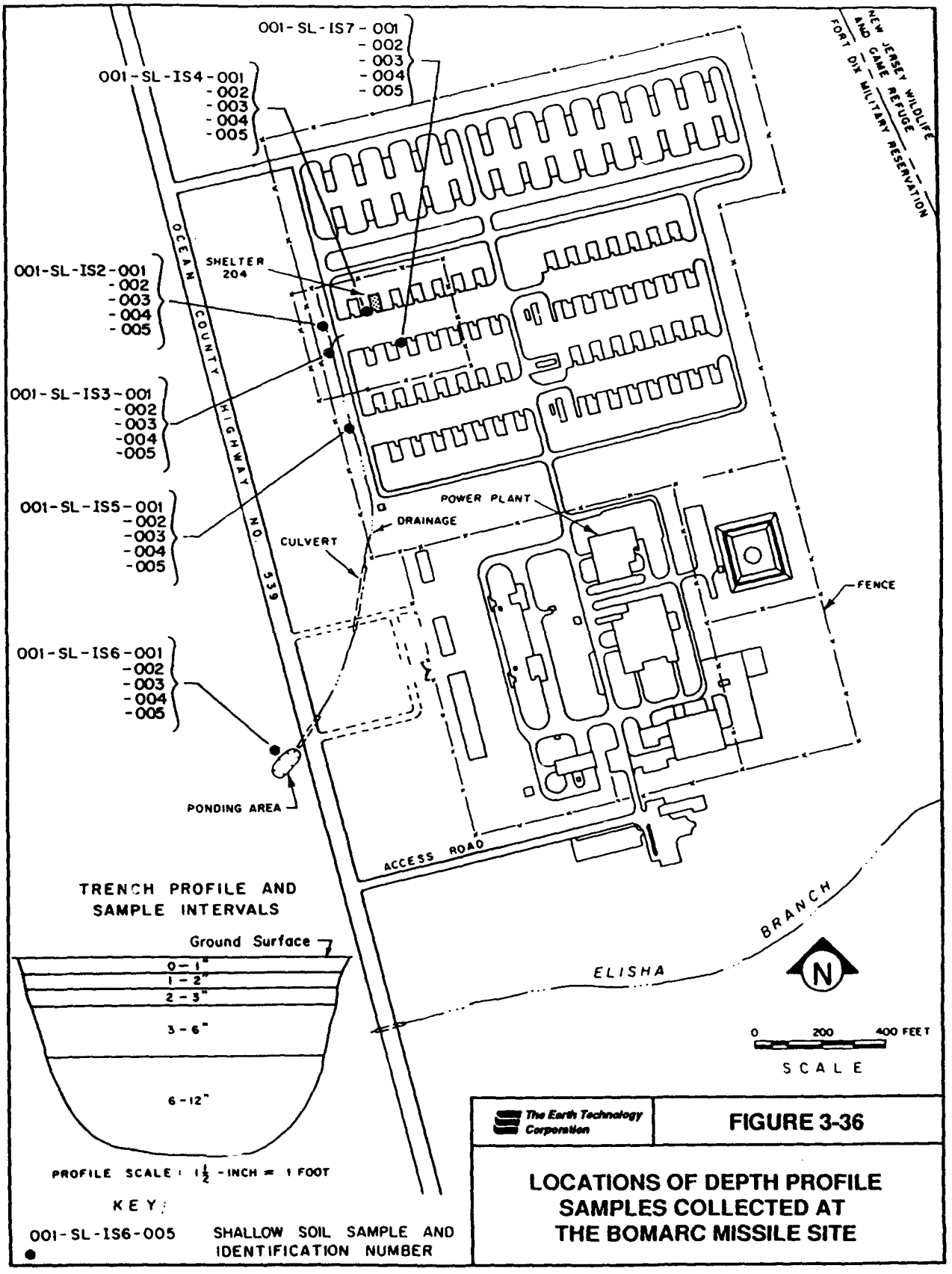
A total of six sediment samples were collected from the floor of the communication bunker. Five of these samples were screened onsite for gross alpha and gross gamma contamination and stored onsite. The sixth sample was sent to Teledyne Isotopes for plutonium analysis by alpha spectroscopy.

After surface water samples were collected (see Section 3.6.2.2.2), all of the standing water from the communication bunker was removed using a sump pump. Sediment samples were collected using a decontaminated sampling device attached to an extension rod. The device was lowered into the bunker using the rod, and then pulled across the bunker floor. Sediment was collected from the floor directly below the manhole cover (Figure 3-11). After the device was removed from the bunker, sediment was transferred with a decontaminated stainless-steel spoon from the device to a sample jar. Enough sample was collected for each sample to fill one 8-ounce glass sample jar.

As sediment samples were collected, sample bottles were labeled, noting the date and time of sample collection, sample number, name of the samplers, and analyses to be performed.

3.6.2.6.4 Depth Profile Sampling

Depth profile soil samples were collected at six locations near Shelter 204 (Figure 3-36). Samples were collected from six discreet depth intervals at each location in order to determine the depth distribution of plutonium within the upper foot of the soil column (Figure 3-36). These samples were shipped to Teledyne Isotopes, where they were sieved into two discrete size fractions (greater than 20 microns and less than 20 microns) prior to analysis by alpha spectroscopy. The purpose in sieving the samples was to identify the relative concentration of radioactive particles in each grain size fraction, since grain size affects respirability of particles. The 20 micron size screen was used because it was the smallest available screen size.


001-SL-IS7-001
-002
-003
-004
-005
001-SL-IS4-001
-002
-003
-004
-005
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
OCEAN COUNTY HIGHWAY NO. 539
001-SL-IS2-001
-002
-003
-004
-005
SHELTER 204
001-SL-IS3-001
-002
-003
-004
-005
001-SL-IS5-001
-002
-003
-004
-005
POWER PLANT
DRAINAGE
CULVERT
FENCE
001-SL-IS6-001
-002
-003
-004
-005
PONDING AREA
ACCESS ROAD
ELISHA BRANCH
N
0 200 400 FEET
SCALE
TRENCH PROFILE AND SAMPLE INTERVALS
Ground Surface
0-1"
1-2"
2-3"
3-6"
6-12"
PROFILE SCALE: 1½-INCH = 1 FOOT
KEY:
001-SL-IS6-005 SHALLOW SOIL SAMPLE AND IDENTIFICATION NUMBER
The Earth Technology Corporation
FIGURE 3-36
LOCATIONS OF DEPTH PROFILE SAMPLES COLLECTED AT THE BOMARC MISSILE SITE

At five of the six sampling locations, a decontaminated shovel was used to excavate a trench one foot in depth. A decontaminated spatula was used to collect composite soil samples from the following intervals: 0-0.5, 0.5-1.0, 1.0-2.0, 2.0-3.0, 3.0-6.0, and 6-12 inches bgs. At the sixth sampling location, an approximately six inch layer of fill material was found to overlay the original ground surface. This layer was removed, with the result that the trench was excavated to a total depth of 1.5 feet. Composite soil samples at this location were collected from the following intervals: 0-6, 6-7, 7-8, 8-9, 9-12, and 12-18 inches bgs.

The 3-inch by 4-inch spatula was pushed through the soil at the base of each sampling interval and then lifted. The soil wa' then transferred into an 8-ounce sample jar. Soil samples retrieved at thicker intervals were sampled vertically in increments until the depth interval was achieved. Enough sample was collected at each horizon to fill two 8-ounce sample jars.

Once a sample jar was filled, it was capped, labeled, and stored in a cooler where it awaited shipment to the laboratory. Coolers were sealed with chain-of-custody seals until they could be prepared for shipment. Sample labels noted the sample number, date and time of sample collection, sampling interval, sampler, and analyses to be performed.

Prior to shipment to the laboratory, each sample was counted for the quantity and dosage of radiation (Pu-239) as required by the DOT, using an HPG. All equipment was decontaminated after sampling, using the procedures outlined in Section 3.6.2.10.

3.6.2.6.5 Soil Sampling to Investigate Surface Deposition Modeling

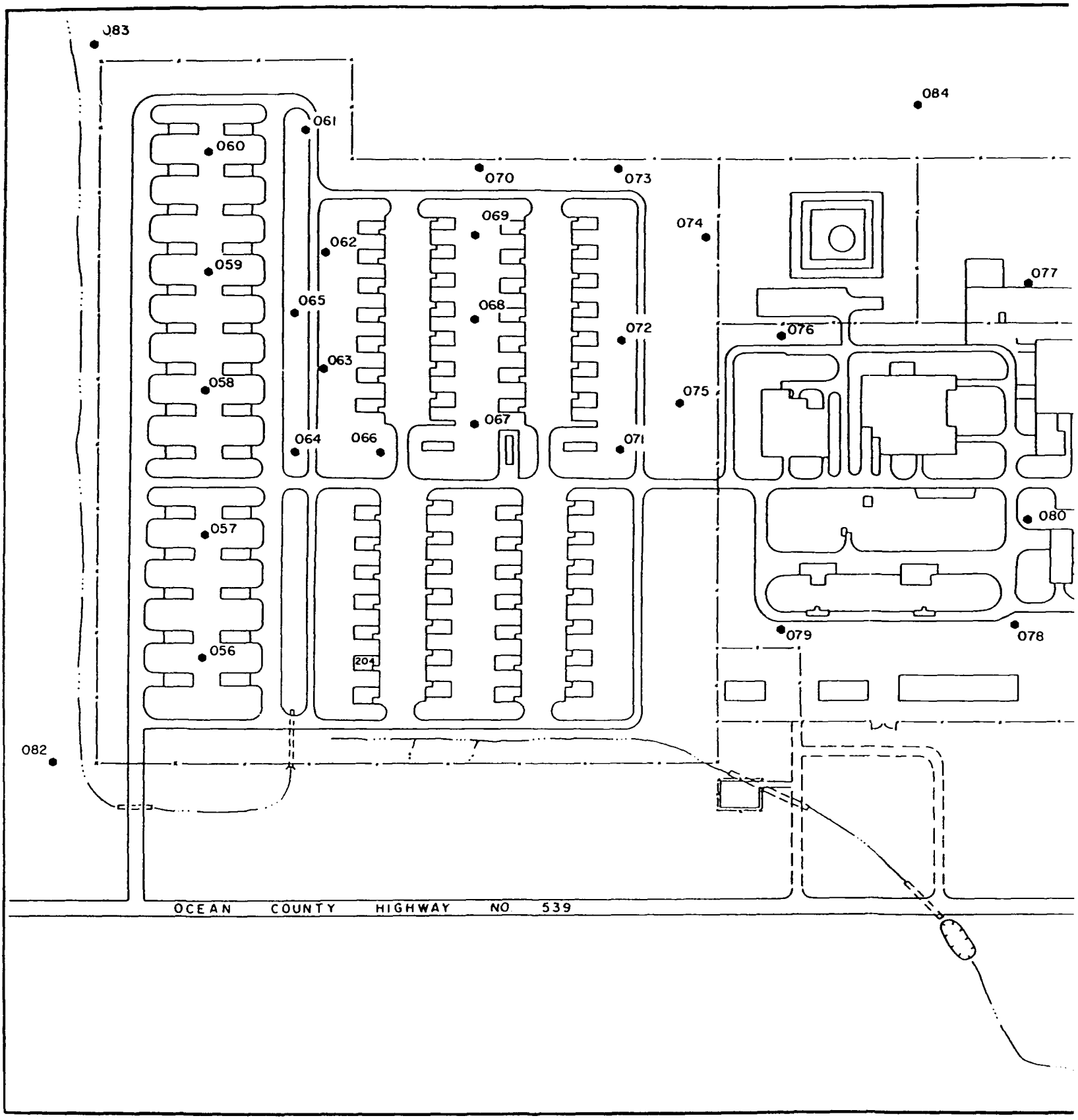
A total of 30 shallow soil samples were collected to investigate the modeling predictions (Figure 3-18). These samples were collected using a 6-inch brass sleeve which was pushed vertically into the soil. The sample collected in the brass sleeve was then transferred to a 250 ml Nalgene™ jar. Each sample was screened by the HPG in the field to determine the sample signature (i.e., thorium vs. plutonium).

3.6.2.6.6 Random Soil Sampling

Thirty (30) random samples were collected from within the fenced portion of the BOMARC Missile Site to provide a set of soil data that was representative of the site (Figure 3-37). Prior to collecting the sample, each location was surveyed with the FIDLER, and the reading was recorded. Samples were then collected using a 6-inch brass sleeve, in the same technique described in Section 3.6.2.6.5.

3.6.2.6.7 Soil/Sediment Samples from the Elisha Branch

Twenty (20) soil/sediment samples were collected from the drainage of the Elisha Branch, south of the BOMARC Missile Site (Figure 3-38). Prior to collecting the sample, each location was surveyed with the FIDLER, and the reading was recorded. Samples were then collected using a 6-inch brass sleeve, in the same technique described in Section 3.6.2.6.5.


083
084
061
060
070
073
069
074
062
059
077
065
068
072
076
063
058
075
067
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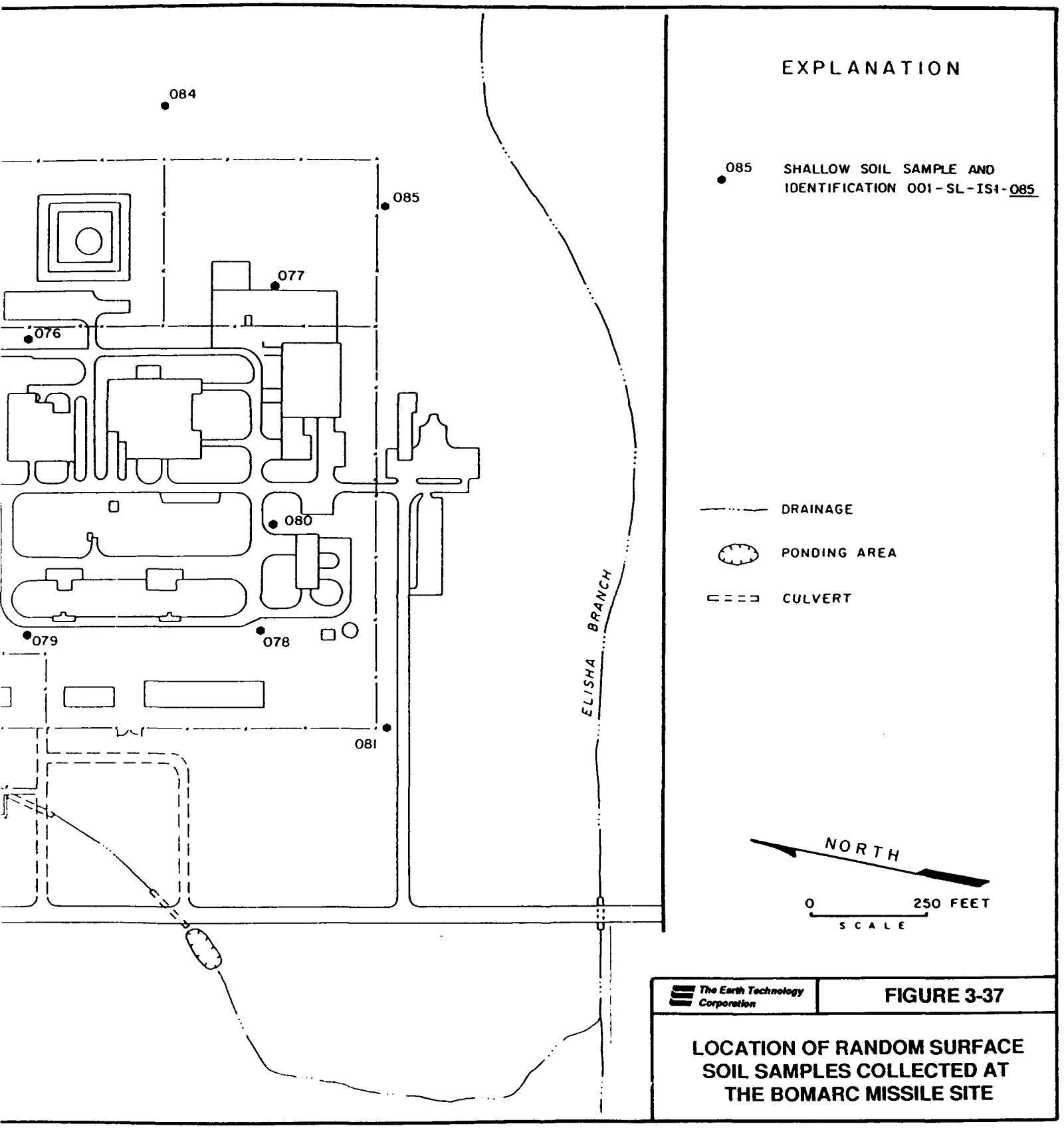
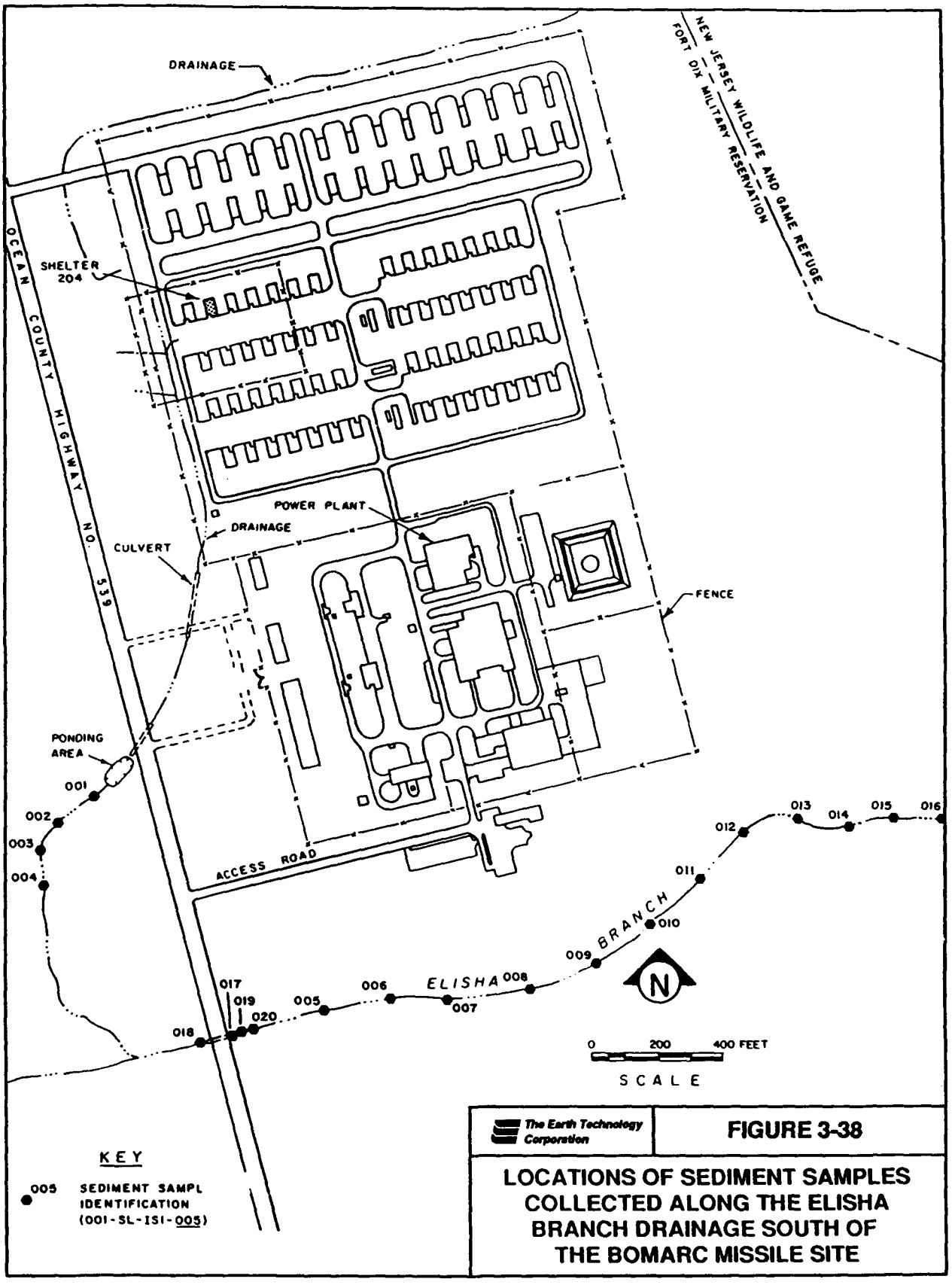
066
071
057
080
079
078
056
204
082
OCEAN COUNTY HIGHWAY NO 539



The Earth Technology Corporation

FIGURE 3-37

LOCATION OF RANDOM SURFACE SOIL SAMPLES COLLECTED AT THE BOMARC MISSILE SITE


DRAINAGE
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
SHELTER 204
OCEAN COUNTY HIGHWAY NO. 539
POWER PLANT
DRAINAGE
CULVERT
FENCE
PONDING AREA
001
002
003
004
ACCESS ROAD
011
012
013
014
015
016
BRANCH
010
009
ELISHA
008
007
006
005
017
019
020
018
N
0 200 400 FEET
SCALE
KEY
005 SEDIMENT SAMPL IDENTIFICATION (001-SL-ISI-005)
The Earth Technology Corporation
FIGURE 3-38
LOCATIONS OF SEDIMENT SAMPLES COLLECTED ALONG THE ELISHA BRANCH DRAINAGE SOUTH OF THE BOMARC MISSILE SITE

3.6.2.6.8 Soil Sampling from Historical "Hot Spots"

Five soil samples were collected northeast of Shelter 204 from locations identified during previous surveys as containing higher activity than most of the points surveyed (Figure 3-39). Each sampling location was carefully screened with the HPG and FIDLER, and the values were recorded. Samples were collected using a 6-inch brass sleeve, in the same technique described in Section 3.6.2.6.5.

3.6.2.6.9 Soil Sampling from Boreholes

Based on the in-situ survey of the BOMARC Missile Site, 26 boreholes were drilled between the missile shelters, along the ditch, and near the ponding area west of Highway 539 (Figure 3-40). At each borehole, three samples were collected: the first was a surface soil sample collected from 0.0 to 0.5 feet, using a brass sleeve as described in Section 3.6.2.6.5; the second was a subsurface sample collected between 2 to 4 feet; and the third was also a subsurface sample, collected either from between 4 and 6 feet or between 8 and 10 feet below the ground surface. The subsurface samples were collected using a split-spoon and auger method.

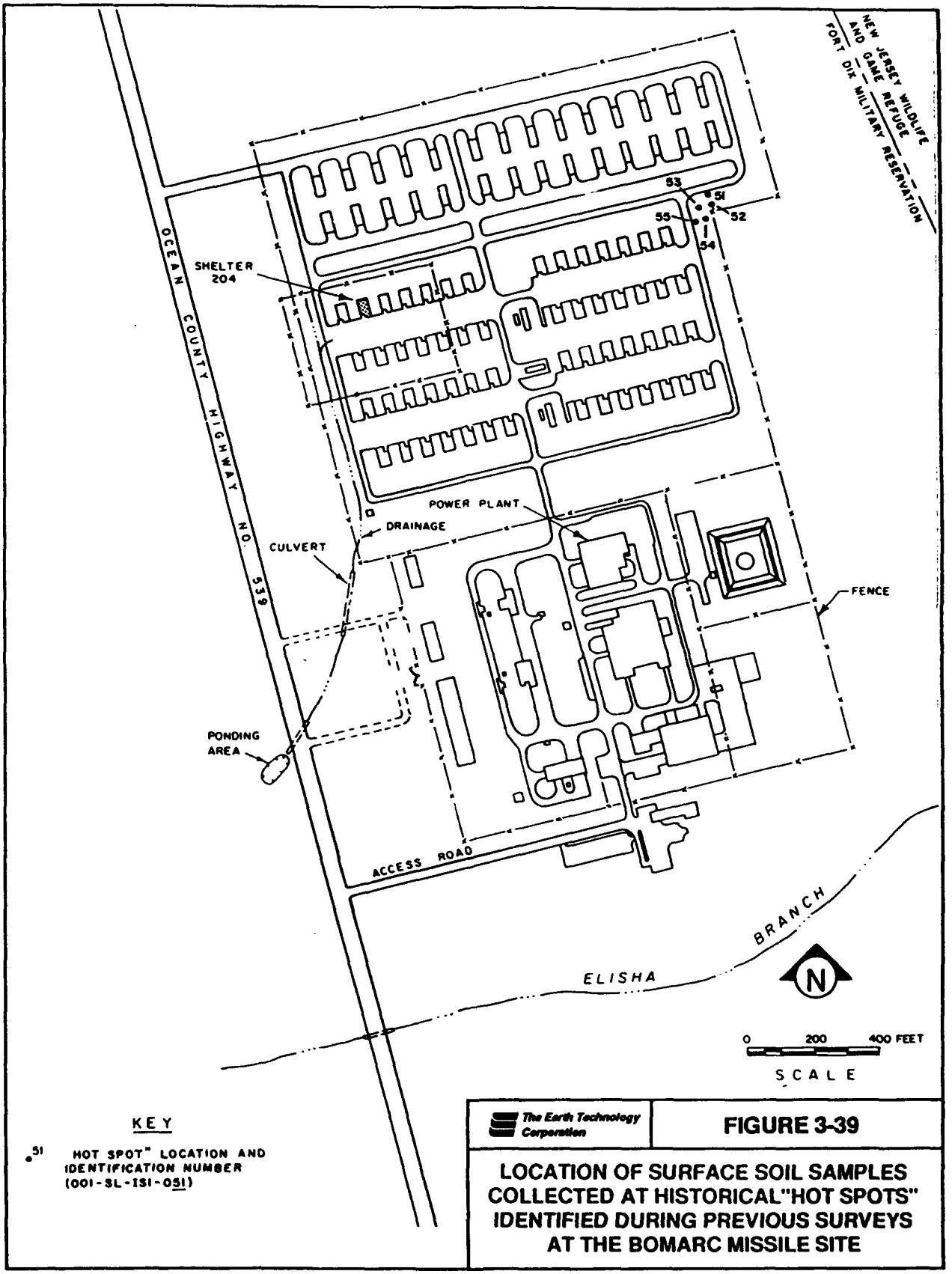
3.6.2.7 Concrete/Asphalt Coring and Sampling

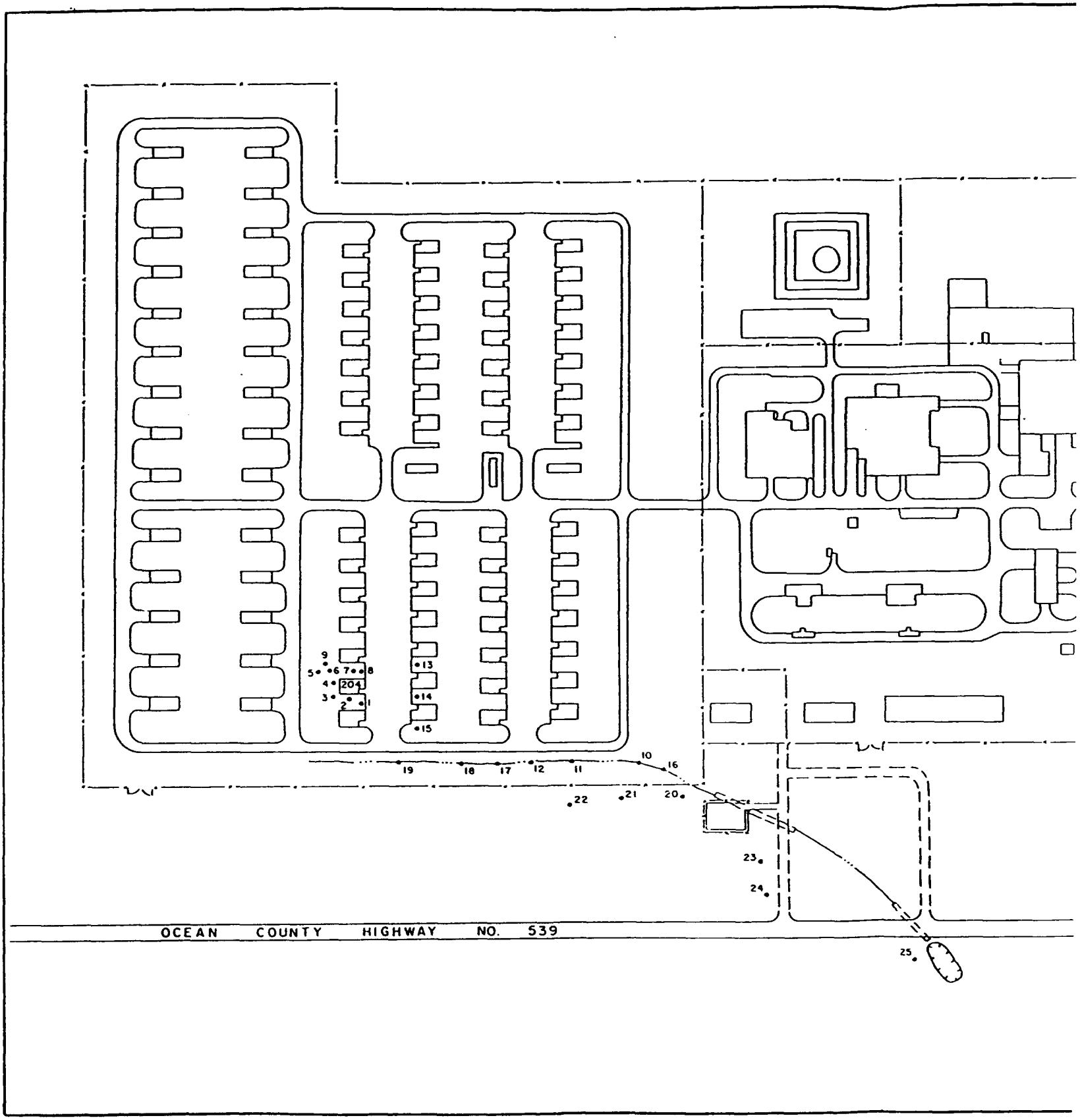
A total of 22 coreholes were drilled through the concrete and asphalt at the BOMARC site. Three concrete coreholes were drilled through the floor of Shelter 204, and 19 concrete/asphalt coreholes (including one duplicate) were drilled through Lorin Street (the concrete apron), in front of Shelter 204 (Figure 3-16). These coreholes were drilled for the purpose of measuring the radiation levels in the cores, as well as to allow access for the sampling of underlying soils.

The Hoffman Diamond Products Heavy Duty Core Drill used to drill these coreholes utilized a two-speed, 18-amp drill, mounted to a 42-inch-high drill stand. The core bits used were 4 inches in diameter, as long as 20 inches in length, and had diamond-impregnated teeth. Water was used in drilling to cool the bit and to help remove the drill cuttings from the corehole. A new, 55-gallon drum partially filled with distilled water was used as a water source. A garden hose was used to connect the water supply to a hose attachment on one side of the drill.

Acrylic core covers were designed by SAIC and custom-made by GeoTechnical Services Inc., to fit the Hoffman Diamond Products Core Drill. Each cover was cut from 0.5-inch clear acrylic and stood 5 inches high, 10 inches wide, and 15 inches long (Figure 3-41). The core cover was used during the drilling operation to prevent core drilling water and cuttings from spraying the drill operator and contaminating equipment in the surrounding area.

The area immediately surrounding the drilling site was initially covered with strippable paint in order to prevent the spread of contamination. The paint covered an area of 4 square feet and prevented any Pu-239 from contaminating the concrete surface. The drill stand and drill were positioned such that the base of the drill was upslope of the corehole. This positioning was important to reduce the possibility of contaminating the drill with drilling water or cuttings.


NEW JERSEY WILDLIFE AND GAME REFUGE — FORT DIX MILITARY RESERVATION
OCEAN COUNTY HIGHWAY NO. 539
SHELTER 204
POWER PLANT
DRAINAGE
CULVERT
FENCE
PONDING AREA
ACCESS ROAD
ELISHA BRANCH
51
52
53
54
55
N
0 200 400 FEET
SCALE
KEY
•51 HOT SPOT" LOCATION AND IDENTIFICATION NUMBER (001-SL-ISI-051)
The Earth Technology Corporation
FIGURE 3-39
LOCATION OF SURFACE SOIL SAMPLES COLLECTED AT HISTORICAL "HOT SPOTS" IDENTIFIED DURING PREVIOUS SURVEYS AT THE BOMARC MISSILE SITE


9
5
6
7
8
4
204
3
2
1
13
14
15
19
18
17
12
11
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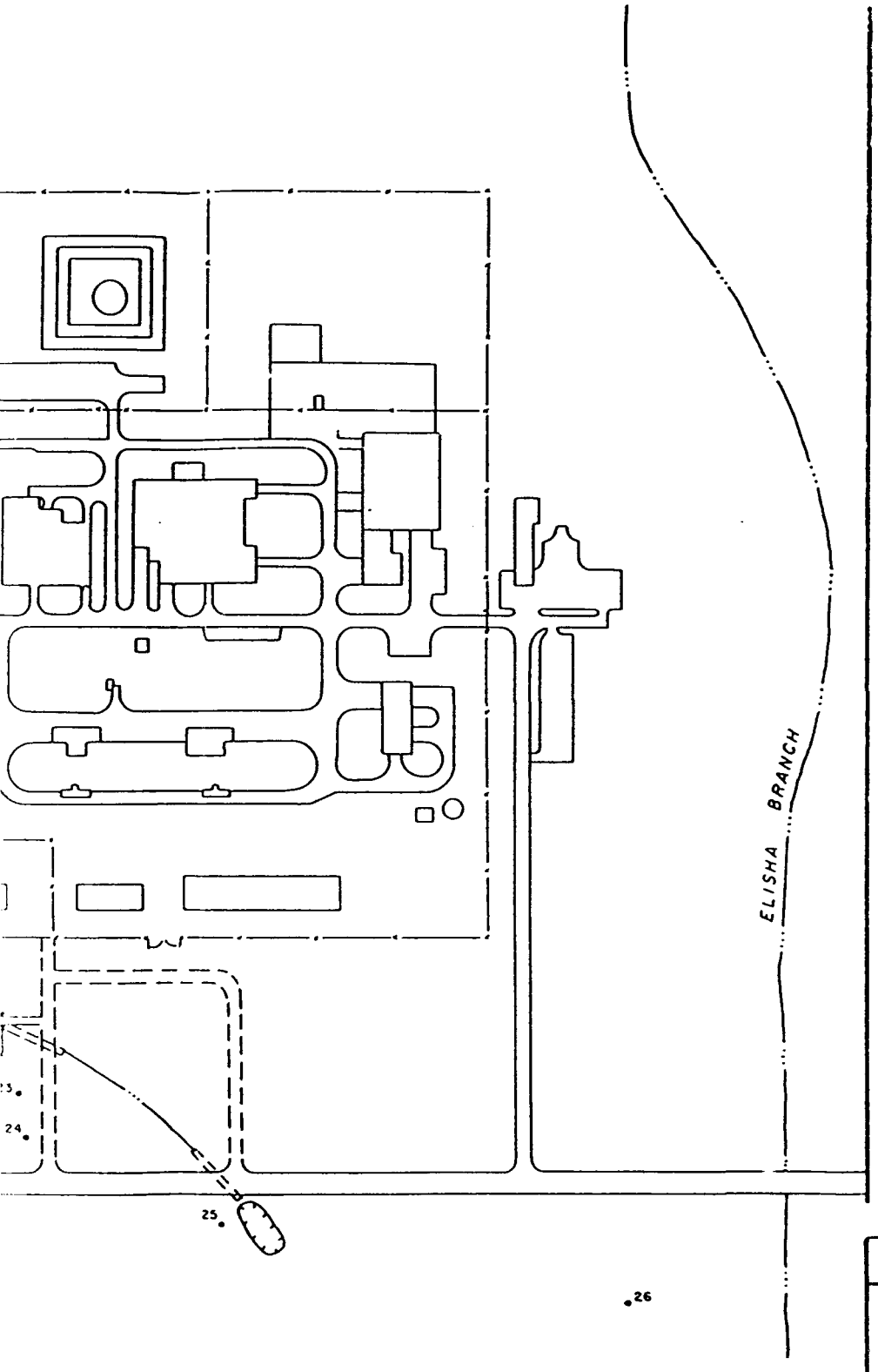
16
22
21
20
23
24
25
OCEAN COUNTY HIGHWAY NO. 539



EXPLANATION

20 BOREHOLE LOCATION AND IDENTIFICATION NUMBER (B20)

DRAINAGE

PONDING AREA

CULVERT

NORTH

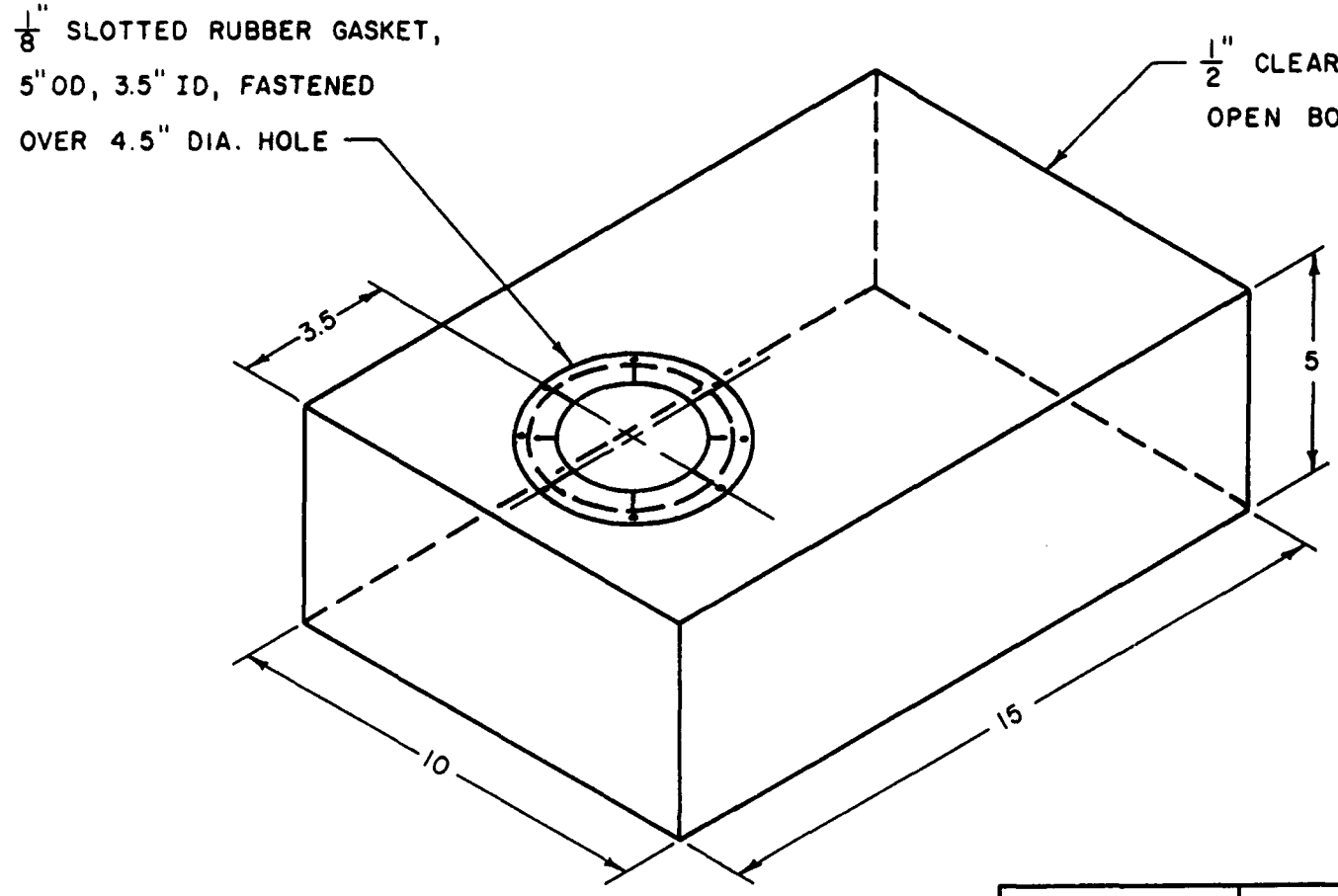
0 250 FEET

SCALE

The Earth Technology Corporation

FIGURE 3-40

LOCATION OF BOREHOLE SOIL SAMPLES COLLECTED AT THE BOMARC MISSILE SITE



SCALE : 1" / 4 = 1'

The Earth Technology Corporation

FIGURE 3-41

SCHEMATIC DIAGRAM OF THE ACRYLIC BOX USED TO COVER THE CORE DRILL

After a core cover was positioned over the drill site, the core bit was lowered through a circular hole in the top of the core cover. A rubber gasket mounted around the inside of the core cover hole prevented drill cuttings or water from spraying the drill operator. The transparency of the cover was advantageous for it allowed the drill operator and assistants to see the cuttings as they emerged from the hole.

During the drilling operation, a Hako Minuteman wet/dry vacuum system with a 55-gallon drum adapter was used to collect drilling water and cuttings as they flowed from the corehole. It was equipped with a High Efficiency Particulate Airborne (HEPA) filter to prevent particulate matter from entering the drill operators' breathing zone. This vacuum system transported the drilling waste into the 55-gallon drum, which was double-lined with heavy-duty plastic bags.

All drilling equipment was carefully wiped off with paper towels and then scanned with the PAC-4G meter between coreholes. Strippable paint was removed and disposed of in a lined, 55-gallon drum, along with disposable clothing worn by the field workers.

As core samples were removed from the corehole, they were labeled with an arrow indicating the top of the core sample. Samples were also labeled with the date and time of sample collection, sample number, sample interval, sampler, and FIDLER readings on the sample and background. Samples were then sealed in a plastic Ziplock™ bag and containerized in a 4-inch PVC casing with slip-on PVC caps. The PVC sample containers were labeled in the same manner as the samples. These samples were stored in Shelter 207 for future analysis or disposal.

3.6.2.8 Rust Samples

One rust sample was collected from the top surface of the inner lid to the power bunker (Figure 3-9). After the bunker was opened (see Section 3.6.2.2.2), this sample was collected by scraping the lid with a stainless-steel spoon and transferring the sample into sample jars. A total of two 8-ounce sample jars were filled.

Five additional rust samples were collected from the center of the floor of Shelter 204 in 8-foot spacings. The samples were deposited into Ziplock™ plastic bags and labeled. All of these rust samples were stored at the site for potential future analysis.

3.6.2.9 Health Protection Sampling

The following sections discuss the health protection sampling.

3.6.2.9.1 Field Measurements

Instruments capable of measuring radiation levels and organic vapor concentrations were used in combination with strict field safety practices to assure the health and safety of all field personnel during sampling operations.

Prior to the commencement of sampling activities, three high-volume air samplers (Model GMWL-2000H) were used to collect baseline ambient air samples over a five-day period, from three positions around Shelter 204. The purpose of this sampling was to determine the baseline gross alpha and gross beta activity around the study area.

The high-volume air samplers were run continuously during concrete/asphalt, shallow soil, borehole soil, sediment, and surface water sampling operations in the vicinity of Shelter 204. The baseline samples were shipped to Battelle Columbus laboratory for analysis, while the samples collected during field operations were scanned onsite using a PAC-4G alpha radiation meter. Some of the scanned samples were sent to the SAIC Laboratory in Rockville, Maryland, while others were saved onsite so that in the event of a contamination incident or evidence of exposure, they could be sent for a more definitive analysis.

During wipe sampling activities, a PAC-4G meter was used to measure the amount of alpha activity at the majority of the wipe sampling locations before samples were collected. This procedure helped bring the samplers' attention to areas where alpha activity was concentrated and to ensure that adequate levels of personal protection were being worn.

PAC-4G and PAC-1S alpha meters were used during concrete/asphalt, shallow soil, sediment, and surface water sampling to screen samples for removable surface activity levels and to check personnel and equipment for contamination. The relatively large surface area of these two probes made them very effective for this type of screening. A Johnson RML-1A Alpha meter was also used to check the hands and feet of field workers as well as the tires of their field vehicles prior to leaving the job site.

Although workers wore air-purifying respirators equipped with HEPA filters during intrusive activities, nasal smears were taken from workers on a regular basis during the field work, particularly during concrete/asphalt coring, soil coring, bunker sampling, and after cleaning the floor of Shelter 204. The purpose of this sampling was to determine if workers inhaled any radioactive dust particles while performing these activities. These samples were analyzed onsite using a Ludlum 2000, Model 19, alpha scintillation detector.

Either a Foxboro Model 128GC OVA flame ionization detector or an HNu photo-ionization detector was used at each sampling site to continuously screen the ambient air for organic vapor concentrations.

3.6.2.9.2 Laboratory Measurements (Including Dosimetry).

Prior to the commencement of any field activities, a total of 13 ambient air samples were collected almost continuously over a five-day period from three sampling stations situated in a triangular pattern around the perimeter of the study area. These samples were submitted to Battelle Columbus Laboratory for gross alpha and gross beta analyses. The results from the analysis of these samples were used as a baseline for comparison during and after sampling in order to ensure the health and safety of both workers and the local public.

Dosimetry badges supplied by ICN Dosimetry and specific for low-level gamma radiation were worn by all field personnel for the purpose of tracking radiation dosages while performing field work. These badges were replaced with new ones at the end of each month, while the old badges were shipped to ICN Laboratory for analysis. The site Certified Health Physicist was responsible for seeing that workers did not exceed their maximum yearly dose.

Urine samples were collected from field personnel over a 24-hour period prior to the commencement of field work. These samples were shipped to Teledyne Isotopes Laboratory to be analyzed by alpha spectroscopy for plutonium and americium. The purpose in running these analyses was to identify a baseline concentration of those radionuclides in the urine of each worker prior to the commencement of field work.

3.6.2.10 Contamination Control and Equipment Decontamination Procedures

The following sections discuss contamination control and equipment decontamination procedures.

3.6.2.10.1 Contamination Control

In order to prevent the spread of radioactive contamination from the study area, disposable clothing was worn by all workers while performing field work inside the exclusion zone. Prior to exiting the exclusion zone, workers removed their Tyvek suits and outer latex gloves. These garments were deposited in a waste drum. Rubber booties were screened for radiation using the PAC-4G meter. If the booties were found to be clean, they were removed and left just inside the exclusion zone. When booties showed signs of contamination, they were disposed of in the waste drum. As each booty was removed, the clean foot of the sampler was placed outside the exclusion zone. The clean inner gloves were the last garments to be removed and were also thrown into the waste drum.

Prior to coring operations, plastic sheeting was taped to the ground surface around the drilling locations to prevent drilling water and drill cuttings from spreading contamination to the surrounding area. At the completion of the coring operation, this sheeting was folded onto itself and deposited in a waste drum. Strippable paint was also used to prevent the spread of any contamination and, upon removal, it was discarded as contaminated waste in a waste drum.

A Hako Minuteman wet/dry vacuum system with a 55-gallon drum adaptor was used while core drilling to collect potentially contaminated drilling water and cuttings. This vacuum system pulled drilling waste into a double-thickness plastic bag lining the 55-gallon drum. Inside Shelter 204 the vacuum system was used to remove dust, dirt, and rust from the building foundation prior to laying the plastic sheeting. The vacuum was equipped with a HEPA filter to prevent respirable-sized particles from being expelled from the exhaust. This reduced the chance of workers inhaling radioactive dust particles.

All disposable clothing, respirator filters, paper towels, decontamination water, and drill cuttings were drummed. All waste drums were labeled noting the type of waste contained. These drums

were also labeled as potentially radioactive. Drums containing waste materials were stored on s..e inside a locked launcher shelter pending disposal by the Air Force.

3.6.2.10.2 Radiological Decontamination

All drilling, soil, and air sampling equipment used only to collect samples for radiological analysis was wiped off with dry paper towels after use in order to remove dust and dirt which could contain radioactive particles. When necessary, the paper towels were moistened with potable water to aid in cleaning. After each piece of equipment was cleaned and dried, it was scanned with the PAC-4G alpha detector in order to confirm that it was free of contamination. If contamination was detected, the above procedure was repeated until the contamination was removed. The geometry of certain equipment, such as the split spoon sampler, is such that effective scanning with the PAC-4G was not possible. Decontamination was checked by analyzing wipe samples of the decontaminated surfaces. A Hako Minuteman wet/dry vacuum system and strippable paint were also used to prevent the spread of contamination. At the end of the field effort all equipment was again screened before being removed from the site. Certain equipment (i.e., the core drilling equipment and the HEPA-filtered wet/dry vacuum) could not be fully decontaminated, so were disposed of as radioactive waste.

3.6.2.10.3 Chemical Decontamination

All soil and water sampling equipment except the barrel water filter used to collect samples for inorganic analysis was decontaminated by: (1) washing in laboratory-grade detergent (Alconox) and potable water, (2) rinsing with potable water, (3) rinsing with ASTM Type II reagent water, (4) rinsing with pesticide-grade methanol, and (5) rinsing with pesticide-grade hexane. After each piece of equipment was allowed to air dry, it was scanned with the PAC-4G alpha detector to assure no radiological contamination and then was wrapped in foil. If the PAC-4G alpha detector detected any contamination, the entire decontamination procedure was repeated.

The acrylic composition of the barrel water filter required a unique decontamination procedure. The barrel filter was decontaminated using the following procedure: (1) washing in laboratory-grade detergent (Alconox) and potable water, (2) rinsing with potable water, (3) rinsing with 0.1 normal nitric acid (HNO_3), and (4) rinsing with ASTM Type II reagent water. A radiation scan was performed to assure no radiological contamination was present. If any were detected, the entire procedure was repeated.

3.6.3 Sample Preservation Methods, Required Containers, and Holding Times

The following sections discuss sample preservation methods, required containers, and holding times.

3.6.3.1 Sample Preservation Methods

Water samples collected for gross alpha, gross beta, plutonium, total metals, and dissolved metals were preserved with concentrated HNO_3 to a pH less than 2. Water samples collected for TCL volatile organics, semi-volatile organics, and pesticide/PCB analysis were cooled with ice to a temperature of four degrees centigrade.

Soil samples collected for TCL volatile organic, semi-volatile organic, pesticide/PCB, and TAL metal analysis were preserved by cooling to a temperature of four degrees centigrade. Soil samples collected for gross alpha, gross beta, and plutonium analysis did not require preservation.

Ambient air, wipe, and concrete/asphalt core samples did not require preservation. Samples collected for chemical analysis were shipped in a metal cooler cooled to four degrees centigrade. All other samples were also shipped in a metal cooler but not cooled.

3.6.3.2 Required Containers

After collection, ambient air sample filters were: (1) sealed in a large Ziplock™ plastic storage bag, (2) placed in a large manila envelope, and (3) screened for radiation levels prior to being shipped to the laboratory for radiation analysis.

Wipe samples were analyzed for radiation only. These samples were containerized in Ziplock™ plastic storage bags.

The 4-inch diameter concrete and/or asphalt core samples collected were containerized in 4-inch PVC casing with slip caps. These samples were screened on site for radiation only and were not shipped.

Water samples collected for TCL volatile organic analysis were containerized in the required 40 ml, Teflon-capped glass vial. Water samples collected for radiation and metal analysis were containerized in 16 ounce polyethylene bottles. All other chemical analysis samples were containerized in a one-half gallon, amber glass jug.

Soil samples collected for radiation analysis through the concrete and/or asphalt coreholes around Shelter 204 were collected using a 2 inch by 6 inch brass sleeve. Once collected, these samples were transferred to an 8 ounce plastic jar for shipment. All other soil and sediment samples for both radiation and chemical analysis were containerized in 8 ounce, Teflon-capped, glass jars.

All containers were supplied by the respective laboratories.

3.6.3.3 Holding Times

For radiological samples where the primary contaminant of interest is plutonium, several points need to be considered. In terms of traditional holding times, plutonium is treated as a metal and, with proper preservation, has a 6-month holding time for aqueous samples before significant plating on the sample container occurs. Soils and sediments to be analyzed for plutonium do not have a specific holding time.

For chemical analysis samples, Table 3-8 shows the holding times observed during this investigation. As indicated in the table, several ground water samples analyzed for volatile organics, pesticides/PCBs, and mercury, and two background soil samples analyzed for mercury exceeded holding times specified for this project. These missed holding times affect the validity of the data, but do not affect the technical conclusions made for this project. Chemical analyses of ground water would have been considered in remedial planning if ground water required remediation due to the presence of radionuclides. Since radionuclides from the site were not detected, the chemical data were not used for that purpose. Chemical contamination at the BOMARC site is currently being investigated under a separate IRP effort. The missed holding times for mercury in the two background soil samples also do not affect technical conclusions presented in the report, because mercury was not identified in elevated concentrations in any of the site soil samples.

3.6.4 Field Quality Assurance/Quality Control (QA/QC) Program (Summary of Contractor's QAPP)

Field quality control samples were collected for samples to be analyzed for non-radioactive contamination (TCL and TAL parameters). Some of those samples also had radiological analyses performed on them.

One blind duplicate sample, one equipment blank, and one ambient condition blank were collected for ground water sampling quality control. The blind duplicate sample collected from well PU-7 was prepared by filling two complete sets of water sample bottles after well stabilization. The duplicate sample was labeled as a sample collected from a non-existent well designated PU-10.

A ground water sampling equipment blank and an ambient condition blank were prepared immediately before the purging and sampling of well PU-2. The equipment blank was prepared by pouring ASTM Type II water through the decontaminated stainless steel and Teflon™ bailers, into the decontaminated barrel filter, and then collecting this water in sample bottles. The ambient condition blank was prepared by pouring the ASTM Type II water directly into the water sample bottles at the sampling site.

Table 3-8

BOMARC Missile Site
Summary of Analysis Dates and Holding Times
(Organic Analyses)

Sample Numbers	Sampling Date	Volatiles SW8240		Pesticides/PCBs SW8080		
		Analysis Date	Number of Days Out of Holding[1]	Extraction Date	Number of Days Out of Holding[1]	Analysis Date
GW-PU1-001	6/28/89	7/10/89	5	7/17/89	12	7/24/89
GW-PU2-001	6/30/89	7/10/89	3	7/17/89	10	7/24/89
GW-PU5-001	6/29/89	7/10/89	4	7/17/89	11	7/24/89
GW-PU7-001	6/29/89	7/11/89	5	7/17/89	11	7/24/89
GW-PU10-001	6/29/89	7/11/89	5	7/17/89	11	7/24/89
AMB-PU2-001	6/30/89	7/11/89	4	NR	-	NR
EQU-PU2-001	6/30/89	7/11/89	4	7/17/89	10	7/24/89
Trip Blank (30925)	6/29/89	7/11/89	5	NR	-	NR
Trip Blank Re-analysis	6/29/89	7/11/89	5	NR	-	NR

NR = Not Required

[1] Holding time is 7 days.

Table 3-8 (Continued)

BOMARC Missile Site
Summary of Analysis Dates and Holding Times
(Inorganic Analyses)

Sample Numbers	Sampling Date	Mercury SW7470		
		Digestion Date	Number of Days Out of Holding*	Analysis Date
001-GW-PU1-001 TOT	6/28/89	9/1/89	37	9/1/89
001-GW-PU1-001 DIS	6/28/89	9/1/89	37	9/1/89
001-GW-PU2-001 TOT	6/30/89	9/1/89	35	9/1/89
001-GW-PU2-001 DIS	6/30/89	9/1/89	35	9/1/89
001-GW-PU5-001 TOT	6/29/89	9/1/89	36	9/1/89
001-GW-PU5-001 DIS	6/29/89	9/1/89	36	9/1/89
001-GW-PU7-001 TOT	6/29/89	9/1/89	36	9/1/89
001-GW-PU7-001 DIS	6/29/89	9/1/89	36	9/1/89
001-GW-PU10-001 TOT	6/29/89	9/1/89	36	9/1/89
001-GW-PU10-001 DIS	6/29/89	9/1/89	36	9/1/89
001-AMB-PU2-001 DIS	6/30/89	9/1/89	35	9/1/89
001-EQU-PU2-001 TOT	6/30/89	9/1/89	35	9/1/89
001-SL-BK1-001	8/1/89	10/4/89	34	10/6/89
001-SL-BK2-001	8/1/89	10/4/89	34	10/6/89

* Holding time is 28 days.

In an attempt to collect valid split soil samples for plutonium analysis, a sufficient quantity of material was collected in several locations to provide sample splits. These samples were taken into the possession of the oversight agency (U. S. EPA) for grinding, homogenizing, and sample splitting. Laboratory errors invalidated these samples, so no data is available on these field samples. Interpolations from field readings has allowed limited use of these samples in establishing contamination values for the site.

3.6.5 Radioactive Waste Containment

Provided here is a summary of radioactive waste containment procedures. All waste generated that was known or suspected to be radiologically contaminated was containerized in new 30- and 55-gallon, DOT-approved (Specification 7A) steel drums as required by Title 49 Code of Federal Regulations (CFR) 178. Each drum was single-lined with a heavy-duty yellow plastic liner marked with the magenta radiation symbol. When a drum was filled, the plastic liner was fastened closed and the drum was sealed. Each drum was labeled, inventoried, and transported to the interim holding area (Shelter 207) to await pick-up and disposal by the Air Force low-level radiological waste disposal contractor. At the end of the field effort, the doors to Shelter 207 were welded closed to ensure the integrity of the drums until proper disposition could take place.

3.6.6 Transportation Considerations

In order to transport radiologically contaminated samples, including to a laboratory for analysis, certain considerations must be addressed. Those considerations include adhering to all State and Federal regulations for shipping and licensing. All SAIC samples transported from the BOMARC site were prepared and shipped in accordance with DOT requirements as outlined in 49 CFR Part 173, particularly Subpart I, which addresses transportation of radioactive materials. These DOT requirements satisfy State of New Jersey requirements for transporting radioactive materials as outlined in the New Jersey Administrative Code (N.J.A.C 7:28-12). This section also incorporates, by reference, NRC regulations set forth in 10 CFR Part 71.

An inventory of all samples, including such information as the known or suspected isotope(s) and the total sample activity must be prepared before any samples are transported off site. Shipping records were prepared for all samples leaving the BOMARC site. A copy of the shipping record used to transport samples to Teledyne Isotopes is included in Appendix D. At the time of this inventory, or before, such items as sample containers, packaging, placarding of vehicles, routes to destination, and notification of authorities must be considered.

The destination or receiving point for all samples being shipped must possess a valid and appropriate radioactive materials license and be capable of handling the particular radioactive isotope in the quantities being sent. The Teledyne Isotopes, TMA Eberline, SAIC Rockville, and Battelle Columbus Division Laboratory were all properly licensed. Copies of their licenses are included in Appendix E.

The specific procedures used to prepare and ship samples from the BOMARC site are summarized below.

1. All soil samples were containerized in 250 ml Nalgene™ bottles. Water samples were collected in 500 ml Nalgene™ bottles. After the sample was collected, the cap on each bottle was tightened, then sealed with electrical tape.

2. The outside of all bottles were wiped for removable alpha activity, and the wipe samples were counted on the Ludlum 2000 Scaler. Samples were also scanned using the HPG prior to leaving Shelter 210. The Am-241 activity was recorded, and the Pu-239 activity was calculated.

3. Packing of all samples was done in accordance with 49 CFR Part 173. The soil sample bottles were each placed in individual Ziplock™ plastic bags and placed in cardboard boxes. Each sample was separated in the box by cardboard partitions. Shipping documents and chain of custody forms for the samples in that box were enclosed in sealed plastic bags and placed inside the box. The boxes were sealed at all openings with packaging tape and strapping tape. A chain-of-custody seal was placed on all openings of each box.

   The water sample bottles were each placed in individual Ziplock™ bags, wrapped in bubble wrap, and placed upright in coolers. The coolers were filled with a clay-type kitty litter in sufficient quantities to absorb the water from the samples should spillage occur. Shipping documents and chain-of-custody forms for the samples in that cooler were enclosed in sealed plastic bags and placed inside the cooler. The drains were taped shut, and the coolers were sealed at all openings with packaging and strapping tape. A chain-of-custody seal was placed on the lid of each cooler.

   Following these procedures, each box contained:

   - Solid (soil, sediment) samples
   - A copy of the shipping documents, including the Radioactive Materials Shipping Record, showing the activity of individual samples as well as the total activity for the box
   - Chain-of-Custody records.

   Each cooler contained:

   - Water samples

- A copy of the shipping documents, including the Radioactive Materials Shipping Record showing the activity of individual samples as well as the total activity for the box

- Chain-of-Custody records.

4. Radiation stickers were placed on each container and corresponding information (number of samples per box, date shipped, and box number) was recorded for the shipping manifest.

5. The vehicle was placarded on all four sides with signs reading "Radioactive".

6. Sample containers (boxes and coolers) and the van were screened with an alpha counter prior to passing through the gate and leaving the final check point of the BOMARC site.

7. Transportation of the samples to Teledyne Isotopes was by van, driven by one of the radiation site workers. The shipment was transported to Teledyne Isotopes in Westwood, NJ via the Garden State Parkway (GSP). GSP police were notified prior to transport and they gave permission for use of the highway, providing that compliance with all State and Federal regulations was maintained. The transportation of the samples to the laboratory required approximately one hour, and the trip was completed without incident.

Wipe samples were shipped to Teledyne Isotopes by Federal Express. Screening indicated very low activity, thus permitting this form of shipment. Transportation of environmental air samples to Battelle Columbus was by U.S. Postal Service. The samples were screened for alpha activity prior to shipment and were found to be non-radioactive. Water samples shipped to TMA Eberline went by way of Federal Express. Again, screening indicated very low activity, thus permitting this form of transportation.

3.7 Laboratory Program

The following sections discuss the laboratory program.

3.7.1 Identification of Laboratories

Radiological samples were analyzed by one of four offsite laboratories: Battelle Columbus Division Laboratory (baseline environmental air samples), TMA Eberline (gross alpha and gross beta analysis on water samples), Teledyne Isotopes (plutonium/americium analyses by alpha spectroscopy) and SAIC Rockville (environmental air samples). Chemical samples were analyzed by Metatrace Laboratories.

3.7.2 Description of Analytical Parameters and Laboratory QA/QC Program

Summary information is presented here on the laboratory analyses and QA/QC programs for the laboratories used on this project. Additional details on these laboratories and analyses may be found in Appendix L (Analytical Data), in the Laboratory Informal Technical Information Report (ITIR), and in the Quality Assurance Project Plan (QAPP). Chemical samples were analyzed by MetaTrace Laboratories.

3.7.2.1 Teledyne Isotopes

Samples sent to Teledyne Isotopes were analyzed for plutonium by alpha spectroscopy by isotope dilution methods using a Canberra 7404 System with multichannel analyzer by standard method PRO-052-32. This method is summarized in the following subsections.

3.7.2.1.1 Determination of Plutonium, Uranium, Americium, Curium, and Thorium by Alpha Spectroscopy

This sequential radiochemical procedure for analyzing various alpha-emitting nuclides by alpha spectroscopy uses isotope dilution methods. It applies to aqueous samples as well as to solids such as soils and sediments, air particulate filters, and wipes.

Measured quantities of the appropriate isotope dilution spikes (Pu, U, Am, Cm, Th) are first added to an aliquot of the sample. Solid samples are leached in nitric acid and filtered. For aqueous samples, the alpha emitting nuclides are co-precipitated with iron hydroxide. In all cases, the prepared sample is dissolved in 7N HNO_3 and passed through an anion exchange column. The effluent is saved for U, Am, and Cm processing, if appropriate.

Thorium is stripped from the column using 9N HCl, then plutonium is stripped using 1N HNO_3 followed by 5% hydroxylamine hydrochloride solution. These portions are evaporated, then dissolved in O.1N HNO_3 and electroplated onto stainless-steel disks.

The original column effluent is evaporated, dissolved in 9N HCl, then passed through another anion exchange column. The effluent is converted to 1.1N HNO_3 solution and is electroplated onto a stainless-steel disk for Am and Cm analysis, as appropriate.

Iron is stripped from the second column using an HCl and HI solution. Uranium is then stripped from the column using 0.1N HCl. This effluent is converted to 0.1 N HNO_3 and is electroplated onto a stainless-steel disk for uranium analysis, if appropriate.

Electroplated disks are assayed on an alpha spectrometer equipped with surface-barrier silicon diode detectors which are housed in vacuum chambers. The energy regions corresponding to the desired nuclides are integrated (determined by analyzing isotopic standards). The isotope dilution spike peak is also integrated and is used in the calculation of sample activity in order to quantify chemical yield and counting efficiency.

3.7.2.1.2 Detection Capability

Detection capability depends upon the sample aliquot used in the analysis, the background and efficiency of the counting instrument, and upon the counting interval.

The minimum detectable level (MDL) for alpha-emitting nuclides in soil, sediment, or solid samples is nominally 1.7×10^{-2} pCi/gm at the 4.66 sigma level (1.0×10^{-2} pCi/gm at the 2.83 sigma level). These figures are based on a 10 gm aliquot of sample, a chemical yield of 0.20 (lower than for other sample types), a counting efficiency of 0.20, a counting interval of 1,000 minutes, and a background of 0.01 cpm. The MDL for environmental water samples is nominally 1.3×10^{-1} pCi/L at the 4.66 sigma level (8×10^{-2} pCi/L at the 2.83 sigma level). These are based on a 0.5L aliquot of sample, a chemical yield of 0.5, and other parameter values as stated above.

For in-plant liquids the nominal MDL is 6.6×10^{-9} μCi/ml at the 4.66 sigma level (4.0×10^{-9} μCi/ml at the 2.83 sigma level). These values are based on a 10 ml aliquot of sample, a chemical yield of 0.5, and other parameters as stated above. Finally, the nominal MDL for air particulate filters or wipes is 6.6×10^{-2} pCi per sample at the 4.66 sigma level (4.0×10^{-2} pCi per sample at the 2.83 sigma level). In this case, the sample aliquot is taken as unity, with other parameters assigned as with liquid samples.

3.7.2.1.3 Calculation of the Sample Activity or of the MDL

Calculation of the results is performed by computer according to the algorithms.

If the net activity is equal to or less than a designated multiple of the background counting error, the activity is below the limits of detection and a MDL ("minimum detectable level") or a LT ("less than") is reported.

The LT value can be specified by stating a predetermined multiple of the background counting error. A multiple of 4.66 is used for the calculation of LT values unless another value such as 2.83 is stated.

3.7.2.1.4 Analysis of Quality Control Samples for Teledyne Isotopes

Blank and spiked samples provide a means of determining the precision and accuracy of the monitoring process. Analysis of spiked samples of known concentration and activity provides a means of determining accuracy. Analysis of replicate samples provides a means of determining precision. Analysis of blank samples provides a means to detect contamination and to check adequacy of background subtraction and purity of reagents and chemicals used.

Blank, Spike and Replicate Samples. Blank, spiked, and replicate samples are analyzed in each laboratory totaling at least 5% of the analytical sample load. Quality Control samples prepared by contractors may be used in computing this percentage. Spikes are prepared from NBS

standards or the equivalent. Blank and spiked samples are submitted for analysis as unknowns, where possible. These blanks and spikes may include blind replicates.

The results of the spiked and blank samples are reported to the quality assurance manager as soon as possible. They are kept on file in the office of the quality assurance department. These results are analyzed and corrective actions are taken, if necessary. The acceptance criteria depend on the particular analysis and should fall within 3 standard deviations of the EPA one sigma, one determination as specified in EPA-600-4-81-004, February 1981, "Environmental Radioactivity Laboratory Intercomparison Studies Program", Table 3, Page 8.

EPA Intercomparison Samples. Samples are submitted by the EPA on a nation-wide basis to participating laboratories from the Environmental Monitoring Systems Laboratory, Post Office Box 15027, Las Vegas, Nevada 80114. All samples which are applicable to the analyses performed at Teledyne Isotopes will be analyzed and the results submitted to the EPA. The acceptance criteria is $\pm$ three normalized deviations from the known. The method of calculating the normalized deviation is described in EPA-600-4-81-004, February 1981, "Environmental Radioactivity Laboratory Intercomparison Studies Program".

The results of the EPA intercomparison tests are analyzed by the quality assurance manager. Form IWL-35R is prepared giving the normalized deviation from the known and the grand average of all the participants in the cross-check. This report of results is sent to the laboratory manager, the laboratory supervisor, and the technician who performed the analysis for their information and any necessary action.

If the results to the EPA cross-check analyses are beyond the $\pm$ two sigma limits as specified in the EPA Report of Results, Form IWL-49 is prepared comparing the results with previous tests to indicate whether or not a trend is indicated. Documentation of corrective action is included in the reply to the report.

The results of all EPA cross-check analyses are documented in Quality Control Manual IWL-0032-361 and a copy sent to all interested customers every six months.

3.7.2.2 Battelle Columbus Division Laboratory

Samples obtained from the baseline high-volume environmental air sampling were sent to Battelle Columbus Division Laboratory for gross alpha and gross beta analyses.

The activity measurements were conducted using a Tennelec Series III 5100 Automatic Alpha and Beta/Gamma Counting System.

Samples from the filters were prepared by cutting a circular section 4.45 cm in diameter from the as-received filter. Both before and after weight measurements were performed following a 24-hour exposure to controlled humidity and temperature conditions. This exposure allowed the moisture content of the filter to equilibrate with the room conditions. Without such exposure,

the variation in moisture content of the filter would affect the accuracy of the particulate mass determination.

Each sample was counted for 40 minutes and the measured activity scaled up to the area of the entire filter. The activity measurements are corrected for instrument background. Values are stated in units of disintegrations per minute (dpm). The gross activity measurements are combined with the filtered air volume to provide activity concentrations in units of dpm per cubic meter (dpm/m^3).

3.7.2.3 TMA Eberline

Water samples requiring analysis for gross alpha and gross beta were sent to TMA Eberline. They were analyzed using a Berthold Model 770-2 gas proportional counter, by standard EPA method for drinking water, EPA-600/4-08-032, Method 900.0. Quality control samples and procedures, as outlined below, were followed to ensure the quality of the analyzed samples.

Precautions were taken in the laboratory to avoid cross-contamination of samples and to assure the reporting of accurate results. Quality control samples were analyzed along with routine samples to indicate when results might be in error due to improper operation or calibration of equipment, inadequate training of personnel, some deficiency in the procedure, or cross-contamination from other samples. Laboratory precision was ensured by using the procedures described in the following subsections.

3.7.2.3.1 Reference Radioactive Sources

Reference radioactive sources were counted weekly to check instrument stability. The reference sources were prepared so that they contained sufficient activity to give good counting statistics in a reasonably short counting time. The isotopic content of the standards have a long half-life or have a high enough purity to allow accurate correction of the activity for decay. The reference radioactive source is not an efficiency standard; however, a standard may be used for both stability and efficiency determinations. If two successive determinations of the established mean for a reference radioactive source or counts fell outside the two standard deviation limits, and in the same direction (both above or both below), an assignable cause was sought and the situation corrected.

3.7.2.3.2 Duplicate Analyses

In this method, duplicate aliquots of randomly selected samples were processed with each batch of samples (a batch is a set of 20 samples). The analyst always processes samples in accordance with routine standard operating procedures. The evaluation of the duplicate analyses was based on examination of the difference between the duplicates. This was done by the Quality Control Representative. A statistical analysis of the data may be performed when a cursory evaluation indicates problems with the results. If the two results agree within the two standard deviation

limits, more detailed evaluation is not required. Duplicate analyses are included in the monthly Quality Control report.

3.7.2.3.3 Detection and Elimination of Bias

Where possible, the TMA/Eberline laboratory calibrates with solution standards that are traceable to the National Institute of Standards and Technology (NIST). However, traceability to NIST is not always possible and the laboratory may have to rely on other suppliers (e.g., Amersham-Searle, International Atomic Energy Agency, U.S. Department of Energy (DOE), and U.S. EPA). Standards in the appropriate geometry or form are used to determine efficiency of instruments on a weekly basis. In the calibration process, the ideal standard will be a known quantity of the radionuclide to be measured, prepared in exactly the same geometry as the samples and counted under the same conditions. In this way, factors such as self-absorption, back-scattering, sample geometry, and detector efficiency will be accounted for empirically.

3.7.2.3.4 Spiked Samples

A known quantity of calibrated radioactive standard solution was added to an aliquot of the sample or to a "blank" sample for replicate analyses. When the entire analytical system is operating properly, the laboratory record will demonstrate the accuracy and precision of the data. Divergent data from the spiked samples will point out problem areas. For example, if the data are consistently higher or lower than the known value, they indicate bias in the analytical procedure. This may require a search for personnel errors, restandardization of carriers or tracers, and/or recalibration of counting equipment.

3.7.2.3.5 Internal Tracer

The radioactive tracer was added in a chemical and physical form appropriate to the analytical procedure to help assure uniform reproduction of the path followed by radionuclides present in the sample.

3.7.2.3.6 Replicate Analyses

Replicate spiked samples were used, whenever practicable, when an internal tracer is not used as a routine part of the analytical procedure. Calibration standards are periodically counted and calibration standard solutions used to spike blank samples, to allow for quality control, where replicates are impractical. Results of spiked samples are included in the monthly Quality Control report.

3.7.2.3.7 Background Determination

A number of equipment and environmental factors contribute to variation in counting or instrument background. The background of each system is determined and recorded with

sufficient frequency to provide a firm statistical basis for that measurement and also to assure response to potential instrument problems or other artifacts such as uncontrolled contamination.

These background determinations include use of items which most closely duplicate the analytical configuration in type, geometry, and with any associated fixtures. In some cases, true blanks are not available, but the closest practicable analog is used.

Some systems and samples are sufficiently stable to require no change in backgrounds used for data reduction (e.g., uranium daughter gamma-rays found in gamma spectra due to adjacent building materials and earth). In this case, backgrounds will be compared to historical data to ensure sufficient stability. Other systems experience enough variability to require computed backgrounds based upon running averages.

Background data are recorded in the log book for that specific instrument along with calibration data and instrument maintenance records. Results of blanks processed with batches of samples will be included in the monthly Quality Control report.

In addition to the internal quality control samples described above, the laboratory participates in collaborative testing or interlaboratory comparison programs. Natural or synthetic samples carefully prepared to contain known concentrations of the radionuclides are sent to participating laboratories by an independent referee group such as the Quality Assurance Branch of the National Radiation Assessment Division of the U.S. EPA in Las Vegas, Nevada, the Environmental Measurements Laboratory, U.S. DOE in New York, and the International Atomic Energy Agency in Vienna, Austria. After statistically comparing the resulting data from triplicate analyses of the special standard sample, the degree of analytical validity of the results is reported and updated performance information is returned to each participant. The program thus enables each laboratory to document the precision and accuracy of radioactivity measurements, identify instrumental and procedural problems, and compare performance with other laboratories.

3.7.2.4 MetaTrace

Ground water and soil samples obtained for chemical analysis were analyzed by Metatrace. Chemical analyses of soil and ground water samples were not originally planned for this project, because the main concern at the BOMARC site is radionuclide contamination. Chemical analyses were added at the request of the U.S. EPA in order to ensure that any remedial actions planned for the site were capable of addressing any chemical contaminants that may have been present.

Since chemical sampling and analysis were added to the scope of work subsequent to completion of project planning documents, including the Quality Assurance Project Plan, it was determined that major revisions to planning documents were not required for the purposes of addressing the relatively minor amount of chemical analyses to be done. Rather, it was decided to specify that all analyses be conducted according to U.S. EPA Contract Laboratory Program (CLP) protocols,

as per the U.S. EPA CLP Statements of Work for Organics Analysis (updated 4/89) and Inorganics Analysis (Updated 6/89).

U.S. EPA CLP protocols will not be restated here. Applicable limits of detection, frequency and type of QA/QC data and establishment of QA/QC sample control limits are as specified in the referenced documents, and can be found therein.

The data validation for this effort consisted of a review of holding times, associated blanks, surrogate recoveries, matrix spike/duplicate results and second column confirmation results. No tuning or calibration review was conducted as part of this effort. The resulting data quality is EPA level III.

4.0 RESULTS AND SIGNIFICANCE OF FINDINGS

4.1 Presentation and Discussion of Results

The following sections discuss and present results from this investigation.

4.1.1 Site Geology

A general description of the geology in the BOMARC Missile Site region is included in Subsection 2.2. The following presents geologic data gathered during this investigation. These interpretations are based on past site-specific studies and logs obtained from boreholes completed as part of this RI/FS.

Twenty-six shallow boreholes were drilled at the BOMARC Missile Site during this investigation. The boreholes were drilled to approximately 10 feet bgs and were located in the vicinity of Shelter 204 and along the concrete/asphalt drainage ditch. Two of the boreholes were drilled in the ponding area across New Jersey Route 539. Soil boring logs completed during this investigation are presented in Appendix C.

The shallow borings revealed the Cohansey Sand, a relatively homogeneous sand unit. The sand is a medium to fine, poorly graded sand with intermixed silt lenses. Lenses of fine gravel to coarse sand were also observed. A yellowish stain is apparent throughout with some shades of red, brown, gray, and white being found.

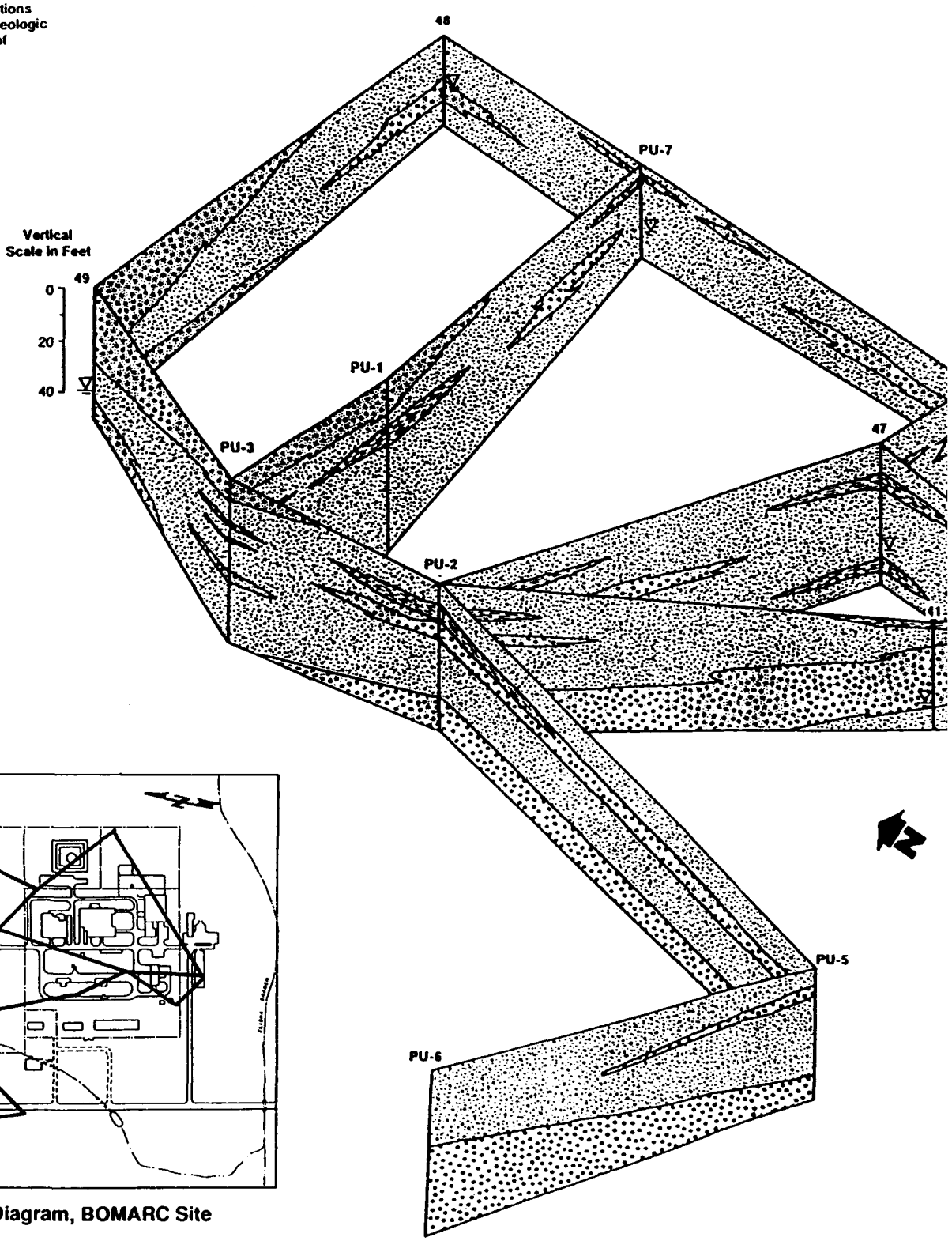
Previous investigations (Weston, 1989) encountered this medium to fine sand unit extending to a maximum depth of 40 feet bgs in some areas of the BOMARC Missile Site. Beneath this, a coarse to fine sand with a maximum thickness of 30 feet was encountered. These units are shown in the fence diagram (Figure 4-1) adapted from a previous study (Weston, 1989). As this diagram shows, the BOMARC Missile Site is underlain by an interfingering of coarse to medium sands with lenses of gravel and clay throughout.

4.1.2 Site Hydrogeology

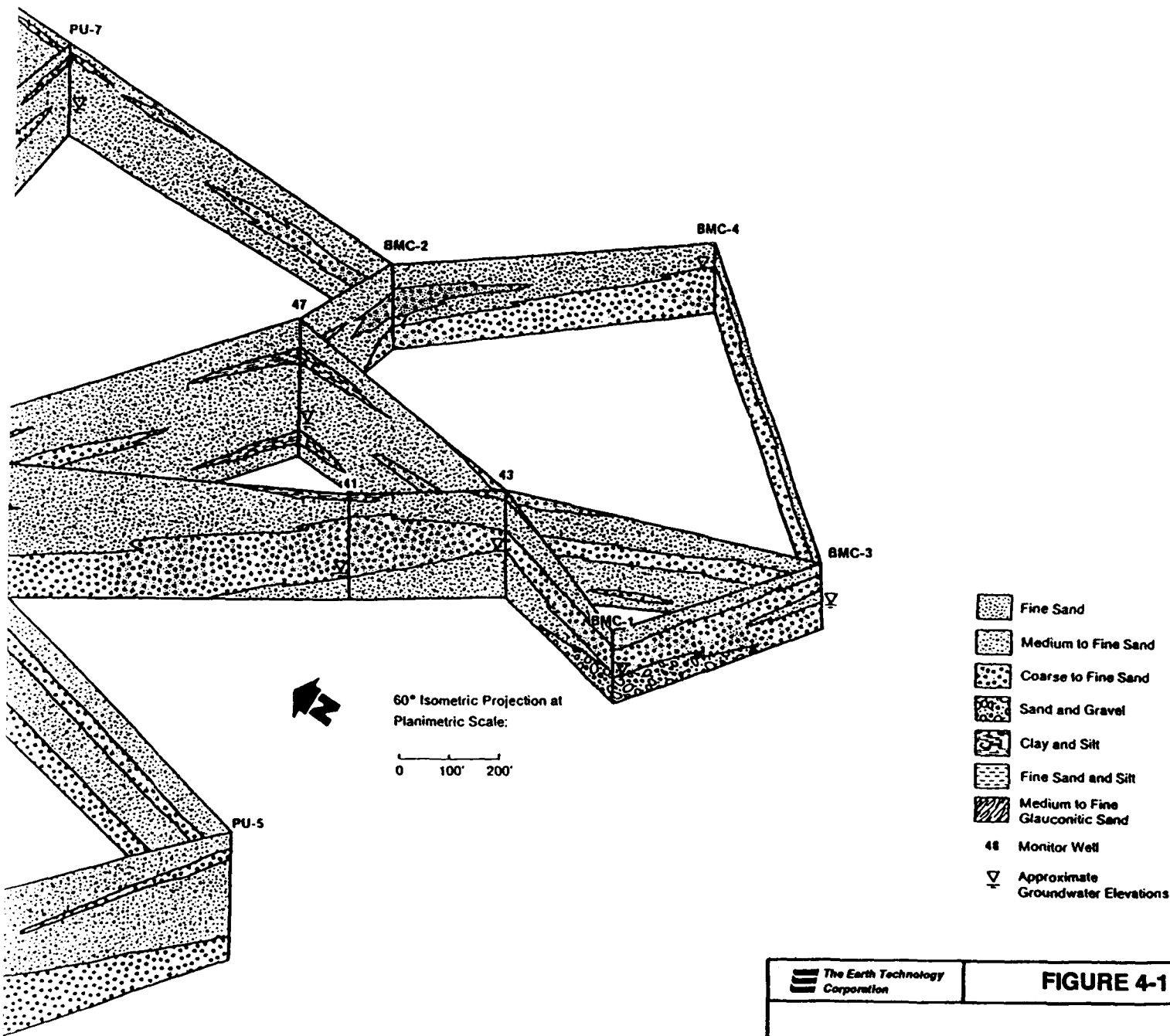
Ground water encountered in monitoring wells at the BOMARC Missile Site is under unconfined conditions. Ground water level measurements were taken in each of ten monitoring wells prior to sampling. These readings were referenced to the top of the casing (TOC) using a Solinst electronic sounder and were later converted to ground water elevations using TOC survey data from previous investigations. Ground water elevations (in feet above MSL) are plotted and contoured as shown in Figure 4-2.

The purpose in contouring ground water elevation data is to provide information on ground water flow direction and ground water gradient. Ground water flows downgradient in a direction perpendicular to elevation contour lines. Gradient is a unitless measurement of the difference in ground water elevation (feet) between two monitoring wells, divided by the distance (feet) between the two wells. In general, if all other factors are equal, the steeper the gradient, the greater the flow velocity of the ground water.

Note:
Correlation lines are drawn for illustrative purposes only. Actual Conditions between wells may vary. Additionally, geologic units are generalized, and intermixing of units may occur.



Location of Fence Diagram, BOMARC Site



Adapted from: Weston, 1988.

The Earth Technology Corporation

FIGURE 4-1

FENCE DIAGRAM
BOMARC MISSILE SITE

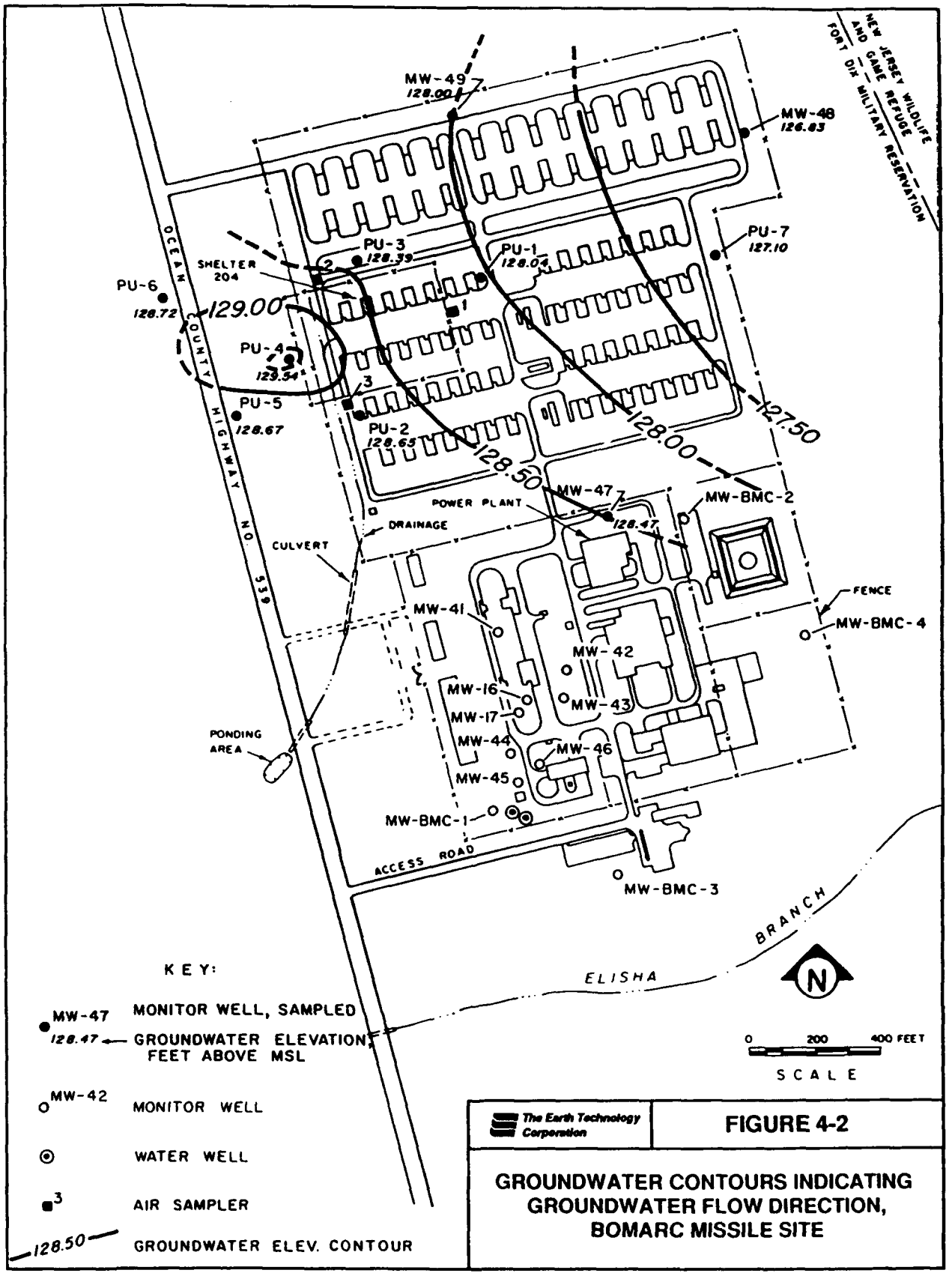


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FIGURE 4-2

GROUNDWATER CONTOURS INDICATING GROUNDWATER FLOW DIRECTION, BOMARC MISSILE SITE

Figure 4-2 identifies a ground water divide generally trending northwest-southeast, with the axis of the divide located very close to well PU-4. This divide causes ground water in wells PU-5 and PU-6 to flow to the west-southwest, and ground water in the wells PU-1, PU-3, PU-7, MW-47, MW-48, and MW-49 to flow to the east-northeast. There presently is not enough information to determine if ground water screened in wells PU-2 and PU-4 is flowing to the northeast or the southwest. The ground water gradient is as steep as 0.005 between wells PU-1 and PU-4, decreases to less than 0.001 between wells PU-1 and MW-48, and averages around 0.002 across the study area.

Field information collected during well purging is presented in Table 4-1. Included in this table are the calculated discharge rates (gpm) and estimated specific capacity (gpm/ft) for each well sampled. The discharge rate is the rate at which water is removed from the well, and the specific capacity is defined as the yield per unit of drawdown. Specific capacity calculations are only estimates because a bailer was used in the purging of the wells instead of a pump, resulting in inconsistent and relatively slow discharge rates. Very little, if any, drawdown resulted from the slow rate of water discharge; therefore, estimates of transmissivity were not made since the results would be unreliable.

The water column varied in thickness from 4.37 feet in well PU-4 to 14.55 feet in well MW-49. The maximum drawdown recorded at the end of purging was 0.57 feet in well PU-4, indicating that the formation has a good recovery rate. The maximum purging discharge rate was 0.3 gpm. Estimated specific capacities ranged from a low of 0.37 gpm/ft in well PU-4 to a high of 29.00 gpm/ft in well MW-49.

4.1.3 Analytical Results

4.1.3.1 Ground water

Filtered and unfiltered ground water samples and one duplicate were collected from ten monitoring wells installed by previous contractors around the northern portion of the BOMARC facility (total of 22 samples). The wells sampled included PU-1 through PU-7 and MW-47 through MW-49 (Figure 4-2). The procedures used in sampling are outlined in Section 3.6.2.1. All samples were shipped to the laboratory to be analyzed for gross alpha and gross beta. Samples from five of the wells (PU-3, PU-6, PU-7, MW-48, MW-49) with a sixth sample, PU-10, as a duplicate from well PU-7, were also analyzed for Pu-239 by alpha spectroscopy.

The results from the laboratory analyses of the above samples are presented in Table 4-2. The activities reported for gross alpha and gross beta have an error factor attached to them ranging from ± 2 pCi/L to ± 7 pCi/L. Also included in this table are method detection limits and Federal and State Action Levels.

Only one well (samples PU-7 and PU-10, a duplicate of PU-7) contained gross alpha in a filtered sample in concentrations exceeding State and Federal Action Levels. One of these samples (PU-7) exceeded the action level only if the positive error factor was added to the reported

Table 4-1

Well Purging Data for BOMARC Missile Site

Well	Depth to Bottom of Screen (TOC) (Ft)	Depth to Static Water Level below TOC (Ft)	Groundwater Elevation above msl	Gallons In Water Column Before Purging (Gal)	Purging Time (Min)	Drawdown (Ft)	Feet per Minute of drawdown (Ft/min)	Gallons of Water Bailed (Gal)	Well Volumes Bailed
PU-1	67.80	54.85	128.04	1.9	--	--	--	7.5	3.9
PU-2	56.55	45.66	128.65	1.6	30	--	--	6.5	4.1
PU-3	58.60	48.67	128.39	1.6	83	0.00	0.00	9.0	5.6
PU-4	52.50	48.13	129.54	0.7	14	0.57	0.04	3.0	4.3
PU-5	52.96	40.34	128.67	1.9	48	--	--	8.0	4.2
PU-6	47.55	39.55	128.72	1.3	29	0.00	0.00	5.0	3.8
PU-7	36.92	25.20	127.10	1.8	33	--	--	6.5	3.6
MW-47	53.80	41.15	128.47	1.9	33	0.22	0.01	10.0	5.3
MW-48	32.50	18.90	126.83	2.1	38	0.05	0.00	10.5	5.1
MW-49	53.65	39.10	128.00	2.2	31	0.00	0.00	9.0	4.1

* Data not collected.
** CO= Cloudy

Table 4-1 (continued)

Well Purging Data for BOMARC Missile Site

Well	Feet of Drawdown per gallon (Ft/gal)	Discharge (Q) or (gpm)	Estimated Specific Capacity (Q/S) or (Gpm/Ft)	Final Water pH***	Final pH*** Change	Final Water Specific Conductance (μmhos)/cm)	Final Change Specific Conductance (μmhos/cm)	Final Water Temperature (°C)	Final Temperature Change (°C)	Final Water Appearance**
PU-1	--	--	--	5.00	0.00	48	0	16.5	0	*
PU-2	--	0.22	--	4.04	0.01	48	0	14.0	0	*
PU-3	0.00	0.11	11.00	4.34	0.03	59	1	14.5	0.1	CO
PU-4	0.19	0.21	0.37	3.57	0.04	115	6	12.8	0.0	CO
PU-5	--	0.17	--	5.05	0.00	58	0	13.0	0.0	*
PU-6	0.00	0.17	17.00	4.37	0.01	35	0	13.0	0.2	CO
PU-7	--	0.20	--	4.29	0.01	95	3	16.0	0.2	CO
MW-47	0.02	0.30	1.36	4.39	0.01	100	2	14.4	0.0	CO
MW-48	0.00	0.28	5.60	5.10	0.02	81	2	15.0	0.0	CO
MW-49	0.00	0.29	29.00	7.05	0.04	80	1	14.5	0.04	CO

* Data not collected.
** CO= Cloudy.
*** Standard Units.

Table 4-2
Analytical Data for Ground Water Samples Collected at the BOMARC Missile Site

Sample ID	Date/Time Collected	Filtered/ Unfiltered	Preservation	Total Volume (ml)	Parameter	Method	Method Detection Limit (pCi/L)	Activity (pCi/L)	Standards and Action Levels (a)	
									Federal	State
PU1	06-28-89 1730	UF	HNO3 HNO3	900	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	16 +-4 13 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU1	06-28-89 1730	F	HNO3 HNO3	780	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	3 +-2 0 +-3	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU2	06-30-89 0915	UF	HNO3 HNO3	1010	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	13 +-4 15 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU2	06-30-89 0915	F	HNO3 HNO3	800	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	3 +-2 9 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU2	06-30-89 0945	UF	HNO3 HNO3	995	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	5 +-3 0 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU2	06-30-89 0945	F	HNO3 HNO3	975	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	4 +-3 0 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU3	07-07-89 1615	UF	HNO3 HNO3 HNO3	930	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	29 +-6 22 +-4 <3.03E-02	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU3	07-07-89 1615	F	HNO3 HNO3 HNO3	1000	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	0 +-3 6 +-4 <5.0E-02	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU4	07-08-89 0700	UF	HNO3 HNO3	960	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	13 +-4 8 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU4	07-08-89 0700	F	HNO3 HNO3	1020	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	9 +-3 16 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
001-G-PU5-001	06-29-89 1100	UF	HNO3 HNO3	995	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	6 +-3 5 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
001-G-PU6-001	07-07-89 1100	UF	HNO3 HNO3	925	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	16 +-4 14 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU5	07-07-89 1100	F	HNO3 HNO3	1000	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	5 +-3 9 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L

Table 4-2 (continued)
Analytical Data for Ground Water Samples Collected at the BOMARC Missile Site

Sample ID	Date/Time Collected	Filtered/ Unfiltered	Preservation	Total Volume (ml)	Parameter	Method	Method Detection Limit (pCi/L)	Activity (pCi/L)	Standards and Action Levels (a)	
									Federal	State
PU6	07-07-89 1100	F	HNO3 HNO3	1000	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	0 +-3 4 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU6	06-29-89 1615	UF	HNO3 HNO3 HNO3	925	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	51 +-7 33 +-5 <3.0E-02	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU7	06-29-89 1615	F	HNO3 HNO3 HNO3	775	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	13 +-4 14 +-4 <2.0E-02	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU7	06-29-89 1630	UF	HNO3 HNO3 HNO3	850	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	17 +-4 15 +-4 <1.0E-01	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU10	06-29-89 1630	F	HNO3 HNO3 HNO3	685	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	17 +-4 19 +-4 <5.0E-02	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
PU10	07-08-89 1000	UF	HNO3 HNO3	960	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	12 +-4 10 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
MW47	07-08-89 1000	F	HNO3 HNO3	985	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	8 +-3 6 +-3	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
MW47	07-06-89 1200	UF	HNO3 HNO3	985	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	9 +-3 10 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
MW48	07-06-89 1200	F	HNO3 HNO3	790	Gross Alpha Gross Beta	EPA-60/4-80-032 EPA-60/4-80-032	3 2	0 +-3 0 +-4	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
MW48	07-06-89 1555	UF	HNO3 HNO3 HNO3	900	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	40 +-7 37 +-5 <5.0E-02	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
001-GW-MW49-001	07-06-89 1555	UF	HNO3 HNO3 HNO3	900	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	40 +-7 37 +-5 <5.0E-02	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L
001-GW-MW49-001	07-06-89 1555	F	HNO3 HNO3 HNO3	845	Gross Alpha Gross Beta Pu-239	EPA-60/4-80-032 EPA-60/4-80-032 PRO-052-32	3 2 1.0	4 +-3 7 +-4 <3.0E-02	15 pCi/L 50 pCi/L	15 pCi/L 50 pCi/L

(a) Federal Action Levels: Alpha - Safe Drinking Water Act (SDWA); 40n CFR 141.154
Beta - SDWA; 40 CFR 141.16; 50 pCi/L from guidance provided in the Federal Register, Friday 7/9/76, FR 41, vol. 133, p. 28402

State Action Levels: New Jersey Administrative Code, Title 7. Department of Environmental Protection, Chapter 28, Bureau of Radiation Protection

activity. A total of eight wells (PU-1, PU-2, PU-3, PU-4, PU-6, PU-7, and its duplicate PU-10, MW-48 and MW-49) contained gross alpha in unfiltered samples in concentrations exceeding State and Federal Action Levels. Three of the samples (PU-2, PU-4, PU-10) exceeded the action level only if the positive factor was added to the reported activity.

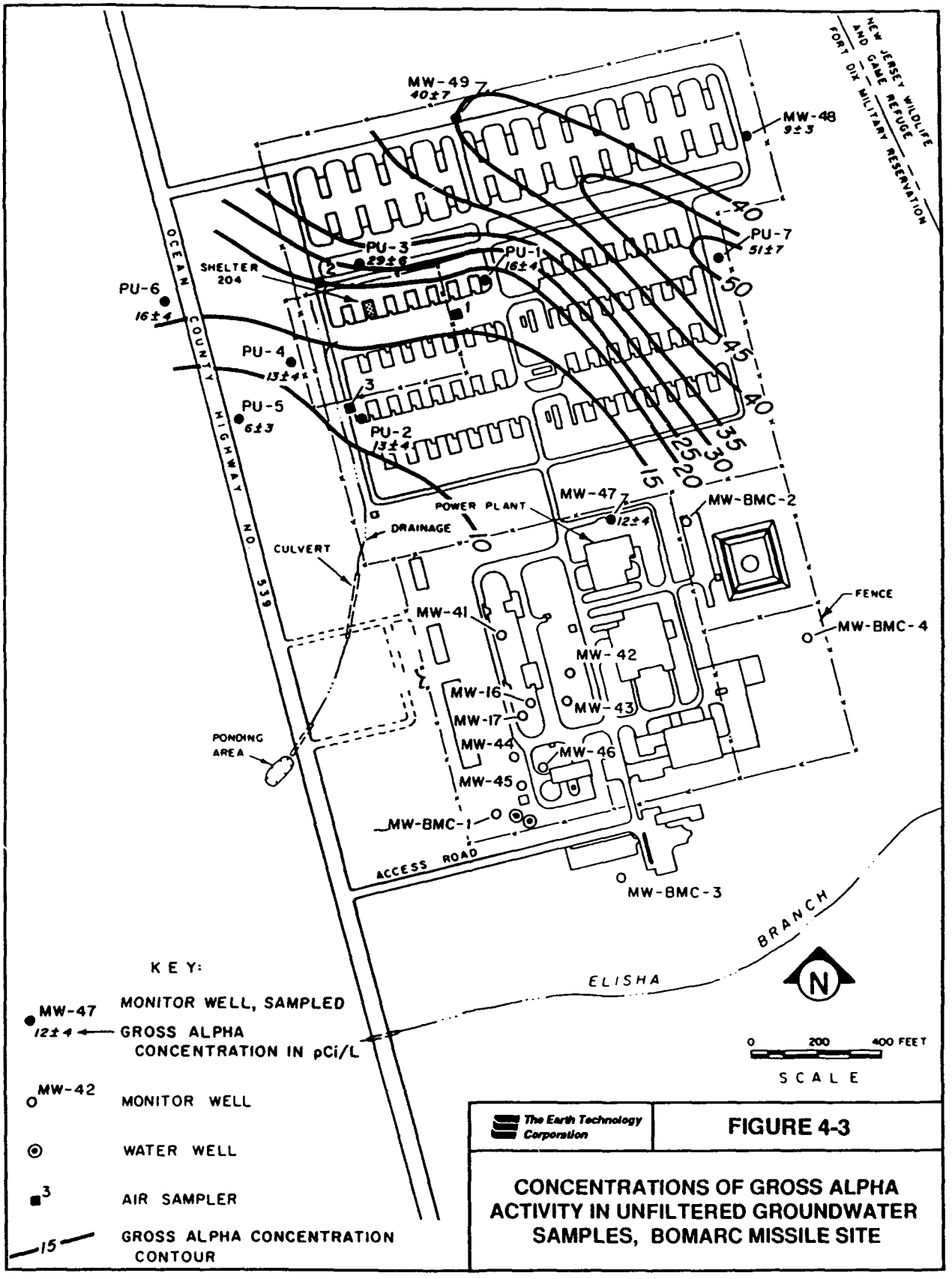
It should be noted that the turbid nature of the ground water sampled made filtration very difficult. During the filtration process, it was necessary to replace filters several times to acquire the volume of sample needed for analysis. A cloudy appearance of the sample water after filtration suggests that a substantial portion of the suspended material was not removed by the filter. This was especially true for the sample collected from well PU-7. Since this was the only filtered sample which showed gross alpha concentrations exceeding State and Federal Action Levels, it appears that either the filter was incorrectly positioned or that this sample should have been filtered more than once to remove all of the suspended particulate matter. Because of technical problems with the barrel filter at this well, it is most likely that water containing sediment passed through the apparatus.

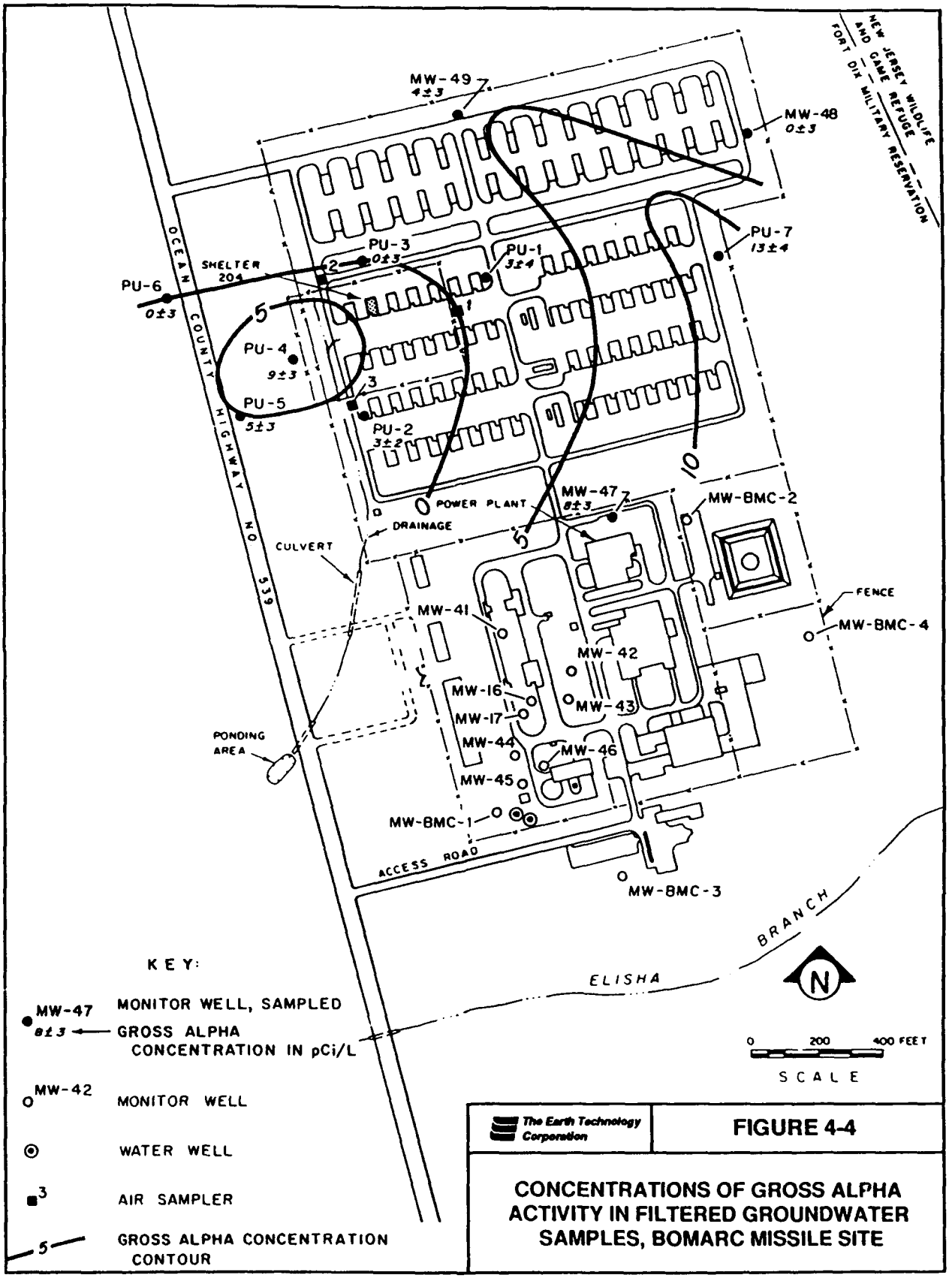
To aid interpretation of the results, the filtered and unfiltered concentrations of gross alpha and gross beta in the ground water were contoured and are presented below (Figure 4-3, Figure 4-4, Figure 4-5, and Figure 4-6). The results from the Pu-239 analyses were not plotted since no concentrations were identified above the method detection limit.

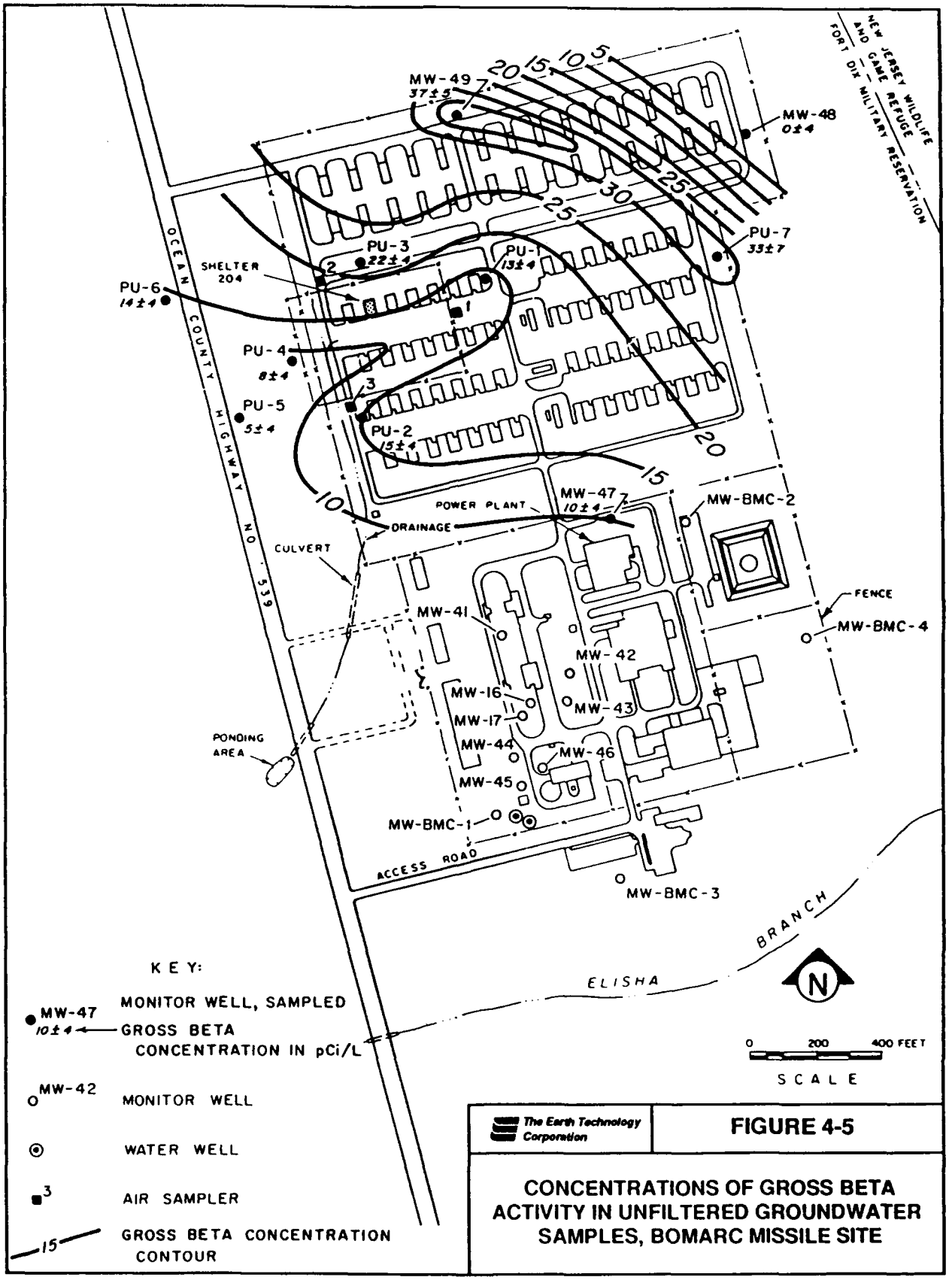
Figure 4-3 illustrates how the gross alpha activity in unfiltered ground water increases steadily to the north and east, with the highest concentration being found in wells PU-7 and MW-49. Comparing these results to contoured ground water elevation data (Figure 4-2), there is apparent correspondence in ground water flow direction and increasing gross alpha concentration.

The gross alpha results from filtered ground water samples are contoured in Figure 4-4. Although only one of the filtered samples showed gross alpha activity above the State and Federal Action Levels, there is a detectable increase in activity towards the east, with localized highs on the west side near wells PU-4 and PU-5 and one on the east side at well PU-7. Ground water from well MW-48 showed no detection of gross alpha activity in the filtered sample. Although gross alpha was detected in these wells, it should be noted that the alpha spectroscopy analyses did not detect any plutonium in either filtered or unfiltered ground water samples that was above the method detection limit of 1 pCi/L.

Although no gross beta concentrations in unfiltered ground water were found to exceed the State and Federal Action Levels, a plot of the concentrations detected (Figure 4-5) showed a very similar pattern to the unfiltered gross alpha plot. In this diagram, relatively low levels of activity were detected in wells along the drainage south of Shelter 204 (wells PU-2, PU-4, and PU-5). However, activity increased substantially downgradient (to the east) with the most activity detected in samples collected from wells PU-7 and MW-49.


MW-49
40±7
MW-48
9±3
PU-7
51±7
PU-3
29±6
PU-1
16±4
SHELTER
204
PU-6
16±4
PU-4
13±4
PU-5
6±3
PU-2
13±4
OCEAN COUNTY HIGHWAY NO 539
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
POWER PLANT
DRAINAGE
CULVERT
MW-47
12±4
MW-BMC-2
FENCE
MW-BMC-4
MW-41
MW-42
MW-16
MW-43
MW-17
MW-44
MW-46
MW-45
MW-BMC-1
ACCESS ROAD
MW-BMC-3
PONDING AREA
ELISHA BRANCH
N
0 200 400 FEET
SCALE
KEY:
MW-47
12±4
MONITOR WELL, SAMPLED
GROSS ALPHA CONCENTRATION IN pCi/L
MW-42
MONITOR WELL
WATER WELL
3
AIR SAMPLER
15
GROSS ALPHA CONCENTRATION CONTOUR
The Earth Technology Corporation
FIGURE 4-3
CONCENTRATIONS OF GROSS ALPHA ACTIVITY IN UNFILTERED GROUNDWATER SAMPLES, BOMARC MISSILE SITE


MW-49
4±3
MW-48
0±3
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
PU-7
13±4
PU-3
0±3
PU-1
3±4
SHELTER 204
PU-6
0±3
PU-4
9±3
PU-5
5±3
PU-2
3±2
OCEAN COUNTY HIGHWAY NO 539
POWER PLANT
MW-47
8±3
MW-BMC-2
DRAINAGE
CULVERT
FENCE
MW-41
MW-BMC-4
MW-42
MW-16
MW-43
MW-17
MW-44
MW-46
PONDING AREA
MW-45
MW-BMC-1
ACCESS ROAD
MW-BMC-3
BRANCH
ELISHA
N
0 200 400 FEET
SCALE
KEY:
MW-47 8±3 GROSS ALPHA CONCENTRATION IN pCi/L
MONITOR WELL, SAMPLED
MW-42 MONITOR WELL
WATER WELL
3 AIR SAMPLER
5 GROSS ALPHA CONCENTRATION CONTOUR
The Earth Technology Corporation
FIGURE 4-4
CONCENTRATIONS OF GROSS ALPHA ACTIVITY IN FILTERED GROUNDWATER SAMPLES, BOMARC MISSILE SITE


MW-49
37±5
MW-48
0±4
PU-7
33±7
PU-3
22±4
PU-1
13±4
SHELTER
204
PU-6
14±4
PU-4
8±4
PU-5
5±4
PU-2
15±4
OCEAN COUNTY HIGHWAY NO. 539
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX — MILITARY RESERVATION
POWER PLANT
DRAINAGE
MW-47
10±4
MW-BMC-2
CULVERT
FENCE
MW-BMC-4
MW-41
MW-42
MW-16
MW-43
MW-17
MW-44
MW-46
MW-45
PONDING AREA
MW-BMC-1
ACCESS ROAD
MW-BMC-3
ELISHA BRANCH
N
0 200 400 FEET
SCALE
KEY:
MW-47 10±4 GROSS BETA CONCENTRATION IN pCi/L
MONITOR WELL, SAMPLED
MW-42 MONITOR WELL
WATER WELL
3 AIR SAMPLER
15 GROSS BETA CONCENTRATION CONTOUR
The Earth Technology Corporation
FIGURE 4-5
CONCENTRATIONS OF GROSS BETA ACTIVITY IN UNFILTERED GROUNDWATER SAMPLES, BOMARC MISSILE SITE

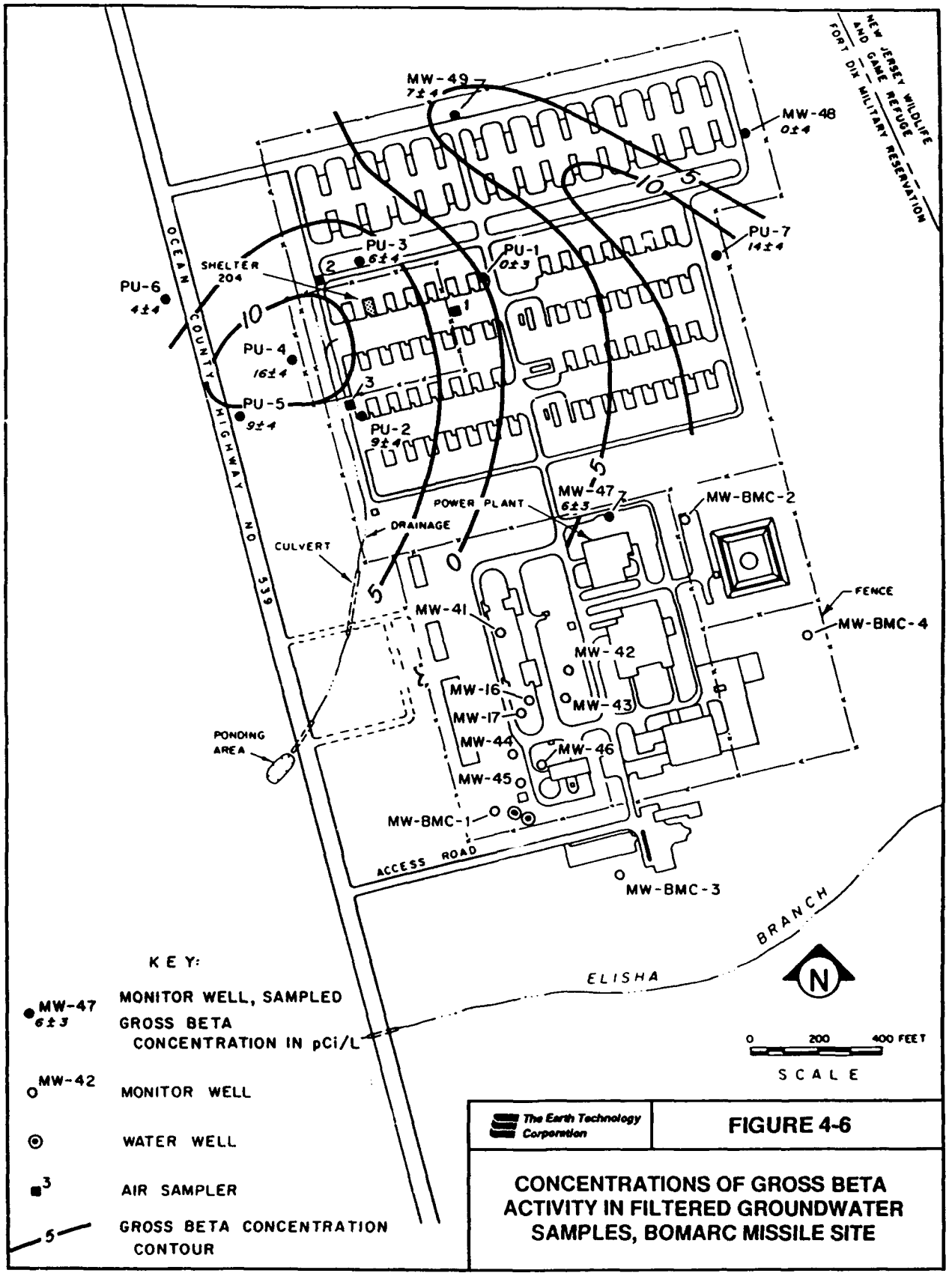


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FIGURE 4-6

CONCENTRATIONS OF GROSS BETA ACTIVITY IN FILTERED GROUNDWATER SAMPLES, BOMARC MISSILE SITE

None of the plutonium and americium isotopes expected on this site are beta emitters, except Pu-241, which is formed as a neutron absorption product of Pu-239 prior to its decay to Am-241. Quantities of Pu-241 are orders of magnitude less than Pu-239 or Pu-240, and its half-life is less than 14 years, so it is not likely to be a large source of beta emissions.

None of the filtered samples analyzed for gross beta showed concentrations exceeding the State and Federal Action Levels. A high of 16 $\pm$ 4 pCi/L was detected in ground water collected from well PU-4 (Figure 4-6). Lower activity was found in well PU-1 to the east, and increasing concentrations were noted in wells toward the eastern and northeastern boundaries. No activity was detected in well MW-48 which is the easternmost well sampled.

It should be noted that the environmental investigation (Weston, 1989), performed in 1987, detected Pu-239 (0.9 $\pm$ 0.3 pCi/L) in the first unfiltered ground water samples collected from well PU-4 after the well was installed. It was thought that the well may have been contaminated when it was constructed.

At least two explanations can be found to explain the general increase in gross alpha and gross beta activity to the northeast. The first is that contaminants have migrated downgradient from the source area (presumably Shelter 204 and/or surrounding contaminated soils). This hypothesis could be of special interest if plutonium had been detected in any of the well samples. Because none of the samples from the wells showed measurable plutonium, it would appear that the gross alpha and beta activities are not due to plutonium contamination.

The second possibility is that the generally increasing activity levels in ground water to the northeast may be related to the ground water recharge area centered around well PU-4. The local ground water is acidic, with a pH on the site ranging from 3.57 to 7.05 (Table 4-1) and averaging 4.72. This pH is consistent with the normal acidity found in the area of around 4.5 (USGS, 1969, 1970, 1972, 1974, 1978, 1982, and 1983). Uranium and thorium are both found naturally in this area, and both are readily leached in acidic or oxidizing environments (Garrels and Christ, 1959; Rogers and Adams, 1967; Cordfunke, 1969).

No plutonium was found in any of the wells during this field effort, indicating that the alpha activity was caused by a different radioactive isotope, such as naturally occurring uranium, thorium, radium, or radon. Since 1985, the USGS and the NJDEPE have been studying the distribution of uranium, radium, and radon in ground water in southern New Jersey (Szabo, USGS; NJDEPE Research Investigation, 1990; Zapecza and Szabo, 1989). Their studies include the Cohansey-Kirkwood aquifer in parts of five counties (Camden, Gloucester, Salem, Atlantic, and Cumberland). Eighty-two wells were sampled in the Cohansey-Kirkwood aquifer; 26 of the wells exceeded 5 pCi/L of combined radium. The gross alpha particle activity exceeded 5 pCi/L for 25 of the 26 wells with high combined radium. The highest level of contamination was 14 pCi/L.

Personnel from the U.S. Air Force Armstrong Laboratory resampled wells PU-3 and PU-6 in January 1992. Both filtered and unfiltered samples were collected and analyzed for gross alpha, gross beta, Pu-239, Th-232, U-234, U-235, U-238, and Ra-226 in an effort to determine which radionuclides were present in the samples, causing the observed elevated gross alpha activity. Results of this effort indicate that naturally-occurring uranium isotopes are present in the samples

and are the cause of the elevated gross alpha activities observed. The presence of Pu-239 in well sediments is most likely due to well construction activities rather than mobilization of Pu-239 in groundwater. Results of the sampling and analysis by the Armstrong Laboratory are presented in Appendix R.

The activity pattern seen at the BOMARC site may suggest that low activity rainwater infiltrates the ground surface near well PU-4; as it migrates through the ground, it leaches naturally occurring alpha emitters. All uranium isotopes are alpha emitters, as are Th-227, Th-228, Th-230, and Th-232. Thorium-231 and Th-234 are both beta emitters. The acidic ground water would also gradually pick up naturally occurring radioactive gases such as radon (an alpha emitter), which is quite soluble in water. Most of the activity is in the suspended (unfiltered) phase. There is insufficient data to determine if that activity is migrating as particulates in the ground water or if it was dislodged during well drilling and/or sampling, although the latter is considered most likely.

This hypothesis does not adequately explain the lack of activity in ground water from well MW-48; some other pattern of ground water migration or dilution may be developing near well MW-48 that would cause this lowered activity. There are extensive paved and grassy areas, natural and man-made surface drainages, underground structures such as drainage conduits and tunnels, and other ditches, all of which could influence surface recharge and underground flow. Well coverage in that area is insufficient to confirm this hypothesis.

In addition to the ground water sampling for plutonium, four samples were collected for chemical analysis. Samples were analyzed for U.S. EPA Target Compound List (TCL) organics and Target Analyte List (TAL) metals. Low levels of volatile organics and semi-volatile organics were detected in the ground water samples. There were no pesticides/PCBs detected in the ground water samples and metals concentrations did not appear to be elevated.

Table 4-3 shows volatile organics detected in the ground water samples. Methylene chloride, trichloroethene, acetone, and 1,2-dichloroethene were detected in ground water samples. Both methylene chloride and acetone were detected in blank samples and thus are attributed to laboratory contamination and/or contaminated ASTM Type II water supplied by the lab for preparation of field blanks. Neither methylene chloride nor acetone were detected by previous ground water sampling at the site. Trichloroethene and 1,2-dichloroethene are shown to be present in ground water at the BOMARC Missile Site. The levels of these contaminants range from 8 μg/l to 81 μg/l. These contaminants were detected in wells PU-2 and PU-7.

Table 4-4 shows semi-volatile organics detected in the ground water samples. Bis(2-ethylhexyl)phthalate and dibenzofuran were detected. Both of these contaminants were detected in blank samples and their presence is attributed to laboratory contamination. In addition, detection of these contaminants was not consistent between field duplicates, again indicating laboratory contamination. There were no semi-volatile contaminants detected in the ground water at the BOMARC Missile Site that were attributed to site conditions.

Tables 4-5 and 4-6 show data for the total metals and dissolved metals analyses completed on ground water samples collected at the BOMARC Missile Site. Examination of ground water

Table 4-3

Volatile Organics Detected in Ground Water Samples

Analyte*	Units	CRDL	Federal MCL**	N.J. MCL***	Sample Identification 001-GW-PU1	001-GW-PU2	001-GW-PU5	001-GW-PU7	001-GW-PU10 (Dup of PU7)
Methylene Chloride	µg/l	5	--	--	44 (B)	--	29 (B)	37 (B)	32 (B)
Trichloroethene	µg/l	5	5	1	--	61	--	7	8
Acetone	µg/l	10	--	--	--	--	13 (B)	--	--
1,2-Dichloroethene (Total)	µg/l	5	--	10	--	--	--	62	81

B = Detected in Blank Sample
CRDL = Contract Required Detection Limit
* = EPA CLP methodology was used for all analyses
** = Taken from "Drinking Water Regulations and Health Advisories", April 1990
*** = Taken from "New Standards for Safe Drinking Water In New Jersey", 1989

Table 4-4

Semi-Volatile Organics Detected in Ground Water Samples

Analyte*	Units	CRDL	Federal MCL**	N.J. MCL***	Sample Identification: 001-GW-PU1	001-GW-PU2	001-GW-PU5	001-GW-PU7	001-GW-PU10 (Dup of PU7)
bis(2-ethyl-hexyl)phthalate	µg/l	10	--	--	--	--	2 (J,B)	5 (J,B)	--
Dibenzofuran	µg/l	10	--	--	--	--	--	--	3 (J,B)

B = Detected in Blank Sample
J = Estimated Value
CRDL = Contract Required Detection Limit
* = EPA CLP methodology was used for all analyses
** = Taken from "Drinking Water Regulations and Health Advisories", April 1990
*** = Taken from "New Standards for Safe Drinking Water In New Jersey", 1989

Table 4-5

Total Metals Concentrations for Ground Water Samples

Analtye*	Units	Sample Identification CRDL	Federal MCL**	N.J. MCL***	001-GW-PU1	001-GW-PU2	001-GW-PU5	001-GW-PU7	001-GW-PU10 (Dup. of PU7)
Aluminum	µg/l	200	--	--	25,450	6,278	38,180	176,800	183,800
Antimony	µg/l	60	--	--	ND	ND	ND	ND	ND
Arsenic	µg/l	10	--	50	5.5(B)	ND	ND	17.0	120
Barium	µg/l	200	--	1,000	68.5	72.0(B)	78.0(B)	196.2(B)	210.3
Beryllium	µg/l	5	--	--	ND	ND	1.9	3.8	4.9
Cadmuim	µg/l	5	--	10	ND	ND(N)	ND(N)	ND(N)	ND(N)
Calcium	µg/l	5,000	--	--	3003	3,226(B)	3,289(B)	8,117	8,083
Chromium	µg/l	10	--	50	51.0	21.6	139.0	251.8	266.0
Cobalt	µg/l	50	--	--	ND	ND	9.5(B)	29.1(B)	39.0
Copper	µg/l	25	--	--	60.2	21.0	42.9	104.4	117.1
Iron	µg/l	100	--	--	92890(N)	16,180(N)	171,700(N)	399,700(N)	430,000(N)
Lead	µg/l	5	--	50	9.7	8.16	20.4	39.8	40.9
Magnesium	µg/l	5,000	--	--	2,749(B)	1,984(B)	1,178(B)	3,105(B)	3,160(B)
Manganese	µg/l	15	--	--	69.4	42.9	60.9	497.5	518.4
Mercury	µg/l	0.2	--	2	0.28	0.32	1.15	3.48	3.3
Nickel	µg/l	40	--	--	ND	ND	21.9	61.8	69.1
Potassium	µg/l	5,000	--	--	2,172(B)	ND	2,763(B)	4002(B)	4,466(B)
Selenium	µg/l	5	--	--	ND	ND	ND	ND	ND
Silver	µg/l	10	--	--	ND	ND	ND	ND	ND
Sodium	µg/l	5,000	--	--	1,376(B,E)	1,730(B,E)	8,555(E)	3,426(B,E)	3,531(B,E)
Thallium	µg/l	10	--	--	ND	ND	ND	ND	ND
Vanadium	µg/l	50	--	--	138.8(B)	13.3(B)	1,621	534	603.1
Zinc	µg/l	20	--	--	49.7	26.4	47.5	164.6	177.3

B = Below contract required detection limit
E = Estimated value due to the presence of interference
N = Spike sample recovery not within control limits
ND = Not detected
CRDL = Contract Required Detection Limit
* = EPA CLP methodology was used for all analyses
** = Taken from "Drinking Water Regulations and Health Advisories", April 1990
*** = Taken from "New Standards for Safe Drinking Water In New Jersey", 1989

Table 4-6

Filtered Groundwater Metals Concentrations for Groundwater Samples

Analtye*	Units	Sample Identification CRDL	Federal MCL**	N.J. MCL***	001-GW-PU1	001-GW-PU2	001-GW-PU5	001-GW-PU7	001-GW-PU10 (Dup. of PU7)
Aluminum	µg/l	200	--	--	5,106	112.3(B)	5,149	8,605	1,378
Antimony	µg/l	60	--	--	ND	ND	ND	ND	ND
Arsenic	µg/l	10	--	50	ND	ND	ND	4.79(B)	ND
Barium	µg/l	200	--	1,000	87.4(B)	102.8(B)	114.8(B)	225.3	172.6(B)
Beryllium	µg/l	5	--	--	ND	ND	ND	ND	ND
Cadmuim	µg/l	5	--	10	ND(N)	ND(N)	ND(N)	ND(N)	ND(N)
Calcium	µg/l	5,000	--	--	2,383	3,097(B)	3,056(B)	6,018	6,168
Chromium	µg/l	10	--	50	12.6	ND	20.4	14.1	ND
Cobalt	µg/l	50	--	--	ND	ND	ND	ND	9.8(B)
Copper	µg/l	25	--	--	51.4	15.8(B)	ND	ND	ND
Iron	µg/l	100	--	--	12,550(N)	200.4(N)	24,690(N)	23,300(N)	1,358(N)
Lead	µg/l	5	--	50	14.3	4.87(B)	7.01	3.74(B)	3.85(B)
Magnesium	µg/l	5,000	--	--	2,493(B)	2,134(B)	918.5(B)	2,092(B)	2,153(B)
Manganese	µg/l	15	--	--	24.7	36.1	16.3	380.8	433.2
Mercury	µg/l	0.2	--	2	ND	ND	ND	0.24	ND
Nickel	µg/l	40	--	--	ND	41.9	ND	ND	20
Potassium	µg/l	5,000	--	--	ND	ND	ND	322(B)	2,868(B)
Selenium	µg/l	5	--	--	4.0	ND	ND	ND	ND
Silver	µg/l	10	--	--	ND	ND	ND	ND	ND
Sodium	µg/l	5,000	--	--	1,716(B,E)	2,546(B,E)	9,971(E)	6,868(E)	5,075(E)
Thallium	µg/l	10	--	--	ND	ND	ND	ND	ND
Vanadium	µg/l	50	--	--	24.8(B)	ND	25.6(B)	32.9(B)	ND
Zinc	µg/l	20	--	--	147.8	62.9	54.6	140.2	62.8

B = Below contract required detection limit
E = Estimated value due to the presence of interference
N = Spike sample recovery not within control limits
ND = Not detected
CRDL = Contract Required Detection Limit
* = EPA CLP methodology was used for all analyses
** = Taken from "Drinking Water Regulations and Health Advisories", April 1990
*** = Taken from "New Standards for Safe Drinking Water in New Jersey", 1989

metals data reveals irregularities which suggest that the data are not completely representative of site ground water conditions. The primary factor affecting the representativeness of the data was the abundant sediment contained in water samples drawn from the site monitoring wells. Unfiltered water samples ranged in clarity from opaque to cloudy, with most samples described as opaque. Therefore, data for unfiltered water samples (total metals concentrations) is considered representative of the metals content of suspended sediments as well as the metals content of site ground water. This is because field acidification of samples can potentially solubilize naturally-occurring metals that are present in fine-grained suspended sediments. The contributions by sediments to the total metals concentrations observed are especially evident in the highly elevated concentrations of aluminum and iron. Maximum concentrations of total aluminum (183,800 μg/l) and total iron (430,000 μg/l) observed are well above concentrations of these metals normally observed in even the acidic ground water of the Pinelands region.

These metals are, however, abundant in sediments, especially clays. The concentrations observed are also orders of magnitude greater than concentrations observed in field-filtered samples from the same wells, indicating that removal of sediments by filtration drastically reduces concentrations of metals in site ground water samples.

Field-filtered ground water samples normally give a more representative indication of metals concentrations that are available for transport through an aquifer. These metals can exist either as dissolved species or as colloidal material that passes thought the 0.45 micron filters used in field filtration.

Analytical results for metals for field-filtered samples from the BOMARC Missile Site are considered non-representative of actual site ground water conditions for the following reasons:

- Field-filtered samples were somewhat turbid following filtration, indicating incomplete removal of sediments.

- The sample from well PU-2 was the only sample described as "clear" by the laboratory following filtration. Concentrations of aluminum and iron in this sample were orders of magnitude less than concentrations of aluminum and iron observed in samples from other wells, indicating a possible correlation between sample turbidity and sample metals content, and also indicating the presence of suspended sediments in the field-filtered samples other than the sample from well PU-2.

- Comparison of metals concentrations between the sample from well PU-7 and a blind duplicate from the same well (designated as PU-10) for unfiltered samples indicates that results are for the most part comparable. However, comparison of results for filtered samples reveals that exclusive of common dissolved ground water constituents (calcium, magnesium, manganese, sodium) and especially for aluminum and iron, results are generally not in agreement. This is thought to be indicative of inconsistent filtration efficiency, resulting in inconsistent metals content.

Due to the factors discussed above, the elevated metals concentrations observed in both filtered and unfiltered ground water samples from the BOMARC Missile Site are considered indicative of both dissolved metals and suspended metals. As a consequence, the total concentrations of metals observed are probably not available for transport through the aquifer. Concentrations of metals observed in filtered samples should not be used to indicate concentrations of dissolved metals in ground water at the site.

4.1.3.2 Surface Water Sampling

A total of 17 surface water samples were collected during the field effort on the BOMARC Missile Site. Filtered and unfiltered environmental surface water samples were collected from 15 locations around Shelter 204.

Two surface water samples were also collected, one each, from the power and communication bunkers in front of Shelter 204. Because these latter two samples are of such a disparate nature and produced very different results, they are treated separately in Section 4.1.3.2.2 (Bunker Samples).

4.1.3.2.1 Rainwater Runoff and Environmental Samples

No surface water is found on the BOMARC Missile Site except during heavy rainstorms. Of the 15 surface water samples collected, 14 were collected from around Shelter 204 during heavy rainstorms (Figure 3-5). The last sample was collected south of the BOMARC Missile Site from standing water in the swampy area near the headwaters of the Elisha Branch.

Both filtered and unfiltered environmental surface water samples were collected. The procedures used in sampling are outlined in Section 3.6.2.2.1. All samples were sent to the laboratory for gross alpha and gross beta analysis. The results of those analyses are presented in Table 4-7.

Three unfiltered samples showed low levels (4 to 5 pCi/L) of gross alpha activity (Figure 4-7), all of which were well below the State and Federal Standard of 15 pCi/L. No gross alpha activity was detected in any of the filtered samples collected (Figure 4-8), indicating that the alpha activity found in the unfiltered samples was due to suspended particles rather than to dissolved material.

Nine unfiltered samples showed low levels (5 to 20 pCi/L) of gross beta activity (Figure 4-9), all of which were well below the State and Federal Standard of 50 pCi/L. Low levels of gross beta activity (3 to 8 pCi/L) were found in four filtered samples (Figure 4-10), again, all below the regulatory standard. In three samples (001-SW-006, 001-SW-012, and 001-SW-015), beta activity was detected in both the filtered and unfiltered samples, indicating that at least some of the activity was in solution. However, in the majority of the samples, there was no beta activity found in solution, and all levels were below regulatory standards.

No activity of any kind (alpha or beta), in either the unfiltered or filtered samples, was detected from samples collected on the concrete pad in front of Shelter 204. The only samples showing alpha activity were unfiltered samples collected from the unlined ditch northwest of Shelter 204 and from a lined portion of the drainage ditch south of Shelter 204 where sediment collects (Figure 4-7). All samples showing beta activity were collected from locations where either the drainage was unlined or where sediment had a tendency to collect (Figures 4-9 and 4-10).

Table 4-7

Analytical Data for Surface Water Samples Collected at the BOMARC Missile Site

Sample ID	Date Collected	Filtered/ Unfiltered	Total Volume	Preser-vative	Parameter	Method	Method Detection Limit	Activity (pCi/L)	Standards and Action Levels (a)	
									Federal	State
001-SW-001-001	7-20-89	UF	995 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-3	15 pCi/L	15 pCi/L
	7-20-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-001-002	7-20-89	F	1010 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-3	15 pCi/L	15 pCi/L
	7-20-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-002-001	7-20-89	UF	975 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-3	15 pCi/L	15 pCi/L
	7-20-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-002-002	7-20-89	F	895 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-3	15 pCi/L	15 pCi/L
	7-20-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-003-001	7-20-89	UF	990 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-3	15 pCi/L	15 pCi/L
	7-20-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-003-002	7-20-89	F	980 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-3	15 pCi/L	15 pCi/L
	7-20-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-004-001	7-20-89	UF	995 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-3	15 pCi/L	15 pCi/L
	7-20-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-004-002	7-20-89	F	1000 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-3	15 pCi/L	15 pCi/L
	7-20-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	3 +-3	50 pCi/L	50 pCi/L
001-SW-006-001	9-14-89	UF	925 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	4 +-2	15 pCi/L	15 pCi/L
	9-14-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	10 +-4	50 pCi/L	50 pCi/L
001-SW-006-002	9-14-89	F	920 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-14-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	8 +-3	50 pCi/L	50 pCi/L
001-SW-007-001	9-14-89	UF	950 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-14-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	8 +-3	50 pCi/L	50 pCi/L
001-SW-007-002	9-14-89	F	945 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-14-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-008-001	9-14-89	UF	980 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	5 +-3	15 pCi/L	15 pCi/L
	9-14-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	20 +-4	50 pCi/L	50 pCi/L

Table 4-7 (continued)

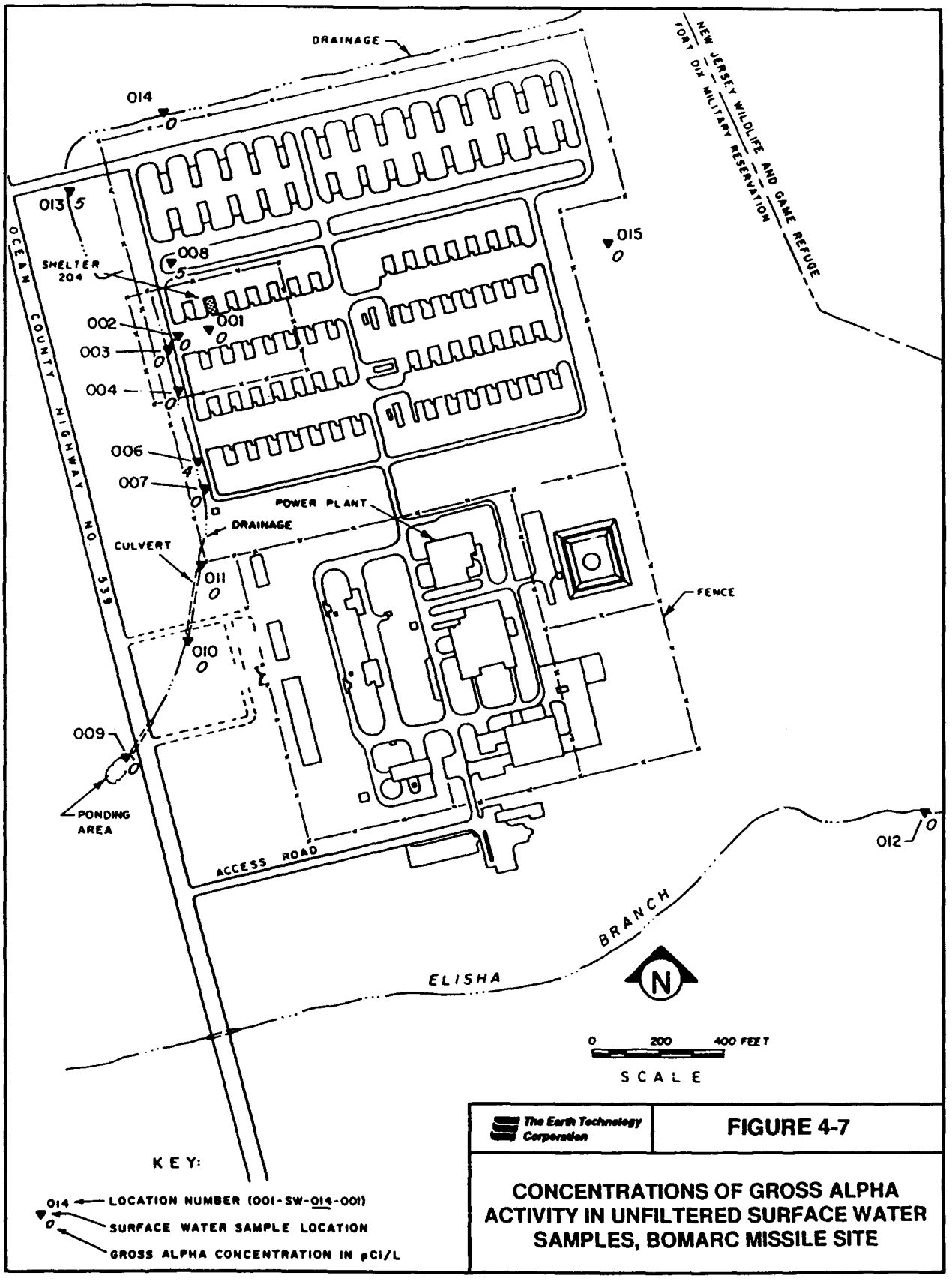
Analytical Data for Surface Water Samples Collected at the BOMARC Missile Site

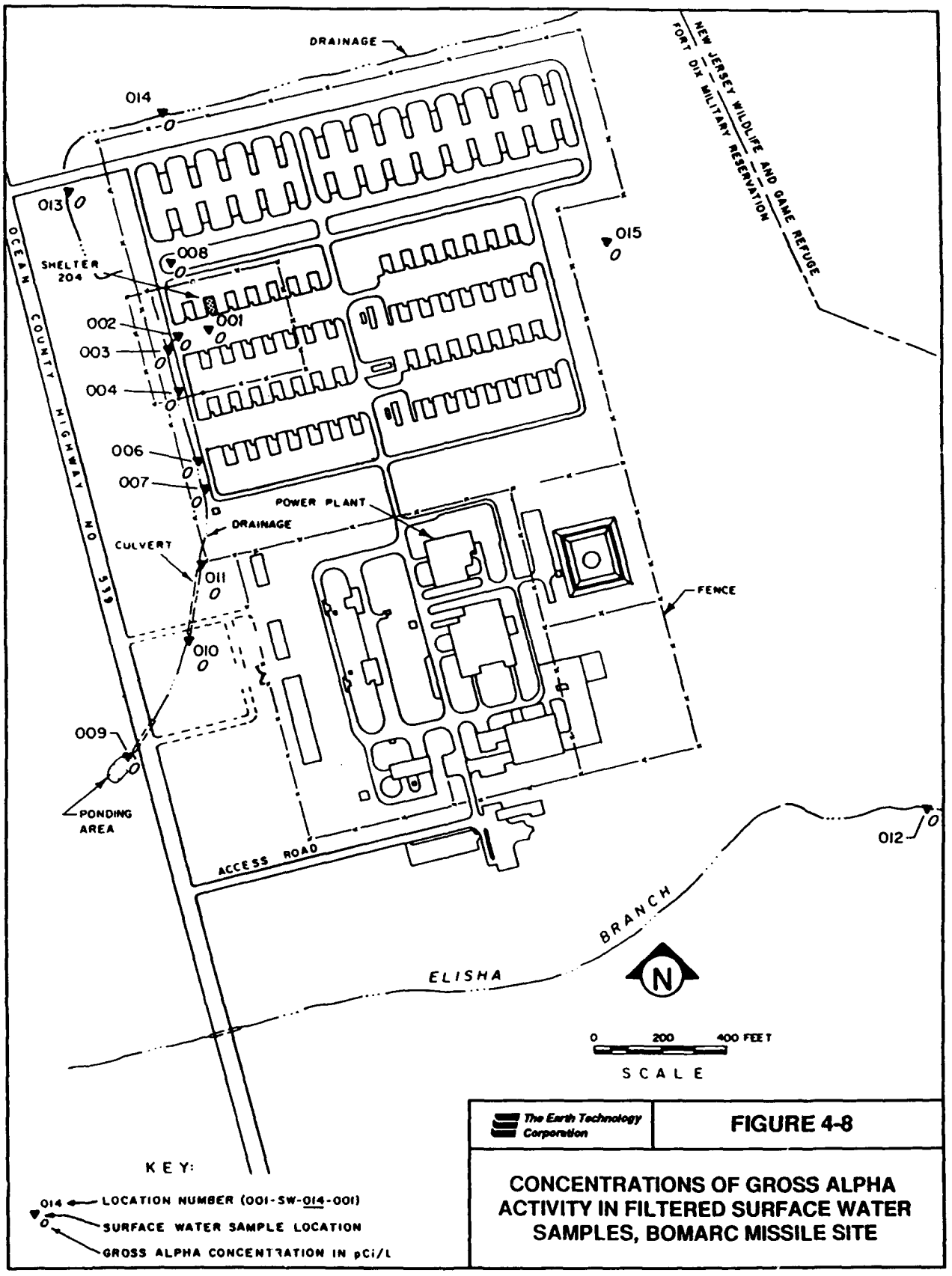
Sample ID	Date Collected	Filtered/ Unfiltered	Total Volume	Preser-vative	Parameter	Method	Method Detection Limit	Activity (pCi/L)	Standards and Action Levels (a)	
									Federal	State
001-SW-008-002	9-14-89	F	990 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-14-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-009-001	9-14-89	UF	960 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-14-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	6 +-3	50 pCi/L	50 pCi/L
001-SW-009-002	9-14-89	F	950 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-14-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-010-001	9-14-89	UF	960 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-14-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	6 +-3	50 pCi/L	50 pCi/L
001-SW-010-002	9-14-89	F	965 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-14-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-011-001	9-19-89	UF	945 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-011-002	9-19-89	F	965 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-012-001	9-19-89	UF	955 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	5 +-3	50 pCi/L	50 pCi/L
001-SW-012-002	9-19-89	F	945 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	5 +-4	50 pCi/L	50 pCi/L
001-SW-013-001	9-19-89	UF	940 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	5 +-3	15 pCi/L	15 pCi/L
	9-19-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	20 +-4	50 pCi/L	50 pCi/L
001-SW-013-002	9-19-89	F	940 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-014-001	9-19-89	UF	970 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	5 +-3	50 pCi/L	50 pCi/L

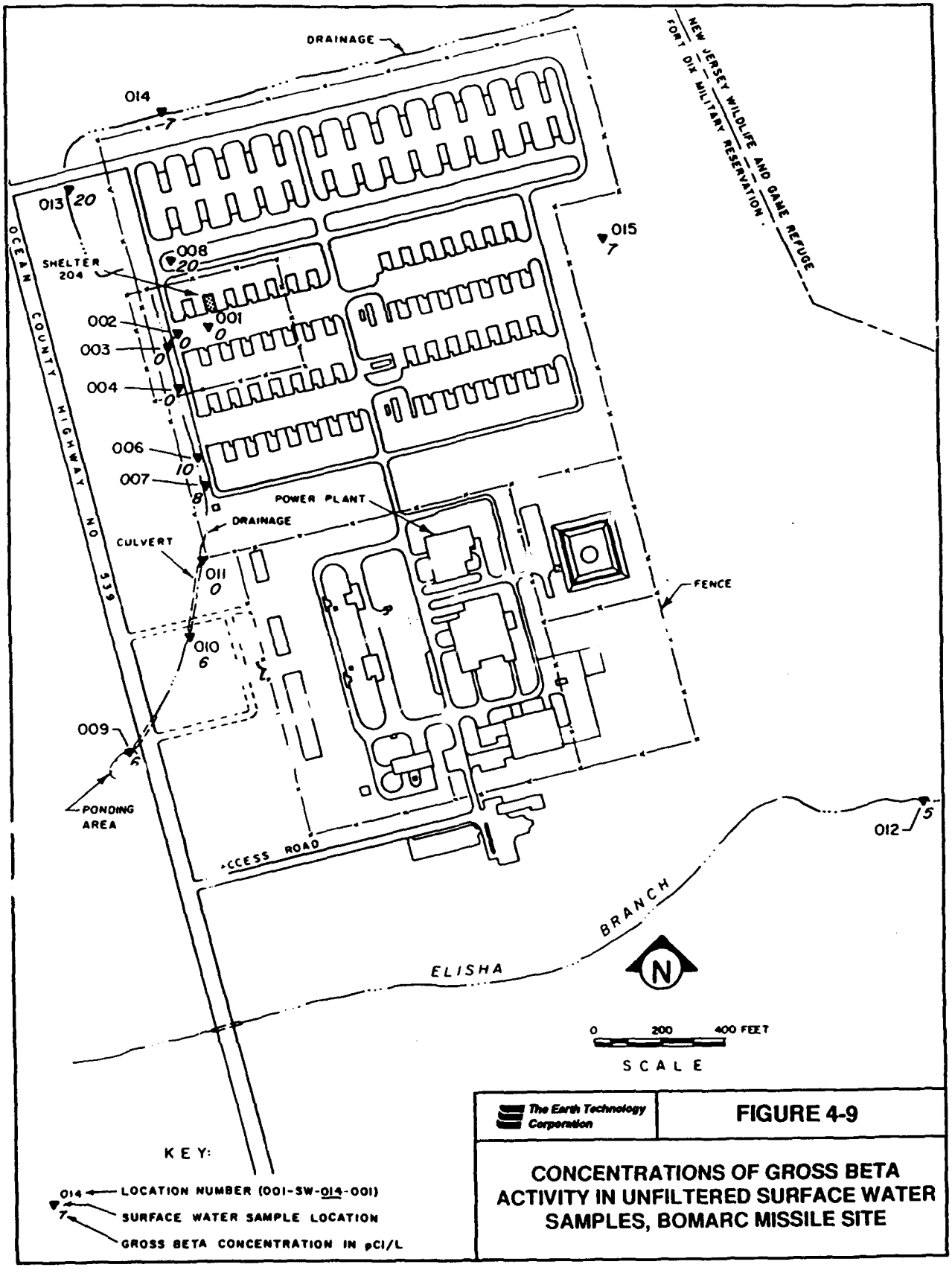
Table 4-7 (continued)

Analytical Data for Surface Water Samples Collected at the BOMARC Missile Site

Sample ID	Date Collected	Filtered/ Unfiltered	Total Volume	Preser-vative	Parameter	Method	Method Detection Limit	Activity (pCi/L)	Standards and Action Levels (a)	
									Federal	State
001-SW-014-002	9-19-89	F	985 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	0 +-4	50 pCi/L	50 pCi/L
001-SW-015-001	9-19-89	UF	925 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	UF		HNO3	Gross Beta	EPA-60/4-80-032	2	7 +-4	50 pCi/L	50 pCi/L
001-SW-015-002	9-19-89	F	950 ml	HNO3	Gross Alpha	EPA-60/4-80-032	3	0 +-5	15 pCi/L	15 pCi/L
	9-19-89	F		HNO3	Gross Beta	EPA-60/4-80-032	2	6 +-4	50 pCi/L	50 pCi/L


DRAINAGE
014
013
008
SHELTER 204
001
002
003
004
006
007
015
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
OCEAN COUNTY HIGHWAY NO 539
POWER PLANT
DRAINAGE
CULVERT
011
010
009
FENCE
PONDING AREA
ACCESS ROAD
012
BRANCH
ELISHA
N
0 200 400 FEET
SCALE
KEY:
014 LOCATION NUMBER (001-SW-014-001)
SURFACE WATER SAMPLE LOCATION
GROSS ALPHA CONCENTRATION IN pCi/L
The Earth Technology Corporation
FIGURE 4-7
CONCENTRATIONS OF GROSS ALPHA ACTIVITY IN UNFILTERED SURFACE WATER SAMPLES, BOMARC MISSILE SITE

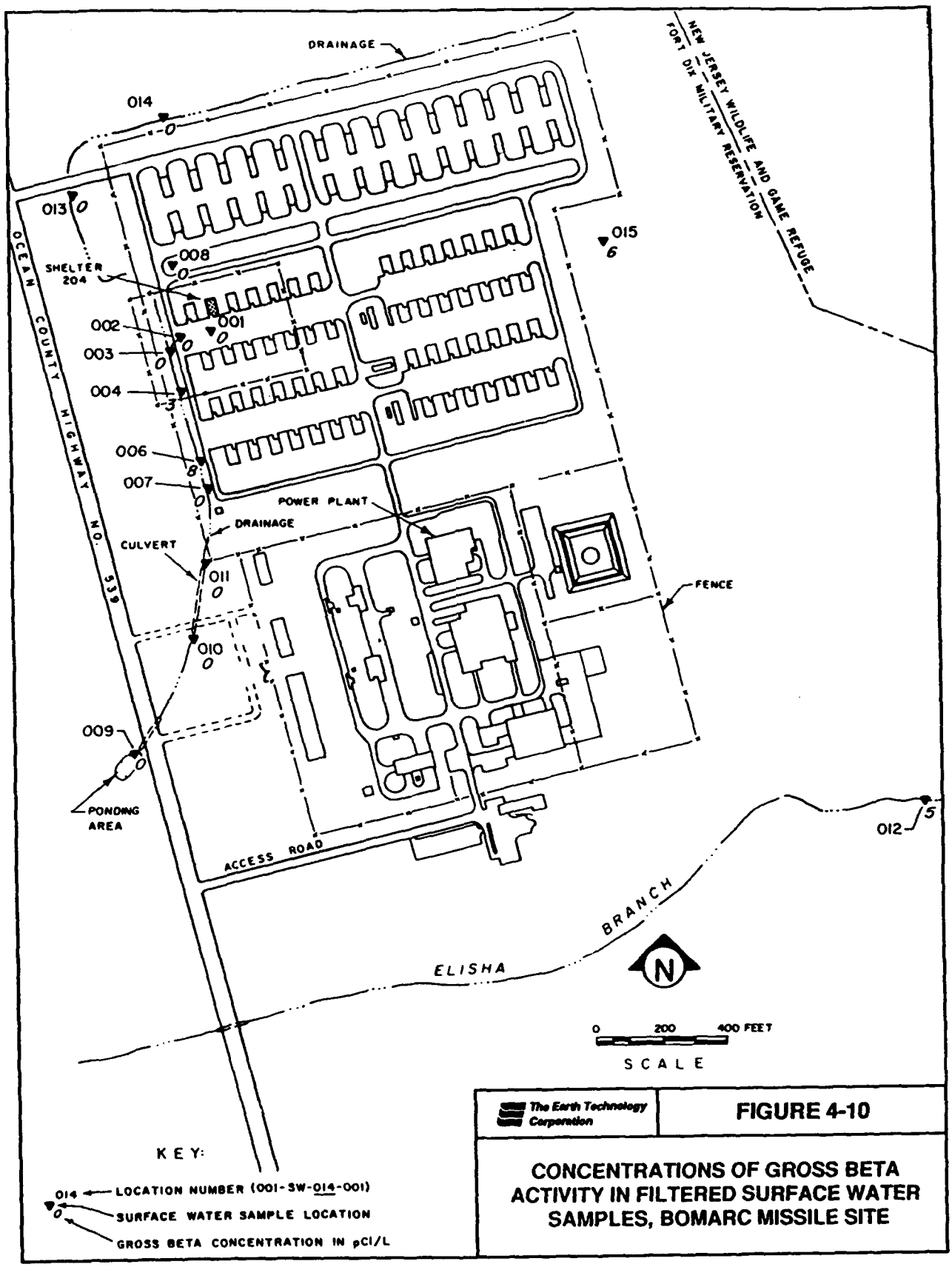

DRAINAGE
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
014
013
015
008
SHELTER 204
001
002
003
004
006
007
OCEAN COUNTY HIGHWAY 616
POWER PLANT
DRAINAGE
CULVERT
011
010
009
FENCE
PONDING AREA
ACCESS ROAD
012
ELISHA BRANCH
N
0 200 400 FEET
SCALE
KEY:
014 — LOCATION NUMBER (001-SW-014-001)
SURFACE WATER SAMPLE LOCATION
GROSS ALPHA CONCENTRATION IN pCi/L
The Earth Technology Corporation
FIGURE 4-8
CONCENTRATIONS OF GROSS ALPHA ACTIVITY IN FILTERED SURFACE WATER SAMPLES, BOMARC MISSILE SITE



The Earth Technology Corporation

FIGURE 4-9

CONCENTRATIONS OF GROSS BETA ACTIVITY IN UNFILTERED SURFACE WATER SAMPLES, BOMARC MISSILE SITE


DRAINAGE
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
014
013
015
SHELTER 204
008
001
002
003
004
006
007
OCEAN COUNTY HIGHWAY NO. 539
POWER PLANT
DRAINAGE
CULVERT
011
010
009
FENCE
PONDING AREA
ACCESS ROAD
012
BRANCH
ELISHA
N
0 200 400 FEET
SCALE
KEY:
014 ← LOCATION NUMBER (001-SW-014-001)
SURFACE WATER SAMPLE LOCATION
GROSS BETA CONCENTRATION IN pCi/L
The Earth Technology Corporation
FIGURE 4-10
CONCENTRATIONS OF GROSS BETA ACTIVITY IN FILTERED SURFACE WATER SAMPLES, BOMARC MISSILE SITE

The specific isotope(s) providing the source of the alpha and beta activity are not identified but are very likely to be naturally occurring isotopes of uranium, thorium, or potassium and their daughters. Naturally occurring values of gross alpha and gross beta in unfiltered surface water samples (Table 4-8) in nearby parts of the Toms River and adjacent drainage basins range from <0.4 pCi/L to 40.1 pCi/L for alpha and from 2.5 pCi/L to 98 pCi/L for beta (USGS, 1969, 1970, and 1972). Averages for those surface water values are 8.0 pCi/L for gross alpha and 14.7 pCi/L for gross beta. Even if the highest values are eliminated, the average for gross alpha is 3.4 pCi/L and the average for gross beta is 5.4 pCi/L. The values on the BOMARC site are comparable to the environmental surface water samples collected in other parts of the Toms River and adjacent basins.

Plutonium is a very strong alpha emitter; if particles large enough to be filtered out were present in the unfiltered samples, the gross alpha count probably should have been much higher than it was in any of the surface water environmental samples. Alpha screening of the filters used to filter the water (Table 4-9) indicated that none of the samples had large quantities of alpha emitters suspended in the water. Only two of the samples (010 and 011) showed consistent alpha activity on the filters. Those samples were collected from unlined portions of the drainage ditch above and below a concrete culvert outside of the perimeter fence. Neither the filtered nor the unfiltered water samples from either of those locations contained any alpha activity.

The pattern that emerges from this sampling suggests that the presence of soil and sediment provide an environment conducive to generating low levels of beta and some random alpha activity. No strong alpha emitters (including plutonium) are being carried in solution. All results indicate that normal environmental levels of gross alpha and gross beta in surface water are present in the surface water around the BOMARC site, and that plutonium is not being dissolved or carried in suspension through this medium.

Data from the BOMARC site was entered into a computerized mathematical model [U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC-6) model] to investigate plutonium (sediment) transport and dispersion into the drainage ditch and ponding area west of Highway 539. The model is a one-dimensional, steady-state, open-channel flow, sediment transport model developed to analyze scour and deposition of sediments in natural or man-made water channels. The model performs this analysis by modeling the interaction between the water-sediment mixture, sediment material forming the channel's boundary, and the hydraulics of flow. The report of that modeling is included as Appendix G.

The intent of the modeling was to define the worst-case scenario for plutonium transport and dispersion from Shelter 204, along the drainage ditch, and into the ponding area west of Highway 539 during the fire-fighting efforts at the BOMARC site. This model incorporates scenarios both with and without the earthen dam that firefighters erected to prevent or retard water flow down the drainage ditch.

Table 4-8

Typical Levels of Gross Alpha and Gross Beta in Natural Waters
near the BOMARC Missile Site, New Jersey

Water Year	Location (*b)	Dissolved alpha (filtered water) (pCi/L)	Suspended alpha (filter) (pCi/L)	Gross alpha (*c) (unfiltered water) (pCi/L)	Dissolved beta (filtered water) (pCi/L)	Suspended beta (filter) (pCi/L)	Gross beta (*c) (unfiltered water) (pCi/L)
1969	1	1.5	0.5	2.0	4.3	2.0	6.3
1969	2	40.0	0.1	40.1	98.0	<0.4	98.0
1970	1	7.8	<0.8	7.8	6.0	2.6	8.6
1970	2	5.2	1.4	6.6	7.8	2.9	10.7
1972	1	1.8	0.2	2.0	3.4	0.9	4.3
1972	2	1.7	0.5	2.2	4.7	1.1	5.8
1972	3	0.3	0.7	1.0	2.8	1.3	4.1
1972	3	<0.4	<0.1	<0.4	2.6	<0.4	2.6
1972	3	2.0	<0.1	2.0	4.0	<0.4	4.0
1972	3	--	--	--	2.5	<0.4	2.5
	Mean	7.5	0.57	8.0	13.6	1.8	14.7

(*a) Source: Modified from USGS Water Resources Data for New Jersey

(*b) Locations
1. Toms River at Toms River, NJ, Station number 01408700
2. Metedeconk River at Laurelton, NJ, Station number 01408155 (North of Toms River)
3. Delaware River at Trenton, NJ, Station number 01463500

(*c) Derived by adding dissolved and suspended values

Table 4-9

Alpha Count Results from Screening Filters Used in Surface Water Sampling at the BOMARC Missile Site

Sample Number*	Gross Count** (CPM)	Time (min)	Net Count Rate*** (CPM)
001-SW-007-A	15	5	2.1
001-SW-007-B	0	5	<BKG
001-SW-007-C	3	5	<BKG
001-SW-008-A	2	5	<BKG
001-SW-009-A	0	5	<BKG
001-SW-009-A	2	5	<BKG
001-SW-010-A	6	5	0.3
001-SW-010-B	6	5	0.3
001-SW-010-C	11	5	1.3
001-SW-011-A	11	5	1.3
001-SW-011-B	10	5	1.1
001-SW-012-A	1	5	<BKG
001-SW-013-A	4	5	<BKG
001-SW-013-B	5	5	0.1
001-SW-013-C	1	5	<BKG
001-SW-014-A	4	5	<BKG
001-SW-014-B	3	5	<BKG
001-SW-015-A	3	5	<BKG
001-SW-015-B	0	5	<BKG
001-SW-015-C	3	5	<BKG

* Multiple filters assigned sequential letters A, B, etc.
** Filters screened using Ludlum 2000 alpha counter.
*** Determined by dividing gross count by time counted and subtracting background of filters (0.9 CPM).

BKG = Background

The model also addressed precipitation events prior to the covering of the drainage ditch with asphalt in 1967, and the effect of those events on possible re-suspension and transport of plutonium. The model determined the magnitude of storm under worst case conditions that would be required to cause erosion of the asphalt in the drainage ditch, thus allowing further distribution of plutonium in the environment.

The sediment transport model predicted that most or all of the plutonium probably moved along the ditch into the ponding area west of Highway 539 in the seven years before the ditch was covered with asphalt. If that were the case, a large enough storm could conceivably again move any remaining loose plutonium along the uncovered portions of the ditch or from the ponding area by physical transport. However, sampling results indicate that during the three precipitation events sampled, no plutonium was in solution or being carried in the surface water of these areas.

In-situ radiological survey results and soil sampling results for the concrete apron and asphalt-lined ditch are presented later in this chapter. These results indicate that contrary to sediment transport modeling predictions, the majority of plutonium transported by fire-fighting runoff was not transported to the ponding area west of Highway 539, but remains beneath the concrete apron and asphalt-lined portion of the ditch. This apparent discrepancy between predicted and observed plutonium transport is due to the conservative assumptions used for the various modeling scenarios. Modeling assumptions were deliberately conservative in order to assure worst-case downstream transport predictions. These worst-case downstream transport predictions were used to define the extent of downstream sediment sampling, i.e., sediment sampling was extended downstream past the area of worst-case predicted downstream transport.

4.1.3.2.2 Bunker Samples

Two surface water samples were collected, one each, from the power and communications bunkers in front of Shelter 204 (Figures 3-6 and 3-7). The procedures used to collect these samples are described in Section 3.6.2.2.2. Both samples were unfiltered. The samples were sent to the laboratory for plutonium analysis by alpha spectroscopy, and the results are shown on Table 4-10. Other samples were collected but were not analyzed.

The sample collected from the power bunker contained 210 pCi/L of plutonium, and the sample from the communication bunker contained 24 pCi/L of plutonium. These bunkers were not sealed with concrete at the time of the missile fire, which could have allowed either contaminated water from the fire fighting effort to drain in, or loose contamination from the manhole covers to fall in when the covers were removed or disturbed. In either case it is not unexpected to find plutonium contamination inside of these underground bunkers. The samples collected during the 1989 field effort were not filtered, so it is not known whether any Pu-239 was in solution, or whether it was all suspended in the water. Although care was taken not to disturb the bottom sediment, the possibility that most of the radioactive material was suspended rather than dissolved in the water is very high, both because the plutonium oxide is relatively insoluble, and because the water appeared to contain some suspended sediment.

Table 4-10

Analytical Data for Surface Water Samples Collected From the Communication and Power Bunkers Near Shelter 204 at the BOMARC Missile Site

Sample ID	Date Collected	Bunker Type	Filtered/ Unfiltered	Perservation	Parameter	Method	Method Detection Limit (pCi/L)	Activity (pCi/L)
001-SW-PB1-001	10-04-89	Power Bunker	UF	HN03	Pu-239	PRO-052-32	1.0	2.1+-0.1E+02
001-SW-CB1-005	10-08-90	Communication	UF	HN03	Pu-239	PRO-052-32	1.0	2.4+-0.1E+01

The power bunker is closer to the center drainage of the street in front of Shelter 204, which may account for the higher levels of Pu-239 in that bunker. Water carrying plutonium from the fire fighting, or later runoff from Shelter 204 would have flowed over both bunker covers and may have settled in greater concentrations over the power bunker lid. This would have allowed the water to percolate in, or allowed plutonium particles to lodge against the lid so they could fall in later when the lid was removed. The random nature of grab samples may also be the reason for the different levels of contamination observed in the two bunkers.

4.1.3.3 Ambient Air Sampling and Modeled Surface Deposition Patterns

The following sections discuss the ambient air sampling and modeled surface deposition patterns.

4.1.3.3.1 Baseline Environmental Air Sampling

A total of 13 air samples were collected from three locations (Figure 3-4) around Shelter 204 prior to the commencement of field work, for the purpose of identifying a baseline concentration of radionuclides in the ambient air. These samples were collected using three Sierra Instruments high-volume air samplers. The locations of the samplers and details on sampling and calibration procedures are outlined in Section 3.6.2.3.1.

The results from the analyses of the background samples (Table 4-11) were compared to maximum allowable alpha and beta activity as outlined in the Code of Federal Regulations (CFR 10), Part 20, Chapter 1. All the alpha and beta emissions at the BOMARC facility are not likely to have been derived from one isotope, so the non-specific element values listed in the 10 CFR 20 table were used. These values were 0.27 dpm/m^3 or 6×10^{-13} μCi/ml for gross alpha and 4.5×10^5 dpm/m^3 or 1×10^{-6} μCi/ml for gross beta in air.

The 13 air samples analyzed showed both gross alpha and gross beta concentrations in ambient air to be well below regulatory guidelines. The highest alpha and beta activity was detected on filter 096562, where 1.34×10^{-2} dpm/m^3 and 8.6×10^{-2} dpm/m^3 were recorded, respectively. These concentrations were only 0.049 and 0.0000001 times the maximum allowable gross alpha and gross beta activity. By comparing the gross alpha values of the samples to the blank filter, it can be seen that only two of the sample filters contain alpha activity that even exceeds the blank filter activity. Beta activity on the sample filters is higher than on the blank, but in only three samples is it more than two times the background (usually indicating a "real" value). In no sample was the value three times background.

Since the radiation detected in ambient air around the BOMARC facility was found in typical background concentrations, field work proceeded without the need for routine respiratory protection, as long as no intrusive work was being performed, and no dust or dirt were disturbed. No risk to the local population appears to be derived from these typically background-level ambient air concentrations.

Table 4-11

Results of the Baseline Environmental Gross Alpha/Gross Beta Activity Measurements of Filters from the High Volume Air Samplers at the BOMARC Missile Site

Station Number	Filter Number	Air Volume (cu meters)	Material Concentration (µg/cu meter of air)	Alpha Activity (dpm)	Beta Activity (dpm)	Activity per Unit Volume of Air: Alpha (dpm/cu meter)	Activity per Unit Volume of Air: Beta (dpm/cu meter)	Minimum Detectable Activity: Alpha (dpm/cu meter)	Minimum Detectable Activity: Beta (dpm/cu meter)
1	096561	2112	27.9	13.0	121	6.16E-3	5.7E-2	5.25E-4	7.75E-4
2	096562	2027	30.1	27.2	175	1.34E-2	8.6E-2	5.47E-4	8.07E-4
3	096563	2112	30.9	ND	162	ND	7.7E-2	5.25E-4	7.75E-4
1	096564	1206	17.8	13.0	202	1.08E-2	8.4E-2	9.20E-4	1.357E-3
3	096565	2000	20.3	2.0	115	1.0E-2	5.8E-2	5.54E-4	8.18E-4
2	096566	2058	23.6	2.0	138	9.7E-4	6.7E-2	5.39E-4	7.95E-4
1	096567	2181	18.6	ND	108	ND	5.0E-2	5.08E-4	7.50E-4
3	096568	1894	22.7	7.7	97	4.1E-3	5.1E-2	5.85E-4	8.64E-4
2	096569	1686	19.0	5.3	111	3.1E-3	6.6E-2	6.58E-4	9.71E-4
1	096570	2213	25.0	5.3	88	2.4E-3	4.0E-2	5.01E-4	7.39E-4
3	096571	1854	36.4	19.5	60	1.05E-2	3.2E-2	5.98E-4	9.46E-4
2	096572	1868	37.8	13.0	76	7.0E-3	4.1E-2	5.95E-4	9.41E-4
1	096573	1998	37.4	6.5	49	3.3E-3	2.5E-2	5.55E-4	8.78E-4
	BLANK	---	---	13.0	61	---	---	---	---

ND = Not Detected
dpm = Disintegrations per Minute

4.1.3.3.2 Routine Environmental Air Sampling

During intrusive sampling the high-volume air samplers (Figure 3-4) were operated to assess any airborne releases of plutonium. Six filters from the most intensive work at the site (especially the cleaning of Shelter 204) were sent to the laboratory for gross alpha analysis. The results of those analyses are shown on Table 4-12. As listed in 10 CFR 20, the maximum allowable alpha activity is 6×10^{-13} μCi/ml (see Section 4.1.3.3.1 for details on these limits). None of the samples collected during the intrusive activity exceeded that limit. The highest activity shown on any of the air filters was 4.2×10^{-16} μCi/ml. Using the same reasoning as in Section 4.1.3.3.1 above, it is apparent that none of the dust with adsorbed plutonium or americium from the cleaning of Shelter 204 escaped to be deposited on the filters in the high-volume samplers.

Table 4-12

Results of the Routine Environmental Gross Alpha Activity Measurements of Filters from the High Volume Air Samplers at the BOMARC Missile Site

Filter Number	Activity Per Filter (μCi)***	Filtrate Volume (ml)	Activity Per Volume (μCi/ml)
17976*	<3.5E-07	0.00E-01	0
17977	<1.2E-11	3.02E+04	<3.9E-16
17978	<1.2E-11	2.83E+04	<4.2E-16
17979	<7.3E-14	4.79E+06	<1.5E-20
17980	<3.9E-14	9.06E+06	<4.3E-21
17981**	<3.0E-14	9.06E+06	<3.3E-21

* Background
** Duplicate of 17980
*** Note: "<" indicates minimal detectable activity. This value varies with instrument calibration for a particular day.

μCi = MicroCuries
ml = Milliliters

4.1.3.3.3 Modeled Surface Deposition Patterns

During the summer of 1989, Battelle Northwest was contracted to perform analyses of the original 1960 accident and resulting fire and to predict surface deposition patterns. These analyses comprised a study of the plutonium warhead burn and modeling of possible airborne releases and surface deposition from the accident. The entire Battelle study is attached as Appendix H (Modeled Surface Deposition Patterns from the 1960 BOMARC Missile Accident).

The purpose of these analyses was twofold: (1) to provide guidance for field soil sampling by identifying areas downwind of the accident site where possible surface deposition occurred from the plutonium released to the atmosphere in the fire plume, and (2) to identify potential onsite "hot spots" of surface-deposited particulates from the fire plume. Once potential deposition areas were identified, they were investigated by FIDLER surveys and the results were confirmed through laboratory analysis of soil samples.

The meteorological code used in this analysis was MESOI 2.0 (Ramsdell et al., 1983). This model provides a mathematical description of atmospheric transport and surface deposition on horizontal spatial scales similar to the accident. The code has been demonstrated in describing air concentrations downwind from radioactive releases in similar terrain to the BOMARC

accident site (Savannah River Plant in South Carolina, Ramsdell et al., 1984). The code was selected because it can compute transport and deposition over short distances (up to 10 km).

A description of the MESOI 2.0 code, the input used to run MESOI 2.0, modifications made to MESOI 2.0, the model-produced deposition patterns, recommended areas for sampling, and a comparison of the modeled plutonium deposition with the FIDLER survey is found in Appendix H.

Inputs and assumptions used in the model runs included the following:

- In order to evaluate the potential error in predicted transport and plutonium deposition as a result of winds that are small in magnitude and variable in direction, the model was run in two different modes: (1) winds were allowed to vary linearly in time between hourly observations, and (2) winds were assumed to be constant throughout the hour until the next observation.

- In order to account for the variety of particle sizes likely produced during the fire and the associated particle settling velocities, the model was modified to allow the particles entrained in the puff to settle towards the surface with time. Six particle sizes were used (<5 microns to 200 microns) with settling velocities ranging from 0.01 meters/second to 3.0 meters/second.

- The model was run with 2 plume release heights: 123 meters (observed height of the plume) and 1800 meters (estimated height of a slightly heated plume with little or no plutonium entrainment).

- The source term (amount of plutonium available for transport) for atmospheric release of plutonium was estimated at 0.5 gram to 7.5 grams from the plutonium burning study. All model runs used the unit source term of 1.0 gram, because MESOI 2.0 is linear and any increase in source term value would be reflected in a proportional increase in estimated deposition. Results can therefore be scaled to reflect other source terms.

In summary, the model simulations were three hours in duration, the source terms were fixed at 1.0 gram, two plume release heights were used (123m and 1800m), two methods were used to evaluate wind fields, and a series of settling velocities were used. For all these cases, the 10 minute positions of the plume (puffs) and the cumulative surface deposition values were noted and plotted on a map.

The results from the surface deposition modeling are detailed in Appendix H and summarized below:

- When the 123 meter plume height, zero settling velocity, and both constant and time varying winds are modeled, the winds keep the plume in or near the accident site during the first two hours of the accident.

- All simulations done with the 123 meter release height produced maximum predicted deposition very near the source. The furthest predicted deposition for 20 micron particles was in an area 0.7 km southeast of the source.

- When the 1800 meter release height was used, large particles (75 and 200 microns) produced predicted maximum deposition at 2.5 km southeast of the source. For particles <20 microns, the maximum predicted deposition location was just west of the intersection of Highways 539 and 70.

- Based on the model results, two areas were recommended for FIDLER surveys and shallow soil sampling. These are the two pie-shaped outlines depicted in Figure 3-17. The sampling transects (Transects A, B, C, and D) are also depicted in this figure.

4.1.3.4 Wipe Sampling Results

Wipe sampling was performed in 21 missile launch shelters and in the communication bunker in front of Shelter 204.

4.1.3.4.1 Missile Launch Shelters

Wipe sampling was performed on 21 missile launch shelters, including Shelter 204 and 20 other shelters in the nearby vicinity (Figure 3-15). The wipe sampling was done to determine the presence, location, and quantity of removable surface contamination in those shelters. Locations of sampling stations and techniques used are presented in Section 3.6.2.5 of this report.

Prior to collecting wipe samples at most stations, a PAC-4G (alpha radiation detection meter) measurement was taken for screening purposes and to corroborate the wipe sampling results.

PAC-4G measurements at wipe sampling stations. The results from background PAC-4G measurements collected between July 5 and August 17, 1990 identified average background activity levels at the site to be 13.2 $\pm$ 4.0 "clicks" per minute, which corresponds to 66 $\pm$ 20 counts per minute (CPM) (Table 4-13).

Two electroplated alpha emitter standards were used at least daily to monitor and affirm the PAC-4G calibration: Am-241 with an alpha particle energy of 5.4 Mev, and Th-230 with 4.7 Mev. Interpolation was used to determine the efficiency for the 5.1 Mev alpha particle emitted by Pu-239. Analyses have shown that the material associated with the BOMARC accident, through decay, currently has approximately a 6 to 1 ratio of Pu-239 to Am-241. Therefore, the final counting efficiency used was a properly weighted response assuming that 6 to 1 ratio. This efficiency was calculated at 0.353 cpm/dpm. The average background activity was then determined as follows:

Table 4-13

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
Shelter 101								
101-WP-001-001	30-JULY-89	215	BKG	2-SEPT-89	2	BKG	BKG	
101-WP-003-001	30-JULY-89	263	BKG	2-SEPT-89	0	BKG	BKG	
101-WP-005-001	30-JULY-89	311	BKG	2-SEPT-89	---	---	---	
101-WP-007-001	30-JULY-89	311	BKG	2-SEPT-89	---	---	---	
101-WP-009-001	30-JULY-89	215	BKG	2-SEPT-89	---	---	---	
101-WP-011-001	30-JULY-89	---	---	2-SEPT-89	3	0.1	0.4	
101-WP-012-001	30-JULY-89	263	BKG	2-SEPT-89	3	0.1	0.4	
101-WP-013-001	30-JULY-89	383	68	2-SEPT-89	0	BKG	BKG	
101-WP-014-001	30-JULY-89	287	BKG	2-SEPT-89	4	0.3	1.2	
101-WP-016-001	30-JULY-89	239	BKG	2-SEPT-89	3	0.1	0.4	
101-WP-020-001	30-JULY-89	239	BKG	2-SEPT-89	1	BKG	BKG	
101-WP-022-001	30-JULY-89	---	BKG	2-SEPT-89	5	0.5	2.0	
101-WP-024-001	30-JULY-89	---	BKG	2-SEPT-89	---	---	---	
101-WP-028-001	30-JULY-89	239	BKG	2-SEPT-89	3	0.1	0.4	
101-WP-029-001	30-JULY-89	---	---	2-SEPT-89	0	BKG	BKG	
101-WP-030-001	30-JULY-89	359	44	2-SEPT-89	1	BKG	BKG	
101-WP-031-001	30-JULY-89	---	---	2-SEPT-89	1	BKG	BKG	
101-WP-032-001	30-JULY-89	---	---	2-SEPT-89	5	0.5	2.0	
101-WP-037-001	30-JULY-89	---	---	2-SEPT-89	5	0.5	2.0	
101-WP-038-001	30-JULY-89	---	---	2-SEPT-89	1	BKG	BKG	
101-WP-039-001	30-JULY-89	---	---	2-SEPT-89	1	BKG	BKG	
101-WP-040-001	30-JULY-89	---	---	2-SEPT-89	5	0.5	2.0	
101-WP-041-001	30-JULY-89	---	---	2-SEPT-89	0	BKG	BKG	
101-WP-042-001	30-JULY-89	---	---	2-SEPT-89	1	BKG	BKG	
101-WP-043-001	30-JULY-89	---	---	2-SEPT-89	3	0.1	0.4	
101-WP-044-001	30-JULY-89	---	---	2-SEPT-89	3	0.1	0.4	
101-WP-105-001	30-JULY-89	---	---	2-SEPT-89	0	BKG	BKG	
101-WP-107-001	30-JULY-89	---	---	2-SEPT-89	4	0.3	1.2	
101-WP-109-001	30-JULY-89	---	---	2-SEPT-89	4	0.3	1.2	
Shelter 102								
102-WP-001-001	30-JULY-89	287	BKG	15-AUG-89	6	0.7	2.8	
102-WP-003-001	30-JULY-89	359	44	15-AUG-89	7	0.9	3.5	
102-WP-005-001	30-JULY-89	287	BKG	15-AUG-89	1	BKG	BKG	
102-WP-007-001	30-JULY-89	263	BKG	15-AUG-89	4	0.3	1.2	
102-WP-009-001	30-JULY-89	311	BKG	15-AUG-89	4	0.3	1.2	
102-WP-011-001	30-JULY-89	---	---	15-AUG-89	3	0.1	0.4	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
102-WP-012-001	30-JULY-89	287	BKG	15-AUG-89	5	0.5	2.0	
102-WP-013-001	30-JULY-89	---	---	15-AUG-89	4	0.3	1.2	
102-WP-014-001	30-JULY-89	383	68	15-AUG-89	4	0.3	1.2	
102-WP-016-001	30-JULY-89	213	BKG	15-AUG-89	5	0.5	2.0	
102-WP-020-001	30-JULY-89	287	BKG	15-AUG-89	4	0.3	1.2	Rusty
102-WP-022-001	30-JULY-89	287	BKG	15-AUG-89	2	BKG	BKG	
102-WP-024-001	30-JULY-89	311	BKG	15-AUG-89	3	0.1	0.4	
102-WP-028-001	30-JULY-89	239	BKG	15-AUG-89	2	BKG	BKG	
102-WP-030-001	30-JULY-89	311	BKG	15-AUG-89	2	BKG	BKG	
102-WP-031-001	30-JULY-89	---	---	15-AUG-89	4	0.3	1.2	
102-WP-032-001	30-JULY-89	---	---	15-AUG-89	3	0.1	0.4	
102-WP-037-001	30-JULY-89	---	---	15-AUG-89	3	0.1	0.4	
102-WP-038-001	30-JULY-89	---	---	15-AUG-89	4	0.3	1.2	
102-WP-039-001	30-JULY-89	---	---	15-AUG-89	2	BKG	BKG	
102-WP-040-001	30-JULY-89	---	---	15-AUG-89	2	BKG	BKG	
102-WP-041-001	30-JULY-89	---	---	15-AUG-89	4	0.3	1.2	
102-WP-042-001	30-JULY-89	---	---	15-AUG-89	6	0.7	2.8	
102-WP-043-001	30-JULY-89	---	---	15-AUG-89	2	BKG	BKG	
102-WP-044-001	30-JULY-89	---	---	15-AUG-89	2	BKG	BKG	
Shelter 103								
103-WP-002-001	30-JULY-89	359	44	16-AUG-89	---	---	BKG	
103-WP-004-001	30-JULY-89	263	BKG	16-AUG-89	---	---	BKG	
103-WP-006-001	30-JULY-89	239	BKG	16-AUG-89	---	---	BKG	
103-WP-008-001	30-JULY-89	287	BKG	16-AUG-89	---	---	BKG	
103-WP-010-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	
103-WP-015-001	30-JULY-89	311	BKG	16-AUG-89	---	---	BKG	
103-WP-017-001	30-JULY-89	311	BKG	16-AUG-89	---	---	BKG	
103-WP-019-001	30-JULY-89	263	BKG	16-AUG-89	---	---	BKG	
103-WP-021-001	30-JULY-89	287	BKG	16-AUG-89	---	---	BKG	
103-WP-023-001	30-JULY-89	197	BKG	16-AUG-89	---	---	BKG	
103-WP-025-001	30-JULY-89	335	20	16-AUG-89	---	---	BKG	
103-WP-027-001	30-JULY-89	383	68	16-AUG-89	7	0.9	3.5	
103-WP-029-001	30-JULY-89	192	BKG	16-AUG-89	3	0.1	0.4	
103-WP-033-001	30-JULY-89	---	---	16-AUG-89	2	BKG	BKG	
103-WP-034-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	
103-WP-035-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	
103-WP-036-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	
103-WP-037-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
103-WP-038-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	
103-WP-039-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	
103-WP-040-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	
103-WP-041-001	30-JULY-89	---	---	16-AUG-89	2	BKG	BKG	
103-WP-042-001	30-JULY-89	---	---	16-AUG-89	---	---	BKG	
103-WP-043-001	30-JULY-89	---	---	16-AUG-89	3	0.1	0.4	
103-WP-044-001	30-JULY-89	---	---	16-AUG-89			BKG	
Shelter 104								
104-WP-002-001	29-JULY-89	215	BKG	16-AUG-89	---	---	BKG	
104-WP-004-001	29-JULY-89	239	BKG	16-AUG-89	---	---	BKG	
104-WP-006-001	29-JULY-89	259	BKG	16-AUG-89	---	---	BKG	
104-WP-008-001	29-JULY-89	407	92	16-AUG-89	---	---	BKG	
104-WP-010-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-015-001	29-JULY-89	239	BKG	16-AUG-89	---	---	BKG	
104-WP-017-001	29-JULY-89	263	BKG	16-AUG-89	4	0.3	1.2	
104-WP-019-001	29-JULY-89	333	20	16-AUG-89	---	---	BKG	
104-WP-021-001	29-JULY-89	383	68	16-AUG-89	---	---	BKG	Rust
104-WP-023-001	29-JULY-89	359	44	16-AUG-89	---	---	BKG	
104-WP-025-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-027-001	27-JULY-89	335	20	16-AUG-89	---	---	BKG	Rusty, some grease
104-WP-029-001	27-JULY-89	311	BKG	16-AUG-89	5	0.5	2.0	
104-WP-033-001	27-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-034-001	27-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-035-001	27-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-036-001	27-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-037-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-038-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-039-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-040-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-041-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-042-001	29-JULY-89	---	---	16-AUG-89	2	BKG	BKG	
104-WP-043-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
104-WP-044-001	29-JULY-89	---	---	16-AUG-89	---	---	BKG	
Shelter 105								
105-WP-001-001	30-JULY-89	311	BKG	17-AUG-89	---	---	BKG	
105-WP-003-001	30-JULY-89	287	BKG	17-AUG-89	---	---	BKG	
105-WP-005-001	30-JULY-89	168	BKG	17-AUG-89	6	0.7	2.8	
105-WP-007-001	30-JULY-89	359	44	17-AUG-89	3	0.1	0.4	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
105-WP-009-001	30-JULY-89	311	BKG	17-AUG-89	---	---	BKG	
105-WP-011-001	30-JULY-89	---	---	17-AUG-89	2	BKG	BKG	
105-WP-012-001	30-JULY-89	192	BKG	17-AUG-89	---	---	BKG	
105-WP-013-001	30-JULY-89	383	68	17-AUG-89	---	---	BKG	
105-WP-014-001	30-JULY-89	239	BKG	17-AUG-89	---	---	BKG	
105-WP-016-001	30-JULY-89	215	BKG	17-AUG-89	---	---	BKG	
105-WP-020-001	30-JULY-89	311	BKG	17-AUG-89	---	---	BKG	
105-WP-022-001	30-JULY-89	192	BKG	17-AUG-89	---	---	BKG	
105-WP-024-001	30-JULY-89	311	BKG	17-AUG-89	---	---	BKG	
105-WP-028-001	30-JULY-89	239	BKG	17-AUG-89	---	---	BKG	
105-WP-030-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-031-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-032-001	30-JULY-89	---	---	17-AUG-89	5	0.5	2.0	
105-WP-037-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-038-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-039-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-040-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-041-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-042-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-043-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
105-WP-044-001	30-JULY-89	---	---	17-AUG-89	---	---	BKG	
Shelter 106								
106-WP-001-001	29-JULY-89	287	BKG	03-SEPT-89	5	0.5	2.0	
106-WP-003-001	29-JULY-89	287	BKG	03-SEPT-89	2	BKG	BKG	
106-WP-005-001	29-JULY-89	383	68	03-SEPT-89	3	0.1	0.4	
106-WP-007-001	29-JULY-89	---	---	03-SEPT-89	2	BKG	BKG	
106-WP-009-001	29-JULY-89	---	---	03-SEPT-89	4	0.3	1.2	
106-WP-011-001	29-JULY-89	---	---	03-SEPT-89	2	BKG	BKG	
106-WP-012-001	29-JULY-89	383	68	03-SEPT-89	1	BKG	BKG	
106-WP-013-001	29-JULY-89	---	---	03-SEPT-89	4	0.3	1.2	
106-WP-014-001	27-JULY-89	359	44	03-SEPT-89	3	0.1	0.4	
106-WP-016-001	27-JULY-89	335	20	03-SEPT-89	4	0.3	1.2	
106-WP-020-001	27-JULY-89	359	44	03-SEPT-89	1	BKG	BKG	
106-WP-022-001	27-JULY-89	263	BKG	03-SEPT-89	0	BKG	BKG	
106-WP-024-001	27-JULY-89	263	BKG	03-SEPT-89	3	0.1	0.4	
106-WP-028-001	27-JULY-89	---	---	03-SEPT-89	5	0.5	2.0	
106-WP-030-001	27-JULY-89	455	140	03-SEPT-89	3	0.1	0.4	
106-WP-031-001	27-JULY-89	---	---	03-SEPT-89	4	0.3	1.2	
106-WP-032-001	27-JULY-89	---	---	03-SEPT-89	3	0.1	0.4	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
106-WP-037-001	29-JULY-89	---	---	03-SEPT-89	1	BKG	BKG	
106-WP-038-001	29-JULY-89	---	---	03-SEPT-89	3	0.1	0.4	
106-WP-039-001	29-JULY-89	---	---	03-SEPT-89	0	BKG	BKG	
106-WP-040-001	29-JULY-89	---	---	03-SEPT-89	4	0.3	1.2	
106-WP-041-001	29-JULY-89	---	---	03-SEPT-89	0	BKG	BKG	
106-WP-042-001	29-JULY-89	---	---	03-SEPT-89	3	0.1	0.4	
106-WP-043-001	29-JULY-89	---	---	03-SEPT-89	1	BKG	BKG	
106-WP-044-001	29-JULY-89	---	---	03-SEPT-89	0	BKG	BKG	
Shelter 127								
127-WP-001-001	30-JULY-89	263	BKG	15-AUG-89	7	0.9	3.5	
127-WP-003-001	30-JULY-89	359	44	15-AUG-89	3	0.1	0.4	
127-WP-005-001	30-JULY-89	503	188	15-AUG-89	4	0.3	1.2	
127-WP-007-001	30-JULY-89	598	283	15-AUG-89	1	BKG	BKG	
127-WP-009-001	30-JULY-89	431	116	15-AUG-89	3	0.1	0.4	
127-WP-011-001	30-JULY-89	---	---	15-AUG-89	2	BKG	BKG	
127-WP-012-001	30-JULY-89	359	44	15-AUG-89	1	BKG	BKG	
127-WP-013-001	30-JULY-89	407	92	15-AUG-89	3	0.1	0.4	
127-WP-014-001	30-JULY-89	431	116	15-AUG-89	5	0.5	2.0	
127-WP-016-001	30-JULY-89	335	20	15-AUG-89	3	0.1	0.4	
127-WP-020-001	30-JULY-89	383	68	15-AUG-89	4	0.3	1.2	
127-WP-022-001	30-JULY-89	431	116	15-AUG-89	3	0.1	0.4	
127-WP-024-001	30-JULY-89	359	44	15-AUG-89	1	BKG	BKG	
127-WP-028-001	30-JULY-89	407	92	15-AUG-89	1	BKG	BKG	
127-WP-030-001	30-JULY-89	479	164	15-AUG-89	4	0.3	1.2	
127-WP-031-001	30-JULY-89	---	---	15-AUG-89	3	0.1	0.4	
127-WP-032-001	30-JULY-89	---	---	15-AUG-89	3	0.1	0.4	
127-WP-037-001	30-JULY-89	---	---	15-AUG-89	5	0.5	2.0	
127-WP-038-001	30-JULY-89	---	---	15-AUG-89	6	0.7	2.8	
127-WP-039-001	30-JULY-89	---	---	15-AUG-89	2	BKG	BKG	
127-WP-040-001	30-JULY-89	---	---	15-AUG-89	4	0.3	1.2	
127-WP-041-001	30-JULY-89	---	---	15-AUG-89	5	0.5	2.0	
127-WP-042-001	30-JULY-89	---	---	15-AUG-89	3	0.1	0.4	
127-WP-043-001	30-JULY-89	---	---	15-AUG-89	3	0.1	0.4	
127-WP-044-001	30-JULY-89	---	---	15-AUG-89	1	BKG	BKG	
Shelter 159								
159-WP-002-001	30-JULY-89	---	---	04-SEPT-89	3	0.1	0.4	
159-WP-004-001	30-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
159-WP-006-001	30-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
159-WP-008-001	30-JULY-89	---	---	04-SEPT-89	1	BKG	BKG	
159-WP-010-001	30-JULY-89	---	---	04-SEPT-89	3	0.1	0.4	
159-WP-015-001	30-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
159-WP-017-001	30-JULY-89	---	---	04-SEPT-89	1	BKG	BKG	
159-WP-019-001	30-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
159-WP-021-001	30-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
159-WP-023-001	30-JULY-89	---	---	04-SEPT-89	0	BKG	BKG	
159-WP-025-001	30-JULY-89	---	---	04-SEPT-89	3	0.1	0.4	
159-WP-027-001	30-JULY-89	---	---	04-SEPT-89	3	0.1	0.4	
159-WP-029-001	30-JULY-89	---	---	04-SEPT-89	5	0.5	2.0	
159-WP-033-001	30-JULY-89	---	---	04-SEPT-89	5	0.5	2.0	
159-WP-034-001	30-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
159-WP-035-001	30-JULY-89	---	---	04-SEPT-89	5	0.5	2.0	
159-WP-036-001	30-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
159-WP-037-001	30-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
159-WP-038-001	30-JULY-89	---	---	04-SEPT-89	3	0.1	BKG	
159-WP-039-001	30-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
159-WP-040-001	30-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
159-WP-041-001	30-JULY-89	---	---	04-SEPT-89	6	0.7	2.8	
159-WP-042-001	30-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
159-WP-043-001	30-JULY-89	---	---	04-SEPT-89	1	BKG	BKG	
159-WP-044-001	30-JULY-89	---	---	04-SEPT-89	6	0.7	2.8	
Shelter 201								
201-WP-001-001	29-JULY-89	383	68	04-SEPT-89	1	BKG	BKG	
201-WP-003-001	29-JULY-89	359	44	04-SEPT-89	5	0.5	2.0	
201-WP-005-001	29-JULY-89	263	BKG	04-SEPT-89	4	0.3	1.2	
201-WP-007-001	29-JULY-89	431	116	04-SEPT-89	0	BKG	BKG	
201-WP-009-001	29-JULY-89	407	92	04-SEPT-89	4	0.3	1.2	
201-WP-011-001	29-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
201-WP-012-001	29-JULY-89	311	BKG	04-SEPT-89	4	0.3	1.2	
201-WP-013-001	29-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
201-WP-014-001	29-JULY-89	359	44	04-SEPT-89	2	BKG	BKG	
201-WP-016-001	29-JULY-89	431	116	04-SEPT-89	2	BKG	BKG	
201-WP-020-001	29-JULY-89	287	BKG	04-SEPT-89	1	BKG	BKG	
201-WP-022-001	29-JULY-89	335	20	04-SEPT-89	4	0.3	1.2	
201-WP-024-001	29-JULY-89	287	BKG	04-SEPT-89	3	0.1	0.4	
201-WP-028-001	29-JULY-89	263	BKG	04-SEPT-89	3	0.1	0.4	
201-WP-030-001	29-JULY-89	359	44	04-SEPT-89	1	BKG	BKG	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
201-WP-031-001	29-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
201-WP-032-001	29-JULY-89	---	---	04-SEPT-89	1	BKG	BKG	
201-WP-037-001	29-JULY-89	---	---	04-SEPT-89	1	BKG	BKG	
201-WP-038-001	29-JULY-89	---	---	04-SEPT-89	5	0.5	2.0	
201-WP-039-001	29-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
201-WP-040-001	29-JULY-89	---	---	04-SEPT-89	3	0.1	0.4	
201-WP-041-001	29-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
201-WP-042-001	29-JULY-89	---	---	04-SEPT-89	7	0.9	3.5	
201-WP-043-001	29-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
201-WP-044-001	29-JULY-89	---	---	04-SEPT-89	1	BKG	BKG	
Shelter 202								
202-WP-001-001	31-JULY-89	144	BKG	08-SEPT-89	50	9.5	37.4	
202-WP-003-001	31-JULY-89	287	BKG	08-SEPT-89	7	0.9	3.5	
202-WP-005-001	31-JULY-89	479	164	08-SEPT-89	16	2.7	10.6	
202-WP-007-001	31-JULY-89	407	92	08-SEPT-89	1	BKG	BKG	
202-WP-009-001	31-JULY-89	335	20	08-SEPT-89	6	0.7	2.8	
202-WP-011-001	31-JULY-89	---	---	08-SEPT-89	4	0.3	1.2	
202-WP-012-001	31-JULY-89	407	92	08-SEPT-89	3	0.1	0.4	
202-WP-013-001	31-JULY-89	455	140	08-SEPT-89	5	0.5	2.0	
202-WP-014-001	31-JULY-89	479	164	08-SEPT-89	2	BKG	BKG	
202-WP-016-001	31-JULY-89	279	267	08-SEPT-89	9	1.3	5.1	
202-WP-020-001	31-JULY-89	527	212	08-SEPT-89	3	0.1	0.4	
202-WP-022-001	31-JULY-89	407	92	08-SEPT-89	3	0.1	0.4	
202-WP-024-001	31-JULY-89	383	68	08-SEPT-89	1	BKG	BKG	
202-WP-028-001	31-JULY-89	407	92	08-SEPT-89	23	4.1	16.1	
202-WP-030-001	31-JULY-89	335	20	08-SEPT-89	2	BKG	BKG	
202-WP-031-001	31-JULY-89	---	---	08-SEPT-89	3	0.1	0.4	
202-WP-032-001	31-JULY-89	---	---	08-SEPT-89	4	0.3	1.2	
202-WP-037-001	31-JULY-89	---	---	08-SEPT-89	16	2.7	10.6	
202-WP-038-001	31-JULY-89	---	---	08-SEPT-89	4	0.3	1.2	
202-WP-039-001	31-JULY-89	---	---	08-SEPT-89	2	BKG	BKG	
202-WP-040-001	31-JULY-89	---	---	08-SEPT-89	6	0.7	2.8	
202-WP-041-001	31-JULY-89	---	---	08-SEPT-89	7	0.9	3.5	
202-WP-042-001	31-JULY-89	---	---	08-SEPT-89	5	0.5	2.0	
202-WP-043-001	31-JULY-89	---	---	08-SEPT-89	3	0.1	0.4	
202-WP-044-001	31-JULY-89	---	---	08-SEPT-89	2	BKG	BKG	
Shelter 203								
203-WP-002-001	29-JULY-89	192	BKG	10-SEPT-89	4	0.3	1.2	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
203-WP-004-001	29-JULY-89	335	20	10-SEPT-89	3	0.1	0.4	
203-WP-006-001	29-JULY-89	311	BKG	10-SEPT-89	3	0.1	2.8	
203-WP-008-001	29-JULY-89	215	BKG	10-SEPT-89	6	0.7	2.8	Blood Red Color (oily)
203-WP-010-001	29-JULY-89	---	BKG	10-SEPT-89	7	0.9	3.5	
203-WP-015-001	29-JULY-89	335	20	10-SEPT-89	1	BKG	BKG	
203-WP-017-001	29-JULY-89	263	BKG	10-SEPT-89	3	0.1	0.4	
203-WP-019-001	29-JULY-89	239	BKG	10-SEPT-89	2	BKG	BKG	
203-WP-021-001	29-JULY-89	239	BKG	10-SEPT-89	3	0.1	0.4	
203-WP-023-001	29-JULY-89	383	68	10-SEPT-89	0	BKG	BKG	
203-WP-025-001	29-JULY-89	263	BKG	10-SEPT-89	4	0.3	1.2	
203-WP-027-001	29-JULY-89	287	BKG	10-SEPT-89	2	BKG	BKG	
203-WP-029-001	29-JULY-89	263	BKG	10-SEPT-89	6	0.7	2.8	
203-WP-033-001	29-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
203-WP-034-001	29-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
203-WP-035-001	29-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	Peeling Paint, Rust
203-WP-036-001	29-JULY-89	---	---	10-SEPT-89	6	0.7	2.8	
203-WP-037-001	29-JULY-89	---	---	10-SEPT-89	6	0.7	2.8	
203-WP-038-001	29-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
203-WP-039-001	29-JULY-89	---	---	10-SEPT-89	1	BKG	BKG	
203-WP-040-001	29-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
203-WP-041-001	29-JULY-89	---	---	10-SEPT-89	1	BKG	BKG	
203-WP-042-001	29-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
203-WP-043-001	29-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
203-WP-044-001	29-JULY-89	---	---	10-SEPT-89	6	0.7	2.8	
Shelter 204								
204-WP-001-001	31-AUG-89	2107	2011	05-SEPT-89	5	0.5	2.0	
204-WP-002-001	31-AUG-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-003-001	31-AUG-89	24	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-004-001	31-AUG-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-005-001	31-AUG-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-006-001	31-AUG-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-007-001	31-AUG-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-008-001	31-AUG-89	24	BKG	05-SEPT-89	32	5.9	23.0	
204-WP-009-001	31-AUG-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-010-001	31-AUG-89	48	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-011-001	31-AUG-89	48	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-012-001	31-AUG-89	72	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-013-001	31-AUG-89	24	BKG	05-SEPT-89	1	BKG	BKG	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
204-WP-014-001	31-AUG-89	96	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-015-001	31-AUG-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-016-001	31-AUG-89	72	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-017-001	31-AUG-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-018-001	31-AUG-89	48	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-019-001	31-AUG-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-020-001	31-AUG-89	24	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-021-001	31-AUG-89	24	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-022-001	31-AUG-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-023-001	31-AUG-89	47,875	47,780	05-SEPT-89	6	0.7	2.8	
204-WP-024-001	31-AUG-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-025-001	31-AUG-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-026-001	31-AUG-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-027-001	31-AUG-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-028-001	31-AUG-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-029-001	31-AUG-89	48	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-030-001	31-AUG-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-031-001	31-AUG-89	24	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-032-001	31-AUG-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-033-001	31-AUG-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-034-001	31-AUG-89	48	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-035-001	31-AUG-89	96	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-036-001	31-AUG-89	206	110	05-SEPT-89	5	0.5	2.0	
204-WP-037-001	31-AUG-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-038-001	31-AUG-89	814	718	05-SEPT-89	5	0.5	2.0	
204-WP-039-001	31-AUG-89	215	119	05-SEPT-89	2	BKG	BKG	
204-WP-040-001	31-AUG-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-041-001	31-AUG-89	168	72	05-SEPT-89	4	0.3	1.2	
204-WP-042-001	31-AUG-89	72	BKG	05-SEPT-89	7	0.9	3.5	
204-WP-043-001	31-AUG-89	72	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-044-001	31-AUG-89	168	72	05-SEPT-89	2	BKG	BKG	
204-WP-045-001	31-AUG-89	48	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-046-001	31-AUG-89	48	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-047-001	01-SEP-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-048-001	01-SEP-89	311	215	05-SEPT-89	3	0.1	0.4	
204-WP-049-001	01-SEP-89	530	407	05-SEPT-89	3	0.1	0.4	
204-WP-050-001	01-SEP-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-051-001	01-SEP-89	144	48	05-SEPT-89	3	0.1	0.4	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
204-WP-052-001	01-SEP-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-053-001	01-SEP-89	192	96	05-SEPT-89	6	0.7	2.8	
204-WP-054-001	01-SEP-89	479	383	05-SEPT-89	4	0.3	1.2	
204-WP-055-001	01-SEP-89	72	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-056-001	01-SEP-89	2202	2106	05-SEPT-89	3	0.1	0.4	
204-WP-057-001	01-SEP-89	503	407	05-SEPT-89	4	0.3	1.2	
204-WP-058-001	01-SEP-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-059-001	01-SEP-89	48	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-060-001	01-SEP-89	508	412	05-SEPT-89	0	BKG	BKG	
204-WP-061-001	01-SEP-89	48	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-062-001	01-SEP-89	144	BKG	05-SEPT-89	529	105.3	414.5	
204-WP-063-001	01-SEP-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-064-001	01-SEP-89	48	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-065-001	01-SEP-89	72	BKG	05-SEPT-89	6	0.7	2.8	
204-WP-066-001	01-SEP-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-067-001	01-SEP-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-068-001	01-SEP-89	24	BKG	05-SEPT-89	7	0.9	3.5	
204-WP-069-001	01-SEP-89	48	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-070-001	01-SEP-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-071-001	01-SEP-89	24	BKG	05-SEPT-89	6	0.7	2.8	
204-WP-072-001	01-SEP-89	24	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-073-001	01-SEP-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-074-001	01-SEP-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-075-001	01-SEP-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-076-001	01-SEP-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-077-001	01-SEP-89	48	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-078-001	01-SEP-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-079-001	01-SEP-89	24	BKG	05-SEPT-89	6	0.7	2.8	
204-WP-080-001	01-SEP-89	24	BKG	05-SEPT-89	5	0.5	2.0	
204-WP-081-001	01-SEP-89	24	BKG	05-SEPT-89	0	BKG	BKG	
204-WP-082-001	01-SEP-89	48	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-083-001	01-SEP-89	48	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-084-001	01-SEP-89	72	BKG	05-SEPT-89	7	0.9	3.5	
204-WP-085-001	01-SEP-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-086-001	01-SEP-89	72	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-087-001	01-SEP-89	407	311	05-SEPT-89	12	1.9	7.5	
204-WP-088-001	01-SEP-89	120	24	05-SEPT-89	5	0.5	2.0	
204-WP-089-001	01-SEP-89	24	BKG	05-SEPT-89	4	0.3	1.2	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
204-WP-090-001	01-SEP-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-091-001	01-SEP-89	24	BKG	05-SEPT-89	0	BKG	BKG	
204-WP-092-001	01-SEP-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-093-001	01-SEP-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-094-001	01-SEP-89	48	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-095-001	01-SEP-89	24	BKG	05-SEPT-89	2	BKG	BKG	
204-WP-096-001	01-SEP-89	24	BKG	05-SEPT-89	4	0.3	1.2	
204-WP-097-001	01-SEP-89	24	BKG	05-SEPT-89	3	0.1	0.4	
204-WP-098-001	01-SEP-89	144	48	05-SEPT-89	29	5.3	20.9	
204-WP-099-001	01-SEP-89	24	BKG	05-SEPT-89	1	BKG	BKG	
204-WP-100-001	01-SEP-89	24	BKG	05-SEPT-89	3	0.1	0.4	
Shelter 205								
205-WP-001-001	29-JULY-89	215	BKG	09-SEPT-89	3	0.1	0.4	
205-WP-003-001	29-JULY-89	311	BKG	09-SEPT-89	6	0.7	2.8	
205-WP-005-001	29-JULY-89	431	116	09-SEPT-89	8	1.1	4.3	
205-WP-007-001	29-JULY-89	335	20	09-SEPT-89	6	0.7	2.8	
205-WP-009-001	29-JULY-89	383	68	09-SEPT-89	52	9.9	39	
205-WP-011-001	29-JULY-89	---	---	09-SEPT-89	6	0.7	2.8	
205-WP-012-001	29-JULY-89	---	---	09-SEPT-89	4	0.3	1.2	
205-WP-013-001	29-JULY-89	---	---	09-SEPT-89	6	0.7	2.8	
205-WP-014-001	29-JULY-89	335	20	09-SEPT-89	2	BKG	BKG	
205-WP-016-001	29-JULY-89	---	---	09-SEPT-89	6	0.7	2.8	
205-WP-020-001	29-JULY-89	263	BKG	09-SEPT-89	5	0.5	2.0	
205-WP-022-001	29-JULY-89	263	BKG	09-SEPT-89	3	0.1	0.4	
205-WP-024-001	29-JULY-89	407	92	09-SEPT-89	5	0.5	2.0	
205-WP-028-001	29-JULY-89	359	44	09-SEPT-89	0	BKG	BKG	
205-WP-030-001	29-JULY-89	311	BKG	09-SEPT-89	3	0.1	0.4	
205-WP-031-001	29-JULY-89	---	---	09-SEPT-89	2	BKG	BKG	
205-WP-032-001	29-JULY-89	---	---	09-SEPT-89	1	BKG	BKG	
205-WP-037-001	29-JULY-89	---	---	09-SEPT-89	4	0.3	1.2	
205-WP-038-001	29-JULY-89	---	---	09-SEPT-89	5	0.5	2.0	
205-WP-039-001	29-JULY-89	---	---	09-SEPT-89	4	0.3	1.2	
205-WP-040-001	29-JULY-89	---	---	09-SEPT-89	3	0.1	0.4	
205-WP-041-001	29-JULY-89	---	---	09-SEPT-89	2	BKG	BKG	
205-WP-042-001	29-JULY-89	---	---	09-SEPT-89	4	0.3	1.2	
205-WP-043-001	29-JULY-89	---	---	09-SEPT-89	2	BKG	BKG	
205-WP-044-001	29-JULY-89	---	---	09-SEPT-89	3	0.1	0.4	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
Shelter 206								
206-WP-001-001	31-JULY-89	239	BKG	09-SEPT-89	5	0.5	2.0	
206-WP-003-001	31-JULY-89	239	BKG	09-SEPT-89	6	0.7	2.8	
206-WP-005-001	31-JULY-89	263	BKG	09-SEPT-89	3	0.1	0.4	
206-WP-007-001	31-JULY-89	383	68	09-SEPT-89	4	0.3	1.2	
206-WP-009-001	31-JULY-89	215	BKG	09-SEPT-89	4	0.3	1.2	
206-WP-011-001	31-JULY-89	479	164	09-SEPT-89	3	0.1	0.4	
206-WP-012-001	31-JULY-89	359	44	09-SEPT-89	0	BKG	BKG	
206-WP-013-001	31-JULY-89	335	20	09-SEPT-89	5	0.5	2.0	
206-WP-014-001	31-JULY-89	479	164	09-SEPT-89	4	0.3	1.2	
206-WP-016-001	31-JULY-89	359	44	09-SEPT-89	6	0.7	2.8	
206-WP-020-001	31-JULY-89	455	140	09-SEPT-89	2	BKG	BKG	
206-WP-022-001	31-JULY-89	527	212	09-SEPT-89	1	BKG	BKG	
206-WP-024-001	31-JULY-89	383	68	09-SEPT-89	3	0.1	0.4	
206-WP-028-001	31-JULY-89	407	92	09-SEPT-89	1	BKG	BKG	
206-WP-030-001	31-JULY-89	383	68	09-SEPT-89	3	0.1	0.4	
206-WP-031-001	31-JULY-89	---	---	09-SEPT-89	6	0.7	2.8	
206-WP-032-001	31-JULY-89	---	---	09-SEPT-89	3	0.1	0.4	
206-WP-037-001	31-JULY-89	---	---	09-SEPT-89	3	0.1	0.4	
206-WP-038-001	31-JULY-89	---	---	09-SEPT-89	2	BKG	BKG	
206-WP-039-001	31-JULY-89	---	---	09-SEPT-89	8	1.1	4.3	
206-WP-040-001	31-JULY-89	---	---	09-SEPT-89	3	0.1	0.4	
206-WP-041-001	31-JULY-89	---	---	09-SEPT-89	5	0.5	2.0	
206-WP-042-001	31-JULY-89	---	---	09-SEPT-89	2	BKG	BKG	
206-WP-043-001	31-JULY-89	---	---	09-SEPT-89	4	0.3	1.2	
206-WP-044-001	31-JULY-89	---	---	09-SEPT-89	4	0.3	1.2	
Shelter 207								
207-WP-002-001	28-JULY-89	143.6	BKG	10-SEPT-89	6	0.7	2.8	
207-WP-004-001	28-JULY-89	215.4	BKG	10-SEPT-89	6	0.7	2.8	
207-WP-006-001	28-JULY-89	167.6	BKG	10-SEPT-89	4	0.3	1.2	
207-WP-008-001	28-JULY-89	275.4	BKG	10-SEPT-89	5	0.5	2.0	Oily Surface
207-WP-010-001	28-JULY-89	---	---	10-SEPT-89	5	0.5	2.0	Greasy Surface
207-WP-015-001	28-JULY-89	263	BKG	10-SEPT-89	0	BKG	BKG	
207-WP-017-001	28-JULY-89	239	BKG	10-SEPT-89	2	BKG	BKG	Peeled Paint
207-WP-019-001	28-JULY-89	263	BKG	10-SEPT-89	2	BKG	BKG	Rust and Paint
207-WP-021-001	28-JULY-89	263	BKG	10-SEPT-89	2	BKG	BKG	
207-WP-023-001	28-JULY-89	192	BKG	10-SEPT-89	1	BKG	BKG	
207-WP-025-001	28-JULY-89	215	BKG	10-SEPT-89	6	0.7	2.8	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
207-WP-027-001	28-JULY-89	215	BKG	10-SEPT-89	4	0.3	1.2	
207-WP-029-001	28-JULY-89	---	---	10-SEPT-89	7	0.9	3.5	
207-WP-033-001	28-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
207-WP-034-001	28-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
207-WP-035-001	28-JULY-89	---	---	10-SEPT-89	6	0.7	2.8	Peeling Paint
207-WP-036-001	28-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	Peeling Paint-Rusty
207-WP-037-001	28-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
207-WP-038-001	28-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
207-WP-039-001	28-JULY-89	---	---	10-SEPT-89	1	BKG	BKG	
207-WP-040-001	28-JULY-89	---	---	10-SEPT-89	6	0.7	2.8	
207-WP-041-001	28-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
207-WP-042-001	28-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
207-WP-043-001	28-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
207-WP-044-001	28-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
Shelter 208								
208-WP-002-001	27-JULY-89	---	---	07-SEPT-89	5	0.5	2.0	
208-WP-004-001	27-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
208-WP-006-001	27-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
208-WP-008-001	27-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
208-WP-010-001	27-JULY-89	---	---	07-SEPT-89	4	0.3	1.2	
208-WP-015-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-017-001	27-JULY-89	---	---	07-SEPT-89	8	1.1	4.3	
208-WP-019-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-021-001	27-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
208-WP-023-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-025-001	27-JULY-89	---	---	07-SEPT-89	15	2.5	9.8	
208-WP-027-001	27-JULY-89	---	---	07-SEPT-89	5	0.5	2.0	
208-WP-029-001	27-JULY-89	---	---	07-SEPT-89	4	0.3	1.2	
208-WP-033-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-034-001	27-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
208-WP-035-001	27-JULY-89	---	---	07-SEPT-89	4	0.3	1.2	
208-WP-036-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-037-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-038-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-039-001	27-JULY-89	---	---	07-SEPT-89	1	BKG	BKG	
208-WP-040-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-041-001	27-JULY-89	---	---	07-SEPT-89	1	BKG	BKG	
208-WP-042-001	27-JULY-89	---	---	07-SEPT-89	6	0.7	2.8	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
208-WP-043-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
208-WP-044-001	27-JULY-89	---	---	07-SEPT-89	1	BKG	BKG	
Shelter 209								
209-WP-001-001	27-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	
209-WP-003-001	27-JULY-89	---	---	07-SEPT-89	8	1.1	4.3	
209-WP-005-001	27-JULY-89	---	---	07-SEPT-89	4	0.3	1.2	
209-WP-007-001	27-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
209-WP-009-001	27-JULY-89	---	---	07-SEPT-89	9	1.3	5.1	
209-WP-011-001	27-JULY-89	---	---	07-SEPT-89	1	BKG	BKG	
209-WP-012-001	27-JULY-89	---	---	07-SEPT-89	4	0.3	1.2	
209-WP-013-001	27-JULY-89	---	---	07-SEPT-89	1	BKG	BKG	
209-WP-014-001	28-JULY-89	---	---	07-SEPT-89	4	0.3	1.2	
209-WP-016-001	28-JULY-89	95.8	BKG	07-SEPT-89	5	0.5	2.0	
209-WP-018-001	28-JULY-89	167.6	BKG	07-SEPT-89	11	1.7	6.7	
209-WP-020-001	28-JULY-89	167.6	BKG	07-SEPT-89	5	0.5	2.0	Rust
209-WP-022-001	28-JULY-89	95.8	BKG	07-SEPT-89	2	BKG	BKG	
209-WP-024-001	28-JULY-89	287.3	BKG	07-SEPT-89	1	BKG	BKG	
209-WP-026-001	28-JULY-89	119.7	BKG	07-SEPT-89	299	59.3	233	
209-WP-028-001	28-JULY-89	143.6	BKG	07-SEPT-89	7	0.9	3.5	
209-WP-030-001	28-JULY-89	287.3	BKG	07-SEPT-89	1	BKG	BKG	
209-WP-031-001	28-JULY-89	---	---	07-SEPT-89	3	0.1	0.4	Difficult location
209-WP-032-001	28-JULY-89	---	---	07-SEPT-89	4	0.3	1.2	unable to take
209-WP-037-001	27-JULY-89	---	---	07-SEPT-89	1	BKG	BKG	reading
209-WP-038-001	28-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
209-WP-039-001	28-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
209-WP-040-001	28-JULY-89	---	---	07-SEPT-89	4	0.3	1.2	
209-WP-041-001	28-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
209-WP-042-001	28-JULY-89	---	---	07-SEPT-89	2	BKG	BKG	
209-WP-043-001	28-JULY-89	---	---	07-SEPT-89	5	0.5	2.0	
209-WP-044-001	28-JULY-89	---	---	07-SEPT-89	6	0.7	2.8	
Shelter 210								
210-WP-001-001	21-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
210-WP-002-001	21-JULY-89	---	---	10-SEPT-89	6	0.7	2.8	
210-WP-003-001	21-JULY-89	---	---	10-SEPT-89	12	1.9	7.5	
210-WP-004-001	21-JULY-89	---	---	10-SEPT-89	7	0.9	3.5	
210-WP-005-001	21-JULY-89	---	---	10-SEPT-89	7	0.9	3.5	
210-WP-006-001	21-JULY-89	---	---	10-SEPT-89	10	1.5	5.9	
210-WP-007-001	21-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
210-WP-008-001	21-JULY-89	---	---	10-SEPT-89	0	BKG	BKG	
210-WP-009-001	21-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
210-WP-010-001	21-JULY-89	---	---	10-SEPT-89	126	24.7	97.2	
210-WP-011-001	21-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
210-WP-012-001	21-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
210-WP-013-001	21-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
210-WP-014-001	21-JULY-89	---	---	10-SEPT-89	1	BKG	BKG	
210-WP-015-001	21-JULY-89	---	---	10-SEPT-89	39	7.3	28.7	
210-WP-016-001	21-JULY-89	---	---	10-SEPT-89	7	0.9	3.5	
210-WP-017-001	25-JULY-89	---	---	10-SEPT-89	5	0.5	2.0	
210-WP-018-001	25-JULY-89	---	---	10-SEPT-89	19	3.3	13.0	
210-WP-019-001	25-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
210-WP-020-001	25-JULY-89	---	---	10-SEPT-89	7	0.9	3.5	
210-WP-021-001	25-JULY-89	---	---	10-SEPT-89	5	0.5	2.0	
210-WP-022-001	25-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
210-WP-023-001	25-JULY-89	---	---	10-SEPT-89	2	BKG	BKG	
210-WP-024-001	25-JULY-89	---	---	10-SEPT-89	8	1.1	4.3	
210-WP-025-001	25-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
210-WP-026-001	25-JULY-89	---	---	10-SEPT-89	6	0.7	2.8	
210-WP-027-001	25-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
210-WP-028-001	25-JULY-89	---	---	10-SEPT-89	5	0.5	2.0	
210-WP-029-001	25-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
210-WP-030-001	25-JULY-89	---	---	10-SEPT-89	5	0.5	2.0	
210-WP-031-001	25-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
210-WP-032-001	25-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
210-WP-033-001	25-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
210-WP-034-001	25-JULY-89	---	---	10-SEPT-89	3	0.1	0.4	
210-WP-035-001	25-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
210-WP-036-001	25-JULY-89	---	---	10-SEPT-89	7	0.9	3.5	
210-WP-037-001	25-JULY-89	---	---	10-SEPT-89	18	3.1	12.2	
210-WP-038-001	25-JULY-89	---	---	10-SEPT-89	7	0.9	3.5	
210-WP-039-001	25-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
210-WP-040-001	25-JULY-89	---	---	10-SEPT-89	4	0.3	1.2	
210-WP-041-001	25-JULY-89	---	---	10-SEPT-89	10	1.5	5.9	
210-WP-042-001	25-JULY-89	---	---	10-SEPT-89	5	0.5	2.0	
210-WP-043-001	25-JULY-89	---	---	10-SEPT-89	1	BKG	BKG	
210-WP-044-001	25-JULY-89	---	---	10-SEPT-89	15	2.5	9.8	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
Shelter 212								
212-WP-001-001	26-JULY-89	---	---	06-SEPT-89	5	0.5	2.0	
212-WP-003-001	26-JULY-89	---	---	06-SEPT-89	4	0.3	1.2	
212-WP-005-001	26-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-007-001	26-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-009-001	26-JULY-89	---	---	06-SEPT-89	7	0.9	3.5	
212-WP-011-001	27-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-012-001	27-JULY-89	---	---	06-SEPT-89	1	BKG	BKG	
212-WP-013-001	27-JULY-89	---	---	06-SEPT-89	1	BKG	BKG	
212-WP-016-001	27-JULY-89	---	---	06-SEPT-89	6	0.7	2.8	
212-WP-018-001	27-JULY-89	---	---	06-SEPT-89	3	0.1	0.4	
212-WP-020-001	27-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-022-001	27-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-024-001	27-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-026-001	27-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-028-001	27-JULY-89	---	---	06-SEPT-89	9	1.3	5.1	
212-WP-030-001	27-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-032-001	27-JULY-89	---	---	06-SEPT-89	3	0.1	0.4	
212-WP-037-001	27-JULY-89	---	---	06-SEPT-89	3	0.1	0.4	
212-WP-038-001	27-JULY-89	---	---	06-SEPT-89	5	0.5	2.0	
212-WP-039-001	27-JULY-89	---	---	06-SEPT-89	4	0.3	1.2	
212-WP-040-001	27-JULY-89	---	---	06-SEPT-89	3	0.1	0.4	
212-WP-041-001	27-JULY-89	---	---	06-SEPT-89	3	0.1	0.4	
212-WP-042-001	27-JULY-89	---	---	06-SEPT-89	2	BKG	BKG	
212-WP-043-001	27-JULY-89	---	---	06-SEPT-89	6	0.7	2.8	
212-WP-044-001	27-JULY-89	---	---	06-SEPT-89	4	0.3	1.2	
Shelter 216								
216-WP-002-001	31-JULY-89	383	68	04-SEPT-89	4	0.3	1.2	
216-WP-004-001	31-JULY-89	407	92	04-SEPT-89	2	BKG	BKG	
216-WP-006-001	31-JULY-89	503	188	04-SEPT-89	2	BKG	BKG	
216-WP-008-001	31-JULY-89	215	BKG	04-SEPT-89	1	BKG	BKG	Rust
216-WP-010-001	31-JULY-89	---	---	04-SEPT-89	3	0.1	0.4	
216-WP-015-001	31-JULY-89	407	92	04-SEPT-89	1	BKG	BKG	
216-WP-017-001	31-JULY-89	383	68	04-SEPT-89	3	0.1	0.4	
216-WP-019-001	31-JULY-89	287	BKG	04-SEPT-89	2	BKG	BKG	Rust
216-WP-021-001	31-JULY-89	551	236	04-SEPT-89	1	BKG	BKG	Rust
216-WP-023-001	31-JULY-89	335	20	04-SEPT-89	3	0.1	0.4	
216-WP-025-001	31-JULY-89	407	92	04-SEPT-89	3	0.1	0.4	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
216-WP-027-001	31-JULY-89	646	331	04-SEPT-89	3	0.1	0.4	Rust
216-WP-029-001	31-JULY-89	407	92	04-SEPT-89	1	BKG	BKG	
216-WP-033-001	31-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
216-WP-034-001	31-JULY-89	---	---	04-SEPT-89	3	0.1	0.4	
216-WP-035-001	31-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
216-WP-036-001	31-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
216-WP-037-001	31-JULY-89	---	---	04-SEPT-89	0	BKG	BKG	
216-WP-038-001	31-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
216-WP-039-001	31-JULY-89	---	---	04-SEPT-89	4	0.3	1.2	
216-WP-040-001	31-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
216-WP-041-001	31-JULY-89	---	---	04-SEPT-89	2	BKG	BKG	
216-WP-042-001	31-JULY-89	---	---	04-SEPT-89	1	BKG	BKG	
216-WP-043-001	31-JULY-89	---	---	04-SEPT-89	1	BKG	BKG	
216-WP-044-001	31-JULY-89	---	---	04-SEPT-89	3	0.1	0.4	
Shelter 228								
228-WP-001-001	31-JULY-89	---	---	03-SEPT-89	5	0.5	2.0	
228-WP-003-001	31-JULY-89	---	---	03-SEPT-89	4	0.3	1.2	
228-WP-005-001	31-JULY-89	---	---	03-SEPT-89	1	BKG	BKG	
228-WP-007-001	31-JULY-89	---	---	03-SEPT-89	3	0.1	0.4	
228-WP-009-001	31-JULY-89	---	---	03-SEPT-89	0	BKG	BKG	
228-WP-011-001	31-JULY-89	---	---	03-SEPT-89	6	0.7	2.8	
228-WP-012-001	31-JULY-89	---	---	03-SEPT-89	5	0.5	2.0	
228-WP-013-001	31-JULY-89	---	---	03-SEPT-89	2	BKG	BKG	
228-WP-014-001	31-JULY-89	---	---	03-SEPT-89	6	0.7	2.8	
228-WP-016-001	31-JULY-89	---	---	03-SEPT-89	1	BKG	BKG	
228-WP-020-001	31-JULY-89	---	---	03-SEPT-89	2	BKG	BKG	
228-WP-022-001	31-JULY-89	---	---	03-SEPT-89	6	0.7	2.8	
228-WP-024-001	31-JULY-89	---	---	03-SEPT-89	4	0.3	1.2	
228-WP-028-001	31-JULY-89	---	---	03-SEPT-89	1	BKG	BKG	
228-WP-030-001	31-JULY-89	---	---	03-SEPT-89	2	BKG	BKG	
228-WP-031-001	31-JULY-89	---	---	03-SEPT-89	3	0.1	0.4	
228-WP-032-001	31-JULY-89	---	---	03-SEPT-89	6	0.7	2.8	
228-WP-037-001	31-JULY-89	---	---	03-SEPT-89	4	0.3	1.2	
228-WP-038-001	31-JULY-89	---	---	03-SEPT-89	1	BKG	BKG	
228-WP-039-001	31-JULY-89	---	---	03-SEPT-89	2	BKG	BKG	
228-WP-040-001	31-JULY-89	---	---	03-SEPT-89	3	0.1	0.4	
228-WP-041-001	31-JULY-89	---	---	03-SEPT-89	3	0.1	0.4	

* See notes at end of table.

Table 4-13 (continued)

Removable Surface Alpha Activity on Wipe Samples Obtained from Shelters at the BOMARC Missile Site and PAC-4G Measurements

Identification, Location	Date Collected	PAC-4G (Fixed Radioactivity) Total dpm/100 sq cm*	PAC-4G (Fixed Radioactivity) dpm/100 sq cm* (Net)	WIPE SAMPLE RESULTS (Removable Radioactivity Measured with Ludlum 2000) Date Counted	5 Minute Count*	Surface Activity (Net cpm)*	dpm/100 sq cm (Net)*	Remarks
228-WP-042-001	31-JULY-89	---	---	03-SEPT-89	4	0.3	1.2	
228-WP-043-001	31-JULY-89	---	---	03-SEPT-89	2	BKG	BKG	
228-WP-044-001	31-JULY-89	---	---	03-SEPT-89	1	BKG	BKG	

*NOTES:
Average Filter Background = 2.0 dpm/100 sq cm
Filter Lower Limit of Detection = 4.6 dpm/100 sq cm
Ludlum Counting Efficiency = 0.254 cpm/dpm
Ludlum Background = 0.5 cpm
Ludlum Net cpm = (5 minute count divided by 5) then subtract background of 0.5 cpm

PAC-4G Background = 315 dpm/100 sq cm
PAC-4G LLD = 192 dpm/100 sq cm

PAC-4G Values For Shelter 204 Samples:
PAC-4G Background = 48 dpm/100 sq cm
PAC-4G LLD = 85 dpm/100 sq cm

BKG = Background
--- = No Reading or Calculation Not Performed

$$\frac{66.0 \text{ cpm}}{0.353 \text{ cpm/dpm}} = 186.97 \text{ dpm}$$

Since the surface area of the probe was 59 cm^2, the average background becomes:

$$\frac{186.97 \text{ dpm}}{59 \text{ cm}^2} = \frac{316.90 \text{ dpm}}{100 \text{ cm}^2}$$

By performing the background analysis based upon the observed distribution of background, one can be 95% confident of the sensitivity by utilizing two standard deviations of the data universe. In this fashion, the equivalent lower limit of detection (LLD) is 192 dpm/100 cm^2.

The average background activity was subtracted from each PAC-4G measurement. A total of over 100 sampling stations in 14 shelters were found to have activity levels exceeding background conditions (Table 4-14). For the exact sampling locations, refer to Figures 3-16 to 3-21, and Figures 3-23 to 3-28, as well as Tables 3-5 and 3-6.

To aid in evaluating the significance of the results from this portion of the investigation, the results were compared to guidelines published by the Nuclear Regulatory Commission in their NRC Guide 1.86 (NRC, 1974) for alpha activity on surfaces. Those guidelines are:

20 dpm/100 cm^2 for removable alpha activity
100 dpm/100 cm^2 for average alpha activity
300 dpm/100 cm^2 for maximum alpha activity

The highest activity levels, as expected, were detected in Shelter 204. A total of 18 of the stations sampled in this shelter showed activity levels above background. Twelve (12) of these stations showed activity levels greater than the regulatory guidelines for average activity of 100 dpm/100 cm^2. The samples with the highest activity were collected from Sampling Stations 204-WP-001-001 (2,011 dpm/100 cm^2), 204-WP-023-001 (47,780 dpm/100 cm^2), and 204-WP-056-001 (2,106 dpm/100 cm^2). Unexpectedly, Shelter 216 had two stations with activity above the NRC average of 100 dpm/100 cm^2 and one station with alpha activity above the NRC maximum of 300 dpm/100 cm^2.

At least one sampling station in seven additional shelters (Shelters 106, 127, 201, 202, 205, 206, and 216) showed activity levels to exceed 100 dpm/100 cm^2 as measured with the PAC-4G. The PAC-4G measurements did not allow determination of whether the activity was removable or fixed.

Planchet counter measurements of wipe samples collected in missile launch shelters. After being surveyed with the PAC-4G, each sampling station was carefully wiped at the locations, using techniques described in Section 3.6.2.5. The wipes were then analyzed on site, using a Ludlum Model 2000 Scaler with an alpha scintillation detector (planchet counter). The results from those samples found to exceed background activity are presented in Table 4-15. For the exact sample locations, refer to Figures 3-16 through 3-21, 3-23 through 3-28, and to Tables 3-5 and 3-6.

Table 4-14
Summary of PAC-4G Measurements with Readings Above Background

Shelter Number	Sampling Station Number	PAC-4G Measurement with Background Subtracted (dpm/100 cm^2)
101	13	68
	30	44
102	3	44
	14	68
103	2	44
	25	20
	27	68
104	8	92
	19	20
	21	68
	23	44
	27	20
105	7	44
	13	68
106	5	68
	12	68
	14	44
	16	20
	20	44
	30	140
127	3	44
	5	188
	7	283
	9	116
	12	44
	13	92
	14	116
	16	20
	20	68
	22	116
	24	44
	28	92
	30	164
201	1	68
	3	44
	7	116
	914	44
	16	116
	22	20
	30	44
202	5	164
	7	92
	9	20
	12	92
	13	140
	14	164
	16	267
	20	212
	22	92
	24	68
	28	92
	30	20
203	4	20
	15	20
	23	68

Table 4-14 (continued)
Summary of PAC-4G Measurements with Readings Above Background

Shelter Number	Sampling Station Number	PAC-4G Measurement with Background Subtracted (dpm/100 cm^2)
204	1	2,011
	23	47,780
	36	110
	38	718
	39	119
	41	72
	44	72
	48	215
	49	407
	51	48
	53	96
	54	383
	56	2,106
	57	407
	60	412
	87	311
	88	24
	98	48
205	5	116
	7	20
	9	68
	14	20
	24	92
	28	44
206	7	68
	11	164
	12	44
	13	20
	14	164
	16	44
	20	140
	22	212
	24	68
	28	92
	30	68
216	2	68
	4	92
	6	188
	15	92
	17	68
	21	236
	23	20
	25	92
	27	31
	29	92

Note: PAC-4G lower limit of detection is 192 dpm/100cm^2.

Table 4-15

Summary of Ludlum 2000 Planchet Counter Readings Above Background

Identification and Location	Planchet Counter Total dpm/100 sq cm	Identification and Location	Planchet Counter Total dpm/100 sq cm
101-WP-011-001	0.4	106-WP-031-001	1.2
101-WP-012-001	0.4	106-WP-032-001	0.4
101-WP-014-001	1.2	106-WP-038-001	0.4
101-WP-016-001	0.4	106-WP-040-001	1.2
101-WP-022-001	2.0	106-WP-042-001	0.4
101-WP-028-001	0.4	127-WP-001-001	3.5
101-WP-032-001	2.0	127-WP-003-001	0.4
101-WP-037-001	2.0	127-WP-005-001	1.2
101-WP-040-001	2.0	127-WP-009-001	0.4
101-WP-043-001	0.4	127-WP-013-001	0.4
101-WP-044-001	0.4	127-WP-014-001	2.0
101-WP-107-001	1.2	127-WP-016-001	0.4
101-WP-109-001	1.2	127-WP-020-001	1.2
102-WP-001-001	2.8	127-WP-022-001	0.4
102-WP-003-001	3.5	127-WP-030-001	1.2
102-WP-007-001	1.2	127-WP-031-001	0.4
102-WP-009-001	1.2	127-WP-032-001	0.4
102-WP-011-001	0.4	127-WP-037-001	2.0
102-WP-012-001	2.0	127-WP-038-001	2.8
102-WP-013-001	1.2	127-WP-040-001	1.2
102-WP-014-001	1.2	127-WP-041-001	2.0
102-WP-016-001	2.0	127-WP-042-001	0.4
102-WP-020-001	1.2	127-WP-043-001	0.4
102-WP-024-001	0.4	159-WP-002-001	0.4
102-WP-031-001	1.2	159-WP-004-001	1.2
102-WP-032-001	0.4	159-WP-010-001	0.4
102-WP-037-001	0.4	159-WP-019-001	1.2
102-WP-038-001	1.2	159-WP-025-001	0.4
102-WP-041-001	1.2	159-WP-027-001	0.4
102-WP-042-001	2.8	159-WP-029-001	2.0
103-WP-027-001	3.5	159-WP-033-001	2.0
103-WP-029-001	0.4	159-WP-034-001	1.2
103-WP-043-001	0.4	159-WP-035-001	2.0
104-WP-017-001	1.2	159-WP-036-001	1.2
104-WP-029-001	2.0	159-WP-037-001	1.2
105-WP-005-001	2.8	159-WP-041-001	2.8
105-WP-007-001	0.4	159-WP-044-001	2.8
105-WP-032-001	2.0	201-WP-003-001	2.0
106-WP-001-001	2.0	201-WP-005-001	1.2
106-WP-005-001	0.4	201-WP-009-001	1.2
106-WP-009-001	1.2	201-WP-011-001	1.2
106-WP-013-001	1.2	201-WP-012-001	1.2
106-WP-014-001	0.4	201-WP-022-001	1.2
106-WP-016-001	1.2	201-WP-024-001	0.4
106-WP-024-001	0.4	201-WP-028-001	0.4
106-WP-028-001	2.0	201-WP-038-001	2.0
106-WP-030-001	0.4	201-WP-040-001	0.4
201-WP-042-001	3.5	204-WP-020-001	2.0
202-WP-001-001	37.4	204-WP-021-001	2.0
202-WP-003-001	3.5	204-WP-022-001	1.2
202-WP-005-001	10.6	204-WP-023-001	2.8
202-WP-009-001	2.8	204-WP-024-001	1.2
202-WP-011-001	1.2	204-WP-025-001	1.2
202-WP-012-001	0.4	204-WP-026-001	1.2
202-WP-013-001	2.0	204-WP-027-001	0.4
202-WP-016-001	5.1	204-WP-029-001	1.2
202-WP-020-001	0.4	204-WP-030-001	1.2
202-WP-022-001	0.4	204-WP-031-001	2.0
202-WP-028-001	16.1	204-WP-032-001	1.2
202-WP-031-001	0.4	204-WP-033-001	0.4
202-WP-032-001	1.2	204-WP-036-001	2.0
202-WP-037-001	10.6	204-WP-038-001	2.0
202-WP-038-001	1.2	204-WP-040-001	0.4
202-WP-040-001	2.8	204-WP-041-001	1.2
202-WP-041-001	3.5	204-WP-042-001	3.5

Table 4-15 (Continued)

Summary of Ludlum 2000 Planchet Counter Readings Above Background

Identification and Location	Planchet Counter Total dpm/100 sq cm	Identification and Location	Planchet Counter Total dpm/100 sq cm
202-WP-042-001	2.0	204-WP-045-001	2.0
202-WP-043-001	0.4	204-WP-046-001	2.0
203-WP-002-001	1.2	204-WP-047-001	1.2
203-WP-004-001	0.4	204-WP-048-001	0.4
203-WP-006-001	2.8	204-WP-049-001	0.4
203-WP-008-001	2.8	204-WP-051-001	0.4
203-WP-010-001	3.5	204-WP-053-001	2.8
203-WP-017-001	0.4	204-WP-054-001	1.2
203-WP-021-001	0.4	204-WP-056-001	0.4
203-WP-025-001	1.2	204-WP-057-001	1.2
203-WP-029-001	2.8	204-WP-059-001	0.4
203-WP-033-001	0.4	204-WP-061-001	0.4
203-WP-034-001	1.2	204-WP-062-001	414.5
203-WP-035-001	1.2	204-WP-065-001	2.8
203-WP-036-001	2.8	204-WP-066-001	0.4
203-WP-037-001	2.8	204-WP-068-001	3.5
203-WP-043-001	0.4	204-WP-069-001	0.4
203-WP-044-001	2.8	204-WP-071-001	2.8
204-WP-001-001	2.0	204-WP-072-001	2.0
204-WP-002-001	0.4	204-WP-074-001	0.4
204-WP-003-001	2.0	204-WP-079-001	2.8
204-WP-008-001	23.0	204-WP-080-001	2.0
204-WP-011-001	2.0	204-WP-082-001	0.4
204-WP-012-001	2.0	204-WP-083-001	1.2
204-WP-015-001	1.2	204-WP-084-001	3.5
204-WP-016-001	0.4	204-WP-085-001	0.4
204-WP-017-001	0.4	204-WP-086-001	1.2
204-WP-018-001	2.0	204-WP-087-001	7.5
204-WP-088-001	2.0	207-WP-002-001	2.8
204-WP-089-001	1.2	207-WP-004-001	2.8
204-WP-092-001	1.2	207-WP-006-001	1.2
204-WP-093-001	0.4	207-WP-008-001	2.0
204-WP-094-001	0.4	207-WP-010-001	2.0
204-WP-096-001	1.2	207-WP-025-001	2.8
204-WP-097-001	0.4	207-WP-027-001	1.2
204-WP-098-001	20.9	207-WP-029-001	3.5
204-WP-100-001	0.4	207-WP-035-001	2.8
205-WP-001-001	0.4	207-WP-037-001	0.4
205-WP-003-001	2.8	207-WP-038-001	1.2
205-WP-005-001	4.3	207-WP-040-001	2.8
205-WP-007-001	2.8	207-WP-041-001	0.4
205-WP-009-001	39	207-WP-042-001	0.4
205-WP-011-001	2.8	207-WP-043-001	0.4
205-WP-012-001	1.2	207-WP-044-001	0.4
205-WP-013-001	2.8	208-WP-002-001	2.0
205-WP-016-001	2.8	208-WP-010-001	1.2
205-WP-020-001	2.0	208-WP-015-001	0.4
205-WP-022-001	0.4	208-WP-017-001	4.3
205-WP-024-001	2.0	208-WP-019-001	0.4
205-WP-030-001	0.4	208-WP-023-001	0.4
205-WP-037-001	1.2	208-WP-025-001	9.8
205-WP-038-001	2.0	208-WP-027-001	2.0
205-WP-039-001	1.2	208-WP-029-001	1.2
205-WP-040-001	0.4	208-WP-033-001	0.4
205-WP-042-001	1.2	208-WP-035-001	1.2
205-WP-044-001	0.4	208-WP-036-001	0.4
206-WP-001-001	2.0	208-WP-037-001	0.4
206-WP-003-001	2.8	208-WP-038-001	0.4
206-WP-005-001	0.4	208-WP-040-001	0.4
206-WP-007-001	1.2	208-WP-042-001	2.8
206-WP-009-001	1.2	208-WP-043-001	0.4
206-WP-011-001	0.4	209-WP-001-001	0.4
206-WP-013-001	2.0	209-WP-003-001	4.3
206-WP-014-001	1.2	209-WP-005-001	1.2
206-WP-016-001	2.8	209-WP-009-001	5.1

Table 4-15 (Continued)

Summary of Ludlum 2000 Planchet Counter Readings Above Background

Identification and Location	Planchet Counter Total dpm/100 sq cm	Identification and Location	Planchet Counter Total dpm/100 sq cm
206-WP-024-001	0.4	209-WP-012-001	1.2
206-WP-030-001	0.4	209-WP-014-001	1.2
206-WP-031-001	2.8	209-WP-016-001	2.0
206-WP-032-001	0.4	209-WP-018-001	6.7
206-WP-037-001	0.4	209-WP-020-001	2.0
206-WP-039-001	4.3	209-WP-026-001	233
206-WP-040-001	0.4	209-WP-028-001	3.5
206-WP-041-001	2.0	209-WP-031-001	0.4
206-WP-043-001	1.2	209-WP-032-001	1.2
206-WP-044-001	1.2	209-WP-040-001	1.2
209-WP-043-001	2.0	212-WP-040-001	0.4
209-WP-044-001	2.8	212-WP-041-001	0.4
210-WP-002-001	2.8	212-WP-043-001	2.8
210-WP-003-001	7.5	212-WP-044-001	1.2
210-WP-004-001	3.5	216-WP-002-001	1.2
210-WP-005-001	3.5	216-WP-010-001	0.4
210-WP-006-001	5.9	216-WP-017-001	0.4
210-WP-007-001	0.4	216-WP-023-001	0.4
210-WP-009-001	1.2	216-WP-025-001	0.4
210-WP-010-001	97.2	216-WP-027-001	0.4
210-WP-013-001	1.2	216-WP-034-001	0.4
210-WP-015-001	28.7	216-WP-035-001	1.2
210-WP-016-001	3.5	216-WP-036-001	1.2
210-WP-017-001	2.0	216-WP-039-001	1.2
210-WP-018-001	13.0	216-WP-044-001	0.4
210-WP-020-001	3.5	228-WP-001-001	2.0
210-WP-021-001	2.0	228-WP-003-001	1.2
210-WP-024-001	4.3	228-WP-005-001	1.2
210-WP-025-001	0.4	228-WP-007-001	0.4
210-WP-026-001	2.8	228-WP-011-001	2.8
210-WP-027-001	0.4	228-WP-012-001	2.0
210-WP-028-001	2.0	228-WP-014-001	2.8
210-WP-029-001	1.2	228-WP-022-001	2.8
210-WP-030-001	2.0	228-WP-024-001	1.2
210-WP-031-001	1.2	228-WP-031-001	0.4
210-WP-032-001	0.4	228-WP-032-001	2.8
210-WP-033-001	1.2	228-WP-037-001	1.2
210-WP-034-001	0.4	228-WP-040-001	0.4
210-WP-035-001	1.2	228-WP-041-001	0.4
210-WP-036-001	3.5	228-WP-042-001	1.2
210-WP-037-001	12.2		
210-WP-038-001	3.5		
210-WP-039-001	1.2		
210-WP-040-001	1.2		
210-WP-041-001	5.9		
210-WP-042-001	2.0		
210-WP-044-001	9.8		
212-WP-001-001	2.0		
212-WP-003-001	1.2		
212-WP-009-001	3.5		
212-WP-016-001	2.8		
212-WP-018-001	0.4		
212-WP-028-001	5.1		
212-WP-032-001	0.4		
212-WP-037-001	0.4		
212-WP-038-001	2.0		
212-WP-039-001	1.2		

Note: PAC-4B lower limit of detection is 192 dpm/100cm^2.

The planchet counter and sample filter background was determined by review of several weeks of background counts of blank filters from the same manufacturing lot as the filters used to collect the wipe samples. The results showed the background to be 0.50 ± 0.25 cpm. The 0.25 is one standard deviation above the background.

Two electroplated alpha-emitter standards were used daily to monitor and affirm the Ludlum 2000 calibration: Am-241 with an alpha particle energy of 5.4 Mev, and Th-230 at 4.7 Mev. Interpolation was used to determine the efficiency for the 5.1 Mev alpha particle from Pu-239. Analyses have shown that the material associated with the BOMARC accident has decayed to about a 6 to 1 ratio of Pu-239 to Am-241. Therefore, the final counting efficiency used was a properly weighted response assuming that 6 to 1 ratio. This efficiency was calculated at 0.254 cpm/dpm. The average background activity was then determined. The conversion is first made from cpm to dpm:

$$\frac{0.5 \text{ cpm}}{0.254 \text{ cpm/dpm}} = 2.0 \text{ dpm}$$

Since 100 cm^2 were wiped, the average background is:

2.0 dpm/100 cm^2

Using 4.66 standard deviations as the definition for the LLD:

$$4.66 \times 0.25 \text{ cpm} \times \frac{1}{0.254 \text{ cpm/dpm}} = 4.6 \text{ dpm/100 cm}^2$$

The average background activity was subtracted from each planchet counter measurement. Over 300 wipe samples collected from the shelters were found to have removable activity levels exceeding background conditions (Table 4-15). All shelters showed the presence of some removable alpha activity, but most of that was not expected to be plutonium. Naturally occurring isotopes of uranium and thorium found both in construction materials and in airborne particles would account for at least a portion of the removable alpha activity.

To aid in evaluating the significance of the results from this portion of the investigation, the results were compared to guidelines established by the NRC in Guide 1.86 (NRC, 1974) for alpha activity on surfaces. Those guidelines are:

20 dpm/100 cm^2 for removable alpha activity
100 dpm/100 cm^2 for average alpha activity
300 dpm/100 cm^2 for maximum alpha activity

The highest activity levels, as expected, were detected in Shelter 204. Many of the stations sampled in this shelter showed activity levels above background. Three (3) of these stations showed activity levels greater than the regulatory guidelines for removable activity of 20 dpm/100 cm^2. The sample with the highest activity was collected from Sampling Station 204-WP-062-001 (414.5 dpm/100 cm^2).

At least one sampling station in four additional shelters (Shelters 202, 205, 209, and 210) showed removable activity levels exceeding 20 dpm/100 cm^2. When all wipe samples from each shelter were averaged, these four shelters also produced higher than average levels of removable alpha activity. Shelters 202, 205, and 209 were probably contaminated during the fire, fire-fighting, and decontamination activities. Shelter 210 may also have been contaminated during that time, or during later activities. Shelter 210 has been used as a staging area for several years for radiological sampling activities, and may have been contaminated as a result of personnel entry during these operations. In addition, since active missile support activities continued for 12 years at the BOMARC facility after the Shelter 204 accident, it is very possible that the contamination identified in any of these upwind shelters may have been carried in during that active period.

Laboratory analyses of wipe samples from missile launch shelters. Ten wipe samples and one blank were submitted to the laboratory for plutonium analyses by alpha spectroscopy. The results of those analyses are presented on Table 4-16, along with the readings from the stations surveyed with the PAC-4G and wipes counted on the Ludlum 2000 planchet counter, for comparison. Although removable activity was found on many of the wipes that were analyzed on site using the Ludlum 2000 planchet counter, none of the wipe samples submitted to the laboratory for analysis were reported to contain Pu-239 at levels above the laboratory detection limit.

Samples collected from Shelter 204 were analyzed on site using the HPG to determine if removable activity was attached to the rust that flakes off Shelter 204. Although the material is too coarse to be properly sampled with wipes, the information is included here because of its nature as removable activity. Table 4-17 presents the data from those samples. Three of the samples contained too little activity to register on the HPG, but two samples did contain removable and detectable Pu-239. The samples with the removable activity were collected from the center of the floor of the shelter, at distances of 23 and 32 feet, respectively, from the front of the shelter. This leads to the conclusion that removable activity does, indeed, flake off of the shelter structure due to weathering.

4.1.3.4.2 Communication Bunker

Five wipe samples were collected from within the communicatic bunker (see Section 3.6.2.5.3 for details). Samples were taken at points from one to two feet below the opening of the cover to the bunker (Figures 3-29 and 3-30). All screening readings taken with the PAC-4G showed a high alpha count (Table 4-18). Based on the limited number of samples collected, it would appear that the alpha concentration increases with depth in the bunker. This bunker (as well as the power bunker) were sealed with concrete in 1967. The surface of the concrete covering was not noticeably contaminated before being chipped away, but rust samples collected from the manhole covers after the concrete was removed were contaminated (Table 4-19).

Table 4-16

Laboratory Analyses of Wipe Samples Collected from Shelters 202, 204, and 206 at the BOMARC Missile Site

Sample ID	Ludlum Date Collected	PAC-4G* Counts/Min	dpm/100 sq. cm	Parameter	Method	Activity (pCi/L)	Remarks
001-WP-001-001	10-21-89	-	-	Pu-239	PRO-052-32	<6.0 E-02	Blank
202-WP-016-001	07-31-89	125	5.1	Pu-239	PRO-052-32	NA	Hot
204-WP-004-001	08-31-89	88	BKG	Pu-239	PRO-052-32	<1.0 E-02	Right side, 4th beam
204-WP-023-001	08-31-89	10,000	2.8	Pu-239	PRO-052-32	<1.0 E-02	Left side, below 3rd beam, top of gear guide
204-WP-036-001	08-31-89	43	2.0	Pu-239	PRO-052-32	<1.0 E-02	Rt wall, across 20 ft and up 5 ft from front
204-WP-038-001	08-31-89	34	2.0	Pu-239	PRO-052-32	<2.0 E-02	Rt wall, across 40 ft and up 5 ft from front
204-WP-056-001	09-01-89	92	0.4	Pu-239	PRO-052-32	<8.0 E-02	Bottom of 0.6'x1.2' cutout, midpt of shelter
204-WP-086-001	09-01-89	3	1.2	Pu-239	PRO-052-32	<9.0 E-02	Top 1st light in ctrl rm from frnt of shelter
204-WP-044-001	08-31-89	7	BKG	Pu-239	PRO-052-32	<2.0 E-02	Lft wall, across 40 ft and up 5 ft from front
204-WP-011-001	08-31-89	2	2.0	Pu-239	PRO-052-32	<2.0 E-02	Right side, 9th beam
206-WP-022-001	07-31-89	22	-	Pu-239	PRO-052-32	NA	

(NA) = Lab unable to locate sample numbers 81583 and 81584 at the time of analysis.

*The detection limit for PAC-4G is 2 cpm.

Table 4-17

HPG Data for Rust Samples Collected from Shelter 204
at the BOMARC Missile Site

Sample ID	Sample Location	Count Date	HPG SCREENING DATA		
			Am-241 Activity (μCi/Sample)	2-Sigma Error (%)	Pu-239 Activity (μCi/Sample)
001-SO-204-001	Shelter 204	10-14-89	<3.14 E-04	-	-
001-SO-204-002	Shelter 204	10-14-89	<7.23 E-04	-	-
001-SO-204-003	Shelter 204	10-14-89	7.76 E-04	47.8	4.65 E-03
001-SO-204-004	Shelter 204	10-14-89	1.46 E-03	92.2	8.76 E-03
001-SO 204-005	Shelter 204	10-14-89	<2.28 E-04	-	-

Note: "<" indicates minimal detectable activity. This value varies with instrument calibration for a particular day.

Table 4-18

Wipe Sample Results from the Communication Bunker,
BOMARC Missile Site

Sample Number	Direct Alpha Count with PAC-4G (CPM)	Gross Alpha (CPM)	Location
204-WP-C58-001	7,000	167	West side, 1 foot below surface
204-WP-C59-001	4,000	165	North side, 1 foot below surface
204-WP-C60-001	80,000	2329	South east side, 2 feet below surface
204-WP-C61-001	80,000	1958	South east side, 2 feet below surface
204-WP-C62-001	1,500	184	South east side, 1 foot below surface

Note: Detection limits is 100 cpm for PAC-4G and 1 cpm for gross alpha.

Table 4-19

HPG Data for Rust Samples Collected from the Bunkers
at the BOMARC Missile Site

			HPG SCREENING DATA		
Sample ID	Sample Location	Count Date	Am-241 Activity (μCi/Sample)	2-Sigma Error (%)	Pu-239 Activity (μCi/Sample)
001-SO-CB1-001	Commun. Bunker	10-14-89	2.15	10	12.9
001-SO-PB1-002	Power Bunker	10-14-89	2.93	10	17.6

Note: Minimal detectable activities, which varies with instrument calibration for a particular day, are comparable to those given in Table 4-17.

Moisture on the concrete was noted under the manhole cover. That moisture may be either from percolation around the concrete cover, or from condensation of evaporative water from the bunker itself or from the materials underlying the concrete. In either case, the moisture then most likely seeps downward into the bunker, carrying any Pu-239 or Am-241 particles still clinging to the concrete or manhole cover with it. As the moisture causes the lid to rust more, the plutonium that is fixed to it also flakes off and drops down into the bunker.

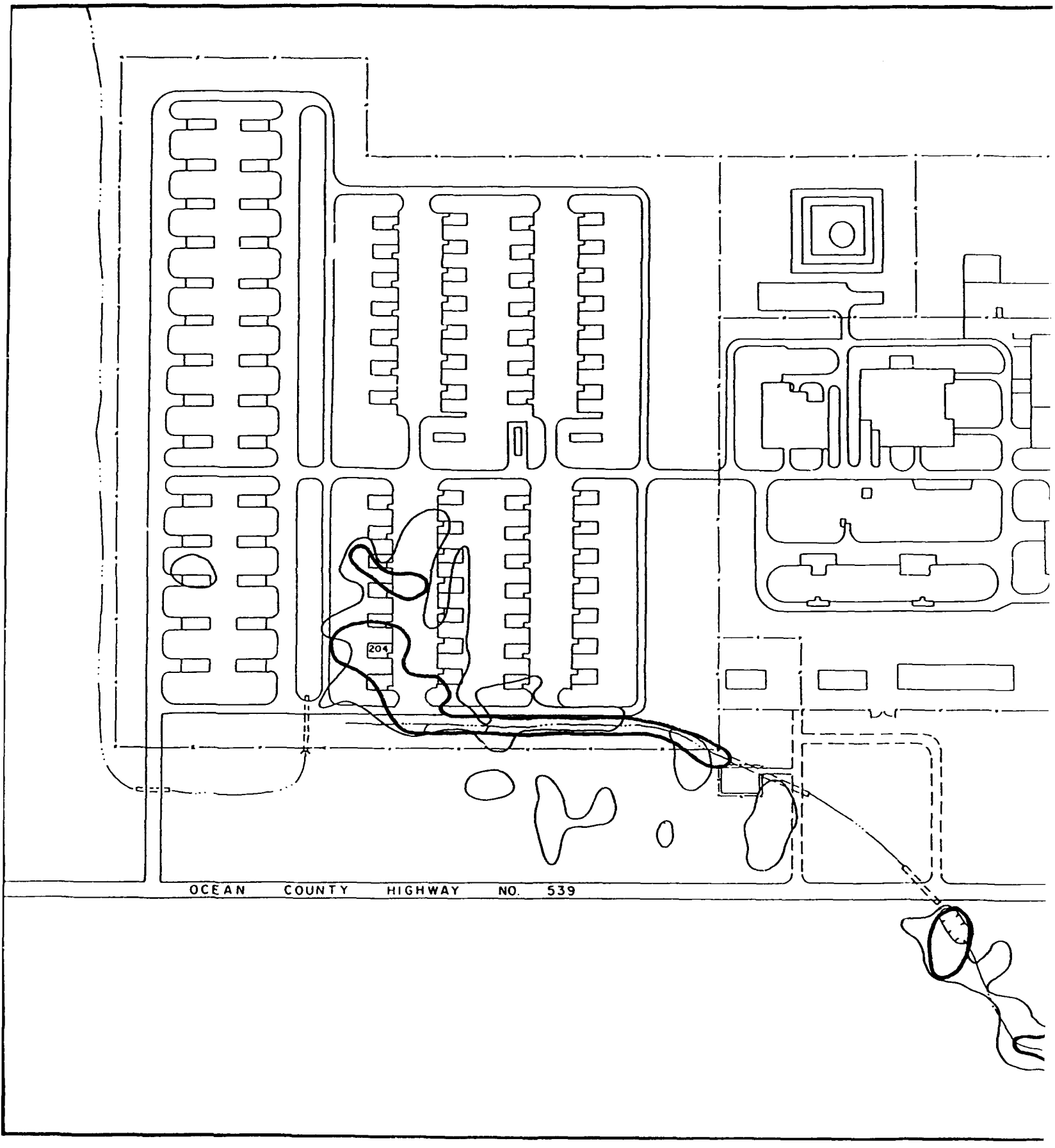
Because this bunker was sealed, and sampling did not indicate any means of contaminant entry around or through the sealing material, it is believed that contamination occurred prior to sealing the bunkers with concrete. It is probable that all removable contamination inside of this bunker was introduced at the time of the fire, and/or from runoff and any maintenance activities that occurred after the fire, but prior to sealing the utility bunkers with concrete.

4.1.3.5 HPG Survey Results

In-situ measurements were taken using a hyperpure germanium detector (HPG) (see Appendix F for complete list of measurements) at the intersections of a 60-foot by 60-foot grid laid out over the northwestern portion of the BOMARC facility and extending to the southwest following the major drainage (Plate 4-1 and Figure 3-9). The results from the survey have been contoured and are presented in summary form on Figure 4-11. Table 4-20 shows the survey points where Am-241 was detected. No background corrections were performed on the data obtained. Preliminary background measurements collected at four points on the site indicated there was no background activity in the 60 KeV region being measured for Am-241.

The measurements taken inside the BOMARC facility property fence showed that the activity was concentrated primarily inside the concertina wire and along the drainage ditch. The highest activity readings were identified where Lorin Street meets the drainage ditch. That is the point where runoff water from the fire-fighting effort, and any rainfall runoff, would be slowed by contact with the sand of the drainage ditch (prior to asphalting). At least some immediate percolation of water, and deposition of any plutonium carried by that water, would occur at that point.

Another high activity area lies directly east of the concrete apron. This may be the original decontamination station used by Shelter 204 fire fighters. This area also has less attenuation of the Am-241 x/gamma ray than the areas covered by concrete, simply because there is no concrete covering the original (1960) surface. Shelter 208 showed high levels of activity. This is not unexpected since this is the shelter where radioactive waste from previous surveys is presently being stored, and it is the first shelter to the east of the concrete pad. The HPG could have received some reading from the material stored in the shelter or from scattered contamination from transport of that material into the shelter.


204
OCEAN COUNTY HIGHWAY NO. 539

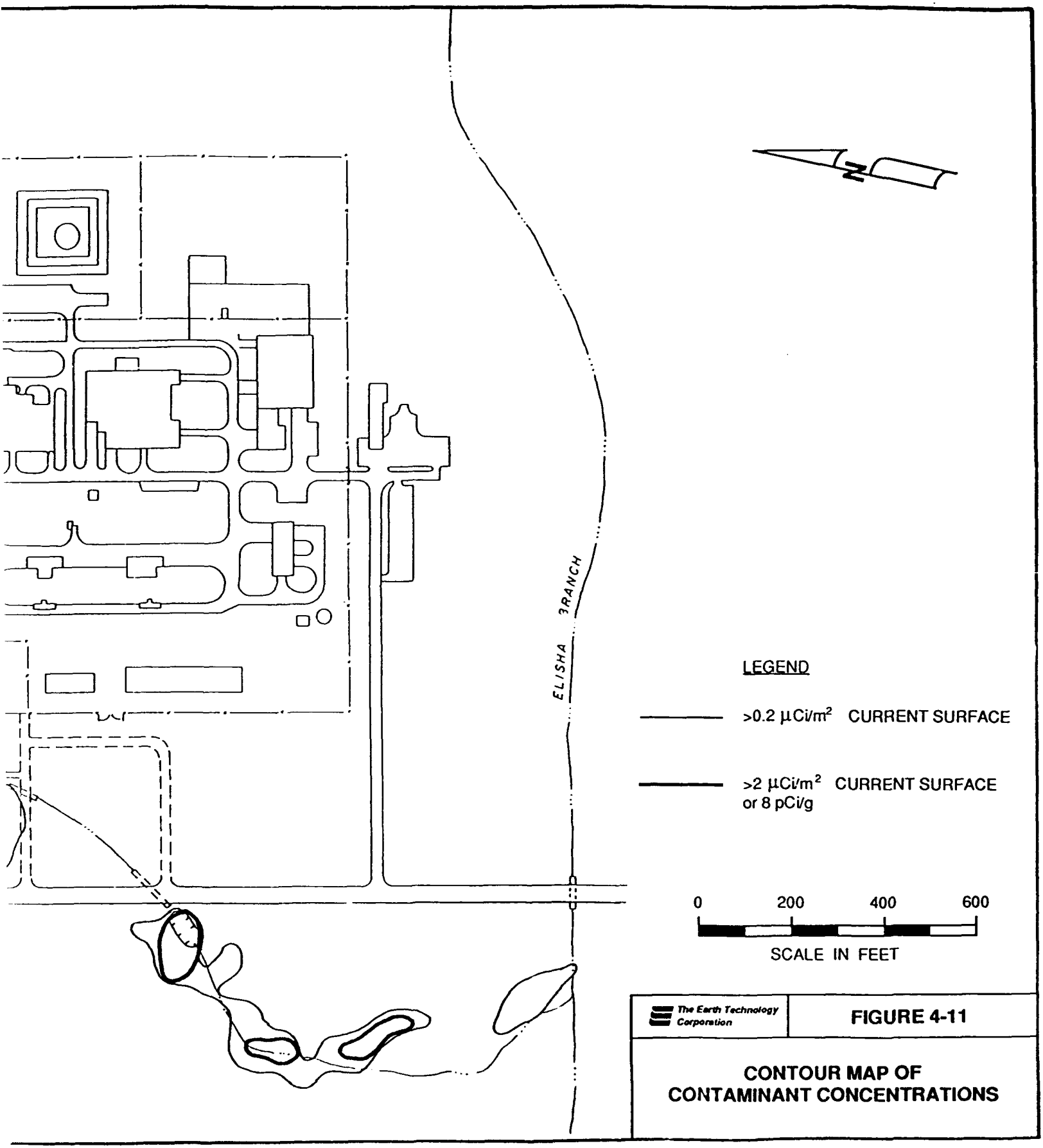


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FIGURE 4-11

CONTOUR MAP OF CONTAMINANT CONCENTRATIONS

Table 4-20

Summary of Positive In-Situ Gamma Ray Measurements at the BOMARC Missile Site

Sample Location	AM-241 Activity (µCi/sq. meter)	2-Sigma Error (%)	PU-239 Activity (µCi/sq. meter)	Location
11A	.0238	57.4	.0143	Outside Fence
18A	.0889	18.8	.533	Outside Fence
10B	.0555	34.6	.333	Outside Fence
11B	.0773	21.4	.464	Outside Fence
13B	.0648	27.6	.389	Outside Fence
15B	.0358	40.4	.215	Outside Fence
20B	.0642	23.2	.385	Outside Fence
13C	.0821	28.6	.493	Outside Fence
14C	.0229	80.0	.137	Outside Fence
15C	.0566	41.2	.340	Outside Fence
19C	.0257	68.4	.154	Outside Fence
20C	.289	10.0	1.73	Outside Fence
13D	.0593	30.6	.356	Outside Fence
14D	.0169	78.6	.101	Outside Fence
17D	.0414	37.4	.248	Outside Fence
20D	.0875	29.2	.525	Outside Fence
13E	.0348	39.8	.209	Outside Fence
17E	.0276	39.2	.166	Outside Fence
20E	.118	19.8	.708	Outside Fence
26F	.0332	61.8	.199	Outside Fence
25H	.114	22.2	.684	Outside Fence
26H	.815	10.0	4.89	Outside Fence
26I	1.03	10.0	6.18	Outside Fence
28I	.145	11.0	.870	Outside Fence
41I	.0433	50.2	.260	Outside Fence
27J	.0827	18.6	.496	Outside Fence
39J	.250	10.0	1.5	Outside Fence
40J	.0772	21.6	.463	Outside Fence
29K	.120	15.8	.72	Outside Fence
34K	.206	10.0	1.24	Outside Fence
35K	.245	10.0	1.47	Outside Fence
38K	.0825	26.4	.495	Outside Fence
39K	.0551	28.4	.331	Outside Fence
29L	.425	10.0	2.55	Outside Fence
30L	.484	10.0	2.9	Outside Fence
32L	.206	10.6	1.24	Outside Fence
33L	.373	10.0	2.24	Outside Fence
31M	.0809	26.6	.485	Outside Fence
8R	0.0583	31.6	.35	Inside Fence
9R	0.136	16.6	.816	Inside Fence
11R	0.0209	90.4	.125	Inside Fence
6S	0.673	10	4.04	Inside Fence
8S	0.11	15.8	.66	Inside Fence
10S	0.0452	35.8	.271	Inside Fence
99T	0.115	20.4	.69	Inside Fence
7T	0.338	12.6	2.03	Inside Fence
8T	1.85	10	11.1	Inside Fence
10T	.0579	33.8	.347	Inside Fence
11T	0.0293	39.6	.176	Inside Fence

Table 4-20 (Continued)

Summary of Positive In-Situ Gamma Ray Measurements at the BOMARC Missile Site

Sample Location	AM-241 Activity (μCi/sq. meter)	2-Sigma Error (%)	PU-239 Activity (μCi/sq. meter)	Location
6U	0.0622	38	.373	Inside Fence
8U	0.0505	41.2	.303	Inside Fence
10U	0.0465	26.8	.279	Inside Fence
11U	0.0185	63.2	.111	Inside Fence
5V	0.0815	24.2	.489	Inside Fence
6V	0.0634	18	.380	Inside Fence
7V	0.682	10	4.09	Inside Fence
8V	0.409	10	2.45	Inside Fence
9V	0.13	21	.78	Inside Fence
10V	0.0436	33.2	.262	Inside Fence
11V	0.0107	105.4	.0642	Inside Fence
6W	0.125	13.8	.75	Inside Fence
7W	1.61	10	9.66	Inside Fence
8W	0.0833	19	.5	Inside Fence
9W	0.107	17.4	.642	Inside Fence
10W	0.0542	33.6	.325	Inside Fence
13W	0.033	40.8	.198	Inside Fence
5X	0.0479	33.8	.287	Inside Fence
6X	0.04	61.6	.240	Inside Fence
8X	8.64	10	51.8	Inside Fence
9X	0.913	10	5.48	Inside Fence
10X	.0283	71	.170	Inside Fence
11X	0.0667	27.2	.418	Inside Fence
12X	0.118	22.5	.708	Inside Fence
13X	0.0111	125.4	.0666	Inside Fence
2Y	0.0188	57.8	.113	Inside Fence
4Y	0.0296	64.6	.178	Inside Fence
6Y	0.11	19.6	.66	Inside Fence
7Y	0.0396	40	.238	Inside Fence
8Y	4.06	10	24.4	Inside Fence
9Y	0.0925	24.6	.555	Inside Fence
10Y	0.141	14	.846	Inside Fence
11Y	0.0257	56.8	.154	Inside Fence
12Y	0.0885	27.6	.531	Inside Fence
13Y	0.0957	18.4	.574	Inside Fence
14Y	0.0937	17	.562	Inside Fence
15Y	0.0732	22.8	.439	Inside Fence
17Y	0.0203	63	.122	Inside Fence
11Z	0.0816	32.2	.49	Inside Fence
18Z	0.0867	33.6	.52	Inside Fence
ES9	0.018	67.4	.108	Inside Fence
ES23	0.064	42.2	.384	Inside Fence

Note: Minimal detectable activities vary with instrument calibration for a particular day.

There were 23 points measured inside the property fence that were not part of the original grid (see Plate 4-1). These points are identified with the designation "ES", followed by a number. These areas were surveyed because they had been identified in previous surveys or by high background readings as potential areas of activity. Points ES9 and ES23 were the only two of these points which showed measurable Am-241 activity. Point ES9 is located just outside the concertina wire behind Building 212. This activity may be caused by tracking of particles from contaminated areas into this location. The missile facility was not closed until 1972 and routine maintenance and other operations took place here until then. Surveys of contamination could also have inadvertently tracked unfixed particles from contaminated areas into previously uncontaminated areas.

Point ES23 was in a drainage behind Shelter 202. This drainage would undoubtedly have carried some of the water from Shelter 204 that initially was flowing out the back doors of the shelter during the fire-fighting effort. This activity may simply be a remnant of that fire-fighting activity, or there may be a pattern developing that would indicate more recent migration to the north along the drainage ditch.

Outside the BOMARC property fence, the highest activity was detected in the ponding area to the west of Highway 539 (Fort Dix property). Activity was also detected just north of the drainage ditch and to the west of Highway 539. The remainder of the activity to the west of Highway 539 is in the low lying area between the road and a low ridge that lies west of the ponding area. There was no activity detected along the dirt road leading west of Highway 539 into the firing range (lines 36 and 37), but activity was identified south of the dirt road, following the drainage (see Figure 4-11).

This trend follows the natural drainage of the area and indicates that some migration of plutonium has followed the movement of water in this area. Historical records show that several large storms have taken place in the last 30 years which were of sufficient size to transport water out of the ponding area west of Highway 539. The lack of activity along the dirt road to the firing range could simply be due to the "plowing" effect that vehicular traffic would have on the dirt surface, thus diluting any contamination and covering it with a masking layer of soil.

Patches of activity were detected east of Highway 539, between the highway and the BOMARC perimeter fence. Activity was detected in the drainage leading from the BOMARC site to a transformer station outside the perimeter fence and east of Highway 539. From the transformer station, the activity follows the north edge of the paved driveway along a small borrow ditch, but stops before it reaches Highway 539. If the water from the fire-fighting effort overtopped the earthen dam, this is the direction that it might have flowed. Also, large storms could overload the concrete culverts under the road that follows the perimeter fence, and any overflow would likely be along that secondary drainage bordering the paved driveway. There was also a small amount of activity detected just south of where the ditch passes under Route 539.

Line 11 (Plate 4-1) shows a spot where activity is apparently extending beyond the perimeter fence from the site. Line 13 shows a line of activity that stops before it reaches the road. Line 17 also has two points which showed some measurable activity. These areas of contamination may represent locations where the smoke plume from the fire touched down, or where contaminated soil from the earthen dam or other activities may have been deposited. Depending

on the placement of the earthen dam at the time of the fire, any overtopping of that dam could have allowed contaminated water to flow in unexpected directions. Routine activities on the facility may also have caused transport of materials from contaminated to non-contaminated areas.

4.1.3.6 FIDLER Survey Results

Two separate in-situ surveys were performed using the FIDLER. The first survey was used to determine the extent of contamination on the concrete apron south of Shelter 204 prior to the concrete coring. The second survey was performed to investigate the modeled surface deposition patterns.

4.1.3.6.1 Concrete Apron Survey

Historic surveys on the concrete/asphalt pad and street in front of Shelter 204 have been conducted at regular intervals by various organizations within the Air Force since the 1960 accident. All of the surveys have indicated the presence of fixed contamination on or under the pad. Field studies, at times, have also located loose contamination on the pad. When discovered, this loose contamination has been removed. Contamination that works its way upward (possibly by diffusion) through cracks in the asphalt/concrete is of particular historic concern, especially with the abundance of plant material that also grows through these cracks. Soils surrounding the area and rust flakes from Shelter 204 are also possible sources of radioactive contamination on the apron. In an effort to eliminate any loose contamination, these plant materials, soils, and rust flakes have been removed, drummed, and stored in Shelter 208 by Air Force personnel at periodic intervals since 1960.

A FIDLER survey of the concrete pad adjacent to Shelter 204 was conducted on the site during the 1989 field season prior to any intrusive work (coring, soil sampling, wipe sampling). The purpose of the FIDLER survey was to establish coring locations by defining the extent of the Pu-239/Am-241 contamination. The FIDLER was used because of its ability to discriminate gamma rays of a particular energy, such as the 60 KeV x/gamma ray emitted by the Am-241 isotope. Prior to surveying, the FIDLER was checked with an Am-241 source and the background (1,200 cpm) was measured.

The survey grid was established on 10-foot centers and extended from Von Braun Drive east to Shelters 209 and 210. A total of 330 points were surveyed for an average of one minute and the values recorded (Table 4-21). The results of the survey were plotted on a grid map and contoured (Figure 4-12). The survey data were plotted using only count data from "fixed" radioactive contamination. Any loose contamination was removed.

Table 4-21

FIDLER Survey on the Concrete Apron South of Shelter 204
at the BOMARC Missile Site

Sampling Point	Counts per Minute (cpm)	Comments
1	2,000	
2	1,700	
3	2,100	
4	2,100	
5	3,500	
6	3,000	
7	2,300	
8	2,500	
9	2,400	
10	2,200	
11	1,600	
12	1,500	
13	1,700	
14	3,500	
15	18,000	Concrete core location
16	2,100	
17	1,900	
18	2,100	
19	1,800	
20	1,600	
21	2,000	Concrete core location
22	1,600	
23	2,600	
24	10,000	
25	5,000	
26	2,000	
27	1,600	
28	1,600	
29	6,000	Concrete core location
30	2,000	
31	1,500	
32	1,400	
33	1,500	
34	15,000	Concrete core location
35	5,000	
36	1,500	
37	1,500	
38	1,400	
39	1,900	
40	1,600	
41	1,500	
42	1,600	
43	1,900	
44	11,000	
45	3,100	
46	1,500	
47	1,500	
48	1,200	
49	1,900	
50	1,400	
51	1,200	
52	1,500	
53	1,500	
54	3,800	
55	11,000	
56	3,900	Concrete core location
57	1,300	
58	1,500	
59	1,600	

Table 4-21 (continued)

FIDLER Survey on the Concrete Apron South of Shelter 204
at the BOMARC Missile Site

Sampling Point	Counts per Minute (cpm)	Comments
60	1,500	
61	4,000	Concrete core location
62	1,500	
63	1,700	
64	21,000	Concrete core location
65	4,500	
66	1,300	
67	1,500	
68	1,300	
69	1,500	Concrete core location
70	1,400	
71	1,300	
72	1,200	
73	2,600	
74	2,900	
75	12,000	
76	2,000	
77	1,500	
78	1,500	
79	1,400	
80	1,100	
81	1,500	
82	2,600	
83	3,000	
84	3,800	
85	11,000	
86	1,300	
87	1,400	
88	1,400	
89	1,300	
90	1,100	
91	2,100	
92	7,000	
93	2,900	
94	2,100	
95	2,600	
96	1,300	
97	1,400	
98	1,400	
99	1,400	
100	1,300	
101	6,000	
102	15,000	Concrete core location
103	2,900	
104	1,500	
105	3,800	Concrete core location
106	1,600	
107	1,200	
108	1,200	
109	1,300	
110	1,100	
111	19,000	
112	19,000	
113	2,200	
114	1,500	
115	1,600	
116	1,400	
117	1,400	

Table 4-21 (continued)

FIDLER Survey on the Concrete Apron South of Shelter 204
at the BOMARC Missile Site

Sampling Point	Counts per Minute (cpm)	Comments
118	1,500	Concrete core location
119	1,500	
120	1,100	
121	18,000	
122	13,000	
123	1,400	
124	1,100	
125	1,300	
126	1,200	
127	1,200	
128	1,400	
129	1,400	
130	1,400	
131	20,000	
132	7,000	
133	1,500	
134	1,200	
135	1,100	
136	1,200	
137	1,400	
138	1,400	
139	1,300	
140	1,000	
141	11,000	
142	3,100	Concrete core location
143	1,200	
144	1,200	
145	1,100	Concrete core location
146	1,000	
147	1,300	
148	1,400	
149	1,700	
150	1,100	
151	1,600	
152	1,300	
153	1,300	
154	1,100	
155	1,500	
156	1,200	
157	1,300	
158	1,200	Concrete core location
159	3,100	
160	1,100	
161	2,400	
162	1,200	
163	1,300	
164	1,500	
165	1,300	
166	1,200	
167	1,500	
168	1,500	
169	1,200	
170	1,300	
171	1,300	
172	2,200	Concrete core location
173	1,000	
174	1,100	
175	15,000	Concrete core location

Table 4-21 (continued)

FIDLER Survey on the Concrete Apron South of Shelter 204
at the BOMARC Missile Site

Sampling Point	Counts per Minute (cpm)	Comments
176	1,200	
177	1,100	
178	1,100	
179	1,000	
180	2,600	
181	1,200	
182	1,300	
183	1,100	
184	1,100	
185	1,600	
186	1,300	
187	1,100	
188	1,000	
189	1,100	
190	1,100	
191	1,700	
192	1,300	
193	1,500	
194	1,400	
195	1,300	
196	1,500	
197	1,200	
198	1,300	
199	1,300	
200	1,300	
201	900	
202	1,200	
203	1,200	
204	1,300	
205	1,300	
206	1,100	
207	1,300	
208	1,300	
209	1,000	
210	900	
211	800	
212	500	
213	1,000	
214	1,300	
215	1,200	
216	1,400	
217	1,200	
218	1,100	
219	1,500	
220	1,100	
221	1,200	
222	1,200	
223	1,200	
224	1,300	
225	1,400	
226	1,200	
227	1,200	
228	1,100	
229	1,400	
230	1,200	
231	1,300	
232	1,400	
233	1,100	

Table 4-21 (continued)

FIDLER Survey on the Concrete Apron South of Shelter 204
at the BOMARC Missile Site

Sampling Point	Counts per Minute (cpm)	Comments
234	1,200	
235	1,300	
236	1,300	
237	1,500	
238	1,100	
239	1,200	
240	1,100	
241	3,000	Concrete core location
242	1,500	
243	1,200	
244	1,200	
245	1,300	
246	1,100	
247	1,300	
248	1,200	
249	1,400	Concrete core location
250	1,100	
251	2,300	
252	1,800	
253	2,500	
254	1,600	
255	3,300	
256	2,900	
257	11,000	
258	4,000	
259	36,000	
260	8,000	
261	1,400	
262	2,100	
263	4,300	
264	2,500	
265	4,400	
266	2,100	
267	3,300	
268	4,400	
269	7,000	
270	1,000	
271	800	
272	1,300	
273	2,900	
274	8,000	
275	3,900	
276	2,000	
277	2,600	
278	1,200	
279	1,000	
280	1,000	
281	900	
282	1,100	
283	2,900	
284	4,100	
285	2,000	
286	1,000	
287	900	
288	1,300	
289	800	
290	800	
291	900	

Table 4-21 (continued)

FIDLER Survey on the Concrete Apron South of Shelter 204
at the BOMARC Missile Site

Sampling Point	Counts per Minute (cpm)	Comments
292	2,500	
293	1,200	
294	2,000	
295	1,100	
296	800	
297	1,000	
298	8,000	
299	900	
300	1,100	
301	900	
302	1,200	
303	900	
304	1,600	
305	1,000	
306	1,000	
307	1,500	
308	900	
309	800	
310	1,300	
311	1,100	
312	1,000	
313	1,400	
314	1,100	
315	1,000	
316	900	
317	900	
318	800	
319	900	
320	1,000	
321	900	
322	900	
323	1,000	
324	900	
325	900	
326	900	
327	900	
328	900	
329	1,000	
330	1,000	

Note: Lower limit of detection is 80 cpm.

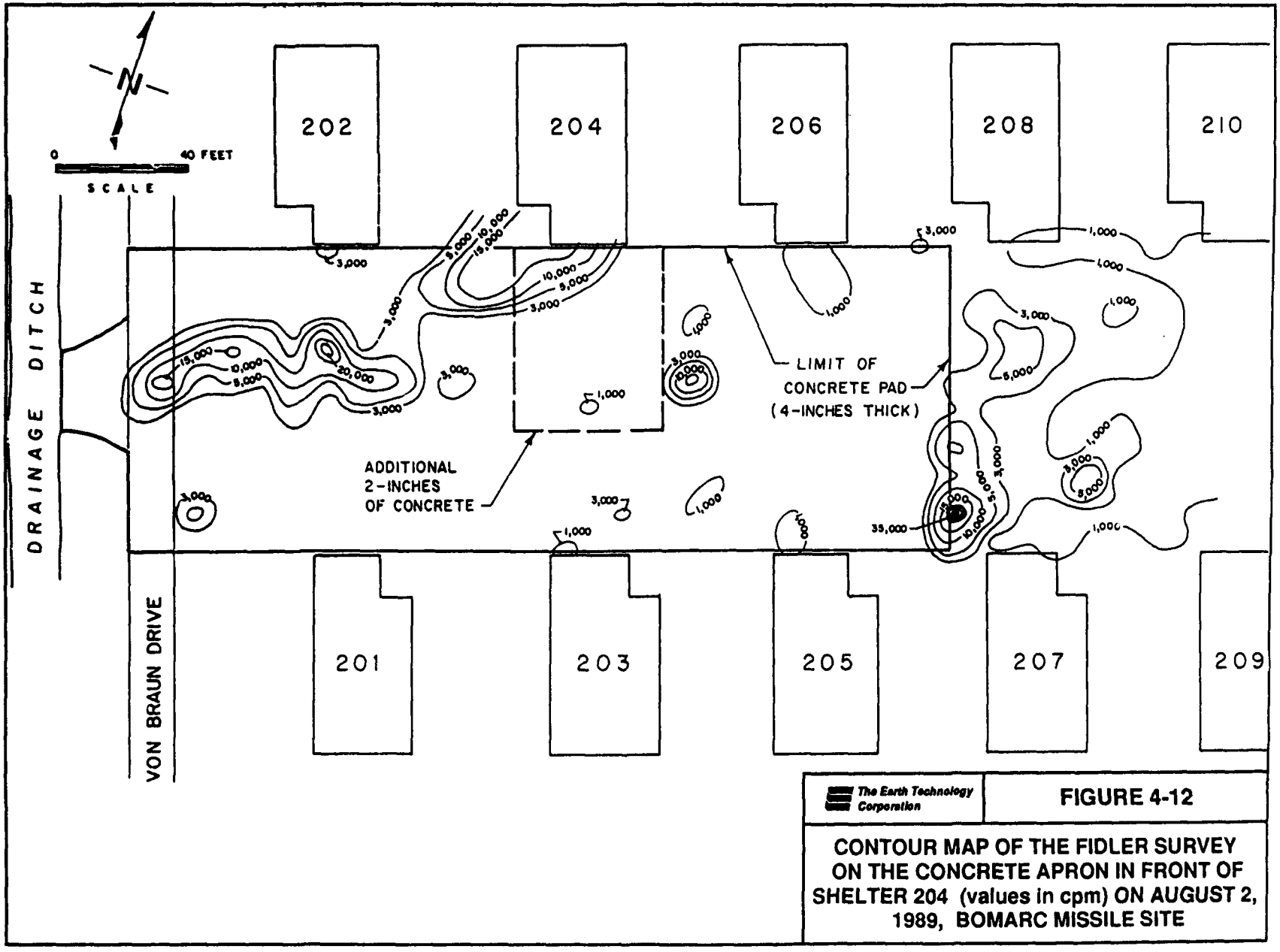

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FIGURE 4-12

CONTOUR MAP OF THE FIDLER SURVEY ON THE CONCRETE APRON IN FRONT OF SHELTER 204 (values in cpm) ON AUGUST 2, 1989, BOMARC MISSILE SITE

Although Pu-239/Am-241 are particles and are not fluid, contours of the results were drawn to show the areas of high concentration. Due to the shielding effect produced by the concrete, the values from the FIDLER survey are not representative of the actual amount of Pu-239/Am-241 activity present.

The gross values from the FIDLER survey ranged from 500 cpm to 36,000 cpm on the grid points. A total of 68 survey points had values exceeding background by two times or more, and 17 of these points fell between the ranges of 11,000 to 36,000 cpm. The majority of the 17 points exceeding 11,000 cpm were located to the west of Shelter 204, forming a path extending to the drainage ditch. This path is representative of the direction of flow of the runoff water on the apron during the fire. Three other points with elevated activity were located upgradient of Shelter 204. These may have been tracked there by emergency personnel and equipment. However, the shielding presented by the concrete pad would make the areas covered by it appear to contain lower radioactivity than the adjacent uncovered surface if attenuation were not taken into account. If the concrete pad were removed, the contours would probably merge in a more continuous pattern, reflecting that the levels of contamination decrease rapidly to the east. If the concrete pad had extended a few feet further to the east, little or no contamination would register in that area due to the attenuation from the concrete.

One localized area of relatively high readings was found on the asphalt apron approximately 35 to 40 feet in front (south) of Shelter 208. Discrete values in this area ranged from 2,900 to 8,000 cpm (Figure 4-12). This area on the asphalt apron is cracked and contains abundant vegetative growth. The location may have been a staging area or a decontamination area for emergency equipment and personnel. Contamination could also result from the storage of contaminated materials in Shelter 208, or from the transport of those materials into the shelter. In addition, the vegetation may be providing passages in the concrete pad that allow additional contamination to escape upward onto or near the surface of the apron.

In addition to the high readings at the survey grid points, several other locations were noted as having high FIDLER readings. These values and locations are:

31,000 cpm between points 232 and 324
50,000 cpm between points 310 and 300
60,000 cpm between points 258 and 268
34,000 cpm between points 257 and 258
60,000 cpm between points 219 and 209
70,000 cpm between points 73 and 74.

All of the survey locations were scanned with the PAC-4G alpha detector to determine if any contamination was on the surface prior to coring. Only the location between points 73 and 74 had any surface contamination (2,500 cpm). The contamination at this location was removed so that only 100 cpm was detectable with the PAC-4G. The area was then fixed with enamel spray paint.

The entire apron was surveyed repeatedly with a PAC-4G (or equivalent) alpha monitoring instrument. Several locations had much higher readings than the surrounding areas. At least two locations were found that had removable contamination (70,000 and 250,000 cpm). At one

location, the contamination was simply loose, and was removed by vacuuming prior to additional work; at the other location, the contamination was in a crack in the concrete where the contaminant had evidently worked upward. The material in the crack was partially removed, and the unremovable portion was fixed in place using enamel spray paint.

All surface contamination was either removed and disposed of as radioactive waste, or, if not removable, was fixed in place with a strippable compound. No trackable, known contamination was left in place untreated.

4.1.3.6.2 FIDLER Survey to Investigate Modeled Surface Deposition Patterns

FIDLER readings were collected at a total of 134 stations across the potential surface deposition zone identified in the modeling study. The objective of this survey was to identify areas of activity from which shallow soil samples would later be collected. The data from both the survey and the soil samples were to be incorporated into the modeling study to validate the conclusions regarding potential locations of surface deposited plutonium resulting from entrainment of particles in the smoke plume from the fire.

The samples with activities that measured above background levels during this investigation are presented in Table 4-22 and shown on Plate 4-2. To aid in data interpretation, the areas showing higher levels of activity along transects A, B, and C have been outlined as shown in Figure 4-13. Sampling locations along transect D are shown in Figure 4-14.

The FIDLER instrument (Eberline ESP-2/PHA, S/N 00648 and Bicron "FIDLER" C5, S/N A880Q) was calibrated and set to detect the 60 KeV gamma radiation emitted by Am-241. Uranium and thorium found naturally in the background soils also emit 60 KeV gamma radiation, and therefore contribute to the reading. If there are high concentrations of these radionuclides, they will affect the count rates obtained by the FIDLER (i.e., those radionuclides will also be measured in the total count).

The surveys were conducted at ground surface using 15 minute counts. Based on the ambient background and characteristics of the FIDLER equipment, the lower limit of detection for Pu-239 was calculated to be about 0.05 to 0.07 $\mu Ci/m^2$, which equates to less than 10 to 20 cpm above background using the FIDLER. This presumes a background count rate of 141 cpm (actual field measurement). If the background count rate were lower, this value would decrease proportionately. If the activity detected exceeds 160 cpm, then there is a positive reading, which should be investigated to determine if plutonium and/or americium are likely to be present.

By definition, the lower limit of detection (LLD) is the lowest value at which it can be stated that a positive reading (i.e., a reading above background) on an instrument has been obtained within a specified level of confidence. The 95% confidence level is typically used throughout this report.

As such, the LLD of 0.07 $\mu Ci/m^2$, plus the background activity, is the lowest limit at which a clear positive indication of americium/plutonium can be predicted using the equipment described. This would represent about 160 cpm (0.13 $\mu Ci/m^2$). That 160 cpm includes the background plus any other activity present. Below this number, any positive indication falls within the normal

Table 4-22

Results of FIDLER Survey to Investigate Air Modeling

Sample ID	Gross CPM	Net CPM*	DPM	DPM/ meter squared	μCi/ meter squared
BULLS EYE/204	99.33	18.33	4.20E2	3.31E4	1.49E-2
B1/B	154.67	73.64	1.69E3	1.33E5	6.00E-2
A1/A	102.00	21.00	4.81E2	3.80E4	1.71E-2
B2/B	92.00	11.00	2.52E2	1.99E4	8.96E-3
SOIL(1)	96.67	15.67	3.59E2	2.83E4	1.28E-2
SOIL(2)	106.00	25.00	5.73E2	4.52E4	2.04E-2
SOIL(3)	115.33	34.33	7.87E2	6.21E4	2.80E-2
SOIL(4)	125.33	44.33	6.02E3	8.02E4	3.61E-2
SOIL(5)	128.67	47.67	1.09E3	8.62E4	3.88E-2
SOIL(6)	115.33	34.33	7.87E2	6.21E4	2.80E-2
SOIL(7)	112.00	31.00	7.1E2	5.61E4	2.52E-2
B-8	82.00	1.00	2.29E1	1.81E3	8.14E-4
B-9	112.67	31.67	7.25E2	5.73E4	2.58E-2
B-10	103.33	22.33	5.12E2	4.04E4	1.82E-2
B-11	115.33	34.33	7.87E2	6.21E4	2.80E-2
B-12	127.33	46.33	1.06E3	8.38E4	3.77E-2
B-13	108.67	27.67	6.34E2	5.00E4	2.25E-2
B-14	130.00	49.00	1.12E3	8.86E4	3.99E-2
B-15	124.67	43.67	1.00E3	7.90E4	3.56E-2
B-16	108.67	27.67	6.34E2	5.00E4	2.25E-2
B-17	112.67	31.67	7.25E2	5.73E4	2.58E-2
B-18	96.67	15.67	3.59E2	2.83E4	1.28E-2
B-19	106.67	25.67	5.88E2	4.64E4	2.09E-2
B-7	80.0	<BKG	<BKG	<BKG	<BKG
B-6	99.33	18.33	4.20E2	3.31E4	1.49E-2
B-5	186.00	105.00	2.41E3	1.90E5	8.55E-2
B-4	86.00	5.00	1.15E2	9.04E3	4.07E-3
A-2	122.00	41.00	9.39E2	7.41E4	3.34E-2
A-3	89.33	8.33	1.91E2	1.51E4	6.78E-3
A-4	106.00	25.00	5.73E2	4.52E4	2.05E-2
A-5	130.67	49.67	1.14E3	8.98E4	4.05E-2
A-6	99.33	18.33	4.10E2	3.31E4	1.49E-2
A-7	103.33	22.33	5.12E2	4.04E4	1.82E-2
A-8	117.33	36.33	8.32E2	6.57E4	2.96E-2
A-9	102.00	21.00	4.81E2	3.80E4	1.71E-2
A-10	95.33	14.33	3.28E2	2.59E4	1.17E-2
A-11	142.00	61.00	1.40E3	1.10E5	4.98E-2
A-12	123.33	42.33	9.70E2	7.65E4	3.45E-2
A-13	110.67	29.67	6.80E2	5.36E4	2.42E-2
A-14	175.33	94.33	2.16E3	1.71E5	7.68E-2
A-15	102.67	21.67	4.96E2	3.92E5	1.76E-2
A-16	92.67	11.67	2.67E2	2.11E4	9.50E-3
A-17	92.00	11.00	2.52E2	1.99E4	8.96E-3
A-18	88.67	7.67	1.76E2	1.39E4	6.24E-3
A-19	90.00	9.00	2.06E2	1.63E4	7.33E-3
A-20	99.33	18.33	4.20E2	3.31E4	1.49E-2
A-21	101.33	20.33	4.66E2	3.68E4	1.66E-2
A-22	87.33	6.33	1.45E2	1.15E4	5.16E-3
A-23	82.00	1.00	2.29E1	1.81E3	8.14E-4
A-24	114.67	33.66	7.71E2	6.09E4	2.74E-2
A-25	108.00	27.00	6.19E2	4.88E4	2.20E-2
A-26	112.00	31.00	7.10E2	5.61E4	2.52E-2
B-20	97.33	16.33	3.74E2	2.95E4	1.33E-2
B-21	91.33	10.33	2.37E2	1.87E4	8.42E-3
B-22	94.00	13.00	2.98E2	2.35E4	1.06E-2
B-23	90.67	9.67	2.21E2	1.75E4	7.87E-3
B-24	114.67	33.66	7.71E2	6.09E4	2.74E-2
B-25	100.67	19.67	4.51E2	3.56E4	1.60E-2
B-26	107.33	26.33	6.03E2	4.76E4	2.14E-2
B-27	97.33	16.33	3.74E2	2.95E4	1.33E-2
B-28	95.33	14.33	3.28E2	2.59E4	1.17E-2
B-29	107.33	26.33	6.03E2	4.76E4	2.14E-2
B-30	94.67	13.67	3.13E2	2.47E4	1.11E-2
B-31	85.33	4.33	9.93E1	7.84E3	3.53E-3
B-32	91.33	10.33	2.37E2	1.87E4	8.42E-3

* Net = Gross - Background; Background = 81 cpm

Table 4-22 (continued)

Results of FIDLER Survey to Investigate Air Modeling

Sample ID	Gross CPM	Net CPM*	DPM	DPM/ meter squared	µCi/ meter squared
B-33	90.00	9.00	2.06E2	1.63E4	7.33E-3
B-34	79.00	<BKG	<BKG	<BKG	<BKG
B-35	85.33	4.33	9.93E1	7.84E3	3.53E-3
B-36	101.33	20.33	4.66E2	3.68E4	1.66E-2
B-37	88.00	7.00	1.60E2	1.27E4	5.70E-3
B-38	86.67	5.67	1.30E2	1.02E4	9.62E-3
B-39	90.67	9.67	2.21E2	1.75E4	7.87E-3
B-40	91.33	10.33	2.37E2	1.87E4	8.42E-3
B-41	90.67	9.67	2.21E2	1.75E4	7.87E-3
B-42	114.00	33.00	7.56E2	5.97E4	2.69E-2
B-43	104.67	23.67	5.42E2	4.28E4	1.93E-2
C-1	91.33	10.33	2.37E2	1.87E4	8.42E-3
C-2	102.00	21.00	4.81E2	3.80E4	1.71E-2
C-3	98.00	17.00	3.89E2	3.07E4	1.38E-2
C-4	104.67	23.67	5.42E2	4.28E4	1.93E-2
C-5	117.33	36.33	8.32E2	6.57E4	2.96E-2
C-6	97.33	16.33	3.74E2	2.95E4	1.33E-2
C-7	148.67	67.67	1.55E3	1.22E5	5.51E-2
C-8	107.33	26.33	6.03E2	4.76E4	2.14E-2
C-9	95.33	14.33	3.28E2	2.59E4	1.17E-2
C-10	96.00	15.00	3.44E2	2.71E4	1.22E-2
C-24	88.67	7.67	1.76E2	1.39E4	6.24E-3
C-23	88.67	7.67	1.76E2	1.39E4	6.24E-3
C-22	100.00	19.00	4.35E2	3.44E4	1.55E-2
C-21	74.00	<BKG	<BKG	<BKG	<BKG
C-26	73.00	<BKG	<BKG	<BKG	<BKG
C-19	95.33	14.33	3.28E2	2.59E4	1.17E-2
C-18	85.33	4.33	9.92E1	7.84E3	3.53E-3
C-17	113.33	32.33	7.41E2	5.85E4	2.63E-2
C-16	105.33	24.33	5.57E2	4.40E4	1.98E-2
C-15	94.00	13.00	2.98E2	2.35E4	1.06E-2
C-11	97.33	16.33	3.74E2	2.95E4	1.33E-2
C-12	92.00	11.00	2.52E2	1.99E4	8.96E-3
C-13	98.67	17.67	4.05E2	3.19E4	1.44E-2
C-14	95.33	14.33	3.28E2	2.59E4	1.17E-2
A-27	82.00	1.00	2.29E1	1.81E3	8.14E-4
A-28	87.33	6.33	1.45E2	1.15E4	5.16E-3
A-29	88.67	7.67	1.76E2	1.39E4	6.24E-3
A-30	86.67	5.67	1.30E2	1.02E4	4.62E-3
A-31	92.00	11.00	2.52E2	1.99E4	8.96E-3
A-32	79.33	<BKG	<BKG	<BKG	<BKG
A-33	85.33	4.33	9.92E1	7.84E3	3.53E-3
A-34	76.67	<BKG	<BKG	<BKG	<BKG
A-35	90.67	9.67	2.21E2	1.75E4	7.87E-3
A-36	86.00	5.00	1.15E2	9.04E3	4.07E-3
A-37	77.33	<BKG	<BKG	<BKG	<BKG
A-38	74.67	<BKG	<BKG	<BKG	<BKG
A-39	75.33	<BKG	<BKG	<BKG	<BKG
A-40	80.00	<BKG	<BKG	<BKG	<BKG
A-41	70.00	<BKG	<BKG	<BKG	<BKG
A-42	76.00	<BKG	<BKG	<BKG	<BKG
A-43	82.00	1.00	2.29E1	1.81E3	8.14E-4
D-1	135.33	54.33	1.24E3	9.82E4	4.43E-2
D-2	120.00	39.00	8.93E2	7.05E4	3.18E-2
D-3	108.00	27.00	6.19E2	4.88E4	2.20E-2
D-4	140.00	59.00	1.35E3	1.07E5	4.81E-2
D-5	160.00	79.00	1.81E3	1.43E5	6.43E-2
D-6	115.33	34.33	7.86E2	6.21E4	2.80E-2
D-7	104.67	23.67	5.42E2	4.28E4	1.93E-2
D-8	107.33	26.33	6.03E2	4.76E4	2.14E-2
D-9	110.67	29.67	6.80E2	5.36E4	2.42E-2
D-10	104.00	23.00	5.27E2	4.16E4	1.87E-2
D-11	111.33	30.33	6.95E2	5.36E4	2.47E-2
D-12	103.33	22.33	5.12E2	4.04E4	1.82E-2
D-13	156.00	75.00	1.72E3	1.36E5	6.11E-2
D-14	125.33	44.33	1.02E3	8.02E4	3.61E-2

* Net = Gross - Background; Background = 81 cpm

Table 4-22 (continued)

Results of FIDLER Survey to Investigate Air Modeling

Sample ID	Gross CPM	Net CPM*	DPM	DPM/ meter squared	μCi/ meter squared
D-15	112.00	31.00	7.10E2	5.61E4	2.52E-2
D-16	157.33	76.33	1.75E3	1.38E5	6.22E-2
D-17	139.33	58.33	1.34E3	1.06E5	4.76E-2
D-18	114.00	33.00	7.56E2	5.97E4	2.69E-2
D-19	120.00	39.00	8.93E2	7.05E4	3.18E-2
D-20	112.67	31.67	7.25E2	5.73E4	2.58E-2
A-44	90.67	9.67	2.21E2	1.75E4	7.87E-3
A-45	88.00	7.00	1.60E2	1.27E4	5.70E-3
A-46	86.67	5.67	1.30E2	1.02E4	4.62E-3
A-47	104.67	23.67	5.42E2	4.28E4	1.93E-2
A-48	95.33	14.33	3.28E2	2.59E4	1.17E-2
A-49	97.33	16.33	3.74E2	2.95E4	1.33E-2
A-50	105.33	24.33	5.57E2	4.40E4	1.98E-2
A-51	100.00	19.00	4.35E2	3.44E4	1.55E-2
A-52	103.33	22.33	5.12E2	4.04E4	1.82E-2

* Net = Gross - Background; Background = 81 cpm
Note: Lower limit of detection is 80 cpm or 0.07 $\mu Ci/m^2$.

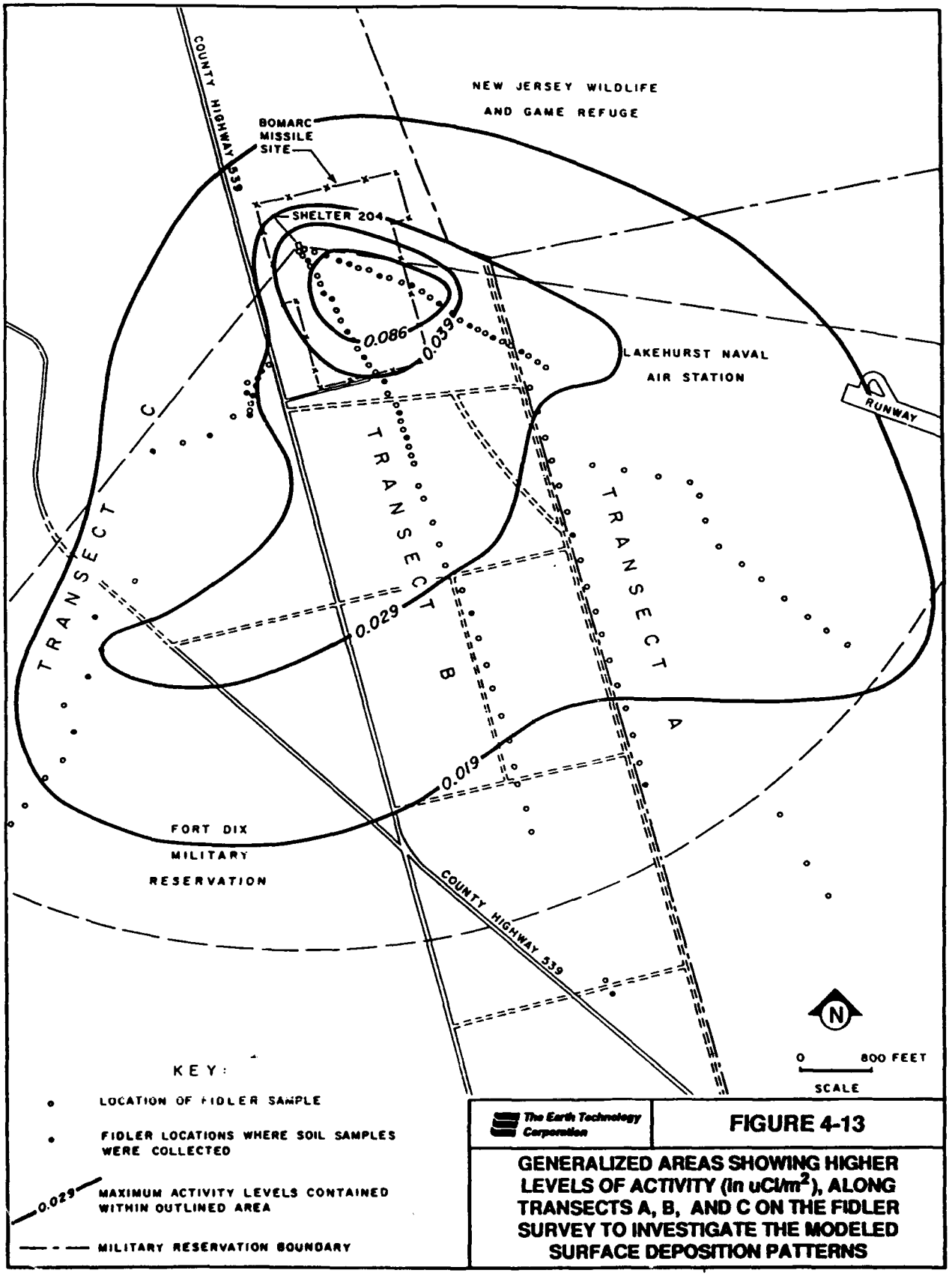

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FIGURE 4-13

GENERALIZED AREAS SHOWING HIGHER LEVELS OF ACTIVITY (in uCi/m^2), ALONG TRANSECTS A, B, AND C ON THE FIDLER SURVEY TO INVESTIGATE THE MODELED SURFACE DEPOSITION PATTERNS

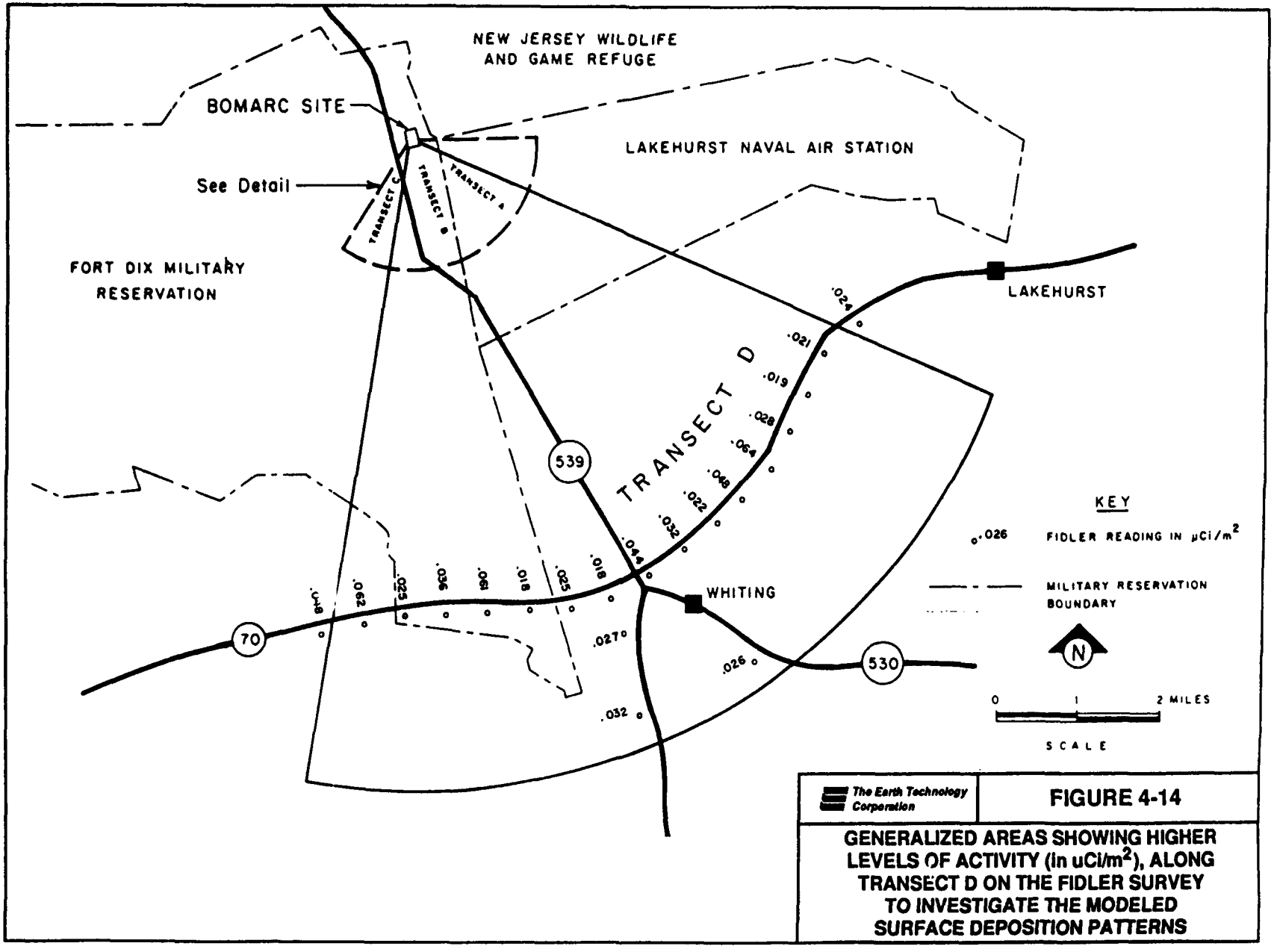

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FIGURE 4-14

GENERALIZED AREAS SHOWING HIGHER LEVELS OF ACTIVITY (In uCi/m^2), ALONG TRANSECT D ON THE FIDLER SURVEY TO INVESTIGATE THE MODELED SURFACE DEPOSITION PATTERNS

variation of ambient background and is most likely (but not definitely) to be simply background. Above this number, the value is much more likely to reflect true contamination above background.

The LLD does not mean the detector cannot measure activity less than that number. In fact, significant data can be gathered from values below the LLD. Data below the LLD can be used to show that the ambient activity of a site is less than the measured value. For example, a count rate of 80 cpm would indicate that the activity at the site would be less than:

$$\frac{0.13\ \mu Ci/m^2 * 80\ cpm}{160\ cpm} = 0.065\ \mu Ci/m^2$$

This count rate of 0.065 $\mu Ci/m^2$ (background plus any other activity present) would be primarily derived from ambient background, indicating that any contamination in the area would be substantially less than 0.035 $\mu Ci/m^2$ of Pu-239. The value for positive detection is based on 160 cpm. This is equivalent to 0.13 $\mu Ci/m^2$, of which less than 0.07 $\mu Ci/m^2$ would be Pu-239 (based on the Am-241; Pu-239 activity ratio of 1:6 assumed in this document). Thus, for 160 cpm the activity detected is 0.13 $\mu Ci/m^2$ and therefore the Pu-239 activity may be about half of this value.

It should be noted that these calculation only address the first few inches of soil, since 2 inches of soil (silica-based, i.e., sandy soil) reduces the count rate by a factor of more than seven. Specifically, the efficiency decreases to 67% at 1 cm, to 45% at 2 cm, to 29% at 3 cm, to 20% at 4 cm, and to 13% of 5 cm. This indicates that this lower limit of detection in the first inch of soil, using the FIDLER, would be on the order of 0.2 to 1 $\mu Ci/m^2$, depending on the Pu-239 distribution in the soil.

FIDLER readings in the BOMARC Missile Site area during the 1989 survey ranged between 70 and 186 cpm. The 10 highest count rates from that survey are at points B-5 (186 cpm), A-15 (175 cpm), D-5 (160 cpm), D-16 (157 cpm), D-13 (156 cpm), B1/B (155 cpm), D-4 (140 cpm), D-1 (135 cpm), and B-14 (130 cpm); and with a soil sample (Soil [5], 129 cpm).

Based on the above numbers, and assuming surface contamination, it is probable that the areal concentration in the areas surveyed is less than 0.13 $\mu Ci/m^2$ (most of the values were at or below the proposed action level); near surface (within 2 cm) areal concentrations should be less than 0.7 $\mu Ci/m^2$ of Pu-239. Assuming a soil density of 1.6 g/cm^3, and that only about the first cm of soil contains contamination and/or contributes significantly to the count rate, the 0.7 $\mu Ci/m^2$ would be equivalent to 1.1×10^2 pCi/g of soil.

The data distribution from the 1989 survey approximates a log normal distribution. Based on evaluating the data distribution (assuming a log normal distribution) for these values, most (all but 5 of the more than 140 data points) are within two standard deviations ($\pm$44 cpm) of the median of 102.

Points A-15 and B-5 are the only locations that indicate positive potential for Pu-239 contamination above about 0.13 $\mu Ci/m^2$, indicating a possible Pu-239 concentration of approximately half this value. These two locations may have significant surface Am-241 and Pu-239 concentrations, or they could represent variations in ambient background.

Below an areal concentration of 0.13 $\mu Ci/m^2$, it is not possible, using the FIDLER, to identify areas clearly requiring further investigation. However, since the data from the survey are statistically so closely grouped, it is probable that all of the results are indicative of variations in natural background.

In general, the data from the 1989 survey do not appear to show any positive correlation between the higher count rate values and the possible distribution patterns of the release, with the possible exception of the "D" transect along Highway 70. However, those values on Transect D appear to be randomly distributed within the transect.

None of the data along Transect D exceed the limit of 160 cpm, indicating that they fall within the range of normal background. If a contaminated plume had touched ground in this area, a more consistent pattern of contamination should be evident. The lack of pattern in the locations of these highest count rates along Transect D, and the fact that they fall within the range of normal background, support the assertion that the results are probably attributable to background. Thus, it would appear that no surface areal concentrations greater than 0.13 $\mu Ci/m^2$ or 2×10^1 pCi/g (the limit of the Pu-239 activity would be about half these values) are present in the areas along Highway 70 surveyed with the FIDLER.

To address the possibility that the higher values associated with Transect D in 1989 [D-1 (135 cpm), D-4 (140 cpm), D-5 (160 cpm), D-13 (156 cpm), D-16 (157 cpm)] could represent positive plutonium values, a second FIDLER survey was performed in October 1990. The instrumentation used was the same as for the 1989 survey. However, background and efficiencies on the instrumentation could not be reproduced due to a combination of field use and electronic aging, so the instrument combination was optimized for best performance.

The values from the survey data range between 56 and 164 cpm. Like the 1989 data, these also appear to be on a log normal distribution, which is consistent with background. Several background readings were taken upgradient and upwind in an attempt to determine the ambient background for the local area surrounding the BOMARC Missile Site. It is worth noting that the four highest count rates obtained during the 1990 survey were in areas that were miles upwind and upgradient (clearly ambient background samples). This lends credence to the assumption that the count rate distribution found along Highway 70 represents ambient background and provides evidence for the wide variability of ambient background in the area.

A soil sample was taken for analysis from one of the areas where the FIDLER reading was the highest along Highway 70. It contained no Pu-239 (or less than the detection limit of 1 pCi/gm), but it did contain positive readings for uranium and thorium, again supporting the argument that the count rate found with the FIDLER is reflecting the presence of uranium and thorium, and total values are consistent with ambient background.

In summary, all of the data obtained from both FIDLER surveys and the soil sampling indicate that the count rate distribution found along Highway 70 represents ambient background. Thus, it would appear that no significant surface areal concentrations of plutonium or americium are present in the areas surveyed with the FIDLER along Highway 70.

4.1.3.7 Cores

A total of 22 cores (including one duplicate) were drilled through the concrete pad inside and south of Shelter 204 in order to assess the location and magnitude of contamination within the apron. The approximate thickness and composition of each of the 22 coreholes drilled inside Shelter 204 and along Lorin Street is shown in Figure 4-15. Most coreholes revealed that a layer of concrete roughly 4 inches thick was laid over the original asphalt surface. The coreholes drilled inside and just outside of Shelter 204 confirmed that two or more layers of asphalt or concrete exist over the original ground surface. Core 15 showed an additional layer of asphalt, placed when the drainage ditch was asphalted.

Core 16 penetrated the concrete in a location that originally was a grassy area, so no asphalt was present. The Pu-239 activities detected at the top and bottom of each corehole, and the highest activity detected within the core (in most cases at the original ground surface at the time of the accident), are presented in Table 4-23 and contoured in Figures 4-16, 4-17, and 4-18.

Plutonium-239 activity levels were less than 1.0 μCi at the top of each of the 22 coreholes, with the exception of coreholes 11 and 14 where activity levels were 1.34 and 16.1 μCi, respectively (Figure 4-16). These two locations also showed radioactivity during the FIDLER survey of the apron (see Section 4.1.3.6.1).

Nine cores revealed Pu-239 activity levels greater than 1.0 μCi on a core surface generally equivalent to the original ground surface (Figure 4-17). Samples 001-CC-C15-002 and 001-CC-C17-002 contained the highest readings within their respective cores. These two samples showed their highest activity at the ground surface that existed prior to a second pouring of concrete or asphalt. Samples 001-CC-C11-002 and 001-CC-C15-002 revealed activity levels as high as 1,070 μCi and 542 μCi, respectively. The contouring of these results reveals a plume at the level of the original surface that is elongated in a southwest direction and follows the surface water drainage pattern (past and present) from Shelter 204. Samples 001-CC-C15-002 and 001-CC-C17-002 showed highest activity on a core surface one layer higher than the original ground surface. The fact that both lie in drainage paths that would allow fresh material to be repeatedly deposited through water and sediment movement during precipitation events probably accounts for the radioactivity at this level in the core sequence.

Relatively low activity levels were detected at the bottom of each of the 22 coreholes. Only coreholes 11 (9.60 μCi) and 17 (1.67 μCi) showed activity levels exceeding 1.0 μCi (Figure 4-18). These are located under the portions of the original surface that was heavily contaminated during the fire-fighting effort. This activity at the bottom of the core may reflect some migration of contamination along the cracks in the concrete. Both holes showed evidence of contamination in the soil samples collected from beneath them. The possibility of the soil being contaminated during drilling cannot be dismissed.

In all cases, the contours indicate that plutonium followed the local drainage patterns down the apron to the drainage ditch. These results indicate that, in general, the pouring of concrete and/or asphalt layers over top of the original ground surface at the time of the Shelter 204 accident effectively worked to fix the majority of the plutonium contamination under the concrete and to inhibit further migration of Pu-239.

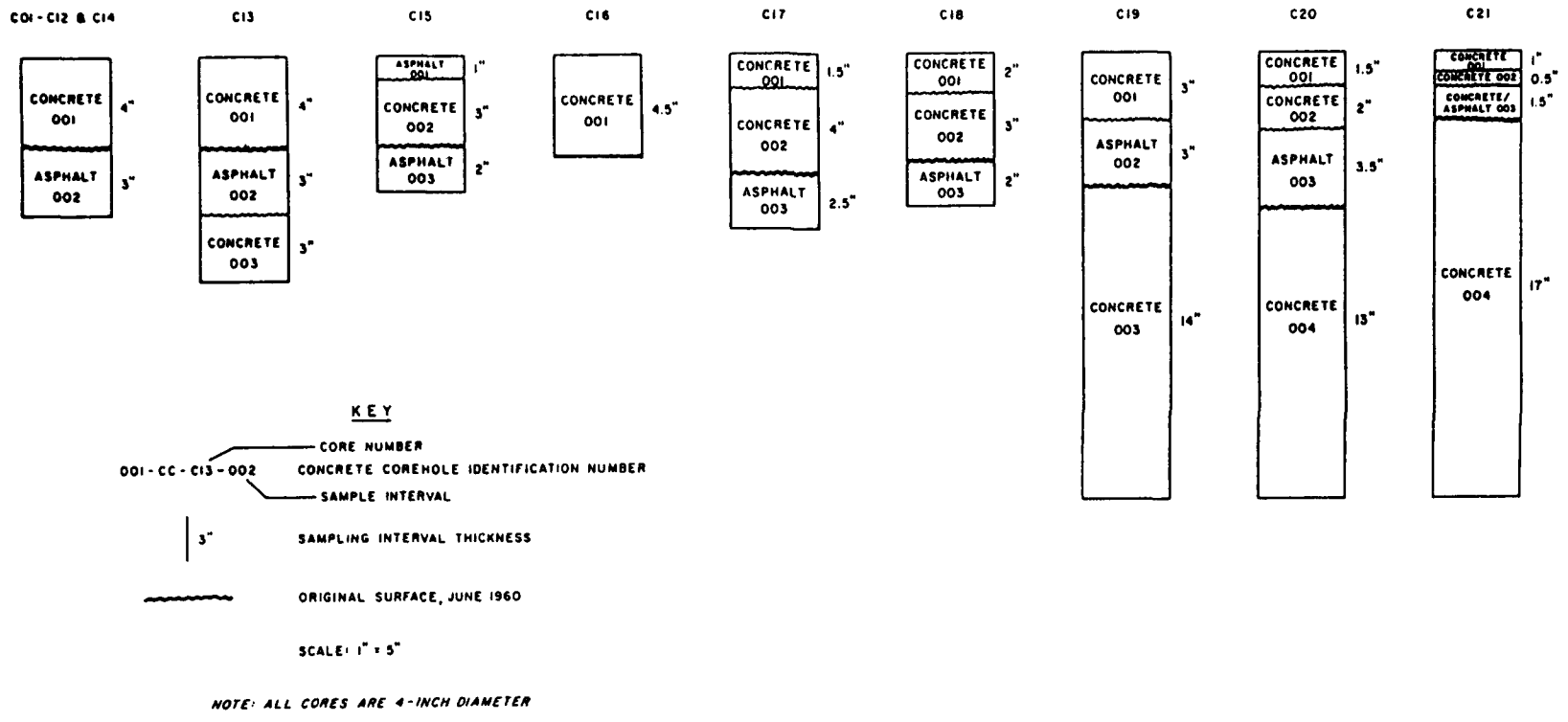

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FIGURE 4-15

GENERALIZIED THICKNESS AND COMPOSITIONS OF CONCRETE CORES, BOMARC MISSILE SITE

Table 4-23

HPG Data for Cement Core Samples Collected at the BOMARC Missile Site

Sample Number	Composition	Thickness (Inches)	Part of Core	AM-241 Activity (μCi/sample)***	2-Sigma Error (%)	PU-239 Activity (μCi/sample)
001-CC-C01-001	Concrete		Top	<3.25E-04		
001-CC-C01-001	Concrete	4"	Bottom	5.62E-04	58.20	3.37E-03
001-CC-C01-002	Asphalt		Top	<4.46E-04		
001-CC-C01-002	Asphalt	7"	Bottom	<4.33E-04		
001-CC-C02-001	Concrete		Top	<3.19E-04		
001-CC-C02-001	Concrete	4"	Bottom	2.82E-03	20.40	1.69E-02
001-CC-C02-002	Asphalt		Top	<2.40E-04		
001-CC-C02-002	Asphalt	6"	Bottom	9.78E-04	31.70	5.87E-03
001-CC-C2A-001	**		Top	<4.53E-04		
001-CC-C2A-001	**		Bottom	<4.89E-04		
001-CC-C03-001	Concrete		Top	3.48E-02	10.00	2.09E-01
001-CC-C03-001	Concrete	3"	Bottom	3.67E-02	10.00	2.20E-01
001-CC-C03-002	Asphalt		Top	2.90E-02	10.00	1.74E-01
001-CC-C03-002	Asphalt	4.5"	Bottom	5.13E-04	50.50	3.08E-03
001-CC-C04-001	Concrete		Top	<2.77E-04		
001-CC-C04-001	Concrete	4"	Bottom	8.15E-02	10.00	4.89E-01
001-CC-C04-002	Asphalt		Top	7.04E-02	10.00	4.22E-01
001-CC-C04-002	Asphalt	7"	Bottom	<2.04E-04		
001-CC-C05-001	Concrete		Top	<2.35E-04		
001-CC-C05-001	Concrete	4"	Bottom	1.23E-03	14.50	7.38E-03
001-CC-C05-002	Asphalt	7"	Pieces*	3.58E-04	96.80	2.15E-03
001-CC-C06-001	Concrete and		Top	<3.41E-04		
001-CC-C06-001	Asphalt	7"	Bottom	<4.33E-04		
001-CC-C07-001	Concrete		Top	1.32E-03	68.80	7.92E-03
001-CC-C07-001	Concrete	4"	Bottom	3.91E-02	10.00	2.35E-01
001-CC-C07-002	Asphalt		Top	7.50E-02	10.00	4.50E-01
001-CC-C07-002	Asphalt	7"	Bottom	1.34E-03	15.40	8.04E-03
001-CC-C08-001	Concrete		Top	<2.03E-04		
001-CC-C08-001	Concrete	5"	Bottom	4.43E-03	11.60	2.66E-02
001-CC-C08-002	Asphalt		Top	2.66E-03	21.40	1.60E-02
001-CC-C08-002	Asphalt	8"	Bottom	<2.35E-04		
001-CC-C09-001	Concrete		Top	<2.51E-04		
001-CC-C09-001	Concrete	5"	Bottom	<2.68E-04		
001-CC-C09-002	Asphalt		Top	7.93E-03	11.60	4.76E-02
001-CC-C09-002	Asphalt	8"	Bottom	<3.46E-04		
001-CC-C10-001	Concrete		Top	3.00E-02	10.00	1.80E-01
001-CC-C10-001	Concrete	5"	Bottom	5.14E-01	10.00	3.08E+00
001-CC-C10-002	Asphalt		Top	1.95E+00	10.00	1.17E+01
001-CC-C10-002	Asphalt	7"	Bottom	5.02E-03	10.00	3.01E-02
001-CC-C11-001	Concrete		Top	2.23E-01	10.00	1.34E+00
001-CC-C11-001	Concrete	4"	Bottom	5.24E+00	10.00	3.14E+01
001-CC-C11-002	Asphalt		Top	1.79E+02	10.00	1.07E+03
001-CC-C11-002	Asphalt	6"	Bottom	1.60E+00	10.00	9.60E+00
001-CC-C12-001	Concrete		Top	8.83E-03	13.80	5.30E-02
001-CC-C12-001	Concrete	4"	Bottom	5.28E-03	21.40	3.17E-02
001-CC-C12-002	Asphalt		Top	7.06E-04	38.80	4.24E-03
001-CC-C12-002	Asphalt	6"	Bottom	2.51E-03	17.80	1.51E-02
001-CC-C13-001	Concrete		Top	<4.89E-04		
001-CC-C13-001	Concrete	4"	Bottom	2.58E-01	10.00	1.55E+00

Table 4-23 (continued)

HPG Data for Cement Core Samples Collected at the BOMARC Missile Site

Sample Number	Composition	Thickness (Inches)	Part of Core	AM-241 Activity (μCi/sample)***	2-Sigma Error (%)	PU-239 Activity (μCi/sample)
001-CC-C13-002	Asphalt	7"	Pieces*	2.67E-03	13.00	1.60E-02
001-CC-C13-003	Concrete		Top	<2.76E-04		
001-CC-C13-003	Concrete	10"	Bottom	<2.63E-04		
001-CC-C14-001	Concrete		Top	2.68+00	10.00	1.61E+01
001-CC-C14-001	Concrete	4"	Bottom	2.58E-01	10.00	1.55E+00
001-CC-C14-002	Asphalt		Top	1.21E+01	10.00	7.26E+01
001-CC-C14-002	Asphalt	6"	Bottom	9.60E-01	10.00	5.76E+00
001-CC-C14-003	Asphalt	Loose	Pieces*	2.75E-03	10.00	1.65E-02
001-CC-C15-001	Asphalt		Top	2.19E-02	10.00	1.31E-01
001-CC-C15-001	Asphalt	1"	Bottom	2.78E+00	10.00	1.67E+01
001-CC-C15-002	Concrete		Top	9.04E+01	10.00	5.42E+02
001-CC-C15-002	Concrete	4"	Bottom	1.28E+00	10.00	7.68E+00
001-CC-C15-003	Asphalt		Top	5.76E-02	10.00	3.46E-01
001-CC-C15-003	Asphalt	6"	Bottom	4.45E-03	15.60	2.67E-02
001-CC-C16-001	Concrete		Top	9.25E-04	48.40	5.55E-03
001-CC-C16-001	Concrete	4.5"	Bottom	7.46E-02	10.00	4.48E-01
001-CC-C17-001	Concrete		Top	<9.86E-05		
001-CC-C17-001	Concrete	1.5"	Bottom	<1.08E-04		
001-CC-C17-002	Concrete		Top	6.90E-01	10.00	4.14E+00
001-CC-C17-002	Concrete	5.5"	Bottom	2.56E-03	31.00	1.54E-02
001-CC-C17-003	Asphalt		Top	4.95E-01	10.00	2.97E+00
001-CC-C17-003	Asphalt	8"	Bottom	2.78E-01	10.00	1.67E+00
001-CC-C18-001	Concrete		Top	7.09E-04	57.20	4.25E-03
001-CC-C18-001	Concrete	2"	Bottom	<2.41E-04		
001-CC-C18-002	Concrete		Top	2.54E-03	23.20	1.52E-02
001-CC-C18-002	Concrete	5"	Bottom	3.85E-03	15.40	2.31E-02
001-CC-C18-003	Asphalt		Top	2.94E-02	10.00	1.76E-01
001-CC-C18-003	Asphalt	7"	Bottom	<2.53E-04		
001-CC-C19-001	Concrete		Top	1.74E-03	22.40	1.04E-02
001-CC-C19-001	Concrete	3"	Bottom	2.90E-01	10.00	1.74E+00
001-CC-C19-002	Asphalt		Top	2.48E-01	10.00	1.49E+00
001-CC-C19-002	Asphalt	6"	Bottom	2.62E-01	10.00	1.57E+00
001-CC-C19-003	Concrete		Top	3.71E+00	10.00	2.23E+01
001-CC-C19-003	Concrete	20"	Bottom	1.42E-03	60.80	8.52E-03
001-CC-C20-001	Concrete		Top	<1.06E-04		
001-CC-C20-001	Concrete	1.5"	Bottom	<1.06E-04		
001-CC-C20-002	Concrete		Top	2.23E-03	12.00	1.34E-03
001-CC-C20-002	Concrete	3.5"	Bottom	6.21E-02	10.00	3.73E-01
001-CC-C20-003	Asphalt		Top	3.26E+00	10.00	1.96E+01
001-CC-C20-003	Asphalt	7"	Bottom	1.09E+01	10.00	6.53E+01
001-CC-C20-004	Concrete		Top	5.60E+00	10.00	3.36E+01
001-CC-C20-004	Concrete	20"	Bottom	2.65E-02	10.00	1.59E-01
001-CC-C21-001	Concrete		Top	<1.13E-04		
001-CC-C21-001	Concrete	1"	Bottom	<1.09E-04		
001-CC-C21-002	Concrete		Top	<1.53E-04		
001-CC-C21-002	Concrete	1.5"	Bottom	<1.55E-04		
001-CC-C21-003	Concrete/Asphalt		Top	2.23E-01	10.00	1.34E+00
001-CC-C21-003	Concrete/Asphalt	3"	Bottom	6.50E-02	10.00	3.90E-01
001-CC-C21-004	Concrete		Top	6.35E-02	10.00	3.81E-01
001-CC-C21-004	Concrete	20"	Bottom	8.09E-04	43.40	4.85E-03

* The sample was broken during drilling, and the pieces were counted.
** Earth Technology retained these samples.
*** Note: "<" indicates minimal detectable activity. This value varies with instrument calibration for a particular day.

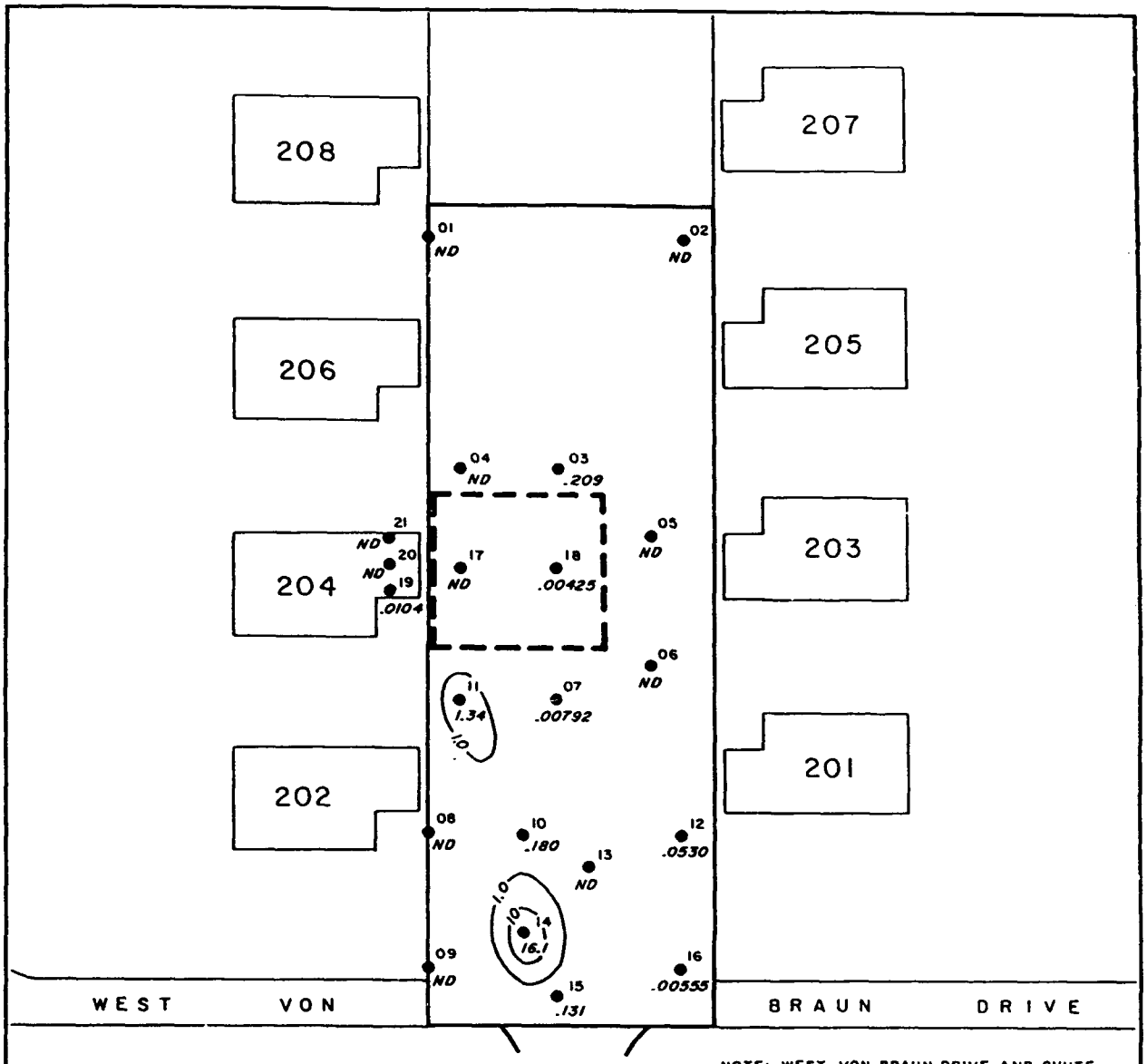
208
207
206
205
204
203
202
201
01 ND
02 ND
04 ND
03 .209
21 ND
20 ND
19 .0104
17 ND
18 .00425
05 ND
06 ND
11 1.34
10
07 .00792
08 ND
10 .180
12 .0530
13 ND
1.0
10
14 16.1
09 ND
15 .131
16 .00555
WEST VON
BRAUN DRIVE
KEY
03 — CORE SAMPLE LOCATION & NUMBER
.209 — UNIT MEASURED IN µCi/SAMPLE
ND NOT DETECTED
NR NO READING
ASPHALT AND 4-INCH CONCRETE PAD
ASPHALT, 4-INCH CONCRETE AND ADDITIONAL 2-INCHES CONCRETE
NOTE: WEST VON BRAUN DRIVE AND CHUTE HAVE 2-INCHES OF ASPHALT ON TOP OF THE CONCRETE.
0 50 FEET
SCALE
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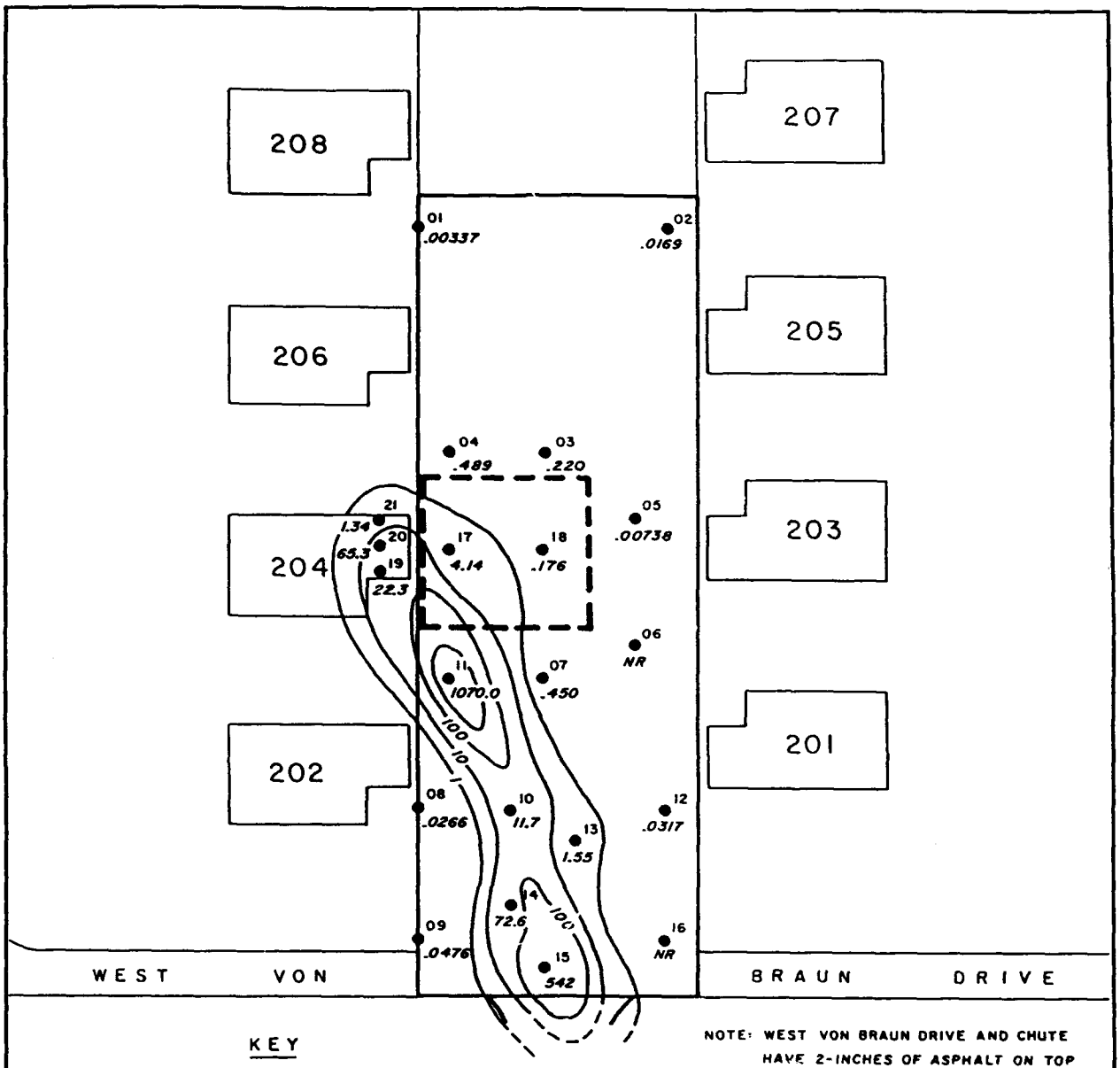
FIGURE 4-16
CONCRETE CORE ACTIVITY AT PRESENT (1989) SURFACE OF THE CONCRETE APRON IN FRONT OF SHELTER 204, BOMARC MISSILE SITE


208
207
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204
203
202
201
01
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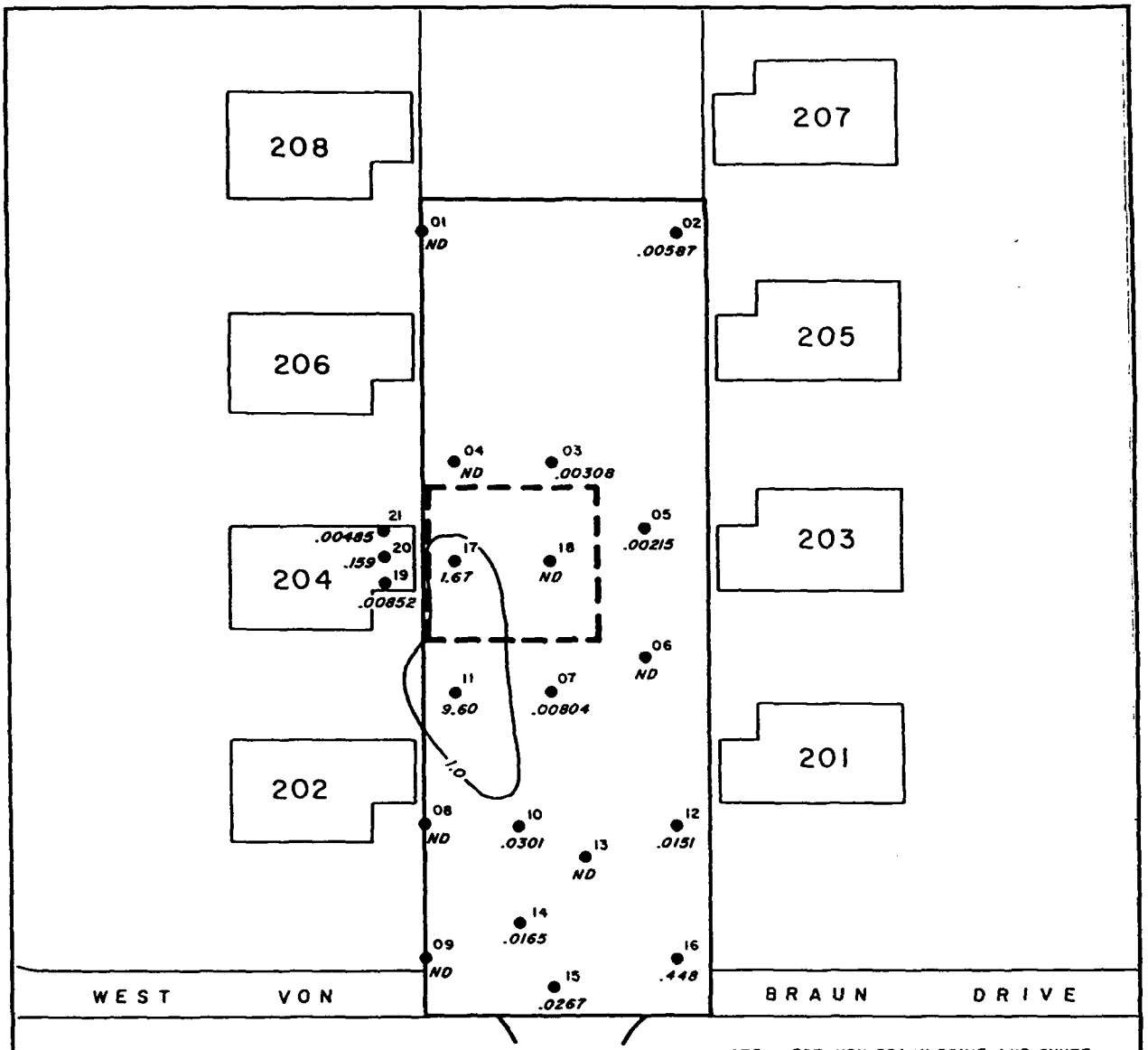
03
.220
04
.489
05
.00738
06
NR
07
.450
08
.0266
09
.0476
10
11.7
11
1070.0
12
.0317
13
1.55
14
72.6
15
542
16
NR
17
4.14
18
.176
19
22.3
20
65.3
21
1.34
100
10
1
100
WEST VON
BRAUN DRIVE
KEY
03 — CORE SAMPLE LOCATION & NUMBER
.209 — UNIT MEASURED IN µCi/SAMPLE
ND NOT DETECTED
NR NO READING
ASPHALT AND 4-INCH CONCRETE PAD
ASPHALT, 4-INCH CONCRETE AND ADDITIONAL 2-INCHES CONCRETE
NOTE: WEST VON BRAUN DRIVE AND CHUTE HAVE 2-INCHES OF ASPHALT ON TOP OF THE CONCRETE.
0
50 FEET
SCALE
The Earth Technology Corporation
FIGURE 4-17
CONCRETE CORE ACTIVITY AT JUNE 1960 SURFACE OF THE STREET IN FRONT OF SHELTER 204, BOMARC MISSILE SITE



KEY

- 03 — CORE SAMPLE LOCATION & NUMBER
- .209 — UNIT MEASURED IN μCi/SAMPLE
- ND — NOT DETECTED
- NR — NO READING
- ASPHALT AND 4-INCH CONCRETE PAD
- ASPHALT, 4-INCH CONCRETE AND ADDITIONAL 2-INCHES CONCRETE

NOTE: WEST VON BRAUN DRIVE AND CHUTE HAVE 2-INCHES OF ASPHALT ON TOP OF THE CONCRETE.

0 50 FEET
SCALE

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FIGURE 4-18

CONCRETE CORE ACTIVITY ON THE BOTTOM OF CONCRETE CORE AT THE SOIL CONTACT, BOMARC MISSILE SITE

4.1.3.8 Soils

During the course of the BOMARC remedial investigation, EPA Region II exercised oversight of field activities and obtained split samples of environmental media (soil, surface water, ground water) to verify the results of the Air Force contractor laboratory radioanalysis. Due to the non-uniform distribution of plutonium in discrete particles within site soils, collection of split soil samples by the EPA field oversight contractor presented technical problems.

Both the Air Force and EPA believed that it would be impossible to obtain split samples in the field with approximately equal concentrations of plutonium, due to the non-uniform distribution of plutonium in site soils. Both parties agreed that if a soil sample was to be split in the field, it was likely that one half of the sample would contain the bulk of any plutonium present, and the other half would contain substantially less plutonium, due to the occurrence of plutonium in discreet particles. Since the purpose of split sample analysis by the EPA was to perform a quality control check on the Air Force contractor laboratory, the analysis of split samples containing unequal portions of analyte was considered essentially useless, because analytical results for split samples would not be comparable.

In an attempt to solve this problem, EPA proposed to use a customized sample preparation scheme to generate split samples with equivalent concentrations of plutonium. Under EPA's proposed sample preparation scheme, samples would not be split in the field, but would be shipped to an EPA laboratory for processing. There the samples would be mechanically pulverized so that soil particles were less than one micron in diameter, and homogenized so that pulverized plutonium particles would theoretically be equally distributed in the sample. The samples would then be split, with one half of the sample returned to the Air Force contractor laboratory for analysis, and the remaining half being analyzed by the EPA laboratory. Using this scheme, EPA hoped to obtain split samples with equivalent concentrations of plutonium.

EPA took possession of nineteen soil samples generated by the Air Force RI/FS contractors. EPA intended to process the samples as described above and return half of each sample to the Air Force contractor laboratory for analysis. However, subsequent to EPA taking possession of the soil samples, technical and institutional problems encountered by the EPA laboratory prevented processing and analysis of the samples, and the data points represented by the nineteen samples were lost.

All of the lost samples were screened in the field with a hyper-pure germanium detector prior to shipment offsite, and thirteen of the nineteen samples were also screened with a FIDLER instrument. While these field measurements are not considered as accurate as laboratory analysis by alpha spectroscopy, they do provide a close approximation of the actual level of radioactivity in the samples. Since some of the lost data points were considered critical to the RI/FS, EPA suggested that the best approach to including the lost samples in the RI/FS report would be to assign values for plutonium concentration to the lost samples based on linear regression analysis of existing data points. The Air Force agreed that short of obtaining actual analytical data, assigning values was a second best approach.

Using this approach, samples that were analyzed both in the field (FIDLER and hyper-pure germanium detector surveys) and in the laboratory were analyzed to determine the degree of

correlation between field analytical values and laboratory analytical values generated using alpha spectroscopy. Preliminary analysis indicated that there was better correlation between FIDLER measurements and laboratory data than between hyper-pure germanium detector surveys and laboratory data. Therefore, linear regression analysis was performed using FIDLER readings and corresponding alpha spectroscopy data generated for the same samples.

A population consisting of fourteen soil samples was selected for analysis. This population included all soil samples for which laboratory alpha spectroscopy analysis was performed and for which the FIDLER detector registered above-background readings in the field. Details on methodology and results of linear regression analysis can be found in Appendix I.

Linear regression analysis was used to predict plutonium activity values for those samples in possession of EPA that had FIDLER readings above background. These assigned values are used in the RI/FS report as necessary, and wherever they appear, it is noted that the values were assigned rather than derived by laboratory analysis. Of the nineteen samples in possession of EPA, eleven had FIDLER readings above background. As agreed by EPA and the Air Force, the remaining eight samples, which had either no FIDLER data or FIDLER readings close to background, were assigned values of zero for purposes of the RI/FS report.

4.1.3.8.1 Soil Borings

Based on readings taken during the in-situ survey of the site, sampling points were established around Shelter 204, along the drainage ditch, and in the vicinity of the ponding area. A total of 26 surface soil samples were collected using a brass sleeve, and 52 subsurface soil samples were collected using a split-spoon and auger method. The purpose of this sampling effort was to delineate and/or confirm the extent of vertical contamination and to establish a reliable estimate of the quantity of contaminated soil. The surface samples were collected within an interval of 0.0 to 0.5 feet and the subsurface samples were collected in the intervals between 2 to 4, 4 to 6, and 8 to 10 feet at the same locations. Subsurface samples were not collected from each interval in every borehole. The sampling procedure is outlined in Section 3.6.2.6.9. All samples were shipped to the laboratory to be analyzed for Pu-239.

The results from the laboratory analyses of the above samples are presented in Table 4-24. Average fallout levels of plutonium for the United States (U.S. EPA, 1990) range from 0.001 to 0.003 $\mu Ci/m^2$ and average 0.002 $\mu Ci/m^2$ in the top 1 cm of soil. If an average soil density of 1.6 g/cm^3 is used, then the average concentration of plutonium in U. S. soil is 0.13 pCi/g. The U.S. EPA (1990) also cites another average concentration of 0.06 pCi/g. Based on these two figures, an assumed average background fallout concentration level of 0.1 pCi/g will be used for soil comparisons at this site.

Table 4-24

Analytical and Field Data for Soil Samples from Borehole Locations at the BOMARC Missile Site

Sample ID	Date Collected	Depth (ft)	FIDLER (cpm)	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)	Location Remarks
001-SL-B01-001	10-03-89	0-0.5	481	Pu-239	PRO-052-32	0.04	3.3 +-0.5E 00	
001-SS-B01-002	10-10-89	2-4	110	Pu-239	PRO-052-32	0.04	8.1 +-0.2E 00	
001-SS-B01-003	10-10-89	8-10	110	Pu-239	PRO-052-32	0.04	3.9 +-0.1E+01	
001-SL-B02-001	10-03-89	0-0.5	29,000	Pu-239	PRO-052-32	0.04	2.0 +-0.1E 00	
001-SS-B02-002	10-09-89	2-4	90-110	Pu-239	PRO-052-32	0.04	2.7 +-2.0E-02	
001-SS-B02-003	10-09-89	8-10	90-110	Pu-239	PRO-052-32	0.04	2.3 +-0.9E-02	
001-SL-B03-001	09-29-89	0-0.5	1840	Pu-239	PRO-052-32	0.04	19.8*	12.2 ft NW corner Sh 204
001-SS-B03-002	10-09-89	2-4	90-110	Pu-239	PRO-052-32	0.04	5.5 +-1.5E-02	62.7 feet north of apron
001-SS-B03-003	10-09-89	8-10	90-110	Pu-239	PRO-052-32	0.04	0*	
001-SL-B04-001	09-29-89	0-0.5	2360	Pu-239	PRO-052-32	0.04	23.2*	13.5 ft NE corner Sh 204
001-SS-B04-002	10-09-89	2-4	100-120	Pu-239	PRO-052-32	0.04	2.0 +-0.4E-01	9 ft north of shelter 204
001-SS-B04-003	10-09-89	8-10	100-120	Pu-239	PRO-052-32	0.04	<1.0E-02	
001-SL-B05-001	10-02-89	0-0.5	7220	Pu-239	PRO-052-32	0.04	1.7 +-0.1E+01	104.7 feet north of apron
001-SS-B05-002	10-05-89	2-4	101	Pu-239	PRO-052-32	0.04	6.0 +-2.0E-01	23 ft west of shelter 206
001-SS-B05-003	10-05-89	4-6	80	Pu-239	PRO-052-32	0.04	1.7 +-0.3E-01	
001-SL-B06-001	10-02-89	0-0.5	2180	Pu-239	PRO-052-32	0.04	5.1 +-0.1E+01	76.8 feet north of apron
001-SS-B06-002	10-05-89	2-4	104	Pu-239	PRO-052-32	0.04	1.7 +-0.1E-00	20.9 ft west shelter 206
001-SS-B06-003	10-05-89	4-6	107	Pu-239	PRO-052-32	0.04	5.4 +-1.1E-02	
001-SL-B07-001	10-02-89	0-0.5	41,400	Pu-239	PRO-052-32	0.04	131*	37 feet north of apron
001-SS-B07-002	10-04-89	2-4	93	Pu-239	PRO-052-32	0.04	2.1 +-0.8E-02	20.4 ft west shelter 206
001-SS-B07-003	10-04-89	4-6	100	Pu-239	PRO-052-32	0.04	3.1 +-0.3E-01	
001-SL-B08-001	10-02-89	0-0.5	43,700	Pu-239	PRO-052-32	0.04	2.4 +-0.1E+02	5.5 ft north of apron and
001-SS-B08-002	10-04-89	2-4	93	Pu-239	PRO-052-32	0.04	6.1 +-0.5E-01	19.3 ft west of Sh 206
001-SS-B08-003	10-04-89	8-10	100	Pu-239	PRO-052-32	0.04	3.1 +-0.5E-01	
001-SL-B09-001	10-02-89	0-0.5	29,800	Pu-239	PRO-052-32	0.04	107.6*	36.6 ft north of Sh 206
001-SS-B09-002	10-05-89	2-4	97	Pu-239	PRO-052-32	0.04	1.2 +-0.1E 00	Parallel to NW corner
001-SS-B09-003	10-05-89	4-6	92	Pu-239	PRO-052-32	0.04	7.7 +-0.6E-01	
001-SL-B10-001	10-03-89	0-0.5	577	Pu-239	PRO-052-32	0.04	1.8 +-0.1E+02	
001-SS-B10-002	10-11-89	2-4	130	Pu-239	PRO-052-32	0.04	0*	
001-SS-B10-003	10-11-89	8-10	130	Pu-239	PRO-052-32	0.04	<3.0E-02	

Table 4-24 (Continued)

Analytical and Field Data for Soil Samples from Borehole Locations at the BOMARC Missile Site

Sample ID	Date Collected	Depth (ft)	FIDLER (cpm)	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)	Location Remarks
001-SL-B11-001	10-03-89	0-0.5	200	Pu-239	PRO-052-32	0.04	1.8 +-0.1E 00	
001-SS-B11-002	10-11-89	2-4	130	Pu-239	PRO-052-32	0.04	2.4 +-0.8E-02	
001-SS-B11-003	10-11-89	4-6	130	Pu-239	PRO-052-32	0.04	<1.0E-02	
001-SL-B12-001	10-03-89	0-0.5	103	Pu-239	PRO-052-32	0.04	1.0 +-0.1E 00	
001-SS-B12-002	10-11-89	2-4	120	Pu-239	PRO-052-32	0.04	<2.0E-02	
001-SS-B12-003	10-11-89	8-10	120	Pu-239	PRO-052-32	0.04	<4.0E-03	
001-SL-B13-001	10-06-89	0-0.5	752	Pu-239	PRO-052-32	0.04	1.8 +-0.1E 00	
001-SS-B13-002	10-10-89	2-4	110	Pu-239	PRO-052-32	0.04	6.2 +-0.2E 00	
001-SS-B13-003	10-10-89	4-6	110	Pu-239	PRO-052-32	0.04	1.5 +-0.4E-01	
001-SL-B14-001	10-06-89	0-0.5	9,500	Pu-239	PRO-052-32	0.04	6.3 +-0.1E+01	
001-SS-B14-002	10-10-89	2-4	110	Pu-239	PRO-052-32	0.04	0*	
001-SS-B14-003	10-10-89	4-6	110	Pu-239	PRO-052-32	0.04	6.9 +-0.2E-01	
001-SL-B15-001	10-06-89	0-0.5	2,050	Pu-239	PRO-052-32	0.04	21.2*	Between Sh. 201 and road
001-SS-B15-002	10-10-89	2-4	100	Pu-239	PRO-052-32	0.04	<4.0E-03	
001-SS-B15-003	10-10-89	4-6	100	Pu-239	PRO-052-32	0.04	1.0 +-0.3E-01	
001-SL-B16-001	10-10-89	0-0.5	100-120	Pu-239	PRO-052-32	0.04	2.2 +-0.5E-01	In ditch, TETC collected
001-SS-B16-002	10-10-89	2-4	100-120	Pu-239	PRO-052-32	0.04	1.9 +-0.9E-02	
001-SS-B16-003	10-10-89	8-10	100-120	Pu-239	PRO-052-32	0.04	2.3 +-0.6E-01	
001-SL-B17-001	10-11-89	0-0.5	97	Pu-239	PRO-052-32	0.04	3.7 +-0.1E 00	In ditch/drainage
001-SS-B17-002	10-11-89	2-4	120	Pu-239	PRO-052-32	0.04	6.0 +-5.0E-02	
001-SS-B17-003	10-11-89	4-6	120	Pu-239	PRO-052-32	0.04	<2.0E-02	
001-SL-B18-001	10-11-89	0-0.5	116	Pu-239	PRO-052-32	0.04	8.3 +-1.2E-02	In ditch/drainage
001-SS-B18-002	10-12-89	2-4	100-120	Pu-239	PRO-052-32	0.04	**Invalid sample	
001-SS-B18-003	10-12-89	4-6	100-120	Pu-239	PRO-052-32	0.04	9.4 +-1.0E-01	
001-SL-B19-001	10-11-89	0-0.5	203	Pu-239	PRO-052-32	0.04	2.3 +-0.1E 00	In ditch/drainage
001-SS-B19-002	10-12-89	2-4	120	Pu-239	PRO-052-32	0.04	7.7 +-0.6E-01	
001-SS-B19-003	10-12-89	4-6	120	Pu-239	PRO-052-32	0.04	9.1 +-3.0E-02	
001-SL-B20-001	10-11-89	0-0.5	97	Pu-239	PRO-052-32	0.04	<4.0E-02	Outside fence
001-SS-B20-002	10-12-89	2-4	100	Pu-239	PRO-052-32	0.04	1.0 +-0.1E+01	
001-SS-B20-003	10-12-89	4-6	100	Pu-239	PRO-052-32	0.04	<7.0E-03	

Table 4-24 (Continued)

Analytical and Field Data for Soil Samples from Borehole Locations at the BOMARC Missile Site

Sample ID	Date Collected	Depth (ft)	FIDLER (cpm)	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)	Location Remarks
001-SL-B21-001	10-11-89	0-0.5	111	Pu-239	PRO-052-32	0.04	1.7 +-0.6E-02	Outside fence
001-SS-B21-002	10-12-89	2-4	100	Pu-239	PRO-052-32	0.04	3.0 +-0.5E-01	
001-SS-B21-003	10-12-89	4-6	100	Pu-239	PRO-052-32	0.04	5.9 +-0.6E-01	
001-SL-B22-001	10-11-89	0-0.5	118	Pu-239	PRO-052-32	0.04	3.4 +-0.2E-01	Outside fence
001-SS-B22-002	10-12-89	2-4	100	Pu-239	PRO-052-32	0.04	<4.0E-03	
001-SS-B22-003	10-12-89	4-6	100	Pu-239	PRO-052-32	0.04	<6.0E-03	
001-SL-B23-001	10-11-89	0-0.5	110	Pu-239	PRO-052-32	0.04	5.1 +-0.2E 00	Near transformer station
001-SS-B23-002	10-12-89	2-4	100	Pu-239	PRO-052-32	0.04	6.6 +-1.6E-02	
001-SS-B23-003	10-12-89	4-6	100	Pu-239	PRO-052-32	0.04	6.0 +-2.0E-03	
001-SL-B24-001	10-11-89	0-0.5	99	Pu-239	PRO-052-32	0.04	4.4 +-0.4E-01	Near transformer station
001-SS-B24-002	10-12-89	2-4	100	Pu-239	PRO-052-32	0.04	**Invalid sample	
001-SS-B24-003	10-12-89	4-6	100	Pu-239	PRO-052-32	0.04	<6.0E-03	
001-SL-B25-001	10-11-89	0-0.5	234	Pu-239	PRO-052-32	0.04	3.9 +-0.3E 00	W of Hwy 539, N of ditch,
001-SS-B25-002	10-16-89	2-4	200	Pu-239	PRO-052-32	0.04	3.8*	near ponding area.
001-SS-B25-003	10-16-89	4-6	200	Pu-239	PRO-052-32	0.04	2.9 +-1.6E-02	
001-SL-B26-001	10-11-89	0-0.5	100	Pu-239	PRO-052-32	0.04	2.0 +-0.8E-02	
001-SS-B26-002	10-16-89	2-4	100	Pu-239	PRO-052-32	0.04	2.8 +-0.9E-02	
001-SS-B26-003	10-16-89	4-6	100	Pu-239	PRO-052-32	0.04	1.8 +-0.7E-02	

* Samples held by EPA that were invalidated. Concentrations shown are assigned values calculated by linear regression analysis of FIDLER data. Values at or near background or with no FIDLER data were assigned a value of 0.

Invalid Sample:

** The bottles containing 001-SS-B24-002 and 001-SS-B18-002 were broken in the laboratory and the contents were inadvertently intermixed. Therefore the results are invalid for both samples.

With the exception of boreholes 18, 20, 21, and 26, all of the samples collected from the top six inches of soil exceeded the average plutonium fallout level by several orders of magnitude. Ten of the 4 to 6 and 8 to 10 foot interval samples exceeded that average. As illustrated on Figures 4-19, 4-20, 4-21, and 4-22, the quantity of Pu-239 generally decreased with the depth interval of soil collection. This supports the hypothesis that there is little vertical migration of plutonium, and the majority of Pu-239 is in the top few inches of the soil.

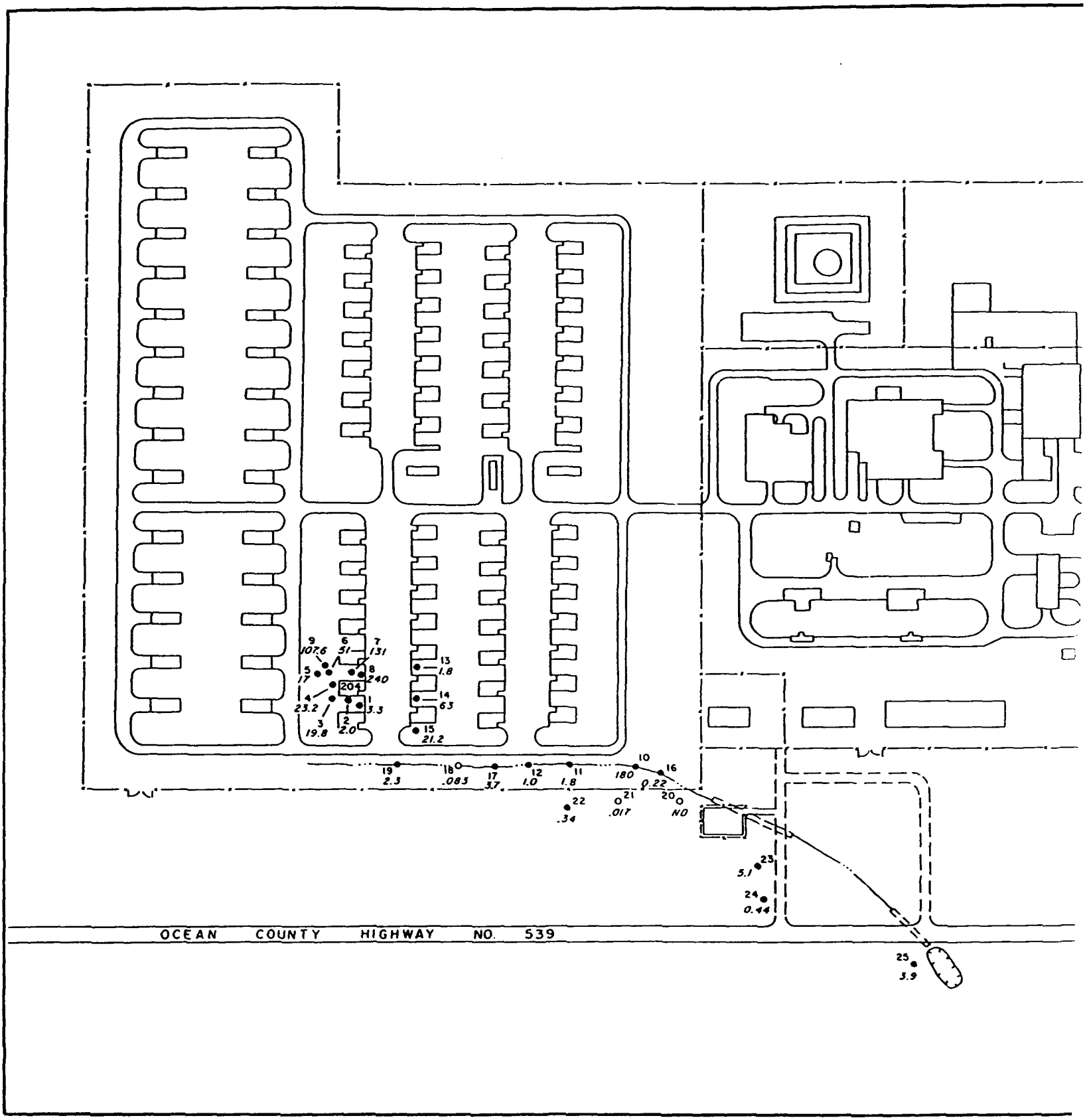
Figures 4-19, 4-20, 4-21, and 4-22 show the locations and concentrations of Pu-239 in the four sampling intervals. The highest concentration of Pu-239 is found to be around Shelter 204. High concentrations are also found between Shelters 203 and 205 and along the drainage ditch. The second highest activity reading (180 pCi/gm) was detected in surface soil sample 001-SL-B10-001 which was collected in the main surface water drainage, approximately midway between Shelter 204 and where the drainage passes under Highway 539. This is most likely due to the runoff from the large amounts of water used to extinguish the 1960 fire. The relatively high activity level detected outside the main drainage in sample 001-SL-B23-001 (5.1 pCi/gm) may be a result of contaminated fire-fighting water overflowing the earthen dam and pooling in the roadside drainage ditch from which this sample was collected. The highest concentration of Pu-239 (240 pCi/gm) was found to be between Shelters 204 and 206, 19.3 feet west of Shelter 206 and 5.5 feet north of the concrete apron.

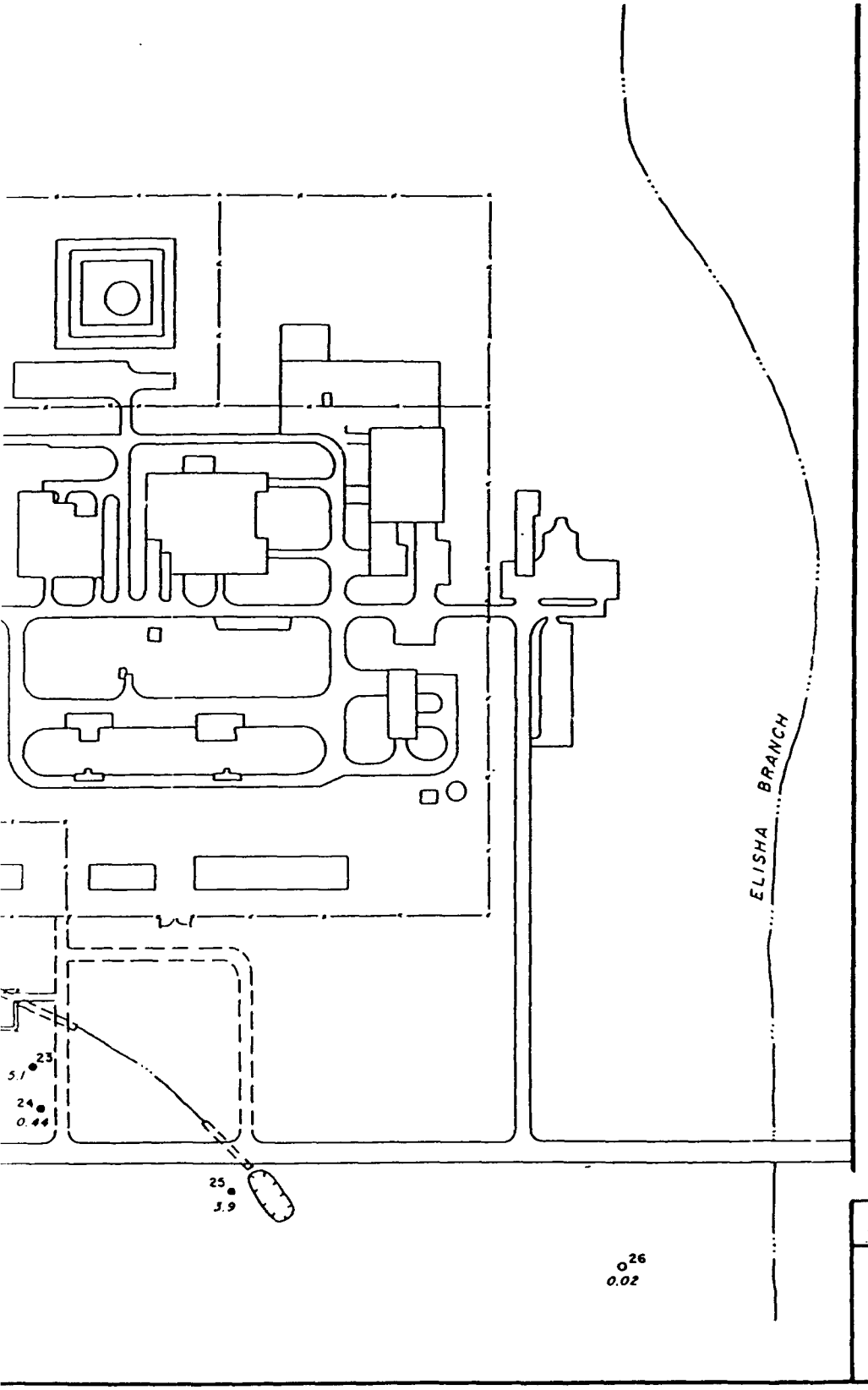
The relative lack of contamination found between Shelters 202 and 204 results from recent soil removal activity in this area. A total of 23 55-gallon drums of soil were excavated from between Shelters 202 and 204 in 1987. This material was shipped to the Nevada Test Site to be used in testing the TRUclean^{R} process, a plutonium extraction process designed by AWC, Inc.

4.1.3.8.2 Shallow Soil Samples Collected from Coring Locations

Shallow soil samples (58) were collected from 21 concrete coring locations during the field investigation. Three soil samples were collected from each corehole in 6-inch brass sleeves. The samples were collected from intervals of 0 to 6, 6 to 12, and 12 to 18 inches to identify the vertical extent of the Pu-239 contamination. This information, combined with the areal location of the coreholes, defined the horizontal and vertical extent of the contamination of the soil under the pad. The procedures used to collect the samples are outlined in Section 3.6.2.6.2. All samples were shipped to the laboratory to be analyzed for Pu-239. The results from the laboratory analyses of the above samples are presented in Table 4-25.

A total of 50 soil samples were collected from 18 coring locations on the concrete apron in front of Shelters 201 through 208. The soil samples from the 0 to 6-inch interval contained the highest concentrations of Pu-239 contamination ranging from 0.049 to 120 pCi/gm. A concentration map (Figure 4-23) of the values of Pu-239 detected at this depth interval illustrates the extent of the contamination. Soil samples collected from the 6 to 12 inch interval contained concentrations of Pu-239 ranging from <0.02 to 6.7 pCi/gm (Figure 4-24). Soil samples collected from the 12 to 18-inch depth interval contained concentrations of Pu-239 ranging from 0.031 to 1.1 pCi/gm (Figure 4-25).


9
107.6
6
51
7
131
5
17
8
240
204
4
23.2
1
3.3
3
19.8
2
2.0
13
1.8
14
6.3
15
21.2
19
2.3
18
.083
17
3.7
12
1.0
11
1.8
10
180
16
0.22
20
NO
21
.017
22
.34
23
5.1
24
0.44
25
3.9
OCEAN COUNTY HIGHWAY NO. 539



EXPLANATION

18 — BOREHOLE NUMBER
● — BOREHOLE LOCATION
.083 — PLUTONIUM (pCi/gm.)

o — PLUTONIUM (pCi/gm.) LESS THAN 0.1

ND — NOT DETECTED

DRAINAGE

PONDING AREA

CULVERT

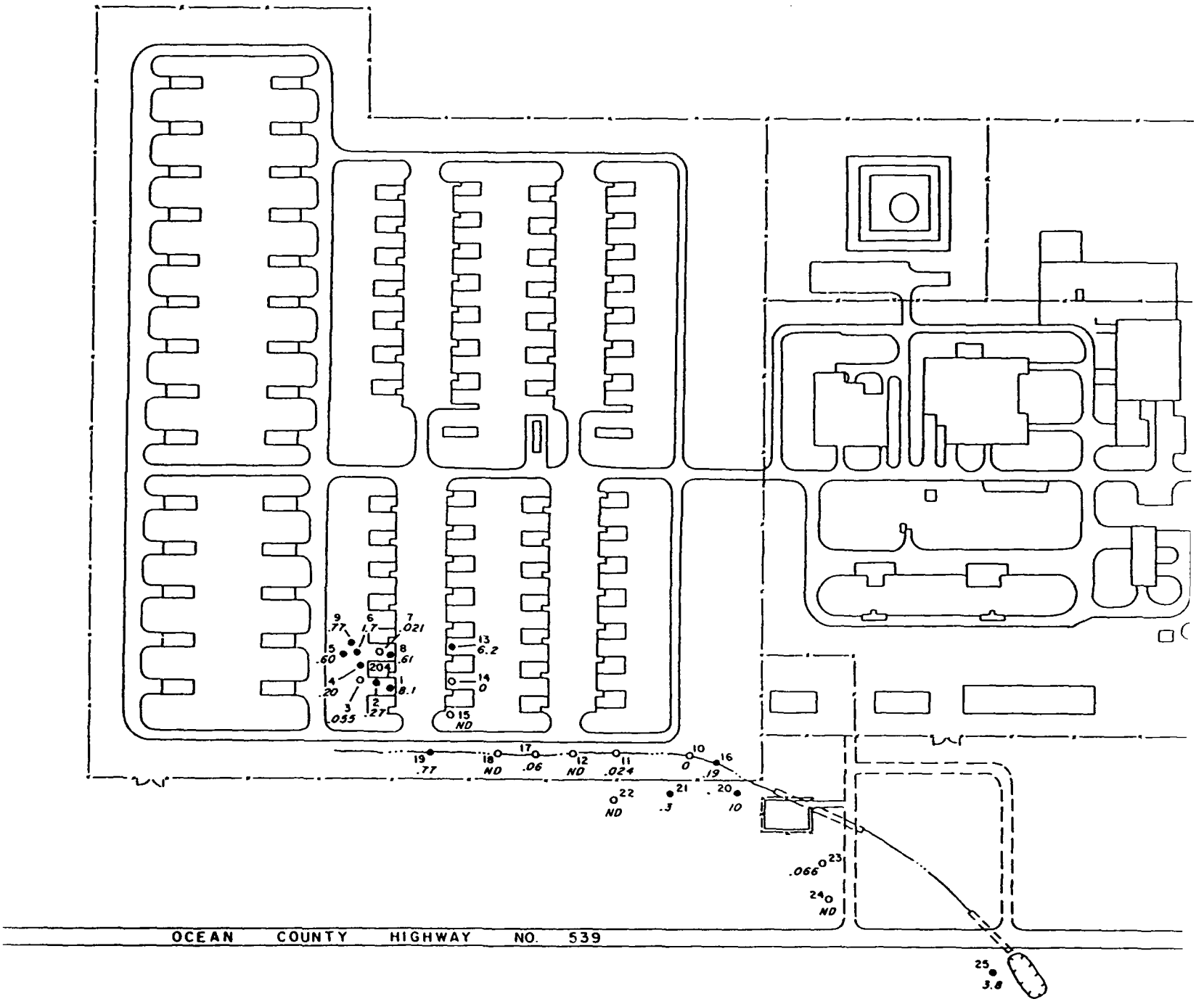
NORTH

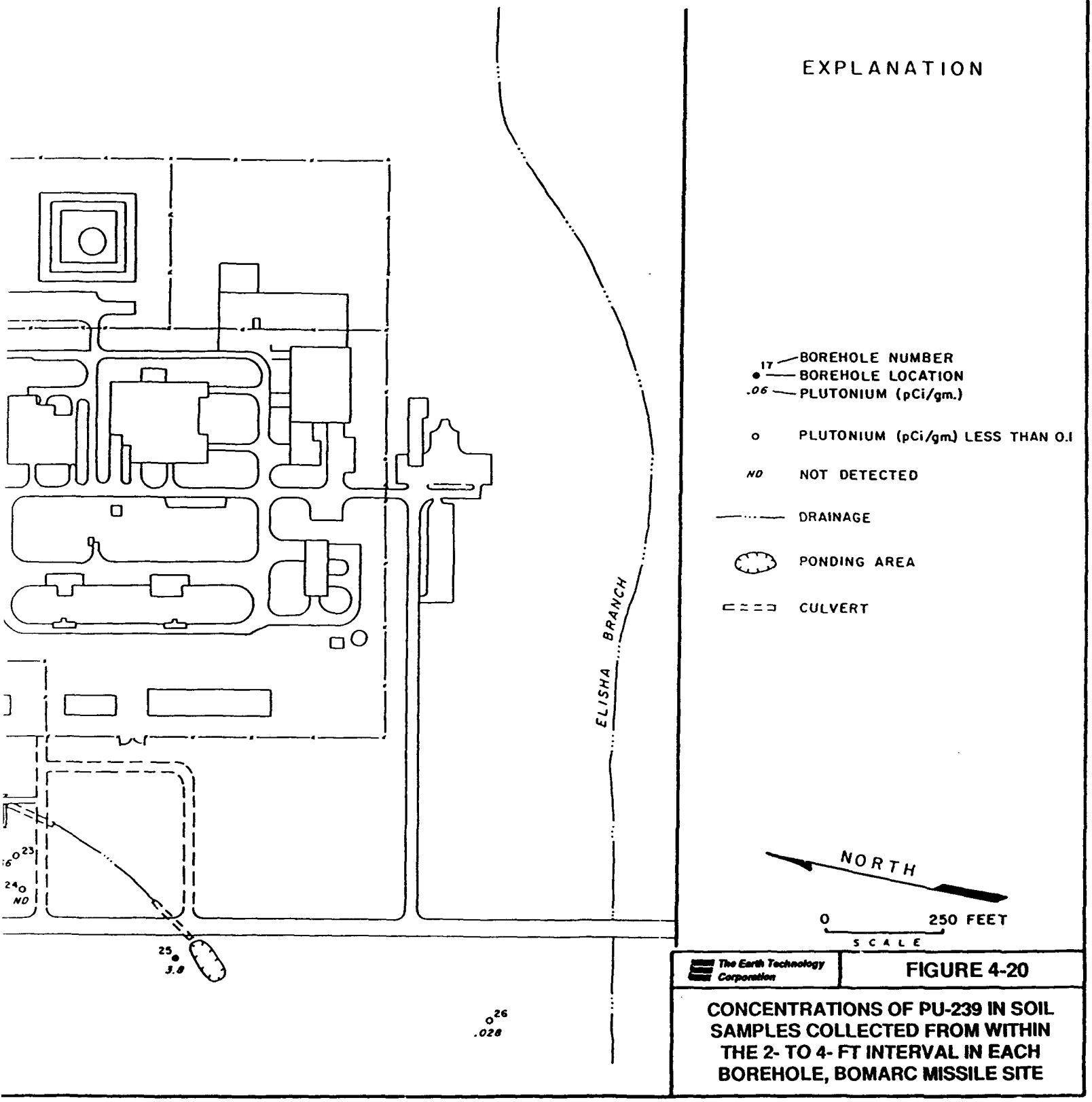
0 250 FEET
SCALE

The Earth Technology Corporation

FIGURE 4-19

CONCENTRATIONS OF PU-239 IN SOIL SAMPLES COLLECTED FROM WITHIN THE 0- TO 0.5- FT INTERVAL IN EACH BOREHOLE, BOMARC MISSILE SITE

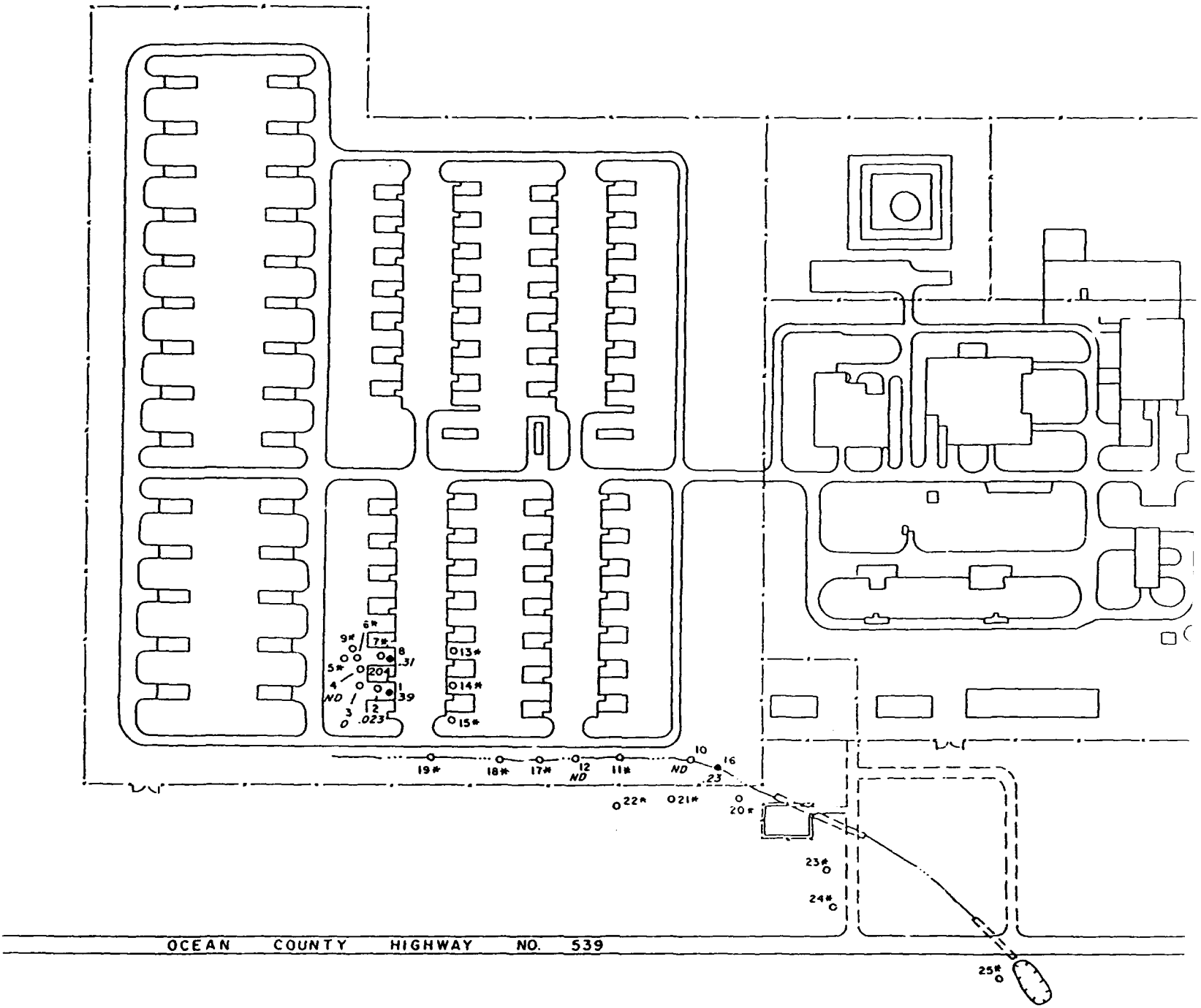

9 .77
6 1.7
7 .021
5 .60
8 .61
204
4 .20
1 8.1
3 .055
2 .27
13 6.2
14 0
15 ND
19 .77
18 ND
17 .06
12 ND
11 .024
10 0
16 .19
22 ND
21 .3
20 10
.066 23
24 ND
25 3.8
OCEAN COUNTY HIGHWAY NO. 539

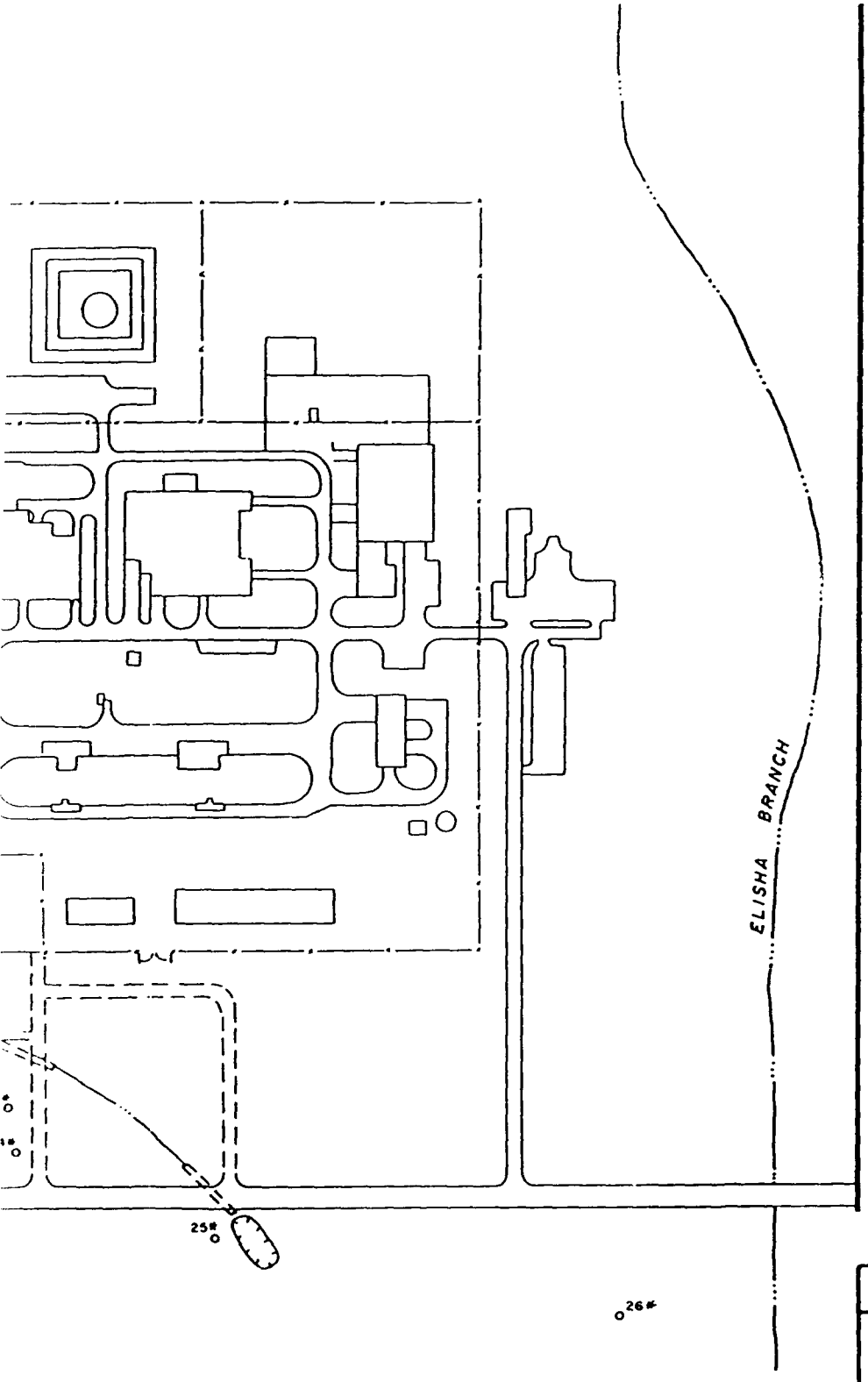


The Earth Technology Corporation

FIGURE 4-20

CONCENTRATIONS OF PU-239 IN SOIL SAMPLES COLLECTED FROM WITHIN THE 2- TO 4- FT INTERVAL IN EACH BOREHOLE, BOMARC MISSILE SITE


6*
9*
7*
8
.31
5*
201
4
ND
1
39
3
0
.023
013*
014*
015*
19*
18*
17*
12
ND
11*
10
ND
16
.23
022*
021*
20*
23*
24*
25*
OCEAN COUNTY HIGHWAY NO. 539



EXPLANATION

1 — BOREHOLE NUMBER
• — BOREHOLE LOCATION
39 — PLUTONIUM (pCi/gm.)

o PLUTONIUM (pCi/gm.) LESS THAN 0.1

ND NOT DETECTED

* NO SAMPLE TAKEN AT THIS INTERVAL

DRAINAGE

PONDING AREA

CULVERT

NORTH

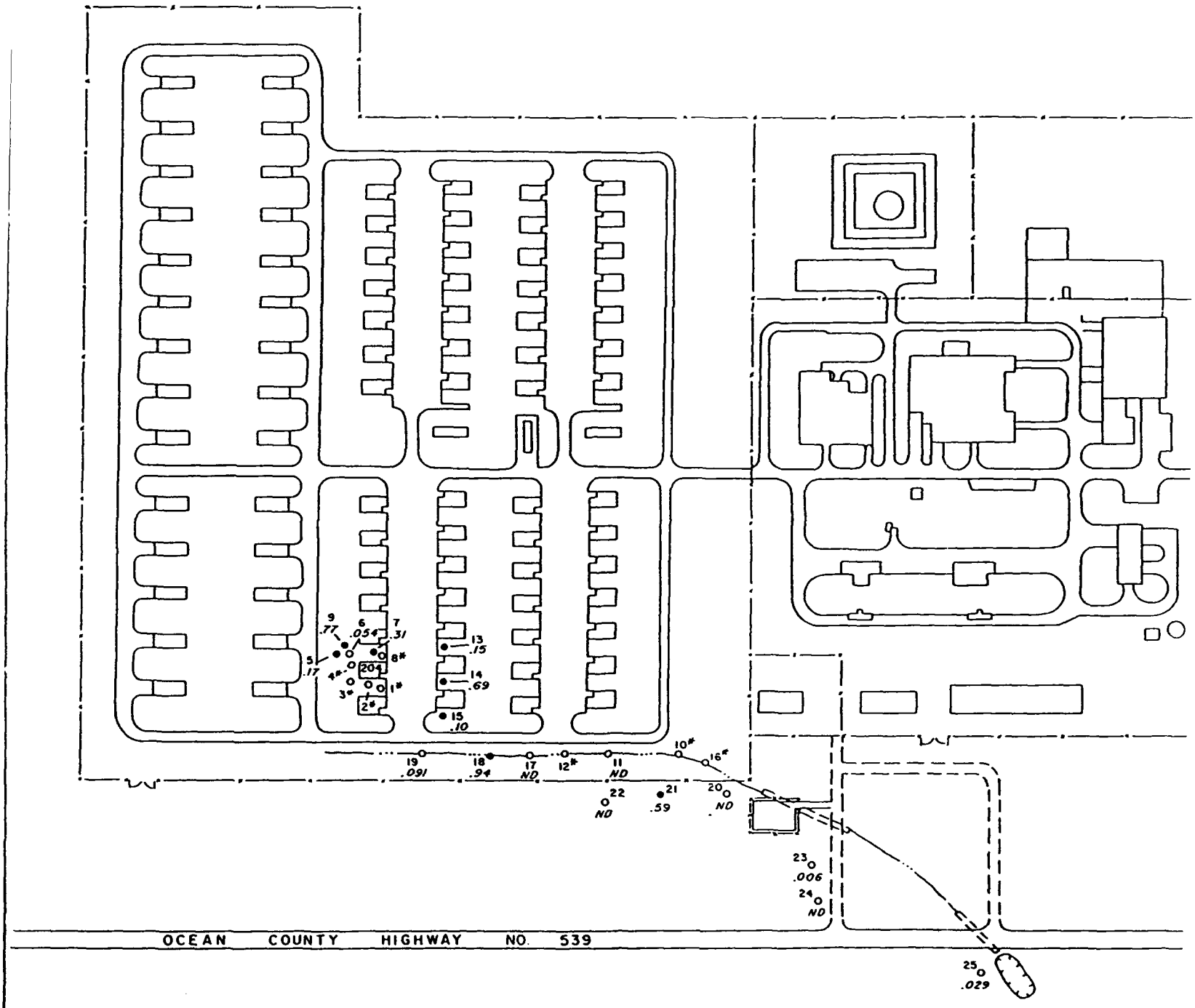
0 250 FEET

SCALE

The Earth Technology Corporation

FIGURE 4-21

CONCENTRATIONS OF PU-239 IN SOIL SAMPLES COLLECTED FROM WITHIN THE 4- TO 6- FT INTERVAL IN EACH BOREHOLE, BOMARC MISSILE SITE


9
.77
6
.054
7
.31
5
.17
4#
204
8#
3#
1#
2#
13
.15
14
.69
15
.10
19
.091
18
.94
17
ND
12#
11
ND
10#
16#
22
ND
21
.59
20
ND
23
.006
24
ND
25
.029
OCEAN COUNTY HIGHWAY NO. 539

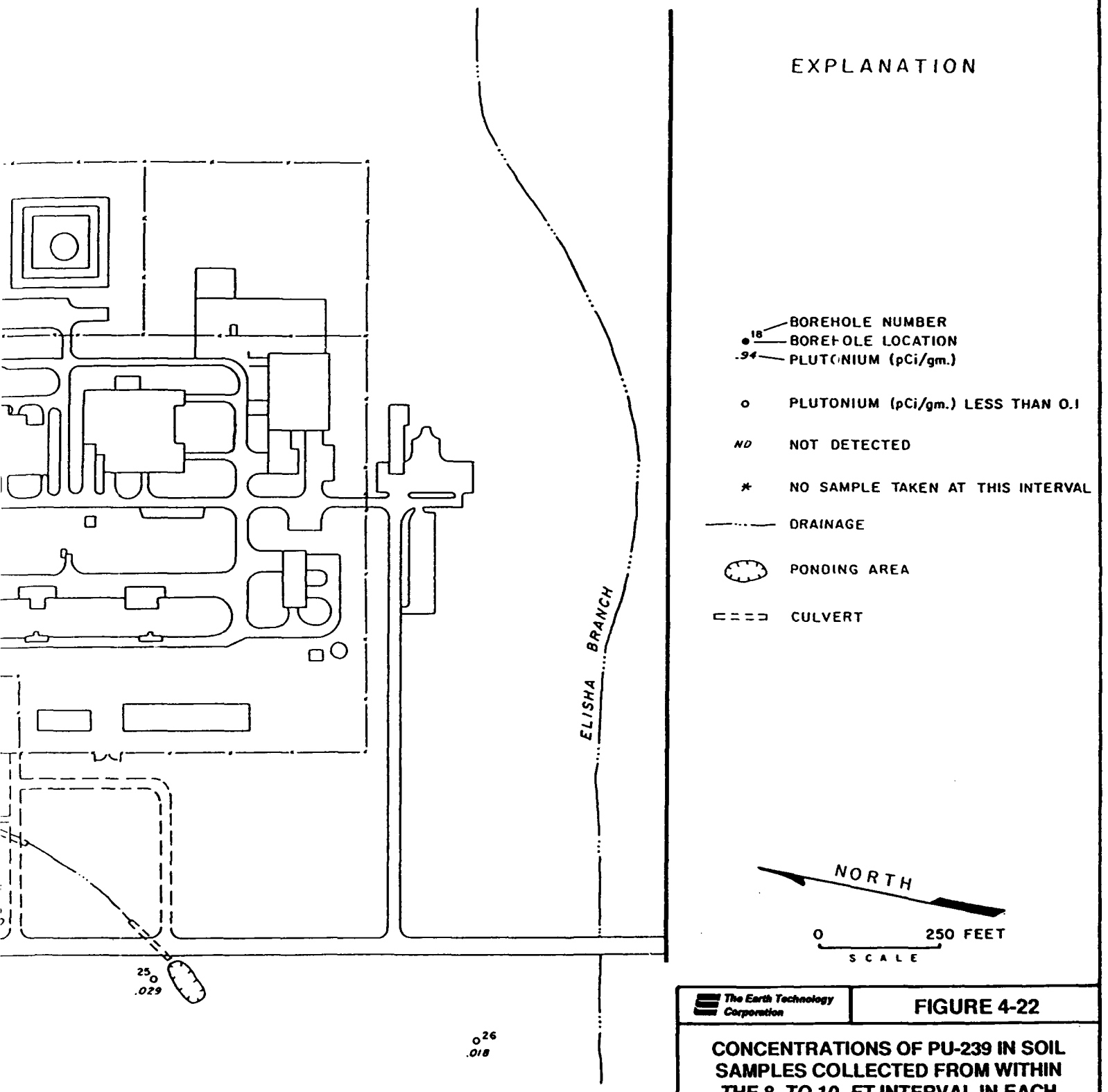


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FIGURE 4-22

CONCENTRATIONS OF PU-239 IN SOIL SAMPLES COLLECTED FROM WITHIN THE 8- TO 10- FT INTERVAL IN EACH BOREHOLE, BOMARC MISSILE SITE

Table 4-25

Analytical Data for Shallow Soil Samples from Concrete Core Locations at BOMARC Missile Site

Sample ID	Coring Location Number	Date Collected	Time Collected	Depth Interval	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)
001-SL-C01-001	241	08-09-89	1120	0-6"	Pu-239	PRO-032-10	0.04	1.5 +-0.2E-01
001-SL-C01-002	241	08-09-89	1120	6-12"	Pu-239	PRO-032-10	0.04	3.6 +-0.6E-01
001-SL-C01-003	241	08-09-89	1120	12-18"	Pu-239	PRO-032-10	0.04	1.9 +-0.4E-01
001-SL-C02-001	249	08-11-89	0853	0-6"	Pu-239	PRO-032-10	0.04	4.9 +-2.4E-02
001-SL-C02-002	249	08-11-89	0853	6-12"	Pu-239	PRO-032-10	0.04	6.2 +-2.0E-02
001-SL-C02-003	249	08-11-89	0853	12-18"	Pu-239	PRO-032-10	0.04	NA*
001-SL-C03-001	175	09-13-89	1535	0-6"	Pu-239	PRO-032-10	0.04	2.0 +-0.5E-01
001-SL-C03-002	175	09-13-89	1535	6-12"	Pu-239	PRO-032-10	0.04	4.2 +-1.8E-01
001-SL-C03-003	175	09-13-89	1535	12-18"	Pu-239	PRO-032-10	0.04	1.8 +-0.4E-01
001-SL-C04-001	172	09-13-89	1450	0-6"	Pu-239	PRO-032-10	0.04	3.2 +-0.3E 00
001-SL-C04-002	172	09-13-89	1450	6-12"	Pu-239	PRO-032-10	0.04	1.3 +-0.5E-01
001-SL-C04-003	172	09-13-89	1450	12-18"	Pu-239	PRO-032-10	0.04	1.1 +-0.2E 00
001-SL-C05-001	158	09-13-89	1700	0-6"	Pu-239	PRO-032-10	0.04	2.8 +-1.7E-01
001-SL-C05-002	158	09-13-89	1700	6-12"	Pu-239	PRO-032-10	0.04	3.3 +-0.7E-02
001-SL-C05-003	158	09-13-89	1700	12-18"	Pu-239	PRO-032-10	0.04	2.1 +-0.3E-01
001-SL-C06-001	118	09-15-89	1035	0-6"	Pu-239	PRO-032-10	0.04	6.9 +-4.7E-02
001-SL-C06-002	118	09-15-89	1035	6-12"	Pu-239	PRO-032-10	0.04	9.8 +-2.9E-02
001-SL-C06-003	118	09-15-89	1035	12-18"	Pu-239	PRO-032-10	0.04	3.2 +-1.9E-02
001-SL-C07-001	105	09-15-89	1101	0-6"	Pu-239	PRO-032-10	0.04	1.5 +-0.3E-01
001-SL-C07-002	105	09-15-89	1101	6-12"	Pu-239	PRO-032-10	0.04	5.4 +-2.3E-02
001-SL-C07-003	105	09-15-89	1101	12-18"	Pu-239	PRO-032-10	0.04	4.6 +-2.4E-02
001-SL-C08-001	61	09-15-89	1715	0-6"	Pu-239	PRO-032-10	0.04	5.8 +-0.3E 00
001-SL-C08-002	61	09-15-89	1715	6-12"	Pu-239	PRO-032-10	0.04	<2.0E-02
001-SL-C08-003	61	09-15-89	1715	12-18"	Pu-239	PRO-032-10	0.04	8.0 +-2.1E-02
001-SL-C10-001	64	09-15-89	1605	0-6"	Pu-239	PRO-032-10	0.04	1.2 +-0.1E+02
001-SL-C10-002	64	09-15-89	1605	6-12"	Pu-239	PRO-032-10	0.04	6.7 +-0.2E 00
001-SL-C10-003	64	09-15-89	1605	12-18"	Pu-239	PRO-032-10	0.04	2.0 +-0.6E-01
001-SL-C11-001	102	09-15-89	1122	0-6"	Pu-239	PRO-032-10	0.04	6.3 +-0.2E 00
001-SL-C11-002	102	09-15-89	1122	6-12"	Pu-239	PRO-032-10	0.04	1.1 +-0.1E 00
001-SL-C11-003	102	09-15-89	1122	12-18"	Pu-239	PRO-032-10	0.04	5.0 +-0.5E-01

Table 4-25 (continued)

Analytical Data for Shallow Soil Samples from Concrete Core Locations at BOMARC Missile Site

Coring Location Sample ID	Date Number	Time Collected	Depth Collected	Interval	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)
001-SL-C12-001	69	09-15-89	1501	0-6"	Pu-239	PRO-032-10	0.04	1.0 +-0.2E-01
001-SL-C12-002	69	09-15-89	1501	6-12"	Pu-239	PRO-032-10	0.04	1.1 +-0.3E-01
001-SL-C12-003	69	09-15-89	1501	12-18"	Pu-239	PRO-032-10	0.04	3.1 +-1.7E-02
001-SL-C13-001	56	09-15-89	1545	0-6"	Pu-239	PRO-032-10	0.04	2.7 +-0.4E-01
001-SL-C13-002	56	09-15-89	1545	6-12"	Pu-239	PRO-032-10	0.04	7.7 +-1.8E-02
001-SL-C13-003	56	09-15-89	1545	12-18"	Pu-239	PRO-032-10	0.04	1.1 +-0.1E 00
001-SL-C14-001	34	10-13-89	0846	0-6"	Pu-239	PRO-032-10	0.04	2.6 +-0.1E 00
001-SL-C14-002	34	10-13-89	0846	6-12"	Pu-239	PRO-032-10	0.04	1.7 +-0.5E-01
001-SL-C14-003	34	10-13-89	0846	12-18"	Pu-239	PRO-032-10	0.04	8.5 +-1.8E-02
001-SL-C15-001	15	10-01-89	1710	0-6"	Pu-239	PRO-032-10	0.04	3.9 +-0.1E+01
001-SL-C15-002	15	10-01-89	1710	6-12"	Pu-239	PRO-032-10	0.04	2.8 +-0.3E-01
001-SL-C15-003	15	10-01-89	1710	12-18"	Pu-239	PRO-032-10	0.04	3.1 +-0.6E-01
001-SL-C16-002	29	09-15-89	1710	6-12"	Pu-239	PRO-032-10	0.04	8.0 +-0.7E-01
001-SL-C16-003	29	09-15-89	1710	12-18"	Pu-239	PRO-032-10	0.04	2.8 +-0.5E-01
001-SL-C17-001	142	09-15-89	0910	0-6"	Pu-239	PRO-032-10	0.04	7.7 +-0.6E-01
001-SL-C17-002	142	09-15-89	0910	6-12"	Pu-239	PRO-032-10	0.04	5.0 +-0.5E-01
001-SL-C17-003	142	09-15-89	0910	12-18"	Pu-239	PRO-032-10	0.04	6.9 +-0.7E-01
001-SL-C18-001	145	09-15-89	0830	0-6"	Pu-239	PRO-032-10	0.04	4.7 +-0.6E-01
001-SL-C18-002	145	09-15-89	0830	6-12"	Pu-239	PRO-032-10	0.04	3.8 +-1.4E-02
001-SL-C18-003	145	09-15-89	0830	12-18"	Pu-239	PRO-032-10	0.04	3.3 +-1.0E-02
001-SL-C19-001	331	09-28-89	1640	0-6"	Pu-239	PRO-032-10	0.04	1.5 +-0.1E+02
001-SL-C19-002	331	09-28-89	1640	6-12"	Pu-239	PRO-032-10	0.04	1.1 +-0.4E-01
001-SL-C19-003	331	09-28-89	1640	12-18"	Pu-239	PRO-032-10	0.04	2.6 +-0.6E-01
001-SL-C20-001	332	09-28-89	1615	0-6"	Pu-239	PRO-032-10	0.04	1.0 +-0.1E+02
001-SL-C20-002	332	09-28-89	1615	6-12"	Pu-239	PRO-032-10	0.04	1.4 +-0.1E+03
001-SL-C20-003	332	09-28-89	1615	12-18"	Pu-239	PRO-032-10	0.04	3.6 +-0.1E 00
001-SL-C21-002	333	09-28-89	1305	6-12"	Pu-239	PRO-032-10	0.04	1.9 +-0.9E 00
001-SL-C21-003	333	09-28-89	1305	12-18"	Pu-239	PRO-032-10	0.04	1.3 +-0.1E 00

* Not analyzed

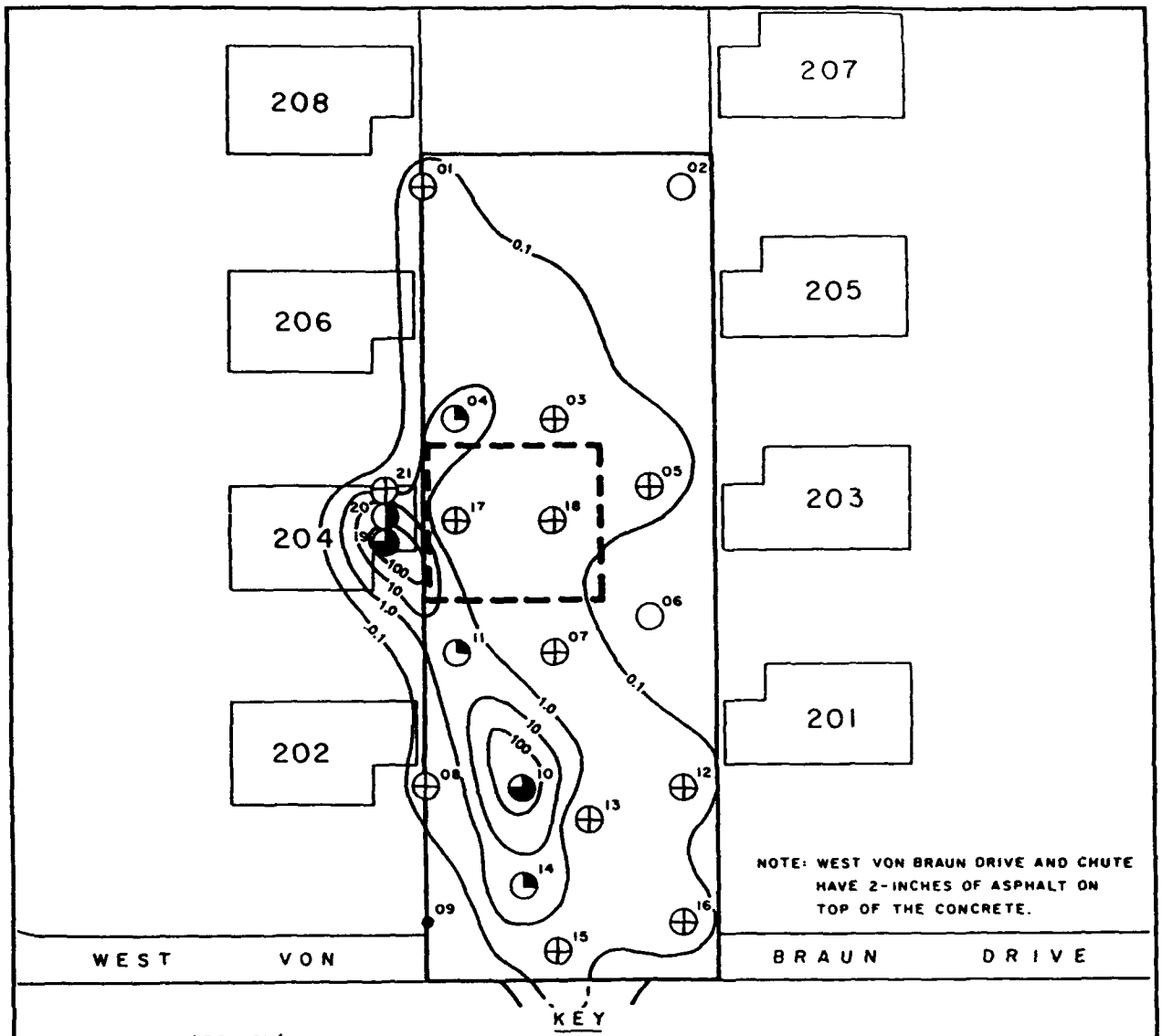

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FIGURE 4-23

CONCENTRATIONS OF PU-239 IN SOIL SAMPLES COLLECTED FROM THE 0- TO 6- INCH INTERVAL BELOW EACH CONCRETE CORE, BOMARC MISSILE SITE

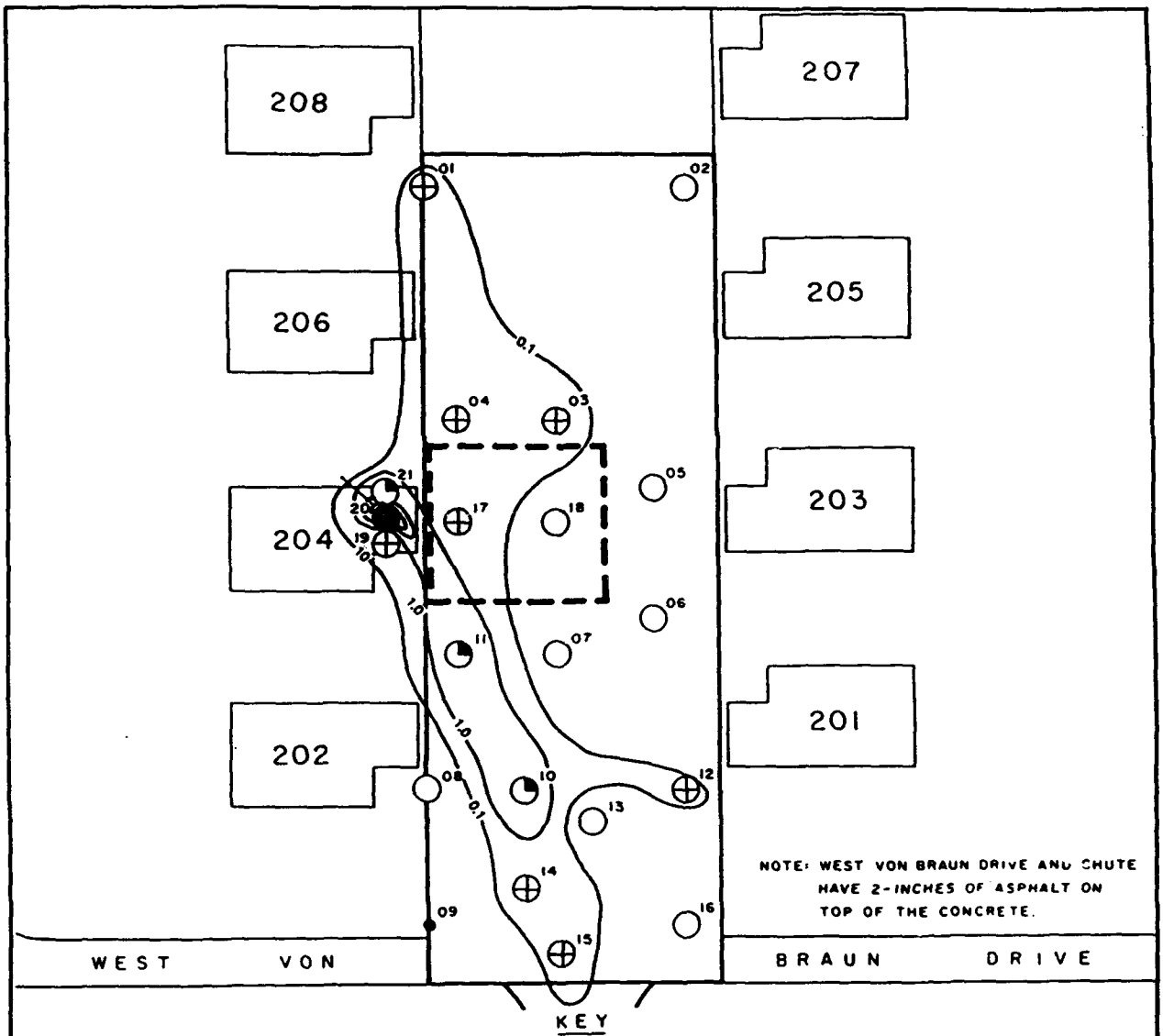

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FIGURE 4-24

CONCENTRATIONS OF PU-239 IN SOIL SAMPLES COLLECTED FROM THE 6- TO 12- INCH INTERVAL BELOW EACH CONCRETE CORE, BOMARC MISSILE SITE

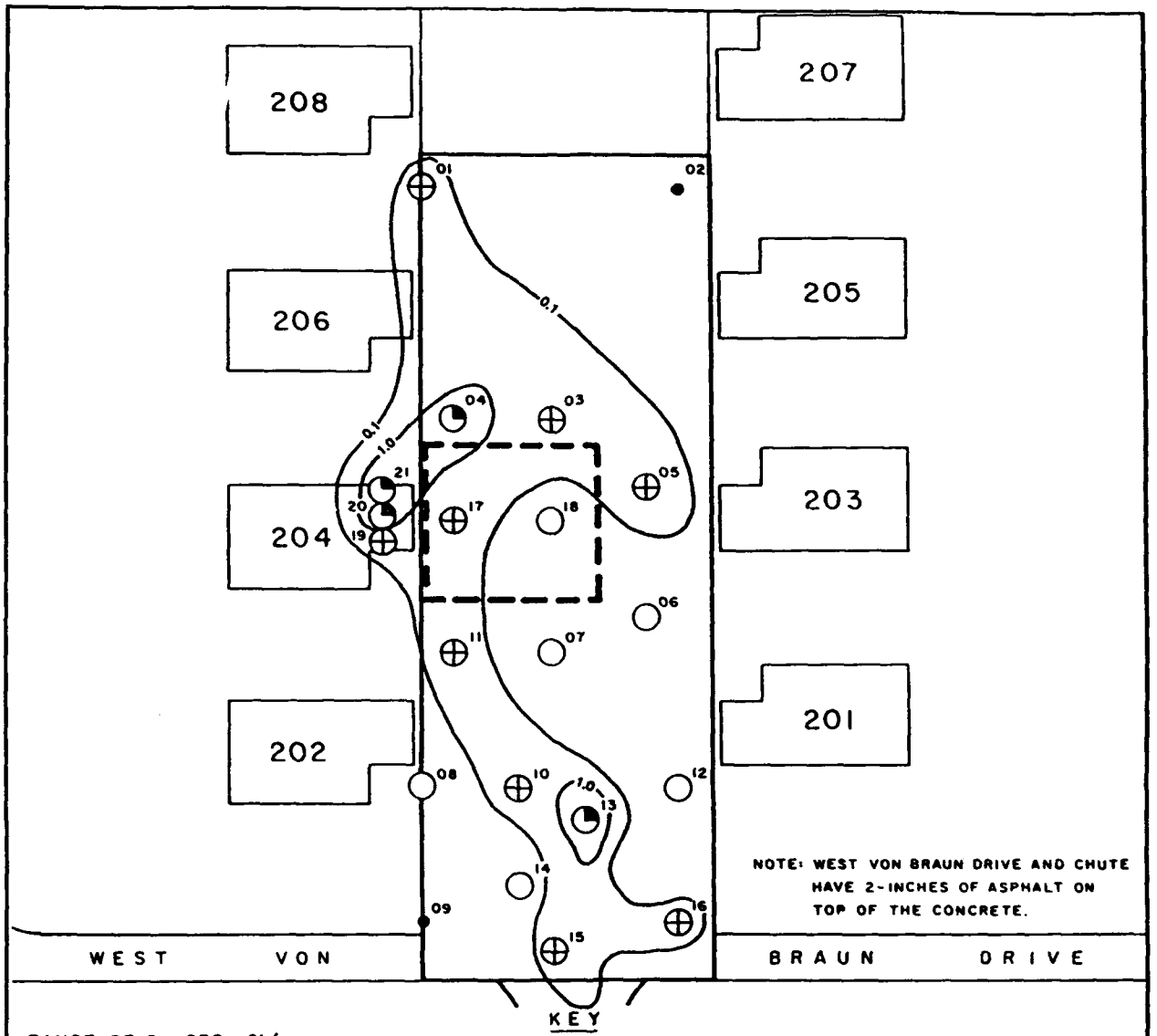

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FIGURE 4-25

CONCENTRATIONS OF PU-239 IN SOIL SAMPLES COLLECTED FROM THE 12- TO 18- INCH INTERVAL BELOW EACH CONCRETE CORE, BOMARC MISSILE SITE

Eight soil samples from three separate depth intervals were collected from the inside of Shelter 204 for Pu-239 analysis and the results are listed in Table 4-25. Soil samples collected from the 0 to 6 inch depth interval contained Pu-239 concentrations ranging from 1.9 to 150 pCi/gm (Figure 4-23). Soil samples collected from the 6 to 12 inch depth interval contained Pu-239 concentrations ranging from 0.11 to 1,400 pCi/gm (Figure 4-24). Soil samples collected from the 12 to 18-inch depth interval contained Pu-239 concentrations ranging from 0.26 to 3.6 pCi/gm (Figure 4-25).

When comparing the depth intervals and the values of the Pu-239 concentrations, there is a general trend of the Pu-239 concentrations decreasing with depth. Pu-239 is relatively insoluble in water and tends to adhere to soil. Therefore it appears that the Pu-239 has not been transported deeply into the soil. However, concrete core data (Table 4-25), indicate a lack of Pu-239 contamination. Because of this, it is possible that the Pu-239 contamination was introduced into the soil during the concrete core drilling process and exacerbated during the core sampling process. Screening of the core sides with the PAC-4G indicated some contamination. This contamination was removable with a paper towel, which indicates that the Pu-239 was freshly introduced.

During concrete coring, water was used to lubricate the coring bit and keep Pu-239 dust particles from becoming airborne. Plutonium-239-contaminated water was collected with a HEPA filter vacuum. At drilling locations within Shelter 204 more water than normal was needed while drilling through 18 inches of concrete, and not all of the water could be vacuumed up until the drill bit had penetrated the concrete. The contaminated drill water flowing out of the core bit possibly contaminated the soil at the bottom of the corehole.

In addition to the plutonium sampling, eight soil samples from beneath the concrete pad and the asphalt drainage ditch were collected for chemical analysis. The results from these analyses are displayed in Tables 4-26, 4-27 and 4-28. Volatile organic and semi-volatile organic compounds were detected in the soil samples. There were no pesticide/PCB contaminants detected in the soil samples. Concentrations of metals detected were within naturally-occurring background ranges.

Table 4-26 shows volatile organics detected in the eight soil samples. Acetone was detected in two of the samples at concentrations of 0.027 and 0.020 mg/kg. Other contaminants are attributed to laboratory contamination due to their presence in blank samples.

Table 4-27 shows semi-volatile organics detected in the eight soil samples. Diethylphthalate, phenanthrene, fluoranthene, pyrene, butylbenzyphthalate, di-n-octylphthalate, and benzoic acid are found in low parts per billion levels. Bis(2-ethylhexyl)phthalate was found in slightly higher concentrations in most of the samples.

Table 4-26

Volatile Organics Detected in Soil Samples

Analyte*	Units	CRQL	001-SL-AP1	001-SL-AP2	001-SL-AP3	001-SL-AP4
Methylene Chloride	mg/kg	.005	.005 (J,B)	.006 (B)	.006 (B)	.004 (J,B)
Chloroform	mg/kg	.005	.009	--	.009 (B)	.006 (B)
Acetone	mg/kg	.010	--	.027	--	--

Analyte*	Units	CRQL	001-SL-AP5 (dup of AP3)	001-CC-C01	001-CC-C02	001-CC-C21
Methylene Chloride	mg/kg	.005	.004 (J,B)	.007 (B)	.004 (J,B)	--
Chloroform	mg/kg	.005	.007 (B)	.009 (B)	.008 (B)	--
Acetone	mg/kg	--	--	--	--	.020

J = Estimated Value
B = Detected in Blank Sample
CRQL = Contract Required Quantitation Limit
* = EPA CLP methodology was used for all analysis

Table 4-27

Semi-Volatile Organics Detected in Soil Samples

Analyte*	Units	CRQL	Sample Identification 001-SL-AP1	001-SL-AP2	001-SL-AP3	001-SL-AP4	001-SL-AP5
Diethylphthalate	mg/kg	.330	.120 (J,B)	.090 (J,B)	.080 (J,B)	.060 (J,B)	.060 (J,B)
Phenathrene	mg/kg	.330	.060 (J)	--	--	--	--
Fluoranthene	mg/kg	.330	.110 (J)	.040 (J)	--	--	--
Pyrene	mg/kg	.330	.140 (J)	.040 (J)	--	--	--
Butylbenzyl Phthalate	mg/kg	.330	.080 (J)	--	--	--	--
bis(20ethylhexyl)phthalate	mg/kg	.330	.780	.650	.820	.410	.450
Di-n-Octylphthalate	mg/kg	.330	.050 (J)	--	--	--	--
Benzoic Acid	mg/kg	1.600	--	--	--	.050 (J)	--

Analyte*	Units	CRQL	Sample Identification 001-CC-C01	001-CC-C02	001-CC-21
Diethylphthalate	mg/kg	.330	.040 (J,B)	--	--
Phenathrene	mg/kg	.330	--	--	--
Fluoranthene	mg/kg	.330	--	--	--
Pyrene	mg/kg	.330	--	--	--
Butylbenzyl Phthalate	mg/kg	.330	--	--	--
bis(20ethylhexyl)phthalate	mg/kg	.330	.170 (J)	--	.320
Di-n-Octylphthalate	mg/kg	.330	--	--	--
Benzoic Acid	mg/kg	1.600	--	--	--

J = Estimated Value
B = Detected in Blank Sample

CRQL = Contract Required Quantitation Limit
* = EPA CLP methodology was used for all analyses

Table 4-28

Metals Detected in Soil Samples

Analyte	Units	CRDL	001-SL-AP1	001-SL-AP2	001-SL-AP3	001-SL-AP4	001-SL-AP5
Aluminum	mg/kg	40	1830	1133	604.5	607.4	1036
Antimony	mg/kg	12	ND	ND	ND	ND	ND
Arsenic	mg/kg	2	0.94(B)	ND	ND	ND	ND
Barium	mg/kg	40	2.5(B)	ND	ND	ND	ND
Beryllium	mg/kg	1	ND	ND	ND	ND	ND
Cadmium	mg/kg	1	ND	ND	ND	ND	ND
Calcium	mg/kg	1000	305(B)	146.1(B)	79.8(B)	59.5(B)	110.9(B)
Chromium	mg/kg	2	16.6	46.0	22.0	14.9	16.0
Cobalt	mg/kg	10	ND	ND	ND	ND	ND
Copper	mg/kg	5	ND	2.7(B)	ND	ND	ND
Iron	mg/kg	20	2456	3586	2283	2745	3150
Lead	mg/kg	1	12.5	5.9	4.3	5.7	3.7
Magnesium	mg/kg	1000	102(B)	73.5(B)	22.4(B)	38.9(B)	39.2(B)
Manganese	mg/kg	3	6.3	11.7	5.2	4.5	5.0
Mercury	mg/kg	0.2	ND	ND	ND	ND	ND
Nickel	mg/kg	8	ND	22.0	8.4	5.9(B)	5.6(B)
Potassium	mg/kg	1000	ND	ND	ND	ND	ND
Selenium	mg/kg	1	ND	ND	ND	ND	ND
Silver	mg/kg	2	ND	ND	ND	ND	ND
Sodium	mg/kg	1000	52.8(B)	29.1	27.0(B)	21.6(B)	27.4
Thallium	mg/kg	2	ND	ND	ND	ND	ND
Vanadium	mg/kg	10	ND	ND	ND	ND	ND
Zinc	mg/kg	4	12.6	21.4	6.3	15.2	7.8

Table 4-28 (continued)

Metals Detected in Soil Samples

Analyte*	Units	CRDL	001-CC-C01	001-CC-C02	001-CC-C21	001-SL-BK1*	001-SL-BK2*
Aluminum	mg/kg	40	10900	3302	1623(E)	4970(E)	2065(E)
Antimony	mg/kg	12	ND	ND	ND(N)	ND(N)	ND(N)
Arsenic	mg/kg	2	0.93(B)	ND	ND	ND	1.1(B)
Barium	mg/kg	40	96.6	3.2(B)	ND	6.8(B)	7.7(B)
Beryllium	mg/kg	1	0.42(B)	ND	ND	ND	0.3(B)
Cadmium	mg/kg	1	ND	ND	ND	ND	ND
Calcium	mg/kg	1000	5419	279.3(B)	28.7(B)	22.1(B)	127.1(B)
Chromium	mg/kg	2	49.8	17.4	4.2	6.9	7.7
Cobalt	mg/kg	10	15.2	ND	ND	ND	1.7(B)
Copper	mg/kg	5	22.4	26.1	33.1	ND	6.8
Iron	mg/kg	20	4195	5304	2417	3716	3513
Lead	mg/kg	1	2.8	3.6	3.0(N)	2.8(N)	130.9(N)
Magnesium	mg/kg	1000	2306	156.7(B)	30.6(B)	129.8(B)	145.9(B)
Manganese	mg/kg	3	102.6	8.6	5.3(E)	8.3(E)	14.0(E)
Mercury	mg/kg	0.2	ND	ND	ND	ND	ND
Nickel	mg/kg	8	ND	3.9(B)	ND	ND	ND
Potassium	mg/kg	1000	1015(B)	ND	ND	ND	ND
Selenium	mg/kg	1	1.5	ND	ND(N)	0.5(B,N)	ND(N)
Silver	mg/kg	2	2.9	ND	ND	ND	ND
Sodium	mg/kg	1000	75.9(B)	31.0(B)	29.7(B)	15.4	32.0(B)
Thallium	mg/kg	2	ND	ND	ND	ND	ND
Vanadium	mg/kg	10	ND	ND	ND	ND	ND
Zinc	mg/kg	4	14.3	13.5	13.0	5.6(E)	16.7(E)

* = Background samples.
B = Below contract required detection limit.
E = Estimated value due to the presence of interference.
N = Spike sample recovery not within control limits.
ND = Non-detection
CRDL = Contract-required detection limit.

Concentrations of total semi-volatile detected in soil samples were generally less than 1 mg/kg and were in no case as great as 2 mg/kg. Phthalates are commonly used in a variety of products as plasticizer, and as a consequence, are widespread in the environment. Their presence is possibly due to anthropogenic background effects, rather than site activities. Other compounds detected are asphalt components and are probably present due to leaching from the asphalt cover in the ditch.

Table 4-28 shows metal concentrations detected in the eight soil samples and two background soil samples. Metal concentrations observed in most of the samples are within the ranges observed in background soil samples and are therefore attributed to background conditions. Lead levels range from 2.8 to 12.5 mg/kg with one background sample reaching 130.9 mg/kg. The high background level for lead in this sample is probably due to automobile traffic on New Jersey Route 539, adjacent to the sampling site.

For sample 001-CC-C01 elevated levels of several metals were observed. Levels of aluminum, barium, calcium, cobalt, magnesium, and manganese were an order of magnitude above levels observed in any other sample, including background samples. Calcium, aluminum, and magnesium are major components of cement, so the probable source for these metals is the concrete that was cored to allow access for soil sampling. Concrete dust or water used to lubricate and cool the drill bit probably contaminated the sample and was the cause of not only elevated calcium, aluminum, and magnesium, but also barium, cobalt, and manganese, which can be present in cement in small quantities. Since the sampling location is up-grade from Shelter 204 and beneath the asphalt apron, it is unlikely that metals associated with the missile accident contaminated the sample.

Tentatively identified compounds (TICs) were detected in soil sample 001-SL-AP3 collected for volatile organic analysis. TICs are compounds that are not included in the TCL, and are therefore not standardized to allow for positive identification. TICs are tentatively identified based on a mass spectral library search. Four unknown volatile organic TICs were detected in soil sample 001-SL-AP3. Estimated concentrations of these four TICs ranged from .12 to .63 mg/kg with a total concentration of 1.56 mg/kg.

TICs were detected in all eight soil samples collected for semi-volatile organic analysis. Twenty semi-volatile organic TICs were detected in each of the following soil samples: 001-SL-AP1, 001-SL-AP2, 001-SL-AP3, 001-SL-AP4, and 001-SL-AP5. Estimated concentrations of individual TICs range from .29 to 10.00 mg/kg, .29 to 7.20 mg/kg, .37 to 5.80 mg/kg, .21 to 5.90 mg/kg, and .23 to 12.00 mg/kg, respectively. Total estimated concentration of semi-volatile organic TICs for soil samples 001-SL-AP1 through 001-SL-AP5 are 37.65 mg/kg, 33.65 mg/kg, 31.40 mg/kg, 25.98 mg/kg, and 33.26 mg/kg, respectively.

Of the twenty TICs identified in the five soil samples, 13 are listed as unknown compounds in sample 001-SL-AP1, 14 in sample 001-SL-AP2, 16 in sample 001-SL-AP3, 15 in sample 001-SL-AP4, and 13 in sample 001-SL-AP5. The semi-volatile organic TICs and the concentrations of these compounds are shown in Table 4-29.

Table 4-29

Semi-Volatile Organic TICs Detected in Soil Samples

		Sample Identification		
TIC	Units	001-SL-AP1	001-SL-AP2	001-SL-AP3
3-Penten-2-one, 4-methyl-	mg/kg	.290(J)	--	--
Heptane, 2,5-Dimethyl-	mg/kg	.30 (B)	--	--
2-Pentanone, 4-Hydroxy-4-methyl-	mg/kg	7.50 (B)	6.10 (B)	5.80 (B)
Heptane, 2,3,-Dimethyl-	mg/kg	.67 (B)	.60 (B)	.58 (B)
Heptane, 3,4-Dimethyl-	mg/kg	.42 (B)	.38 (B)	.37 (B)
3-Hexyn-2-OL, 5-methyl-	mg/kg	2.50 (B)	--	--
P.P DDD	mg/kg	.60	--	--
Octane, 3-methyl-	mg/kg	--	.29	--
Octane, 2-methyl-	mg/kg	--	1.00	--
3-Hexene - 2,5-Dione	mg/kg	--	2.?1	1.10
Octane, 4-methyl-	mg/kg	--	--	--
Heptane, 3,5-Dimethyl-	mg/kg	--	--	--
Heptane, 2,4-Dimethyl-	mg/kg	--	--	--

B = Detected in blank sample

Table 4-29 (continued)

Semi-Volatile Organic TICs Detected in Soil Samples

		Sample Identification				
TIC	Units	001-SL-AP4	001-SL-AP5	001-CC-C01	001-CC-C02	001-CC-C21
3-Penten-2-one, 4-methyl-	mg/kg	--	--	.19 (B)	.20 (B)	--
Heptane, 2,5-Dimethyl-	mg/kg	--	--	--	.20 (B)	--
2-Pentanone, 4-Hydroxy-4-methyl-	mg/kg	5.10 (B)	6.10 (B)	4.8 (B)	4.50 (B)	--
Heptane, 2,3,-Dimethyl-	mg/kg	.46 (B)	.61 (B)	.46(B)	.49 (B)	.34 (B)
Heptane, 3,4-Dimethyl-	mg/kg	.29 (B)	.35 (B)	.30 (B)	.33 (B)	--
3-Hexyn-2-OL, 5-methyl-	mg/kg	--	--	--	--	--
P.P DDD	mg/kg	--	--	--	--	--
Octane, 3-methyl-	mg/kg	--	--	.18	--	--
Octane, 2-methyl-	mg/kg	--	--	.77	--	--
3-Hexene - 2,5- Dione	mg/kg	2.40	1.20	2.50	3.20	--
Octane, 4-methyl-	mg/kg	.77	.98	--	.86	--
Heptane, 3,5-Dimethyl-	mg/kg	--	.25	--	--	--
Heptane, 2,4-Dimethyl-	mg/kg	--	4.80 (B)	--	--	--

B = Detected in blank sample

Fourteen semi-volatile organic TICs were detected in soil samples 001-CC-C01 and 001-CC-C02. Twelve semi-volatile organic TICs were detected in soil sample 001-CC-C21. Individual TIC estimated concentrations ranged from .17 to 4.80 in sample 001-CC-C01, .15 to 4.50 mg/kg in sample 001-CC-C02, and .15 to 2.70 mg/kg in sample 001-CC-C21. Total estimated concentrations of semi-volatile organic TICs for soil samples 001-CC-C01, 001-CC-C02, and 001-CC-C21 are 12.49 mg/kg, 15.74 mg/kg, and 11.22 mg/kg, respectively.

Several samples contained tentatively identified compounds (TICs) in the semivolatile fraction that were also tentatively identified in the method blank for EPA Method 625. Field sample numbers affected are as follows: 001-SL-AP1, 001-SL-AP2, 001-SL-AP3, 001-SL-AP4, 001-SL-AP5, 001-SL-CC1, 001-SL-CC2, and 001-SL-C21. TIC method blank contaminants included heptane, octane, hexene and pentanone derivatives as well as other unidentified compounds. Data were qualified as a result of the identified contamination.

Levels of nonradioactive chemical contaminants in soils are below the Federal and State Action Levels specified in draft RCRA corrective action regulations and guidance.

4.1.3.8.3 Depth Profile Samples

The Pu-239 activity from depth profile samples collected at six sampling stations is presented in Table 4-30. These results are also presented in bar charts (Figures 4-26 through 4-31). Details on sample collection methods and rationale are given in Section 3.6.2.6.4. A total of 12 sample fractions collected from Stations 001-SL-IS2, 001-SL-IS3, 001-SL-IS4, and 001-SL-IS5 recorded Pu-239 activities > 10,000 pCi/gm. These were the stations nearest Shelter 204 and along the path that contaminated water traveled during the fire-fighting effort in June 1960. The Pu-239 was found to be concentrated in the top 6 inches of soil at each of the sampling stations, with the exception of 001-SL-IS3 where high levels of activity (110,000 pCi/gm) were detected as deep as 18 inches. Only trace amounts of activity were detected in sample fractions collected from Stations 001-SL-IS6 and 001-SL-IS7.

The majority of the activity detected was in the <20 micron size fraction. The highest activity in the >20 micron fraction was 1,200 pCi/gm, detected in one sample collected from the 2 to 3 inch interval at sampling station IS2, and one sample collected from the 7 to 8 inch interval at station IS3. The highest activity levels detected in the <20 micron fraction of the same sampling intervals were 45,000 pCi/gm and 4,800 pCi/gm respectively.

The activity of three sample fractions collected from Station 001-SL-IS3 exceeded 100,000 pCi/gm. It is not unexpected that the highest activity levels were identified in samples collected from that station, since it is located at the point where water used to extinguish the Shelter 204 fire first entered the unlined drainage ditch. Since samples were not collected below 18 inches at Station 001-SL-IS3, the depth of this high activity zone is unknown.

This area of the drainage ditch was heavily contaminated by water from the fire-fighting effort and the decontamination that followed. Sampling has repeatedly demonstrated that higher levels of contamination are present here than over most of the site. In drilling through the asphalt to

Table 4-30

Analytical Data for Depth Profile Samples, Including Particle Size Characterization

Sample ID	Date Collected	Depth Interval	Fidler at Surface (cpm)	Parameter	Method	Method Detection Limit (pCi/gm)	Particle Size	Activity (pCi/gm dry)
001-SL-IS2-001	10-07-89	0-1"	40,000	Pu-239	PRO-052-32	0.04	> 20u	6.6 +-0.1E+02
001-SL-IS2-001	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	2.1 +-0.1E+04
001-SL-IS2-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	> 20u	5.7 +-0.1E+02
001-SL-IS2-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	3.8 +-0.1E+04
001-SL-IS2-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	2.1 +-0.1E+02
001-SL-IS2-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	7.9 +-0.1E+03
001-SL-IS2-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	5.5 +-0.1E+02
001-SL-IS2-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	1.9 +-0.1E+04
001-SL-IS2-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	1.2 +-0.1E+03
001-SL-IS2-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	4.5 +-0.1E+04
001-SL-IS2-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	1.2 +-0.1E+02
001-SL-IS2-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	2.6 +-0.1E+03
001-SL-IS2-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	1.2 +-0.1E+02
001-SL-IS2-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	6.2 +-0.1E+03
001-SL-IS2-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	4.0 +-0.1E+02
001-SL-IS2-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	8.5 +-0.1E+03
001-SL-IS2-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	8.9 +-0.3E 00
001-SL-IS2-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	1.6 +-0.1E+02
001-SL-IS2-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	4.0 +-0.1E+01
001-SL-IS2-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	2.7 +-0.1E+02
001-SL-IS3-001	10-07-89	0-6"	3000	Pu-239	PRO-052-32	0.04	> 20u	9.0 +-0.7E-01
001-SL-IS3-001	10-07-89	0-6"		Pu-239	PRO-052-32	0.04	< 20u	3.0 +-0.1E+01
001-SL-IS3-002	10-07-89	0-6"		Pu-239	PRO-052-32	0.04	> 20u	7.1 +-0.1E+01
001-SL-IS3-002	10-07-89	0-6"		Pu-239	PRO-052-32	0.04	< 20u	2.3 +-0.1E+02
001-SL-IS3-003	10-07-89	6-7"		Pu-239	PRO-052-32	0.04	> 20u	1.3 +-0.1E+02
001-SL-IS3-003	10-07-89	6-7"		Pu-239	PRO-052-32	0.04	< 20u	5.5 +-0.1E+02
001-SL-IS3-004	10-07-89	6-7"		Pu-239	PRO-052-32	0.04	> 20u	5.8 +-0.1E+01
001-SL-IS3-004	10-07-89	6-7"		Pu-239	PRO-052-32	0.04	< 20u	1.5 +-0.1E+05
001-SL-IS3-005	10-07-89	7-8"		Pu-239	PRO-052-32	0.04	> 20u	1.2 +-0.1E+03
001-SL-IS3-005	10-07-89	7-8"		Pu-239	PRO-052-32	0.04	< 20u	1.7 +-0.1E+04
001-SL-IS3-006	10-07-89	7-8"		Pu-239	PRO-052-32	0.04	> 20u	4.1 +-0.1E+02
001-SL-IS3-006	10-07-89	7-8"		Pu-239	PRO-052-32	0.04	< 20u	4.8 +-0.1E+03
001-SL-IS3-007	10-07-89	8-9"		Pu-239	PRO-052-32	0.04	> 20u	5.5 +-0.1E+02
001-SL-IS3-007	10-07-89	8-9"		Pu-239	PRO-052-32	0.04	< 20u	7.2 +-0.1E+03
001-SL-IS3-008	10-07-89	8-9"		Pu-239	PRO-052-32	0.04	> 20u	2.4 +-0.1E+02
001-SL-IS3-008	10-07-89	8-9"		Pu-239	PRO-052-32	0.04	< 20u	5.4 +-0.1E+03
001-SL-IS3-009	10-07-89	9-12"		Pu-239	PRO-052-32	0.04	> 20u	5.7 +-0.1E+02
001-SL-IS3-009	10-07-89	9-12"		Pu-239	PRO-052-32	0.04	< 20u	1.2 +-0.1E+05
001-SL-IS3-010	10-07-89	12-18"		Pu-239	PRO-052-32	0.04	> 20u	4.8 +-0.1E+02
001-SL-IS3-010	10-07-89	12-18"		Pu-239	PRO-052-32	0.04	< 20u	1.1 +-0.1E+05

Table 4-30 (continued)

Analytical Data for Depth Profile Samples, Including Particle Size Characterization

Sample ID	Date Collected	Depth Interval	Fidler at Surface (cpm)	Parameter	Method	Method Detection Limit (pCi/gm)	Particle Size	Activity (pCi/gm dry)
001-SL-IS3-011	10-07-89	9-12"		Pu-239	PRO-052-32	0.04	> 20u	2.7 +-0.1E+02
001-SL-IS3-011	10-07-89	9-12"		Pu-239	PRO-052-32	0.04	< 20u	2.2 +-0.1E+04
001-SL-IS3-012	10-07-89	12-18"		Pu-239	PRO-052-32	0.04	> 20u	2.8 +-0.1E 00
001-SL-IS3-012	10-07-89	12-18"		Pu-239	PRO-052-32	0.04	< 20u	5.7 +-0.1E+02
001-SL-IS4-001	10-07-89	0-1"	1800	Pu-239	PRO-052-32	0.04	> 20u	1.5 +-0.1E+02
001-SL-IS4-001	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	1.3 +-0.1E+04
001-SL-IS4-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	> 20u	4.4 +-0.1E+01
001-SL-IS4-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	4.2 +-0.1E+03
001-SL-IS4-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	1.6 +-0.1E+02
001-SL-IS4-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	9.9 +-0.1E+02
001-SL-IS4-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	6.3 +-0.1E+01
001-SL-IS4-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	6.7 +-0.1E+03
001-SL-IS4-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	1.9 +-0.1E+02
001-SL-IS4-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	1.3 +-0.1E+04
001-SL-IS4-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	1.6 +-0.1E+02
001-SL-IS4-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	6.1 +-0.1E+03
001-SL-IS4-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	2.9 +-0.1E+01
001-SL-IS4-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	5.5 +-0.1E+02
001-SL-IS4-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	1.3 +-0.1E 00
001-SL-IS4-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	1.8 +-0.1E+03
001-SL-IS4-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	1.6 +-0.1E 00
001-SL-IS4-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	1.0 +-0.1E+02
001-SL-IS4-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	1.4 +-0.3E-01
001-SL-IS4-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	8.2 +-1.8E-01
001-SL-IS5-001	10-07-89	0-1"	14,000	Pu-239	PRO-052-32	0.04	> 20u	5.4 +-0.2E 00
001-SL-IS5-001	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	1.7 +-0.2E 00
001-SL-IS5-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	> 20u	6.5 +-0.1E 00
001-SL-IS5-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	4.2 +-0.1E+02
001-SL-IS5-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	2.1 +-0.1E+01
001-SL-IS5-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	1.3 +-0.1E+02
001-SL-IS5-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	2.0 +-0.1E+02
001-SL-IS5-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	1.8 +-0.1E+04
001-SL-IS5-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	7.8 +-0.1E+01
001-SL-IS5-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	1.4 +-0.1E+04
001-SL-IS5-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	5.1 +-0.1E+01
001-SL-IS5-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	5.0 +-0.1E+02
001-SL-IS5-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	1.0 +-0.1E-01
001-SL-IS5-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	1.6 +-0.2E 00
001-SL-IS5-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	2.7 +-0.1E-01

Table 4-30 (continued)

Analytical Data for Depth Profile Samples, Including Particle Size Characterization

Sample ID	Date Collected	Depth Interval	Fidler at Surface (cpm)	Parameter	Method	Method Detection Limit (pCi/gm)	Particle Size	Activity (pCi/gm dry)
001-SL-IS5-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	3.2 +-0.1E+01
001-SL-IS5-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	6.0 +-0.5E-01
001-SL-IS5-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	1.3 +-0.4E 00
001-SL-IS5-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	2.2 +-0.1E-01
001-SL-IS5-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	2.4 +-0.4E 00
001-SL-IS6-001	10-07-89	0-1"	300	Pu-239	PRO-052-32	0.04	> 20u	5.0 +-0.1E+01
001-SL-IS6-001	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	NA*
001-SL-IS6-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	> 20u	7.1 +-0.1E+02
001-SL-IS6-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	4.1 +-0.1E+02
001-SL-IS6-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	1.5 +-0.1E+01
001-SL-IS6-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	7.9 +-0.4E 00
001-SL-IS6-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	9.1 +-0.2E+01
001-SL-IS6-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	9.8 +-0.4E+01
001-SL-IS6-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	2.2 +-0.1E+01
001-SL-IS6-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	6.2 +-0.5E 00
001-SL-IS6-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	9.1 +-0.3E 00
001-SL-IS6-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	3.6 +-0.4E 00
001-SL-IS6-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	1.1 +-0.1E 00
001-SL-IS6-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	2.1 +-0.2E 00
001-SL-IS6-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	9.1 +-0.9E-01
001-SL-IS6-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	6.9 +-0.5E 00
001-SL-IS6-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	1.7 +-0.4E-01
001-SL-IS6-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	2.6 +-0.1E+01
001-SL-IS6-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	2.3 +-0.2E-01
001-SL-IS6-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	1.9 +-0.4E 00
001-SL-IS7-001	10-07-89	0-1"	13,000 -	Pu-239	PRO-052-32	0.04	> 20u	1.9 +-0.1E+01
001-SL-IS7-001	10-07-89	0-1"	14,000	Pu-239	PRO-052-32	0.04	< 20u	7.6 +-0.1E+01
001-SL-IS7-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	> 20u	1.2 +-0.1E+01
001-SL-IS7-002	10-07-89	0-1"		Pu-239	PRO-052-32	0.04	< 20u	1.2 +-0.1E+03
001-SL-IS7-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	1.3 +-0.1E+01
001-SL-IS7-003	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	9.4 +-0.3E+01
001-SL-IS7-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	> 20u	2.6 +-0.1E+02
001-SL-IS7-004	10-07-89	1-2"		Pu-239	PRO-052-32	0.04	< 20u	1.1 +-0.1E+03
001-SL-IS7-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	8.9 +-0.2E 00
001-SL-IS7-005	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	6.8 +-0.3E+01
001-SL-IS7-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	> 20u	1.5 +-0.1E+01
001-SL-IS7-006	10-07-89	2-3"		Pu-239	PRO-052-32	0.04	< 20u	4.2 +-0.3E+01
001-SL-IS7-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	6.0 +-0.5E-01
001-SL-IS7-007	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	3.4 +-0.6E 00

Table 4-30 (continued)

Analytical Data for Depth Profile Samples, Including Particle Size Characterization

Sample ID	Date Collected	Depth Interval	Fidler at Surface (cpm)	Parameter	Method	Method Detection Limit (pCi/gm)	Particle Size	Activity (pCi/gm dry)
001-SL-IS7-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	> 20u	1.3 +-0.1E 00
001-SL-IS7-008	10-07-89	3-6"		Pu-239	PRO-052-32	0.04	< 20u	1.5 +-0.1E+01
001-SL-IS7-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	4.3 +-0.8E-01
001-SL-IS7-009	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	3.9 +-0.1E+02
001-SL-IS7-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	> 20u	1.4 +-0.1E-01
001-SL-IS7-010	10-07-89	6-12"		Pu-239	PRO-052-32	0.04	< 20u	1.3 +-0.1E 00

* There was not sufficient sample after sieving (20 micron) to analyze for sample #97772

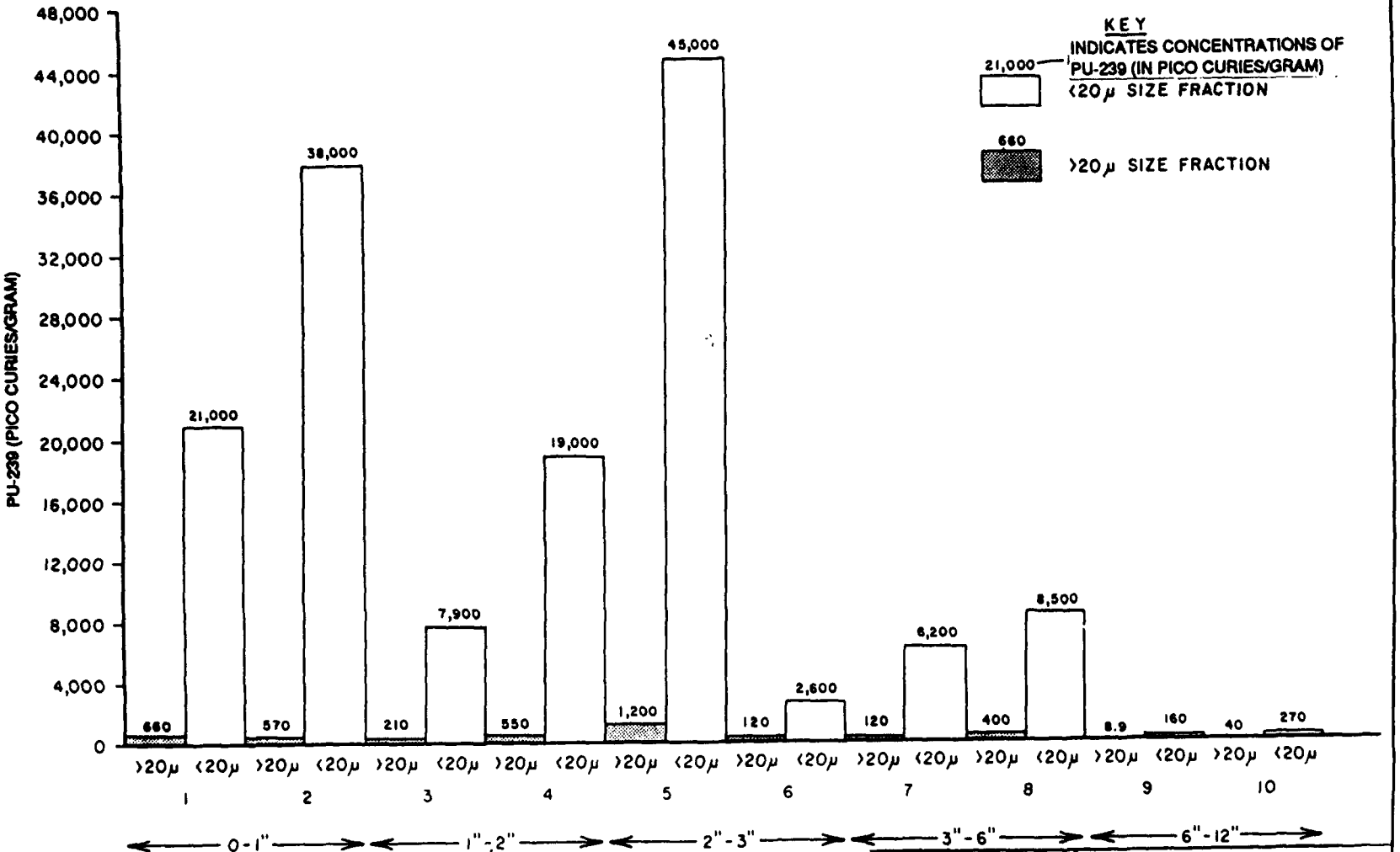

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FIGURE 4-26

CONCENTRATIONS OF PU-239 (in pCi/g) WITH RESPECT TO DEPTH AND PARTICLE-SIZE DISTRIBUTION FOR SAMPLE 001-SL-IS2, BOMARC MISSILE SITE

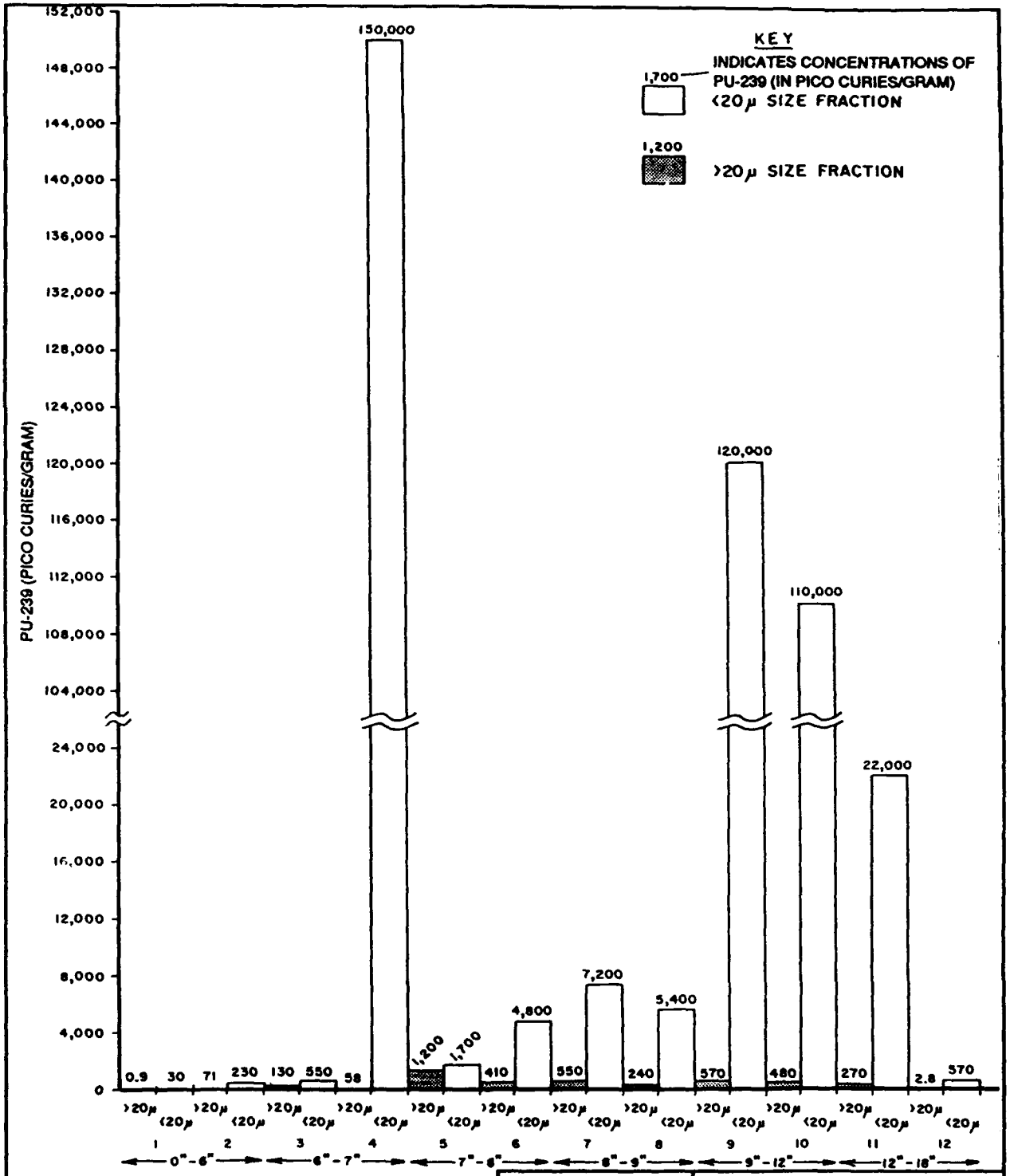

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FIGURE 4-27

CONCENTRATIONS OF PU-239 (in pCi/g) WITH RESPECT TO DEPTH AND PARTICLE-SIZE DISTRIBUTION FOR SAMPLE 001-SL-IS3, BOMARC MISSILE SITE

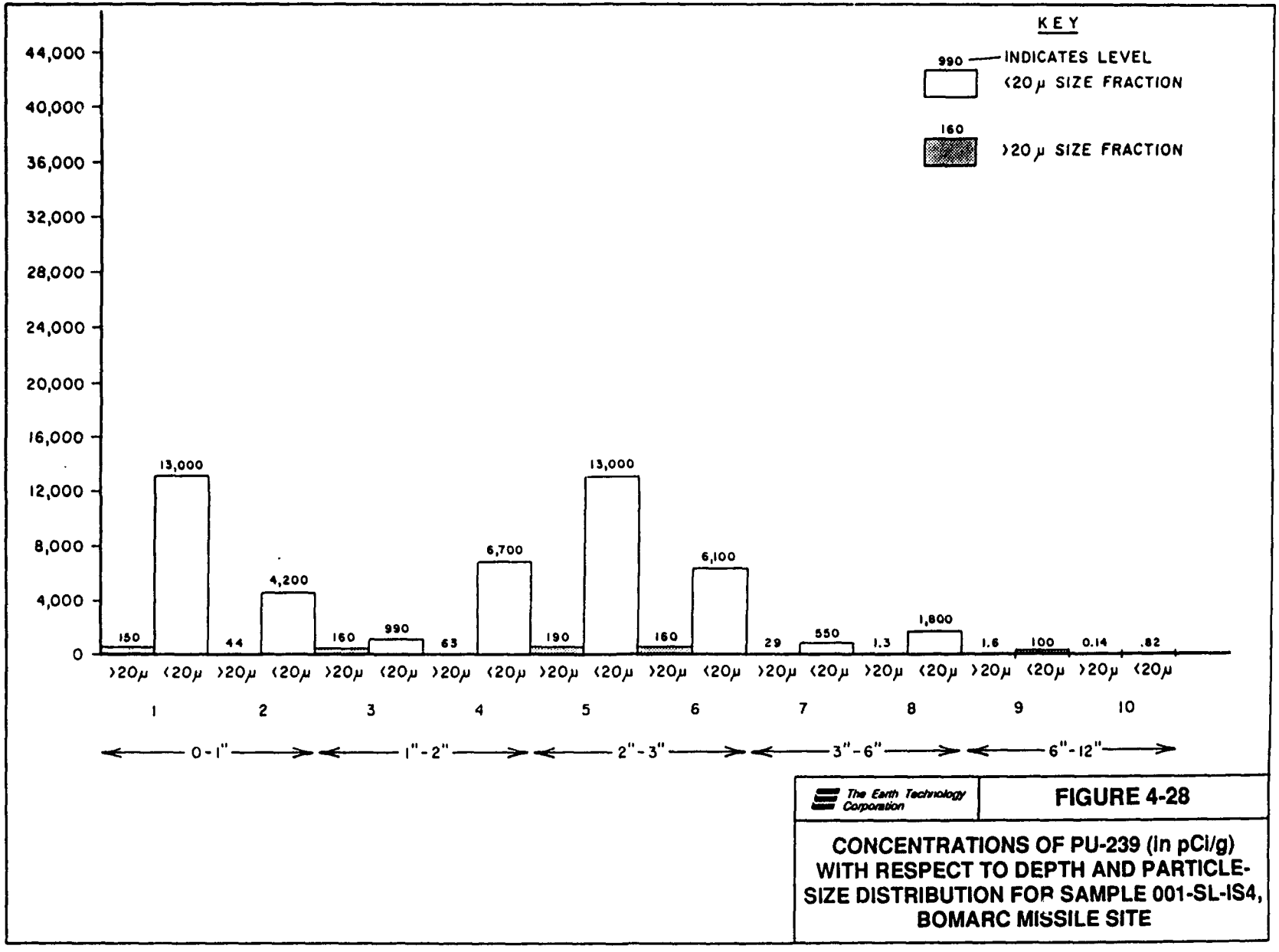

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FIGURE 4-28

CONCENTRATIONS OF PU-239 (in pCi/g) WITH RESPECT TO DEPTH AND PARTICLE-SIZE DISTRIBUTION FOR SAMPLE 001-SL-IS4, BOMARC MISSILE SITE

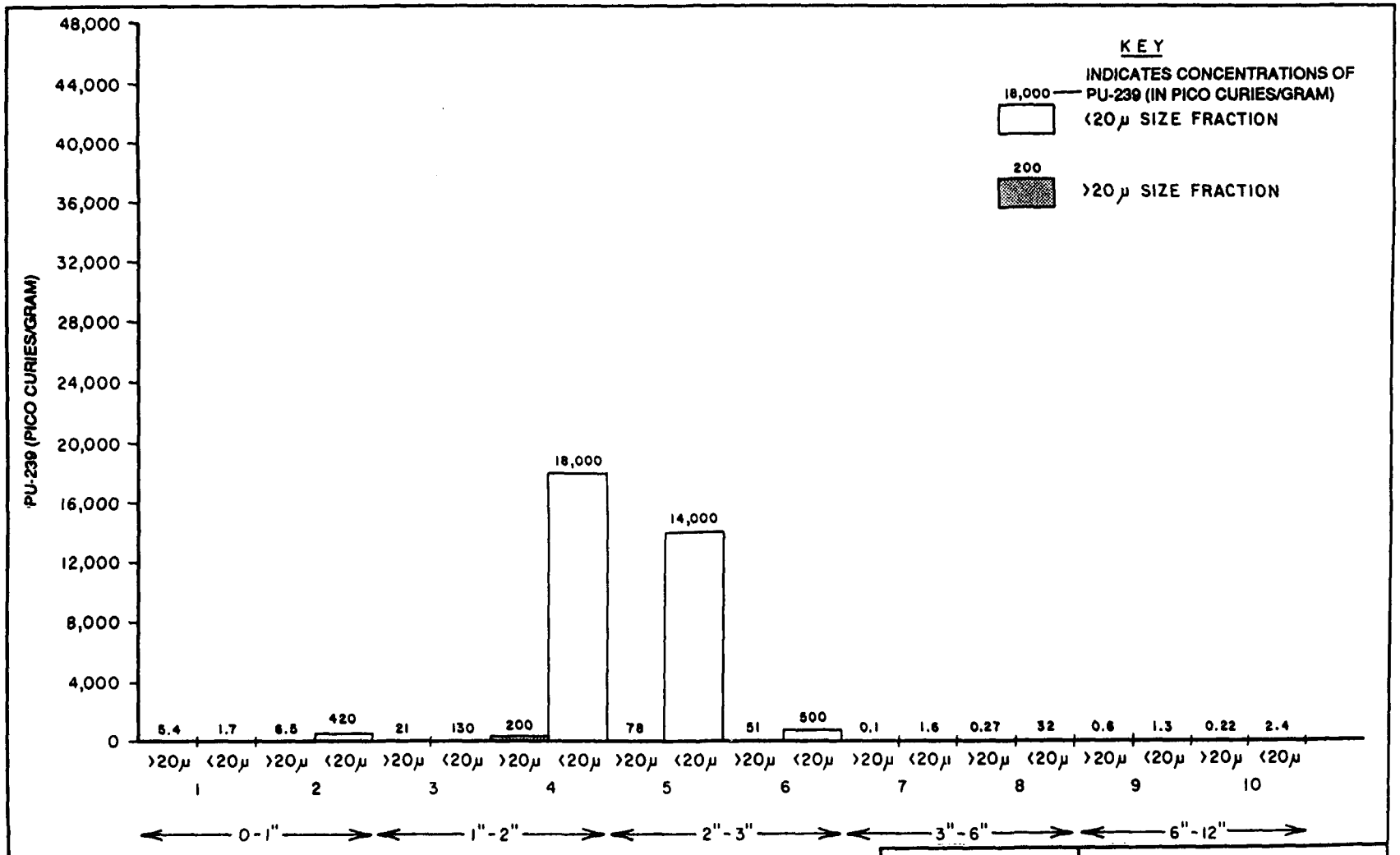

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FIGURE 4-29

CONCENTRATIONS OF PU-239 (in pCi/g) WITH RESPECT TO DEPTH AND PARTICLE-SIZE DISTRIBUTION FOR SAMPLE 001-SL-IS5, BOMARC MISSILE SITE

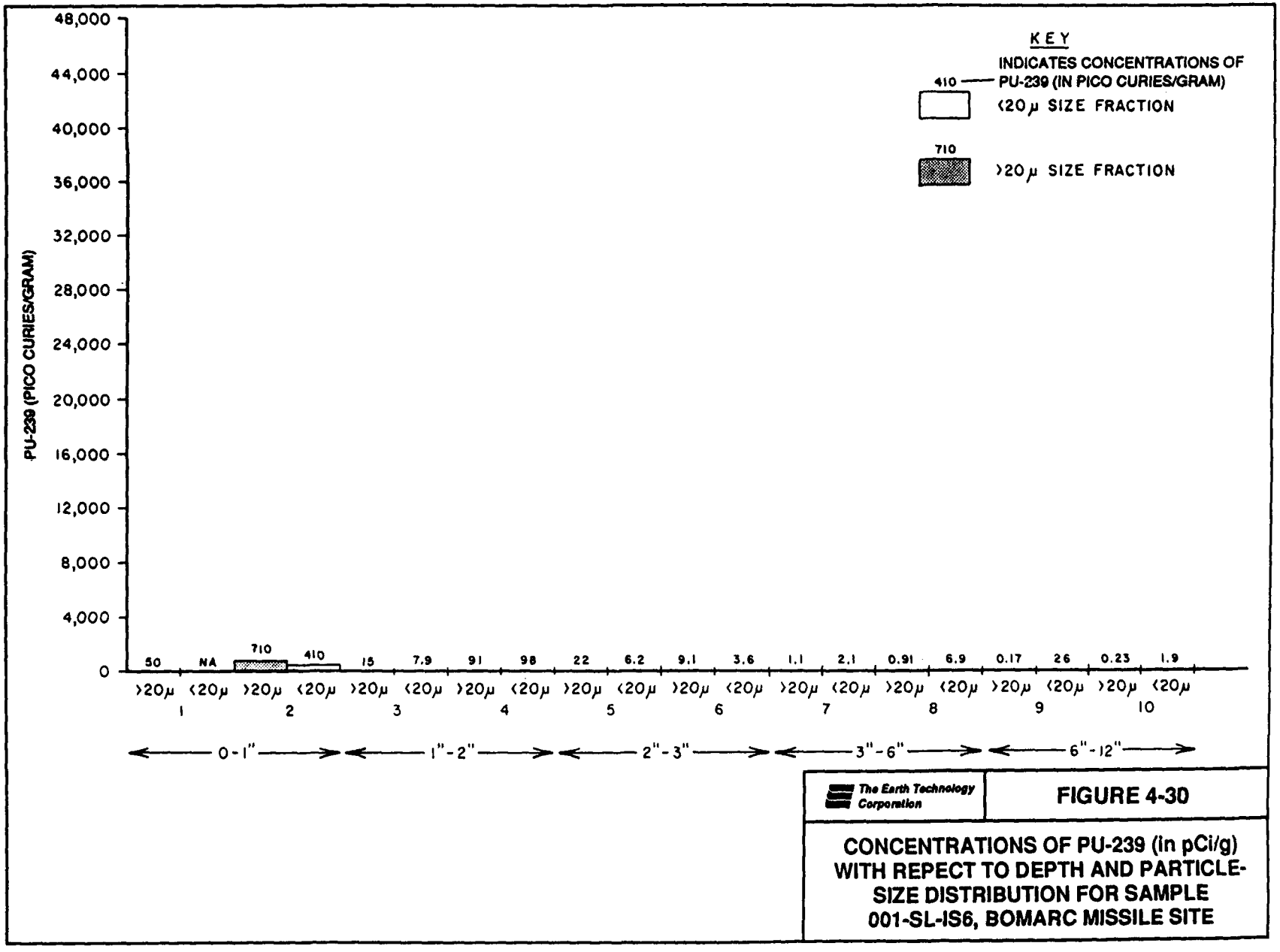

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FIGURE 4-30

CONCENTRATIONS OF PU-239 (in pCi/g) WITH REPECT TO DEPTH AND PARTICLE-SIZE DISTRIBUTION FOR SAMPLE 001-SL-IS6, BOMARC MISSILE SITE

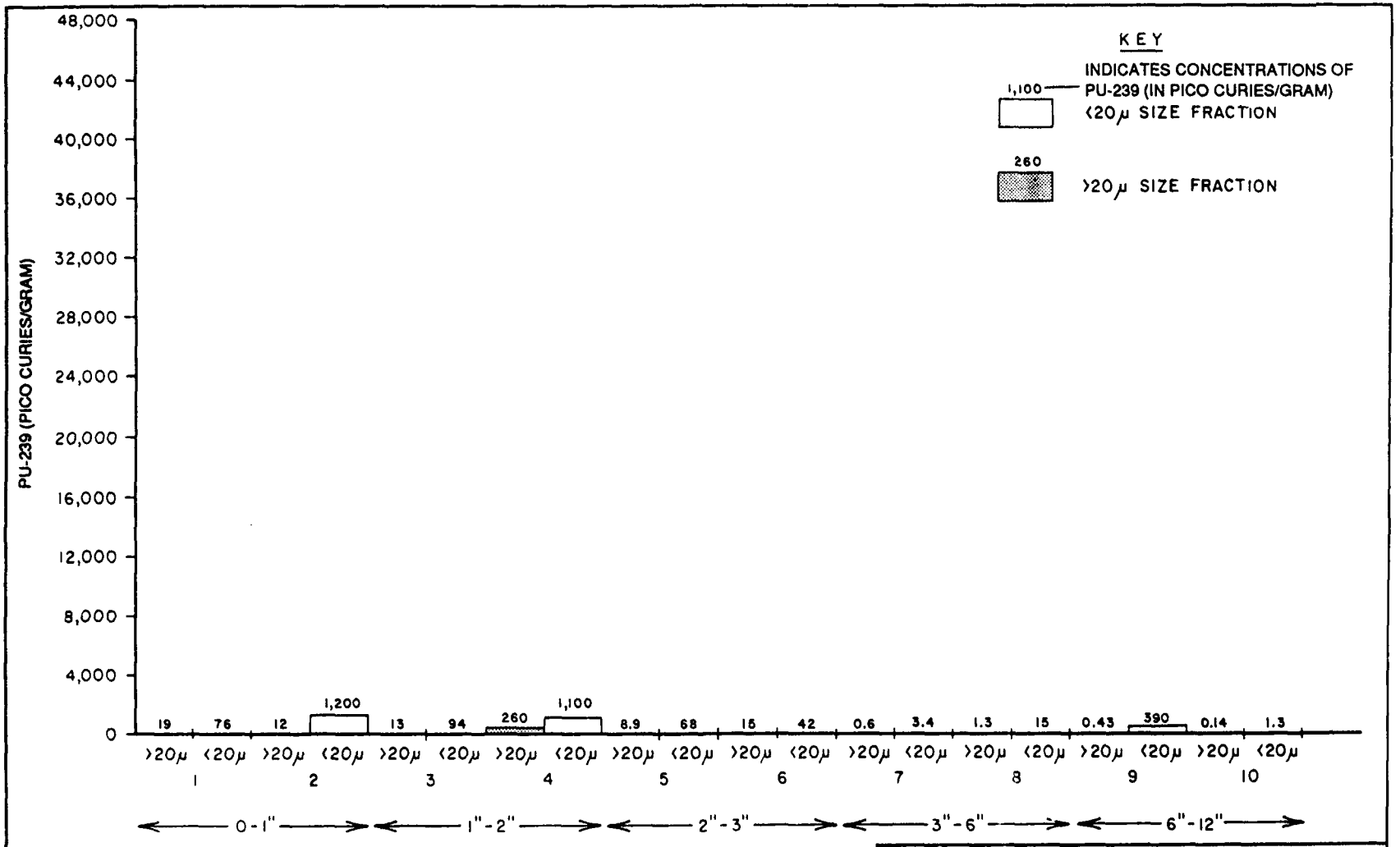

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FIGURE 4-31

CONCENTRATIONS OF PU-239 (in pCi/g) WITH RESPECT TO DEPTH AND PARTICLE SIZE DISTRIBUTIONFOR SAMPLE 001-SL-IS7, BOMARC MISSILE SITE

sample, an unexpected 6-inch layer of clean sand was found to have been placed over the oil-stained sand under the asphalt. The oil-stained sand was sprayed with motor oil after the missile accident in 1960, in an effort to stabilize plutonium contamination in the ditch. The clean layer of sand above the oil-stained sand is believed to have been placed over the oil-treated sand both to stabilize known plutonium contamination and to provide an even surface prior to laying the asphalt. The additional clean fill helps to explain the greater depth at which plutonium is found at this sampling location.

The relatively low activity identified in samples collected from Station 001-SL-IS6 is primarily due to its distance from Shelter 204, as well as being outside of the drainage which carried the contaminated water. Soil collected from Station 001-SL-IS7, although located within 200 feet southeast of Shelter 204, does not appear to have come into contact with contaminated materials. Neither water nor the smoke plume from the fire were reported to have traveled in the southeast direction, so the lack of contamination in that direction is not unexpected.

4.1.3.8.4 Shallow Soil Samples Collected From FIDLER Stations to Investigate Surface Deposition Modeling

A total of 30 shallow soil samples were collected from FIDLER survey stations within the perimeter of the surface deposition zone predicted by the air model. The purpose of the soil sampling was to determine if the modeling results were reasonable and to investigate predicted deposition patterns. These soil samples were analyzed in the laboratory for Pu-239 activity and the results are presented in Table 4-31. Figures 3-17 and 3-18 show sample locations, and Plate 4-2 is a map of the FIDLER survey sample stations and the values (in cpm) obtained at each station.

To illustrate where Pu-239 activity is concentrated in soil, zones of maximum activity levels have been outlined in Figure 4-32. Note that these are not contour lines but rather are lines that bound areas where maximum activity has been observed.

The results identify an activity plume elongated in a northeast-southwest direction, with the highest activity identified where the surface water drainage first crosses to the west side of County Highway 539. In this area, activity levels were observed as high as 5.5 pCi/gm in sample 001-SL-IS1-039. The next highest reading was 0.29 pCi/g in sample 001-SL-IS1-41. Elevated activity levels were also identified in samples 001-SL-IS1-44 (0.14 pCi/g), and 001-SL-IS1-46 (0.13 pCi/g). Average fallout across the United States is estimated at 0.1 pCi/g (see section 4.1.3.8.1). Activity levels to the southeast of Shelter 204 dropped quickly with increasing distance, to below average background levels. The location of these elevated activities corresponds well to eyewitness reports of the direction in which smoke from the fire went. The fact that the highest levels of contamination are near Shelter 204 and along the surface water drainage also attest to the water-borne nature of much of the particulate contamination during the fire-fighting and later storm events.

Table 4-31

Analytical Data for Shallow Soil Samples Obtained from FIDLER Survey Locations at the BOMARC Missile Site

Sample ID	Date Collected	Transect /Point	Depth	Parameter	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)	Remarks
001-SL-IS1-021	09-29-89	A-11	0-6"	PU-239	0.04	0*	Outside fence, soil
001-SL-IS1-022	09-29-89	A-14	0-6"	PU-239	0.04	<3.0E-02	Woods
001-SL-IS1-023	09-29-89	A-17	0-6"	PU-239	0.04	1.6 +-1.3E-02	Followed bearing S31E
001-SL-IS1-024	09-29-89	A-20	0-6"	PU-239	0.04	<2.0E-02	Next to Elisha Branch, S31E
001-SL-IS1-025	09-29-89	A-23	0-6"	PU-239	0.04	2.5 +-1.9E-02	East of tank tracks along side of berm/drainage
001-SL-IS1-026	09-29-89	A-33	0-6"	PU-239	0.04	<6.0E-03	300' south of A-32
001-SL-IS1-027	09-29-89	A-43	0-6"	PU-239	0.04	0*	300' south of A-42
001-SL-IS1-028	09-29-89	B-33	0-6"	PU-239	0.04	<3.0E-01	100' east, off road
001-SL-IS1-029	09-29-89	B-43	0-6"	PU-239	0.04	2.3 +-1.4E-02	30' south across road (random sample)
001-SL-IS1-030	09-29-89	B-23	0-6"	PU-239	0.04	1.2 +-0.8E-02	Side road, 100ft
001-SL-IS1-031	09-29-89	B-20	0-6"	PU-239	0.04	2.9 +-1.2E-02	
001-SL-IS1-032	09-29-89	B-17	0-6"	PU-239	0.04	6.0 +-1.5E-02	Soil
001-SL-IS1-033	09-29-89	B-14	0-6"	PU-239	0.04	<2.0E-02	25' off road to east, soil
001-SL-IS1-034	09-29-89	B-11	0-6"	PU-239	0.04	0*	Near building, soil
001-SL-IS1-035	09-29-89	B-8	0-6"	PU-239	0.04	2.5 +-1.4E-02	150' west of guard shack, soil, HV=1000
001-SL-IS1-036	10-06-89	C-12	0-6"	PU-239	0.04	0*	300' west of C-11, 200' south off road
001-SL-IS1-037	10-06-89	C-14	0-6"	PU-239	0.04	3.3 +-1.1E-02	At crossroad (300' south)
001-SL-IS1-038	10-06-89	C-10	0-6"	PU-239	0.04	2.4 +-1.2E-02	Past fork on south side of road, 132 feet
001-SL-IS1-039	10-06-89	C-7	0-6"	PU-239	0.04	5.9 +-0.2E 00	
001-SL-IS1-040	10-06-89	C-2	0-6"	PU-239	0.04	0*	100' SW of C-1, 20' south of drainage
001-SL-IS1-041	10-06-89	C-4	0-6"	PU-239	0.04	2.9 +-0.6E-01	100'
001-SL-IS1-042	10-06-89	C-6	0-6"	PU-239	0.04	1.7 +-1.2E-02	
001-SL-IS1-043	10-06-89	C-20	0-6"	PU-239	0.04	<8.0E-03	Bombing practice area
001-SL-IS1-044	10-06-89	C-18	0-6"	PU-239	0.04	1.4 +-0.3E-01	200' E of road, parallel to EW road, 100' from road
001-SL-IS1-045	10-06-89	C-16	0-6"	PU-239	0.04	1.0 +-0.4E-01	Past intersection 1/10 mile then west 300 feet
001-SL-IS1-046	10-06-89	A-4	0-6"	PU-239	0.04	1.3 +-0.3E-01	
001-SL-IS1-047	10-06-89	A-5	0-6"	PU-239	0.04	3.5 +-1.8E-02	
001-SL-IS1-048	10-06-89	A-8	0-6"	PU-239	0.04	<2.0E-02	Behind shelter 123, soil
001-SL-IS1-049	10-06-89	B-2	0-6"	PU-239	0.04	0*	SE corner shelter 205, soil
001-SL-IS1-050	10-06-89	B-7	0-6"	PU-239	0.04	<1.0E-02	Soil

* Sample retained by CDM/EPA and invalidated. Concentrations shown are assigned values calculated by linear regression analysis of FIDLER data. Values at or near background or with no FIDLER data were assigned a value of 0.

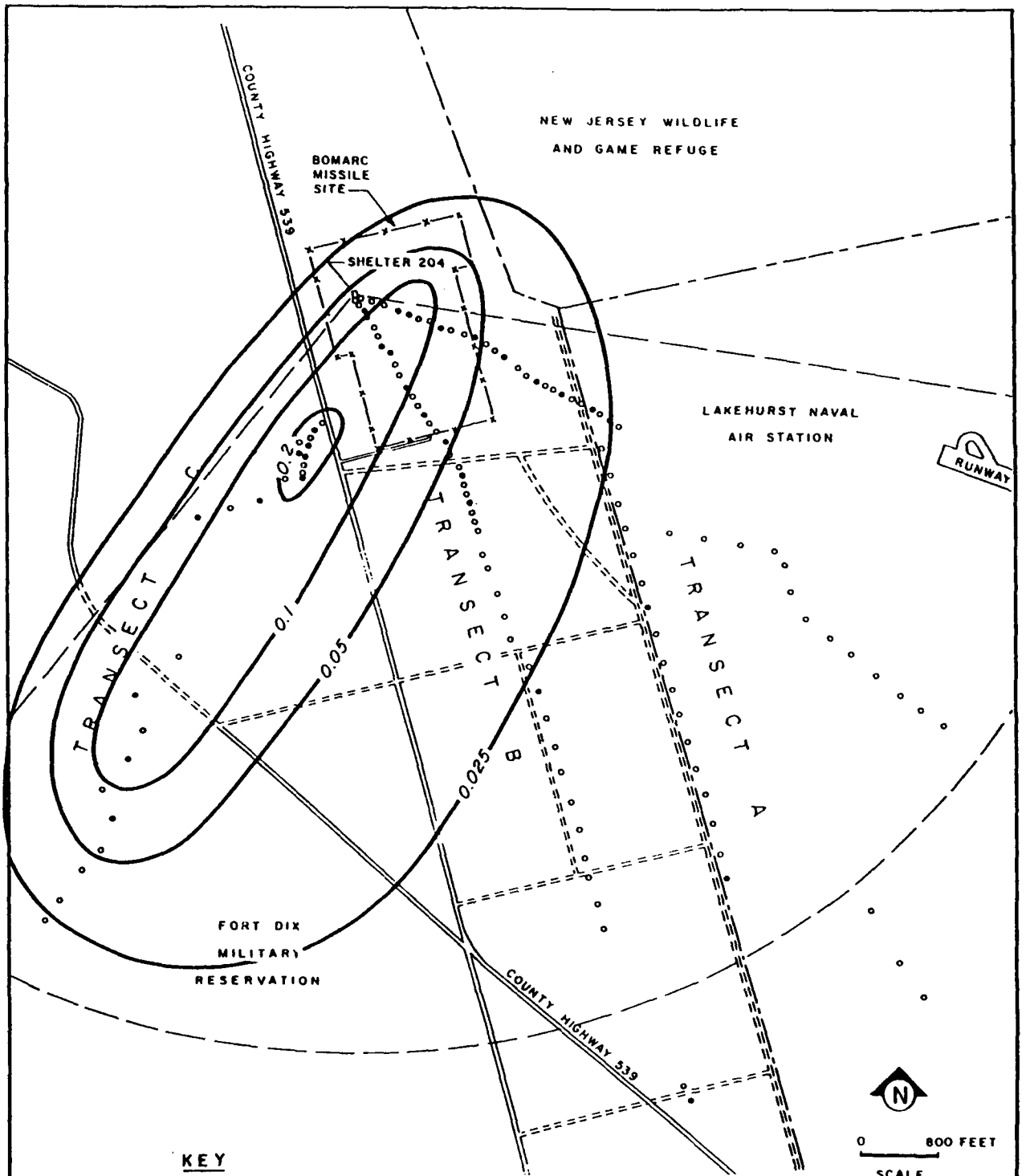

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FIGURE 4-32

CONCENTRATIONS OF PU-239 IN SOIL SAMPLES COLLECTED FROM FIDLER STATIONS TO VALIDATE THE AIR MODEL, BOMARC MISSILE SITE

4.1.3.8.5 Sampling at Historical "Hot Spots"

Five shallow soil samples were collected from an area on the east side of the facility that has historically shown radioactive contamination (Figure 4-33). Readings were taken using the HPG at eight stations. No measurable radiation in the energy ranges of interest (60 KeV for Am-241) was found. However, based on the historical readings, the area was resurveyed using the FIDLER, and those stations showing the highest activity levels were sampled. The results are presented in Table 4-32. Samples 001-SL-IS1-052 and 001-SL-IS1-53 showed activity levels to be below the laboratory detection limit of 0.02 pCi/g, while samples 001-SL-ID1-051 and 001-SL-IS1-054 showed activity levels of 0.13 pCi/g and 0.014 pCi/g, respectively. The one sample collected for the EPA (001-SL-IS1-055) was invalidated due to cross contamination at the EPA laboratory prior to analysis. The activity value assigned to this sampling station was 3.3 pCi/g calculated by linear regression analysis of FIDLER data.

These results were compared to an assumed average activity level for soils in the United States (0.1 pCi/g). The activity levels detected in samples 001-SL-IS1-051 and 001-SL-ISS1-054 were just above the average activity level. Sample 001-SL-IS1-055 exceeded the average U.S. concentration by 33 times. Since the activity for sample 001-SL-IS1-055 was not measured in the laboratory but rather was calculated based on FIDLER data, the accuracy of this data is considered less than that of samples analyzed in the laboratory.

4.1.3.8.6 Random Soil Sampling

Thirty (30) random soil samples were collected within the fenced area of the BOMARC Missile Site (Figure 4-34). The samples were collected to evaluate, without bias, portions of the site not believed to be contaminated with Pu-239. The sampling technique used is outlined in Section 3.6.2.6.6.

Prior to collecting a sample, each sample location was surveyed with the FIDLER and the data recorded (Table 4-33). The values ranged from 81 to 169 cpm, which were equal to or only slightly above the average daily background reading of 81 cpm. Each sample was then collected in a 6-inch brass sleeve and sent to the laboratory for Pu-239 analysis. Table 4-33 lists the values detected for each of the 30 random soil samples collected. Plutonium concentrations from fallout in the United States average 0.1 pCi/g of dry soil (see section 4.1.3.8.1). Thirteen (13) of the 30 samples exceeded 0.1 pCi/g in plutonium concentration, but only six samples were more than the arbitrary benchmark value of twice the background fallout level.

The values of Pu-239 detected by the laboratory ranged from <0.02 pCi/g to 0.43 pCi/g and the majority of the activity detected was in the area of Shelter 204.

4.1.3.8.7 Sediment From the Elisha Branch

A total of 20 soil/sediment samples were collected from a portion of the Elisha Branch drainage south of the BOMARC Missile Site. The samples were collected in 6-inch brass sleeves. The portion of the drainage ditch sampled between the BOMARC Missile Site and the headwaters of the Elisha Branch is an erosional channel, with only thin accumulations of sediments. The 6-inch brass sleeves were sufficient in most cases to penetrate the full thickness of drainage ditch

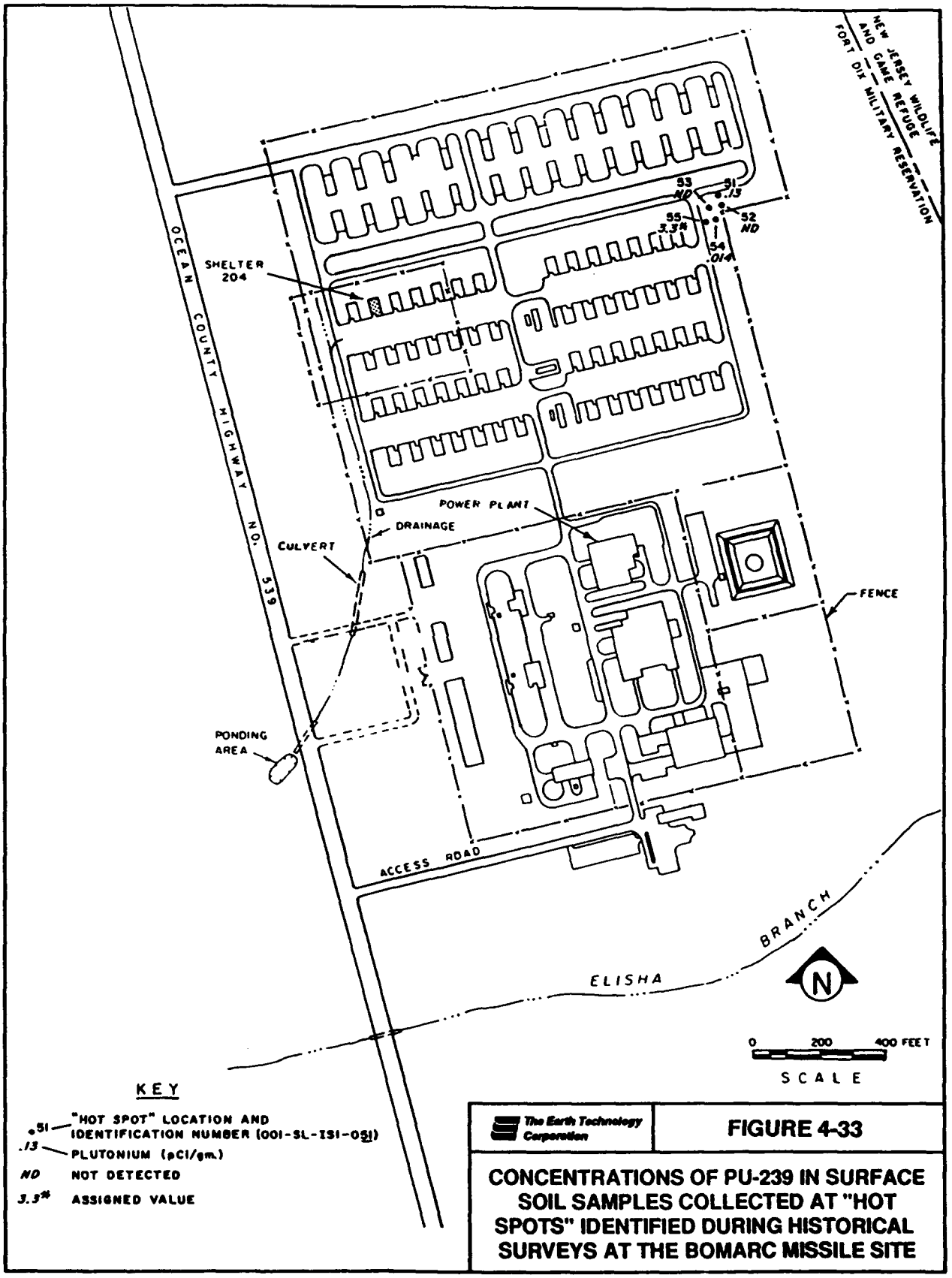

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FIGURE 4-33

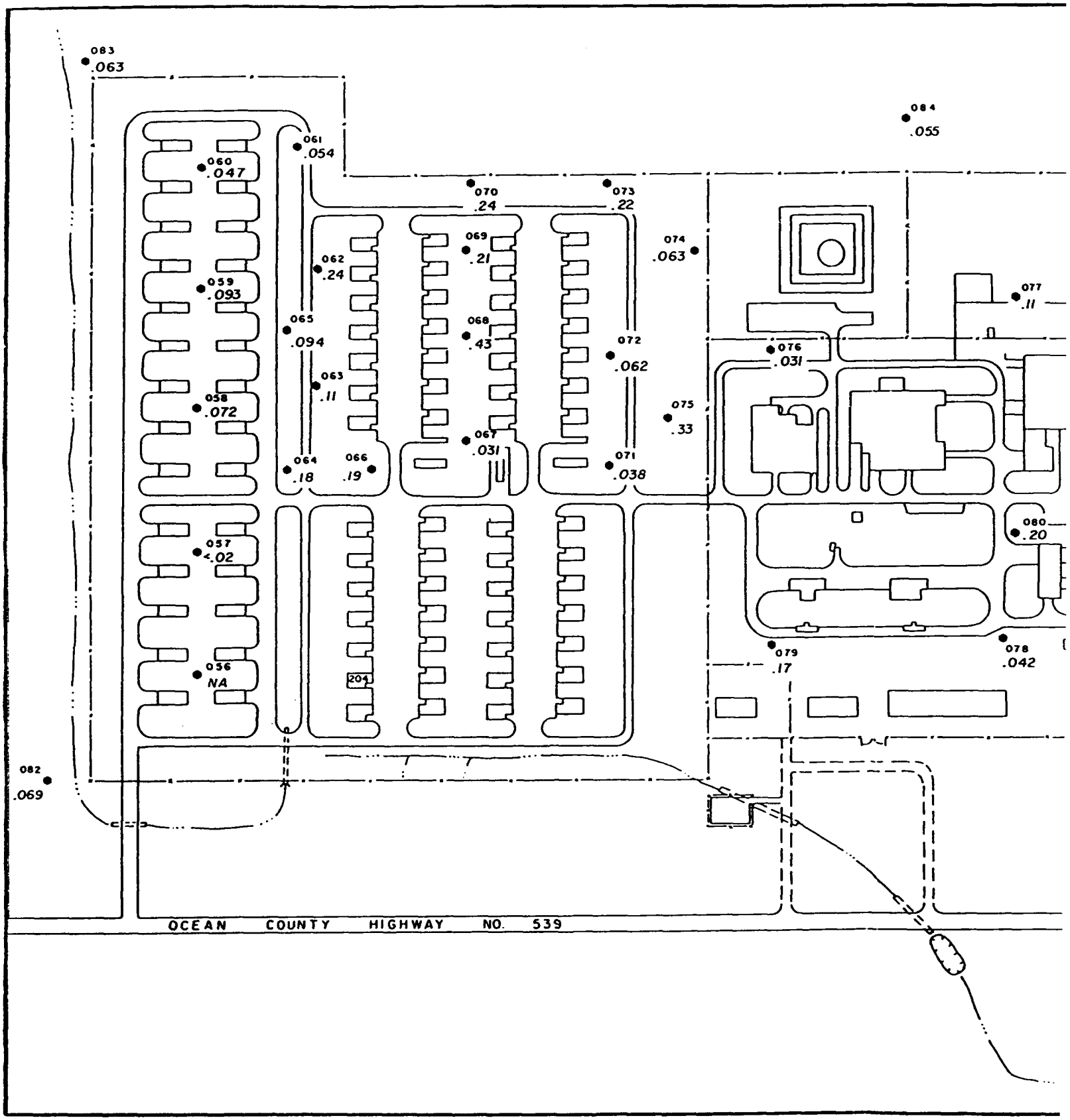
CONCENTRATIONS OF PU-239 IN SURFACE SOIL SAMPLES COLLECTED AT "HOT SPOTS" IDENTIFIED DURING HISTORICAL SURVEYS AT THE BOMARC MISSILE SITE

Table 4-32

Analytical Data for Shallow Soil Samples Collected at Historical "Hot Spots"

Sample ID	Date Collected	Depth Interval	FIDLER Count Per Minute	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)	Location Remarks
001-SL-IS1-051	10-07-89	0-6"	142	Pu-239	PRO-052-32	0.04	1.3 +-0.3E-01	Near NE corner of site
001-SL-IS1-052	10-07-89	0-6"	143	Pu-239	PRO-052-32	0.04	<2.0E-02	
001-SL-IS1-053	10-07-89	0-6"	144	Pu-239	PRO-052-32	0.04	<2.0E-02	
001-SL-IS1-054	10-07-89	0-6"	150	Pu-239	PRO-052-32	0.04	1.4 +-0.7E-02	
001-SL-IS1-055	10-07-89	0-6"	178	Pu-239	PRO-052-32	0.04	3.3*	

* Sample held by EPA that was invalidated. Concentration shown is assigned value calculated by linear regression analysis of FIDLER data. Values at or near background or with no FIDLER data were assigned a value of 0.


083
.063
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076
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066
.19
071
.038
080
.20
057
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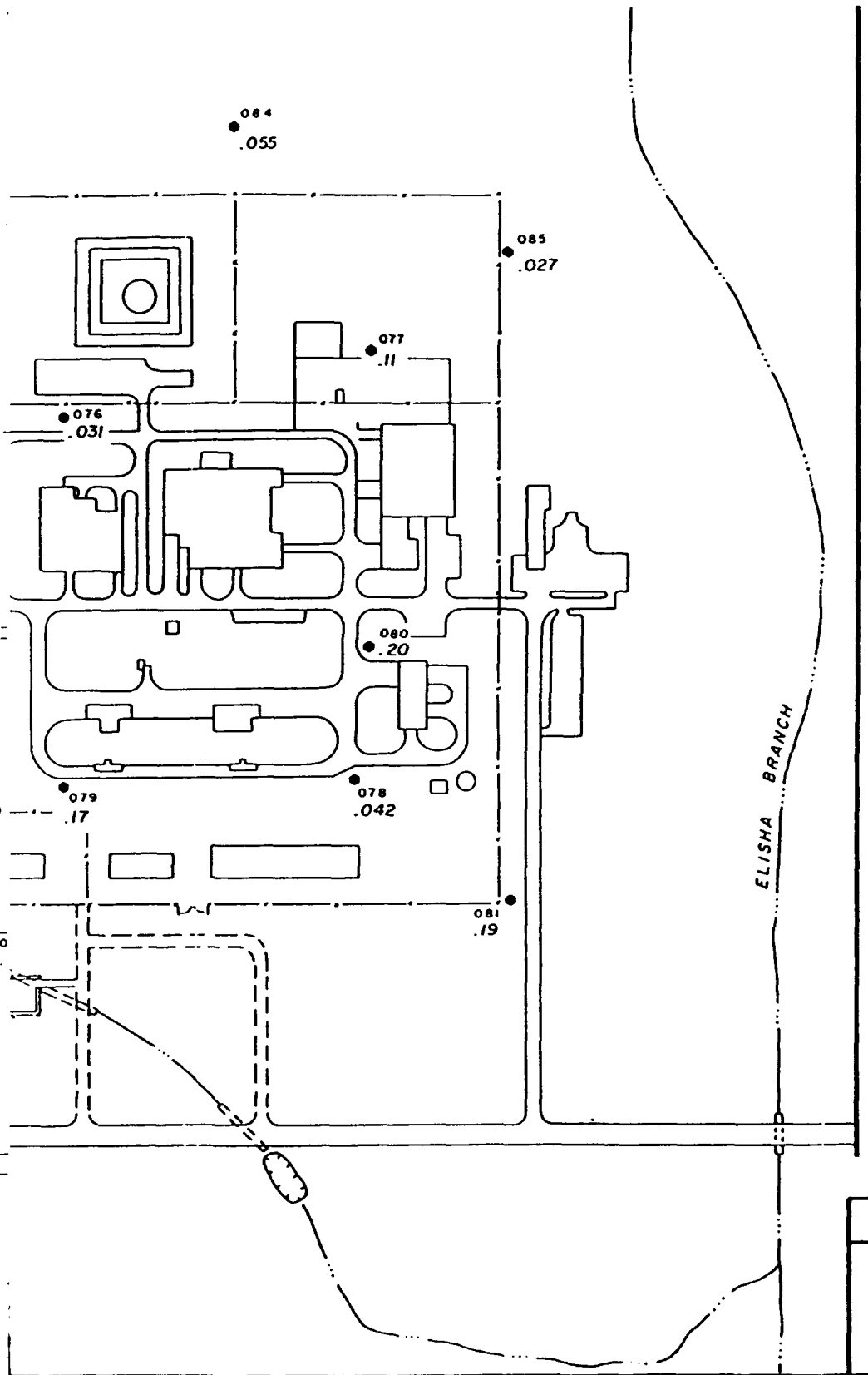
079
.17
078
.042
056
NA
201
082
.069
OCEAN COUNTY HIGHWAY NO. 539



EXPLANATION

085 .027 — SHALLOW SOIL SAMPLE AND IDENTIFICATION 001-SL-IS1-085

Pu-239 ACTIVITY (pCi/gm)

NA — VALUE NOT AVAILABLE

DRAINAGE

PONDING AREA

CULVERT

NORTH

0 250 FEET

SCALE

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FIGURE 4-34

CONCENTRATIONS OF PU-239 IN RANDOM SOIL SAMPLES COLLECTED AT THE BOMARC MISSILE SITE

Table 4-33

Analytical Data for Random Shallow Soil Samples Collected at the BOMARC Missile Site

Sample ID	Date Collected	Depth Interval	FIDLER Count Per Minute	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)	Location Remarks
001-SL-IS1-056	10-08-89	0-6"	119	Pu-239	PRO-052-32	0.04	0*	
001-SL-IS1-057	10-08-89	0-6"	108	Pu-239	PRO-052-32	0.04	<2.0E-02	
001-SL-IS1-058	10-08-89	0-6"	134	Pu-239	PRO-052-32	0.04	7.2 +-2.1E-02	
001-SL-IS1-059	10-08-89	0-6"	111	Pu-239	PRO-052-32	0.04	9.3 +-3.2E-02	
001-SL-IS1-060	10-08-89	0-6"	103	Pu-239	PRO-052-32	0.04	4.7 +-0.7E-02	
001-SL-IS1-061	10-08-89	0-6"	98	Pu-239	PRO-052-32	0.04	5.4 +-1.7E-02	
001-SL-IS1-062	10-08-89	0-6"	142	Pu-239	PRO-052-32	0.04	2.4 +-0.8E-01	
001-SL-IS1-063	10-08-89	0-6"	118	Pu-239	PRO-052-32	0.04	1.1 +-0.3E-01	
001-SL-IS1-064	10-08-89	0-6"	146	Pu-239	PRO-052-32	0.04	1.8 +-0.4E-01	
001-SL-IS1-065	10-08-89	0-6"	115	Pu-239	PRO-052-32	0.04	9.4 +-2.2E-02	
001-SL-IS1-066	10-08-89	0-6"	141	Pu-239	PRO-052-32	0.04	1.9 +-0.4E-01	
001-SL-IS1-067	10-08-89	0-6"	81	Pu-239	PRO-052-32	0.04	3.1 +-1.5E-02	
001-SL-IS1-068	10-08-89	0-6"	114	Pu-239	PRO-052-32	0.04	4.3 +-0.5E-01	
001-SL-IS1-069	10-08-89	0-6"	169	Pu-239	PRO-052-32	0.04	2.1 +-0.2E-01	
001-SL-IS1-070	10-08-89	0-6"	97	Pu-239	PRO-052-32	0.04	2.4 +-0.6E-01	
001-SL-IS1-071	10-08-89	0-6"	85	Pu-239	PRO-052-32	0.04	3.8 +-0.7E-02	
001-SL-IS1-072	10-08-89	0-6"	124	Pu-239	PRO-052-32	0.04	6.2 +-1.5E-02	
001-SL-IS1-073	10-08-89	0-6"	96	Pu-239	PRO-052-32	0.04	2.2 +-0.2E-01	
001-SL-IS1-074	10-08-89	0-6"	81	Pu-239	PRO-052-32	0.04	6.3 +-0.9E-02	
001-SL-IS1-075	10-08-89	0-6"	81	Pu-239	PRO-052-32	0.04	3.3 +-0.6E-01	
001-SL-IS1-076	10-08-89	0-6"	87	Pu-239	PRO-052-32	0.04	3.1 +-1.5E-02	
001-SL-IS1-077	10-08-89	0-6"	93	Pu-239	PRO-052-32	0.04	1.1 +-0.3E-01	
001-SL-IS1-078	10-08-89	0-6"	93	Pu-239	PRO-052-32	0.04	4.2 +-1.4E-02	
001-SL-IS1-079	10-08-89	0-6"	105	Pu-239	PRO-052-32	0.04	1.7 +-0.2E-01	
001-SL-IS1-080	10-08-89	0-6"	127	Pu-239	PRO-052-32	0.04	2.0 +-0.4E-01	
001-SL-IS1-081	10-08-89	0-6"	163	Pu-239	PRO-052-32	0.04	1.9 +-0.2E-01	
001-SL-IS1-082	10-08-89	0-6"	132	Pu-239	PRO-052-32	0.04	6.9 +-0.8E-02	
001-SL-IS1-083	10-08-89	0-6"	167	Pu-239	PRO-052-32	0.04	6.3 +-1.5E-02	
001-SL-IS1-084	10-08-89	0-6"	115	Pu-239	PRO-052-32	0.04	5.5 +-2.0E-02	
001-SL-IS1-085	10-08-89	0-6"	129	Pu-239	PRO-052-32	0.04	2.7 +-1.5E-02	

* Sample retained by CDM/EPA and invalidated. Concentrations shown are assigned values calculated by linear regression analysis of FIDLER data. Values at or near background, or with no FIDLER data were assigned a value of 0.

sediments. The procedures used to obtain the samples are outlined in Section 3.6.2.6.7. Figure 4-35 identifies the sampling locations and associated plutonium concentrations. Prior to collecting the samples, each sample location was screened with the FIDLER and the value was recorded. The FIDLER readings ranged in value from 87 to 163 cpm, just slightly above the average background value of 81 cpm at the site.

Two of the samples collected were retained by the EPA for analysis. Those samples have been assigned a value of 0 pCi/g based on a linear regression analysis. The remaining 18 sediment samples were shipped to the laboratory and analyzed for Pu-239 by alpha spectroscopy (Table 4-34).

A total of six of the samples analyzed exceeded the average United States fallout level of 0.1 pCi/g. The highest level of activity was detected in the intermittent drainage that connects the ponding area to the perennial portion of the Elisha Branch (Figure 4-35). Random soil sampling in the area did not yield any values as high as those in the stream sediments, indicating that the plutonium found in the stream sediments was probably transported by water rather than air.

4.1.3.8.8 Surface Soil Sampling in the Drainage Ditch

In order to determine the areal and vertical extent of contamination in the drainage ditch (Figure 3-31), eight soil samples were collected in brass sleeves from four shallow holes augered in the ditch. At each auger hole, one sample was collected from the 0 to 6 inch interval and one was collected from the 6 to 12 inch interval. The sampling procedure is outlined in Section 3.6.2.6.1. These eight samples were shipped to the laboratory for Pu-239 analysis by alpha spectroscopy.

The results from the laboratory analyses of the above samples are presented in Table 4-35. Those results have been plotted by depth on Figure 4-36 (0 to 6 inches) and Figure 4-37 (6 to 12 inches). At the 0 to 6 inch bgs interval, three of the four samples exceed the average U.S. fallout level of 0.10 pCi/gm, but only the sample at Station 2 (001-SL-002-001) was much higher (2.3 pCi/gm). Those samples taken from the 6 to 12 inch bgs interval were all over the average U.S. fallout level, with three being more than 20 to 40 times higher than the U.S. average.

It would appear that the plutonium contamination remaining in the ditch, prior to the asphalt covering being laid in 1967, had migrated several inches below the surface of the ditch. However, during drilling through the asphalt covering, it was noted that about six inches of clean sand covered the oil-stained sand (see Section 4.1.3.8.3 for discussion). It is believed that this clean sand was placed to contain contaminants and to improve the bed for the asphalt placement. This layer of clean sand may explain the relatively low plutonium values in the top 6 inches of soil, especially in the upper portion of the ditch (at the point where the concrete apron adjoins the ditch) where higher levels of activity were expected.

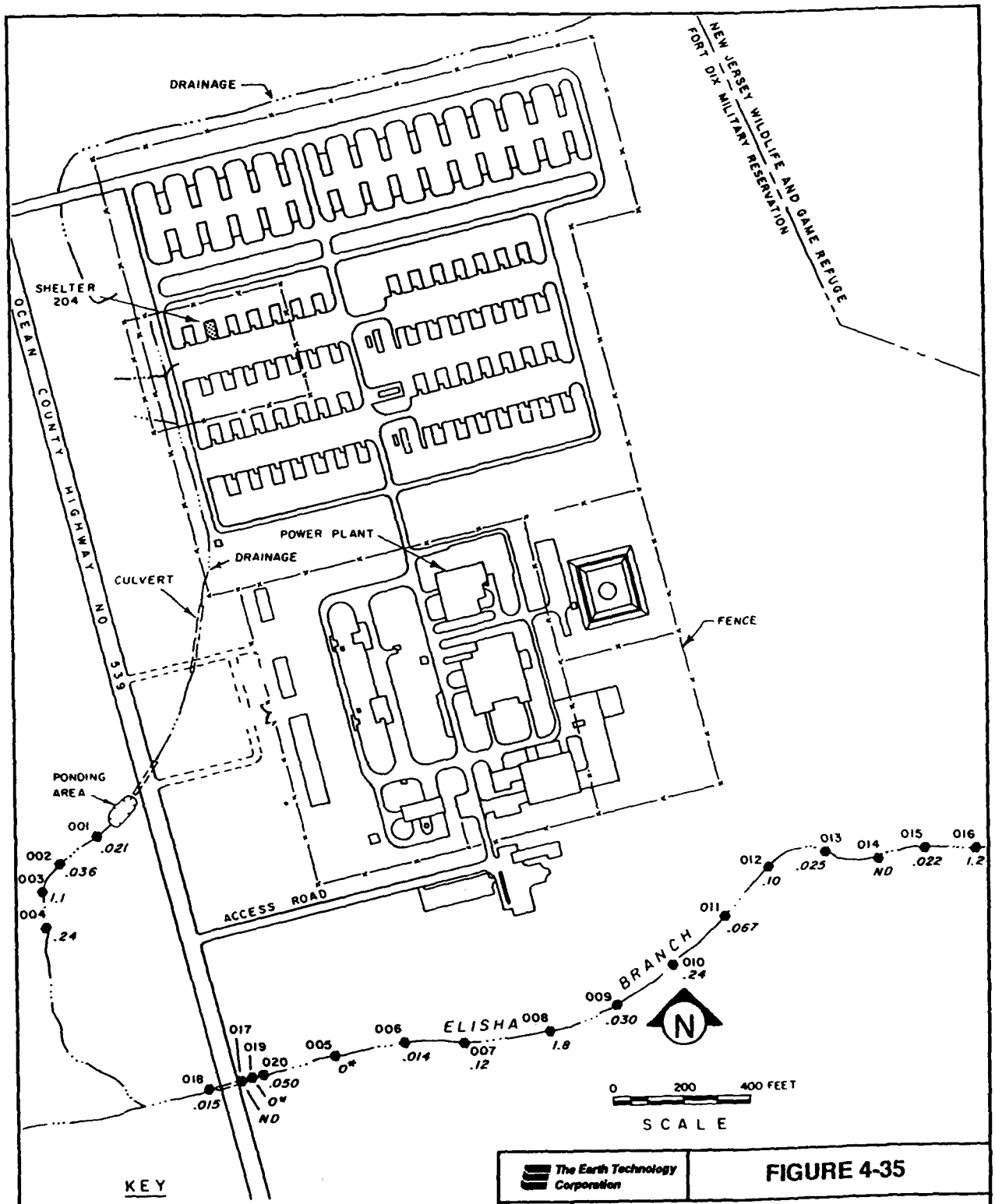
DRAINAGE
NEW JERSEY WILDLIFE AND GAME REFUGE
FORT DIX MILITARY RESERVATION
SHELTER 204
OCEAN COUNTY HIGHWAY NO 539
POWER PLANT
DRAINAGE
CULVERT
FENCE
PONDING AREA
ACCESS ROAD
ELISHA BRANCH
001 .021
002 .036
003 1.1
004 .24
005 0*
006 .014
007 .12
008 1.8
009 .030
010 .24
011 .067
012 .10
013 .025
014 ND
015 .022
016 1.2
017
018 .015
019
020 .050
0* ND
N
0 200 400 FEET
SCALE
KEY
006 SEDIMENT SAMPLE AND IDENTIFICATION (001-SL-IS1-006)
.014 PLUTONIUM (pCi/gm.)
ND NOT DETECTED
0* ASSIGNED VALUE
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FIGURE 4-35
CONCENTRATIONS OF PU-239 IN SOIL/SEDIMENT SAMPLES COLLECTED ALONG THE ELISHA BRANCH, BOMARC MISSILE SITE

Table 4-34

Analytical Data for Soil/Sediment Samples Collected from the Elisha Branch, South of the BOMARC Missile Site

Sample ID	Date Collected	Depth Interval	FIDLER Count Per Minute	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)
001-SL-IS1-001	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	2.1 +-1.1E-02
001-SL-IS1-002	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	3.6 +-1.7E-02
001-SL-IS1-003	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	1.1 +-0.1E 00
001-SL-IS1-004	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	2.4 +-0.5E-01
001-SL-IS1-005	10-08-89	0-6"	99	Pu-239	PRO-052-32	0.04	0*
001-SL-IS1-006	10-08-89	0-6"	104	Pu-239	PRO-052-32	0.04	1.4 +-1.3E-02
001-SL-IS1-007	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	1.2 +-0.3E-01
001-SL-IS1-008	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	1.8 +-0.1E 00
001-SL-IS1-009	10-08-89	0-6"	116	Pu-239	PRO-052-32	0.04	3.0 +-1.2E-02
001-SL-IS1-010	10-08-89	0-6"	163	Pu-239	PRO-052-32	0.04	2.4 +-0.4E-01
001-SL-IS1-011	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	6.7 +-1.8E-02
001-SL-IS1-012	10-08-89	0-6"	112	Pu-239	PRO-052-32	0.04	1.0 +-0.2E-01
001-SL-IS1-013	10-08-89	0-6"	101	Pu-239	PRO-052-32	0.04	2.5 +-1.0E-02
001-SL-IS1-014	10-08-89	0-6"	91	Pu-239	PRO-052-32	0.04	<2.0E-02
001-SL-IS1-015	10-08-89	0-6"	102	Pu-239	PRO-052-32	0.04	2.2 +-1.3E-02
001-SL-IS1-016	09-16-89	0-6"	87	Pu-239	PRO-052-32	0.04	1.2 +-0.1E 00
001-SL-IS1-017	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	<2.0E-02
001-SL-IS1-018	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	1.5 +-1.3E-02
001-SL-IS1-019	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	0*
001-SL-IS1-020	09-16-89	0-6"	Na	Pu-239	PRO-052-32	0.04	5.0 +-2.2E-02

* Samples held by CDM/EPA that were invalidated. Concentrations shown are assigned values calculated by linear regression analysis of FIDLER data. Values at or near background, or with no FIDLER data were assigned a value of 0.

Table 4-35

FIDLER, OVA and Plutonium Activity for Shallow Soil Samples
Collected Along the Drainage Ditch Southwest of Shelter 204 at the BOMARC Missile Site

			Field Screening Data			Laboratory Analysis
Sample ID	Laboratory Sample No.	Date/Time Collected	Depth (inches)	FIDLER (cpm)	OVA (ppm)	Activity* (pCi/gm dry)
001-SL-001-001	82001	8-8-89 0934	0-6	93	0.00	.59
001-SL-001-002	82002	8-8-89 1500	6-12	93	7.00	2.3
001-SL-002-001	82005	8-8-89 1031	0-6	93	0.00	2.3
001-SL-002-002	82004	8-8-89 1035	6-12	93	0.00	2.1
001-SL-003-001	82006	8-8-89 1430	0-6	80	0.00	.16
001-SL-003-002	82007	8-8-89 1435	6-12	80	3.00	4.3
001-SL-004-001	82003	8-8-89 1410	0-6	280	2.00	.081
001-SL-004-002	82000	8-8-89 1412	6-12		2.00	.22

* All samples were analyzed for PU-239 using method PRO-052-32.

Note: Method detection limit is 0.04 pCi/gm.

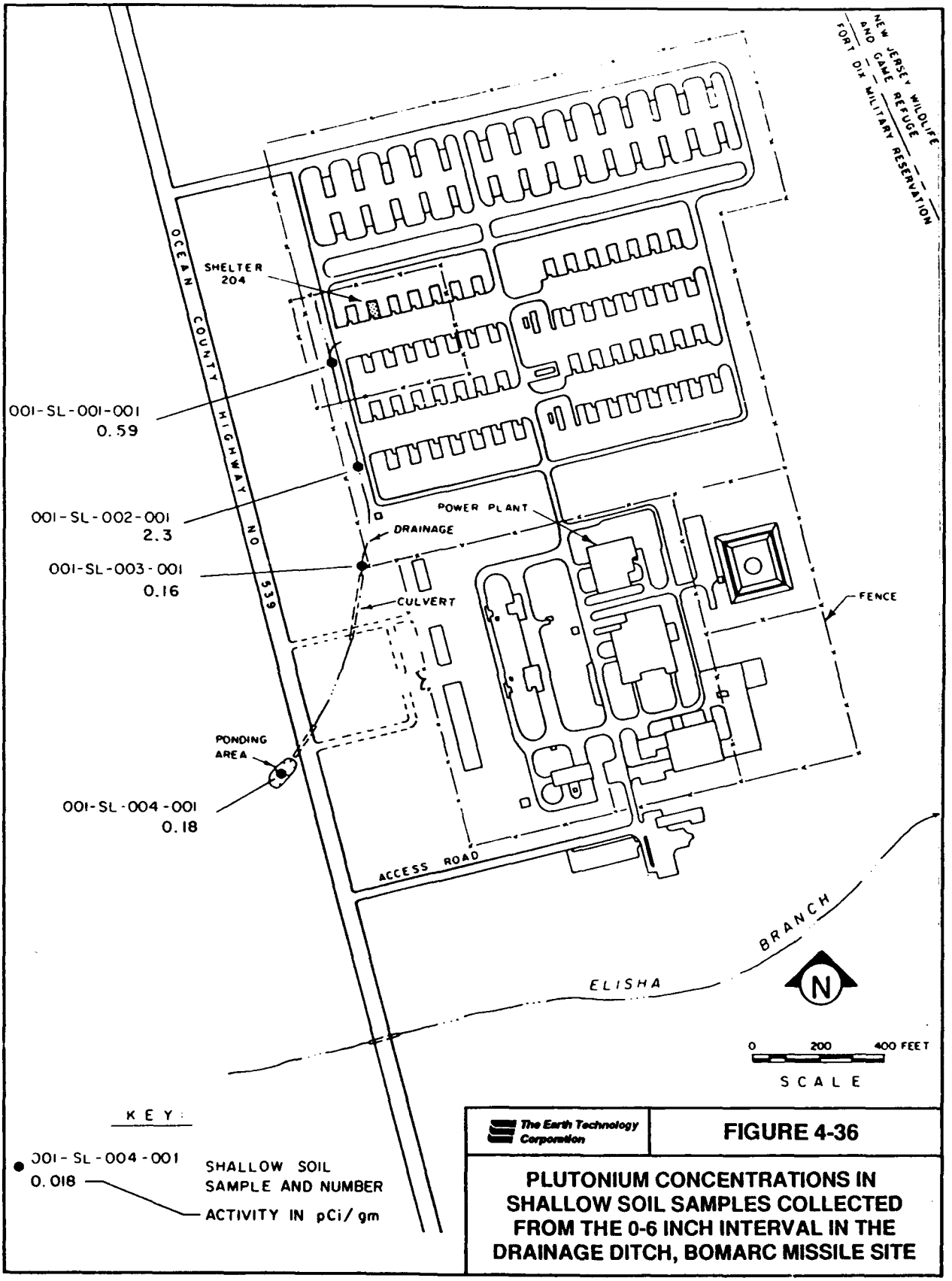

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FIGURE 4-36

PLUTONIUM CONCENTRATIONS IN SHALLOW SOIL SAMPLES COLLECTED FROM THE 0-6 INCH INTERVAL IN THE DRAINAGE DITCH, BOMARC MISSILE SITE

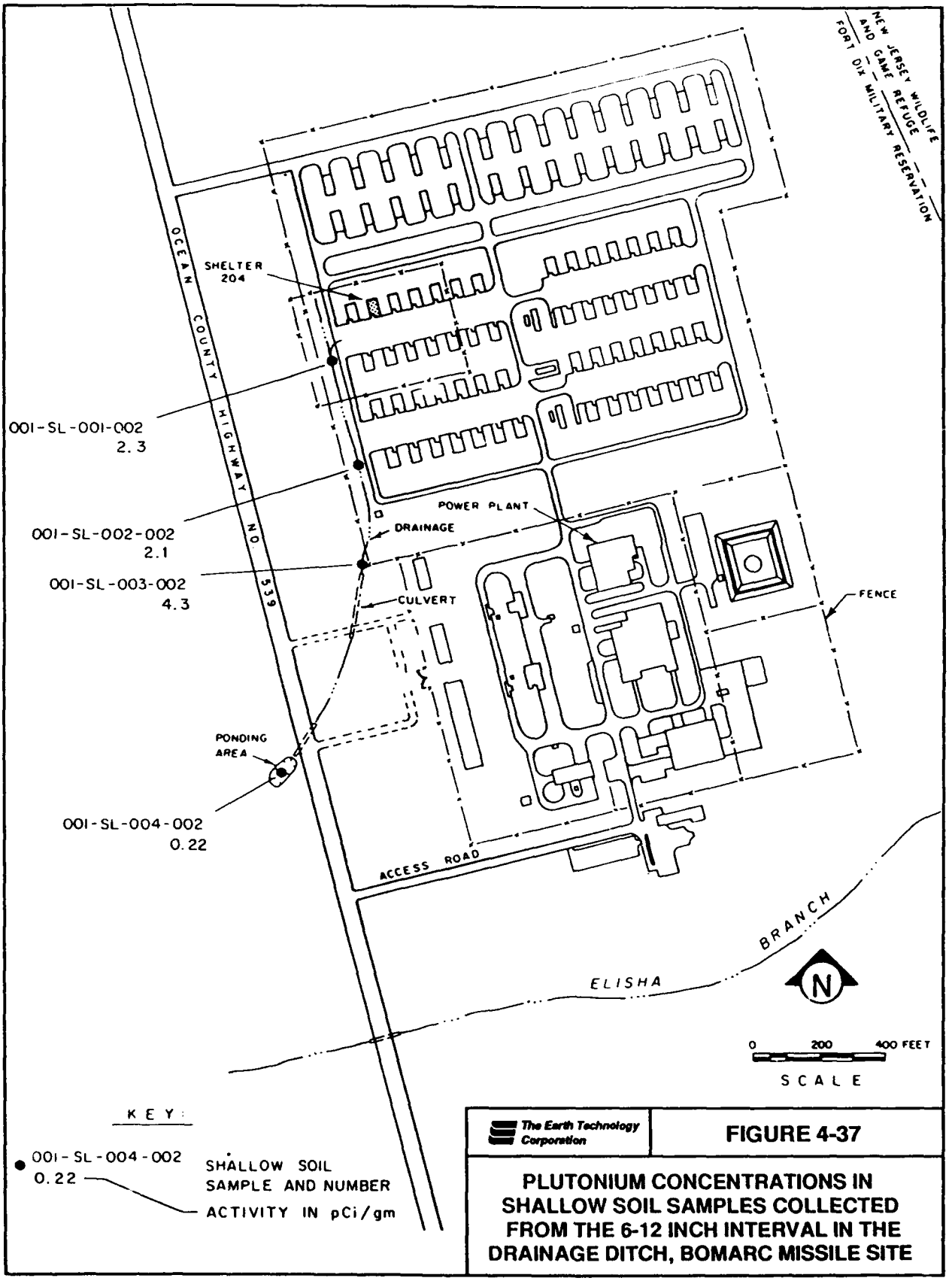

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FIGURE 4-37

PLUTONIUM CONCENTRATIONS IN SHALLOW SOIL SAMPLES COLLECTED FROM THE 6-12 INCH INTERVAL IN THE DRAINAGE DITCH, BOMARC MISSILE SITE

4.1.3.9 Sediment from the Communication Bunker

Six sediment samples were collected from the communication bunker in front of Shelter 204 during the RI/FS Stage 2 sampling program at the BOMARC Missile Site, McGuire AFB, New Jersey. The samples were collected from approximately 8 inches of sediment in the bottom of the bunker. The procedures used to collect the samples are outlined in Section 3.6.2.6.3.

One sample was shipped to the laboratory to be analyzed for Pu-239, while the remaining five samples were kept on site for possible future analysis (Table 4-36). Sample 001-SD-CB1-002 showed 200 pCi/gm of plutonium.

Table 4-36

Analytical Data for Sediment Samples Collected from the Communication Bunker at the BOMARC Missile Site

Sample ID	Parameter	Method	Method Detection Limit (pCi/gm)	Activity (pCi/gm dry)
001-SD-CB1-002	Pu-239	PRO-052-32	0.04	2.0+-0.1E+02

The sediment collected from the communication bunker was contaminated by the runoff water from the fire hoses used to put out the fire in 1960. The traces of plutonium left by the water runoff through the manhole cover and into the bunker were detected with the PAC-4G and the FIDLER. Radiation activity detected with the PAC-4G ranged from 7,000 to 80,000 cpm and activities detected with the FIDLER were as high as 160,000 cpm. Wipe samples obtained from the manhole of the bunker confirmed contamination with Pu-239. Based upon these findings, and the fact that Pu-239 readily adheres to soils and sediments, it appears that the Pu-239 contamination in the sediment is due to the runoff water from the fire. Previous surveys (USAF, 1988) have indicated the presence of plutonium in the space between the manhole cover and the metal supporting rim on other bunkers east and west of Shelter 204. The bunker lid in front of Shelter 202, where runoff from the fire-fighting effort flowed, was especially contaminated.

4.1.3.10 Sample Screening for Transportation and Disposal

Samples collected during the RI/FS investigation of the BOMARC Missile Site were screened onsite for Am-241/Pu-239. The screening methods used to quantify the amount of radioactivity were in accordance with Department of Transportation (DOT) and Nuclear Regulatory Commission (NRC) regulations.

A total of 270 environmental samples were collected at the BOMARC Missile Site for laboratory analysis by Teledyne Isotopes. Prior to shipment, the samples were screened with the HPG detector. Each sample was screened for Am-241/Pu-239 for 10 minutes and the results were recorded. Shipping manifests were prepared that identified the sample, the quantity of Am-241 and Pu-239, and the total amount of Am-241/Pu-239 contamination in each box shipped to the

laboratory. Samples were transported in accordance with DOT regulations, including packaging, appropriate screening, placarding of the vehicle, preparation of records, and notification of authorities.

All samples not shipped off site were screened prior to storage onsite until proper disposal could take place. Values were recorded along with any other data needed for waste disposal.

4.1.3.11 Health Physics Samples

An onsite health physicist was in attendance at the site at all times that field personnel were present during the 1989 field program to assure the health and safety of the workers. In addition to routine sampling and screening of personnel and equipment, several specific types of health physics samples were taken to assure the quality of the protective measures being used and to determine if any plutonium or americium exposure had taken place. All records are on file.

4.1.3.11.1 Dosimetry Results

External exposure to the low-energy x/gamma radiation emitted by Am-241 was monitored through the use of personal dosimeters issued on the site. These dosimeters were obtained through a dosimetry program offered by ICN Dosimetry Services. All personnel on the site were assigned a dosimeter which was worn during any entry to the site and was returned to the badge board upon exit from the site. Badges were issued for a one-month period, at which time they were returned to ICN Dosimetry for analysis. New badges were assigned on the first day of each new month. Upon analysis, the badges of two workers were reported to have received very low levels of x/gamma radiation. Both workers were notified. In both cases the dose received was orders of magnitude below the limits of occupational dose-equivalent recommended by the Department of Energy. Results of all sampling are maintained in the records for this project and are available to workers for examination upon request in writing.

4.1.3.11.2 Urinalysis Results

Baseline bioassay samples in the form of urinalysis were performed for all of the workers on the site who were involved in extended periods of field work or in intrusive activities on the site. The purpose of this sampling was to determine whether and to what extent radionuclides may have entered the body. The bioassay program is implemented when the potential exists for inhalation or ingestion of radioactive materials. Inhalation potential is determined by means of air sampling. All air sampling at the site, and nasal smear samples performed on individuals, indicated that no inhalation of radioactive materials had taken place. Results of all sampling are maintained in the records for this project and are available to workers for examination upon request in writing.

4.1.3.11.3 Nasal Smears

Nasal smears were taken on a regular basis to provide information on respiration of dust or particulate matter containing plutonium or americium, and samples were analyzed onsite using the Ludlum Model 2000 scaler with alpha scintillation detector. All information on sampling was kept in the daily health and safety log book. In addition to routine samples collected,

additional samples were taken during intrusive activities where respiratory protection was being used, to assure the effectiveness of the protection. In no case was there any indication that the respiratory protection had failed to protect the worker.

4.1.4 Sampling or Analytical Problems

4.1.4.1 Loss of Samples

Of the 270 samples sent to the laboratory, 5 samples were lost for purposes of analysis. Two wipe samples were reported missing by the laboratory. The sample containers for soil samples collected from the 2 to 4 foot intervals of boreholes 18 and 24 were broken in the laboratory. The contents were inadvertently intermixed and analyzed before the error was caught. Both samples were declared invalid. After sieving, the less-than-20-micron fraction of the depth profile sample collected from Site IS-6 (0 to 1-inch interval) contained too little material for analysis so no results were obtained.

4.1.4.2 Likelihood that Positive Samples were Contaminated in the Field or Laboratory

The following sections discuss the likelihood that positive samples were contaminated in the field or laboratory.

4.1.4.2.1 Radioanalysis

Other than those samples previously identified in the text as exhibiting contamination, possibly as a result of physical and waterborne dispersion of contaminants during the coring/boring operations, samples are not known to have been contaminated in the field. Laboratory spikes use different isotopes of plutonium, so contamination from that source is not suspected.

4.1.4.2.2 Chemical Analysis

Several samples submitted for chemical analysis exhibited positive results which were attributed to laboratory contamination. Trip blanks supplied by MetaTrace for volatile organic ground water analysis contained elevated levels of methylene chloride and acetone, indicating laboratory contamination as a source of these contaminants. Dibenzofuran and phthalates were also detected in ground water blanks, indicating laboratory contamination. The presence of phthalates in soil samples was attributed to anthropogenic effects, but these compounds can also be present as a result of laboratory contamination. Semi-volatile TIC compounds were also detected in laboratory blanks, and the resulting data were qualified accordingly.

4.1.4.3 Analytical Results Obtained under Out-of-Control Conditions

All radiological samples that were out-of-control were declared invalid and the results were not used. These included soil samples where sample containers were broken and the contents were mixed. Samples retained by EPA were declared invalid, and "replacement" values were determined by linear regression using the FIDLER data obtained in the field. Several chemical samples were analyzed after holding times had expired; these are identified in the text.

4.1.4.4 Corrective Actions Applied to Out-of-Control Events, Including a Chronology of Rerunning Samples and Controls

No samples were re-run. Those radiological samples that were declared invalid were either ignored or had "replacement" values assigned to them for the purposes of data analysis (the EPA samples). A linear regression analysis was performed using FIDLER data from the site in order to assign predicted values to those EPA samples. Samples with field values close to background, or with no reading, were assigned a value of 0.

4.1.5 Significance of Findings

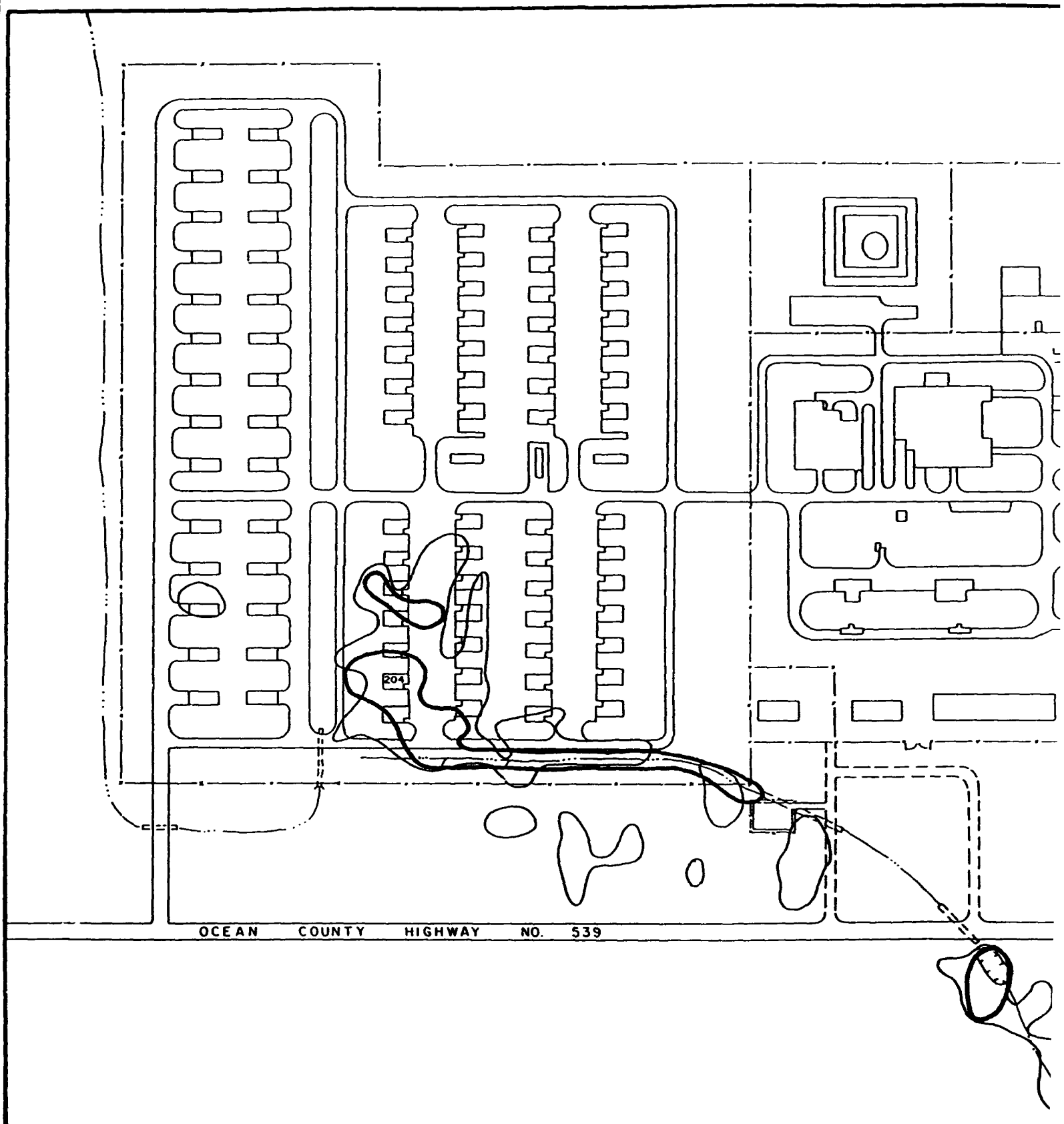
The following section discusses the significance of the findings.

4.1.5.1 Zones of Contamination

Figure 4-38 depicts the areal extent of soils contaminated above both the proposed U.S. EPA Draft Screening Limit (0.2 $\mu Ci/m^2$) and the risk-based cleanup level calculated for this RI/FS (8 pCi/g or 2.0 $\mu Ci/m^2$, see Appendix J and Section 5.1.1.1 for derivations). This figure depicts a composite of the data presented earlier in this section so that the various components may be addressed as a unified entity. Specific components considered for Figure 4-38 include: in-situ surveys; contamination on soil, sediment, asphalt, and concrete surfaces; depth of contamination in soils and sediments, and under the asphalt and concrete coverings.

Known plutonium contamination has been covered with concrete and asphalt. Alpha surveys on and under the concrete on Lorin street, south of Shelter 204, indicate that both removable and fixed contamination can be found on the present concrete/asphalt surface. FIDLER surveys, confirmed by concrete coring, indicate that most of the activity detected by the FIDLER at the surface is generated by the layer of known plutonium/americium contamination "sandwiched" between the 1960 original asphalt surface and the overlying concrete and/or asphalt. Little, if any, migration of plutonium from beneath the original asphalt street surface appears to have occurred, with the possible exception of migration allowed and enhanced by surface cracking and vegetation encroachment. Vegetative growth helps to stabilize soil to prevent resuspension of contaminants, but when plant roots penetrate the concrete fixative layer as they have on this site, the roots provide conduits that permit contamination to move upward to the present surface or downward into the soil. Unsealed cracks in the concrete also provide a vertical passage through which contamination can migrate. Alpha surveys of the concrete pad found both fixed and removable alpha radiation in such cracks.

The HPG in-situ survey was conducted on a grid defined by results of prior Air Force surveys, as well as the necessity to generate data for site areas not previously studied. The results for all soil/sediment data that exceed the proposed EPA soil screening limit are shown on Figure 4-38. Ground water and surface water do not appear to be contaminated by plutonium from the missile accident or related decay products. Removable activity was found on Shelter 204 and, in several situations, at low levels on nearby shelters.


204
OCEAN COUNTY HIGHWAY NO. 539

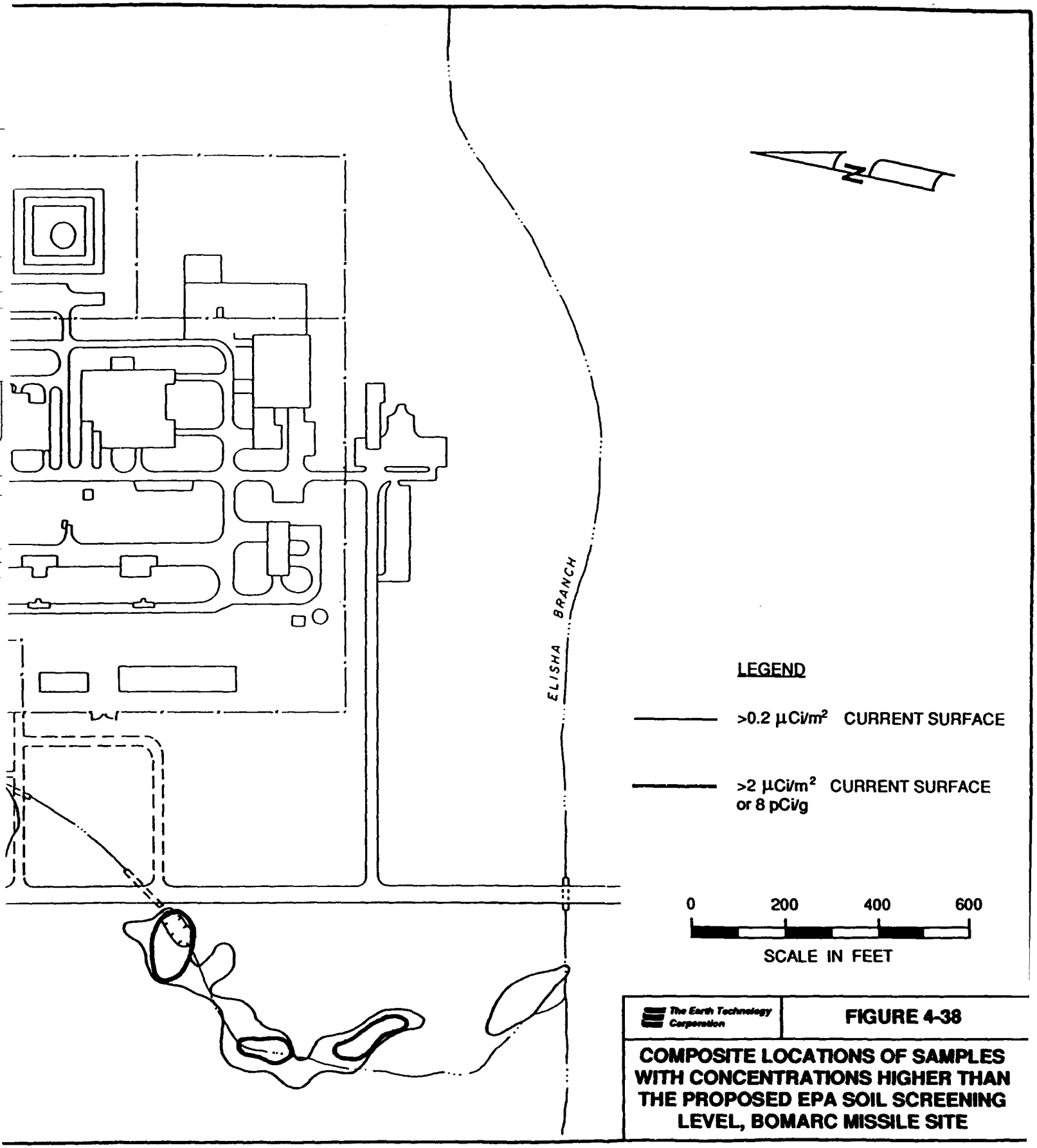


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FIGURE 4-38

COMPOSITE LOCATIONS OF SAMPLES WITH CONCENTRATIONS HIGHER THAN THE PROPOSED EPA SOIL SCREENING LEVEL, BOMARC MISSILE SITE

Evaluation of data from all of the surveys and multimedia sampling shows a reasonably clear pattern of a contamination plume that extends from Shelter 204 and the concrete apron westward, following the drainage ditch across Highway 539 into, and beyond the ponding area. Although slight variations occur between sampling media, instrument used, and time, a general stability in concentration and location of the contaminant plume is apparent. This is true through time as well as being verified by multiple samples and sample types (i.e., in-situ survey and soil sampling in the same specific areas).

4.1.5.2 Contaminant Migration

The following sections discuss contaminant migration.

4.1.5.2.1 Potential to Move Offsite and Off-Base

In order for plutonium contamination to move offsite and off-base, it must be transported by air, water, or physical means. During the missile accident, the fire fight, and subsequent decontamination activities, plutonium was transported by all of these means. The plutonium may have been carried on the smoke plume from the fire to the southwest as reported by eyewitnesses to the accident. Surface deposition modeling suggested that a plume rising higher in the atmosphere than estimated by eyewitnesses would carry the plutonium more to the south or south-southeast. In either case, the smoke plume could have carried the contaminant offsite and off the Air Force facility, although not necessarily off military property. Subsequent contaminant transport by air could take place through resuspension of contaminated, unstabilized soil. Appendix H contains a comparison of surface deposition modelling predictions and field survey results. This study showed that the uncertainties associated with the modelling effort were too great to allow for meaningful comparison.

Water from the fire-fighting effort and subsequent decontamination flowed westward down the asphalt apron and entered the drainage ditch. Open-channel sediment transport modeling indicated that any plutonium in the water would be transported as far as the water flowed. Although the exact location of the earthen dam installed in the ditch to impound fire-fighting run-off was never determined, placement in any of the several likely positions would have resulted in deposition of the plutonium at that point. Any of several large storms after the accident and before the asphalting of the drainage ditch could have removed plutonium and carried it to, or beyond, the ponding area located to the west of Highway 539.

Patterns established through the in-situ surveys and soil sampling confirm that plutonium has moved offsite into and slightly beyond the ponding area. Much of the movement offsite (i.e., outside of the fence boundaries) probably took place during or shortly after the missile accident and prior to asphalting the drainage ditch. After asphalting little, if any, movement would occur of material under the cap, but movement could continue from the unlined portions. Additional movement to and out of the ponding area has probably taken place during major storms since the ditch was asphalted. Unstabilized material will continue to slowly migrate due to runoff from large storms and associated physical transport of contaminated sediments.

During the fire, contaminated materials (including water) were probably transported on the feet and equipment of fire-fighting personnel. Decontamination would have prevented that

contamination from leaving the site at that time. Normal facility activities over the 12 years prior to decommissioning, as well as radiation surveys, maintenance, and scavenging activities after the facility was closed provided innumerable opportunities for physical transport of contaminated materials.

Two other areas are of concern because of potential migration offsite. One is the unlined drainage ditch that flows north from Shelter 204. Although Shelter 204 itself drains to the southwest as already discussed, the shelter lies near a drainage divide on the missile property. Runoff from the immediate vicinity of Shelter 204 does not enter this northward flowing ditch, but it is possible that contaminants entered the ditch during the missile accident site or fire-fighting activities. Data from the HPG Survey does not indicate contamination in this ditch, and surface water samples taken in the ditch were uncontaminated. Therefore, it is considered unlikely that this ditch is transporting contaminants offsite.

The point of intermittent high activity near the northeastern boundary of the facility is located on a steep slope down to the perimeter fence. It is not known how the contamination reached that point or if it is in a mobile form. The contamination does not seem to be migrating; however, it is within about 50 feet of the perimeter fence.

4.1.5.2.2 Rate and Direction of Migration Based on Hydrogeologic Properties

Most of the plutonium that is migrating offsite is along the asphalt-lined drainage ditch and in the ponding area that eventually leads to the Elisha Branch. The drainage is dry, except during large storms. Large storms, however, have sufficient force to transport sediments with adsorbed plutonium. If reports from the eyewitnesses are correct, the water from the fire-fighting effort probably did not travel past the ponding area. The known contamination has traveled about 1,000 feet past the ponding area, based on in-situ survey results. If we assume that all migration of plutonium out of the ponding area took place after June 1960, the rate of migration along the drainage out of the ponding area has been about 33 feet per year. At that rate, any migrating plutonium would reach the swampy areas of the Elisha Branch in about 97 years. However, transport of contaminated sediments does not take place at a constant rate, but is episodic during large storm events. Transport of contaminated sediments can be either much faster or much slower than 33 feet per year, depending on the frequency and magnitude of storm events. Transport rates would be expected to slow considerably once contaminated sediments reach the Elisha Branch due to the essentially flat stream gradient and heavily vegetated nature of the stream channel.

4.1.5.2.3 Time of Travel To Receptors

The path and direction that the plutonium seems to be migrating (along the Elisha Branch drainage) crosses land owned by the military and a wildlife management area. The nearest human receptors are near the eastern edge of Lakehurst NAS, assuming they use water from the Ridgeway Branch of the Toms River. Since the plutonium is likely to stay in the streambed, it would follow a path that is over 10 miles long. If the plutonium continues at the historical rate of migration of 33 feet per year, it would reach the Lakehurst settlement in about 1,600 years.

4.1.5.2.4 Applicability of Solute Transport Models

Plutonium dioxide is nearly insoluble under most natural environmental conditions. Therefore, the major consideration for transport is one of physical transport by wind, water, people, animals, or vehicles. A solute transport model would be of limited usefulness.

4.1.5.2.5 Expected Spacial and Temporal Variations in Concentration

With continued migration and time, the plutonium concentration would be expected to be continually diluted through dispersal of particles in the stream channels until it reached levels indistinguishable from background. Although radioactive decay would take place, the half life of plutonium is so long that it would be a minor factor in reducing risk. Resuspension and subsequent wind transport of plutonium particles is unlikely once they are in the stream sediment. The vegetation cover along the likely sediment transport routes is sufficiently heavy to prevent resuspension and transport through the air pathway.

4.1.5.3 Baseline Radiological Hazard Assessment

The purpose of this section is to summarize the available data on radioactive contamination at the site, describe the methodology used for assessing potential radiological impacts, and present the results of radiological impact calculations for the existing baseline conditions. The approach used for the analyses reported here generally follows the guidance suggested by the Environmental Protection Agency for risk assessment under the Superfund cleanup program (EPA, 1989).

The assessments presented herein evaluate the potential radiological impacts to the general public from existing site conditions in the absence of site remediation or control. These conditions correspond to the "Unrestricted Access" cleanup alternative against which proposed remediation approaches will be compared.

The objective of this baseline radiological hazard assessment is to estimate the baseline risk due to radiological contamination at the BOMARC Missile Site. The scope of this assessment includes the following: 1) a description of existing contamination, 2) methodology for assessing potential radiological impacts, and 3) results of radiological impact calculations for baseline conditions.

4.1.5.3.1 Waste Characterization

The transuranic elements plutonium (primarily Pu-239) and americium (as Am-241) are the principal radionuclides of concern at the BOMARC site. They belong to a group of elements known as actinides that include the elements from atomic number 90 (thorium) through 103 (lawrencium), all of which are radioactive. In general, the chemistry of the actinides is extremely complex. However, the behavior of plutonium, and particularly the oxides of plutonium in the environment, has been sufficiently well studied to permit reliable assessment calculations (Hanson, 1980).

The weapons grade plutonium (WGP) found at the BOMARC site consists of approximately 93 percent Pu-239 and 7 percent Pu-240, with smaller quantities of Pu-238 and Pu-241. Both Pu-

239 and Pu-240 have very long half lives (see Table 4-37) and have not decayed significantly since the accident. Pu-241, however, has a half life of 13.2 years so that approximately 81% of the amount involved in the accident will have decayed away by April 1992. As each nucleus of Pu-241 decays, one nucleus of Am-241 with a half life of 458 years is produced. As a consequence, Am-241 is also of concern at the BOMARC site. For example, after a period of 32 years, (e.g., 1960 - 1992), 1 Ci of Pu-241 would have decayed to 0.21 Ci, and would have produced 2.5×10^{-2} Ci of Am-241. Over a longer period of time, for example 200 years, an initial amount of 1 Ci of Pu-241 would decay to approximately 6.6×10^{-6} Ci, and would also result in 2.5×10^{-2} Ci of Am-241 at the end of the time period. The same amount of Am-241 is present at the end of both 32 and 200 years; this is because over this time period, Am-241 is being produced via the decay of Pu-241 at essentially the same rate that it is decaying away.

Smaller amounts of other daughter products in this decay chain would also exist at the end of these time periods (e.g., ^{237}Np). The Pu-239 decay chain also produces radioactive daughters, but because of the longer half lives of Pu-239 and some of its daughters, much smaller amounts build up. After a period of 32 years, 1 Ci of Pu-239 would have decayed to 0.999 Ci, and would have produced 2.9×10^{-8} Ci of ^{235}U. Over a period of 24,400 years, an initial amount of 1 Ci of Pu-239 would decay to 0.5 Ci, and would result in 8.6×10^{-6} Ci of ^{235}U at the end of the time period.

4.1.5.3.2 Source and Release Characterization

The primary source of information used to assess potential radiological impacts is the record of monitoring results obtained since the time of the accident. The best and most recent data from Air Force surveys were collected in 1987. In particular, site characterization activities have been conducted during 1989 and 1990 as part of the Air Force IRP efforts and the RI/FS process.

Contaminated areas and materials at the BOMARC missile accident site include the structural components of the shelter, manholes (power and communication bunkers, covers, and contents), soil in the shelter area, asphalt, concrete, and materials and sediments in the drainage ditch that crosses Ocean County Highway 539.

Given the nature of the accident, the amount of residual radiological contamination at the BOMARC accident site is difficult to determine accurately. The best available data, summarized in Appendix Q, indicates that a maximum of 300 grams of plutonium was unaccounted for the following the accident.

The primary isotope in WGP is Pu-239, but small quantities of Pu-238, Pu-240, Pu-241, and Am-241 (from beta decay of Pu-241) are expected to be found. These contaminants are found in or on soil, concrete, asphalt and steel. The radioactive contamination is not distributed uniformly over the site, but occurs in discrete "hot spots", which in several instances have been found to be a single particle, presumably containing plutonium oxides. Thus, measurements within a small area can, and do, vary somewhat. This variation is seen in samples that have been collected from the same location but at different times. Generally, however, the samples indicate that the levels of contamination have remained stable over the intervening years.

Table 4-37

Radiological Properties of Specific Nuclides of Plutonium and Americium of Concern at the BOMARC Site[1]

	Pu-238	Pu-239	Pu-240	Pu-241	Am-241
Half life (years)	8.78×10^{1}	2.44×10^{4}	6.58×10^{3}	1.32×10^{1}	4.58×10^{2}
Primary Radiation	ALPHA	ALPHA	ALPHA	BETA	ALPHA
Energy (Mev)	5.50	5.16	5.17	0.021	5.49
Secondary Radiation		GAMMA			PHOTON
Energy (Mev)		0.017			0.060

1. Kocher, D.C., Radioactive Decay Tables, U.S. Department of Energy, DOE/TIC-11026, 1981.

The site characterization data supporting the RI/FS were used to determine characteristics such as maximum concentrations of Pu-239 in soil, depth of contamination, and other physical characteristics. For the purposes of the baseline radiological hazard assessment, the total area of contamination at the BOMARC site is estimated to be 76,500 m^2, with an average Pu-239 contamination level of 32 pCi/g. The ratio of Pu-239 activity to Am-241 activity is 5.9. The details of these assumptions are given in Appendix J.

4.1.5.3.3 Transport and Fate of Contamination

The oxides of plutonium and americium are relatively insoluble in water and have a high affinity for soil particles. As a consequence, these elements are not highly mobile in the environment and are not readily taken up by plants and animals. This is illustrated by the values of the four quantities that are typically used for assessment purposes to define the movement of radionuclides through food chains (see Table 4-38).

The distribution coefficient, K_d, is the ratio between radioactivity adsorbed to soil (pCi/g) and that in solution in surrounding water (pCi/ml). Values of the distribution coefficient vary widely depending on site-specific properties of both soil and water. Americium is generally more mobile than plutonium and has a range of K_d in freshwater of about 10^2 to 4×10^4 ml/g. Plutonium has a range under similar conditions of about 10^2 to 10^7 ml/g. The values given in Table 4-38 are the median values reported. These high values indicate that the actinides adsorb strongly to soils and would not be expected to move readily in solution. Any significant dispersion of actinides in the environment will most likely be due to movement of soil particles themselves, either as wind-blown dusts or as waterborne sediments.

The B_v is a plant uptake factor and is expressed as the ratio between concentration in the above-ground portions of plants growing in the soil (pCi/g) and concentration in soil (pCi/g). As indicated in Table 4-38, plant concentrations of both elements are generally about 500 times smaller than concentrations in soil. The transfer coefficient, F_f, is the ratio between concentration in beef (pCi/kg) and daily intake by beef cattle (pCi/d). The transfer coefficient, F_m, is the ratio between concentration in cow's milk (pCi/L) and daily intake by dairy cows (pCi/d). The values in Table 4-38 indicate that low uptake by animals results in very low concentrations in animal products for human consumption.

4.1.5.3.4 Exposure Pathways

Pathways at the BOMARC site include air, ground water, surface water during heavy runoff, and physical (mechanical) transport. Any plutonium at the site that is not fixed or immobilized (i.e., by concrete or asphalt) is subject to resuspension and transport. The ground water at the site is generally less than 50 feet below the ground surface. The BOMARC facility lies at or very near the top of a hydrologic divide. Any contamination entering the Cohansey aquifer has the potential of being transported to nearby surface water bodies or shallow aquifer wells. Plutonium tends to adhere to soil particles and open-channel modeling indicates that surface water transport of plutonium-contaminated sediments could occur during heavy storm runoff. Any intrusion into contaminated soil or other materials by people or animals could cause contamination to adhere to that person or animal (or to adhere to anything removed by them) and lead to physical transport of plutonium off of the site.

Table 4-38

Environmental Transport Parameters
for Plutonium and Americium

	K_d (ml/g)[a]	B_v (---)[b]	F_f (d/kg)[b]	F_m (d/L)[b]
Plutonium	2.0×10^{4}	2.0×10^{-3}	4.1×10^{-7}	4.5×10^{-6}
Americium	4.0×10^{2}	2.1×10^{-3}	1.6×10^{-6}	2.0×10^{-6}

a. Isherwood, D., Geoscience Data Base Handbook for Modeling a Nuclear Waste Repository, U.S. Nuclear Regulatory Commission, NUREG/CR-0912, UCRL-52719, 1981.

b. Till, J. E., and H. R. Meyer, Radiological Assessment, U.S. Nuclear Regulatory Commission, NUREG/CR-3332, ORNL-5968, 1983.

ml = milliliter
g = gram
d = day
kg = kilogram
L = liter

In general, the calculation of radiation doses to an individual is based on the exposure routes by which each radionuclide causes irradiation. There are four routes considered in this analysis:

1. External exposure from submersion in a radioactive cloud
2. External exposure from radioactivity on the ground
3. Internal dose from inhalation of radioactivity
4. Internal dose from ingestion of contaminated foods and soil.

In order to present a significant hazard from external exposure, a radionuclide must emit penetrating radiation in the form of a gamma ray, x-ray, or energetic beta particle. Among the radionuclides of concern at the BOMARC site, only Am-241 has an x/gamma-ray emission sufficient to pose a potential external exposure hazard (Table 4-37).

Internal dose from ingestion of contaminated foods depends on the uptake of each radionuclide into foods and subsequent uptake by the human body. All actinides are poorly taken up by plants, animals, and people (Table 4-37). Consequently, while some potential exists for radiation dose from ingestion, this will not be the dominant route for plutonium and americium. Intake of contaminated ground water is another potential source of radiological dose from plutonium. However, plutonium and americium are relatively insoluble in ground water, and are not readily transported via ground water movement. Finally, direct ingestion of contaminated soil is a potential source of radiological dose from plutonium. Ingestion of soil occurs more frequently with infants and children than adults, but it can be an important dose contributor.

The route of primary concern for plutonium and americium is inhalation of contaminated particles. This is a consequence of three factors. First, these radionuclides are alpha particle emitters (Table 4-37). Alpha particles have very short ranges in tissue but are very efficient at depositing their energy in a small volume. Second, the chemically inert actinide oxides remain in the lung for long periods of time. Finally, radioactive contamination at the BOMARC site exists in a form which is likely to produce respirable particles during intrusive activities.

Airborne particulates contaminated with plutonium and americium are the dominant hazard associated with activities on the BOMARC site. Resuspension of contaminated soil during undisturbed periods and generation of fugitive dust during remediation activities are the primary mechanisms by which airborne transport may take place.

This analysis considers the baseline case in the absence of site remediation or control ("Unrestricted Access" alternative). Baseline conditions are characterized by long-term, undisturbed conditions during which resuspended material may potentially be dispersed off site to expose the general public. During remedial activities there is an additional potential for fugitive dust which may pose a radiological hazard to workers on site and which may also be dispersed off site to pose a potential hazard to the general public.

4.1.5.3.5 Identification of Receptors

Two types of analyses were conducted for this baseline radiological hazard assessment. The first consists of an analysis of the potential dose to hypothetical maximally exposed individuals

residing on the BOMARC site itself. The second estimates the potential collective dose to the population within 50 miles of the site.

Hypothetical Maximally Exposed Individual. This assessment will evaluate the potential for radiation dose to members of the general public who may inadvertently expose themselves to current levels of contamination at the BOMARC Missile Site. Upper bound estimates of potential doses for a hypothetical maximally exposed individual have been determined using a farm family scenario.

This calculation is fully implemented in a computer code called RESRAD. This code has been developed for the specific purpose of determining cleanup criteria for radioactively contaminated soils (Gilbert et al., 1989). It contains all the potential routes of exposure discussed in Section 4.1.5.3.4 except external exposure from submersion in a radioactive cloud; this pathway would not be significant at the BOMARC Missile Site. Input parameters used and output tables from RESRAD are provided in Appendix J for the farm family scenario.

It is the position of the U.S. Air Force that institutional control of the site will be maintained by the Air Force indefinitely. However, in order to obtain a worst-case estimate of potential risks, a more conservative approach is taken. To estimate the upper bound for doses from intrusion, it will be assumed that institutional control of the site will be lost at some time in the indefinite future and members of the public will have unrestricted access. It will be assumed that an individual continuously resides on the existing BOMARC site and consumes foods grown in areas with the maximum contaminant concentration. In order to provide an upper bound for potential doses, it has been assumed that all the radioactivity on the site is available for transport through the environment. That is, the barriers presented by existing concrete and asphalt covers have been neglected. This scenario is considered extremely unlikely, and is not considered a reasonable exposure scenario. However, for the purposes of obtaining the upper bound estimate of risk, this approach is employed.

Permanent residents, rather than individuals exposed by activities not associated with residential living, have been chosen as the critical population group because the exposure of permanent residents is more likely to be long term and will generally involve exposure by more routes. Nonresident groups, such as construction workers and individuals involved in recreational activities, will receive a much smaller dose than a permanent resident because they will spend less time on site. Scavenging can also occur, but exposure of scavengers can reasonably be assumed to be comparable to that of construction workers. The exposure of construction workers or scavengers is unlikely to last longer than a few months and would generally be limited to working hours. The lifetime exposure for construction workers and scavengers is, therefore, unlikely to exceed the lifetime dose for a permanent onsite resident. Exposure of workers in onsite industrial or commercial buildings can also occur, but this exposure will generally be less than that of residents because the exposure will be limited to working hours and will not include contributions from ingestion of foods grown on site.

Exposure scenarios used for establishing soil guidelines should be bounding in the sense that they correspond to actions, events, and processes that will result in the largest exposure likely to occur to individuals and groups. However, they must also be credible, which implies that the probability of occurrence should be above some threshold value. The basis for specifying a

credible bounding scenario is ill-defined because a threshold probability for distinguishing between a credible and a noncredible scenario has not been established, and it is usually not possible to assign a meaningful probability of occurrence for a scenario (unless the scenario is physically impossible, in which case a zero probability can be assigned). A family-farm scenario, in which a family constructs a home on the contaminated site and raises an appreciable fraction of its food on this site, is considered to be a credible bounding scenario for the purpose of this assessment. Even though such a scenario is very unlikely to occur at the BOMARC site, it cannot be excluded as noncredible at some time in the future.

Potential routes of exposure included in this analysis are external radiation from contaminated ground as well as internal radiation from inhalation, ingestion of food, drinking water, and soil. Both the effective dose equivalent (EDE) and organ dose commitments will be reported. Because of the known behavior of actinides in the environment, inhalation dose will be the dominant route and the lung will be the critical organ.

Potential Offsite Population Dose. Atmospheric dispersion of contaminated material off of the BOMARC site has been evaluated using the appropriate modules of the GENII computer code. GENII is a code developed by Battelle Pacific Northwest Laboratory (PNL) to assess the radiological consequences of releases to the environment (Napier et al., 1988). It allows several options for atmospheric dispersion calculations. Further, it is coupled directly to the dosimetry calculations necessary for assessing the potential impacts to members of the public. Input parameters and output tables from GENII appear in Appendix J of this document.

This assessment uses the straight-line Gaussian plume option for both long-term, undisturbed conditions and for fugitive dust during remediation alternatives. The straight-line Gaussian plume model is the basis for a set of dispersion models that are widely accepted for routine dose assessment applications. For this analysis, annual average air concentrations have been estimated on a 16-sector grid out to a distance of 50 miles (80 km) as a basis for estimating potential impacts to the general public. The meteorological conditions used are those reported for the weather station at McGuire AFB (Station 14706) taken from January 1966 through December 1977 and averaged over that period. The BOMARC site was treated as a circular, ground-level source with a 100-meter radius. The population consists of over nine million people according to projections for 1995 (Table 4-39). Dose commitments for a 50-year period following the year of release are estimated (Table 4-40).

Potential routes of exposure calculated by GENII include external radiation from contaminated air and ground surface as well as internal radiation dose from inhalation and ingestion of contaminated foods. Doses to individuals in each zone were estimated first. Doses for each zone were then multiplied by the projected population within the zone. Resulting population doses were summed over all zones. Both EDE and organ dose commitments are reported in the following section along with estimates of potential health effects.

4.1.5.3.6 Threat to Human Health

The measures of radiological hazard calculated in this assessment are 50-year integrated dose commitments reported in units of rem, often referred to as "dose" for brevity. These are calculated for each of several organs of the body for each radionuclide. Because different

Table 4-39

Distribution of Population Within 50 Miles of the BOMARC Site
(BOMARC Site Population Forecast 1995)
Created 13 Nov 89

Outer Radius (mi) Direction	1	2	3	4	5	10	20	30	40	50
S	0	0	0	0	32	9869	34615	51280	61366	42067
SSW	0	0	0	0	119	8845	32502	50806	58420	69726
SW	0	0	0	0	0	8435	32502	76204	185880	85913
WSW	0	0	0	0	0	8298	32502	59175	314380	328145
W	3	0	68	173	209	8435	32502	158134	868405	630755
WNW	3	45	182	0	328	10099	42144	94159	148676	204130
NW	14	123	187	259	328	19330	89976	145215	81479	96614
NNW	25	112	175	243	313	17046	104397	145806	98141	83055
N	35	80	121	157	177	14119	94513	238987	282427	479833
NNE	35	80	121	167	193	10774	74483	154901	297060	1656262
NE	35	80	121	168	213	9938	71539	121506	41612	595909
ENE	35	80	121	168	213	9938	59417	52431	0	0
E	35	62	74	62	62	9938	38508	4969	0	0
ESE	27	9	0	301	870	9938	38922	9938	0	0
SE	0	0	50	134	1205	9938	38922	33125	0	0
SSE	6	0	117	268	987	9938	38922	56727	22360	0
Total in annulus	2.53E+02	6.71E+02	1.34E+03	2.01E+03	5.25E+03	1.75E+05	8.56E+05	1.45E+06	2.46E+06	4.27E+06
Total in radius	2.53E+02	9.24E+02	2.26E+03	4.36E+03	9.61E+03	1.84E+05	1.04E+06	2.49E+06	4.95E+06	9.23E+06

Table 4-40
Distribution of Population Dose with Distance and Direction from the BOMARC Site (person-rem/year)

Outer Radius (mi)	1	2	3	4	5	10	20	30	40	50
Direction										
S	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.52E-04	2.32E-02	3.22E-02	2.46E-02	1.90E-02	9.44E-03
SSW	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.96E-04	1.46E-02	2.11E-02	1.69E-02	1.26E-02	1.09E-02
SW	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-02	1.67E-02	2.01E-02	3.17E-02	1.06E-02
WSW	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.52E-03	1.47E-02	1.37E-02	4.70E-02	3.57E-02
W	3.30E-04	0.00E+00	5.52E-04	8.65E-04	7.36E-04	1.46E-02	2.23E-02	5.52E-02	1.97E-01	1.03E-01
WNW	2.17E-04	5.21E-04	9.75E-04	0.00E+00	7.60E-04	1.16E-02	1.90E-02	2.17E-02	2.22E-02	2.20E-02
NW	7.83E-04	1.10E-03	7.71E-04	6.58E-04	5.83E-04	1.70E-02	3.12E-02	2.57E-02	9.32E-03	7.99E-03
NNW	1.96E-03	1.39E-03	1.00E-03	8.54E-04	7.71E-04	2.07E-02	.01E-02	3.56E-02	1.55E-02	9.52E-03
N	5.95E-03	2.15E-03	1.50E-03	1.19E-03	9.44E-04	3.70E-02	9.75E-02	1.26E-01	9.63E-02	1.19E-01
NNE	4.46E-03	1.62E-03	1.13E-03	9.56E-04	7.75E-04	2.13E-02	5.83E-02	6.19E-02	7.71E-02	3.11E-01
NE	4.46E-03	1.61E-03	1.12E-03	9.63E-04	8.54E-04	1.97E-02	5.64E-02	4.90E-02	1.09E-02	1.13E-01
ENE	4.31E-03	1.55E-03	1.09E-03	9.32E-04	8.30E-04	1.91E-02	4.54E-02	2.06E-02	0.00E+00	0.00E+00
E	6.66E-03	1.87E-03	1.03E-03	5.33E-04	3.74E-04	2.97E-02	4.58E-02	3.02E-03	0.00E+00	0.00E+00
ESE	3.83E-03	2.02E-04	0.00E+00	1.93E-03	3.92E-03	2.22E-02	3.45E-02	4.54E-03	0.00E+00	0.00E+00
SE	0.00E+00	0.00E+00	4.31E-04	7.09E-04	4.46E-03	1.82E-02	2.84E-02	1.24E-02	0.00E+00	0.00E+00
SSE	6.74E-04	0.00E+00	9.63E-04	1.35E-03	3.51E-03	1.75E-02	2.72E-02	2.03E-02	5.21E-03	0.00E+00
Total in annulus	3.36E-02	1.20E-02	1.06E-02	1.09E-02	1.91E-02	3.07E-01	6.01E-01	5.11E-01	5.44E-01	7.53E-01
Total in radius	3.36E-02	4.56E-02	5.62E-02	6.72E-02	8.62E-02	3.93E-01	9.94E-01	1.51E+00	2.05E+00	2.80E+00

radionuclides irradiate different organs and tissues, a method that expresses the total radiation risk to an individual is used. The International Commission on Radiological Protection (ICRP) has developed a model to equate the sum of the doses received by individual organs and body tissues to a single index of risk, the effective dose equivalent (EDE). The ICRP models for organ committed dose equivalents and effective dose commitments (ICRP, 1977; ICRP, 1979) have been used to develop a set of dose conversion factors that relate concentration in the air and on the ground to external dose rates and intake by inhalation and ingestion to internal dose. These dose conversion factors are presented in Table 4-41.

Health effects resulting from low doses of radiation are of a statistical nature. Knowledge of these delayed effects of low doses of radiation is necessarily indirect. This is because their incidence is too low to be observed against the much higher background incidence of similar effects from other causes. Hence, a relationship between health effect and radiation dose can only be estimated, based on observations made at much higher exposure levels, where effects have been observed in humans, and on carefully conducted animal experiments. In the range of doses under consideration for the BOMARC site the incidence of resulting health effects is very small. There have been no direct measurements of increased cancer incidence rates for low-level radiation exposures. Consequently, these estimates are relevant only to the average collective dose received by large populations of individuals and not to estimates of doses to individuals.

4.1.5.3.7 Carcinogenic Risks

Because expected releases of radioactive material from the BOMARC site would be small and the projected radiation dose to any individual is small, the only effects considered are long-delayed somatic effects. Acute radiation effects require exposures many orders of magnitude greater than those projected for BOMARC remediation. The delayed effects considered in this assessment are potential excess fatal cancers of the lung, bone, and liver.

For the BOMARC site the major concerns are associated with radiation dose to the lung, liver, and bone produced by plutonium isotopes taken into the body by inhalation or ingestion. The most comprehensive analysis of risks associated with this kind of radiation dose are presented in the report by the National Academy of Sciences committee on the Biological Effects of Ionizing Radiation entitled "Health Risks of Radon and Other Internally Deposited Alpha-Emitters" (the BEIR IV Report). The risk factors cited there for lung cancer from internally deposited transuranic radionuclides is 700 lung cancer deaths per million person-rad. For liver the risk estimate is 300 cancer deaths per million person-rad. For bone the range of risk estimates is given as 80 to 1,100 cancer deaths per million person-rad. In order to use these risk estimates, the doses given using the factors in Table 4-41 in units of rem must be converted to units of rads. For external doses from gamma rays no conversion is required. For internal doses from alpha emissions the number of rads can be calculated by dividing the number of rems by 20.

Hypothetical Maximally Exposed Individual. As shown in Table 4-42, radiation doses to a hypothetical, residential intruder are dominated by inhalation of plutonium-contaminated, resuspended dust. This route of exposure accounts for approximately 65% of the total dose. Inhalation of Am-241-contaminated dust contributes about 11% of the dose. Ingestion of

Table 4-41

Dose Conversion Factors for Plutonium and Americium

Radionuclide	EDE	Organ Dose Commitments		
		Bone Surface	Liver	Lung
External dose rate factors [a]				
Air immersion (mrem/yr per $\mu Ci/cm^2$)				
Pu-239	4.3×10^{5}	4.0×10^{5}	2.0×10^{5}	2.4×10^{5}
Am-241	9.7×10^{7}	1.2×10^{8}	6.2×10^{7}	6.9×10^{7}
Ground surface (mrem/yr per $\mu Ci/m^2$)				
Pu-239	3.8×10^{-2}	1.5×10^{-2}	4.8×10^{-3}	8.9×10^{-3}
Am-241	3.0×10^{0}	3.7×10^{2}	1.8×10^{0}	2.0×10^{0}
Internal Dose commitment Factors [b]				
Inhalation (mrem/μCi)				
Pu-239	5.1×10^{5}	9.3×10^{6}	2.0×10^{6}	1.2×10^{5}
Am-241	5.2×10^{5}	9.3×10^{6}	2.0×10^{6}	0
Ingestion (mrem/μCi)				
Pu-239	4.3×10^{3}	7.8×10^{4}	1.6×10^{4}	0
Am-241	4.5×10^{3}	8.1×10^{4}	1.7×10^{4}	0

[a] From DOE/EH-0070, 1988.
[b] From DOE/EH-0071, 1988, using aerosol class or gastrointestinal tract uptake fraction yielding the highest dose per unit intake.

Table 4-42

Dose Contributions for Individual Radionuclides and Routes:
Maximally Exposed Individual

	Percent of Total Dose by Route						
Radionuclide	Ground	Dust	Plant	Meat	Milk	Soil	Total
Am-241	0.2	11.1	0.2	0.1	0.0	3.4	15.0
Pu-239	.01	64.8	0.8	0.4	0.0	19.0	85.0
Total	0.2	75.9	1.0	0.5	0.0	22.4	100.0

plutonium and americium account for an additional 24% of the dose. Taken together, these routes of exposure resulting from internally deposited transuranic alpha-emitters account for more than 99% of the total dose. External gamma radiation dose, primarily from Am-241, accounts for less than 1% of the total. Waterborne radioactivity does not make a significant contribution to ingestion values, even for calculations taken out to periods of greater than 100 years.

Table 4-43 summarizes the potential radiation doses to the maximally exposed individual from each year of residence. This table also presents the total rate of excess fatal cancers and excess fatal cancers of the lung, liver, and bone for a hypothetical population of individuals exposed to these levels of radiation. Cancer risk estimates are intended to be applied to populations rather than to individuals, so only an estimate can be provided for the maximally exposed individual.

The natural incidence rate for all fatal cancers exceeds 2,500 cancers/year per million persons (NAS, 1990). In the United States, the natural incidence rate for liver cancers is about 50 cancers/year per million persons. The corresponding rate for lung cancers is about 600 cancers/year per million persons, and the rate for bone cancers is about 10 cancers/year per million.

It is useful to compare calculated dose rates to those of natural background radiation in the United States (NCRP, 1987). The estimated total dose rate of 47 mrem/year is small compared to the average annual background radiation dose of about 350 mrem/year. Similarly, the lung dose rate of 84 mrem/year calculated for this assessment is less than half of the estimated 200 mrem/year average lung dose rate resulting from exposure to naturally occurring radon.

Excess fatal cancers represented by excess fatal cancers per year per million persons have been converted to excess fatal cancers per lifetime. The conversion was completed by assuming an acceptable 70-year lifetime. The values for excess fatal cancers per lifetime presented in Table 4-43 estimate a health risk for the maximally exposed individual. The total excess fatal cancers per lifetime of 1.3×10^{-3}, or 1.3 excess fatal cancers per one thousand persons averaged over a 70-year lifetime, exceed the cancer risk of 10^{-4} or 100 excess cancers per one million persons averaged over a 70-year lifetime. A lifetime excess cancer risk of less than 10^{-4} is generally considered an acceptable excess cancer risk according to current U.S. EPA guidance.

Offsite Population. The potential baseline dose rates to the population within 50 miles of the BOMARC site are summarized in Table 4-44. The total dose rate of 2.7 person-rem/year is distributed over a population of about 9 million persons within 50 miles of the site. This gives an average of about 3.0×10^{-4} mrem/year to each individual in the population, a value that is several orders of magnitude smaller than that estimated for the hypothetical maximally exposed individual. The estimated total excess fatal cancer rate is very much less than one per year (9.1×10^{-4} cancers/year) over nine million persons. This value can be compared to a natural incidence that exceeds 2,500 cancers/year per million persons. This natural incidence rate corresponds to a lifetime incidence of approximately 20,000 cancer deaths per 100,000 individuals (NAS, 1990).

Table 4-43

Dose Rates and Health Risks: Maximally Exposed Individual

Dose Rates
(mrem/year)

Radionuclide	EDE	Bone Surface	Liver	Lung
Am-241	7	126	27	12
Pu-239	40	734	156	72
Total	47	860	183	84

Excess Fatal Cancers
(cancers/year per million persons)

Total	Bone	Liver	Lung
19	13	3	3

Average Excess Fatal Cancers Per Lifetime
(cancers/lifetime)

Total	Bone	Liver	Lung
1.3×10^{-3}	9.0×10^{-4}	1.9×10^{-4}	2.1×10^{-4}

Table 4-44

Dose Rates and Health Risks: Population within 50 Miles*

Dose Rates
(person-rem/year)

EDE	Bone Surface	Liver	Lung
2.7	51	9	0.4

Excess Fatal Cancers
(cancers/year)

Total	Bone	Liver	Lung
9.1×10^{-4}	7.6×10^{-4}	1.3×10^{-4}	1.3×10^{-4}

* Estimated to be 9.2×10^{9} people in 1995

Average Excess Fatal Cancers Per Lifetime
(cancers/lifetime)

Total	Bone	Liver	Lung
6.9×10^{-6}	5.8×10^{-6}	1.0×10^{-6}	9.8×10^{-11}

As discussed above for the maximally exposed individual, values of excess fatal cancers per million persons have been converted to values of excess fatal cancers per lifetime. Total excess cancers per lifetime (6.9×10^{-9}), as well as average excess cancers per lifetime of the bone, liver, and lung, do not exceed the generally acceptable U.S. EPA criterion of 10^{-6} excess cancers per lifetime. This indicates that the health of the general offsite population is not at risk.

4.1.5.3.8 Threat to Wildlife

The facility is fenced, with no permanent populations of deer or other large vertebrates. Rodents and other small vertebrates do inhabit the area. Vultures and other birds also reside on or near the site. At the levels of plutonium available to this resident wildlife, no threat is believed to exist.

5.0 ALTERNATIVE REMEDIAL MEASURES

This FS provides decision makers with a comprehensive evaluation of potential remedial alternatives to address conditions at the BOMARC Missile site, McGuire Air Force Base, New Jersey. The study utilizes information derived from the RI, RA and previous studies to define remediation objectives and develop feasible remedial action alternatives. The remedial objectives are based on the environmental conditions, contaminant levels, release pathways, and potential receptors. Once remedial objectives have been defined, an array of alternatives designed to achieve these objectives are proposed and screened.

The CERCLA, as amended by the SARA provides the statutory framework for cleaning up hazardous waste sites, and the NCP codifies implementation policy. The process of identifying and selecting remedies for uncontrolled hazardous waste sites is delineated within the NCP. The Air Force IRP is designed to comply with the NCP. This FS was prepared in accordance with the Air Force IRP guidance (version 2.0). Key elements of the process are illustrated in Figure 5-1. As required by the NCP, a wide range of alternatives which support site-specific remedial objectives are proposed and evaluated. For the BOMARC Missile study site, a broad-based approach to developing alternatives within NCP action categories has been adopted. Based on this approach, alternatives within each category defined in Table 5-1 are developed.

Table 5-1

Remedial Alternative Categories

Category	Criteria
1	Alternatives for offsite treatment and/or disposal
2	Alternatives that attain ARARs
3	Alternatives that exceed ARARs
4	Alternatives that do not attain ARARs but reduce risk to acceptable levels
5	No Action

This study documents the process of alternative development and evaluation in accordance with the provisions of CERCLA, SARA, the Air Force IRP, and the NCP. The U.S. EPA's Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA (Interim Final, October 1988) was also used to interpret the statutes and the NCP.

This FS process serves as the mechanism through which optimum remedies are formulated and developed for addressing environmental conditions at the BOMARC Missile site utilizing site, contaminant, regulatory, risk, and technological data. The process employed in this study consists of a phased progression designed to:

- Establish remedial action objectives
- Identify appropriate remedial actions and technologies
- Develop and screen remedial action alternatives
- Conduct a detailed analysis of the alternatives.

FIGURE 5-1
SCHEMATIC OF FEASIBILITY STUDY PROCESS
BOMARC MISSILE SITE

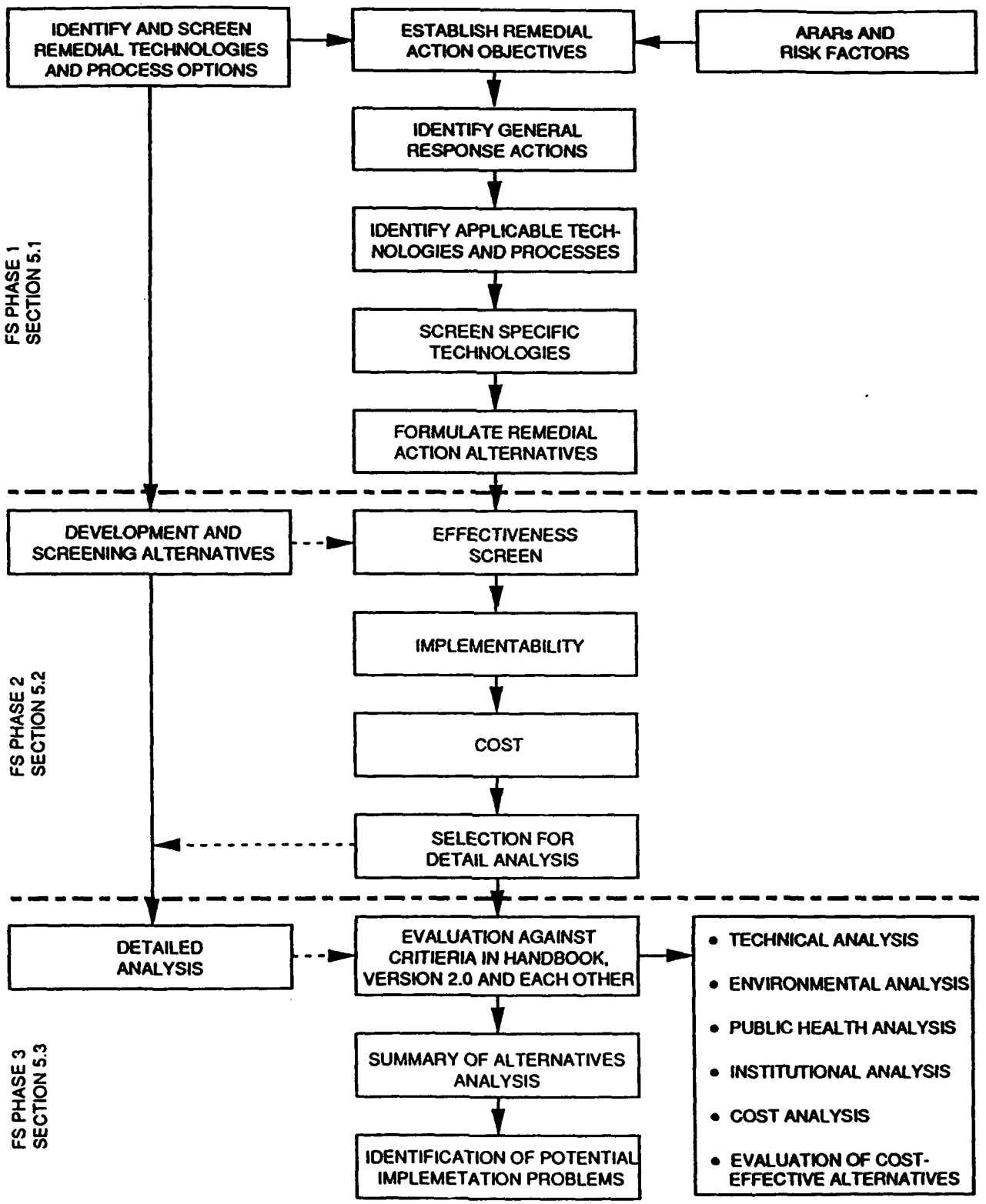


Figure 5-1 presents a schematic of the entire FS process, critical components, and relation to information presented in Sections 5.1 through 5.3 of this report. Information presented in this study is organized in the following manner:

Section 5.0	Introduction
Section 5.1	Identification and screening of technologies; development of remedial alternatives
Section 5.2	Screening of remedial alternatives
Section 5.3	Detailed analysis of remedial alternatives

In Section 5.1, remedial response actions and technologies appropriate for source control of the contaminated soils and structures are developed. Remedial action objectives are presented, and waste types and volumes are given. Remedial technologies and available process options are identified, and those technologies that are technically infeasible due to waste types or site conditions are eliminated from further consideration. Remaining technologies are then assembled into remedial alternatives.

In Section 5.2, remedial alternatives are reviewed according to their public health/environmental impacts, technical feasibility, and cost. Six remedial alternatives are considered in Section 5.2. These alternatives include an unrestricted access alternative, an existing conditions alternative, a limited action alternative, and three source control alternatives. Section 5.2 outlines the screening of the remedial alternatives and summarizes the rationale for retaining or eliminating alternatives.

In Section 5.3, alternatives remaining after development and screening are evaluated in detail. Detailed analysis includes the following:

- Technical Analysis
- Environmental Analysis
- Public Health Analysis
- Institutional Analysis
- Cost Analysis
- Evaluation of Cost-Effective Alternatives (comparative analysis)

The detailed analysis was conducted in accordance with IRP programmatic guidance, and covers the following nine EPA guidance criteria as specified in EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-01:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence along with the degree of certainty that the alternative will prove successful
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Cost
- Implementability

- State acceptance
- Community acceptance

5.1 Preliminary Alternative Remedial Actions

In this section, remedial response actions and technologies appropriate for source control of the contaminated soils and structures are developed. Remedial action objectives are presented. Remedial technologies and available process options are identified, and those technologies that are technically infeasible due to waste types, site conditions or technical requirements are eliminated from further consideration. Remaining technologies are then assembled into remedial alternatives.

5.1.1 Remedial Action Objectives

This section discusses the qualitative and quantitative remedial action objectives. The qualitative remedial objectives pertain to physical characteristics of the contamination while quantitative remedial objectives pertain to radioactive levels of the contamination.

5.1.1.1 Qualitative/Quantitative Remedial Objectives

In general, remedies selected for further consideration shall comply with the requirements of CERCLA as amended by the NCP and SARA. The following general remedial action goals apply to remedies selected for the site:

1. Remedies are protective of human health and the environment.
2. Actions are in compliance with federal and state ARARs.
3. Remedies utilize permanent solutions and onsite mitigation to the maximum extent practical.
4. Solutions effect a reduction in toxicity, mobility, or volume.
5. Recycling options are considered where appropriate.
6. Actions are cost effective.
7. Selected options are readily implementable and effective.
8. Remedies are acceptable to state agencies and the public.

State and public acceptance is not actually addressed within this Draft RI/FS report, but is addressed within the Responsiveness Summary contained in the Record of Decision (ROD) for the site. The ROD will be completed after the Final RI/FS report is issued. The ROD serves as a decision document for selection of a remedial alternative, and gives the rationale for alternative selection.

In addition to the general goals given above, media-specific, quantitative remedial action objectives have been developed using appropriate risk-based and regulatory-based goals. Table 5-2 summarizes the quantitative goals for the remediation of the BOMARC Missile site.

Table 5-2

Quantitative Remedial Objectives

Contaminant Media	Regulatory Goal	Risk-based Goal
Soils	N/A	<8 pCi/g
Structures	NRC Guide 1.86 Criteria:	N/A
	<20 dpm/100cm² Removable Activity	
	<300 dpm/100cm² Maximum Activity	
	<100 dpm/100cm² Average Activity	

For soils, the site-specific risk-based goal for remediation is 8 pCi/g Pu-239. This soil remediation level was derived by modelling radiation dose to a hypothetical maximally exposed individual using the RESRAD model. The RESRAD modelling effort, including derivation of input parameters, is presented in Appendix J to this report. The model was used to estimate the level of residual soil contamination that would result in an annual radiation dose of 4 millirem or less. Four millirem is considered the maximum acceptable annual radiation dose. A residual level of 8 pCi/gram Pu-239 is estimated to produce a dose of no more than 4 millirem per year. This MEI dose rate corresponds to a lifetime cancer risk of less than 10^{-4} (EPA, 1990). The methodology is described in more detail in Section 4.1.5.3 (Baseline Risk Assessment).

In order to estimate areas that may require soil remediation, it is useful to express the soil remediation goal of 8 pCi/g in terms of areal concentration (i.e., μCi/m²). This facilitates using the data generated by the HPG in-situ survey (Section 3.6.2.4), which are the most comprehensive areal contamination survey data available for the site. The soil remediation goal can be converted to an areal concentration as follows.

$$C_{surf} = C_m \times P_b \times d_r \times .01$$

where

C_{surf} = Areal concentration of contamination in soil (μ per m²),
C_m = Mass concentration of contamination in soil (pCi/g),
P_b = bulk density of soil (g per cm³),
d_r = contamination depth (cm)
.01 = unit conversion factor

Assuming a value of 1.6 g/cm³ for bulk soil density and a value of 15.25 cm for contamination depth, the remediation goal of 8 pCi/g can be expressed as an areal concentration of 2 μCi/m². As described in Section 4.1.5.3, the remediation goal was derived assuming a contamination depth of 15.24 cm (6 inches); therefore, the same depth is used in converting back to areal concentration.

Due to the uncertainties associated with conversion of activity per unit mass to areal activity, it is conservatively assumed for the purposes of this FS that areal activities of 1.5 μCi/m² or greater will require remediation.

For structures, no applicable cleanup standard has been promulgated. However, regulations in the U.S. Nuclear Regulatory Commission (NRC) regulatory Guide 1.86 are considered relevant and appropriate if the site is to be released for unrestricted access. For transuranics, limits for surface contamination are 20 disintegrations per minute per 100 square centimeters (dpm/100cm^2) for removable radioactivity, 100 dpm/100 cm^2 for average radioactivity, and 300 dpm/100 cm^2 for maximum radioactivity.

Attainment of the overall and site-specific response goals may be achieved through the use of access controls, active restoration, removal and disposal, containment, or other appropriate strategies specific to media, contaminants, or release pathways. For the purposes of this FS, remedial actions necessary to address conditions at the BOMARC site and achieve response action objectives identified in Table 5-2 will consist of source control measures targeted at contaminant sources (in-place wastes, contaminated soils and sediments). This will be further developed in subsequent sections of this document.

5.1.1.2 Volumes and Types of Contaminated Materials

The contaminants of concern, plutonium and americium, have been detected in the soils, sediments, structural materials and beneath the concrete apron. The location and activity ranges are presented in Figure 5-2. There are five categories of contaminated media, based on physical characteristics and applicable remedial technologies. The remedial technologies will be developed for the following media:

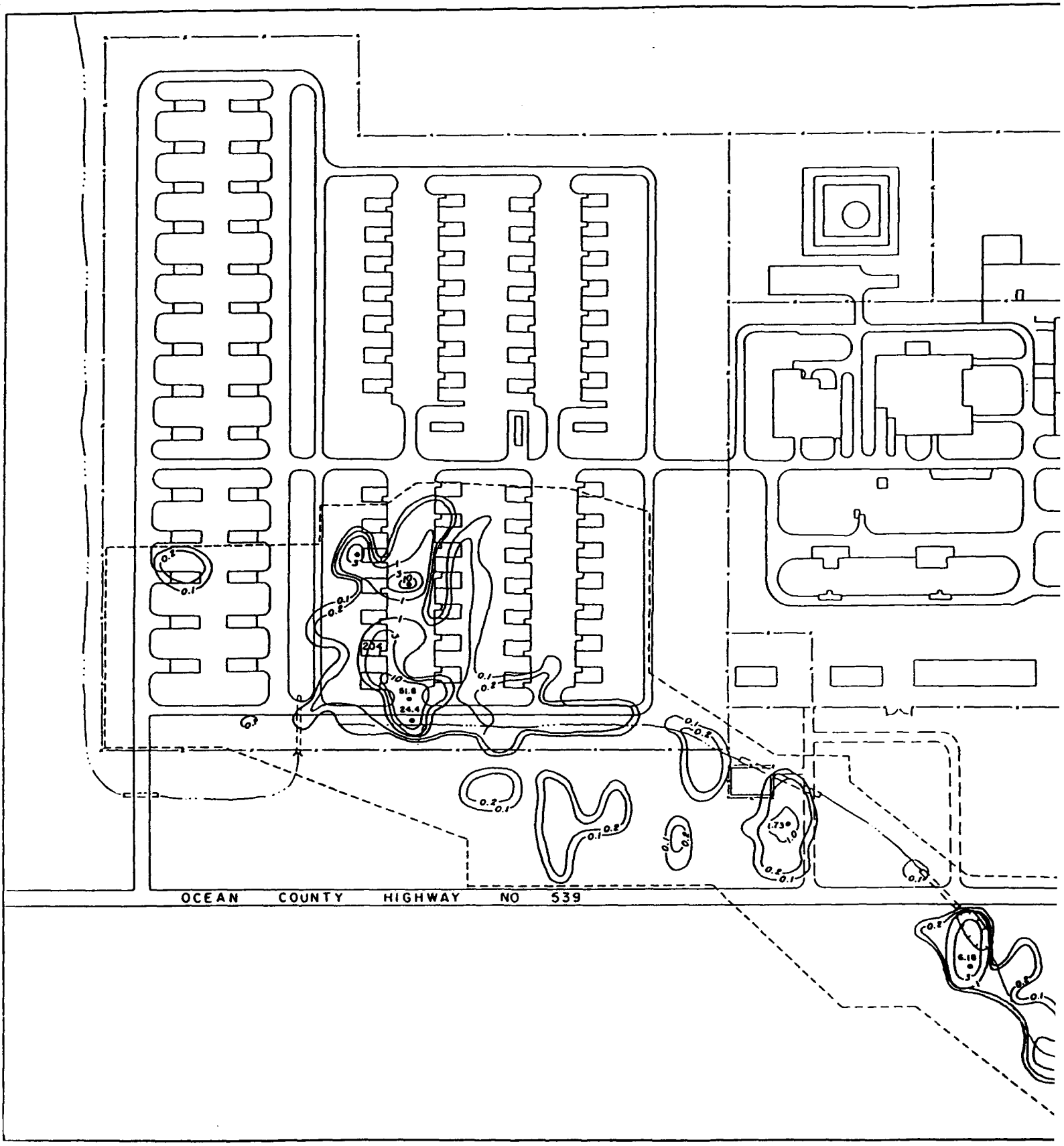
- Contaminated soils and sediments
- Contaminated apron and drainage ditch cover (concrete and asphalt)
- Shelter 204 (above-ground structures)
- Utility structures (underground)
- Missing missile launcher

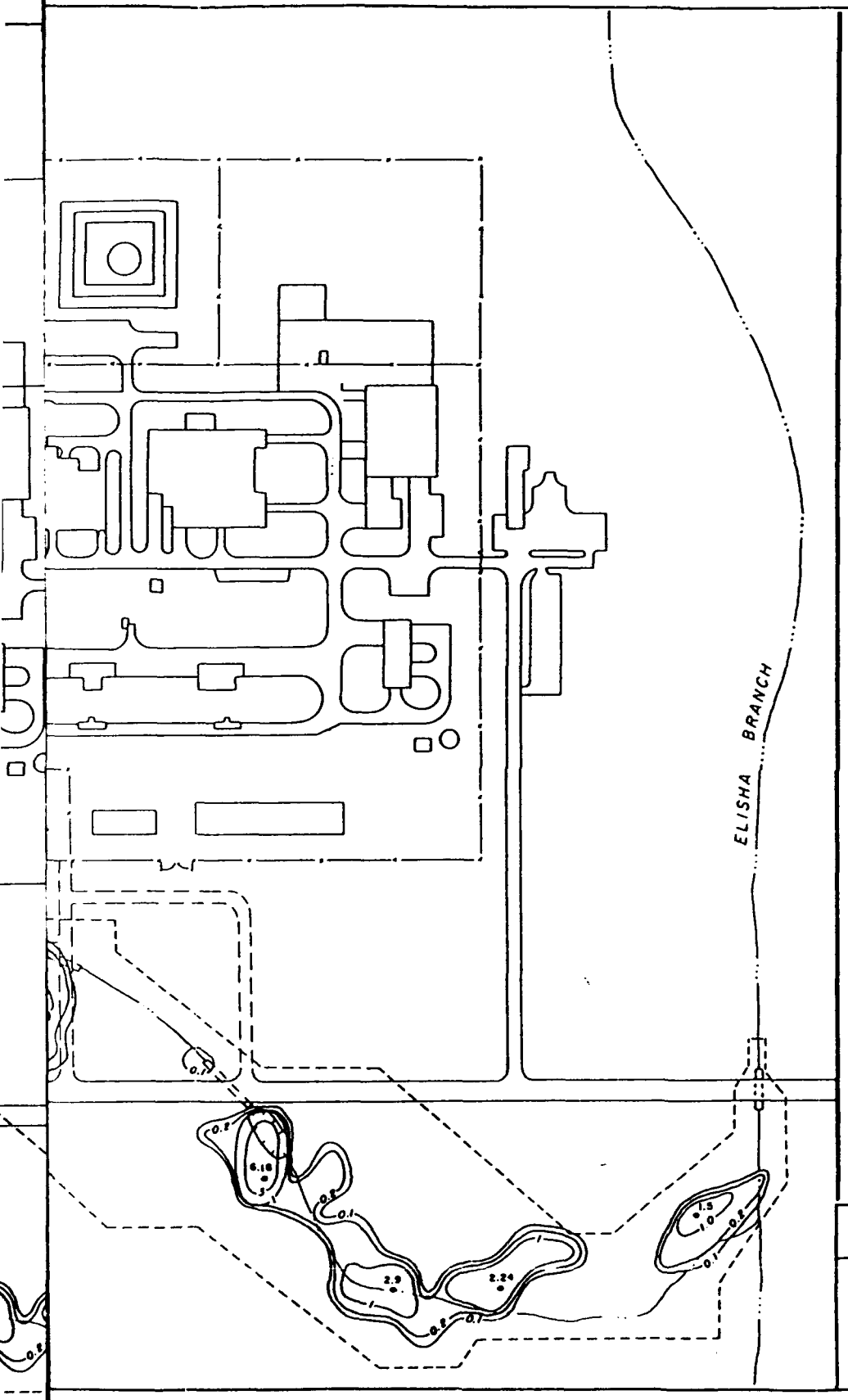
Table 5-3 summarizes estimated areas and volumes of contaminated media.

Contaminated Soil. Based on field data from the RI, radionuclide contamination in soils is mainly in the surficial foot of the soil column and is concentrated in discrete "hot spots". This field observation correlates well with known aqueous solubilities of plutonium and americium isotopes. Radionuclides do not appear to have migrated more than a few inches vertically since the 1960 accident. The current areal extent of contamination appears to be largely the result of fallout from the accident, mechanical tracking, and fire fighting activities, which consisted of flushing Shelter 204 with approximately 30,000 gallons of water.

The depth of plutonium contamination greater than the risk-based cleanup level of 8 pCi/g was generally less than one foot across the site, with a few exceptions, which are discussed below.

Soil borehole sampling data presented in Section 4.1.3.8.1 indicate that plutonium activity for samples taken below a depth of two feet was less than 8 pCi/g in all but two boreholes. At borehole 1, located just west of Shelter 204, the sample from the 2- to 4-foot interval had 8.1 pCi/g plutonium and the sample from the 8- to 10-foot interval had 39 pCi/g plutonium.


OCEAN COUNTY HIGHWAY NO 539



EXPLANATION

0.2 CONTOURS REPRESENT $\mu Ci/m^2$ (Pu)

LIMITS OF IN-SITU SURVEY

DRAINAGE

PONDING AREA

CULVERT

NORTH

0 250 FEET

SCALE

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FIGURE 5-2

AREAS SURVEYED USING THE HPG, WITH CONTOURS REFLECTING LEVELS OF MAGNITUDE OF CONTAMINATION, BOMARC MISSILE SITE

Table 5-3

Estimated Areas and Volumes Affected by Response Objectives

Contaminated Media	Action Level	Area (yd^2)	In-Place[1] Volume (yd^3)	Expanded[2] Volume (yd^3)
Soils and Sediment	8 pCi/g	11,650	5,150	6,200
Concrete Apron	See Table 5-2	2,500	291	582
Asphalt Apron	N/A	3,200	178	356
Asphalt Cover in Drainage Ditch	N/A	1,120	62	124
Shelter 204	See Table 5-2	584	201	402
Utility Bunkers	See Table 5-2	38	18.5	37
Missile Launcher	See Table 5-2	14	5	N/A

1 In-place volumes. Does not include volume increase from excavation.

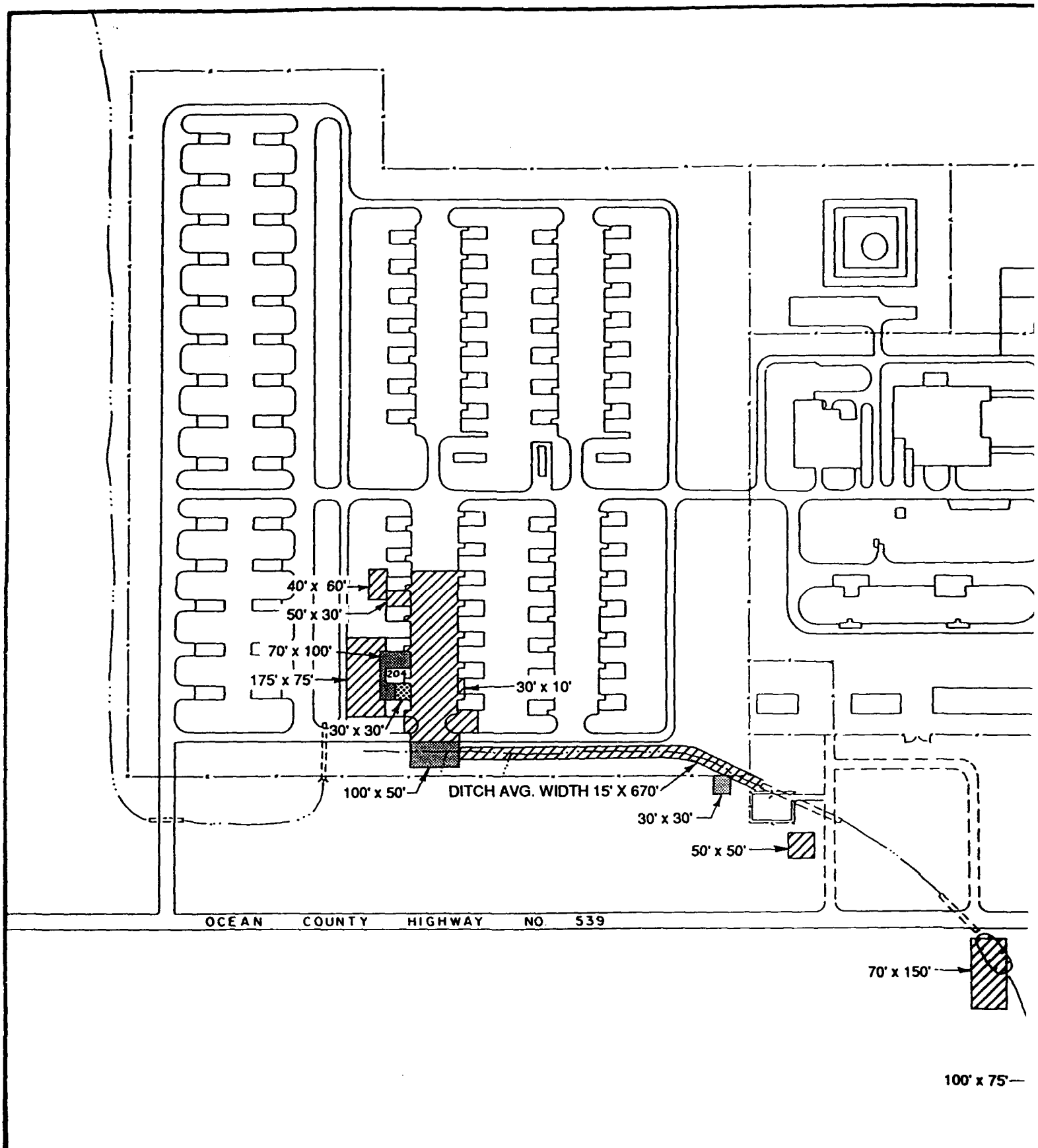
2 Excavated volumes. Includes expansion factor of 0.20 for soils, 2.0 for asphalt and concrete.

This location probably received a heavy discharge of firefighting water, which may be the reason for the increased depth of contamination. Since the full depth of contamination above the 8 pCi/g cleanup level at this location was not defined, any active restoration remedial alternative selected will require pre-design sampling at this location to establish the target depth for remediation. At borehole 20, the sample from the 2- to 4-foot interval had 10 pCi/g plutonium, and the sample from the 4- to 6-foot interval had no plutonium detected.

Soil sampling data presented in Section 4.1.3.8.3 indicates that plutonium contamination in excess of 8 pCi/g extends to a depth of at least 18 inches in a small area of the asphalt-covered drainage ditch just off the concrete apron. Samples below 18 inches were not obtained at this location, so the vertical extent of contamination is undetermined. Since the full depth of contamination above the 8 pCi/g cleanup level at this location was not defined, any active restoration remedial alternative selected will require pre-design sampling at this location to establish the target depth for remediation.

Due to the non-uniform soil deposition of plutonium in discreet particles, it is difficult to contour concentrations of plutonium in site soils with a high degree of accuracy. This makes estimation of volumes of soil requiring remediation problematic. In order to obtain a conservative estimate for volumes of soil to be remediated, several factors were taken into consideration.

One factor considered was the potential effect of demolition of contaminated structures (concrete apron, asphalt cover in drainage ditch, shelter 204) on surrounding soils. Engineering controls designed to minimize the release of contaminants will be implemented during any demolition activities, however it is likely that small amounts of soil beneath and adjacent to the shelter and concrete apron will become contaminated. Any soils affected will require remediation after demolition is complete. In order to estimate the volume of soils affected, "buffer zones" of soils potentially requiring remediation were established beneath and adjacent to the structures. Figure 5-3 shows areas and depths of soils to be remediated.


40' x 60'
50' x 30'
70' x 100'
175' x 75'
201
30' x 10'
30' x 30'
100' x 50'
DITCH AVG. WIDTH 15' X 670'
30' x 30'
50' x 50'
OCEAN COUNTY HIGHWAY NO. 539
70' x 150'
100' x 75'

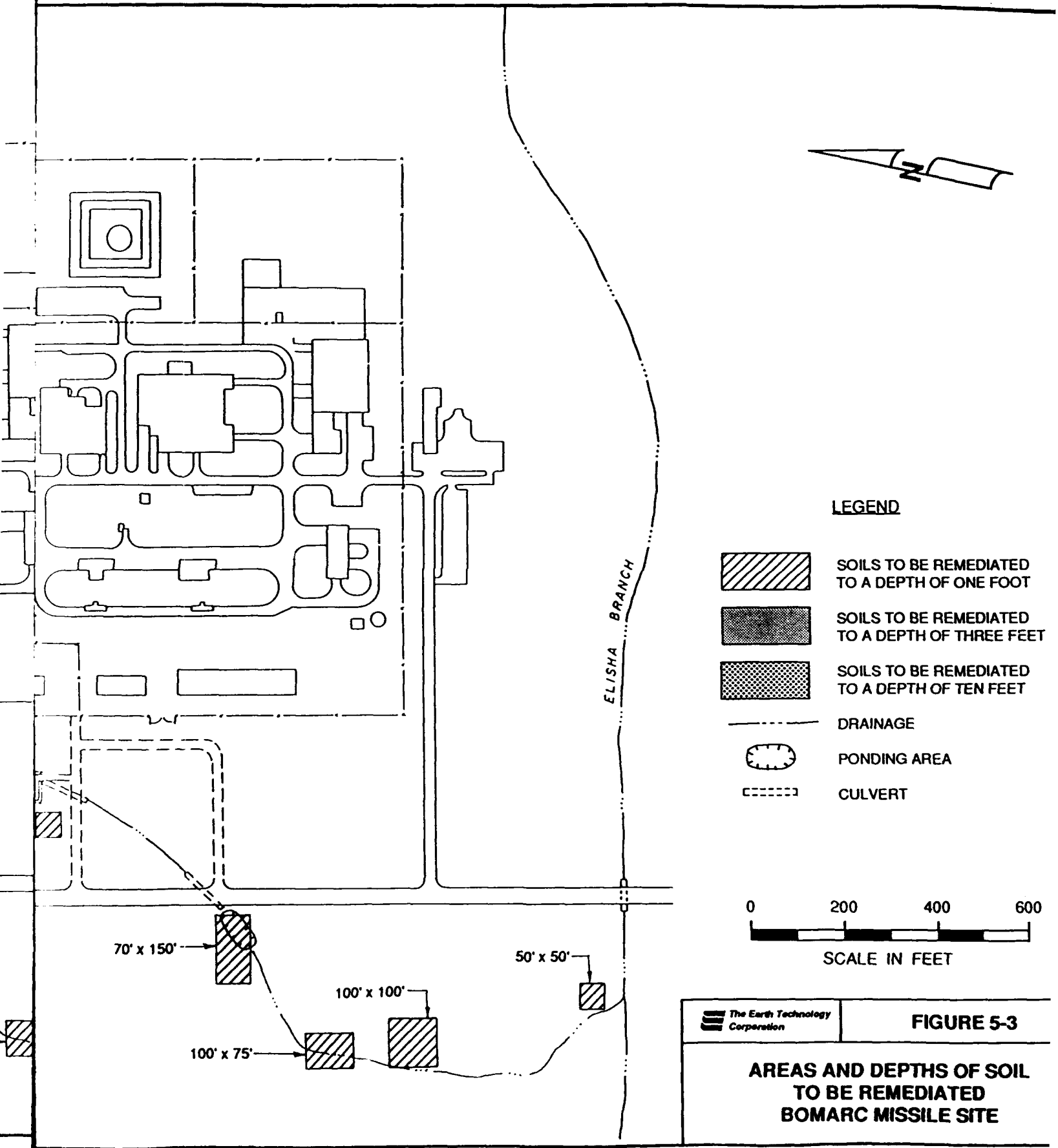


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FIGURE 5-3

AREAS AND DEPTHS OF SOIL TO BE REMEDIATED BOMARC MISSILE SITE

In establishing the "buffer zones" of soils to be remediated, the following assumptions were used:

- 100 percent of the concrete/asphalt apron will be removed. In addition, the contaminated asphalt located just east of the apron (approximately 90 × 70 feet, see Figure 5-4) and small areas located just north and south of the pad at the west end of the pad will be removed. One foot of soil from beneath the concrete and asphalt will require remediation; this equates to a surface area of approximately 3,480 square yards and a volume of approximately 1,400 cubic yards using an expansion factor of 0.20.

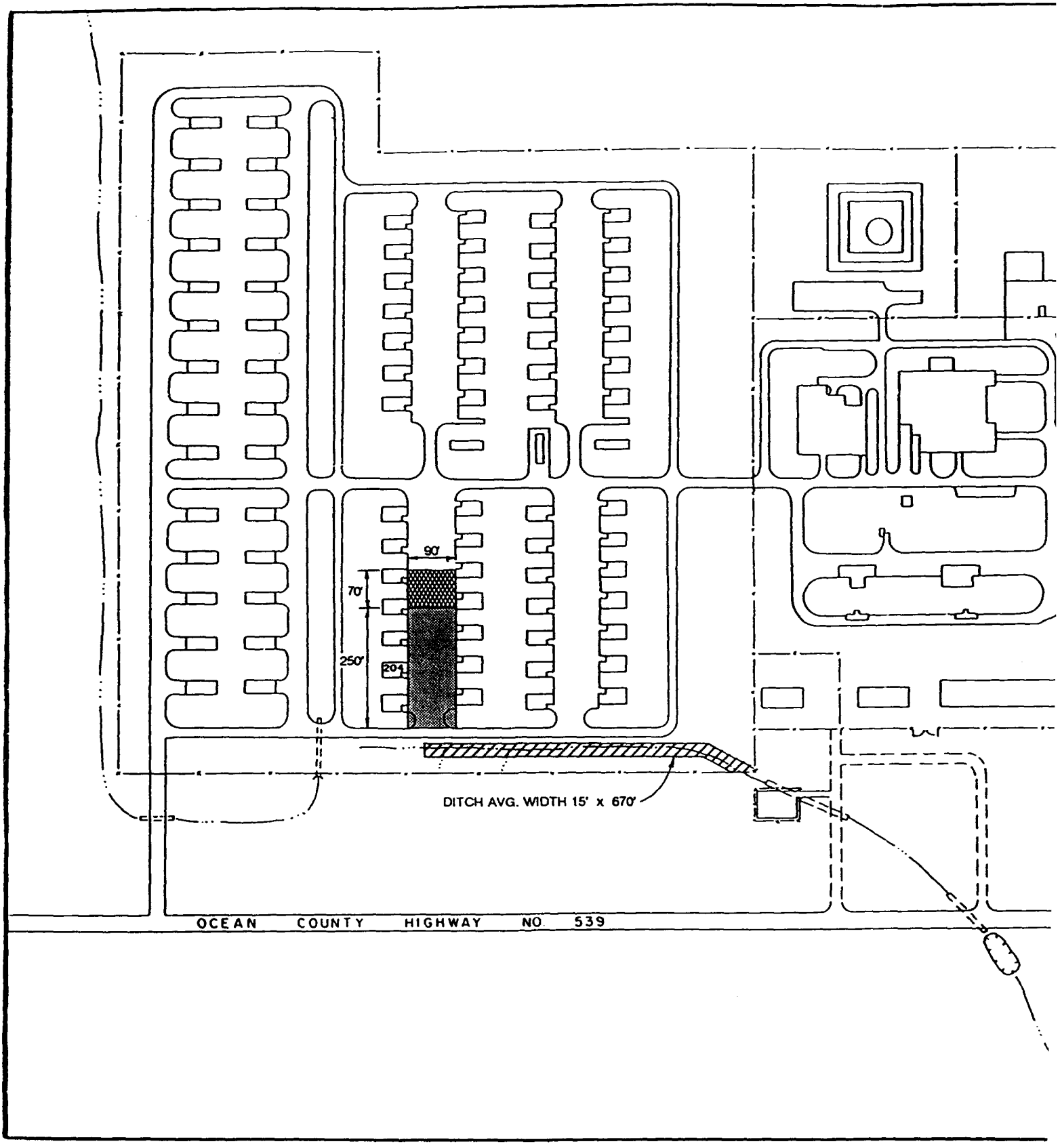
- An area extending beneath shelter 204 and ten to thirty feet from all sides of the shelter will be affected; soils within most of this area will require remediation to a depth of three feet. Soils in a small (30 feet x 30 feet) area just west of Shelter 204 will require remediation to a depth of 10 feet. This equates to a surface area of approximately 775 square yards and a soil volume of approximately 1,215 cubic yards using an expansion factor of 0.20.

In addition to soils from the "buffer zones" described above, several discontinuous areas of contaminated soil will require remediation. These include soils from the following areas:

- Two areas just north and west of Shelter 212 measuring approximately 40 feet by 60 feet and 50 feet x 30 feet, respectively (Figure 5-3). Total surface area is approximately 430 square yards. Assuming a depth of excavation of one foot and an expansion factor of 0.20, the total excavated volume is estimated at 175 cubic yards.

- The asphalt-lined drainage ditch area. Although results of the HPG survey indicate that most of the ditch is well below the risk-based cleanup level, laboratory analyses of soils presented in Sections 4.1.3.8.1 and 4.1.3.8.3 indicate that soils beneath the asphalt are contaminated at levels exceeding the risk-based cleanup level of 8 pCi/g over most of the length of the ditch. These data points represent widely spaced "hotspots," so it is likely that a large portion of soils in the ditch are uncontaminated. However, in order to obtain conservative estimates for volumes of soil to be remediated, it is assumed that all soils beneath the asphalt are contaminated to a depth of one foot except in the area just west of the concrete apron shown on Figure 5-3, where the depth of contamination is assumed to be three feet. That area is discussed separately below. Total area of the asphalt-covered portion of the ditch is approximately 1,120 square yards. Assuming a depth of excavation of one foot and an expansion factor of 0.20 the total volume of soils is estimated at approximately 450 cubic yds.

- The area just west of the concrete apron, measuring approximately 50 feet by 100 feet. Total surface area is approximately 555 square yards. Assuming an excavation depth of three feet and an expansion factor of 0.20, the total excavated volume is estimated at 670 cubic yards.


90'
70'
250'
20'
DITCH AVG. WIDTH 15' x 670'
OCEAN COUNTY HIGHWAY NO. 539

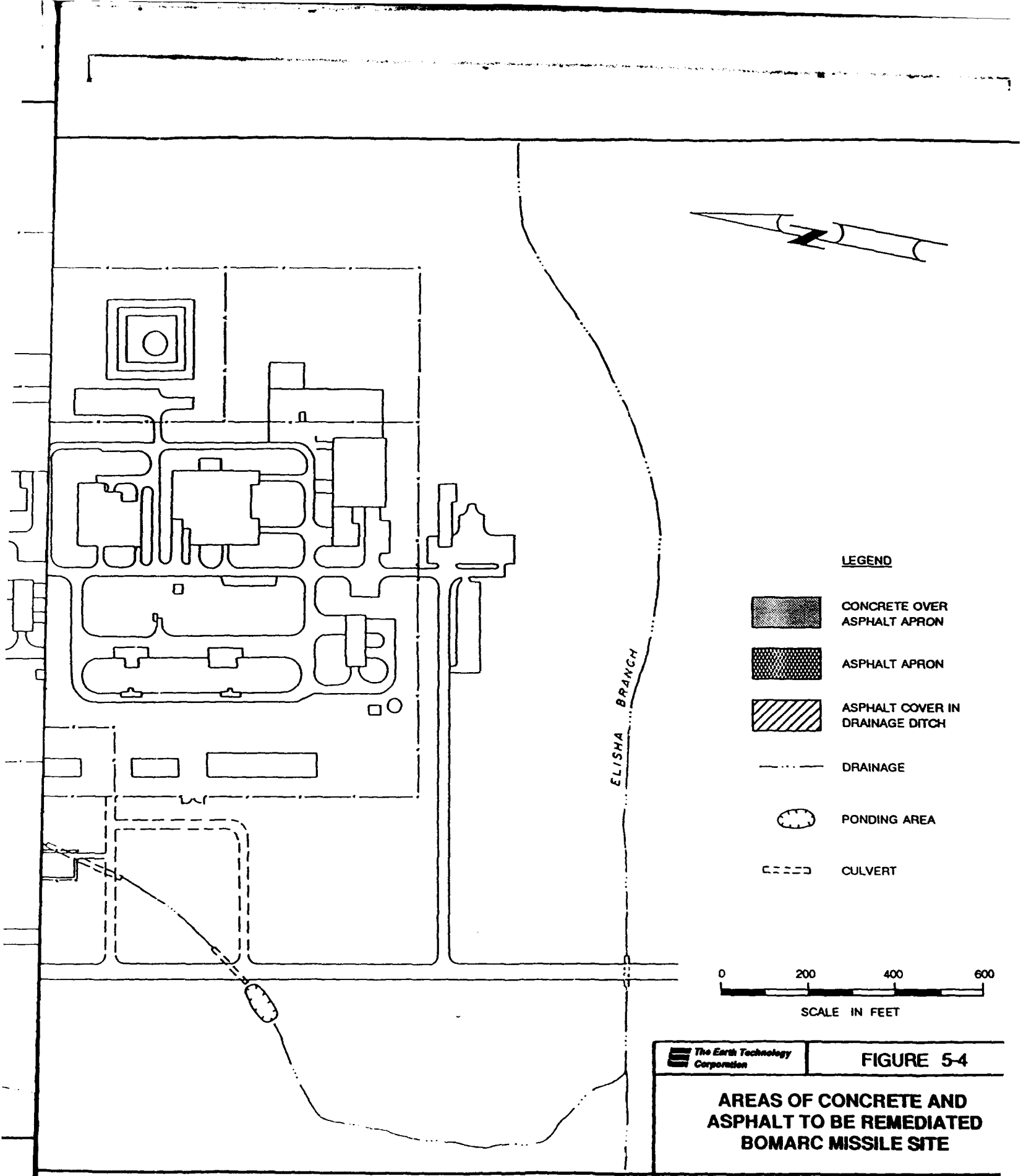


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FIGURE 5-4

AREAS OF CONCRETE AND ASPHALT TO BE REMEDIATED BOMARC MISSILE SITE

- An area north of Shelters 202, 204, and 206, measuring approximately 175 feet by 75 feet. Total area is approximately 1,460 square yards. Assuming a depth of excavation of one foot and an expansion factor of 0.20, the total excavated volume its estimated at 585 cubic yards.

- An area just south of the concrete apron measuring approximately 30 feet by 10 feet. Total area is approximately 33 square yards. Assuming a depth of excavation of one foot and an expansion factor of 0.20, the total excavated volume is estimated at 13 cubic yards.

- An area just west of the drainage ditch where the ditch exits the site perimeter fence measuring approximately 30 feet by 30 feet. This area corresponds to the location of borehole 20. Assuming a depth of excavation of 3 feet and an expansion factor of 0.20, the total excavated volume is estimated at 120 cubic yards.

- An area located east of Highway 539, between the site perimeter fence and the highway measuring approximately 50 feet by 50 feet. Assuming a depth of excavation of one foot and an expansion factor of 0.20, the total excavated volume is estimated at approximately 110 cubic yards.

- Four areas east of Highway 539 measuring approximately 70 feet by 150 feet, 100 feet by 75 feet, 100 feet by 100 feet, and 50 feet by 50 feet, respectively. Total surface area (for all four areas) is approximately 3,390 square yards. Assuming a depth of excavation of one foot and an expansion factor of 0.20, the total excavated volume is estimated at 1,355 cubic yards.

- Soils associated with the missing missile launcher may be contaminated, although the degree of contamination and volume affected are unknown. It is conservatively estimated that 100 cubic yards of soil associated with the launcher will require remediation.

The sum of estimated soil volumes to be remediated is approximately 6,200 cubic yards.

Contaminated Apron. Based on field measurements conducted during the RI, total contaminated area of the apron area in front of Shelter 204 is approximately 28,800 square feet. Concrete core samples had levels of plutonium as high as 1,070 μCi/sample on the contact between concrete and underlying asphalt. Although sampling data from the RI indicates that portions of the apron are uncontaminated, the entire apron will be remediated. This is due to the uncertainties associated with gamma radiation detection through concrete. This 28,800 square foot area includes 6,300 square feet of asphalt not covered by concrete, located just east of the concrete-covered portion of the apron. Based on available information, the thickness of the apron is 4 to 6 inches of concrete and 2 inches of asphalt, yielding a total unexpanded concrete volume of about 291 cubic yds and a total unexpanded asphalt volume of about 178 cubic yds. At the base of the apron is two inches of asphalt upon which strippable paints of unknown composition were initially applied. On top of the paint layer, four inches of concrete were later placed. A small area (2,592 square feet) directly in front of Shelter 204 has an additional two-inch layer of concrete. The surface of the concrete is cracked in several places with tar/asphalt

patch material found in the crevices. Sampling of soils beneath the apron indicates low levels of radionuclide contamination that are probably due at least in part to contamination introduced during the concrete coring process. See Figure 5-4 for the area to be remediated.

The asphalt cover in the drainage ditch will require removal prior to remediation of underlying soils. It is assumed that the entire volume of asphalt is contaminated, and will require remediation. The asphalt-covered portion of the ditch is approximately 670 feet long, with an average width of 15 feet and thickness of 2 inches. This equates to an area of approximately 1,120 square yards, and an unexpanded volume of 62 cubic yards.

Shelter 204. The Shelter is one of a series of above-ground buildings separated from one another by approximately 30 feet. The building consists of steel-reinforced concrete floors and walls, with steel doors and a roof composed of sheet metal and steel I-beams. The six-inch thick concrete pad covering the apron in front of the shelter is contiguous inside the front portion of the shelter, and extends from the front (southern end) of the shelter approximately halfway (30 ft.) to the rear of the shelter. The concrete was poured directly on the existing concrete floor. The dimensions of the shelter are 60 ft × 21 ft × 10 ft. high. The location of the front doors and sheet metal portion of the roof are unknown. Efforts to locate these items are addressed in the discussion of the missing missile launcher. The inside of the shelter consists of two rooms separated lengthwise; a main enclosure used to house the missile, and a smaller control room. The outer walls of the control room are made of concrete blocks. The floors of both rooms have a 3.5 ft. deep concrete pit. The estimated surface area exposed to radionuclides from the missile accident is about 6,066 sq. ft. of concrete and concrete block and 340 sq. ft. of steel doors (excluding I-beams on roof). Only a small portion of this concrete, mainly the floor, is contaminated. It is estimated that 100 percent of the shelter floor and 25 percent of the shelter walls (and I-beams) will require remediation. The total unexpanded volume of material from Shelter 204 is estimated to be 201 cubic yards, or an expanded volume of 402 cubic yards.

Alpha surveys conducted on shelter 204 walls and floor using a PAC-4G instrument showed that the highest activity levels detected in shelter 204 were 2,011 dpm/100cm^2, 47,780 dpm/100cm^2, and 2,106 dpm/100cm^2.

Concrete cores taken through the shelter floor showed levels of plutonium as high as 65 μCi/sample on the original floor.

The building has been unused and exposed to the elements since the missile accident, and the rest of the BOMARC Missile site was closed in 1972.

Utility Bunkers. Underground utility bunkers supporting the missile shelter consist of two steel reinforced concrete compartments each having dimensions of 6 ft. × 4 ft. × 6 ft. deep. The total interior surface area of each bunker is approximately 331 square feet. Bunkers were connected to each other and to the shelter by small diameter conduit carrying communications and electrical wiring, compressed gases, and fluids. Each bunker at the time of the missile accident was accessible by a manhole with steel cover. Presumably, fire-fighting efforts washed small amounts of radioactive debris through the manholes and into the bunkers. Alpha surveys taken in the bunkers during the RI showed activity ranging up to 80,000 cpm. Sediments were encountered and sampled in one bunker; analytical results showed activity of 200 pCi/g. It is assumed that 50 percent of the interior surfaces of the bunkers will require remediation. The

total in-place volume of materials from the utility bunkers is estimated to be 18.5 cubic yards, or an expanded volume of 37 cubic yards.

Missing Missile Launcher. The missile launcher from Shelter 204 was removed from the shelter shortly after the accident. Presumably, the launcher was buried or otherwise disposed of onsite or near the site, although review of records, review of air photos, and interviews have failed to indicate the manner or location of burial. A geophysical investigation was conducted, focusing on areas thought to be likely disposal sites. Two geophysical techniques, magnetic profiling, and GPR profiling, were used in an attempt to identify possible burial locations onsite and near the site. (See section 3.4.1 of the RI report for details). As a result of the surveys, a total of five anomalous areas which could represent the buried launcher were identified. (See Figure 5-5 for locations). These anomalies may also represent the missing Shelter 204 doors and sheet metal portion of the roof.

The only practical means of determining if any of the observed anomalies represents the missing launcher involves excavation and inspection of the anomalies. Since excavation of the anomalies was beyond the scope of the RI/FS, excavation, inspection, and removal/disposal (if applicable) of the anomalies is being addressed as part of potential remedial measures to be used at the site. If the missile launcher is recovered, it will be addressed using remedial technologies appropriate for above-ground structures.

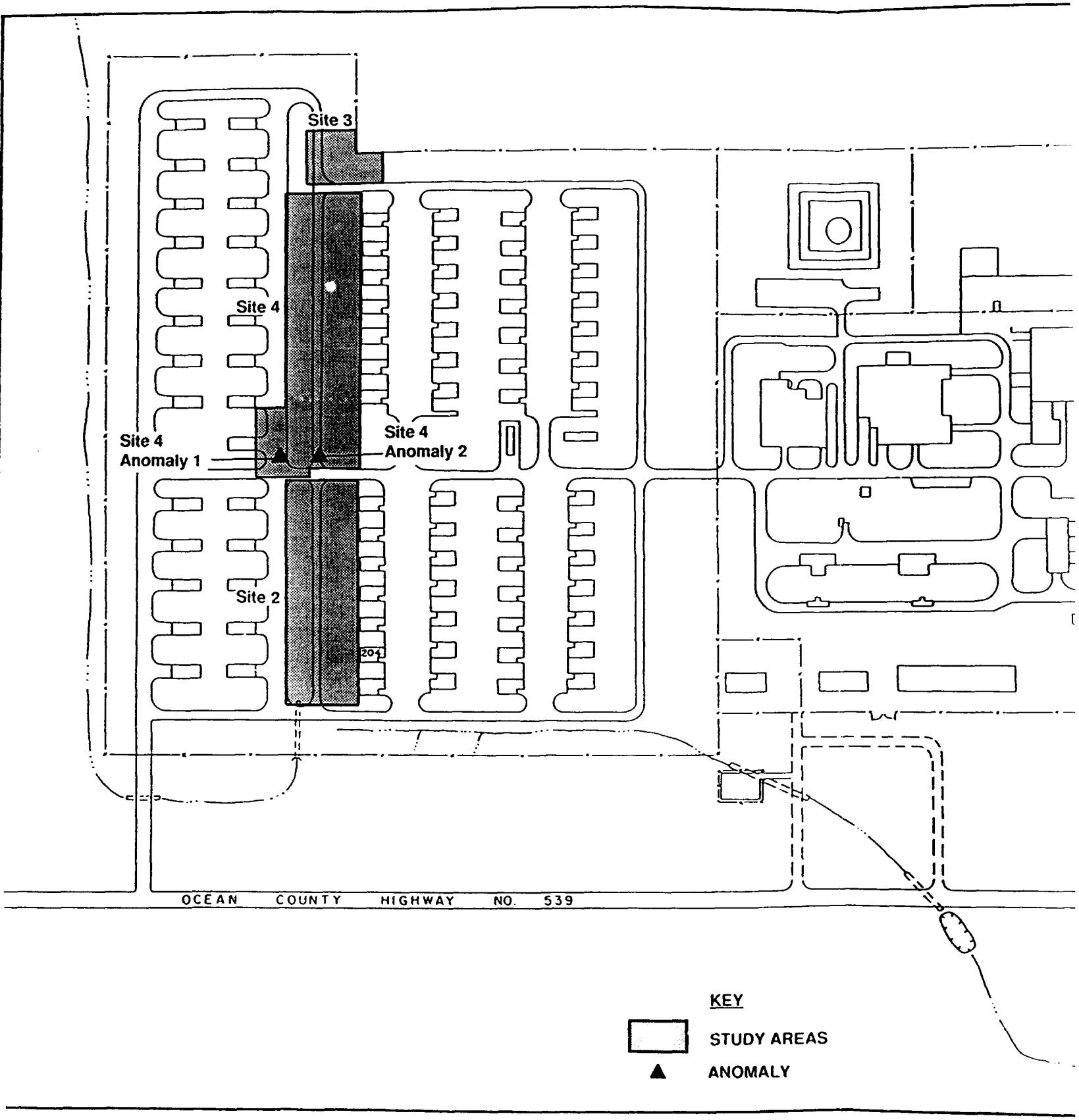
Approximate launcher dimensions were measured at an open shelter onsite. The launcher consisted of two main components; a base plate (8 × 8 ft., .25 inches thick) and missile support (30 × 2 × 2.5 feet). The combined weight is estimated at two to three tons. Due to the potential for significant deformation of the launcher caused by the intense heat of the fire, the launcher may not be in the original form. The estimated volume of material from the missing missile launcher is 5 cubic yards.

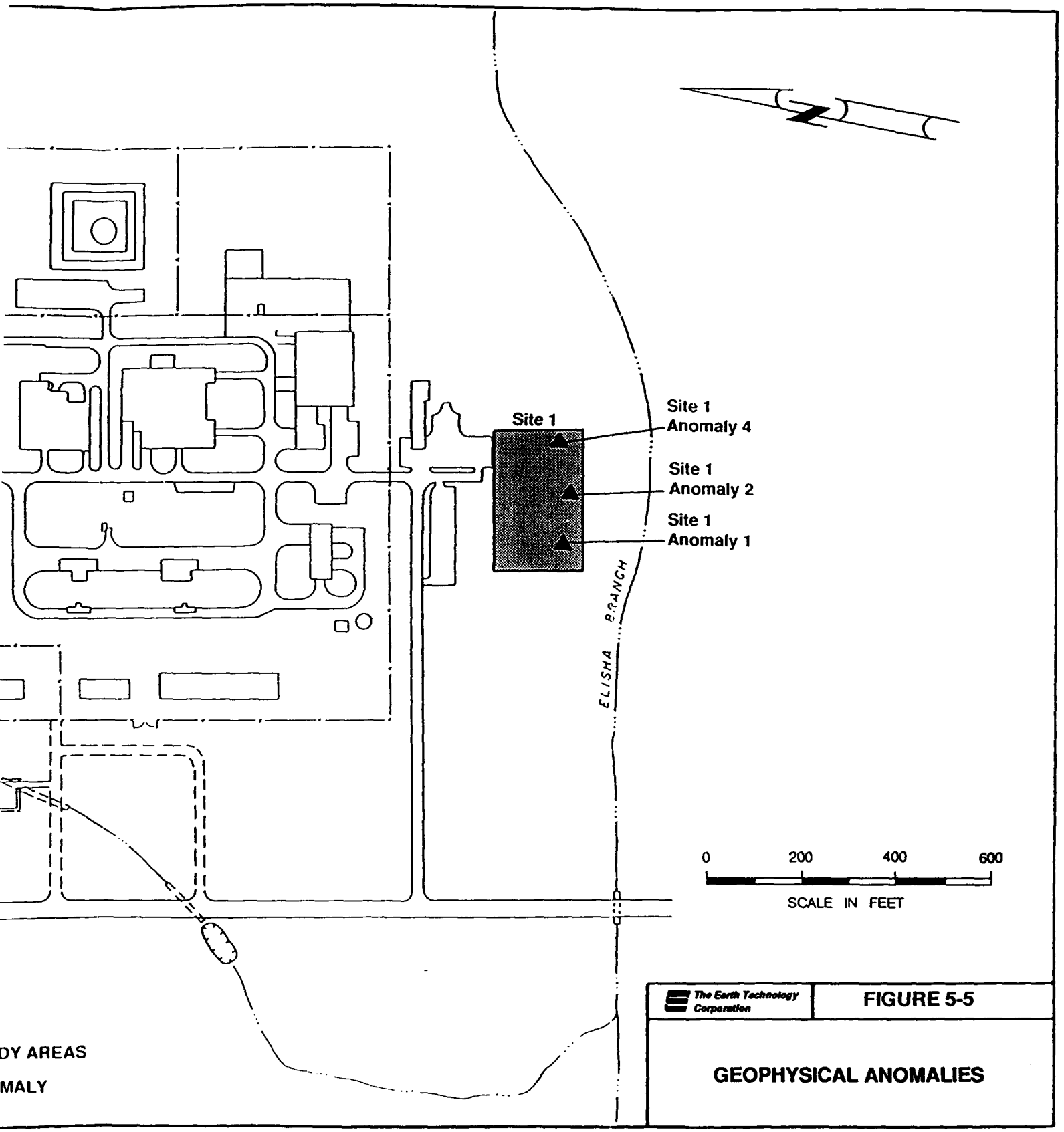
5.1.1.3 ARARs

The DoD conducts its IRP in a manner consistent with CERCLA. The following discussion of ARARs is consistent with the requirements of CERCLA, is consistent with the regulations promulgated by the U.S. EPA pursuant to CERCLA, and is consistent with the guidance published by the EPA with respect to ARARs, even though the concept of ARARs is not directly applicable to the BOMARC site. Federal and state environmental laws other than CERCLA may, of course, apply to the BOMARC site independently of CERCLA.

Remedial actions carried out under CERCLA must attain a degree of clean-up that assures protection of human health and the environment (CERCLA Section 121). Section 121 identifies the necessary degree of cleanup as that which meets "legally ARARs. The U.S. EPA defines ARARs in 40 CFR 300 as follows (EPA 1990):

> "Applicable requirements" means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.


Site 3
Site 4
Site 4
Anomaly 1
Site 4
Anomaly 2
Site 2
204
OCEAN COUNTY HIGHWAY NO. 539
KEY
STUDY AREAS
ANOMALY



The Earth Technology Corporation

FIGURE 5-5

GEOPHYSICAL ANOMALIES

> "Relevant and appropriate requirements" means those cleanup standards, standards of control, and other substantive requirements, criteria or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant , remedial action, location or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

The EPA further defines ARARs as chemical-specific, action-specific, and location-specific (EPA 1988). A chemical-specific requirement is one that sets concentration limits in various environmental media for specific hazardous substances, pollutants, or contaminants. A location-specific requirement sets restrictions on activities that depend on the characteristics of a site or its immediate environs. An action-specific requirement sets controls or restrictions on activities related to the management of hazardous substances.

In the RI/FS process, ARARs are identified on a preliminary basis during scoping of the RI/FS, more comprehensively during the RI/FS process, and definitively at the time of selection of the remedial alternative.

Federal ARARs and State of New Jersey ARARs are discussed in the following subsections. It should be noted that New Jersey has the authority to regulate some environmental activities at the BOMARC site under various federal waivers of sovereign immunity.

5.1.1.3.1 Chemical-Specific Requirements

The contaminants of concern at the BOMARC site for this RI/FS are Pu-238, Pu-239, Pu-240, and Am-241. Other non-radioactive contaminants may be present at the BOMARC site, but these are addressed in a separate IRP RI/FS. The contaminants of concern may be found in surface water, in soil, on surfaces, and in the air if suspended during intrusive activities. In this subsection, chemical-specific regulations that are ARARs are cited. Potential ARARs are cited and regulations or guidance that are provided as to-be-considered items (TBCs) are discussed.

Water Quality Standards. Drinking water standards in 40 CFR 141, "National Primary Drinking Water Regulations," are expressed as MCLs and apply to public water systems. The MCLs in 40 CFR 141 are ARARs if any water is contaminated at the BOMARC site (or at an offsite disposal site) and that water is used for drinking. MCLs in 40 CFR 141 include: gross alpha (excluding uranium), 15 pCi/L; and gross beta, 50 pCi/L. Also, 40 CFR 141.16 states that, "The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year." Pu-238, Pu-239, and Pu-240 are alpha emitters. Am-241 is an alpha and a gamma emitter. Pu-241 is a beta emitter (99+%) and an alpha emitter.

Air Quality Standards. The EPA regulations in 40 CFR 61.102 apply to Air Force facilities and are ARARs. These regulations state that: "Emissions of radionuclides, including iodine, to the ambient air from a facility regulated under this subpart shall not exceed these amounts that

would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr" (54 FR 51654, December 15, 1989).

Soil Concentration Standards. At the present time, no promulgated standards exist for concentrations of Pu-238, Pu-239, Pu-240, Pu-241 or Am-241 in soils. It is expected, however, that EPA's rulemaking proceedings on residual radioactivity in 40 CFR 194 will include residual radioactivity standards for soils (EPA 1986).

Surface Contamination Standards. At the present time, no promulgated standards exist for radionuclide surface contamination at an unlicensed facility. It is expected, however, that EPA's rulemaking proceedings on residual radioactivity in 40 CFR 194 will include residual radioactivity standards for surfaces (EPA 1986). In the meantime, provisional residual radionuclide surface contamination limits for BOMARC equipment and structures could be adapted from similar NRC guidelines. These limits might be similar to those in NRC's regulatory Guide 1.86 (NRC 1974), which for transuranics are: 100, 300, and 20 disintegrations per minute from an area of 100 square centimeters for average, maximum, and removable contamination, respectively.

Fuel Cycle Standards. Although not ARARs for DoD activities, the EPA regulations in 40 CFR 190, "Environmental Radiation Protection Standards for Nuclear Power Operators," bear on radiation in the environment and contain TBCs. These regulations state that: "Operations shall be conducted in such a manner as to provide reasonable assurance that: (a) The annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters expected, to the general environment from uranium fuel cycle operations and to radiation from these operations."

Also not ARARs for the activities of the DoD are the regulations of the U.S. NRC in 10 CFR 20 "Standards for Protection Against Radiation." However, these regulations, like the EPA regulations in 40 CFR 190, bear on radiation in the environment and contain TBCs. In 10 CFR 20 Appendix B, as noted above, there appears a table that gives allowable (by NRC) concentrations of radionuclides in air and water in both restricted and unrestricted areas.

5.1.1.3.2 Action-Specific Requirements

Action-specific requirements set controls or restrictions on the management of hazardous substances. These include the CERCLA regulations in 40 CFR 300.70 that apply to hazardous substances, pollutants, and contaminants, including radionuclides, RCRA corrective action regulations in 40 CFR 264.100 that apply to hazardous wastes (other than radionuclides), and may include the EPA regulations in 40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes,".

Also included are various state laws which restrict the disposal of radioactive wastes within state borders, especially the Low Level Radioactive Waste Policy Amendments Act (LLRWPAA) of 1980, which takes effect in 1993. The LLRWPAA directs states to form compacts for the purposes of low-level radioactive waste disposal. Under the LLRWPAA, member states develop

disposal sites within compact borders for compact member use. When the LLRWPAA takes effect in January 1993, compact states can elect to refuse acceptance of wastes from non-compact states, although non-compact waste shipments are not automatically barred. This has the effect of potentially severely curtailing disposal options for wastes from the BOMARC site, because New Jersey does not belong to a compact with a licensed disposal facility.

Other action-specific requirements associated with offsite disposal of wastes include those stated in 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste." These regulations set standards for disposal facilities, and preclude any commercial disposal site from accepting wastes containing over 100 nCi/g of radioactive materials. In addition, the Nevada Test Site cannot currently accept wastes with over 100 nCi/g of activity, due to institutional constraints imposed by the state of Nevada (Johnston, 1991).

Management or treatment of contaminated soils and structural materials at the BOMARC site might include access and institutional controls, containment, onsite treatment, or removal. And, while Section 121(e) of CERCLA states that no federal, state, or local permit need be obtained for remedial action conducted entirely onsite under CERCLA, cleanup of the BOMARC site is not strictly under CERCLA. Therefore, treatment or offsite disposal of wastes could require one or more permits. Action-specific requirements may include meeting the requirements of, and might possibly include acquiring permits under, the following regulations:

- 40 CFR 52, 60, and 61. Air Quality Regulations: Prevention of Significant Deterioration (PSD) and National Emission Standards for Hazardous Air Pollutants (NESHAP). Both a NESHAP and PSD authorization could be required. Also, best available control technology (BACT) could be required. Radionuclides are no longer PSD affected pollutants; however, other types of emissions could be affected.

- EPA regulations in 40 CFR 193, "Environmental Radiation Standards for Management and Land Disposal of Low-Level Radioactive Wastes," when promulgated by EPA, are expected to contain disposal standards and ground water protection standards for the disposal of low-level radioactive wastes. These regulations will be potential ARARs for both onsite and offsite disposal of radionuclides.

5.1.1.3.3 Location-Specific Requirements

Since the BOMARC site is located in the New Jersey Pinelands, regulations governing the Pinelands apply. Specifically, the New Jersey Regional Low-level Radioactive Waste Disposal Facility Siting Act (the Act) of 1987 prohibits establishment of low-level radioactive waste disposal facilities in the Pinelands. New Jersey does not consider the wastes found at the BOMARC site to be low level radioactive waste, however the Act can be construed as state policy regarding the disposal of radioactive wastes other than low level wastes in the Pinelands. In addition, the Pinelands Comprehensive Management Plan (Section 7:50 - 6.77) states that "No hazardous, toxic, chemical, petroleum, septic, or nuclear waste shall be stored, discharged, or disposed of on any land within the Pinelands."

These requirements affect any remedial alternative that contains provisions for storage or disposal of processed or treated wastes onsite.

Location-specific requirements affect the cleanup actions that can be taken at a given site because of the impact those actions might have on characteristics of the site other than the existence of hazardous substances. For example, in effecting a cleanup, it is necessary to meet the requirements of the following regulations related to historic preservation and species protection:

- 36 CFR 800, 25 CFR 261, 43 CFR 3, and 43 CFR 7, Historic Preservation Regulations. Requirements of the National historic preservation Act in 36 CFR 800, the American Antiquities Act in 25 CFR 261 and 43 CFR 3, and the Archaeological Resources Protection Act and the American Indian Religious Freedom Act in 43 CFR 7 apply to the protection of historic and cultural properties, including both existing properties and those discovered during excavation or construction.

- 50 CFR 10-24 and 50 CFR 402. Species Protection Regulations. Regulations of the Endangered Species Act, the Bald and Golden Eagle Protection Act, and the Migratory Bird Treaty Act in 50 CFR 10-24 and 50 CFR 402 apply to the protection of these species at all times.

5.1.2 General Response Actions

General response actions are media-specific actions which fulfill site-specific remedial objectives. Six general response action categories are developed in this study for addressing environmental conditions at the BOMARC missile site. Response actions developed under the proposed categories incorporate a wide array of alternatives sufficient to meet remedial action goals developed in Section 5.1.1 of this document as well as satisfy NCP criteria. The categories of general response actions to be considered for contaminated media at the BOMARC missile site include:

- Allow Unrestricted Access
- Maintain Existing Conditions
- Limited Action
- Containment
- Onsite Treatment
- Onsite Disposal
- Offsite Disposal

5.1.2.1 Unrestricted Access

The unrestricted access response in this case consists of dropping institutional and access controls currently in place and leaving contaminated materials in place. This response serves as a risk scenario for quantifying risks posed by the site in the absence of remediation or control, including control measures currently in place.

This response is appropriate if risks from baseline conditions in the absence of site remediation or control are shown to be negligible. Due to the extreme persistence of plutonium and americium, risks resulting from future changes in site conditions must also be considered.

This response potentially allows for erosion of contaminated soil, weathering of contaminated structural materials, and offsite migration of plutonium and americium through mass-wasting and sediment transport by water and air. Lack of institutional controls allows for disturbance of the site by development activities, potentially exposing onsite workers and the general public to plutonium and americium through external radiation, inhalation, and ingestion, and exacerbating erosion and sedimentation problems. Public access to the site allows for exposure of the general public through inhalation, external radiation, and ingestion pathways.

5.1.2.2 Existing Conditions

The existing conditions response includes all monitoring, maintenance, and access control actions currently implemented at the site. Contaminated areas are fenced and posted to preclude public access, and existing fences are maintained as necessary. The site is inspected on a regular basis to verify that conditions do not deteriorate to the point that public exposure is a concern. The concrete apron and building structures are maintained and repaired as necessary. Radiological surveys are conducted annually to ensure that contaminants are not migrating from the site. Deed restrictions are maintained to preclude development of the site.

5.1.2.3 Limited Action

The limited action response includes all monitoring, maintenance, and access control actions currently implemented at the site, plus a limited amount of active site restoration. Contaminated areas are fenced and posted to preclude public access, and existing fences are maintained as necessary. The site is inspected on a regular basis to verify that conditions do not deteriorate to the point that public exposure is a concern. The concrete apron and building structures are maintained and repaired as necessary. Radiological surveys are conducted annually to ensure that contaminants are not migrating from the site. Deed restrictions are maintained to preclude development of the site. In addition, limited amounts of the most highly contaminated materials are removed from the site and properly disposed of offsite.

5.1.2.4 Containment

The containment response action involves the installation of engineered barrier structures in or around the contaminated areas to block contaminant resuspension and migration and to reduce chances of direct contact with wastes. Contaminants can migrate offsite via mechanical tracking, air, surface water, (including sediment transport) and potentially, ground water pathways. Onsite exposure to contaminants can occur by direct contact with contaminated soils. Man-made barriers would be erected around the contaminated soils and structures to prevent further migration, or direct contact.

Containment requires long-term maintenance and/or multiple replacement cycles to ensure that containment barriers do not deteriorate to the point that contaminants migrate and become a threat to human health and the environment. Containment also requires long-term institutional controls to ensure that the site is not disturbed.

5.1.2.5 Onsite Treatment

This response action includes both onsite and in-situ treatment alternatives that either immobilize or concentrate and remove plutonium and americium from wastes. A number of physical and chemical treatment technologies can be used to treat surface soils, the concrete/paint/asphalt "sandwich", shelter 204 structures, underground utilities, and the missile launcher. The concentrated radioactive residuals derived from some of the treatment processes require either onsite disposal or transport and offsite storage/disposal.

5.1.2.6 Onsite Disposal

This response consists of excavation of soils, demolition of structures, and placement of wastes in an onsite engineered disposal facility. Disposal of contaminated soils and processed structures in an onsite disposal cell is subject to federal regulations developed by the NRC for disposal of radioactive waste. Wastes are classified according to concentration levels of plutonium and americium.

5.1.2.7 Offsite Disposal

Removal and offsite disposal is commonly used as a permanent source control measure. This response consists of excavation of soils, demolition of structures, and transport/disposal at a permitted offsite disposal facility. Removal of contaminated media eliminates the long-term source for onsite or near-site exposure but presents short-term risks during removal and offsite transport, and long-term risks at the location of disposal. Restoration of excavated areas by filling and regrading is required. A soil sampling or in-situ surveying program is also required to verify the vertical and lateral limits of excavation.

5.1.3 Identification of Remedial Technologies

An array of technologies and process options exist which support potential response actions for the BOMARC missile site. This text is designed to present available technologies along with sufficient information to screen out those technologies that are clearly infeasible due to site conditions, waste characteristics, or technical requirements. Based on the available site database, the following response action components necessary to achieve site remediation objectives have been identified:

- **Unrestricted Access** - No remedial technologies are applied under this response.
- **Existing Conditions** - Elements required to restrict site access, provide institutional controls, and provide long-term monitoring.
- **Limited Action** - Elements required to restrict site access, provide institutional controls, provide long-term monitoring and remove a limited amount of the most highly contaminated materials from the site for offsite disposal.

- **Containment** - Components necessary for the installation and use of engineered controls to isolate or contain radioactive sources or mitigate migration.

- **Onsite Treatment** - Components necessary for the removal of contaminated media, treatment of this media, and subsequent disposal of the processing residuals.

- **Onsite Disposal** - Components necessary for the installation and use of a landfill to isolate radioactive sources and contaminated media; factors for long-term monitoring and permitting.

- **Offsite Disposal** - Components necessary for the removal of contaminated media, consolidating and transporting the media to an offsite location, and final disposal.

Table 5-4 provides a listing of a broad range of potentially applicable technologies involved in remedial responses at the BOMARC Missile site. Technology profiles have been developed which address all components of potential remedial actions, including existing conditions, containment, treatment, and disposal. These are presented in the following sections.

5.1.3.1 Unrestricted Access

No remedial technologies are applied under this response.

5.1.3.2 Existing Conditions

Technologies/actions applicable to this response include:

- Fencing and signs
- Quarterly visual inspections
- Maintenance of apron and structures
- Annual radiological surveys
- Maintaining government control of the site.

Fencing and signs. Fencing and signs are used to preclude access by the public. Fences are six feet in height, topped with barbed or concertina wire. Appropriate warning signs ("No Trespassing" and radiological hazard signs) are posted on the fence at 50-foot intervals.

Table 5-4

Preliminary Remedial Technologies Associated with General Response Actions

Response Action	Remedial Technologies	Process Options	Applicability to Contaminated Media: Soils	Apron	Shelter 204	Utility Bunkers	Missile Launcher
Unrestricted Access	-		x	x	x	x	x
Existing Conditions	Fencing/Signs		x	x	x	x	x
	Visual Inspection/ Maintenance		x	x	x	x	x
	Radiological Surveys		x	x	x	x	x
	Government Control		x	x	x	x	x
Limited Action	Fencing/Signs		x	x	x	x	x
	Visual Inspection/ Maintenance		x	x	x	x	x
	Radiological Surveys		x	x	x	x	x
	Government Control		x	x	x	x	x
	Limited Waste Removal						x
Containment	Capping		x	x	x	x	x
	Vertical Barriers					x	
	Berms				x		
	Coating/Painting				x		
On-Site Treatment	1) Immobilization	In situ grouting	x			x	
		On-site stabilization	x	x			
		In situ vitrification	x	x		x	
	2) Chemical Extraction	Soil Washing	x				
		In situ flushing	x			x	
	3) Physical Separation	Sorting (TRU-cleaning)	x				
		Screening	x				
		Classification	x				
		Gravity Separation	x				
		Flotation	x				
	4) Combined Physical/ Chemical Separation	Chemical/Physical	x				
		Physical/Chemical	x				
		Physical/Washing/Chemical Extraction	x				
	5) Physical Decontamination	Spaller/Scarifier/Impactor		x	x	x	x
		Sand Blasting		x	x	x	x
		Sectioning/Cutting		x	x	x	x

Table 5-4

Preliminary Remedial Technologies Associated with General Response Actions (Continued)

Response Action	Remedial Technologies	Process Options	Applicability to Contaminated Media				
			Soils	Apron	Shelter 204	Utility Bunkers	Missile Launcher
	6) Electrochemical Separation	Electropolishing			x		x
		Electrobrushing			x		x
On-site Disposal	Landfill		x	x	x	x	x
Off-site Disposal	Disposal	LLRW Facility	x	x	x	x	x
		Geologic Repository	x	x	x	x	x

Quarterly visual inspections. Quarterly visual inspections are used to document site conditions. The condition of fencing and signs is inspected to ensure site security. Evidence of site entry is noted. The condition of contaminated media is inspected, and evidence of deterioration or damage is noted. Corrective actions are recommended and carried out if conditions warrant.

Maintenance of apron and structures. Maintenance of apron and structures is performed on an as-needed basis. The cement overlayer is patched and repaired as required. Structures are maintained in a condition that minimizes release of contaminated structural components. Asphalt is sealed and plants removed on a routine annual basis.

Annual radiological surveys. Annual radiological surveys are conducted to verify that contaminants are not migrating offsite. This requires development of a sampling plan that is sufficient to make this verification. Annual sampling includes onsite selected ground water wells, stream sediments in the site drainage pathway, and soils both onsite and offsite. Sampling techniques include a combination of sample collection/laboratory analysis and in-situ survey techniques.

Maintaining government control of the site. Maintaining government control of the site is used to ensure that contaminated media are not disturbed in the future. If the government maintains possession of the site, deed restrictions will probably not be necessary. Otherwise, deed covenants restricting land use are required.

5.1.3.3 Limited Action

The Limited Action response adds excavation and offsite disposal technologies to the currently implemented technologies contained in the "Existing Conditions" response detailed above. Technologies/actions applicable to this response include:

- Fencing and signs
- Quarterly visual inspections
- Maintenance of apron and structures
- Annual radiological surveys
- Maintaining government control of the site
- Excavation and offsite disposal technologies.

Fencing and signs. Fencing and signs are used to preclude access by the public. Fences are six feet in height, topped with barbed or concertina wire. Appropriate warning signs ("No Trespassing" and radiological hazard signs) are posted on the fence at 50-foot intervals.

Quarterly visual inspections. Quarterly visual inspections are used to document site conditions. The condition of fencing and signs is inspected to ensure site security. Evidence of site entry

is noted. The condition of contaminated media is inspected, and evidence of deterioration or damage is noted. Corrective actions are recommended and carried out if conditions warrant.

Maintenance of apron and structures. Maintenance of apron and structures is performed on an as-needed basis. The cement overlayer is patched and repaired as required. Structures are maintained in a condition that minimizes release of contaminated structural components. Asphalt is sealed and plants removed on a routine annual basis.

Annual radiological surveys. Annual radiological surveys are conducted to verify that contaminants are not migrating offsite. This requires development of a sampling plan that is sufficient to make this verification. Annual sampling includes onsite selected ground water wells, stream sediments in the site drainage pathway, and soils both onsite and offsite. Sampling techniques include a combination of sample collection/laboratory analysis and in-situ survey techniques.

Maintaining government control of the site. Maintaining government control of the site is used to ensure that contaminated media are not disturbed in the future. If the government maintains possession of the site, deed restrictions will probably not be necessary. Otherwise, deed covenants restricting land use are required.

Excavation and offsite disposal technologies. Excavation and offsite disposal technologies are used to remove a limited amount of the most highly contaminated materials from the site, and dispose of the materials in a licensed, offsite disposal facility. Offsite disposal technologies are discussed in section 5.1.3.7.

5.1.3.4 Containment

As shown in Table 5-4 there are several remedial technology options available for containing contamination in the five different materials. Preliminary containment technologies include:

- Capping
- Vertical barriers (e.g., slurry walls, vibrated beams, grout curtains)
- Berms
- Coating/Painting

These remedial technologies are discussed below with respect to their applicability to the five contaminated media.

5.1.3.4.1 Capping

Capping involves covering the contaminated soils and/or consolidated structures with a barrier sufficiently thick and impermeable to prevent resuspension of contaminated soils and minimize precipitation infiltration. Cover materials can be either several feet of natural low-permeability soils (e.g., clay) or synthetic membrane liners, or both. The cover may also involve a drainage layer and a vegetative top layer above the impermeable layer which facilitate precipitation collection and removal.

Cap design and construction should consider the need to: 1) prevent resuspension or surface erosion of radionuclides; 2) provide long-term minimization of water infiltration into the contaminated material; 3) function with minimum maintenance; 4) promote lateral drainage and minimize erosion; and 5) have a permeability less than or equal to the permeability of any bottom liner system present or the natural subsoils (U.S. EPA, 1988).

The technology of caps is well developed; however migration of radionuclides in ground water could still potentially occur at some point in the future if site conditions became conducive to solubilization of the radionuclides. Capping involves long-term maintenance costs, and due to the persistence of plutonium and americium, a cap would require multiple replacement cycles for the time period that the wastes remain hazardous.

As indicated in Table 5-4, capping is a technology applicable to all contaminated materials. Capping of above-ground structures, however, would involve demolition and consolidation of the structures prior to capping. Capping of the asphalt/ paint/concrete apron "sandwich" would require an additional cap or resurfacing of the concrete portion of the apron. To minimize the areal extent of the cap, excavation and consolidation of "hot spot" soils may be necessary. Backfilling or grouting the underground utilities may also be necessary prior to capping the area.

Capping of wastes would not affect waste volumes or toxicity, but would reduce risks by reducing mobility and accessibility.

5.1.3.4.2 Vertical Barriers

Vertical barriers, such as slurry walls, vibrated beams, and grout curtains are engineered structures that are built around the contaminated subsurface soils and structures to prevent migration of contaminants in ground water. They are generally considered to be control technologies for management of migration.

5.1.3.4.3 Berms

Berms are not in themselves effective remedial structures but are used in conjunction with other technologies. Berms are above-ground structures that are usually constructed of earth, concrete, or asphalt materials and are used to control surface water run-on and run-off. This remedial technology may be applicable to Shelter 204 and other above-ground structures, especially if they are decontaminated with fluids that require further containment. In addition, if contaminated wash fluids are stored onsite, the storage facility may need to have berms to contain leaks and spills.

5.1.3.4.4 Coating/Painting

Containment of structural components of Shelter 204 can be accomplished by coating the materials in place. Coating materials used are plastics, epoxies or other suitable compounds. This approach prevents further weathering of surfaces and release of plutonium and americium from surfaces. It also eliminates the need for dismantling building structures, thereby eliminating the potential for release of radionuclides caused during dismantling activities. This

is a major health concern, especially for onsite workers. Coatings used are subject to weathering and deterioration, and would require periodic maintenance and/or replacement.

5.1.3.5 Onsite Treatment

Onsite treatment technologies applicable to the contaminated media at the BOMARC site include a broad range of physical, chemical, in-situ, and excavation/treatment processes. Treatment processes for contaminated soils and structures are grouped under the following categories (see Table 5-4):

- Immobilization (in-situ grouting, onsite stabilization/solidification, in-situ vitrification);
- Chemical Extraction (soil washing and in-situ flushing);
- Physical Separation (sorting [TRU-Clean^{R}], screening, classification, gravity separation, flotation)
- Combined Physical and Chemical Techniques
- Physical Decontamination Techniques
- Electrochemical Separation (electropolishing, electrobrushing)

Many of the onsite treatment technologies involve removal of contaminants from various contaminated media. These contaminants then require disposal in a properly licensed offsite radioactive waste disposal facility. Therefore the following factors related to the feasibility of offsite disposal also influence the feasibility of onsite treatment:

- Existence of properly licensed radioactive waste disposal facilities that can accept wastes.
- Concentration of long-lived radionuclides in the waste residue fraction requiring disposal.
- Volumes of waste residue requiring disposal.
- Creation of mixed hazardous and radioactive wastes through use of chemical reagents.
- Unit costs for transportation and disposal of wastes.

These remedial treatment technologies and associated processes are discussed below with respect to their applicability and feasibility for treatment of radioactive elements and contaminated soils and structures.

5.1.3.5.1 Immobilization Technologies

Immobilization processes generally fix radioactive elements in a matrix through either physical entrapment or chemical reactions or a combination of both physical and chemical processes.

Immobilization processes reduce the leachability, erodibility and resuspension potential of plutonium and americium from soils and structures to the ground water, surface water, and air. They do not reduce the toxicity of the wastes, and in some cases, increase the volume of contaminated materials.

Immobilization processes applicable to radioactive soils and structures include the following in-situ and onsite treatment processes:

- In-situ grouting, for contaminated soils and underground structures.
- Onsite stabilization/solidification for contaminated soils.
- In-situ vitrification for the contaminated soils, and potentially for the concrete apron and underground structures.

These processes do not readily apply to radioactive contamination in Shelter 204 structures without prior demolition and consolidation of the contaminated materials.

In-situ grouting. In-situ grouting uses well-developed grout injection technology. For contaminated surface soils, grout would be injected directly into the soil containing radionuclides. For the underground utilities, grout or cement would be applied to the open spaces and conduits. This technique has been proposed by DOE for by-product radioactive wastes for the Hanford, Washington site (Tamura and Boegly, 1983).

In-situ grouting of soils for stabilization purposes requires extensive and detailed characterization of the soil matrix. Soil parameters such as particle size, moisture content, pH and porosity must be well-characterized with respect to area and depth. Soil/grout ratios and stabilizing agent must be tested prior to in-situ stabilization. In general, chemical grouts are better suited to fine-grained soil with small pores, while cement grouts are best for coarse-grained materials (U.S. EPA, 1988).

In-situ grouting of underground utilities would involve filling the bunkers and conduits with cement or chemical grout. This process immobilizes radionuclides found on the inner surfaces of the bunker and conduits, but does not address contamination outside the utilities and structures. If the open spaces and piping are filled with rain water or ground water, extraction of these liquids may be necessary prior to grout injection, and the liquids could be mixed with the cement prior to injection. Since water table elevations are well below the bottom of the bunker and conduit structures, in-situ grouting may be an effective immobilization technology for soils and underground structures.

In-situ grouting will not reduce the toxicity of wastes, will increase their volume, and will decrease mobility.

Onsite stabilization/solidification. Onsite stabilization/solidification could theoretically apply to both soils and structures, although the structures would have to be cut and ground to reasonable particle sizes that could be processed in pug or drum mixers. Therefore, this process is discussed below with respect to treating contaminated soils.

Onsite stabilization/solidification (S/S) processes can be grouped into two main categories based on the type of stabilizing agent:

- inorganic S/S (cement-based and pozzolanic);
- organic S/S (thermoplastic and organic polymerization).

Inorganic S/S with cements and pozzolans (lime, kiln dust, clays) have been used for hazardous wastes, especially inorganic sludges, to physically and chemically bind heavy metals. Organic S/S themo-plastic binders (asphalt, polymers) have been used primarily with nuclear waste.

Cement-based S/S is a process in which waste materials are mixed with portland cement. Water is added to the mixture, if it is not already present in the waste material, to ensure the proper hydration reactions necessary for bonding the cement. The wastes are incorporated into the cement matrix and, in some cases, undergo physical-chemical changes that further reduce their mobility in the waste-cement matrix. Typically, hydroxides of metals are formed, which are much less soluble than other ionic species of the metals. Small amounts of fly ash, sodium silicate, bentonite, or proprietary additives are often added to the cement to enhance processing. The final product may vary from a granular, soil-like material to a cohesive solid, depending on the amount of reagent added and the types and amounts of wastes stabilized/solidified. Cement-based stabilization/solidification has been applied to plating wastes and nuclear wastes. Cement has also been used with complex wastes containing PCBs, oils, and oil sludges; wastes containing vinyl chloride and ethylene dichloride; resins; stabilized/solidified plastics; asbestos; sulfides; and other materials (Jones 1986; Tittlebaum and Seals 1985).

Pozzolanic stabilization/solidification involves siliceous and aluminosilicate materials, which do not display cementing action alone, but form cementitious substances when combined with lime or cement and water at ambient temperatures. The primary containment mechanism is the physical entrapment of the contaminant in the pozzolan matrix. Examples of common pozzolans are fly ash, pumice, lime kiln dusts, and blast furnace slag. Pozzolans contain significant amounts of silicates, which distinguish them from lime-based materials. The final product can vary from a soft fine-grained material to a hard cohesive material similar in appearance to cement. Pozzolanic reactions are generally much slower than cement reactions. Waste materials that have been stabilized/solidified with pozzolans include nuclear wastes, oil sludges, plating sludges containing various metals (aluminum, nickel, copper, lead chromium, and arsenic), waste acids, and creosote (U.S. EPA, 1989).

Thermoplastic stabilization/solidification is a microencapsulation process in which the waste materials do not react chemically with the encapsulating material. In this technology, a thermoplastic material, such as asphalt (bitumen) or polyethylene, is used to bind the waste constituents into stabilized/solidified mass. The asphalt binder may be heated before it is mixed with a dry waste material, or the asphalt may be applied as a cold mix. In the latter case, compaction is used to remove additional water from the surrounding aggregate/waste particles.

Bitumen may have commercial application for stabilizing/solidifying oil- and gasoline-contaminated soils as well as nuclear wastes (U.S. EPA, 1989).

In this process, the contaminated soils are used to dilute the bitumen. The resulting consistency will vary depending on the density of the soil mixed into the bitumen and the amount of aggregate added to the mixture. Thermoplastic encapsulation can also be applied to electroplating sludges, painting and refinery sludges containing metals and organics, dry incinerator ash, fabric filter dust, and radioactive wastes (Tittlebaum *et al.*, 1985).

Organic polymerization stabilization/solidification relies on polymer formation to complex the wastes without chemically reacting with the waste constituents. Urea-formaldehyde and polyurethane foam are the most commonly used organics polymer for this purpose. Organic polymerization has been used primarily to stabilize/solidify radioactive wastes. At the Rocky Flats Plant, for instance, an area of about four square meters was coated with a 5-cm deep layer of polyurethane foam. After it set, the dried foam and 85% of the activity was removed. This technology has also been applied to hazardous wastes such as organic chlorides, phenols, paint sludges, cyandies, and arsenic. Polymerization can also be applied to flue gas desulfurization sludge, electroplating sludges, nickel/cadmium battery wastes, ketone-contaminated sludge, and chlorine product wastes that have been dewatered and dried (Kyles, Malinowski, and Staczyk 1987).

Stabilization/Solidification techniques will not affect waste toxicity, will increase waste volume, and will decrease mobility. Stabilization/Solidification will also make any future treatment of wastes difficult.

In-situ vitrification. In-situ vitrification (ISV) is a process developed by Battelle Pacific Northwest Laboratories in the early 1980's. Its original application was for the encapsulation of radioactive wastes by the classification of soils.

Although a monolithic form results, this process is not truly a stabilization/solidification process. Because soils are heated to temperatures above the silica melting point (i.e., in excess of 2000°C), in-situ vitrification may also be considered a form of in-situ incineration for wastes destroyed at these temperatures.

The process is operated by the use of four electrodes, which are inserted into the soil in a square pattern at a spacing of about 18 feet. A mixture of graphite and glass frit placed in a shallow trench connects the electrodes in an "X" pattern. Before the process can begin, several supporting operations must be in place. A hood is placed over the area to collect off-gassing volatiles (including metals) and particulate matter. Three trailers provide the services required for the operation of the process: 1) a process control trailer, which varies the current and voltage applied to the electrodes to provide constant power; 2) a support trailer, which houses a transformer and air coolers; 3) and an off-gas trailer, which contains a scrubber system and charcoal filters. These trailers are connected to each other and can be moved as a unit (U.S. EPA, 1989).

When the site is ready, electrical current is applied to the electrodes at a maximum voltage of 4160 volts. Soil, which melts at 2000 to 2500°F, is heated to 3600°F. The melt proceeds at a rate of 4 to 5 tons per hour (U.S. EPA, 1989).

Processing time is a function of the depth of melting and the moisture content of the soil. Evaporation of the soil's moisture adds considerable expense to this operation; dewatering of the entire site may be necessary.

Sites that contain significant amounts of buried metals may not be appropriate candidates for in-situ vitrification, as these metals can produce a conduction path that leads to short-circuiting between electrodes.

When the melt reaches the desired depth, the electrodes are turned off and the melt is allowed to cool. Complete cooling may take several months; however, equipment can be operated on the surface within several days. Moving the equipment from one grid to the next takes 16 hours.

Development of the in-situ vitrification process has been ongoing in the 1980's. Nearly 50 tests (engineering-, pilot-, and full-scale) have been performed. The five areas most appropriate for its application are contaminated soil, burial grounds, tanks with hazardous waste heels, classified wastes, and process sludge and tailings piles.

ISV may be applicable to the contaminated apron and utility bunkers as well as contaminated soils. ISV can vitrify concrete inclusions in a soil matrix under certain conditions, depending on metal content and mass of the concrete.

ISV reduces waste volume by eliminating pore space in soils, reduces mobility, and does not affect toxicity. ISV will make any future treatment of wastes difficult.

5.1.3.5.2 Chemical Extraction Technologies

Chemical extraction removes and concentrates radioactive contaminants through chemical reaction of the source material with a fluid. This extraction with a solution can take place in-situ or can involve a mobile processing unit for excavated soils and structures. Chemical extraction for cleaning radiologically contaminated soils and mill tailings can involve one of the following solutions: (1) water, (2) inorganic salts (3) mineral acid solutions (e.g. fluorosilicic acids), and (4) solutions with complexing reagents (e.g. EDTA) The U.S. Bureau of Mines has developed a mobile unit for recovery of metals from ore-grade materials that uses fluorosilicic acid. The U.S. EPA has also developed a mobile unit using EDTA for washing soils contaminated with heavy metals and certain organic compounds. To date, chemical extraction (or soil washing) has been limited to laboratory and pilot-scale testing on contaminated soils.

Soil Washing. Soil washing of contaminated soils in a mobile unit would involve excavation and mixing of soils with large amounts of aqueous solutions. Contaminated soils enter the unit through a feeder, where a coarse screen removes oversized materials and debris that cannot be treated. The waste passes into a soil scrubber, where it is sprayed with the washing fluid. Soil particles greater than 2 inches in diameter leave the scrubber and settle in a drying bed. The

remaining soil enters a countercurrent extractor, where washing fluid passing counter currently to the soil removes the contaminants. The treated solids then settle on a drying bed. The remainder of the process involves a multi-step waste water treatment for removal of contaminants from the washing fluid before it is recycled (PEI, 1987).

In-situ flushing. In-situ flushing or flushing is a process that uses a ground water extraction/injection system to remove contaminants from soils or underground structures. Pump and treatment systems for ground water are often combined with reinjections of treated ground water upgradient of the extraction wells to produce accelerated flushing and decontamination of soils in-situ. Chemical agents may be added to the reinjected ground water (PEI, 1987).

Given the shallow nature of the contamination at the site, in-situ extraction of contaminants in the soil may not be practical and may adversely affect transport of the radionuclides in soil and existing ground water quality if the flushing solution is not completely recovered.

Chemical extraction technologies generally decrease waste volume and increase toxicity by removing and concentrating contaminants.

5.1.3.5.3 Physical Separation Technologies

Physical separation technologies have been used to separate and concentrate radionuclides in soils and structures. They are volume reduction processes that are used alone or as pre-and post-treatment phases along with chemical extraction treatment schemes. Although they are primarily mechanical methods for separating and concentrating contaminants of concern, chemical agents are sometimes added to enhance the separation process.

For contaminated soils, there are a variety of physical separation technologies, each with a soil particle size range. They include sorting, screening, classification, flotation, and gravity separation. In any given process, a combination of these physical separation techniques may be employed to achieve the required removal of the radionuclide.

Sorting. An example of a sorting process is TRU-Clean^{R}, which has been demonstrated on a pilot scale to effectively remove radioactive contamination in BOMARC soils by greater than 90% (AWC, Inc., 1987). This process involves sorting excavated soil into radioactive and non-radioactive fractions using a conveyor belt equipped with FIDLER (Field Instrument for the Detection of Low Energy Radiation) detectors followed by gravity settling to further segregate and concentrate radiologically contaminated soils.

Screening. Screening (both wet and dry) separates soils (or solid particles) on the basis of particle size. It is normally applied only to particles greater than 250 microns in size. The process can be done dry or by washing water through the screen. Screening is not efficient with damp or fine-grained materials, since they quickly clog the screens (U.S. EPA, 1988). Screening can be applied to a variety of materials, and it is relatively simple and inexpensive. It may be particularly effective as a first operation to remove large particles, followed by other methods.

Screening is a noisy operation and dry screening requires dust control (U.S. EPA, 1988). Wet screening of soil at Rocky Flats (Olsen *et al.*, 1980) removed 99.9% of radionuclides from soil fraction finer than 35 mesh (about 76% of the total soil volume).

Analyses conducted during the RI indicate that the BOMARC site soils generally consist of 85-95% sand-sized or larger particles, and furthermore that radionuclides may have an affinity for smaller-sized particles. Therefore, screening may be applicable to the BOMARC soils.

Classification. Classification separates particles according to their settling rate in a fluid. Several hydraulic, mechanical, and nonmechanical configurations are available. Generally, heavier and coarser particles go to the bottom, and lighter, smaller particles (called froth) are removed from the top. Classifiers are often used with chemical extraction in a volume reduction process. Classification is a relatively low-cost, reliable operation. Soils high in clay or sands high in humus, however, are difficult to process this way (U.S. EPA, 1988).

Flotation. Flotation is a liquid froth separation process often applied to separate specific minerals (particularly sulfides) from ore-grade rock. The process depends more on particle size and surface attraction between the ore and the frothing agents, than on material density. If ore particles can be bound to the froth, flotation is very effective (U.S. EPA, 1988).

Ordinarily, flotation is applied to fine-grained materials; the process often is preceded by grinding to reduce particle size. Flotation as been used to extract radium from uranium mill tailings (U.S. EPA, 1988).

Gravity separation. Gravity separation is used in the uranium and radium ore processing industries. This process takes advantage of the differences in material densities to separate the materials into layers of dense and light minerals. Separation is influenced by particle size, density, shape, and weight. Shaking (e.g. a shaker table) and a variety of other motions are employed to keep the particles apart and in motion; this is an integral part of the process. Gravity separation can be used in conjunction with chemical extraction. One drawback to gravity separation is its generally low through-put (U.S. EPA, 1988).

Additional technologies are required to support separation methods, including sedimentation and filtration, both of which are methods used in wastewater treatment. They may be used individually or together.

Physical separation techniques reduce the volume of waste requiring disposal by removing and concentrating the waste. Mobility is unaffected, but risks are effectively minimized by removing contaminants from the site. Toxicity is increased by increasing the concentration of radionuclides.

5.1.3.5.4 Combined Physical Separation and Chemical Extraction Technologies

The combined physical and chemical separation techniques that can be used to decontaminate radioactive soils and dismantled apron materials are:

- Chemical extraction and physical separation
- Physical separation and chemical extraction
- Physical separation, washing and chemical extraction techniques

Chemical extraction and physical separation. The chemical extraction and physical separation process involves washing the soil with chemical solution, followed by separation of coarse and fine particles. The type of solution used for washing will depend on results from bench- and/or pilot-scale studies.

In 1972, DOE initiated laboratory-scale studies evaluating washing and separation techniques; on the basis of these studies, a washing and separation process was selected for pilot-scale testing for plutonium-contaminated soils. In the pilot-plant test runs, soil contaminated with 45, 284, 7515, 1305, and 675 pCi/g of plutonium were cleaned to 1, 12, 86, 340, and 89 pCi/g, respectively using different processes. The coarse particle weight fraction ranged from 58% to 78%. Soil washing has been shown to work in clay soil. This process may not work for humus soil (U.S. EPA, 1988).

Physical separation and chemical extraction. In the physical separation and chemical extraction process, the soil is first separated into fine and coarse particle fractions. The coarse particle fractions may be washed or extracted. The fine particles are combined with extracted contaminants and can be sent to a secure disposal site. The "clean" coarse fractions are analyzed for residual activity and evaluated for placement at the original site or an alternate site (U.S. EPA, 1988).

An advantage of this process is that soil containing high levels of radioactivity can be treated. Also, various sections of the process have been developed for extracting uranium, and laboratory work is underway in Canada for extracting radium from uranium mill tailings. The main disadvantages of this process are that it is expensive and has high chemical usage. In addition, the use of chemicals raises concerns of further contamination to the environment. The process would need further development work in order to better extract radionuclides from soil (U.S. EPA, 1988).

Physical separation, washing, and chemical extraction. In applying the physical separation, washing, and chemical extraction technique, the contaminated soils can conceivably be washed with a variety of washing fluids, followed by chemical extraction. The nature of the washing fluids and chemicals depends on the contaminants and on the characteristics of the soil. It could be advantageous to separate soil into fine and coarse fractions to reduce the throughput and chemical usage. The treated soil, the fine soil fractions and the collected radionuclides would all require appropriate disposal.

All of the above techniques will theoretically reduce waste volume and increase toxicity by removing and concentrating contaminants. Effects on mobility will depend on the reagents used.

5.1.3.5.5 Physical Decontamination Technologies

In addition to techniques that are applicable to contaminated soils, other physical techniques are available to dismantle and decontaminate buildings and structures. Specific remedial technologies suitable for surfaces and bulk sectioning of equipment and structures include:

- Spaller/scarifier/impactor
- Sandblaster
- Sectioner/cutter

These decontamination techniques are discussed below with respect to their applicability to the asphalt/concrete apron, parts of Shelter 204, and underground utility structures.

Spaller/Scarifier/Scrubber/Impactor. The Spaller/Scarifier/Scrubber/Impactor processes mechanically break down surfaces of concrete walls and floors of buildings. Specific types include concrete spallers, scarifiers, scrubbers, jackhammers and impactors.

Concrete spaller. The concrete spaller has three basic parts: a hydraulic cylinder, a push rod, and a bit with expanding wedges. The cylinder activates the push rod, which is installed inside the bit. The bit is fabricated of steel tubing and the inside diameter tapers at one end. It is split into four equally spaced pieces parallel to its axis; a circular wedge is machined into the tubing at the tapered end.

The push rod is installed inside the tubing. To produce the spalling effect, the rod is pushed towards the end of the bit, which has been placed into a predrilled hole. the wedges are thus forced radially outward against the walls of the hole. As the push rod approaches the bottom of the drilled hole, it forces the wedges away, spalling a 5-cm deep crater (Smith, Konzek, and Kennedy 1978).

The initial drilling of the hole is the single most time-consuming portion of the process. Holes are most effectively drilled in a triangular pattern on 20-cm centers, and each hole can be expected to take about 10 to 15 sec using a compressed air drill. On this basis it will take about 10 min/m^2 ($\sim$ 1 min/ft^2) to drill and spall a concrete surface (Halter and Sullivan 1980a; Halter and Sullivan 1980b).

Scarifier. The scarifier is a tool composed of multiple air-operated piston heads, each of which is faced with five-point or nine-point tungsten carbide bits. It is effective on wall and floors when used in conjunction with containment and a HEPA-filtered vacuum system to contain contaminated dust at the sources. A seven-piston floor unit is capable of removing up to 10 min/m^2 (1 min/ft^2) of surface concrete to a depth of 5 cm (1 in.) (Manion 1980).

Jackhammers and impactors. Jackhammers and impactors are similar in that they involve driving a pick or chisel point into concrete surfaces with high-energy impacts at a rate of several times per second.

Compressed air-powered jackhammers are readily available and easily used by one man; however, they are primarily used on floors because they are heavy and hard to maneuver.

Impactors are more appropriate for removing contaminated concrete wall and ceiling material. Impactors are powered by air or hydraulics and are positioned with linkages similar to those found on tractor-mounted back hoes and excavators (Ureda 1976; Halter and Sullivan 1980a; Halter and Sullivan 1980b).

Sand Blasting. Sand blasting materials such as sand, Al_2O_3, B_2O_3, glass beads, or magnetite grit, are propelled against the contaminated surface at high velocity to remove activity and some of the substrate. By varying the size and conditions of application, the surface can be scoured, polished, or peened (Spencer 1980). The usual size for effective wet blasting is 60 to 5000 mesh (Spencer 1980); larger particles will cause faster surface removal (Remark 1978).

There is no single technique or abrasive material that is universally applicable. The construction material, type of contamination, extent of decontamination desired, and complexity of the surface must all be considered. Voids smaller than the abrasive are not cleaned effectively unless enough material is removed to enlarge the opening. Steel and concrete are usually sandblasted with pressures of 0.4 to 0.45 MPa (80 to 90 psfg).

Dry blasting with sand propelled by compressed air is the most widely used technique industrially. Dust is a problem with this technique, which can be of critical importance in decontamination; therefore, most emphasis lies in wet blasting for decontamination applications (PNL, 1989). Vacuum blasting utilizes a vacuum to collect sand and dust and prevent the spread of contamination.

Wet blasting techniques maintain fine finishes while providing enough action for effective decontamination. In the wet process, sand is mixed with water and propelled by air. Two disadvantages are apparent in the wet technique: 1) the waste water as well as the sand must be retained and monitored prior to disposal and 2) fine sand particles that are formed by destruction of the abrasive are wet and adhere to the surface being cleaned. Often this residue must be removed by brushing with a vacuum. Nevertheless, airborne particulates are reduced (PNL, 1989).

Decontamination factors for exposed smooth surfaces of contaminated laboratory equipment will range from 10 to 50 (Halter and Sullivan 1980a; Smith, Konzek, and Kennedy 1978; Hill 1970).

Sectioning/cutting. Although sectioning/cutting is not strictly a decontamination method, it is a potential first step in component decontamination.

Concrete saws. Concrete saws can be used to section concrete materials. Conventional construction saws can be modified to incorporate containment mechanisms to preclude the spread of contaminants. The cutting blade is cooled by circulated water, which requires collection and containment.

Plasma arc cutting. Plasma arc cutting uses an extremely high-temperature, high-velocity gas arc between an electrode and the piece to be cut. The process can be used on any metal.

The arc saw. The arc saw is reported to be an efficient and cost-effective means of sectioning metal components prior to decontamination for decommissioning.

5.1.3.5.6 Electrochemical Separation Technologies

Electrochemical separation technologies have been used for many years in the metallurgical and chemical industries. In recent years, electrochemical methods, particularly electropolishing, have gained interest in nuclear industry for decontaminating metal surfaces. Electrochemical techniques considered for the BOMARC structures include electropolishing and electrobrushing.

Electropolishing. Electropolishing is used to rapidly decontaminate surfaces of metals from nuclear facilities. For example, stainless steel tools contaminated with plutonium oxide have been reduced from more than 1 million dis/min-100 cm^2 to background in less than 10 min (Arrowsmith and Allen 1978). In this process, the object to be decontaminated serves as the anode in an electrolytic cell (Allen, Arrowsmith, and Budke 1978). Within a certain range of voltage to current density there occurs a progressive dissolution of the surface material. If the voltages and current densities are too low, the surface is attacked nonuniformly, causing etching rather than polishing; voltages that are too high cause severe pitting of the surface. Radioactive material that is on the surface or entrapped in surface imperfections is removed and released into the electrolyte. Typically less than 0.05 mm (2 mils) of material are removed with one treatment. Operating conditions using a phosphoric acid electrolyte typically have solution temperatures of 40 to 80°C, concentrations of 40 to 80%, electrode potentials of 8 to 12 V (dc), current densities of 50 to 500 A/ft^2. and the time intervals of 5 to 30 min (Jumer 1980; Allen, Arrowsmith, and Budke 1978). Hydrogen evolved from this process may require venting.

Electropolishing tanks are constructed of stainless steel because they can be decontaminated by making the walls anodic. Support equipment for an electropolishing system includes a dc power supply, rinse tanks, a ventilation system, and a means of temperature control and mixing of the solutions.

In-situ. In-situ electropolishing is being developed for use on those components that cannot be immersed in a typical electropolishing cell. This capability may be especially useful in decommissioning work to decontaminate tanks, large process equipment pipe interiors, or other large metallic surfaces prior to dismantling. Contact in-situ electropolishing consists of an insulated unit holding the cathode at a fixed distance from the anodic surface to be decontaminated. Electrolyte is pumped through the unit at a slight negative pressure; a test unit is reported to decontaminate 20 cm^2 (3 $in.^2$) of stainless steel in 5 min using a phosphoric-sulfuric electrolyte at a current density of 55 A/ft^2 and a potential of less than 12 V (dc) (Allen, Arrowsmith, and Budke 1978).

Pump stream electropolishing, where the cathode is the pipe nozzle, has been developed to the point where a 1.3-cm (0.5-in) diameter stream of phosphoric acid electrolyte conducting a current of 2 A can reduce the radiation level on a plutonium-contaminated carbon steel component--the anode--from 15,000 dpm/100 cm^2 to background in less than 2 min.

Electrobrushing. Electrobrushing is an electropolishing process on selected surfaces. The component to be decontaminated is the anode while the electrobrush serves as the cathode. The brush itself is a cellulose sponge wetted by a continuous field of an electrolyte, such as 5% sulfuric acid solution inhibited with 1 g/l ethyl guinolium. Since there is some danger of

atmospheric contamination with this process, the furnace must be vented and filtered before release to the atmosphere (Ayres, 1970).

Some advantages of this system are in-situ capability, high decontamination factors, proven useful on pressurized water reactor (PWR) filons, and readily available equipment. Disadvantages of the system include the production of large volumes of aqueous radioactive wastes and excessive attack of the surface by the electrolyte; in addition, if the decontamination is performed manually rather than remotely, the man-rem exposure may be high.

5.1.3.6 Onsite Disposal

Disposal technologies potentially applicable to onsite disposal of radioactive wastes at the BOMARC site including landfilling.

Landfill technology is a proven, well-demonstrated technology that has been used for hazardous, municipal, as well as low-level radioactive wastes (wastes containing long-lived radionuclides with activity less than 100 nCi/g). Landfilling more concentrated wastes may also occur on a case-by-case basis with approval from NRC.

The feasibility of onsite disposal depends on the following factors:

- Availability of sufficient space at the site;
- Concentrations of radionuclides and volumes of waste;
- Whether site conditions meet NRC standards in 10 CFR 61.

Landfill design components include the following:

- Foundation, or subgrade
- Lining system (liners and leachate collection and removal systems)
- Berms (separation between cells)
- Cover (daily and final cover).

State-of-the-art lining systems have one or two composite liners consisting of a geomembrane (High Density Polyethylene, or HDPE) over three feet of compacted clay. The leachate collection and removal system consists of a granular or synthetic drainage layer, collection pipes, a sump, filter and cushion materials. Together, the liners and leachate collection systems minimize leachate migration out of the unit. In the case of landfills with multiple cells, berms are constructed of earthen materials to separate and isolate wastes with in the cells. Berms can also be used to channel precipitation to collector pipes in the leachate collection system. The daily cover consists of soils that are placed over the wastes at the end of the day and also before placement of the final cover. The final cover must be no more permeable than the lining system and typically consists of a bottom composite liner system, a middle drainage layer and an upper vegetative cover. If properly designed, constructed and operated, state-of-the-art landfills can prevent leachate migration out of the unit for a periods of 50 to 100 years (U.S. EPA, 1988).

5.1.3.7 Offsite Disposal

Offsite disposal technologies potentially applicable to radioactive wastes at the BOMARC site include:

- landfill
- geologic repository.

The feasibility of offsite disposal will depend upon the following factors:

- Existence of properly licensed radioactive waste disposal facilities that can accept wastes.
- Concentration of long-lived radionuclides and volumes of untreated wastes.
- Unit costs for waste transportation and disposal.

If a waste treatment alternative that removes and concentrates radionuclides is chosen, offsite disposal of residuals will be part of the alternative.

5.1.3.7.1 Landfill

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Offsite landfilling would not affect waste volume or toxicity, and would decrease waste mobility.

5.1.3.7.2 Geologic Repository

Storage and disposal of waste and petroleum in geologic repositories, or underground mine space is a proven technology and has been demonstrated on a pilot scale for hazardous and nuclear wastes. The Waste Isolation Pilot Plant (or WIPP) is an underground repository in a bedded salt formation in New Mexico. The WIPP is currently receiving DOE Transuranic waste on a pilot-scale and has submitted a permit application to EPA to receive commercial hazardous and mixed wastes. Salt domes have been used by oil/gas companies for storage of liquid petroleum and gas products. Among the different lithologic formations, salt beds and domes are considered by some to be the best for material storage and disposal because of their unique deformation characteristics (i.e., salt deforms plastically while other rock types fracture). Other lithologies considered by DOE for high-level and TRU waste disposal include basalt and granites (U.S. EPA, 1988). Volcanic tuff is currently under consideration at the Yucca Mountain site in Nevada.

Geologic repositories are preferable to landfills for disposal of wastes contaminated with long-lived radionuclides, such as plutonium and americium, because they can theoretically prevent radionuclide exposure to humans for considerably longer time frames than conventional land-disposal technologies (i.e. 300-1000 years for well-sited, designed constructed and operated facilities). The NRC has placed a 10,000 year performance period for these high-level waste repositories. The emphasis of regulatory requirements for geologic repositories is on the siting and design aspects for the facility. These facilities must be located in a suitable formation that is sufficiently isolated from aquifers designated as underground sources of drinking water (USDW). In addition to better performance, estimated costs associated with construction and operation of geologic repositories receiving untreated wastes are comparable to that for landfills receiving untreated wastes (U.S. EPA, 1986).

5.1.4 Screening of Preliminary Remedial Technologies

In this section the general response actions and associated remedial technologies are screened to eliminate inapplicable and infeasible technologies based on site conditions, waste characteristics, and technical requirements. In this section, the results of the screening and the reasons for elimination of remedial technologies are discussed. Those technologies remaining after this screening will be assembled into alternatives and undergo additional analysis and screening.

At this stage in the feasibility study process, remedial technologies will be eliminated if they:

- are difficult to implement
- are unproven technologies
- require unreasonable time frames for implementation
- do not contribute significantly to protection of human health and environment
- involve significant adverse effects.

Special consideration is given to those technologies that:

- permanently contain, immobilize, detoxify or destroy contamination
- reduce the volume of contaminated media
- recycle or recover contaminants
- promote energy recovery.

At this stage, cost is not a significant screening factor and is considered only on a relative basis in comparing technologies that offer the same results. Table 5-5 summarizes the results of this preliminary screening.

5.1.4.1 Unrestricted Access Technologies

No technologies are applied under this general response action, so technology screening does not apply.

5.1.4.2 Existing Conditions Technologies

All technologies applied under this general response action (see section 5.1.3.2 for a list of technologies) are proven, easily implemented technologies. Many of these technologies are currently being implemented at the site. None of the technologies require unreasonable time frames for implementation, and none involve significant adverse effects. Therefore, all technologies applicable under this general response action are retained for further evaluation.

5.1.4.3 Limited Action Technologies

All technologies applied under this general response action (see section 5.1.3.2 for a list of technologies) are proven, easily implemented technologies. Many of these technologies are currently being implemented at the site. None of the technologies require unreasonable time frames for implementation, and none involve significant adverse effects. Potential short-term adverse effects associated with excavation activities can be mitigated and eliminated through properly engineered controls. Therefore, all technologies applicable under this general response action are retained for further evaluation.

5.1.4.4 Containment Technologies

5.1.4.4.1 Capping

Capping is a proven technology that is easily implemented and relatively inexpensive. Capping would be used to contain all contaminated media at the BOMARC Missile site. This would require demolition and consolidation of some onsite structures prior to capping. The most highly contaminated media onsite, including the floor of shelter 204 and the concrete apron, could be capped in-situ, thereby minimizing risks associated with disturbance of contaminants. Capping would reduce the risks of direct contact with wastes, and reduce the risk of resuspension of plutonium and americium to the atmosphere. Capping would also reduce infiltration of precipitation and decrease the already low risk of ground water contamination. Due to the extreme persistence of plutonium and americium, a cap would require multiple replacement

Table 5-5

Preliminary Screening of Remedial Technologies

General Response Action	Remedial Technologies	Description	Eliminate? (Y or N)	Rationale for Elimination
Unrestricted Access	None	Drop access and institutional controls currently in place.	N	
Existing Conditions	Access Restrictions Monitoring Maintenance Deed Restrictions	Reduce exposure by limited access. Document and monitor migration; does not eliminate transport and off-site exposure to radionuclides.	N	
Limited Action	Access Restrictions Monitoring Maintenance Deed Restrictions Limited Waste Removal	Reduce exposure by limiting access. Document and monitor migration; does not eliminate transport and off-site exposure to radionuclides, except for the limited amount of waste removed from the site.	N	
Containment	Capping	Prevents surface resuspension and erosion. Prevents risks from on-site direct contact. Applicable to contaminated soils, debris from remedial action, apron, and underground structures.	N	
	Vertical Barriers	Prevents lateral migration of contaminants in groundwater.	Y	Not applicable as source control technology.
	Berms	Manages surface water runon or runoff. May be used for containment or spill prevention in remedial alternatives producing liquid residual wastes that are stored on-site.	N	
	Coating/Paints	Prevents direct contact with radionuclides on surface of structures.	Y	Site Conditions prevent implementation.
On-Site Treatment	Immobilization	Reduces leaching or resuspension/erosion of radionuclides in soils.	Y	Does not significantly contribute to protection of public health or environment; site conditions make implementation difficult. Potential adverse effects.
	Chemical Extraction	Removes radionuclides from soils and soil-like solids through use of acids, chelants or other chemicals in aqueous solution.	Y	Unproven technology, potential adverse effects.
	Physical Separation	Removes radionuclides from soils and soil-like solids by physical means.	N	

Table 5-5

Preliminary Screening of Remedial Technologies (Continued)

General Response Action	Remedial Technologies	Description	Eliminate? (Y or N)	Rationale for Elimination
	Combined Physical/Chemical Separation	Removes radionuclides from soils and soil-like solids by combined physical and chemical methods.	Y	Unproven technologies, potential adverse effects.
	Physical Decontamination	Removes radionuclides from surfaces of structures. Applicable to Shelter 204, apron, and underground utilities.	N	
	Electrochemical Separation	Removes radionuclides from metal surfaces.	Y	Not effective in concrete or soil, which comprise majority of wastes.
On-Site Disposal	Landfill	Involves soil excavation and decommissioning of structures and placement of debris in a lined cell with a cap.	Y	Unreasonable time frame required for implementation. Site does not meet NRC siting criteria.
Off-Site Disposal	Landfill	Involves removal and transportation of wastes off-site for disposal at a licensed facility.	N	
	Geologic Repository	Involves removal and transportation of wastes to an off-site geologic repository.	Y	Availability of repository is uncertain.

cycles for the time period that wastes remain hazardous. Therefore, capping is considered a relatively short-term remedial alternative for the BOMARC Missile site.

Capping is retained for further evaluation.

5.1.4.4.2 Vertical Barriers

Vertical barriers are not applicable to the site, and are therefore eliminated from further consideration. Vertical barriers would not effectively contribute to protection of human health or the environment because they are designed to prevent migration of contaminants in ground water.

5.1.4.4.3 Berms

Berms are applied as secondary containment for remedial technologies that generate wastewater. The use of berms as part of an overall remedial alternative is retained for further consideration.

5.1.4.4.4 Coating/Painting/Encapsulation

Coating/painting/encapsulation technologies are proven and easily implemented in most cases. At the BOMARC site these technologies are applicable to aboveground structures. Aboveground structures include both steel and concrete components. Steel components are severely weathered, and will likely require preparation prior to application of coatings. This preparation will involve removal of surface rust so that coating materials have a relatively stable surface upon which to adhere. Because much of the remaining activity is likely on the surface of the steel, removal of rust would in effect remove remaining activity, making coating or encapsulation unnecessary. In addition, demolition and capping of structural materials would more effectively contain contaminants. Therefore this technology is eliminated from further consideration.

5.1.4.5 Onsite Treatment Technologies

5.1.4.5.1 Immobilization Technologies

In general, all immobilization technologies offer only very slight benefits because wastes are already relatively immobile and insoluble.

In-situ grouting. In-situ grouting is a proven technology. However, conditions at the BOMARC site (widespread areal distribution and shallow depth of radionuclides) would require excavation and consolidation of soils prior to treatment, potentially resulting in significant adverse impacts. Therefore in-situ grouting is not applicable, and is eliminated from further consideration.

Onsite stabilization/solidification. Onsite stabilization/solidification is a proven technology. This technology would require excavation and consolidation of soils and other materials prior to solidification/stabilization potentially resulting in significant adverse effects. This technology would offer only very slight benefits because radionuclides present at the site are already

relatively insoluble and immobile. Therefore this technology is eliminated from further consideration.

In-situ vitrification. In-situ vitrification would require excavation and consolidation of soils and other contaminated materials prior to implementation, due to the widespread areal extent and shallow depth of soil contamination. This would potentially result in significant adverse impacts. This requirement effectively eliminates the advantages of in-situ vitrification; therefore this technology is eliminated from further consideration.

5.1.4.5.2 Chemical Extraction Technologies

Chemical extraction for transuranic wastes is an unproven technology. These technologies are at the pilot-scale level of development, but to date have not been field tested. Chemical extraction is therefore eliminated from further consideration.

5.1.4.5.3 Physical Separation Technologies

In general, many of the physical separation technologies are adapted from metallic ore recovery processes. These processes are proven for removal of minerals from processed ore, but for the most part are unproven for large-scale field implementation in soil remediation.

Sorting (TRU-Clean^R process). The TRU-Clean^R process has been demonstrated effective in removing transuranics from soils in tests run on several different soil types from sites located across the U.S. (AWC, 1987). Results of these tests suggest that the process (or similar processes) is capable of removing approximately 90% of activity from the BOMARC soils, and reducing contaminated soil volumes by approximately 90%. The 10% residual would be shipped offsite for disposal at a licensed facility. "Clean" soils would be analyzed to ensure that activity was below the 3.0 pCi/g risk-based cleanup level, and returned to the site. The TRU-Clean^R process and similar processes can only be used on soils. Modifications to the basic process would probably be necessary to account for site-specific soil characteristics.

The TRU-Clean^R process (or a similar process) requires excavation and processing of soils, with the accompanying potential for adverse effects associated with excavation. However, since the process is a permanent solution to the problem and significantly reduces waste volume, the potential for adverse effects is balanced by the benefits of permanent site remediation. Therefore this technology is retained for further consideration.

Soil screening. Soil screening is an unproven technology for removal of radionuclides from soil. However, several factors make soil screening a particularly attractive technology. Unique properties of BOMARC soils may contribute to the effectiveness of this technology, potentially making it feasible for use at the site. In addition, the simplicity of the technology makes it relatively easy to evaluate and implement, and therefore very cost-effective.

Preliminary analysis of soil samples separated into size fractions by screening indicates that radionuclides at the site have an affinity for small (< 20 microns) soil particles. Furthermore, since the BOMARC soils are composed of roughly 90 - 95% sand-sized or larger particles, the soils are probably very well-suited to separation of particle sizes by screening. Concentrated

wastes contained in small-size soil fractions separated by the process would require transportation and disposal at an offsite facility. As with the TRU-Clean[R] process the potential adverse effects associated with excavation of contaminated soils could be balanced by the benefits of permanent remediation. Due to the fact that soil screening is an unproven technology, it is eliminated from further consideration.

Classification, flotation, and gravity separation. Classification, flotation, and gravity separation are unproven technologies for remediation of soils contaminated with plutonium, and are therefore eliminated from further consideration.

5.1.4.5.4 Combined Physical Separation and Chemical Extraction

These technologies are currently at the pilot-study stage of development, and have not been implemented in the field for transuranic extraction. In addition, use of chemical solvents may create mixed-waste residues. Therefore, these technologies are considered unproven, and are eliminated from further consideration.

5.1.4.5.5 Physical Decontamination Technologies

Decontamination technologies are proven methods for physical removal of radioactive contaminants from surfaces. As such, these technologies are not applicable to contaminated soils, but are applicable to aboveground and below ground structures, and may be applicable to the concrete apron and missile launcher. Used without engineering controls, these technologies have the potential for significant adverse impacts. Therefore, these technologies will only be implemented using engineering controls to prevent the spread of contaminants. These technologies are difficult to evaluate individually, because combinations are often used to achieve the desired results. These technologies as a group are retained for further consideration.

5.1.4.5.6 Electrochemical Separation Technologies

Electrochemical separation technologies apply to only steel structural components of shelter 204, which comprise only a small fraction of the BOMARC site wastes. Furthermore, only an estimated 25 percent of the steel will require decontamination. Therefore, these technologies are inapplicable, and are eliminated from further consideration.

5.1.4.6 Onsite Disposal Technologies

Landfilling is a proven technology and is relatively easily implemented from a technical standpoint. However, institutional concerns would make permitting of a radioactive waste landfill at the BOMARC Missile site difficult. The protracted time frame associated with the permitting process would require an unreasonable time frame to achieve remedial objectives, even if the site met the NRC siting criteria, which it probably does not. Therefore, this technology is eliminated from further consideration.

5.1.4.7 Offsite Disposal Technologies

The following offsite disposal technologies were considered for the BOMARC Missile site:

- Landfill
- Geologic Repository.

5.1.4.7.1 Landfill

Landfilling of radioactive wastes is a proven technology that is relatively easy to implement. Landfilling is retained for further consideration.

5.1.4.7.2 Geologic Repository

Currently, the permit status and availability of the Waste Isolation Pilot Plant for receipt of wastes is uncertain. Therefore this technology is eliminated from further consideration.

5.1.5 Development of Remedial Alternatives

In this section, remedial technologies retained for further consideration are grouped into remedial alternatives. Individual remedial alternatives may utilize several different technologies in order to address the five contaminated media onsite. The five contaminated media are not considered separate operable units because similar response actions can be used to address each medium within each alternative.

The following five remedial alternatives were assembled in order to provide a wide range of alternatives as required by the NCP:

- Alternative 1 - Unrestricted Access
- Alternative 2 - Existing Conditions
- Alternative 3 - Limited Action
- Alternative 4 - Capping
- Alternative 5 - Onsite Treatment
- Alternative 6 - Removal and Offsite Disposal.

Alternatives 4, 5, and 6 are discussed in detail below with respect to each of the five contaminated media onsite. Alternatives 1, 2, and 3 are not discussed with respect to each contaminated medium because media-specific actions are not undertaken.

Specific instruments are identified for use for several of the alternatives. Note that these instruments are identified for costing purposes only; similar, comparable instruments may also be used.

5.1.5.1 Alternative 1 - Unrestricted Access

The unrestricted access alternative in this case consists of dropping institutional and access controls currently in place and leaving contaminated materials in place. The unrestricted access alternative serves as a risk scenario for quantifying risks posed by the site in the absence of remediation or control, including control measures currently in place. This alternative is functionally equivalent to the "No Action Alternative" required by the NCP.

The unrestricted access alternative potentially allows for erosion of contaminated soil, weathering of contaminated structural materials, and offsite migration of plutonium and americium through mass-wasting and sediment transport by water and air. Lack of institutional controls allows for disturbance of the site by development activities, potentially exposing onsite workers and the general public to plutonium and americium through inhalation, ingestion, and external radiation and exacerbating erosion and sedimentation problems. Public access to the site allows for exposure of the general public through inhalation and ingestion pathways.

The unrestricted access alternative will not reduce risks to human health or the environment, and will not reduce the mobility, toxicity, or volume of the wastes. The unrestricted access alternative is retained for further consideration in accordance with the NCP.

5.1.5.2 Alternative 2 - Existing Conditions

This alternative includes all monitoring, maintenance, and access control actions currently implemented at the site. These actions are designed to protect human health and the environment by accomplishing the following:

1) Restrict public access to the site;
2) Prevent deterioration of existing containment structures;
3) Monitor distribution and potential migration of plutonium and americium onsite and offsite; and
4) Prevent disturbance of the site.

These goals will be accomplished through implementation of the following actions:

- Installation and maintenance of fencing and signs
- Quarterly visual inspections
- Maintenance of concrete apron
- Annual radiological surveys
- Maintaining government control of the site.

Specific instruments are identified for use for this alternative. Note that these instruments are identified for costing purposes only; similar, comparable instruments may also be used.

Fencing and signs. Fencing and signs are used to preclude access by the public. Fences are six feet in height, topped with barbed or concertina wire. Appropriate warning signs ("No Trespassing" and radiological hazard signs) are posted on the fence at 50-foot intervals.

In order to encircle the site, 4,750 linear feet of fence added to the existing 2,200 linear feet of fence installed during the RI, and 100 no trespassing/radiological hazard signs would be required.

Quarterly visual inspections. Quarterly visual inspections are used to document site conditions. The condition of fencing and signs is inspected to ensure site security. Evidence of site entry is noted. The condition of contaminated media is inspected, and evidence of deterioration or damage is noted. Corrective actions are recommended and carried out if conditions warrant.

is noted. The condition of contaminated media is inspected, and evidence of deterioration or damage is noted. Corrective actions are recommended and carried out if conditions warrant.

In order to conduct and document quarterly inspections, a two-person team would be required to conduct the inspections and write up results/recommendations, (one day for inspection, two days for write-up) equating to six person-days per quarter or 24 person-days annually. Inspectors would have to be properly trained in recognition and avoidance of radiological hazards, and would require level "d" of personal protective equipment for site entry. Inspectors would also require access to appropriate radiological survey equipment for clearing themselves and tools for site egress subsequent to onsite inspection activities. A Johnson RML 1-A personnel "Frisker," PAC - 4G or equivalent would be appropriate.

Maintenance of concrete apron. Maintenance of concrete apron is performed on an as-needed basis. The cement overlayer is patched and repaired as required. Asphalt is sealed and plants removed on a routine annual basis.

In order to conduct maintenance operations, it is estimated that a three-person crew would be required for five days annually. This equates to 15 person-days annually. As with site inspectors, maintenance workers would require proper training, level "d" or level "c" of personal protective gear, and suitable radiation detection instrumentation.

Maintenance operations would generate an estimated two (2) 55-gallon drums of low-level radioactive waste (average activity less than 100 nCi/g) annually that would required disposal.

Annual radiological surveys. Annual radiological surveys are conducted to verify that contaminants are not migrating offsite. Surveys would be conducted annually for five years and at five-year intervals thereafter. This requires development of a sampling plan that is sufficient to make this verification. Annual sampling includes onsite selected ground water wells, stream sediments in the site drainage pathway, and soils both onsite and offsite. Sampling techniques include a combination of sample collection/laboratory analysis and in-situ survey techniques.

Annual radiological surveys would require an estimated 50 person-days annually. This level of effort is broken down as follows:

1) Sampling of 10 onsite ground water monitoring wells - 10 person-days.
2) Collection of 20 sediment and 40 soil samples from near-site locations - 10 person-days.
3) FIDLER surveys of near-site locations - 10 person-days.
4) Analysis and write-up of results - 20 person-days.

As with maintenance and inspection tasks, survey personnel would require appropriate training, protective gear, and instrumentation.

Other requirements include rental of a FIDLER detector and analyzer for five days, Laboratory analysis (alpha spectroscopy) for plutonium and americium on 60 soil samples and 10 water samples, and other miscellaneous costs associated with field surveys and report preparation. It

is estimated that four (4) 55-gallon drums of potentially radioactive (less than 100 nanoCuries/gram) of wastes requiring disposal would be generated annually.

Maintaining government control of the site. Maintaining government control of the site is used to ensure that contaminated media are not disturbed in the future. If the government maintains possession of the site, deed restrictions will probably not be necessary. In order to release the property, the government would have to certify that the property is free of contamination. If the property is not free of contamination, the government cannot release it so deed restrictions are essentially already in place.

5.1.5.3 Alternative 3 - Limited Action

This alternative includes all monitoring, maintenance, and access control actions currently implemented at the site, plus removal and offsite disposal of a limited amount of the potentially most highly contaminated materials onsite. Specifically, additional actions include excavation of geophysical anomalies detected onsite that may represent the missile launcher from Shelter 204, and proper offsite disposal of any contaminated materials (launcher, associated hardware, contaminated soils) discovered. These actions are designed to protect human health and the environment by accomplishing the following:

1) Restrict public access to the site;
2) Prevent deterioration of existing containment structures;
3) Monitor distribution and potential migration of plutonium and americium onsite and offsite; and
4) Prevent disturbance of the site.
5) Locate and remove the missing missile launcher, if possible.

These goals will be accomplished through implementation of the following actions:

- Installation and maintenance of fencing and signs
- Quarterly visual inspections
- Maintenance of concrete apron
- Annual Radiological Surveys
- Maintaining government control of the site
- Excavation and Disposal of Missile Launcher.

Specific instruments are identified for use for this alternative. Note that these instruments are identified for costing purposes only; similar, comparable instruments may also be used.

Fencing and signs. Fencing and signs are used to preclude access by the public. Fences are six feet in height, topped with barbed or concertina wire. Appropriate warning signs ("No Trespassing" and radiological hazard signs) are posted on the fence at 50-foot intervals.

In order to encircle the site, 4,750 linear feet of fence added to the existing 2,200 linear feet of fence installed during the RI, and 100 no trespassing/radiological hazard signs would be required.

Quarterly visual inspections. Quarterly visual inspections are used to document site conditions. The condition of fencing and signs is inspected to ensure site security. Evidence of site entry is noted. The condition of contaminated media is inspected, and evidence of deterioration or damage is noted. Corrective actions are recommended and carried out if conditions warrant.

In order to conduct and document quarterly inspections, a two-person team would be required to conduct the inspections and write up results/recommendations, (one day for inspection, two days for write-up) equating to six person-days per quarter or 24 person-days annually. Inspectors would have to be properly trained in recognition and avoidance of radiological hazards, and would require level "d" of personal protective equipment for site entry. Inspectors would also require access to appropriate radiological survey equipment for clearing themselves and tools for site egress subsequent to onsite inspection activities. A Johnson RML 1-A personnel "Frisker," PAC - 4G or equivalent would be appropriate.

Maintenance of concrete apron. Maintenance of concrete apron is performed on an as-needed basis. The cement overlayer is patched and repaired as required. Asphalt is sealed and plants removed on a routine annual basis.

In order to conduct maintenance operations, it is estimated that a three-person crew would be required for five days annually. This equates to 15 person-days annually. As with site inspectors, maintenance workers would require proper training, level "d" or level "c" of personal protective gear, and suitable radiation detection instrumentation.

Maintenance operations would generate an estimated two (2) 55-gallon drums of low-level radioactive waste (average activity less than 100 pCi/g) annually that would required disposal.

Annual radiological surveys. Annual radiological surveys are conducted to verify that contaminants are not migrating offsite. Surveys would be conducted annually for five years and at five-year intervals thereafter. This requires development of a sampling plan that is sufficient to make this verification. Annual sampling includes onsite selected ground water wells, stream sediments in the site drainage pathway, and soils both onsite and offsite. Sampling techniques include a combination of sample collection/laboratory analysis and in-situ survey techniques.

Annual radiological surveys would require an estimated 50 person-days annually. This level of effort is broken down as follows:

1) Sampling of 10 onsite ground water monitoring wells - 10 person-days.
2) Collection of 20 sediment and 40 soil samples from near-site locations - 10 person-days.
3) FIDLER surveys of near-site locations - 10 person-days.
4) Analysis and write-up of results - 20 person-days.

As with maintenance and inspection tasks, survey personnel would require appropriate training, protective gear, and instrumentation.

Other requirements include rental of a FIDLER detector and analyzer for five days, Laboratory analysis (alpha spectroscopy) for plutonium and americium on 60 soil samples and 10 water

samples, and other miscellaneous costs associated with field surveys and report preparation. It is estimated that four (4) 55-gallon drums of potentially radioactive (less than 100 picoCuries/gram) of wastes requiring disposal would be generated annually.

Maintaining government control of the site. Maintaining government control of the site is used to ensure that contaminated media are not disturbed in the future. If the government maintains possession of the site, deed restrictions will probably not be necessary. In order to release the property, the government would have to certify that the property is free of contamination. If the property is not free of contamination, the government cannot release it so deed restrictions are essentially already in place.

Missile launcher. The location of the missile launcher is currently unknown. A geophysical survey was conducted during the RI for the purpose of locating the missile launcher. The results of the geophysical survey (please refer to section 3.4.1) indicated that five magnetic anomalies that could represent the missile launcher exist on or adjacent to the BOMARC site. In order to determine if the anomalies do represent the missile launcher, excavation and visual inspection will be required.

For cost evaluation purposes, it is assumed that all five anomalous areas will be excavated. Resources required for excavation include the following:

1) Rental of a backhoe with operator for ten days;
2) Three-person field crew including a certified health physicist, earth scientist, and engineer for ten days;
3) Rental of appropriate radiological survey equipment including one FIDLER detector with analyzer and one personnel/equipment "Frisker" (Johnson RML 1A, PAC - 4G or equivalent) for ten days.

All personnel associated with this operation will have to be trained in radiological hazard recognition and avoidance, all will require proper equipment for level "C" of personal protection.

Assuming that the launcher is found, additional actions will be required. At present, the level of radioactivity and size/shape of the launcher are unknown. The intense heat associated with the fire in shelter 204 may have partially melted or deformed the launcher. The total weight of the launcher is estimated at two to three tons, and the length is 30 feet. The launcher may have to be sectioned to facilitate removal and transport. Since the launcher may be contaminated and the degree of contamination is unknown, the launcher will have to be surveyed with appropriate radiological survey equipment in order to document the degree of contamination. It is estimated that this effort will require a Certified Health Physicist (CHP) and assistant five days to complete the survey. Surveys will use level "C" of personal protection, and will require rental of a FIDLER probe with analyzer and a personnel/equipment "Frisker" (PAC - 4G or equivalent) for five days.

Due to the possibility that soils surrounding the launcher may be contaminated, soils must be sampled and containerized pending receipt of results of sample analysis. Containerization and sampling of soils will require a three person crew for two days, including a backhoe operator,

CHP, and assistant. All will be equipped with level "C" of personal protection. Two days backhoe rental is also required. Storage of excavated soils will require rental of five 20-cubic yard covered roll-off boxes for two months. Sampling efforts will require analysis of 40 soil samples for plutonium 239 by alpha spectroscopy.

After the launcher and surrounding soils have been characterized with respect to radioactivity, they will be excavated, consolidated for transport, and trucked offsite for disposal.

All excavated areas will be restored to original grade, covered with topsoil, and re-planted with species indigenous to the New Jersey Pinelands.

5.1.5.4 Alternative 4 - Capping

Capping can be used to address all contaminated media onsite. The areal extent of the cap is shown by the shaded area on Figure 5-6, which equals approximately 70,000 square feet. Some of the contaminated media will require preparation/consolidation prior to capping. The preparation required for each medium is described below:

Contaminated soil. A large portion of the soil contaminated above the cleanup level lies within the area to be capped shown on Figure 5-6. Isolated "hot spots" lying outside this area will require excavation and placement within the boundaries of the capped area, as will the asphalt-covered drainage ditch area.

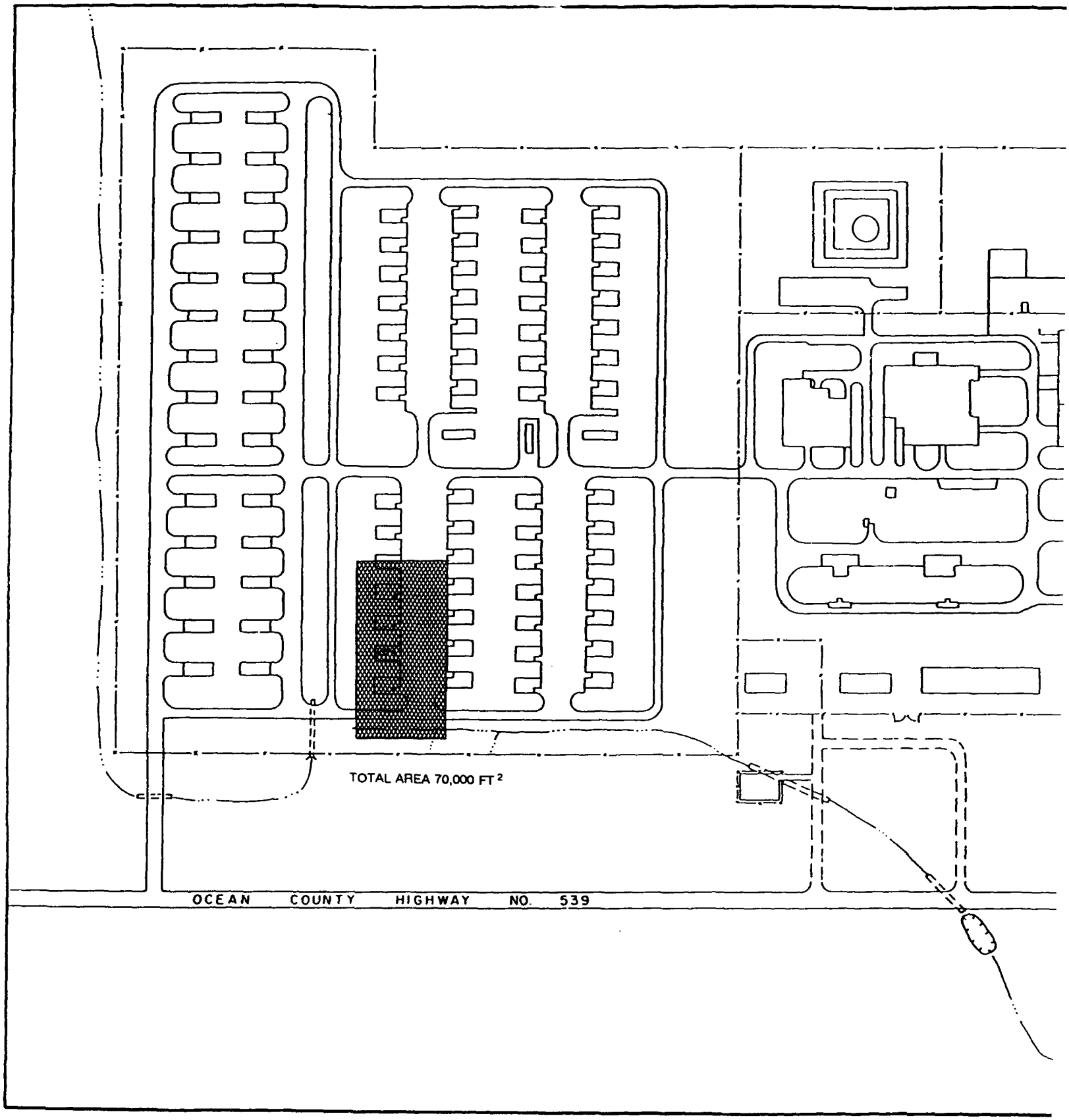
Contaminated apron. Contaminated apron materials will be left in place, and will be used as a base for placement of contaminated soils and other materials that are to be placed beneath the cap.

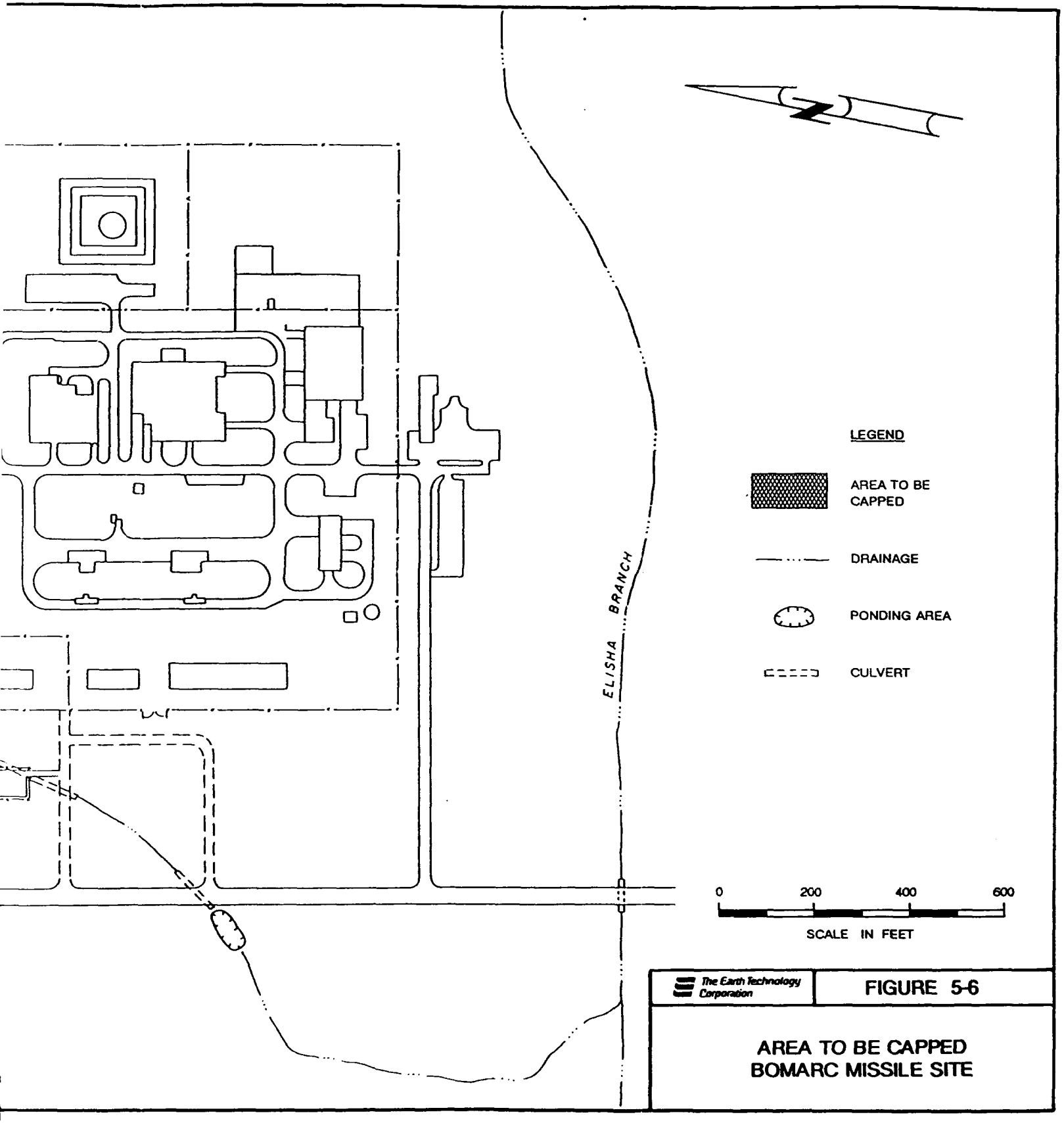
Shelter 204. Above-ground components of the shelter will be disassembled and placed on the concrete apron area prior to capping. Above-ground components include remaining portions of walls and the roof, but not the original floor and the six inches of concrete poured over the original floor. Floor materials will be left in place, and covered by the cap.

Underground utility bunkers. Underground utility bunkers will be pumped full of cement grout prior to capping, in order to fill the underground voids, prevent mobilization of radionuclides on the inner surfaces, and prevent cave-in.

Missile launcher. The location of the missile launcher is currently unknown. A geophysical survey was conducted during the RI for the purpose of locating the missile shelter. The results of the geophysical survey (please refer to section 3.4.1) indicated that five magnetic anomalies that could represent the missile launcher exist on or adjacent to the BOMARC site. In order to determine if the anomalies do represent the missile launcher, excavation and visual inspection will be required.

Specific instruments are identified for use for this alternative. Note that these instruments are identified for costing purposes only; similar, comparable instruments may also be used.


TOTAL AREA 70,000 FT²
OCEAN COUNTY HIGHWAY NO. 539



The Earth Technology Corporation

FIGURE 5-6

AREA TO BE CAPPED
BOMARC MISSILE SITE

For cost evaluation purposes, it is assumed that all five anomalous areas will be excavated. Resources required for excavation include the following:

1) Rental of a backhoe with operator for ten days;
2) Three-person field crew including a certified health physicist, earth scientist, and engineer for ten days;
3) Rental of appropriate radiological survey equipment including one FIDLER detector with analyzer and one personnel/equipment "Frisker" (Johnson RML 1A, PAC - 4G or equivalent) for ten days.

All personnel associated with this operation will have to be trained in radiological hazard recognition and avoidance, all will require proper equipment for level "C" of personal protection.

Assuming that the launcher is found, additional actions will be required. At present, the level of radioactivity and size/shape of the launcher are unknown. The intense heat associated with the fire in shelter 204 may have partially melted or deformed the launcher. The total weight of the launcher is estimated at two to three tons, and the length is 30 feet. The launcher may have to be sectioned to facilitate removal and transport. Since the launcher may be contaminated and the degree of contamination is unknown, the launcher will have to be surveyed with appropriate radiological survey equipment in order to document the degree of contamination. This is necessary to determine if the level of radioactivity associated with the launcher is low enough for the launcher to remain onsite beneath the cap or if on alternate method of disposal must be used. It is estimated that this effort will require a Certified Health Physicist (CHP) and assistant five days to complete the survey. Surveys will use level "C" of personal protection, and will require rental of a FIDLER probe with analyzer and a personnel/equipment "Frisker" (PAC - 4G or equivalent) for five days.

Due to the possibility that soils surrounding the launcher may be contaminated, soils must be sampled and containerized pending receipt of results of sample analysis. Containerization and sampling of soils will require a three person crew for two days, including a backhoe operator, CHP, and assistant. All will be equipped with level "C" of personal protection. Two days backhoe rental is also required. Storage of excavated soils will require rental of five 20-cubic yard covered roll-off boxes for two months. Sampling efforts will require analysis of 40 soil samples for plutonium 239 by alpha spectroscopy.

After the launcher and surrounding soils have been characterized with respect to radioactivity, they will be placed on the concrete apron area, assuming that levels of radioactivity are acceptable. Soils can be trucked to the apron area and dumped from the roll-off boxes. The launcher will require a small crane and flatbed truck for transport. A four-person crew consisting of a CHP, assistant, crane operator, and truck driver will require one day for transport. One-day rental of a container truck, flatbed truck, and crane will be required.

Utilization of heavy equipment onsite will require implementation of protective measures to ensure that the equipment does not become contaminated, and also to ensure that contaminants are not tracked offsite. To the maximum extent possible, equipment will be covered with plastic liners which will be removed and disposed of upon completion of the work. A decontamination

pad will be constructed for cleaning of equipment. Equipment will be cleaned using a high-pressure steam cleaner. The decontamination pad will be constructed so that wash fluids will be contained. Wash fluids will be pumped into 55-gallon drums for disposal. Decontamination and equipment clearance will require a two-person team including a CHP and assistant for five days. Personnel will be equipped with level ,"C" personal protection. Rental of a steam cleaner and personnel/equipment "Frisker" for five days will also be required.

It is estimated that decontamination efforts will generate 10 55-gallon drums of potentially radioactive wastewater requiring disposal. Excavation operations will generate an additional five 55-gallon drums of potentially contaminated disposable materials, including PPE, plastic liners, and other materials.

After wastes have been consolidated on the concrete apron, the cap will be constructed. Multilayered capping systems are a combination of several layers of different materials that serve integrated functions. A typical multilayered system may be composed of the following layers:

(a) Topsoil - usually a settled, but uncompacted surface layer of loams for vegetative (i.e., grasses) support;

(b) Barrier layer or membrane - usually compacted clayey soil or a synthetic membrane or both that impede(s) the passage of water or gas;

(c) Filter - intermediate grain-size layer to prevent fines from penetrating the coarser layer, controls settlement and stabilizes cover;

(d) Buffer layer - usually a sandy soil above and below the barrier layer, protects clays from drying and cracking, synthetic membranes from punctures or tears;

(e) Water/gas drainage layer or channel - poorly graded sand and gravel mixture; channels subsurface water drainage or intercepts and laterally vents gases.

The soil layers are commonly 6 to 12 inches in thickness to compensate for settling. The synthetic layer must be placed correctly and covered carefully to prevent rips in the material. The vegetative cover is usually grass or legumes to avoid long plant roots that may penetrate the barrier layer. Multilayered caps have been used extensively in the 1980's for RCRA closures of surface impoundments. Their design is widely accepted and they are reasonably successful in reducing resuspension, erosion, and direct contact with wastes.

All areas excavated will be restored to original grade, covered with topsoil, and re-planted with species indigenous to the New Jersey Pinelands.

5.1.5.5 Alternative 5 - Onsite Treatment

Onsite treatment involves physical removal of plutonium and americium from contaminated media onsite, concentration of radioactive wastes, and shipment of concentrated wastes offsite for disposal. Treated materials would be redeposited onsite. There is a possibility that the missile launcher, if found, will require offsite disposal without treatment, depending on the

condition of the launcher, technical feasibility of decontamination, and level of radioactivity. Since different technologies are used to treat different contaminated media, the approach for treatment of each contaminated medium within the context of the onsite treatment alternative is given below:

Soils will be treated using the TRU-Clean^{R} process, or a similar process. The TRU-Clean^{R} process has been proven by actual field implementation to effectively remove plutonium and americium from soils (see Section 5.1.4.5.3). This process has been tested on soils from the BOMARC site with favorable results.

This alternative will require the excavation of an estimated 6,200 cubic yards of soil from the areas shown on Figure 5-3. In order to excavate contaminated soils in the asphalt drainage ditch, the asphalt cover will be removed and disposed of as low-level radioactive waste. The estimated volume of asphalt to be removed from the drainage ditch is 124 cubic yards, using an expansion factor of 2.0.

Treatment processes will be conducted indoors so that wastes are protected from wind and water erosion and effectively contained. A process building approximately 20,000 square feet in area, consisting of slab-on-grade construction, steel superstructure, and corrugated sheet-metal roof and walls would be appropriate. A blower system will be installed to maintain negative air pressure inside the structure, and air would be exhausted through HEPA filters in order to control any potential fugitive dust emissions. Within this structure, a secure area for stockpiles will have concrete floors sloped to sumps to facilitate collection of leachate, and will be surrounded by concrete curbs designed to eliminate run-on/run-off. A similarly contained area will be constructed and designated for storage of concentrated waste residuals awaiting offsite shipment.

Additional facilities required include a concrete decontamination pad for heavy equipment used in excavation activities. The pad will be approximately 800 square feet in area, sloped to a collection sump, and surrounded by concrete curbing for containment. Decontamination water will be filtered and recycled in order to minimize generation of wastewater requiring disposal.

It is conservatively estimated that approximately 1,860 cubic yards of concentrated wastes (contaminated soils) will be generated by the TRU-Clean process. This equates to approximately 70% volume reduction. These wastes will require disposal as low-level radioactive waste.

Environmental monitoring will be conducted during soil excavation and treatment activities. Continuous air sampling will be conducted during intrusive activities such as excavation. A network of four to six high-volume air samples will be used to monitor for radioactive particulates. The air samplers are used to draw large volumes of air through filters, and the filters are analyzed for alpha activity in the field daily. If air filter analysis indicates resuspension of plutonium and/or americium, corrective measures such as spraying the soil with water can be implemented to minimize resuspension. Air sampling data collected during intrusive sampling activities of the RI do not indicate that resuspension of radionuclides will pose a serious problem.

Air sampling will require purchase of up to six high-volume air samplers, and will require the services of a radiological technician for maintenance/operation and field sample analysis for approximately 50 percent of the duration of the remedial effort.

Surface water sampling will also be conducted during storm/runoff events, in order to ensure that contaminated sediments are not leaving the site via the surface water pathway. A two-person sampling team will be required for approximately one day per month, equating to 24 person-days annually. Analysis of an estimated 48 water samples for plutonium by alpha spectroscopy will also be required.

Concrete apron. Concrete apron materials will be physically decontaminated using the suite of technologies described in section 5.1.3.4.5. This will be accomplished by sectioning the concrete into manageable-sized pieces of a few square feet each, and removing/segregating the layer of asphalt beneath the concrete. The asphalt, which contains most of the associated radioactivity on its upper surface, will be containerized for offsite disposal as a low-level radioactive waste. The asphalt cannot be decontaminated due to presumed insufficient structural integrity to withstand the physical decontamination techniques under consideration. An estimated 356 cubic yards of asphalt requiring disposal as a radioactive waste will be generated. An estimated 22,500 square feet of concrete, four to six inches thick and contaminated primarily on the lower surface will require decontamination.

Sectioning of concrete will be done outdoors under strict engineering controls designed to prevent resuspension of contaminated particulates. If water or other fluids are used to lubricate or cool sectioning equipment, the fluids will be collected and/or contained. If dust or particulates are generated, a vacuum blower will be used to direct the dust through a HEPA filter to capture the particulates. Air samplers will be placed to monitor sectioning activities.

After separation of asphalt from concrete, sectioned pieces of concrete will undergo decontamination. The concrete will be decontaminated using the technologies described in section 5.1.3.4.5. The same building used to house the TRU-Clean^{R} process will be used to house the decontamination process for structural materials. The building will consist of a concrete slab on-grade with steel superstructure and corrugated sheet metal walls and roof. The building will be approximately 20,000 square feet in area. The floor will have concrete curbing to prevent run-on/run-off, and will be sloped to a collection sump to facilitate the removal of any liquids. The building will be maintained under negative air pressure during working hours, with exhaust vented through HEPA filters.

The decontamination process will generate an estimated 25 cubic yards of low-level radioactive waste requiring disposal.

Following decontamination, sectioned concrete will be surveyed onsite for radioactivity. Concrete found to be contaminated above the release limits given in Table 5-2 will be either reprocessed or disposed of as low-level radioactive waste. Concrete found to be below the release limit will be left onsite.

Shelter 204. Shelter 204 will be processed in the same manner as the concrete apron, with a few exceptions. The steel structural components of the shelter will require a different sectioning

method, such as cutting with a torch. Wipe sample results from the RI indicate that most of the shelter, with the exception of the floor, is largely uncontaminated. Therefore, most of the shelter will be sectioned, scanned for radioactivity, and returned to the site with no decontamination required. Metal components of Shelter 204 requiring decontamination will be decontaminated using abrasive blasting because scarification and impaction methods are not effective on metal surfaces. Concrete components, especially the shelter floor, may require a different sectioning technique than the concrete apron, due to greater amounts of steel reinforcing bars in the concrete and thicker concrete. Soil in the launcher pit will be removed and addressed with other contaminated soils through use of the TRU-Clean process.

The original floor of shelter 204 is covered by approximately six inches of concrete, poured contemporaneously with the concrete apron. Both the upper and lower surfaces of this layer are contaminated. In addition, the upper surface of the original floor is also contaminated. Therefore, the total surface area of floor materials requiring decontamination (assuming that the two slabs of concrete can be separated) is three times the total floor area (1,380 square feet) or 4,140 square feet.

An estimated 25 percent of the total area of the interior concrete walls will require decontamination. This equates to 516 square feet. An estimated 25 percent of steel structural materials will require decontamination; this equates to 604 square feet.

An estimated 10 cubic yards of radioactive wastes will be generated by decontamination operations conducted on shelter 204 structural materials.

Utility bunkers. Utility bunkers will be excavated and removed from the ground after the concrete apron has been removed. Utility bunkers are constructed of concrete, and are box-shaped with dimensions of 6 ft × 4 ft × 6 ft. Total interior surface area of each bunker is 331 square feet, an estimated 50 percent of which will require decontamination. The concrete will be sectioned and decontaminated using technologies described in section 5.1.3.4.5. Concrete will be decontaminated using the same facilities and engineering controls described for the concrete apron. An estimated 2 cubic yards of low-level radioactive waste requiring disposal will be generated.

Missile launcher. Missile launcher must be located, excavated, and processed as described for Alternative 3, except that the launcher will be hauled to the onsite physical decontamination facility rather than placed on the concrete apron for capping. Once the launcher is prepared for processing, it will be decontaminated by abrasive blasting. It is estimated that 100 percent of the surface area of the launcher will require decontamination. Total surface area of the launcher is estimated at 396 square feet.

Disposal contingency for structural materials. It is possible that some of the structural materials proposed for physical decontamination (all contaminated media except soils) cannot be effectively decontaminated using available technologies. This is due to the possibility that radionuclides have migrated below the surface of the structural materials (especially concrete) thereby preventing effective decontamination by removal of surficial contamination. If this is the case, these materials will be disposed of in a permitted offsite low-level radioactive waste facility. Structural materials will first be separated into contaminated and "clean" fractions by onsite

radiological surveys followed by sectioning of contaminated portions of the materials. "Clean" fractions will be left onsite.

All areas excavated will be restored to original grade, covered with topsoil, and replanted with species indigenous to the New Jersey Pinelands.

Specific instruments are identified for use for this alternative. Note that these instruments are identified for costing purposes only; similar, comparable instruments may also be used.

5.1.5.6 Alternative 6 - Offsite Disposal

Under this alternative, all contaminated media would be removed from the site and transported offsite for disposal. Permitted offsite disposal facilities considered included the U.S. Ecology facility in Hanford, Washington, and the U.S. DOE Nevada Test Site.

Different environmental media will be handled and packaged differently, with the common goal of utilizing onsite radioanalysis to limit the total amount of wastes designated for disposal as radioactive waste by separating "clean" materials from contaminated materials to the maximum extent possible. For example, onsite analysis will be used to scan concrete from shelter 204 and the concrete apron prior to final sectioning. Contaminated portions will then be sectioned away from uncontaminated portions for separate disposal.

Specific instruments are identified for use for this alternative. Note that these instruments are identified for costing purposes only; similar, comparable instruments may also be used.

Handling procedures for each contaminated medium are described below:

Soil. Soil will be excavated using conventional excavation equipment. Continuous air monitoring will be performed in work areas, and engineering controls for dust suppression such as spraying the soil with water will be implemented. An estimated 6,200 cubic yards of soil will be excavated from areas shown on Figure 5-3. Soil will be containerized onsite, loaded onto trucks, and trucked to one of the two disposal sites mentioned above.

Concrete/asphalt apron. Concrete/asphalt apron will be sectioned, scanned with a FIDLER instrument, and containerized for transport offsite. Transportation will be by truck to one of the two disposal sites mentioned above. Total volume to be disposed is 938 cubic yards, assuming an expansion factor of 2.0.

All demolition activities will have engineering controls designed to minimize resuspension, and all activities will be monitored using high volume air samplers. Concrete found to be uncontaminated will be left onsite.

In addition, approximately 124 cubic yards of asphalt covering contaminated soils in the drainage ditch will require excavation and disposal.

Shelter 204. Shelter 204 will be sectioned, scanned with a FIDLER instrument, and containerized for offsite transport. Transportation will be by truck to one of the two disposal

Shelter 204. Shelter 204 will be sectioned, scanned with a FIDLER instrument, and containerized for offsite transport. Transportation will be by truck to one of the two disposal sites mentioned above. All demolition activities will be monitored using high volume air samplers. Engineering controls designed to minimize resuspension will be utilized. The total volume of waste materials to be disposed of is estimated at 402 cubic yards. Materials found to be uncontaminated will be left onsite.

Utility bunkers. Utility bunkers will be excavated sectioned, scanned with a FIDLER instrument and containerized onsite. Total volume requiring disposal as radioactive waste is 37 cubic yards. Materials found to be uncontaminated will be left onsite.

Missile launcher. Missile launcher will be excavated as described in section 5.1.6.3. The entire launcher, having an estimated volume of 5 cubic yards and an estimated weight of 2-3 tons will require sectioning and disposal. An estimated 100 cubic yards of contaminated soils will also be associated with the launcher and will require disposal.

All areas excavated will be restored to original grade, covered with topsoil, and replanted with species indigenous to the New Jersey Pinelands.

5.2 Initial Screening of Alternatives

The development of remedial actions consists of a series of evaluations involving successively more specific definition and analysis of potential alternatives. In this section, remedial alternatives for the BOMARC Missile Site developed in Section 5.1 undergo initial screening to eliminate those that are clearly infeasible or inappropriate. To accomplish this, a set of health/environmental-based, technical, and economic criteria are employed to gauge alternative feasibility and distinguish among alternatives. To facilitate the initial screening process, potential alternatives are described to the extent necessary to complete the Phase II-level evaluation. The information presented in this section is organized in the following manner:

Section 5.2.1 Summary of Phase I Results
Section 5.2.2 Identification of Screening Criteria
Section 5.2.3 Initial Screening
Section 5.2.4 Summary of Initial Screening Results

Alternatives which emerge from this evaluation are analyzed in detail in Section 5.3.

5.2.1 Summary of Phase I Results

To this point, information has been presented which establishes the basis for development of remedial alternatives through definition of remedial objectives, requirements, and goals for response actions at the BOMARC Missile Site. Zones of contamination throughout the site along with health-based and regulatory-based clean-up criteria have been developed (see Section 5.1). Technologies which supported general response actions have been identified, examined, and screened to provide the "building blocks" from which remedial alternatives were developed. The five remedial action alternatives developed in Phase I of the FS are:

- An **Unrestricted Access** alternative which provides a basis against which other alternatives may be compared/contrasted;

- An **Existing Conditions** alternative which consists of all monitoring, maintenance, and access controls currently implemented at the site.

- A **Limited Action** alternative which consists of all monitoring, maintenance, and access control actions currently implemented at the site, plus removal and offsite disposal of a limited amount of the most highly contaminated materials onsite;

- An **Onsite Containment** option designed to reduce or eliminate migration of site contaminants through wind dispersion, erosion and runoff, and through leachate generation and subsequent migration in ground water;

- An **Onsite Treatment** approach that employs a volume reduction strategy followed by secure offsite disposal of the plutonium/americium fraction;

- An **Offsite Disposal** option which involves source removal and placement in an approved long-term containment system.

These alternatives represent a broad range of waste management options for the BOMARC Missile Site and incorporate no action, limited action, containment, treatment, and disposal strategies for existing radioactive sources at the facility.

5.2.2 Identification of Screening Criteria

In this section, the criteria employed in the evaluation of alternatives assembled in Section 5.1 are identified. During the Phase I screening process, technologies were evaluated on a process-basis to ensure that particular remedial objectives could be met. In this Phase II screening exercise, assembled alternatives are evaluated to ensure that they are protective of human health and the environment, technically feasible, and cost effective. The three evaluation criteria used to assess alternative strengths and weaknesses include: public health/environmental impacts, technical feasibility, and cost. Elements to be addressed within each broad category include:

- **Public health/environmental impacts:** This analysis will provide an assessment as to the effectiveness of the alternative in providing protection of public health and the environment and reduction of toxicity, mobility, or volume. Both short- and long-term components of effectiveness are considered (construction and implementation period versus the period after remediation).

- **Technical feasibility:** This evaluation identifies which remedial objectives each option satisfies and discusses implementability considerations. These considerations include construction and operation issues, maintainability/reliability, along with the ability to obtain approvals from regulatory agencies, and any capacity issues. Alternatives that may prove extremely difficult to implement, will not achieve remedial objectives within a

reasonable time frame, or that rely on unproven technologies will be modified or eliminated form further consideration.

- **Costs:** Qualitative cost estimates which provide capital as well as operation and maintenance costs are developed for alternatives remaining after the public health/environmental and technical feasibility screening. Alternatives that have costs greatly exceeding those of equally effective alternatives will be eliminated unless significant benefits will be realized.

Prior to the Phase II screening process, alternatives will be sufficiently defined to allow for the differences in screening criteria to be readily discernable.

5.2.3 Initial Screening

This section of the FS evaluates and defines key components of the five remedial action alternatives developed for the remediation of contaminated soils and sediments, concrete and asphalt, above- and below-ground structures, and the launcher system for the BOMARC Missile Site. The format used to accomplish the screening involves:

- A discussion of each alternative which focuses on Phase II-based evaluation concerns. This text should be considered a refinement of alternative discussions presented in Section 5.1.
- Assessment of individual alternatives per each evaluation criteria.
- A discussion of screening results for each alternative along with a rationale supporting the Phase II screening decision.

The following subsections present the Phase II screening discussions for individual remedial action alternatives.

5.2.3.1 Alternative 1 - Unrestricted Access

The NCP requires that a No Action alternative be incorporated into the evaluation and selection of a remedial action for an uncontrolled hazardous waste site. The unrestricted access alternative represents the "strict" no action alternative for management of soils, sediments, construction materials, and launcher at the BOMARC site. Under a "strict" no action approach, institutional and active isolation, containment, or remediation measures would not be employed, and control measures currently implemented would be curtailed. In this manner, the alternative provides a baseline against which all other approaches can be compared/contrasted to evaluate effectiveness at risk reduction. Should current and future risks posed by the site fall below health- and regulatory-based benchmarks, this alternative may be an acceptable remedial selection.

As discussed in Section 5.1.5.1, under the unrestricted access alternative, environmental conditions at the site would remain unchanged, with the existing transport mechanisms

continuing to effect site contamination as defined by the RI and summarized in Section 5.1 of the FS.

Public health/environmental impacts. The effectiveness of the unrestricted access alternative in relation to protection of human health and the environment requires examination of alternative impacts to site sources, migration potential, and receptors. Calculations conducted as part of this study have established an onsite health-based activity level of 8 pCi/g plutonium for soils. As delineated in Fig. 5-2 and discussed in Section 5.1.1.2, several areas contain activity levels above the health-based concentration. This alternative does not operate on source areas and as such is not considered protective. Primary migration routes of concern, through air dispersion and to a lesser degree erosion with subsequent migration in run-off, will remain active. Under the unrestricted access alternative, the potential for present and future migration remains unchanged. An adjacent wetland should act as a sediment trap for run-off collection. Plant uptake of plutonium is virtually zero, with burrowing animals considered to be those primarily affected by onsite contaminants. The risk assessment indicated that significant risk existed for a hypothetical onsite MEI; however, acceptable risk levels currently exist for offsite populations within a 50 mile area surrounding the site.

This alternative does not impact site contaminants with respect to mobility, toxicity, and volume. Plutonium and americium are relatively insoluble and immobile under most environmental conditions. These contaminants have long half-lives resulting in little to no reduction in toxicity in both the short- and long-term. No reduction in volume would occur under the unrestricted access alternative.

Technical feasibility. This alternative does not achieve any of the qualitative or quantitative remedial objectives developed in Section 5.1.1.4. Additionally, there are no construction, operation, permitting, or capacity considerations associated with the option.

Cost. The unrestricted access alternative is a no cost option.

Screening results. This option is retained to serve as a baseline against which all other actions can be compared to as required by the NCP.

5.2.3.2 Alternative 2 - Existing Conditions

The existing conditions alternative developed in Phase I of the FS incorporates all maintenance, monitoring, and access control actions currently implemented at the site. Key components include the following:

- Installation of a physical barrier (fence) which encompasses all areas exhibiting activity levels above 8 pCi/g or 2.0 $\mu Ci/m^2$.
- Maintenance of the site including perimeter fencing, existing containment structures and surface cover.
- Maintaining government control of the site to prevent current/future use of the site.

- Scheduled environmental surveillance consisting of quarterly visual inspections and annual radiological surveys to monitor site conditions and/or detect migration.

Site access control serves two purposes: minimizing disturbance of surface soils through onsite activity, and eliminating the exposure scenario posing the most significant risk (direct exposure to source material with inhalation, ingestion, and external radiation exposure). Maintenance and monitoring of the site would allow for migration detection, and implementation of corrective action, if warranted.

Public health/environmental impacts. The primary components yielding risk reduction provided by this alternative are the isolation of the facility through the use of physical and institutional controls. Of the three major components of risk, contaminant sources, migration of contaminants, and exposure to receptors, this alternative provides protection through eliminating onsite exposure scenarios. The risk assessment completed for conditions at the BOMARC Missile Site indicates that significant risks are posed primarily through onsite exposure scenarios, which are controlled through this alternative. The degree of control in the short-term can be considered effective; however, due to the long-term concerns posed by site contaminants, long-term effectiveness using physical and institutional controls would be difficult to guarantee, i.e. long-term institutional control of the site may be uncertain.

Additionally, source areas are monitored to detect migration through wind dispersion and/or erosion and runoff. Residual risk to persons entering the site without health and safety controls would remain with soil and structural contamination remaining in-place.

This alternative has no effect on the reduction of toxicity, mobility, and volume of contaminants. Physical and institutional controls will ensure that conditions at the site remain unchanged in the short-term, with contaminant mobility expected to be very low, based on contaminant physical characteristics and the current distribution of site contaminants. However, offsite migration of contaminated sediments can still occur over the long-term. Contaminants migrating offsite in suspended sediments in the long term would most likely accumulate in the headwaters of the Elisha Branch, located just southeast of the site. The headwaters of Elisha Branch are very low-gradient wetlands with thick stands of emergent aquatic vegetation and accumulations of organic detritus and fine-grained sediments. These wetlands would most likely trap and hold contaminated sediments originating at the site.

Technical feasibility. The existing conditions alternative satisfies several of the qualitative objectives for remediation of the BOMARC Missile Site. Protection of human health is provided through isolation of the source, thereby eliminating onsite exposure scenarios. The approach is readily implementable, as it is primarily a maintenance and construction activity followed by long-term environmental surveillance. Quantitative remedial objectives for active site remediation are not met by the existing conditions alternative, but risks are effectively reduced by controlling access to the site.

Implementability issues associated with the existing conditions alternative are favorable. Maintenance of the physical barriers as well as maintaining government control of the site are easily completed. Site security along with environmental surveillance will provide a reliable

means of isolating and monitoring source contaminants.There are no permitting or capacity issues associated with this alternative.

Cost. Capital costs associated with this alternative are estimated at $156,800. These costs are primarily associated with fence construction, and monitoring equipment purchase. Operation and maintenance costs tied to environmental surveillance and documentation are anticipated to be $71,000 annually. A thirty year present worth analysis yields a total project cost of approximately $830,000. It should be noted that due to the long-term persistence of site contaminants, additional funding will be required for O&M costs for a significant timeframe.

Screening results. This alternative will be advanced for detailed analysis based on the following points:

- The alternative provides adequate protectiveness for current onsite exposure scenarios along with provisions for monitoring potential future migration, thereby ensuring that additional future remedial actions may be undertaken, if necessary.

- High rating in terms of implementability and cost-effectiveness.

5.2.3.3 Alternative 3 - Limited Action

The Limited Action Alternative developed in Phase I of the FS incorporates all maintenance, monitoring, and access control actions currently implemented at the site plus the removal and offsite disposal of a limited amount of radioactive wastes. Key components include the following:

- Installation of a physical barrier (fence) which encompasses all areas exhibiting activity levels above 8 pCi/g or 2.0 μCi/m^2.

- Maintenance of the site including perimeter fencing, existing containment structures and surface cover.

- Maintaining government control of the site to prevent current/future use of the site.

- Scheduled environmental surveillance consisting of visual inspections and annual radiological surveys to monitor site conditions and/or detect migration.

- Recovery and proper disposal of the missile launcher, if possible.

Site access control serves two purposes: minimizing disturbance of surface soils through onsite activity, and eliminating the exposure scenario posing the most significant risk (direct exposure to source material with inhalation, ingestion, and external radiation exposure). Maintenance and monitoring of the site would allow for migration detection, and implementation of corrective action, if warranted. Removal and offsite disposal of the missile launcher would eliminate risks associated with the inadvertent discovery of the launcher at some time in the future. The levels of radioactivity associated with the launcher are currently unknown.

Public health/environmental impacts. The primary components yielding risk reduction provided by this alternative are the isolation of the facility through the use of physical and institutional controls, and the removal of the missile launcher, which represents an unknown risk. Of the three major components of risk, contaminant sources, migration of contaminants, and exposure to receptors, this alternative provides protection through eliminating onsite exposure scenarios, and reducing the inventory of source materials. The risk assessment completed for conditions at the BOMARC Missile Site indicates that significant risks are posed primarily through onsite exposure scenarios, which are controlled through this alternative. The degree of control in the short-term can be considered effective; however, due to the long-term concerns posed by site contaminants, long-term effectiveness using physical and institutional controls would be difficult to guarantee, i.e. long-term institutional control of the site may be uncertain.

Additionally, source areas are monitored to detect migration through wind dispersion and/or erosion and runoff. Residual risk to persons entering the site without health and safety controls would remain with soil and structural contamination remaining in-place, but would be reduced by an unknown amount through removal of the missile launcher.

This alternative has no effect on the reduction of toxicity, mobility, and volume of contaminants. Physical and institutional controls will ensure that conditions at the site remain unchanged in the short-term, with contaminant mobility expected to be very low, based on contaminant physical characteristics and the current distribution of site contaminants. However, offsite migration of contaminated sediments can still occur over the long-term. Contaminants migrating offsite in suspended sediments in the long term would most likely accumulate in the headwaters of the Elisha Branch, located just southeast of the site. The headwaters of Elisha Branch are very low-gradient wetlands with thick stands of emergent aquatic vegetation and accumulations of organic detritus and fine-grained sediments. These wetlands would most likely trap and hold contaminated sediments originating at the site.

Technical feasibility. The Limited Action alternative satisfies several of the qualitative objectives for remediation of the BOMARC Missile Site. Protection of human health is provided through partial removal of the source and isolation of the remaining source, thereby eliminating onsite exposure scenarios. The approach is readily implementable, as it is primarily a maintenance and construction activity followed by long-term environmental surveillance. Quantitative remedial objectives for active site remediation are not met by the Limited Action alternative, but risks are effectively reduced by controlling access to the site.

Implementability issues associated with the limited action alternative are favorable. Maintenance of the physical barriers as well as securing the appropriate deed restrictions are easily completed. Site security along with environmental surveillance will provide a reliable means of isolating and monitoring source contaminants. Management of the launcher system per alternative requirements is dependent on locating the unit. Permitting and capacity issues associated with this alternative include institutional issues associated with excavation, transport and disposal of the missile launcher, which has a relatively small volume and an unknown amount of radioactivity associated with it.

Cost. Capital costs associated with this alternative range between $285,000 and $510,000, depending on the disposal site used for the missile launcher and associated materials. These

costs are primarily associated with fence construction, launcher removal, and monitoring equipment purchase. Operation and maintenance costs tied to environmental surveillance and documentation are anticipated to be $71,000 annually. A thirty year present worth analysis yields a total project cost ranging between $957,000 and $1,183,000. It should be noted that due to the long-term persistence of site contaminants, additional funding will be required for O&M costs for a significant timeframe.

Screening results. This alternative will be advanced for detailed analysis based on the following points:

- The alternative provides adequate protectiveness for current onsite exposure scenarios along with provisions for monitoring potential future migration, thereby ensuring that additional future remedial actions may be undertaken, if necessary.

- High rating in terms of implementability and cost-effectiveness.

5.2.3.4 Alternative 4 - Capping

This alternative provides an onsite containment option for management of conditions at the BOMARC Missile Site. The capping alternative developed for the facility incorporates all components of the Limited Action approach along with engineered controls targeted at reducing contaminant mobility and accessibility. Key alternative components include:

- Consolidation of materials contaminated above the established clean-up criteria (soil/sediments, above-ground structures, and launcher system) on the concrete apron.

- Construction of a multi-layer cap designed to prevent future migration of source materials through air, soil, and water pathways, and to limit waste accessibility.

- Restoration of the site including regrading and revegetation using native plant species.

This option utilizes a containment strategy to reduce the potential for offsite migration of site contaminants and the potential for onsite exposure.

Public health/environmental impacts. An assessment of public health and environmental impacts for the capping alternative mirrors that of the Limited Action alternative and also uses engineered controls to provide an additional level of protectiveness. This option employs an onsite containment method which acts on all three elements tied to risks: contaminant sources, migration, and exposure to receptors. The site contaminant distribution profile is such that there is widespread areal coverage to a depth of approximately one foot. This condition produces a high surface area from which mass transport may occur. This alternative consolidates high activity sources in a discrete area, reducing surface area. Migration potential is reduced further by containing sources using a multi-layer capping system. Onsite exposure scenarios are controlled through the use of access barriers as in the Limited Action alternative, with the addition of physical barriers to further isolate wastes.

The capping alternative produces a reduction in mobility of contaminants using a containment approach. Site structures and soils/sediments above the health-based clean-up level, are contained below a multi-layered cap which retards infiltration and is designed to minimize or eliminate erosion and subsequent dispersion through air and water pathways. No reduction in toxicity or volume is associated with this option. The magnitude of residual risk remains high as this alternative does not remove any source material from the site. The adequacy and reliability of controls are considered good in the short-term and poor in the long-term based on the length of time source material will remain hazardous above health-based levels. The consolidation of source materials presents significant short-term risks to workers during the remedial action implementation phase. Mitigation of these risks will be managed through the use of engineered controls. The remedial action timeframe is expected to be 1 to 2 years.

Technical feasibility. The Capping remedial action alternative satisfies several of the remedial action objectives; however, key factors severely impact option feasibility. The capping alternative employs onsite mitigation techniques and offers increased short-term protectiveness in terms of human health by reducing migration potential (mobility) over the Limited Action alternative. Containment of low-level radioactive waste will require extensive permitting/licensing; however, this option does not meet the technical requirements dictated by State/Federal regulations. Quantitative remediation objectives are not met by this alternative.

Implementability considerations for the capping alternative are issue specific with the construction phase of the project, particularly the consolidation effort requiring measures which control dispersion of site contaminants due to excavation, transportation, handling, compacting and other activities associated with cap construction. The reliability of the capping technology is considered sufficient for short-term onsite management; however, long-term cap integrity is of significant concern. Environmental surveillance associated with the alternative will adequately provide for detection of migration and additional remedial actions can be taken, should they be necessary. Regulatory approval for the containment system is judged to be unattainable due to engineering issues tied to regulatory requirements, system design requirements, and long-term management.

Cost. Capital costs associated with this alternative are approximately $650,000 and are primarily associated with excavation, consolidation, and construction of the capping system. Operation and maintenance costs linked with cap maintenance and environmental surveillance and documentation are anticipated to be $50,000 annually. A thirty year present worth analysis yields a total project cost of approximately $1.2 M.

Screening results. Although the alternative provides adequate protectiveness for current onsite exposure scenarios and reduces the migration potential over the Limited Action alternative, permitting/licensing issues adversely affect the implementability of this option. This alternative will be dropped from further consideration based on the licensing issue.

5.2.3.5 Alternative 5 - Onsite Treatment

The Onsite Treatment option represents the initial alternative which provides for site restoration through removal of materials above health-based and regulatory-based levels from the site. This approach employs volume reduction, using physical separation techniques, to segregate

radioactive materials followed by offsite disposal of the contaminated fraction. Subsequent to treatment, the site will be restored to allow future use. Key alternative components are:

- Excavation of source soils followed by consolidation prior to treatment, sectioning of contaminated concrete, and excavation of Utility Bunkers and Missile Launcher.

- Treatment of site soils using the TRU-Clean[R] or similar process, and physical removal (abrasive treatment) of contamination from structural materials.

- Transport to and disposal of radioactive materials in an offsite licensed facility, including untreated materials such as contaminated asphalt, which cannot be decontaminated.

- Restoration of the site by backfilling "clean" fraction from TRU-Clean[R] or similar process and other clean fill as needed, followed by grading and revegetation of the site using native plants.

Implementation of this alternative requires the construction of an onsite structure in which staging and processing of soils will be completed.

Public health/environmental impacts. This alternative is an active restoration approach which removes site contaminants thereby directly eliminating risks to human health and the environment. Radioactive material will be disposed of at an offsite facility designed for long-term management of the materials. Long-term effectiveness considerations rank high, as there would be very low to no residual risk subsequent to implementation of the Onsite Treatment alternative based on the proven effectiveness of the TRU-Clean[R] process along with disposal of contaminated structural materials. Reduction of mobility, toxicity, and volume would be achieved through direct physical removal of site contaminants. Short-term effectiveness considerations center on protection of the community and workers during remedial action implementation. This will be achieved by using engineered controls, such as indoor treatment, air monitoring and filtration, etc. Long term benefits derived form site restoration greatly outweigh short-term impacts tied to treatment. Environmental impacts are considered minimal as relative soil volumes requiring excavation are manageable and site restoration is a component of the alternative. The remedial action timeframe is estimated to be 1 to 2 years.

Technical feasibility. The Onsite Treatment remedial action alternative satisfies all qualitative and quantitative remedial action objectives established in Phase I of this feasibility study. The TRU-Clean[R] process represents a field tested treatment scheme designed to efficiently and effectively segregate radiologically contaminated soils from clean soils. Additionally, treatability studies have been completed by the vendor on BOMARC soil samples. Significant volume reductions are anticipated to be in the range of 50% to 95%. Construction and operation issues of the treatment technology components are considered good as the approach has been field tested. Monitoring of alternative effectiveness will be conducted at the excavation and treatment stages. Availability of offsite disposal facilities is considered adequate. A major drawback inherent in this alternative is the limited number of qualified vendors, which may impact project start-up should equipment be dedicated to another remediation project.

Costs. Capital costs associated with this alternative range between $8.46M and $13.53M, depending on the disposal site used, and these costs are primarily associated with excavation, consolidation, construction, treatment and disposal of wastes. There are no O&M costs associated with this option.

Screening results. This alternative provides for clean-up of the BOMARC Missile Site to levels defined by health-based and regulatory-based criteria. As such, the alternative is considered as protective and allows for future use of the facility. This alternative will be carried on for detailed analysis.

5.2.3.6 Alternative 6 - Offsite Disposal

This alternative involves the removal and offsite disposal of source materials above clean-up criteria levels. Option components are similar to Alternative 4 - Onsite Treatment in terms of contaminated media collection, handling, with the exception that all materials are containerized and transported to an offsite licensed disposal facility. Key alternative components include:

- Excavation and containerization of contaminated soils/sediments. Location and excavation of the Missile Launcher.
- Sectioning of contaminated portions of the concrete apron, Shelter 204, Utility Bunker, and Launcher followed by onsite containerization.
- Transportation of contaminated materials to a licensed disposal facility
- Restoration of the site by backfilling, grading and revegetation using native plants.

Public health/environmental impacts. This alternative is an active restoration approach which removes site contaminants thereby directly eliminating risks to human health and the environment. Radioactive material will be disposed of at an offsite facility designed for long-term management of the materials. Long-term effectiveness considerations rank high, as there would be very low to no residual risk subsequent to implementation of the Offsite Disposal option assuming clean-up to health-based and regulatory-based levels. Short-term effectiveness considerations center on protection of the community and workers during remedial action implementation. Management of these risks will be achieved by using engineered controls. Long-term benefits derived from site restoration greatly outweigh short-term impacts tied to disturbance of the site. Environmental impacts are considered minimal as soil volumes requiring excavation are manageable and site restoration is a component of the alternative. The remedial action timeframe is estimated to be 1 year.

Technical feasibility. This remedial action alternative satisfies most qualitative (only onsite mitigation and reduction of mobility, toxicity, or volume are not included in this option) and all quantitative remedial action objectives established in Phase I of this feasibility study. This alternative is primarily a construction activity with excavation and waste consolidation the primary onsite activities. Monitoring of alternative effectiveness will be conducted throughout

the excavation stage to ensure clean-up criteria are achieved. Availability of offsite disposal facilities is considered to be high.

Cost. Capital costs associated with this alternative range from $6.8M to $23.1M depending on the disposal site used. There are no O&M costs associated with this option.

Screening results. This alternative provides for clean-up of the BOMARC Missile Site to levels defined by health-based and regulatory-based criteria. As such, the alternative is considered as protective and allows for future use of the facility. This alternative will be carried on for detailed analysis.

5.2.4 Summary of Initial Screening Results

The objective of Phase II screening of remedial action alternatives is the selection of options which are protective of human health and the environment for the medium/media of interest. Alternatives developed in Phase I spanned a broad spectrum of management approaches, from limited action to isolation, treatment, and removal techniques. Each alternative was fashioned to achieve risk reduction using dissimilar methods to provide decision-makers with a wide range of options. Initial screening indicates that all but one option (Capping) warrants in-depth evaluation through the Detailed Analysis mechanism of the Feasibility Study. Table 5-6 provides a comprehensive summary of the initial screening results.

5.3 Detailed Analysis of Remedial Alternatives

In this section, remedial alternatives warranting serious consideration as indicated by Phase II screening criteria are subjected to an in-depth evaluation. The evaluation begins by individual examination of alternatives followed by a comparative analysis of alternatives. Five evaluation elements, incorporating technical, environmental, institutional, health, and economic aspects are employed to gauge alternative effectiveness and implementability. The results of these assessments are then arrayed to allow comparisons between alternatives. Remedial alternatives to be evaluated in detail include:

- An **Unrestricted Access** alternative as required by the NCP which serves as a basis against which other options are compared or contrasted.

- An **Existing Conditions** alternative which incorporates all monitoring, maintenance, and access controls currently implemented at the site.

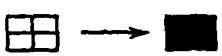
- A **Limited Action** alternative which incorporates all monitoring, maintenance, and access control actions currently implemented at the site, plus removal and offsite disposal of a limited amount of the most highly contaminated materials onsite.

- An **Onsite Treatment** alternative which provides for site remediation using a volume reduction technique followed by offsite management of the contaminated fraction within a system designed for long-term radioactive waste management.

Table 5-6

Summary of Initial Screening Results

Remedial Action Alternative	Remedial Objectives		Public Health/ Environmental Impacts	Technical Feasibility	Costs ($M)	Phase II Screening Results	
	Qualitative	Quantitative				Retained	Eliminated
Unrestricted Access					0	*	
Existing Conditions					0.83	*	
Limited Action					0.96 to 1.18	*	
Onsite Containment					1.2		*
Onsite Treatment					8.5 to 13.5	*	
Offsite Disposal					6.8 to 23.1	*	



- An **Offsite Disposal** alternative that involves complete removal of contaminated media to established cleanup levels followed by offsite transport and placement in a secure system designed for long-term radioactive waste management.

These alternatives represent a wide range of feasible management options using varying risk reduction strategies including access control, treatment, and offsite management options. Incorporated into these approaches are methods that effect risk reduction by acting on contaminant sources and/or onsite and offsite exposure potential. An unrestricted access alternative, functionally equivalent to the "no action alternative" required by the NCP, is also scrutinized as part of the suite of options examined through the Detailed Analysis. The remainder of this section is organized as follows:

Section 5.3.1 Elements of the Detailed Analysis
Section 5.3.2 Detailed Analysis of the Unrestricted Access Alternative
Section 5.3.3 Detailed Analysis of the Existing Conditions Alternative
Section 5.3.4 Detailed Analysis of the Limited Action Alternative
Section 5.3.5 Detailed Analysis of the Onsite Treatment Alternative
Section 5.3.6 Detailed Analysis of the Offsite Disposal Alternative
Section 5.3.7 Comparative Analysis

Each of these sections incorporate the requirements for detailed analysis as outlined in the USAF OEHL IRP Handbook, Version 2.0.

5.3.1 Elements of the Detailed Analysis

In this section, the components employed in the detailed evaluation of the waste management alternatives are introduced. These elements represent an expansion of the criteria used in the Phase II screening and incorporate definitive requirements which alternatives must satisfy as well as additional considerations which differentiate alternatives. The five factors influencing alternative selection incorporate technical, environmental, public health, institutional, and economic issues. Elements to be addressed within each broad category include:

Technical analysis. This component of the detailed analysis considers alternative performance, reliability, implementability and safety.

- Performance evaluations address the reduction in toxicity, mobility, or volume offered by an alternative, compliance with action-specific cleanup criteria, along with a discussion of demonstrated performance.

- Reliability analyses incorporate a discussion assessing the adequacy and reliability of controls along with an identification of alternative monitoring requirements.

- Implementability evaluations incorporate construction and operation issues, the ability to undertake additional actions, regulatory approvals/coordination, along with the availability of option services and any TSDF capacity matters.

- Safety concerns tied to worker and community protection during the remedial action are assessed under this element.

Environmental analysis. The environmental analysis presents a discussion detailing the contaminant sources and migration pathways addressed by each alternative. Inherent in this discussion are both the beneficial and adverse impacts anticipated under each alternative.

Public health analysis. This element considers the potential effects of long-term exposure to residual contamination through characterization of onsite residual contamination, identification of potential exposure routes and identification of potentially affected populations. Alternatives are compared against the functional baseline Unrestricted Access option.

Institutional analysis. Federal, state and local requirements pertaining to the design, operation, and implementation of each alternative are assessed under this element.

Cost analysis. An economic evaluation which includes capital as well as operation and maintenance costs is provided. Present worth and sensitivity analyses are included to allow for cost comparisons between alternatives along with potential economic impacts to individual alternatives due to changes in key assumptions or parameters (e.g., volume of contamination, discount rate, etc.).

5.3.2 Detailed Analysis of the Unrestricted Access Alternative

The Unrestricted Access alternative provides the functional equivalent of the No Action alternative which is required by the NCP to provide a baseline alternative for management of conditions at the BOMARC site. As stated previously, this alternative represents a "strict" no action alternative for soils, sediments, construction materials, and the missing missile launcher under which containment, treatment, or disposal strategies are not employed. This approach leaves the site in an "as is" condition with contaminant sources left in-place, migration mechanisms continuing to act and removal of maintenance requirements for engineered control currently in place. The following subsections consider Phase III evaluation elements for this management approach.

Technical analysis. Only three elements of the technical component (i.e., performance, reliability, and implementability) are relevant under an Unrestricted Access strategy. Toxicity, mobility and volume of contaminants will remain constant in the short-term, however mobility would increase over the long-term as existing containme structures and perimeter fencing deteriorate. Under this scenario, contamination located within the unstabilized areas will continue to slowly migrate through erosion mechanisms. The rates of migration have been estimated at approximately 33 feet per year, with the current extent of contamination about 1,000 feet past the ponding area (see RI for more detail). The characteristics of site contaminants (primarily Pu-239 with small quantities of Pu-238, Pu-240, Pu-241, and Am-241) ensure significant long-term radiological toxicity. Long-term contaminant mobility is of concern for all contaminated media, whether stabilized (asphalt or concrete covered) or unstabilized.

The reliability of this alternative centers on the effectiveness of existing control systems, both engineered and natural. These controls include the asphalt/concrete cover through which

stormwater runoff flows, and fences around the perimeter of the site. During the 1960s, an asphalt and/or concrete cover was placed over ground areas of known contamination, in effect, sandwiching the plutonium/americium contamination. Additional areas which pose risk and exhibit removable and/or fixed contamination include: Shelter 204, utility bunkers, and the missile launcher. Ongoing degradation of the engineered access controls along with structures containing contamination will, over time, expose additional material and allow access to the site.

Implementability considerations pertinent to the Unrestricted Access alternative are minor and focus on the ability to undertake additional actions. Under this approach, additional actions are feasible, with only the potential increase in contaminant distribution affecting future remediation efforts.

Environmental analysis. Under the Unrestricted Access alternative, the contaminant sources (soils and sediments, concrete/asphalt aprons, Shelter 204, utility bunkers, and the missile launcher) remain in an "as is" condition. Mechanisms impacting contaminant migration (physical degradation of structures, erosion through wind and water) continue to effect transport. Estimates of current contaminant migration rates via stormwater runoff are approximately 33 feet per year. At these rates, contamination would reach swampy areas in Elisha Branch in approximately 100 years. Migration to the closest settlement is expected to take approximately 1,600 years through this pathway.

A major concern, should soil/sediment removal be implemented, is the potential for dispersion via the air pathway during excavation and/or treatment. Migration via the air pathway has been examined by evaluating radionuclide exposure from potential atmospheric releases during remediation. This alternative does not have any adverse impact potential for air dispersion of the plutonium and/or americium caused by excavation and/or treatment. As shown by the baseline risk assessment, current and short-term offsite risks are negligible, however, onsite risk is above that considered acceptable. Since no efforts are included in this alternative to secure the site, adverse effects due to onsite exposure could occur. Future remediation of the site, if implemented, would likely involve a greater volume of contaminated soils due to potential continued migration and dispersion.

Public health analysis. As discussed in Phase II of the FS, the effectiveness of the Unrestricted Access alternative in relation to protection to public health requires examination of alternative impacts in the following three areas:

- Site contaminant sources
- Migration potential
- Potential receptors.

The Unrestricted Access approach does not operate on the first element of risk at the site, contaminant sources. Currently, of the five contaminated materials at the facility (soils/sediments, concrete/asphalt apron, Shelter 204, utility bunkers, and the missile launcher), the unstabilized soils and sediments represent the greatest short-term risk due to the potential for onsite exposure. Calculations conducted in the risk assessment indicate that an activity level of 8 pCi/g for soils represents an acceptable protective health-based exposure level. The remedial

investigation indicates that several areas at the facility contain activity levels above the health-based concentration.

There are both short-term and long-term considerations when examining the potential for migration due to the current site conditions and extreme persistence of site contaminants. In the short-term, unstabilized soils and sediments are exhibiting estimated migration rates of 33 feet per year via stormwater erosion and transport. Additional migration via wind erosion may be occurring. These transport routes present a potential for exposure via ingestion and inhalation, which represent the highest risk associated with alpha radiation. Long-term migration due to degradation of the engineered containment surface and structures is also an important issue due to the nature of the contamination. Over the long-term, additional contaminated media will be exposed to migration mechanisms.

Under the Unrestricted Access alternative, there exists the potential for both onsite and offsite exposure to receptors. Section 4 of this text provides current population distributions surrounding the facility along with future projections to 1995. Potentially exposed populations include residents within a five-mile radius of the facility along with workers at the Federal Facilities abutting the facility. The risk assessment considered two risk scenarios, a MEI and residents within a 50 mile radius of the facility. The assessment indicated that significant risk existed for the hypothetical MEI; however, acceptable risk levels currently exist for offsite populations surrounding the site.

Institutional analysis. Under the Unrestricted Access alternative, no actions are implemented and hence, only location and chemical-specific ARARs need to be considered. Currently there are no chemical-specific criteria for soils and surface water in terms of plutonium activity levels; however, future EPA regulations may contain activity-based criteria. For structures, NRC Regulatory Guide 1.86 provides criteria to be considered. For transuranics, limits for surface contamination are 20 disintegrations per 100 square centimeters (dpm/100 cm^2) for removable activity, 300 dpm/100 cm^2 for maximum activity, and 100 dpm/100 cm^2 for average radioactivity. Alpha surveys conducted in Shelter 204 showed that the highest activity levels were 2,011, 47,780, and 2,106 dpm/100 cm^2. The Unrestricted Access alternative does not achieve health-based or regulatory-based cleanup goals established for the site, and does not mitigate risks posed by the site using any other means.

Cost analysis. There are no costs associated with the Unrestricted Access alternative for management of conditions at the BOMARC Missile Site.

5.3.3 Detailed Analysis of the Existing Conditions Alternative

The Existing Conditions alternative provides a strategy for management of conditions and facilities at the BOMARC site as they currently are being managed. Maintenance, monitoring and access controls currently implemented at the site are retained in this alternative, with no deployment of new or additional containment, treatment or disposal methods. Elements of this approach include:

- Maintenance of government control of the site, restricting access to and future use of the land in order to minimize disturbance of the site

- Installation of additional perimeter fence to encompass areas exhibiting activity levels exceeding 8 pCi/g or 2 μCi/m^2 and maintenance of existing and new fence to prevent its deterioration

- Scheduled long-term environmental surveillance of the site, consisting of quarterly visual inspections to monitor site conditions and annual radiological surveys to track contaminant distribution and potential migration

- Maintenance of engineered containment controls at the facility, as required.

The Existing Conditions alternative will be implemented by establishing government policy for retaining control of the site (deed restrictions would be required in the event government control is not maintained); installation of additional fence circumscribing the facility, with maintenance and repair as required; quarterly visual inspections of perimeter fence and engineered containment systems, and repair and maintenance of the containment systems.

Technical analysis. This alternative is similar to the Unrestricted Access alternative in that all contamination remains in-place. Conditions representing significant risk are minimized through an expansion of activities that are currently being conducted. In terms of performance, the Existing Conditions approach does not reduce the mobility, toxicity, or volume of known contamination at the site. This alternative provides a clear improvement over the Unrestricted Access alternative by diminishing the potential risk for adverse human health or ecological impacts through contact with contaminants from the site. However, to achieve this goal, the management requirements are significantly greater.

The short-term effectiveness, measured by the protectiveness of the alternative offered to community and workers in the time period required to implement remedial action, is considered excellent, with environmental impacts in the near future considered to be negligible. However, remedial action objectives of clean-up of the site through the removal of contamination would not be met with this alternative; hence the strict definition of "short-term effectiveness" does not apply to this and any alternative which leaves radioactive contaminants onsite at activities exceeding designated action levels.

The short-term reliability of this alternative involves two components:

- The reliability of physical barriers to eliminate onsite exposure
- The reliability of the current engineered systems with respect to migration of site contaminants.

With respect to the first component, the use of fencing and appropriate warning signs would effectively reduce onsite intrusion and prevent site disturbance. In terms of migration, the RI has indicated that the engineered containment systems, consisting of a concrete cover installed over contaminated asphalt and an asphalt cap installed over contaminated soils have allowed little contaminant migration from soils and contaminated surfaces. However, there is measurable ongoing migration within the storm-water drainways at the facility. In the short-term, maintenance of the existing structures would provide adequate controls to check contaminant transport within stabilized areas.

The long term effectiveness and permanence of this alternative is uncertain. Due to the extreme persistence of the contaminants, the magnitude and sources causing residual risk will remain in perpetuity; hence the reliability of these controls remains uncertain.

Implementability concerns center on reliability, long term monitoring, and O&M issues tied to access restriction and migration management. The alternative allows for additional actions, should they be required (e.g., waste treatment or disposal alternatives) due to the fact that the condition of the wastes remains unchanged. However, long-term considerations of this alternative pertaining to sustained operation in perpetuity are uncertain, since the extreme persistence of the contaminants requires extensive performance periods.

Safety considerations associated with the Existing Conditions alternative are primarily associated with onsite monitoring. Site work will be conducted using an appropriate level of protection followed by suitable decontamination of workers and equipment, based on known and measured (monitored) levels of radioactivity at the site. Engineering controls will be necessary to prevent dispersion of contaminated soils during any intrusive activities including monitoring and routine maintenance. Significant excavation and transportation of radioactive material are avoided in this alternative.

Environmental analysis. Of the three sources of risk, this alternative operates on two: migration potential and potential receptors. The third, contaminant source, is left in place at the site without modification. Sources currently contained using engineered systems (asphalt/concrete caps) will be maintained to eliminate or minimize migration from containment areas. In this manner, migration of contaminated soils/sediments from the BOMARC site will result solely from that currently within uncontained areas at the site. This alternative acts upon potential receptors by reducing/eliminating the exposure scenario posing the greatest risk, i.e, onsite exposure as defined by the MEI scenario developed in the risk assessment.

The beneficial impacts involved with this alternative are most plausible in the present and near-future. In this timeframe, it is anticipated that the physical and institutional techniques employed under this alternative will be reliable; however, in the long-term, the reliability of this approach is uncertain. Selection and implementation of this alternative would also restrict or eliminate the use of the land in perpetuity.

Public health analysis. As discussed above, this alternative employs physical controls to eliminate exposure scenarios posing significant risk from the site. Assuming that the performance of the alternative is reliable in both the short-and long-term, this alternative is protective as defined by the risk assessment. In the short- and long-term, exposure to levels above the 8 pCi/g activity level, which exist in areas onsite, will be eliminated. Migration from areas currently exhibiting transport will continue, with offsite exposure possible in the 75 to 100 year timeframe. However, concentrations of any contaminants migrating offsite are expected to be attenuated below 8 pCi/g. As migration continues, the current concentration profile of plutonium and americium will attenuate. The affected populations will include those surrounding Elisha Branch, downstream of the facility (additional detail provided in the RI). Potential exposure routes of concern include ingestion as well as inhalation of any contaminated materials. These exposure routes are those in which contaminants are deposited internally where alpha radiation is most significant.

As discussed in Phase II, this alternative's primary risk reduction strategy is the isolation of the facility through the use of physical and institutional controls. In the short-term, the degree of control is considered effective; however, due to the long-term persistence of wastes found onsite, long-term effectiveness with respect to protectiveness for onsite exposure using these controls is uncertain. The magnitude of residual contamination remaining onsite using this strategy remains above the 8 pCi/g level in several areas.

Institutional analysis. In order to evaluate the institutional feasibility of the Existing Conditions alternative, chemical-specific, action-specific, and location-specific ARARs must be considered. This alternative does not achieve health-based or regulatory-based cleanup goals established for the site; however, these goals apply only if there is unrestricted access to the site. Since access controls would be implemented, these goals do not apply. Risk reduction would be achieved by eliminating onsite exposure, even though no quantitative cleanup objectives are met.

Cost analysis. A cost estimate has been developed for the Existing Conditions alternative. The cost analysis covers the maintenance of access controls, including replacement and removal costs for fencing after 15 years, quarterly visual inspections and annual monitoring and report preparation. The total cost for this option is $830,000, with total capital costs amounting to $156,800 and $673,200 necessary for O&M over a 30-year period. Potential costs associated with repair and maintenance of containment controls and administrative costs associated with maintenance of governmental control of the site were not incorporated in the calculations of present worth. The cost estimates were developed for a 30-year period of performance, using an assumed interest rate of 10%. A detailed spreadsheet for this alternative is provided in Table 5-7.

5.3.4 Detailed Analysis of the Limited Action Alternative

The Limited Action alternative for management of risks posed by conditions at the BOMARC site represents a strategy aimed at eliminating potential onsite exposure and reduction of future migration potential. This approach incorporates the following elements:

- Restriction of access to and future use of the land in order to minimize disturbance of the site.
- Maintenance to prevent deterioration of existing containment structures.
- Location and removal of the missing missile launcher along with associated contaminated soils.
- Long-term environmental surveillance of the site to track contaminant distribution and potential migration.

This alternative will be implemented by installation of physical barriers about the facility, maintaining government control of the site, excavation and removal of the missile launcher and soils, maintenance of barriers and engineered containment systems, along with quarterly visual inspections and annual radiological surveys.

Table 5-7
Cost Estimate Spreadsheet Existing Conditions

Capital Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Access Controls:					
Fencing, 6 foot Chain Link with barbed wire top	14.55	LF	4750	69,113	Means (0283080500)
Gates (Vehicle/12' wide)	83	LF	48	3,984	Means (0283083100)
Gates (Persons/3' wide)	205	Each	4	820	Means (0283081400)
Signs (every 50')	40	Each	95	3,800	Means (0284120010)
Health Physics Oversite	1455	Day	10	14,550	TETC Estimate
Fence replacement after 15 years *				17,560	TETC Estimate
Demolition of fence *	1.34	LF	4750	1,524	Means (0205540700)
Disposal of fence *	13.15	CY	1583	4,984	Means (0206120100)
Purchase Fidler probe and analyzer	4275	each	1	4,275	Bicron Co.
Subtotal				$120,609	
Engineering @15%				$ 18,091	
Contingency @15%				$ 18,091	
Total Capital Cost				$156,792	

* Discounted @ 10% from 15 yr expense.

Table 5-7
Cost Estimate Spreadsheet Existing Conditions

Operating and Maintenance Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Visual Inspections:					
Personnel Protection ("D")	18	Day	24	432	TETC Estimate
Labor,2 people @ 3 day per quarter/each	75	Hour	192	14,400	TETC Estimate
Eberline PAC-4G Frisker or equivalent	150	Month	4	600	GP Instrument Service
Annual Monitoring/Report Preparation:					
Personnel Protection ("C")	48	Day	30	1,440	TETC Estimate
Labor,2 people @ 25 days/ea	75	Hour	400	30,000	TETC Estimate
Sample Collecting Equipment	50	Day	10	500	TETC Estimate
Eberline PAC-4G Frisker or equivalent	150	Month	1	150	GP Instrument Service
Lab Analysis (Alpha Spectroscopy)	100	Sample	70	7,000	Teledyne Isotope
Transport of used Personnel Protective clothing to Landfill	3.95	Mile	2500	9,875	TETC Estimate
Disposal of used Personnel Protective clothing at Nevada Test Site	10	CF	44	440	AWC Incorporated
Subtotal				$64,837	
Contingency @ 10%				$6,484	
Total Annual O & M Cost				$71,321	

SUMMARY - EXISTING CONDITIONS

30 year Present Worth - O & M[1]	$672,334
Present Worth - Capital	$156,792
Total Present Worth	$829,126

1. RAD Survey is to be done annually for the first five years, then once every five years, thereafter.
2. Assumed interest rate of 10% was used in calculations of present worth.

Technical analysis. This alternative, although similar to the Unrestricted Access alternative in that all contamination except the launcher remains in-place, acts upon the conditions representing significant risk. In terms of performance, the Limited Action approach does not reduce the mobility, toxicity, or volume of known contamination at the site; however, it has provisions for the location and removal of the missile launcher and associated contaminated soils. This represents a refinement over the previous alternative as it decreases site management requirements and potential risk by reducing total site contaminant volumes and removing currently unquantified site contamination.

The short-term effectiveness, measured by the protectiveness of the alternative offered to community and workers in the time period required to implement remedial action, is considered excellent, with environmental impacts in the near future considered to be negligible. However, remedial action objectives of clean-up of the site through the removal of contamination would not be met with this alternative; hence the strict definition of "short-term effectiveness" does not apply to this and any alternative which leaves radioactive contaminants onsite at activities exceeding designated action levels.

The short-term reliability of this alternative involves two components:

- The reliability of physical barriers to eliminate onsite exposure
- The reliability of the current engineered systems with respect to migration of site contaminants.

With respect to the first component, the use of fencing and appropriate warning signs would effectively reduce onsite intrusion and prevent site disturbance. In terms of migration, the RI has indicated that the engineered containment systems, consisting of a concrete cover installed over contaminated asphalt and an asphalt cap installed over contaminated soils have allowed little, contaminant migration from soils and contaminated surfaces. However, there is measurable ongoing migration within the storm-water drainways at the facility. In the short-term, maintenance of the existing structures would provide adequate controls to check contaminant transport within stabilized areas.

Implementability concerns center on the location, excavation and disposal of the launcher system along with long-term O&M issues tied to access restriction and migration management. Five anomalies have been identified during the RI as potentially representing the launcher system. Each of these sites will require excavation to locate the system. Once found, an acceptable disposal site will be required. Two sites, the Nevada Test Site and the U.S. Ecology facility in Hanford, Washington have been identified as disposal sites that are properly licensed and currently can accept wastes with activities less than 100 nCi/g. Acceptance of the launcher and associated materials by a particular facility depends on the level of activity associated with the materials, which is currently unknown. This alternative also allows for additional actions should they be necessary (e.g., waste treatment or disposal alternatives) due to the fact that the condition of the wastes remains unchanged. Once again, long-term considerations of this alternative pertaining to operation are uncertain as the extreme persistence of the contaminants require extensive performance periods.

Safety considerations associated with the Limited Action alternative are primarily associated with the location, excavation, transport and disposal of the potentially contaminated launcher system and associated soils. It will be necessary to determine the level of radioactivity associated with the launcher and site work will be conducted using an appropriate level of protection followed by suitable decontamination of workers and equipment. Engineering controls will be necessary to prevent dispersion of contaminated soils during excavation. Transportation of the material poses a minor risk to the public, with risk increasing with the distance to the disposal facility and volume/activity of the contaminated material.

Environmental analysis. This alternative operates on all three components of risk: site contaminant sources, migration potential, and potential receptors. The missile launcher along with associated contaminated soils, currently an unquantified risk posed by the site, are to be located and removed. In addition to the missile launcher, sources currently contained using engineered systems (asphalt/concrete caps) will be maintained to eliminate/minimize migration from these areas. In this manner, migration of contaminated soils/sediments from the BOMARC site will result only from that currently within the stormwater runoff systems at the site. This alternative acts upon potential receptors by reducing/eliminating the exposure scenario posing the greatest risk, onsite exposure as defined by the MEI scenario developed in the risk assessment.

The beneficial impacts involved with this alternative are most plausible in the present and near-future. In this timeframe, it is anticipated that the physical and institutional techniques employed under this alternative will be reliable; however, in the long-term, the reliability of this approach is uncertain. Selection and implementation of this alternative would also restrict or eliminate the use of the land in perpetuity.

Public health analysis: As discussed above, this alternative employs physical controls to eliminate exposure scenarios posing significant risk from the site. Assuming that the performance of the alternative is reliable in both the short- and long-term, this alternative is protective as defined by the risk assessment. In the short- and long-term, exposure to levels above 8 pCi/g, which exist in areas onsite, will be eliminated. Migration from areas currently exhibiting transport will continue, with offsite exposure possible in the 75 to 100 year timeframe. However, concentrations of any contaminants migrating offsite are expected to be below 8 pCi/g. As migration continues, the current concentration profile of plutonium and americium will attenuate. The affected populations will include those surrounding Elisha Branch, downstream of the facility (additional detail provided in the RI). Potential exposure routes of concern include ingestion as well as inhalation of any contaminated materials. These exposure routes are those in which contaminants are deposited internally where alpha radiation is most significant.

As discussed in Phase II, this alternative's primary risk reduction strategy is the isolation of the facility through the use of physical and institutional controls. In the short-term, the degree of control is considered effective; however, due to the long-term persistence of wastes found onsite, long-term effectiveness with respect to protectiveness for onsite exposure using these controls is uncertain. The magnitude of residual contamination remaining onsite using this strategy remains above the 8 pCi/g level in several areas.

Institutional analysis. In order to evaluate the institutional feasibility of the Limited Action alternative, chemical-specific, action-specific, and location-specific ARARs must be considered. This alternative does not achieve health-based or regulatory-based cleanup goals established for the site; however, these goals apply only if there is unrestricted access to the site. Since access controls would be implemented, these goals do not apply. Risk reduction would be achieved by eliminating onsite exposure, even though no quantitative cleanup objectives are met.

Action-specific ARARs addressing excavation, transport and disposal of the launcher system and associated contaminated soils may require permits and will require adequate controls during these activities. The most significant institutional issues affecting this and other alternatives involving an offsite disposal component are laws and regulations governing offsite disposal facilities. These include performance standards and licensing requirements for the facilities, and especially restrictions on the types of wastes that can be accepted and the places of origin from which wastes can be accepted. There are currently only three operating commercial low-level radioactive waste disposal facilities in the nation licensed to receive the radioisotopes present. They are the Chem-Nuclear facility in Barnwell, South Carolina, and the U.S. Ecology facilities in Beatty, Nevada, and Hanford, Washington. An additional facility licensed for disposal of bulk materials and operated by Envirocare, Inc., located in Utah, has applied for an amendment to its license to allow for disposal of plutonium and may also be available. In addition, no facilities including commercial facilities or government-operated facilities can currently accept wastes with greater than 100 nCi/g of activity. No materials samples during the RI/FS exceeded 100 nCi/g, and no wastes are expected to exceed this threshold. However, it is possible that small amounts of BOMARC waste may exceed 100 nCi/g.

For the purposes of this RI/FS, one DOE disposal facility (Nevada Test Site) and one commercial disposal facility (U.S. Ecology, Hanford, Washington) were selected as representative sites for evaluation of disposal options. The Air Force has no firm response from the DOE as to whether or not DOE will accept the BOMARC waste. It is the Air Force's understanding that the DOE will not consider acceptance of the waste unless the Air Force has been refused disposal permission at all available commercial sites. The Air Force believes it is currently in good standing with the commercial waste sites and has applied for permission to dispose of the BOMARC waste at all four commercial facilities. No response has yet been received from any of the four commercial sites.

The issue that will most impact the Air Force's ability to make an independent decision is the Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA) governing interstate shipment and disposal of radioactive waste. The LLRWPAA places the burden for low-level radioactive waste disposal with the individual states, or with compacts of states, and establishes a schedule for phased implementation. This act has already increased the cost of disposal at the licensed commercial sites through its provisions allowing currently sited states to levy waste surcharges. Costs are projected to escalate even more as states and compacts set fees to support their sites' operations. A more immediate issue affecting any decision is the scheduled closure of the commercial sites on January 1, 1993. On that date, another provision of the LLRWPAA takes effect that closes existing commercial sites to generators outside the state or compact which the site is located. As state and compact agreements now stand, waste generators in New Jersey will have no access to existing sites even if they remain open to member states within the sites' compacts.

In summary, the institutional issues discussed above will negatively impact the implementability of this alternative if there are no commercial sites available due to the LLRWPAA; if the launcher and/or associated soils are too highly contaminated (i.e., above 100 nCi/g) for acceptance at commercial or DOE facilities; or if the Air Force cannot obtain permission from the DOE for disposal of the waste at the Nevada Test Site.

Cost analysis. Two cost estimates have been developed for the Limited Action alternative. Cost option 1 represents the cost of the project should the selected disposal site be Nevada Test Site, while cost option 2 presents expenses associated with disposal at the U.S. Ecology site located near Hanford, Washington. The total cost for option 1 is $957,484 (present worth), with $285,149 representing capital funds required, and $672,000 necessary for operating and maintenance costs. The total cost for option 2 is $1,183,297, with $510,963 representing capital costs, and $672,334 necessary for operating and maintenance costs. The basis for the cost differential is attributable to unit cost difference for disposal. These cost estimates were developed for a 30 year period of performance. Detailed spreadsheets for each alternative are provided as Table 5-8 and 5-9.

Two factors are judged to have significant impact on the Limited Action alternative cost. These factors, the period of performance and the discount rate, have been incorporated into a sensitivity analysis. Since this alternative requires operation in perpetuity, more realistic present worth costs should assess longer timeframes for operation. Table 5-10 presents costs associated with 100, 500, and 1000 years of operation for each Limited Action option. Figure 5-7 provides a graphical representation of these costs. Long-term operation of this alternative (500-1000 years) increases project costs by 30% to 40%. The impact of the discount rate on total project costs over a 30 year performance period is presented on the following pages.

Effect of Discount Rate Variation on Limited Action Alternatives

Discount Rate	5%	10%	15%	20%
Option 1	$1,381,528	$957,484	$753,441	$640,251
Option 2	$1,607,340	$1,183,297	$979,255	$866,065

5.3.5 Detailed Analysis of the Onsite Treatment Alternative

The third alternative advanced for detailed analysis, an Onsite Treatment option, provides for site restoration using a volume reduction/offsite disposal strategy. This approach would remove site contaminants to a level established using a health-based approach. The Onsite Treatment alternative employs a physical separation technique which segregates radioactive materials to effect volume reduction. The contaminated material would be disposed of in an offsite facility designed for the long-term management of transuranic material. This alternative would incorporate the following elements:

- Excavation of source soils containing greater than 8 pCi/g plutonium as delineated within this RI/FS.

Table 5-8
Cost Estimate Spreadsheet Limited Action (Nevada Test Site)

Capital Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Access Controls:					
Fencing, 6 foot Chain Link with barbed wire top	14.55	LF	4750	69,113	Means (0283080500)
Gates (Vehicle/12' wide)	83	LF	48	3,984	Means (0283083100)
Gates (Persons/3' wide)	205	Each	4	820	Means (0283081400)
Signs (every 50')	40	Each	95	3,800	Means (0284120010)
Health Physics Oversite	1455	Day	10	14,550	TETC Estimate
Fence replacement after 15 years *				22,419	TETC Estimate
Demolition of fence *	1.34	LF	4750	1,524	Means (0205540700)
Disposal of fence *	13.15	CY	1583	4,984	Means (0206120100)
Excavation of Anomalies (for Launcher):					
Lease Backhoe	1449	Day	10	14,490	Means (0164080150)1
Crew for Backhoe	574.56	Day	10	5,746	Means (0164080150)1
Storage of soils in two 20 CY Roller boxes (2 wks)	640	Week	2	1,280	FNH Carting
Lab Analysis-sampled Soil	100	Sample	40	4,000	Teledyne Isotope
Health Physics Oversight	1455	Day	10	14,550	TETC Estimate
Purchase Fidler Probe & Analyzer	4275	Each	1	4,275	Biron Company
Hauling Launcher/Soils to Nevada Test Site	4000	20 ton truckload	6	24,000	AWC Incorporated
Offload Charge	2000	LS	1	2,000	Chem Nuclear
Burial of Launcher/Soils	270	CY	103	27,810	AWC Incorporated
Subtotal				$219,346	
Engineering @15%				$ 32,902	
Contingency @15%				$ 32,902	
Total Capital Cost				$285,149	

* Discounted @ 10% from 15 yr expense.

Table 5-8
Cost Estimate Spreadsheet Limited Action (Nevada Test Site)

Operating and Maintenance Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Visual Inspections:					
Personnel Protection ("D")	18	Day	24	432	TETC Estimate
Labor,2 people @ 3 day per quarter/each	75	Hour	192	14,400	TETC Estimate
Eberline PAC-4G Frisker or equivalent	150	Month	4	600	GP Instrument Service
Annual Monitoring/Report Preparation:					
Personnel Protection ("C")	48	Day	30	1,440	TETC Estimate
Labor,2 people @ 25 days/ea	75	Hour	400	30,000	TETC Estimate
Sample Collecting Equipment	50	Day	10	500	TETC Estimate
Eberline PAC-4G Frisker or equivalent	150	Month	1	150	GP Instrument Service
Lab Analysis (Alpha Spectroscopy)	100	Sample	70	7,000	Teledyne Isotope
Transport of used Personnel Protective clothing to Landfill	3.95	Mile	2500	9,875	TETC Estimate
Disposal of used Personnel Protective clothing at Nevada Test Site	10	CF	44	440	AWC Incorporated
Subtotal				$64,837	
Contingency @ 10%				$6,484	
Total Annual O & M Cost				$71,321	

SUMMARY - LIMITED ACTION

30 year Present Worth - O & M[1]	$672,334
Present Worth - Capital	$285,149
Total Present Worth	$957,484

1. RAD Survey is to be done annually for the first five years, then once every five years, thereafter.
2. Assumed interest rate of 10% was used in calculations of present worth.

Table 5-9
Cost Estimate Spreadsheet Limited Action (Hanford, Washington)

Capital Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Access Controls:					
Fencing, 6 foot Chain Link with barbed wire top	14.55	LF	4750	69,113	Means (0283080500)
Gates (Vehicle/12' wide)	83	LF	48	3,984	Means (0283083100)
Gates (Persons/3' wide)	205	Each	4	820	Means (0283081400)
Signs (every 50')	40	Each	95	3,800	Means (0284120010)
Health Physics Oversite	1455	Day	10	14,550	TETC Estimate
Fence replacement after 15 years *				22,419	TETC Estimate
Demolition of fence *	1.34	LF	4750	1,524	Means (0205540700)
Disposal of fence *	13.15	CY	1583	4,984	Means (0206120100)
Excavation of Anomalies (for Launcher):					
Lease Backhoe	1449	Day	10	14,490	Means (0164080150)[1]
Crew for Backhoe	574.56	Day	10	5,746	Means (0164080150)[1]
Storage of soils in two 20 CY Roller boxes (2wks)	640	Week	2	1,280	FNH Carting
Lab Analysis-sampled soil	100	Sample	40	4,000	Teledyne Isotope
Health Physics Oversight	1455	Day	10	14,550	TETC Estimate
Purchase Fidler probe and analyzer	4275	each	1	4,275	Bicron Company
Hauling Launcher/Soils to Hanford, Washington	4163	20 ton truckload	6	24,975	AWC Incorporated
Offload charge	2000	LS	1	2,000	Chem Nuclear
Burial of Launcher/Soils at Hanford, Washington	72.11	CF	2781	200,538	U.S. Ecology
Subtotal				$393,049	
Engineering @15%				$58,957	
Contingency @15%				$58,957	
Total Capital Cost				$510,963	

* Discounted @ 10% from 15 yr expense.

Table 5-9
Cost Estimate Spreadsheet Limited Action (Hanford, Washington)

Operating and Maintenance Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Visual Inspections:					
Personnel Protection ("D")	18	Day	24	432	TETC Estimate
Labor,2 people @ 3 day per quarter/each	75	Hour	192	14,400	TETC Estimate
Eberline PAC-4G Frisker or equivalent	150	Month	4	600	GP Instrument Service
Annual Monitoring/Report Preparation:					
Personnel Protection ("C")	48	Day	30	1,440	TETC Estimate
Labor,2 people @ 25 days/ea	75	Hour	400	30,000	TETC Estimate
Sample Collecting Equipment	50	Day	10	500	TETC Estimate
Eberline PAC-4G Frisker or equivalent	150	Month	1	150	GP Instrument Service
Lab Analysis (Alpha Spectroscopy)	100	Sample	70	7,000	Teledyne Isotope
Transport of used Personnel Protective clothing to Landfill	3.95	Mile	2500	9,875	TETC Estimate
Disposal of used Personnel Protective clothing at Hanford, Washington	10	CF	44	440	AWC Incorporated
Subtotal				$64,837	
Contingency @ 10%				$6,484	
Total Annual O & M Cost				$71,321	

SUMMARY - LIMITED ACTION

30 year Present Worth - O & M[1]	$672,334
Present Worth - Capital	$510,963
Total Present Worth	$1,183,297

1. RAD Survey is to be done annually for the first five years, then once every five years, thereafter.
2. Assumed interest rate of 10% was used in calculations of present worth.

Table 5-10
Limited Action - Sensitivity Analysis Effects of
Period of Performance on Cost

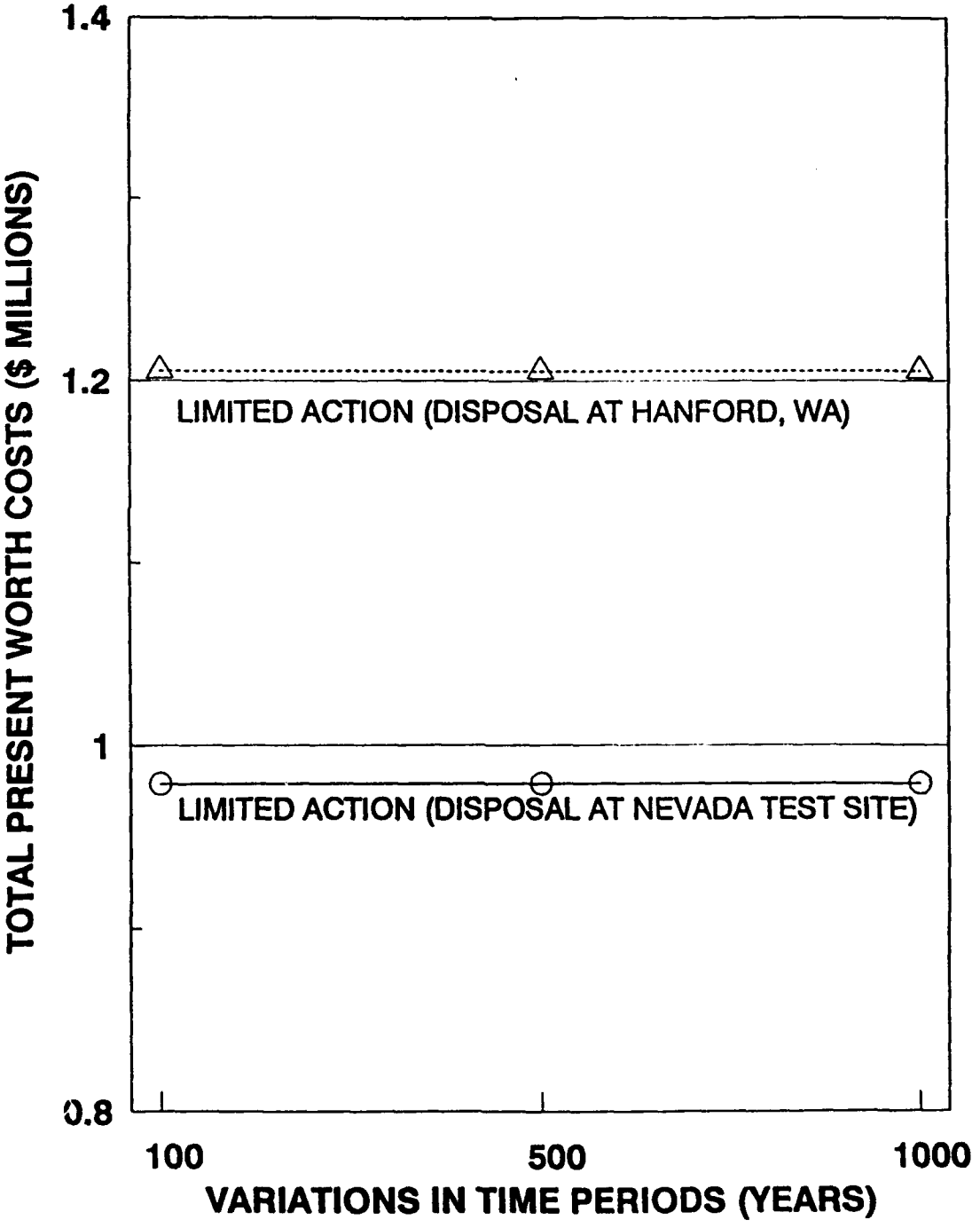
Remedial Alternatives	Present Value for Different Time Periods* 100 Years	500 Years	1000 Years
Limited Action (Disposal at Nevada Test Site)	$998,305	$998,356	$998,356
Limited Action (Disposal at Hanford, WA)	$1,224,118	$1,224,170	$1,224,170

* 30 year present worth costs for these alternatives are:

Limited Action (Disposal at Nevada Test Site)	$957,484
Limited Action (Disposal at Hanford, WA)	$1,183,297

$71,321 is the annual cost of O&M for both alternatives
$285,149 is the total capital cost, Nevada Test Site
$510,963 is the total capital cost, Hanford, WA site
0.1 is the interest rate used

FIGURE 5-7
Sensitivity Analysis
Effects of Period of Performance on Cost



- Treatment of the excavated soils using the TRU-Clean[R] process or a similar process which effects significant volume reduction through separation of soil fraction exhibiting significant activity from clean soils.

- Excavation and sectioning of concrete apron, utility bunkers, and Shelter 204.

- Decontamination of the apron, utility bunkers, and Shelter 204 using physical treatment to remove radioactive contaminants.

- Excavation and removal of the missile launcher.

- Transport and disposal of radioactive materials in an offsite licensed facility designed for long-term management of radioactive materials.

- Restoration of the site by backfilling the "clean" fraction from the TRU-Clean[R] process and other clean fill as needed, followed by grading and revegetation of the site.

The following sections present the detailed analysis of the Onsite Treatment alternative for the BOMARC Missile Site.

Technical analysis. The Onsite Treatment alternative is an active restoration strategy which provides for site restoration to below risk-based levels thereby reducing risks to human health and the environment. Reduction of mobility, toxicity, and volume would be effected through techniques which remove and segregate radioactive material with subsequent offsite disposal.

Testing to evaluate the removal efficiency of the TRU-Clean[R] process as affected by differing soil matrices has been conducted . Initial pilot plant testing conducted at Johnston Island during 1985 and 1986 demonstrated a "somewhat greater than 90% volume reduction and activity removal" from coral-derived soils. Follow-up pilot testing using soil samples obtained from the Nevada Test Site (NTS), the Rocky Flats Plant (RFP) in Colorado, the FUSRAP site in Hazelwood, Missouri, the Monsanto-Mound site in Ohio, and the BOMARC Missile Site in New Jersey has also been completed. A summary of test results is tabularized below:

Site Providing Samples Reduction	Max/Min Removal Efficiency	Max/Min Volume Reduction
NTS Area 11	97%/73%	92%/23%
Rocky Flats	>99%/34%	96%/64%
FUSRAP	100%/53%	>99%/98%
Monsanto	90%/58%	91%/46%
NTS Area 13	>99%/78%	100%/65%
BOMARC Missile Site*	>99%/56%	85%/49%

* During 1987, testing on samples from the BOMARC Missile Site were completed. These samples contained moisture, organic material and asphalt.

Based on these pilot plant test results, the expected performance of BOMARC soils is judged as likely acceptable; however, additional treatability testing is necessary prior to full-scale treatment. Preliminary testing of the BOMARC soils indicates the need for some level of

chemical separation enhancement. This enhancement can be achieved through treating soils with an aqueous enhancement agent. Water-based leachate composition development and application will be required to augment the physical separation of the plutonium/americium from the host soil and optimize volume reduction.

The reliability evaluation focusses on successful completion of treatability testing, and control of potential migration during excavation and treatment of contaminated soils and during decontamination of structural materials. As discussed in the previous paragraph, optimization of the TRU-Clean[R] process for BOMARC soils will require some augmentation/refinement of the process. With respect to controls during operation, engineering controls are available which suppress or filter dust generated during excavation and treatment. Staging and treatment will be conducted within a structure designed specifically for the BOMARC remediation program. Techniques to remove contaminants from structural material have not been field tested under similar conditions and therefore the reliability of these methods are unknown. Should these techniques prove unsatisfactory, the entire structural unit (e.g., asphalt/concrete) will require offsite disposal.

Implementability considerations for the Onsite Treatment alternative involve operational issues along with the availability of services and TSD Facilities. Due to the risks involved with dust generation during excavation and treatment, extensive measures must be undertaken to suppress dust generation and filter any material suspended in the atmosphere. In order to achieve this, operations should be conducted within contained systems which employ HEPA filtration to remove suspended materials. The availability of services encompasses both the treatment contractors and disposal facilities. The TRU-Clean[R] process or similar processes are available through a limited number of vendors. This may impact the start-up of remediation. In addition, permitting requirements and the availability of space within a permitted radioactive disposal site must be considered. At present, several facilities have been evaluated as potential disposal sites, of these, the Nevada Test Site and the U.S. Ecology facility in Hanford Washington are properly licensed and available, and appear to be feasible. However, future changes in the regulatory and/or political environment could affect the availability of these facilities for disposal of wastes from the BOMARC site. These issues are discussed below in the Institutional Analysis.

As discussed above, safety considerations are primarily tied to control of conditions during remediation (excavation, staging, and treatment). To ensure worker and community protection, extensive dust control techniques should be employed. All staging and treatment will be conducted in enclosed structures maintained under negative air pressure, with exhaust vented through HEPA filters. Site workers will be equipped with adequate breathing protection and appropriate decontamination procedures will be used to prevent transport of contaminants on workers and equipment. An additional concern involves the transport of contaminated materials to the disposal facility. This alternative effectively reduces the volume of materials which require transportation over other conventional excavation and disposal approaches.

Environmental analysis. The Onsite Treatment alternative acts upon the source element to achieve risk reduction. With site sources removed, risk through migration potential and onsite exposure is eliminated/minimized. The TRU-Clean[R] process represents a pilot tested treatment scheme (with runs on BOMARC soils) designed to effectively reduce volume with high removal efficiencies. Removal efficiencies experienced on BOMARC soils ranged from >99% to 56% with a 91% average efficiency. Volume reductions ranged from 85% to 49%, averaging 62%.

Long-term benefits associated with the restoration of the site to health-based clean-up levels greatly outweigh short-term impacts presented by this alternative. In general, environmental impacts are considered minimal as relative soil volumes requiring excavation are manageable and site restoration is a component of the alternative. Additionally, the timeframe associated with remediation/site restoration is relatively short-term.

Public health analysis. Residual soil contamination remaining after treatment will include soils below 8 pCi/g. As indicated by the calculation of a risk-based soil cleanup level, this presents an acceptable risk to human health and the environment.

Institutional analysis. In order to evaluate the institutional feasibility of the Onsite Treatment alternative, chemical-specific, action-specific, and location specific ARARs need to be considered. Currently there are no chemical-specific criteria for soils and surface water in terms of plutonium activity levels; however, future EPA regulations may contain activity-based criteria. For structures, NRC Regulatory Guide 1.86 is considered as relevant and appropriate. For transuranics, limits for surface contamination are 20 disintegrations per 100 square centimeters (dpm/100 cm^2) for removable activity, 300 dpm/100 cm^2 for maximum activity, and 100 dpm/100 cm^2 for average radioactivity. This alternative would satisfy these requirements through either decontamination or removal of surficially contaminated materials and would achieve health-based cleanup goals for soil through waste volume reduction followed by offsite disposal of the waste fraction. This is the only alternative evaluated in detail that satisfies the statutory preference stated in SARA for remedies that achieve reduction in mobility, toxicity, or volume.

The most significant institutional issues affecting this and other alternatives involving an offsite disposal component are laws and regulations governing offsite disposal facilities. These include performance standards and [illegible]ing requirements for the facilities, and especially restrictions on the types of wastes that can be accepted and the places of origin from which wastes can be accepted. There are currently only three operating commercial low-level radioactive waste disposal facilities in the nation licensed to receive the radioisotopes present. They are the Chem-Nuclear facility in Barnwell, South Carolina, and the U.S. Ecology facilities in Beatty, Nevada, and Hanford, Washington. An additional facility licensed for disposal of bulk materials and operated by Envirocare, Inc., located in Utah, has applied for an amendment to its license to allow for disposal of plutonium and may also be available. In addition, no facilities including commercial facilities or government-operated facilities can currently accept wastes with greater than 100 nCi/g of activity. No materials samples during the RI/FS exceeded 100 nCi/g, and no wastes are expected to exceed this threshold. Of all whole soil grab samples collected during the RI, the highest observed activity was 1,400 pCi/g. Assuming 90 percent volume reduction, the waste would be concentrated by a factor of 10 to an activity of 14,000 pCi/g, or 14 nCi/g. Undoubtedly, there are isolated "hotspots" of activity exceeding these levels, however, these "hotspots" could be segregated so that concentration above 100 nCi/g would not occur. However, it is possible that small amounts of BOMARC waste may exceed 100 nCi/g.

For the purposes of this RI/FS, one DOE disposal facility (Nevada Test Site) and one commercial disposal facility (U.S. Ecology, Hanford, Washington) were selected as representative sites for evaluation of disposal options. The Air Force has no firm response from the DOE as to whether or not DOE will accept the BOMARC waste. It is the Air Force's understanding that the DOE will not consider acceptance of the waste unless the Air Force has

been refused disposal permission at all available commercial sites. The Air Force believes it is currently in good standing with the commercial waste sites and has applied for permission to dispose of the BOMARC waste at all four commercial facilities. No response has yet been received from any of the four commercial sites.

The issue that will most impact the Air Force's ability to make an independent decision is the Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA) governing interstate shipment and disposal of radioactive waste. The LLRWPAA places the burden for low-level radioactive waste disposal with the individual states, or with compacts of states, and establishes a schedule for phased implementation. This act has already increased the cost of disposal at the licensed commercial sites through its provisions allowing currently sited states to levy waste surcharges. Costs are projected to escalate even more as states and compacts set fees to support their sites' operations. A more immediate issue affecting any decision is the scheduled closure of the commercial sites on January 1, 1993. On that date, another provision of the LLRWPAA takes effect that closes existing commercial sites to generators outside the state or compact which the site is located. As state and compact agreements now stand, waste generators in New Jersey will have no access to existing sites even if they remain open to member states within the sites' compacts.

In summary, the institutional issues discussed above will negatively impact the implementability of this alternative if there are no commercial sites available due to the LLRWPAA; if the launcher and/or associated soils are too highly contaminated (i.e., above 100 nCi/g) for acceptance at commercial or DOE facilities; or if the Air Force cannot obtain permission from the DOE for disposal of the waste at the Nevada Test Site.

For the concrete apron, the highest activity level found during the RI was 1,070 μCi/core, or 1,070,000 nCi/core. Activity levels this high appear to be isolated in localized "hot spots" as indicated by data from the concrete coring program. Activity levels in this range will probably not cause concrete/asphalt wastes to exceed 100 nCi/g, because the weight of the wastes brings activity levels below 100 nCi/g quickly, e.g., for the concrete sample with the highest activity measured, (1,070,000 nCi) only 25 pounds of concrete or asphalt is required to bring the bulk activity level under 100 nCi/g. Strict engineering controls would be required to identify and segregate concrete/asphalt hot spots so that these materials could be disposed of in bulk without treatment to concentrate wastes.

Cost analysis. Two cost estimates have been developed for the Onsite Treatment alternative. Cost option 1 represents the cost of the project should the selected disposal site be the Nevada Test Site, while cost option 2 presents expenses associated with disposal at the U.S. Ecology facility in Hanford, Washington. The total cost for option 1 is $8.46M. The total cost for option 2 is $13.53M. The basis for the cost differential is attributed to unit cost difference for disposal. Detailed spreadsheets for each alternative are provided as Table 5-11 and 5-12.

Two factors are judged to have significant impact on the Onsite Treatment alternative costs. These factors include the total volume of material which must be disposed of (changes in cleanup levels or the performance of structural decontamination may increase volumes) and the unit cost of disposal at the TSD facilities. With respect to the total volume to be treated/disposed of, costs for 1/2, 2, 3, 4, and 5 times the current volumes were calculated. Table 5-13 presents costs associated with each scenario. Figure 5-8 provides a graphical representation of results.

Table 5-11
Cost Estimate Spreadsheet Onsite Treatment (Nevada Test Site Disposal)
Capital Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Site Preparation:					
Treatability Study	70000	LS	1	70,000	AWC Incorporated
Building & pad for process area and stockpile area	400000	LS	1	400,000	TETC/Means Estimate
Mobilization/Demobilization	110000	LS	1	110,000	AWC Incorporated
Grub Woodland/Remove Debris	14810	Acre	1	14,810	Browns Battery
Haul Clean Wood Debris to Municipal Landfill[2]	85	22 ton truckload	5	425	Browns Battery
Excavation of soils	6.70	CY	5167	34,614	Means (0222462200)[1]
Confirmation sampling for soils during excavation	1455	Day	45	65,475	TETC Estimate
Lab Analysis of samples	100	Sample	500	50,000	Teledyne Isotope
Excavation of Anomalies for Missile Launcher	98151	LS	1	98,151	Estimate (Table 5-8)
TRU-Clean® Processing of soil	240	CY	6200	1,488,000	AWC Incorporated
Excavation/Sectioning of Concrete Apron and Utility Bunkers and Shelter 204	339765	LS	1	339,765	Means (0164602400) Means (020728....)
Decontamination and Decommission of Bldg 204, Apron and Utility Bunkers	20	SF	28897	577,940	AWC Incorporated
Decontamination/Disposal of Processing Building and pad	20	SF	63200	1,264,000	AWC Incorporated
Excavation of Asphalt (Apron and Drainage Ditch)	7.14	SY	4317	30,823	Means (0205541710)[1]
Health Physics Oversite	1455	Day	200	291,000	TETC Estimate
Air Monitoring	1000	Day	200	200,000	TETC Estimate
Hauling Processed Soils and Asphalt to Nevada Test Site for burial	4000	20 ton truckload	106	424,000	AWC Incorporated
Burial of soil, asphalt and launcher at Nevada Test Site	270	CY	2315	625,050	AWC Incorporated
Site Restoration:					
Purchase Backfill	3	CY	6200	18,600	TETC Estimate
Bulldozer to move backfill	1.79	CY	6200	11,098	Means (0222082400)
Compact fill in 12" lifts	0.45	CY	6200	2,790	Means (0222265620)
Fertilizing/Seeding w/grass	38	MSF	109	4,142	Means (0293082400)
Subtotal				$6,120,683	
Engineering @15%				$918,102	
Contamination Control Engineering[3] @10%				$507,163	
Contingency @15%				$918,102	
Total Capital Cost				$8,464,051	

Treatment completed within one year, therefore, no Operating and Maintenance Costs.

1. These Means unit costs have been increased using a multiplier of 2.1 taken from the REM IV Cost Estimating Guide by CH2M Hill, March 1987,Table 3, (Factor 6a., Level C and 85 degrees F.). This is for hazardous waste work.
2. Cost figured @ $2.50/mile for 34 miles.
3. Applies to site-related work and includes customized design of contamination control systems.

Table 5-12
Cost Estimate Spreadsheet Onsite Treatment (Hanford, Washington Disposal)
Capital Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Site Preparation:					
Treatability Study	70000	LS	1	70,000	AWC Incorporated
Building & pad for process area and stockpile area	400000	LS	1	400,000	TETC/Means Estimate
Mobilization/Demobilization	110000	LS	1	110,000	AWC Incorporated
Grub Woodland/Remove Debris	14810	Acre	1	14,810	Browns Battery
Haul Clean Wood Debris to Municipal Landfill[2]	85	22 ton truckload	5	425	Browns Battery
Excavation of soils	6.70	CY	5167	34,614	Means (0222462200)[1]
Confirmation sampling for soils during excavation	1455	Day	45	65,475	TETC Estimate
Lab Analysis of samples	100	Sample	500	50,000	Teledyne Isotope
Excavation of Anomalies for Missile Launcher	98151	LS	1	98,151	Estimate (Table 5-8)
TRU-Clean® Processing of soil	240	CY	6200	1,488,000	AWC Incorporated
Excavation/Sectioning of Concrete Apron and Utility Bunkers and Shelter 204	339765	LS	1	339,765	Means (0164602400) Means (020728....)
Decontamination and Decommission of Bldg 204, Apron and Utility Bunkers	20	SF	28897	577,940	AWC Incorporated
Decontamination/Disposal of Processing Building and pad	20	SF	63200	1,264,000	AWC Incorporated
Excavation of Asphalt (Apron and Drainage Ditch)	7.14	SY	4317	30,823	Means (0205541710) 1
Health Physics Oversite	1455	Day	200	291,000	TETC Estimate
Air Monitoring	1000	Day	200	200,000	TETC Estimate
Hauling Processed Soils and Asphalt to Hanford, Washington for burial	4163	20 ton truckload	106	441,278	AWC Incorporated
Burial of soil, asphalt and launcher at Hanford, Washington	72.11	CF	62505	4,507,236	AWC Incorporated
Site Restoration:					
Purchase Backfill	3	CY	6200	18,600	TETC Estimate
Bulldozer to move backfill	1.79	CY	6200	11,098	Means (0222082400)
Compact fill in 12" lifts	0.45	CY	6200	2,790	Means (0222265620)
Fertilizing/Seeding w/grass	38	MSF	109	4,142	Means (0293082400)
Subtotal				$10,020,147	
Engineering @15%				$1,503,022	
Contamination Control Engineering[3] @10%				$507,163	
Contingency @15%				$1,503,022	
Total Capital Cost				$13,533,354	

Treatment completed within one year, therefore, no Operating and Maintenance Costs.

1. These Means unit costs have been increased using a multiplier of 2.1 taken from the REM IV Cost Estimating Guide by CH2M Hill, March 1987,Table 3, (Factor 6a., Level C and 85 degrees F.). This is for hazardous waste work.
2. Cost figured @ $2.50/mile for 34 miles.
3. Applies to site-related work and includes customized design of contamination control systems.

Table 5-13

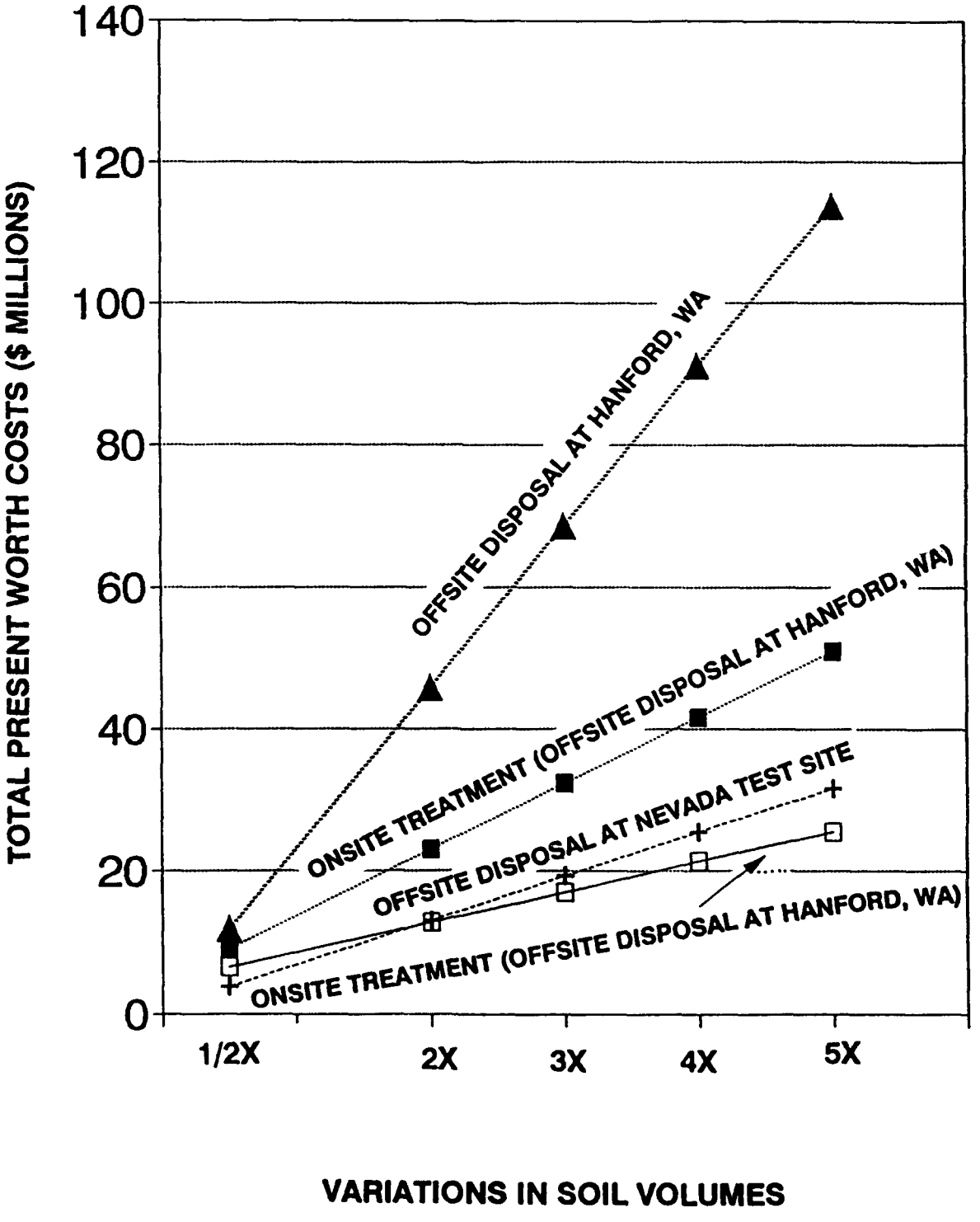
Sensitivity Analysis - Effects of Volume for Disposal on Cost

Remedial Alternatives	Total Cost for Different Volumes of Soils*				
	Volume × ½	Volume × 2	Volume × 3	Volume × 4	Volume × 5
Onsite Treatment (Disposal at Nevada Test Site)	$6,340,359	$12,711,435	$16,958,819	$21,206,202	$25,453,586
Onsite Treatment (Disposal at Hanford, Washington)	$8,875,011	$22,850,040	$32,166,727	$41,483,413	$50,800,100
Offsite Disposal (Disposal at Nevada Test Site)	$3,706,306	$12,988,578	$19,176,760	$25,364,942	$31,553,123
Offsite Disposal (Disposal at Hanford, Washington)	$11,778,566	$45,756,671	$68,408,741	$91,060,810	$113,712,880

* 30 year present worth costs for these alternatives are analyzed, based on a 10% interest rate. Total costs for listed alternatives:

Onsite Nevada	$ 8,464,051
Onsite Hanford	$13,533,354
Offsite Nevada	$ 6,800,396
Offsite Hanford	$23,104,601

FIGURE 5-8
Sensitivity Analysis
Effects of Volume for Disposal on Cost



These data indicate that for option 1, costs range from $6,340,359 to $21,206,202, and for option 2 costs run from $8,875,011 to $41,483,413. The effects of varying unit disposal costs are reflected in Figure 5-9. The scenarios for which costs are presented involve increases in unit disposal costs by a factor of 1.5, 2, and 3. For Option 1, costs range from $8,870,334 to $10,089,181, for Option 2, costs range from $16,463,057 to $25,252,166.

5.3.6 Detailed Analysis of the Offsite Disposal Alternative

The Offsite Disposal alternative represents a removal strategy for management of conditions at the BOMARC Missile Site. The option involves the excavation/removal of contaminated soils and structures at the facility which are above health-based or regulatory-based cleanup levels. As described in Phase II of the FS, option components are similar to Onsite Treatment in terms of contaminated media collection, handling, and transport. Key alternative components include:

- Excavation of source soils containing greater than 8 pCi/g plutonium as delineated in this RI/FS.
- Excavation and sectioning of concrete apron, utility bunkers, and Shelter 204.
- Excavation and removal of the missile launcher.
- Containerization, transport and disposal of radioactive materials in an offsite licensed facility designed for long-term management of radioactive materials.
- Restoration of the site by backfilling with clean fill as needed, followed by grading and revegetation of the site.

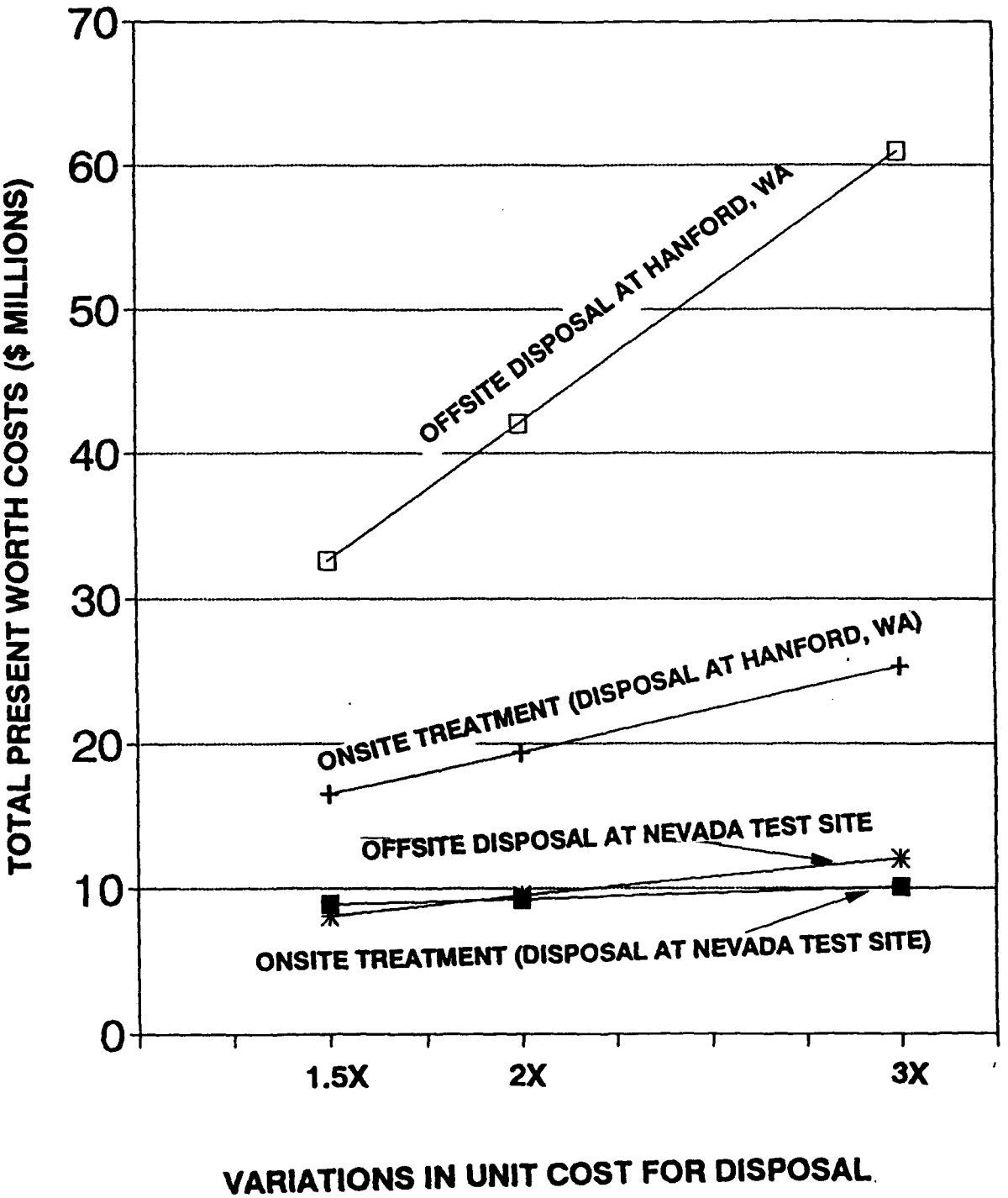
The following sections present the detailed analysis of the Offsite Disposal alternative for the BOMARC Missile Site.

Technical analysis. The Offsite Disposal alternative is an active restoration strategy which provides for site restoration to health-based levels, thereby eliminating risks to human health and the environment. To ensure performance, sampling during excavation will be conducted to ensure cleanup levels are achieved. This removal activity is basically a construction effort, and as such, performance considerations are minimal.

The reliability evaluation centers on the control of potential migration during excavation and loading of contaminated soils and during decommissioning/sectioning of structural materials. With respect to controls during operation, engineering controls are available which suppress or filter dust generated during excavation and bulk containerization.

Implementability considerations for the Offsite Disposal alternative are similar to the Onsite Treatment option and involve operational issues along with the availability of TSD Facilities. Due to the risks involved with dust generation during excavation and treatment, extensive measures must be undertaken to suppress dust generation and filter any material suspended in the atmosphere. In order to achieve this, operations should be conducted within contained systems which employ HEPA filtration to remove suspended materials. The availability of services centers on the long-term disposal facility. The availability of space within a permitted

FIGURE 5-9
Sensitivity Analysis
Effects of Unit Costs for Disposal on Cost



radioactive disposal site is an important consideration and impacts both project schedule and cost. At present, several facilities have been evaluated as potential disposal sites. Of these, the Nevada Test Site and the U.S. Ecology facility in Hanford, Washington are properly licensed and available, and appear to be feasible disposal sites. However, future changes in the regulatory and/or political environment could affect the availability of these facilities for disposal of BOMARC wastes. These issues are discussed below in the Institutional Analysis.

As discussed above, safety considerations are primarily tied to control of conditions during remediation (excavation, staging, and containerization). To ensure worker and community protection, extensive dust control techniques should be employed. Site workers should be equipped with adequate breathing protection and appropriate decontamination procedures should be used to prevent transport of contaminants on workers and equipment. An additional concern involves the transport of contaminated materials to the disposal facility. This alternative is not as effective as the Onsite Treatment alternative in this regard and requires transportation of the entire volume of contaminants to the disposal facility.

Environmental analysis. The Offsite Disposal alternative is similar to the Onsite Treatment approach with respect to this criterion and acts upon the source element to achieve risk reduction. With site sources removed, risks presented by migration potential and onsite exposure to receptors is eliminated. Long-term benefits associated with the restoration of the site to health-based and regulatory-based cleanup levels greatly outweigh short-term impacts presented by this alternative. In general, environmental impacts are considered minimal as relative soil volumes requiring excavation are manageable and site restoration is a component of the alternative.

Public health analysis. Residual contamination remaining after treatment will include soils below 8 pCi/g plutonium. As indicated by the calculation of a health-based cleanup level, this presents an acceptable risk to human health and the environment.

Institutional analysis. In order to evaluate the institutional feasibility of the Offsite Disposal alternative, chemical-specific, action-specific, and location specific ARARs need to be considered. Currently there are no chemical-specific criteria for soils and surface water in terms of plutonium activity levels; however, future EPA regulations may contain activity-based criteria. For structures, NRC Regulatory Guide 1.86 is considered as a TBC. For transuranics, limits for surface contamination are 20 disintegrations per 100 square centimeters (dpm/100 cm^2) for removable activity, 300 dpm/100 cm^2 for maximum activity, and 100 dpm/100 cm^2 for average radioactivity. Alpha surveys conducted in Shelter 204 showed that the highest activity levels were 2,011, 47,780, and 2,106 dpm/100 cm^2. This alternative achieves regulatory-based and risk-based cleanup goals for structures and soils through removal and offsite disposal. This alternative does not satisfies SARA's preference for treatment, and in fact, is the least preferred alternative under SARA where feasible treatment options exist.

The most significant institutional issues affecting this and other alternatives involving an offsite disposal component are laws and regulations governing offsite disposal facilities. These include performance standards and licensing requirements for the facilities, and especially restrictions on the types of wastes that can be accepted and the places of origin from which wastes can be accepted. There are currently only three operating commercial low-level radioactive waste disposal facilities in the nation licensed to receive the radioisotopes present. They are the Chem-

Nuclear facility in Barnwell, South Carolina, and the U.S. Ecology facilities in Beatty, Nevada, and Hanford, Washington. An additional facility licensed for disposal of bulk materials and operated by Envirocare, Inc., located in Utah, has applied for an amendment to its license to allow for disposal of plutonium and may also be available. In addition, no facilities including commercial facilities or government-operated facilities can currently accept wastes with greater than 100 nCi/g of activity. No materials samples during the RI/FS exceeded 100 nCi/g, and no wastes are expected to exceed this threshold. However, it is possible that small amounts of BOMARC waste may exceed 100 nCi/g. For soils, the highest activity level found in a whole soil grab sample during the RI was 13 nCi/g, well below the 100 nCi/g limit. Activity levels this high appear to be isolated in localized "hot spots" as indicated by data from the concrete coring program. Activity levels in this range will probably not cause concrete/asphalt wastes to exceed 100 nCi/g, because the weight of the wastes brings activity levels below 100 nCi/g quickly, e.g., for the concrete sample with the highest activity measured, (1,070,000 nCi) only 25 pounds of concrete or asphalt is required to bring the bulk activity level under 100 nCi/g.

For the purposes of this RI/FS, one DOE disposal facility (Nevada Test Site) and one commercial disposal facility (U.S. Ecology, Hanford, Washington) were selected as representative sites for evaluation of disposal options. The Air Force has no firm response from the DOE as to whether or not DOE will accept the BOMARC waste. It is the Air Force's understanding that the DOE will not consider acceptance of the waste unless the Air Force has been refused disposal permission at all available commercial sites. The Air Force believes it is currently in good standing with the commercial waste sites and has applied for permission to dispose of the BOMARC waste at all four commercial facilities. No response has yet been received from any of the four commercial sites.

The issue that will most impact the Air Force's ability to make an independent decision is the Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA) governing interstate shipment and disposal of radioactive waste. The LLRWPAA places the burden for low-level radioactive waste disposal with the individual states, or with compacts of states, and establishes a schedule for phased implementation. This act has already increased the cost of disposal at the licensed commercial sites through its provisions allowing currently sited states to levy waste surcharges. Costs are projected to escalate even more as states and compacts set fees to support their sites' operations. A more immediate issue affecting any decision is the scheduled closure of the commercial sites on January 1, 1993. On that date, another provision of the LLRWPAA takes effect that closes existing commercial sites to generators outside the state or compact which the site is located. As state and compact agreements now stand, waste generators in New Jersey will have no access to existing sites even if they remain open to member states within the sites' compacts.

In summary, the institutional issues discussed above will negatively impact the implementability of this alternative if there are no commercial sites available due to the LLRWPAA; if the launcher and/or associated soils are too highly contaminated (i.e., above 100 nCi/g) for acceptance at commercial or DOE facilities; or if the Air Force cannot obtain permission from the DOE for disposal of the waste at the Nevada Test Site.

Cost analysis. Two cost estimates have been developed for the Offsite Disposal alternative. Cost option 1 represents the cost of the project should the selected disposal site be Nevada Test Site, while cost option 2 presents expenses associated with disposal at the U.S. Ecology facility

in Hanford, Washington. The total cost for option 1 is $6.8M. The total cost for option 2 is $23.1M. The basis for the cost differential is attributed to unit cost difference for disposal. Detailed spreadsheets for each alternative are provided as Tables 5-14 and 5-15.

Two factors are judged to have significant impact on the Offsite Disposal alternative costs. These factors include the total volume of material which must be disposed of (changes in cleanup levels or the performance of structural decontamination may increase volumes) and the unit cost of disposal at the TSD facilities. With respect to the total volume to be treated/disposed of, costs for 1/2, 2, 3, 4, and 5 times the current volumes were calculated. Table 5-13 presents costs associated with each scenario. Figure 5-8 provides a graphical representation of results. These data indicate that for option 1, costs range from $3,706,306 to $25,364,942, and for option 2 costs range from $11,778,566 to $91,060,810. The effects of varying unit disposal costs are shown in Table 5-16 and graphically represented in Figure 5-9. The scenarios for which costs are presented involve increase in unit disposal costs by a factor of 1.5, 2, and 3. For option 1, costs range from $8,111,206 to $12,043,634. For option 2, disposal at the U.S. Ecology facility, costs range from $32,556,848 for a 1.5 increase in unit costs to $60,913,590 for a tripling of unit disposal costs.

5.3.7 Comparative Analysis

The alternatives evaluated in this Detailed Analysis represent a wide range of management options using varying risk reduction strategies. The alternatives incorporate different methods targeted at one or more elements of risk: contaminant sources, migration potential, and/or onsite and offsite exposure potential as follows:

- The Existing Conditions alternative maintains established institutional controls to manage onsite exposure, the scenario posing greatest risk.
- The Limited Action alternative employs physical and institutional controls to manage onsite exposure, the scenario posing greatest risk.
- The Onsite Treatment alternative provides for site remediation using a volume reduction technique followed by offsite management of the contaminated fraction within a system designed for long-term radioactive waste management.
- The Offsite Disposal alternative involves removal of contaminated media to established cleanup levels followed by offsite transport and placement in a secure system designed for long-term radioactive waste management.

An Unrestricted Access alternative (equivalent to the NCP "No Action Alternative") is also evaluated to provide a basis against which other options are compared or contrasted.

In this section, a comparative analysis is presented in order to assess the relative performance of the four distinct alternatives under each of the detailed evaluation elements. Both narrative discussion and a summary table (Figure 5-10) are employed in this section. The goal of this exercise is to highlight alternative strengths and weaknesses with respect to each other. In this manner, an optimal alternative, which is effective, implementable, and cost-effective can be identified.

Table 5-14
Cost Estimate Spreadsheet
Offsite Disposal (Nevada Test Site Disposal)

Capital Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Grub Woodland/Remove Debris	14,810	Acre	1	14,810	Browns Battery
Haul Clean Wood Debris to Municipal Landfill[2]	85	22 ton truckload	5	425	Browns Battery
Plastic Lining and Tarpaulins for trucks	30	Truck	320	9,600	Waste Processors
Excavation of soils	6.70	CY	5167	34,614	Means (0222425400)[1]
Loading Soil (15% of excavation)				5,192	Means (0222380020)
Excavation/Sectioning of Concrete Apron, Utility Bunkers and Shelter 204	339765	LS	1	339,765	Means (0164602400)[1] Means (020728....)[1]
Excavation of Asphalt (Apron and Drainage Ditch)	7.14	SY	4317	30,823	Means (020[illegible]41710)[1]
Loading concrete/asphalt (15% of excavation)				50,966	Means (0222380020)
Excavation of Anomalies for Missile Launcher	98151	LS	1	98,151	Estimate (Table 5-8)
Alpha spectroscopy (Random sampling every 10 trucks)	100	Sample	32	3,200	
Sealand Containers for media	2600	Each	320	832,000	Chem-Nuclear
Health Physics Oversite	1455	Day	180	261,900	TETC Estimate
Hauling contaminated media to Nevada Test Site	4000	20 ton truckload	320	1,280,000	AWC Incorporated
Offload charge at site	2000	LS	1	2,000	Chem-Nuclear
Burial of contaminated media	270	CY	7469	2,016,630	AWC Incorporated
Purchase Backfill	3	CY	6200	18,600	TETC Estimate
Bulldozer to move backfill	1.79	CY	6200	11,098	Means (0222082400)
Compact Fill 12" Lifts	0.45	CY	6200	2,790	Means (0222265620)
Fertilizing/Seeding w/grass	38	MSF	109	4,142	Means (0293082400)
Subtotal				$5,001,471	
Engineering @ 15%				$750,221	
Contamination Control Engineering @10% of all costs except burial cost[3]				$298,484	
Contingency @15%				$750,221	
Total Cost				$6,800,396	

1. These Means unit costs are increased by the multiplier 2.1 for work with hazardous waste. This factor is from the REM IV Cost Estimating Guide by CH2M Hill, March 1987, Table 3, (Factor 6a., Level C and 85 degrees F.).
2. Cost figured @ $2.50/mile for 34 miles.
3. Includes customized design of contamination control system. The estimate uses Offsite Disposal, therefore, no costs are included for Operations and Maintenance.

Table 5-15
Cost Estimate Spreadsheet
Offsite Disposal (Hanford, Washington Disposal)

Capital Costs

Item	Unit Cost ($)	Units	Number of Units	Total Cost ($)	Source
Grub Woodland/Remove Debris	14,810	Acre	1	14,810	Browns Battery
Haul Clean Wood Debris to Municipal Landfill[2]	85	22 ton truckload	5	425	Browns Battery
Plastic Lining and Tarpaulins for trucks	30	Truck	320	9,600	Waste Processors
Excavation of soils	6.70	CY	5167	34,614	Means (0222425400)[1]
Loading Soil (15% of excavation)				5,192	Means (0222380020)
Excavation/Sectioning of Concrete Apron, Utility Bunkers and Shelter 204	339765			339,765	Means (0164602400)[1] Means (020728....)[1]
Excavation of Asphalt (Apron and Drainage Ditch)	7.14	SY	4317	30,823	Means (0205541710)[1]
Loading concrete/asphalt (15% of excavation)				50,966	Means (0222380020)
Excavation of Anomalies for Missile Launcher	98151	LS	1	98,151	Estimate (Table 5-8)
Alpha spectropscopy (Random sampling every 10 trucks)	100	Sample	32	3,200	
Sealand Containers for media	2600	Each	320	832,000	Chem-Nuclear
Health Physics Oversite	1455	Day	180	261,900	TETC Estimate
Hauling contaminated media to Hanford, Washington	4000	20 ton truckload	320	1,280,000	AWC Inc
Offload charge at site	2000			2000	Chem-Nuclear
Burial of contaminated media	72.11	CF	201663	14,541,919	AWC Inc
Purchase Backfill	3	CY	6200	18,600	TETC Estimate
Bulldozer to move backfill	1.79	CY	6200	11,098	Means (0222082400)
Compact Fill 12" Lifts	0.45	CY	6200	2,790	Means (0222265620)
Fertilizing/Seeding w/grass	38	MSF	109	4,142	Means (0293082400)
Subtotal				$17,541,995	
Engineering @ 15%				$2,631,299	
Contamination Control Engineering @10% of all costs except burial cost[3]				$300,008	
Contingency @15%				$ 2,631,299	
Total Cost				$23,104,601	

1. These Means unit costs are increased by the multiplier 2.1 for work with hazardous waste. This factor is from the REM IV Cost Estimating Guide by CH2M Hill, March 1987, Table 3, (Factor 6a., Level C and 85 degrees F.).
2. Cost figured @ $2.50/mile for 34 miles.
3. Includes customized design of contamination control system. The estimate uses Offsite Disposal, therefore, no costs are included for Operations and Maintenance.

Table 5-16

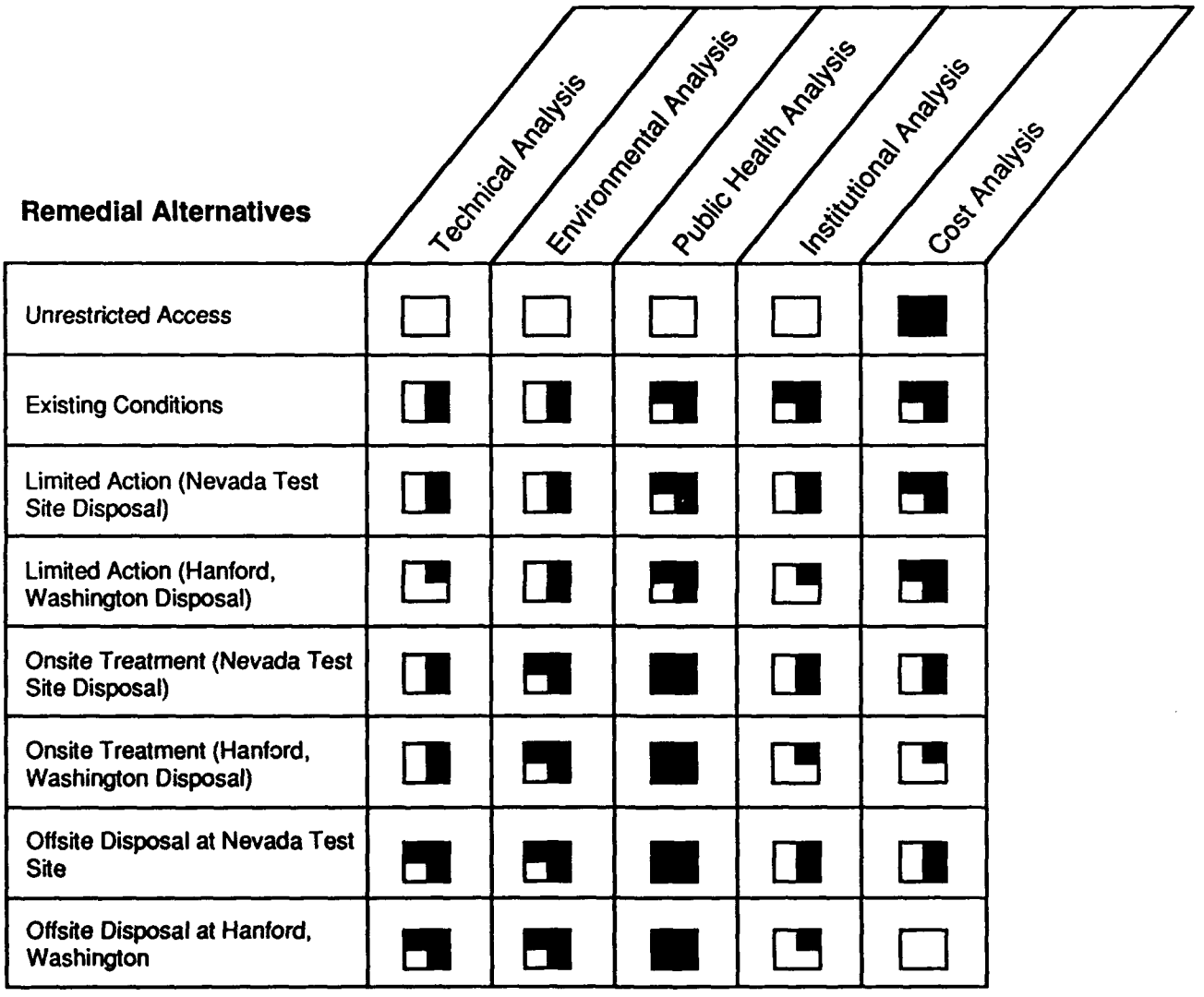
Sensitivity Analysis
Effects of Unit Costs on Total Present Worth Cost

Remedial Alternatives	Total Cost for Different Unit Costs for Disposal*		
	1.5 x Unit Disposal	2 x Unit Disposal	3 x Unit Disposal
Onsite Treatment (Disposal at Nevada Test Site)	$8,870,334	$9,276,616	$10,089,181
Onsite Treatment (Disposal at Hanford, Washington)	$16,463,057	$19,392,760	$25,252,166
Offsite Disposal at Nevada Test Site	$8,111,206	$9,422,015	$12,043,634
Offsite Disposal at Hanford, Washington	$32,556,848	$42,009,096	$60,913,590

*30-year Total Present Worth Cost Bases for these Remedial Alternatives are:

Onsite Treatment with Disposal at Nevada Test Site	$ 8,464,051
Onsite Treatment with Diposal at Hanford, Washington	$13,533,000
Offsite Disposal at Nevada Test Site	$ 6,800,396
Offsite Disposal at Hanford, Washington	$23,104,601

Figure 5-10
Summary of Comparative Analysis of Remedial Alternatives



5.3.7.1 Technical Analysis

The technical analysis of alternatives consists of an evaluation of their performance, reliability, implementability, and safety. The primary performance issue centers on an option's reduction of waste mobility, toxicity, or volume. In this category, the Onsite Treatment approach, employing a volume reduction method followed by secure disposal, affords the highest performance potential. The Offsite Disposal strategy also incorporates reduction in mobility; however, this approach requires offsite transport and secure disposal of 50 to 85 percent greater volumes than the treatment approach. The limited action strategy provides a lesser degree of performance than the two active restoration options through removal of the missile launcher and associated contamination, thereby allowing an onsite management approach to be considered. Maintenance of existing structures and controls, provided in the Existing Conditions strategy, also provide short-term mobility reduction. The Unrestricted Access strategy does not provide any reduction in contaminant mobility, toxicity, or volume as little to not attenuation will occur in the long-term. In terms of demonstrated performance and capability of meeting required specifications for contaminant reduction, the Offsite Disposal option is most preferable, due to its construction activity nature, followed by the treatment alternative, based on pilot plant testing results. The limited action approach follows in demonstrated performance.

Comparative analysis of implementability considerations is more difficult, due to the distinctly different requirements of the feasible approaches. Due to their more complex nature, the Treatment and Disposal options present significantly more challenges than the Existing Conditions, Limited Action, and Unrestricted Access strategies. Each of these approaches poses significant operation-based concerns such as contaminated media collection/segregation, bulking/packaging, transport, and secure disposal. Under the treatment alternative, proper operation of the separation systems is most significant, especially in light of the fact that effective decontamination of the concrete at the site is uncertain. For the Offsite Disposal alternative, tight field control is essential in order to remove only those soils above the health-based clean-up level, with over-excavation significantly impacting disposal costs.

As with implementability, the Treatment and Disposal approaches pose the most significant short-term safety issues to workers and the community. This is due to the potential for release during excavation/treatment at increased rates as compared to current migration rates. The long-term benefits far outweigh these short-term concerns as engineered controls, properly employed, minimize risks during excavation/treatment. The Existing Conditions, Limited Action and Unrestricted Access alternatives rank high in terms of offsite concerns, however, safety issues increase for onsite (Unrestricted Access) and potential long-term onsite (Existing Conditions and Limited Action) exposure scenarios evaluated.

5.3.7.2 Environmental Analysis

Each alternative (excluding the Unrestricted Access alternative) uses distinct means to reduce risks posed by conditions at the BOMARC Missile Site. The Existing Conditions and Limited Action approaches attempt to eliminate onsite exposure to a known amount and level of contamination and minimize transport of onsite stabilized contamination. These strategies address scenarios posing risks within the EPA's benchmark remediation range. In the short-

term, these strategies are considered effective, however their long-term success, a function of the persistent nature of the contamination, remains a major unknown.

Environmental issues associated with Onsite Treatment and Offsite Disposal are essentially similar. Both remediation approaches employ construction elements to collect contaminated media. These options both remove contaminant sources as a means of eliminating exposure scenarios. Both alternatives are ranked highly based on this. This Offsite Disposal alternative is slightly more favorable than Onsite Treatment in terms of short-term risks during implementation, due to decreased waste handling.

5.3.7.3 Public Health Analysis

In terms of residual contamination, three levels may exist after implementation of the five alternatives. The scenarios are:

- Based on the RI, the average surface concentration is approximately 32 pCi/g for Pu-239 and 5.4 pCi/g for Am-241. For the Unrestricted Access Alternative, onsite residual risk for the MEI will remain 1.3×10^{-3} with offsite risk at 7.0×10^{-9}. Uncertainties in these values are associated with missile launcher location and contamination.

- With the Existing Conditions alternative, onsite contaminant levels remain similar to the Unrestricted Access options. Residual source terms are equivalent; however, the exposure scenario posing significant risk (MEI) is controlled, particularly in the short-term.

- Risk reduction for the Limited Action alternative is similar to that of the Existing Conditions alternative, with added risk reduction in the form of launcher removal, which eliminates uncertainties associated with the launcher.

- For both Onsite Treatment and Offsite Disposal, the maximum onsite activity level will be 8 pCi/g after remediation. This level corresponds to an acceptable radiation dose of 4 mrem/yr, which represents a lifetime cancer risk of less than 10^{-4}.

Based on this information, treatment or disposal alternatives are ranked highly, each providing adequate protectiveness for onsite and offsite exposures. Limited Action and Existing Conditions offer risk reduction where necessary; however, contamination remains in-place with long-term management remaining uncertain. The Unrestricted Access approach poses significant risks for onsite exposure scenarios. For the highly ranked options, the primary discriminating factor is the length which contaminants must be transported, the shorter distances being more desirable.

5.3.7.4 Institutional Analysis

The Institutional Analysis assesses an alternative's ability to satisfy requirements contained in Federal, state and local law, regulations and guidance pertaining to design, operation, and

implementation of the alternatives. This analysis incorporates chemical-specific, action-specific and location-specific ARARs and TBCs.

All alternatives except Unrestricted Access effectively achieve risk reduction by eliminating the exposure scenario that causes risk (HMEI scenario). Neither the Existing Conditions nor the Limited Action alternatives achieve quantitative health-based or regulatory-based cleanup criteria; however, these criteria apply to unrestricted sites, and therefore do not apply to either alternative. Neither alternative achieves reduction of mobility, toxicity, or volume, as preferred under SARA.

Both the Onsite Treatment and the Offsite Disposal alternatives achieve health-based and regulatory-based cleanup criteria. The Onsite Treatment alternative achieves these goals through waste volume reduction, as preferred under SARA. The Offsite Disposal alternative achieves these goals through removal and offsite disposal, which under SARA is the least preferred alternative where viable treatment options exist.

Additional institutional issues are associated with offsite disposal of wastes. These issues affect the Limited Action, Onsite Treatment, and Offsite Disposal alternatives, but do not affect the Unrestricted Access or Existing Conditions alternatives, which is an advantage of the latter two alternatives.

All of the alternatives involving an offsite disposal component (Limited Action, Onsite Treatment, Offsite Disposal) have the potential to be severely impacted by institutional issues which prevent the Nevada Test Site and commercial disposal facilities from accepting wastes with activities exceeding 100 nCi/g. If soils, concrete/asphalt or materials associated with the missing missile launcher exceed 100 nCi/g, then the materials in question cannot be disposed of offsite until a high-level waste repository is licensed at some time in the future. RI results indicate that neither soils nor concrete/asphalt materials are likely to exceed 100 nCi/g, however, it is possible that materials not sampled exceed 100 nCi/g. The activity associated with the launcher cannot be determined until the launcher is located and excavated. The uncertainty associated with the activity levels on or around the launcher and associated with materials not sampled during the RI is a disadvantage for the active restoration alternatives.

For all three alternatives involving offsite disposal, availability of an offsite disposal facility that can accept radioactive wastes from New Jersey is also a limiting factor. The LLRWPAA may effectively eliminate the option of disposal in a commercial facility after January 1993. However, as long as wastes are below 100 nCi/g, the Nevada Test Site can accept the wastes. As already discussed, this is a potential problem for all three alternatives with respect to the launcher and other materials. For the Onsite Treatment alternative, this could also be a problem if treatment processes concentrate wastes above 100 nCi/g. However, RI results indicate that with 90 percent volume reduction, concentrated soils will be well below 100 nCi/g. Strict engineering controls will be necessary to prevent concentration of wastes above 100 nCi/g.

5.3.7.5 Cost Analyses

Cost effectiveness is a critical component driving alternative feasibility. Through this FS effort, present worth costs have been developed for each alternative and for key options within

alternatives, where appropriate. Table 5-6 presents a summary of present worth costs for all alternatives. No costs are associated with the Unrestricted Access alternative. For the Existing Conditions alternative, approximately $830,000 is required for a thirty year performance period. For the Limited Action alternative, approximately $957,000 to $1,183,000 is required for a thirty year performance period. A significant factor which may increase costs by 30 to 40 percent is the performance period. Active restoration costs range from $6.8M to $23.1M. The Offsite Disposal option at Nevada Test Site represents the minimum at $6.8M, followed by the two treatment scenarios at $8.46M and $13.53M. The most costly alternative is the Offsite Disposal alternative at Hanford, Washington at $23.1M.

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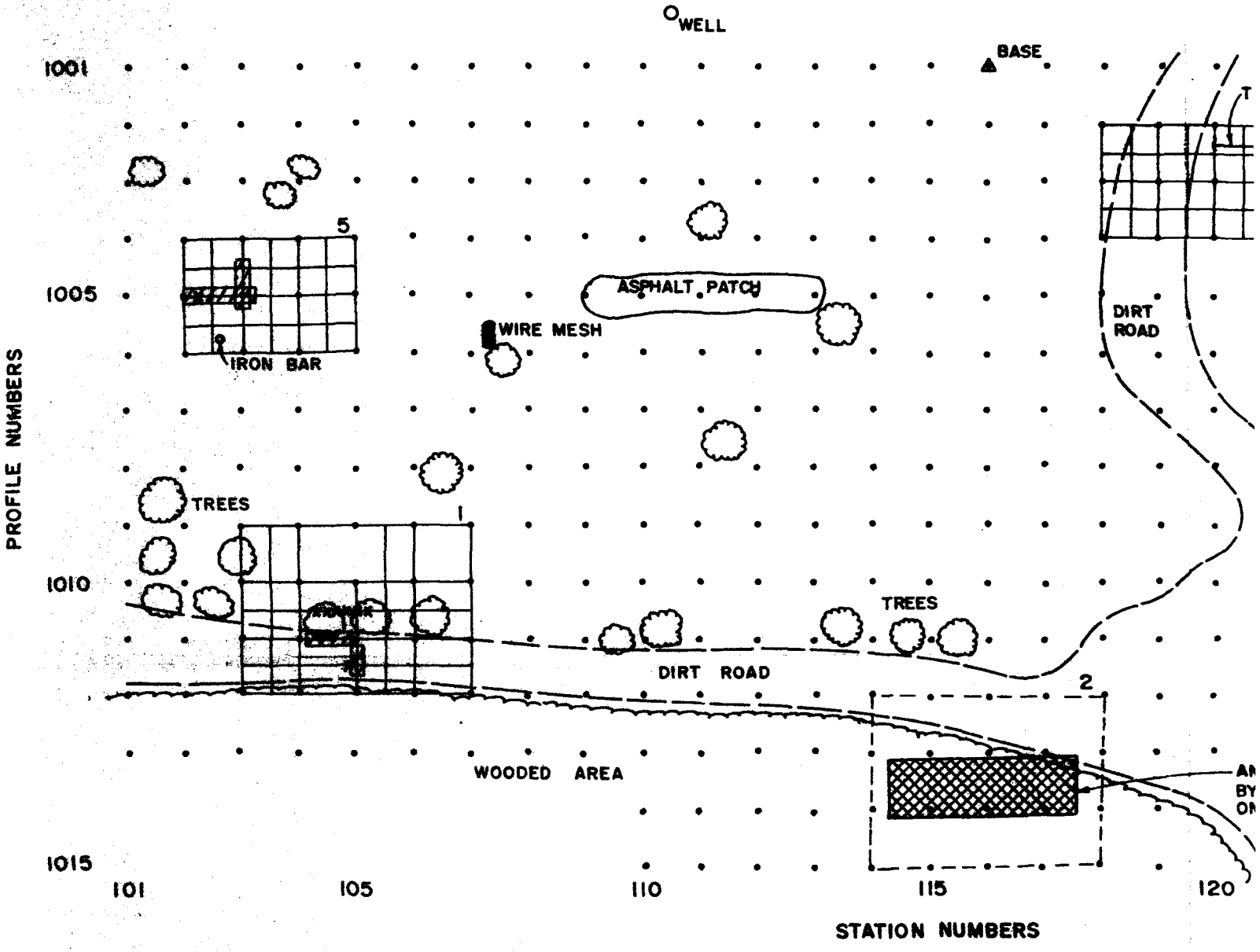

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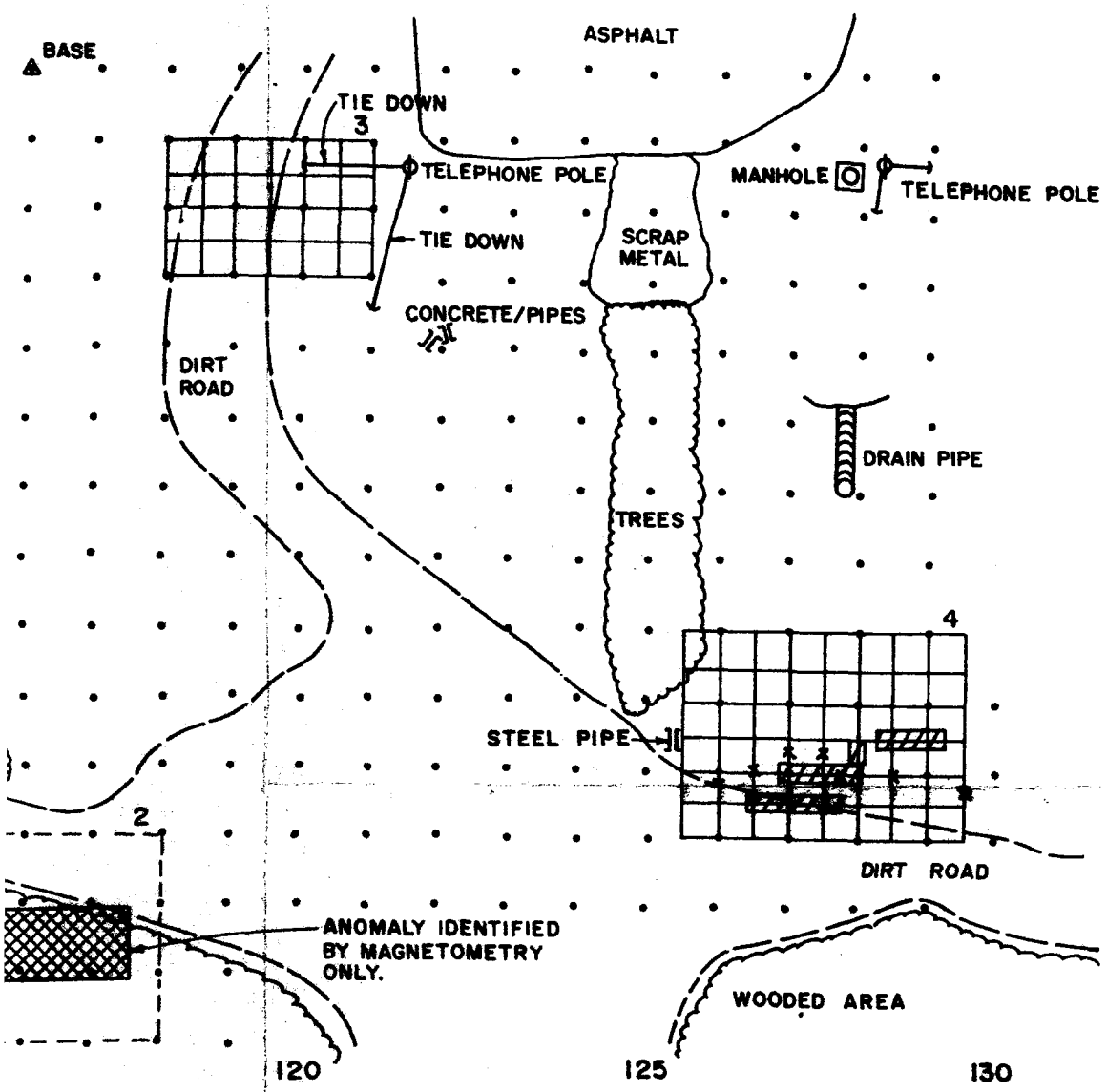

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EXPLANATION

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SCALE IN FEET

PLATE 3-1

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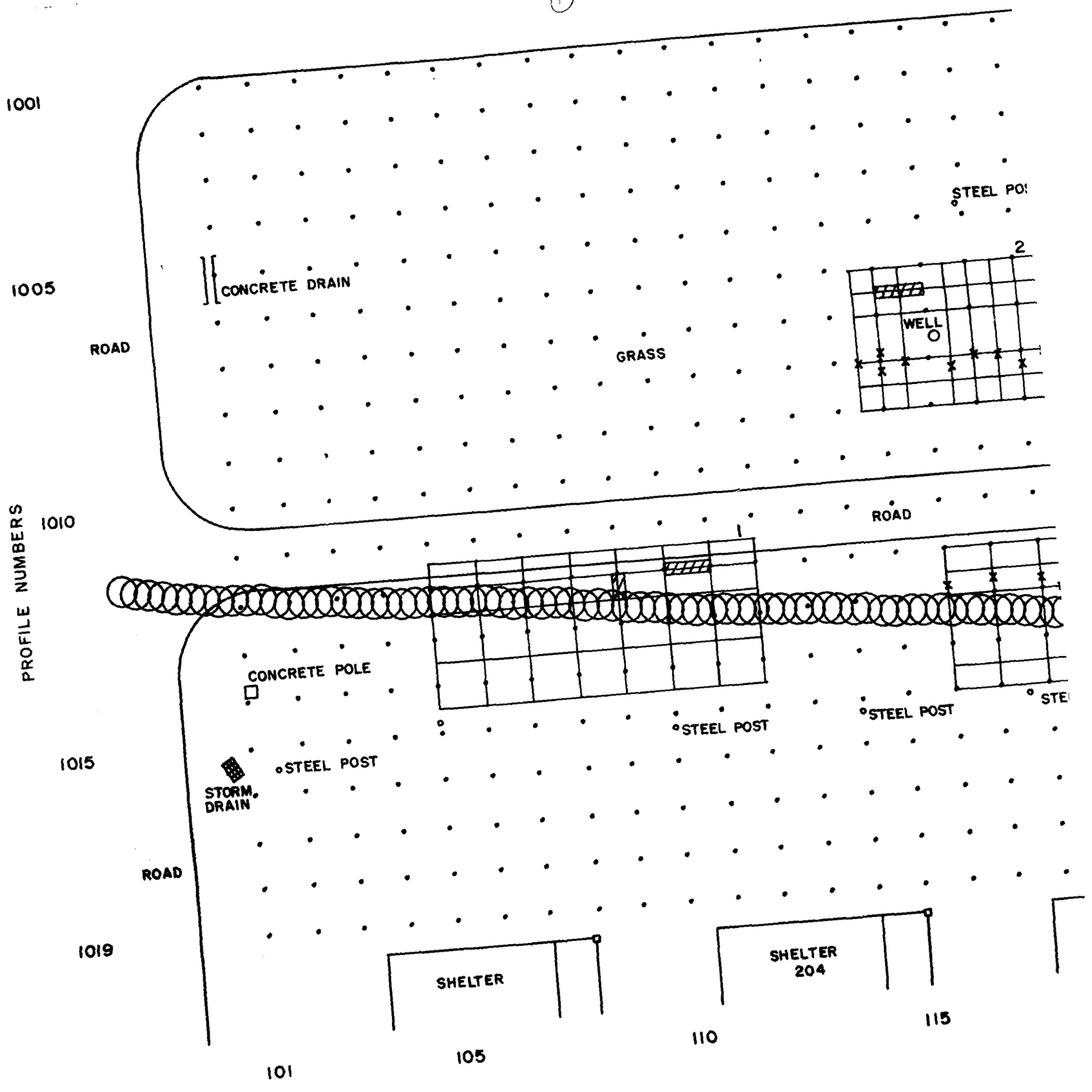
SITE 1 BASE MAP

SHOWING SPK SUBSETS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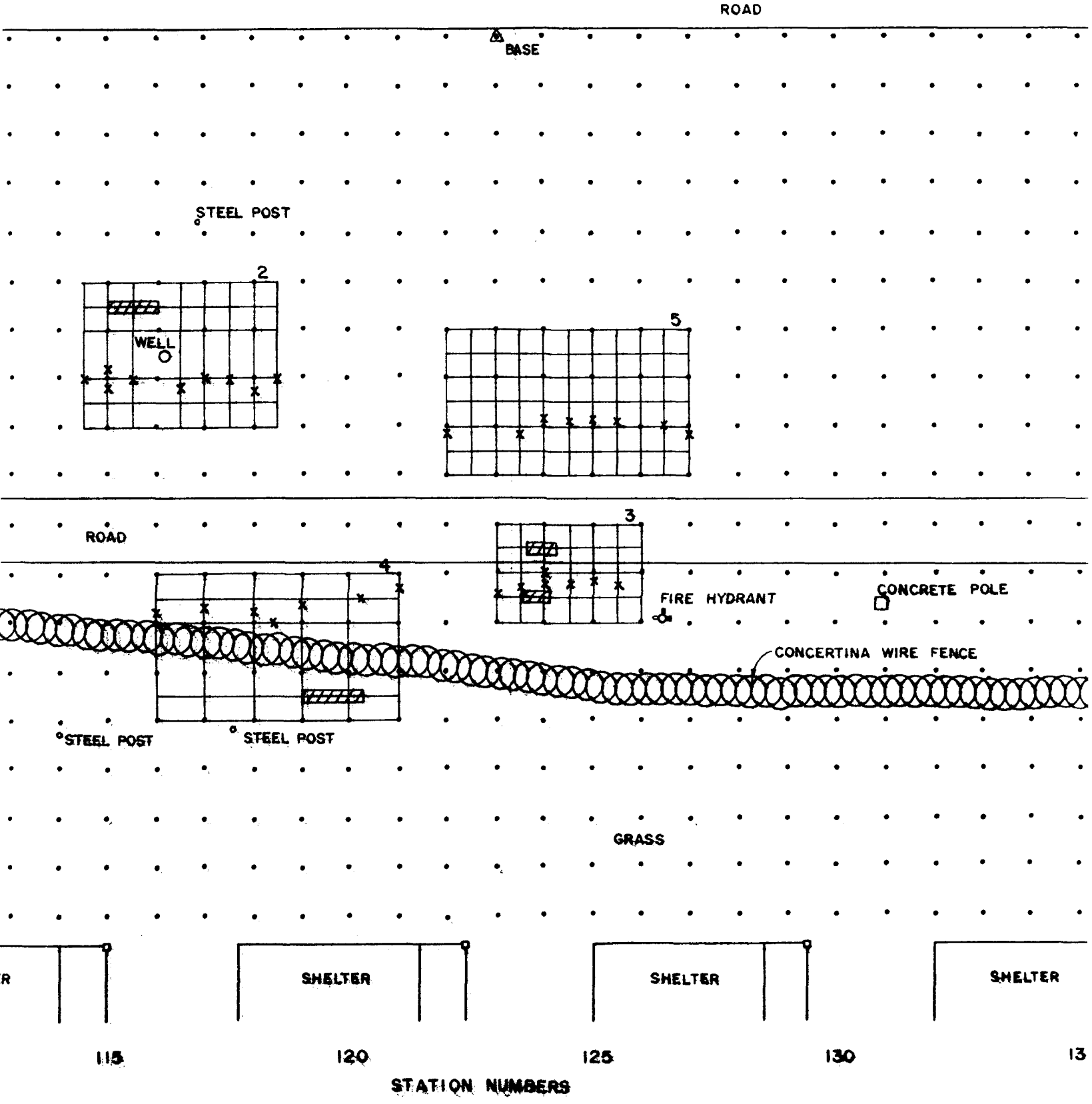
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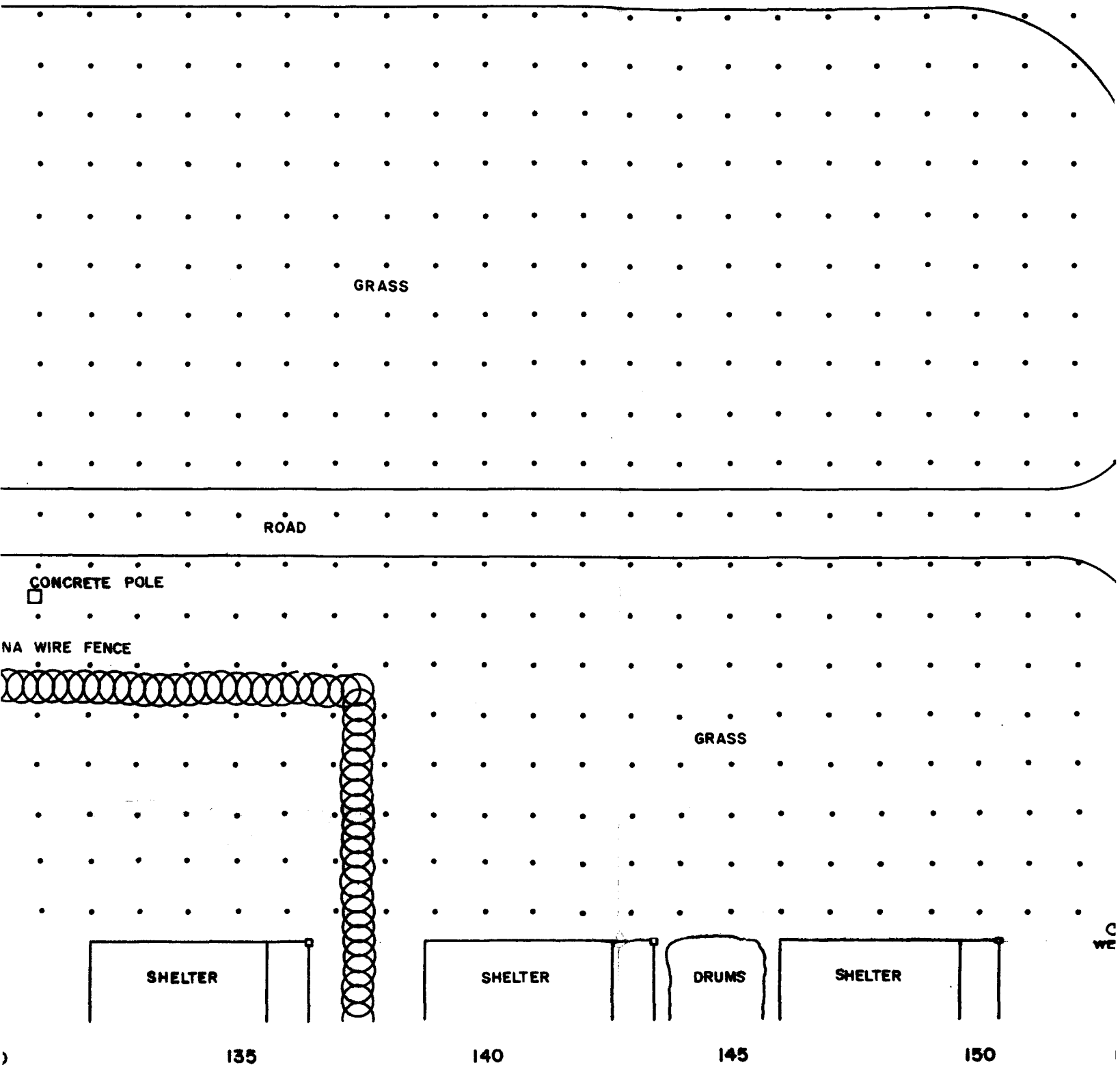
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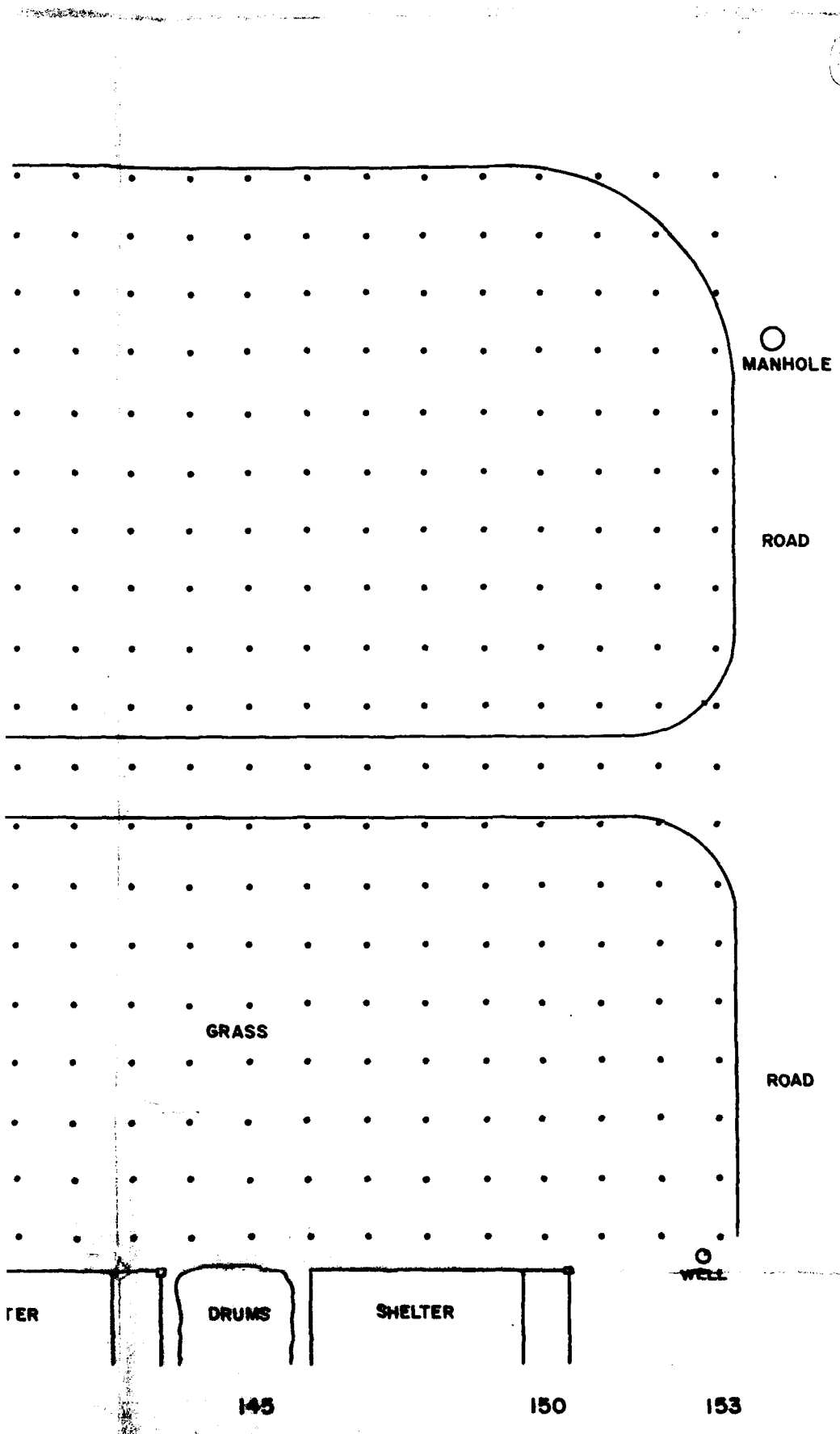
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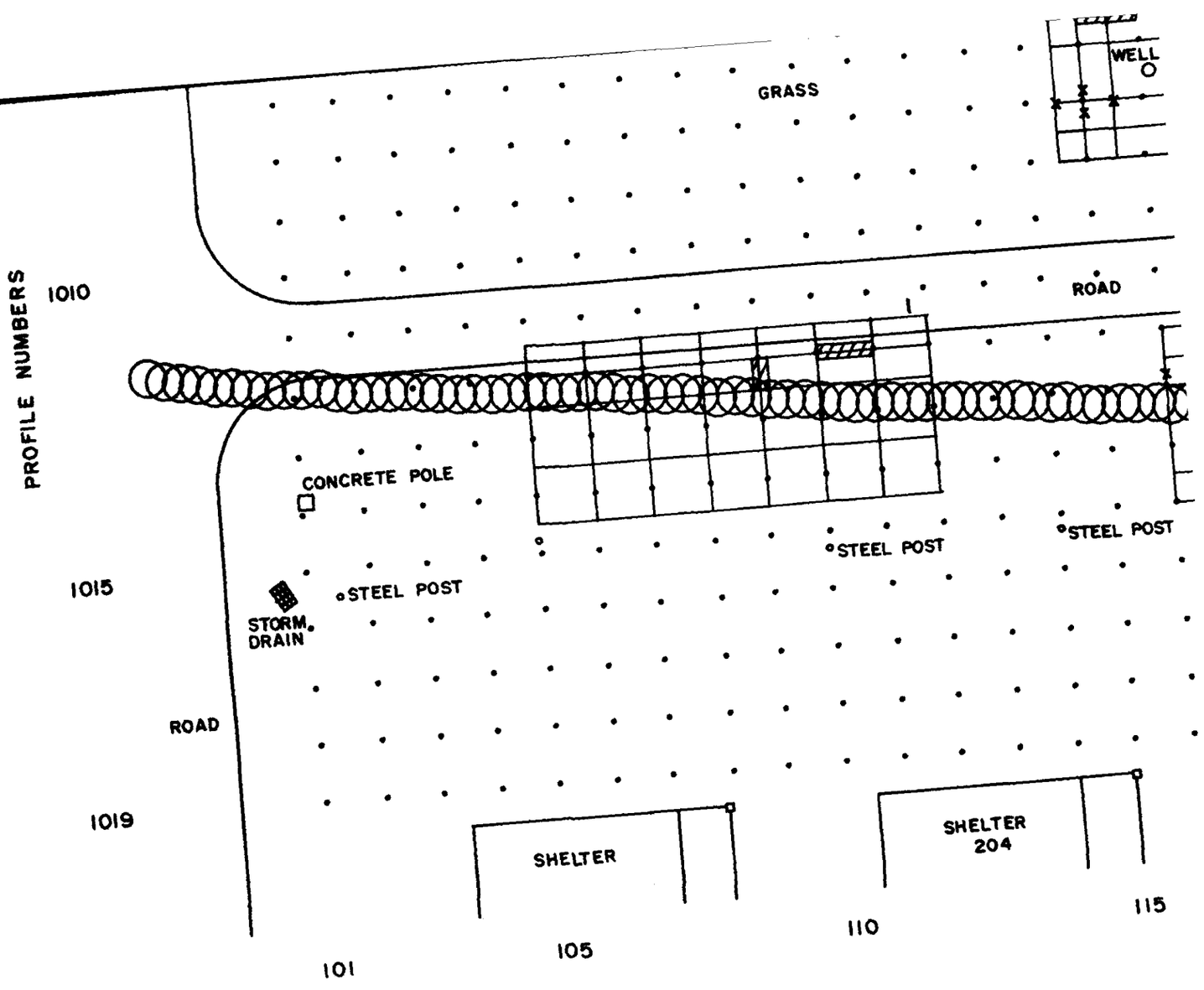
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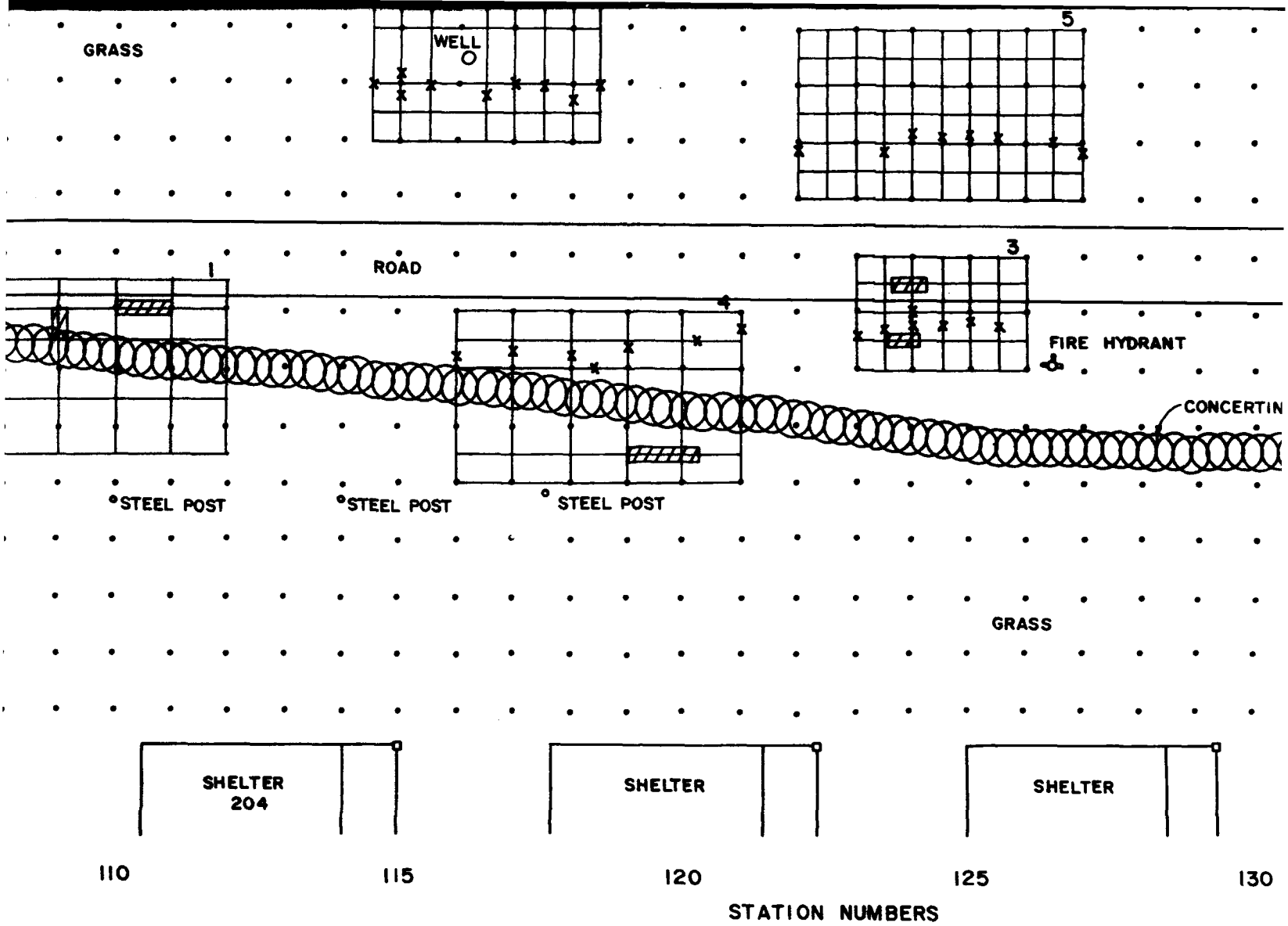
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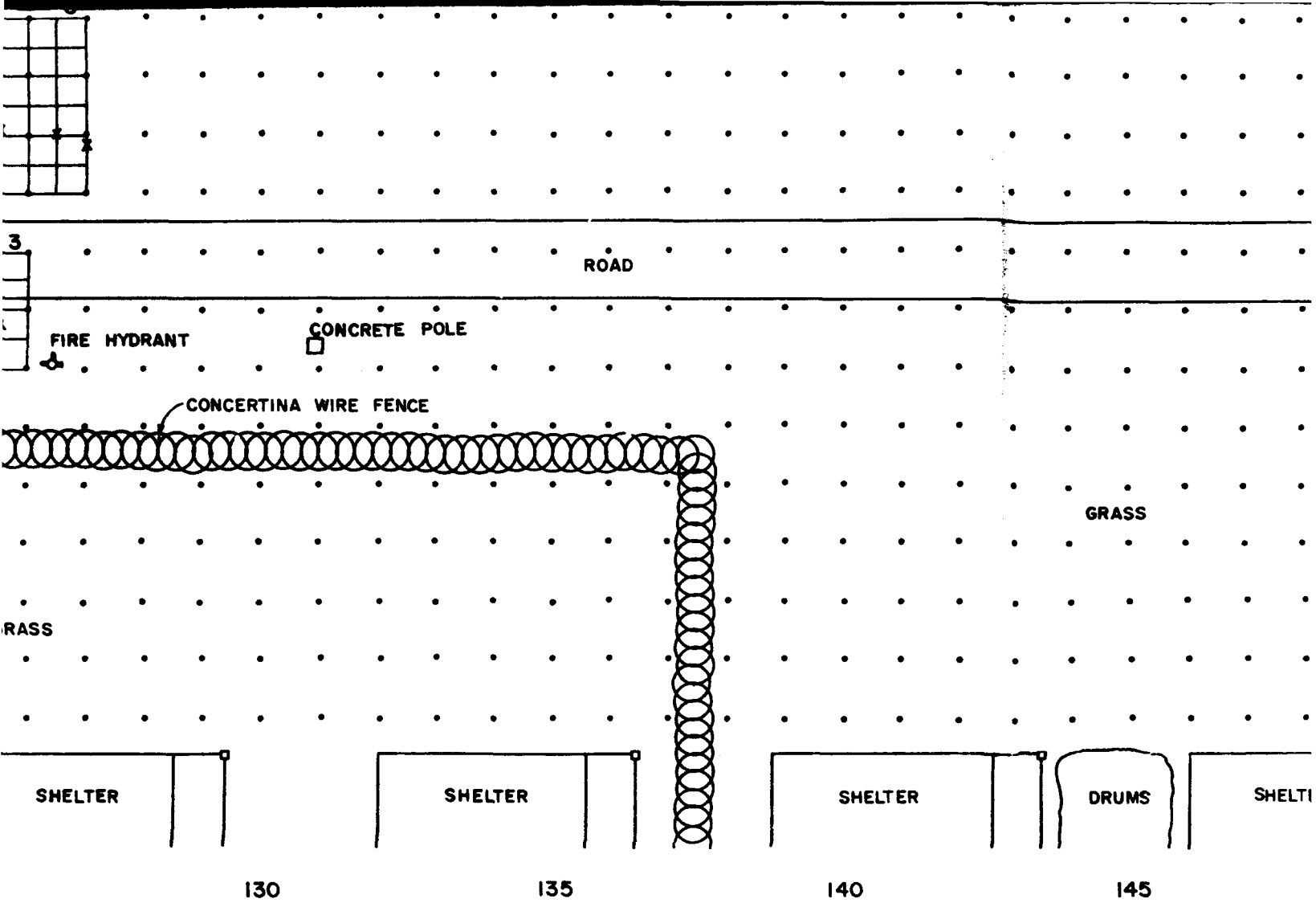

EXPLANATION

- MEASUREMENT STATION
- GPR GRID AND LABEL
- METALLIC TARGET
- DISTURBED SOIL ZONE
- CULTURAL FEATURES AS INDICATED

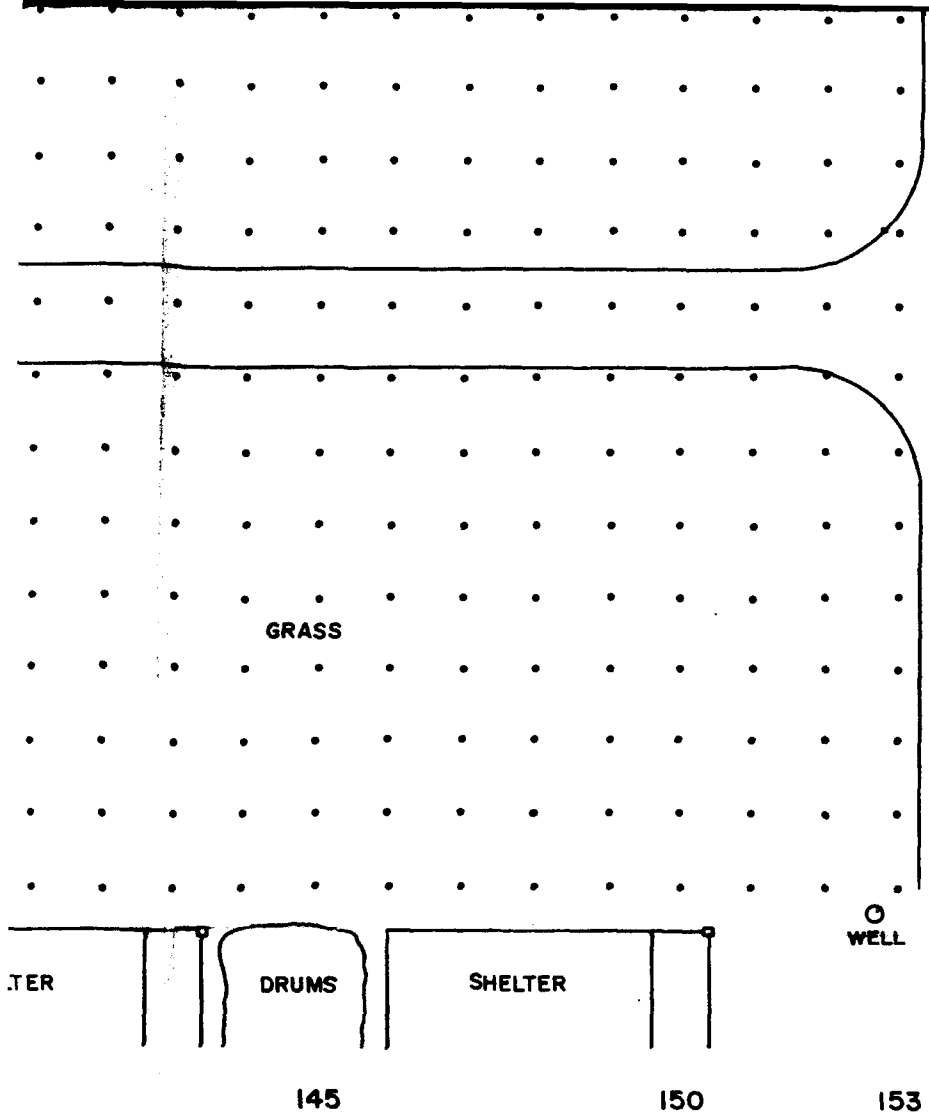

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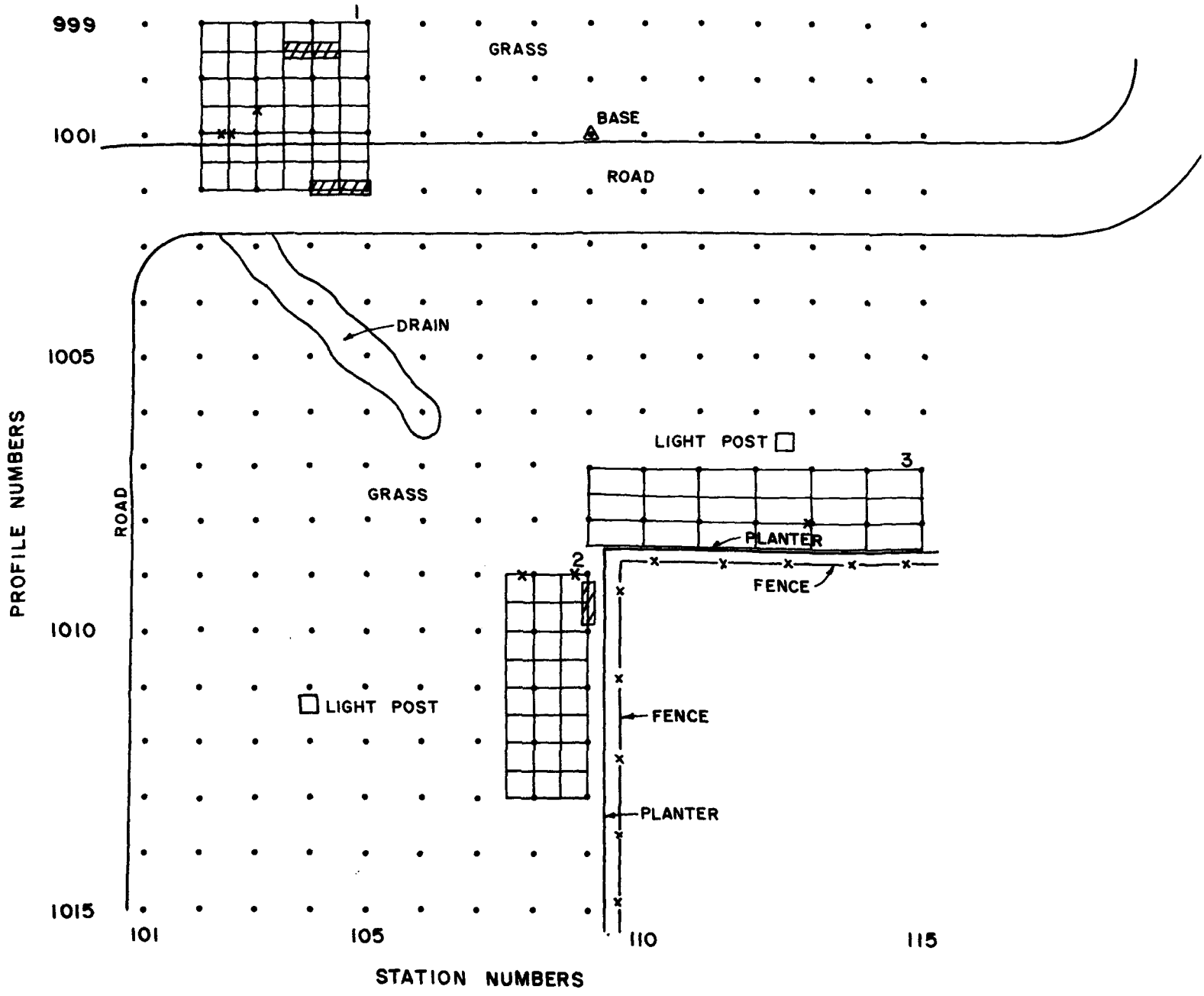
PLATE 3-2

OEHL-BOMARC
SITE 2 BASE MAP
SHOWING GPR RESULTS

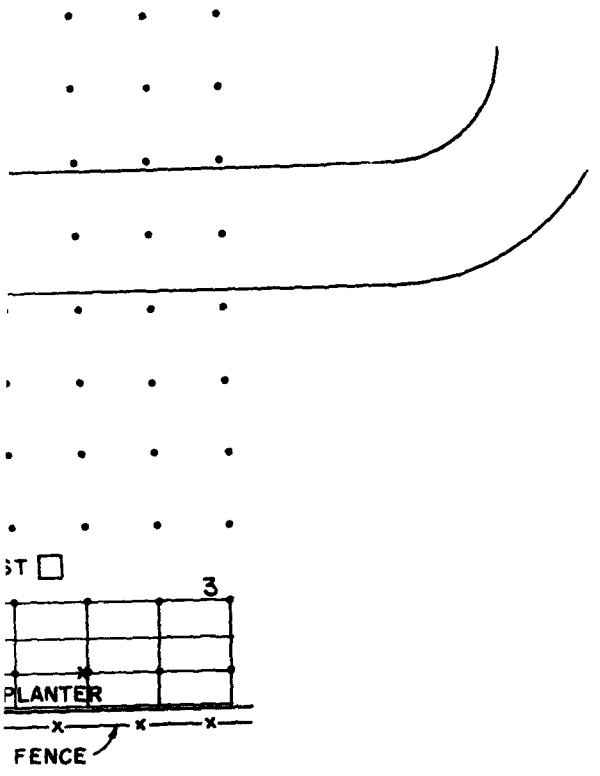


EXPLANATION

- MEASUREMENT STATION
- GPR GRID AND LABEL
- METALLIC TARGET
- DISTURBED SOIL ZONE

CULTURAL FEATURES AS INDICATED

0



NATION

IEASUREMENT STATION

IPR GRID AND LABEL

IETALLIC TARGET

ISTURBED SOIL ZONE

URAL FEATURES AS INDICATED

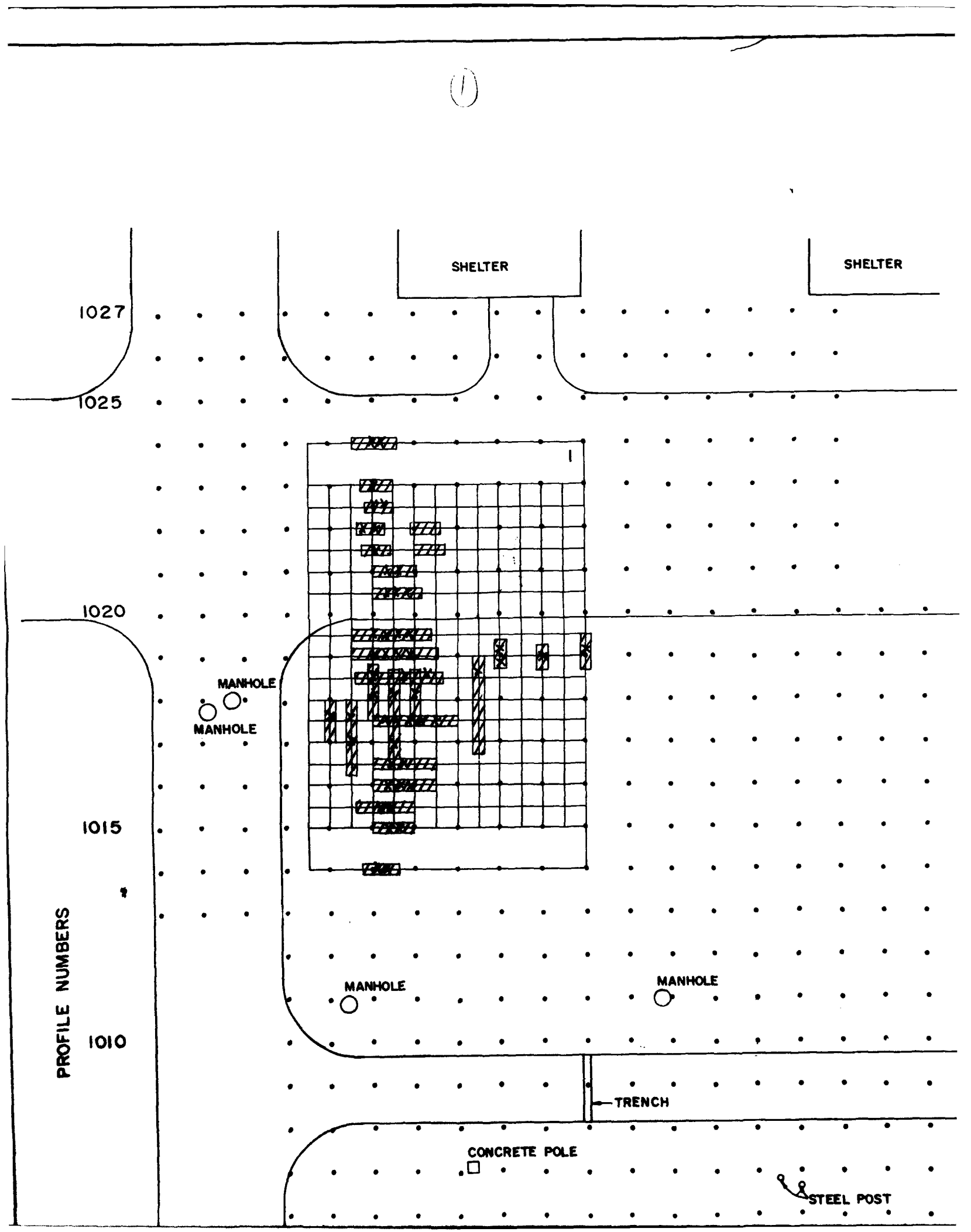
NORTH

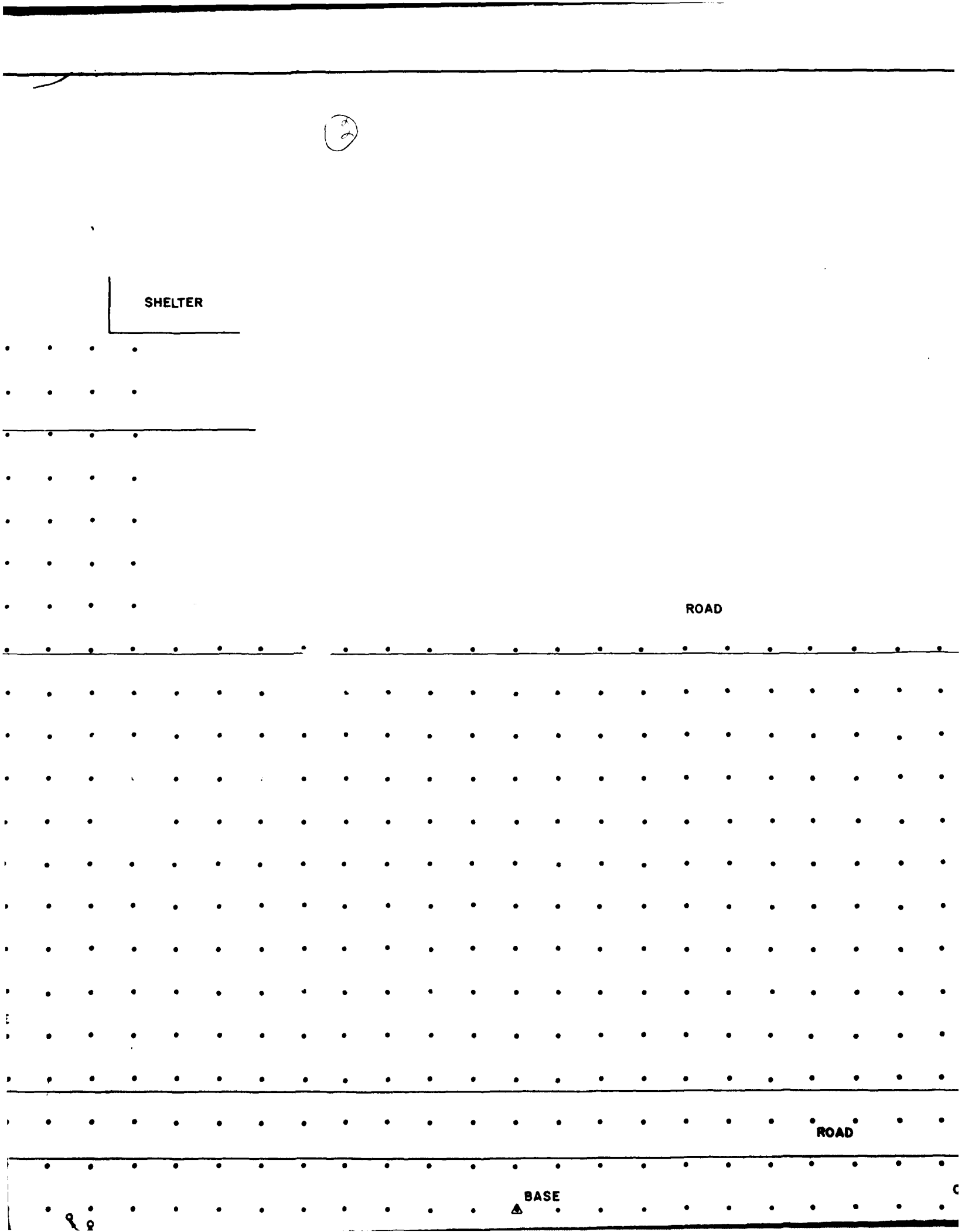
0 20 40

SCALE IN FEET

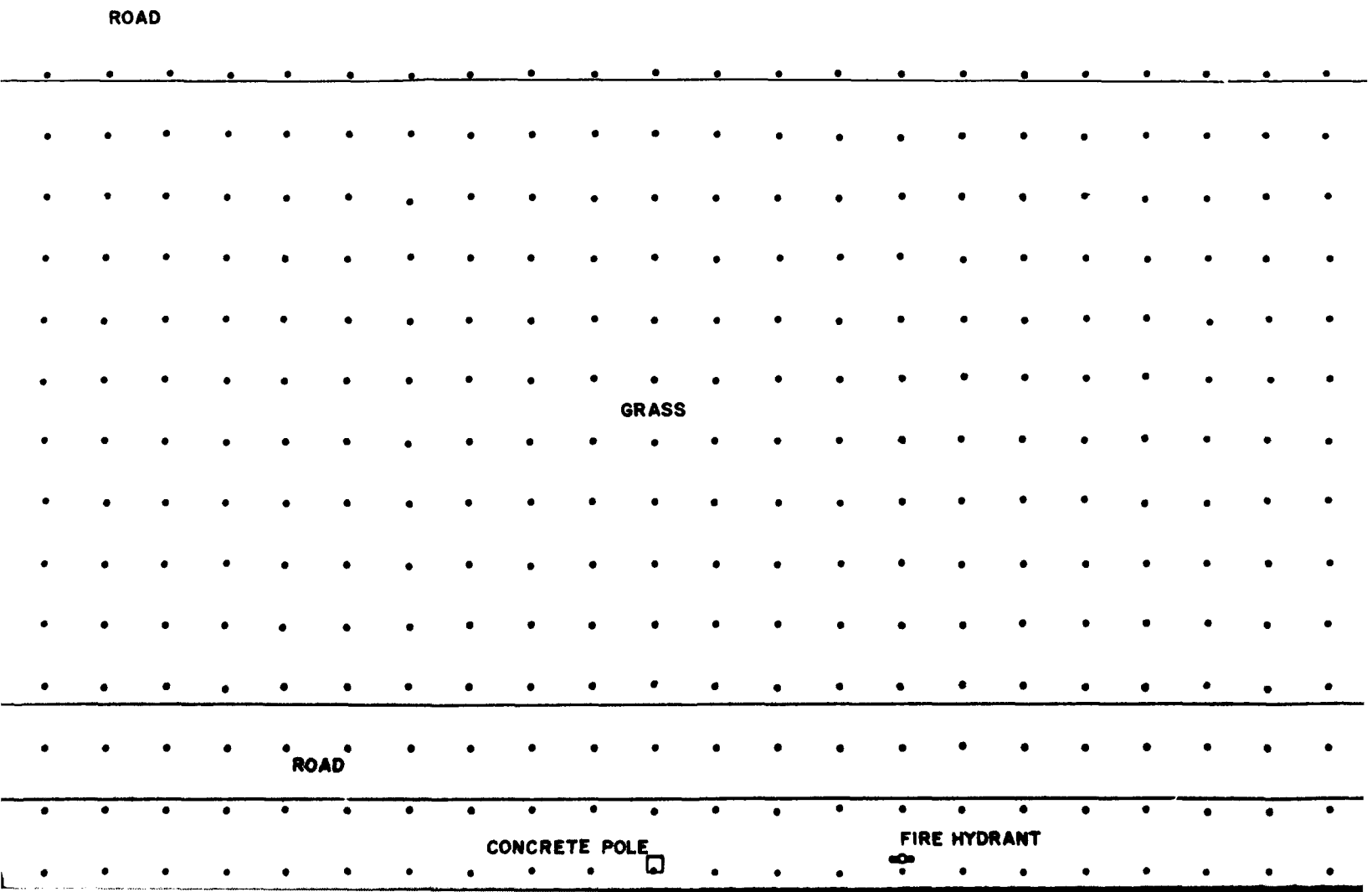
PLATE 3-3

OEHL-BOMARC
SITE 3 BASE MAP
SHOWING GPR RESULTS


SHELTER
SHELTER
1027
1025
1020
1015
1010
PROFILE NUMBERS
MANHOLE
MANHOLE
MANHOLE
MANHOLE
TRENCH
CONCRETE POLE
STEEL POST


SHELTER
ROAD
ROAD
BASE

(3)

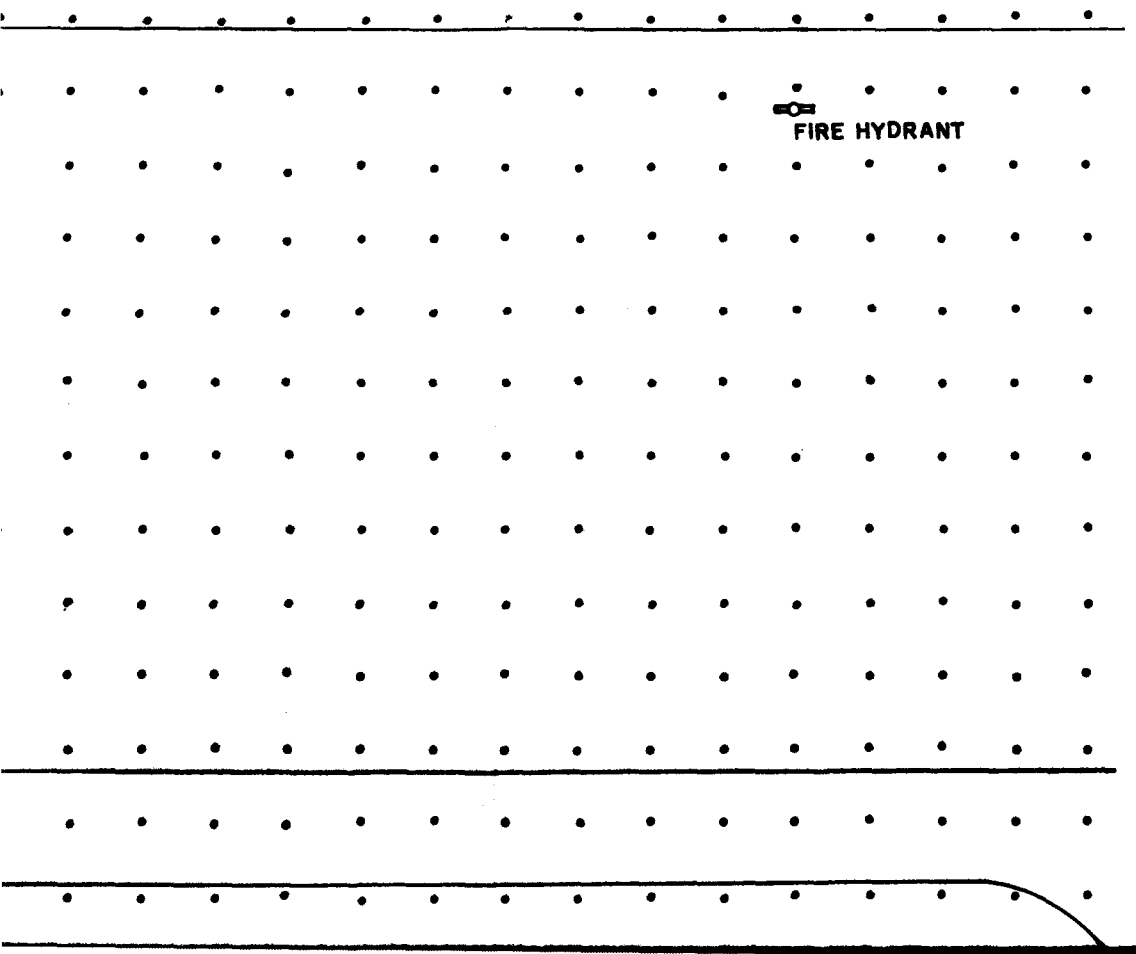


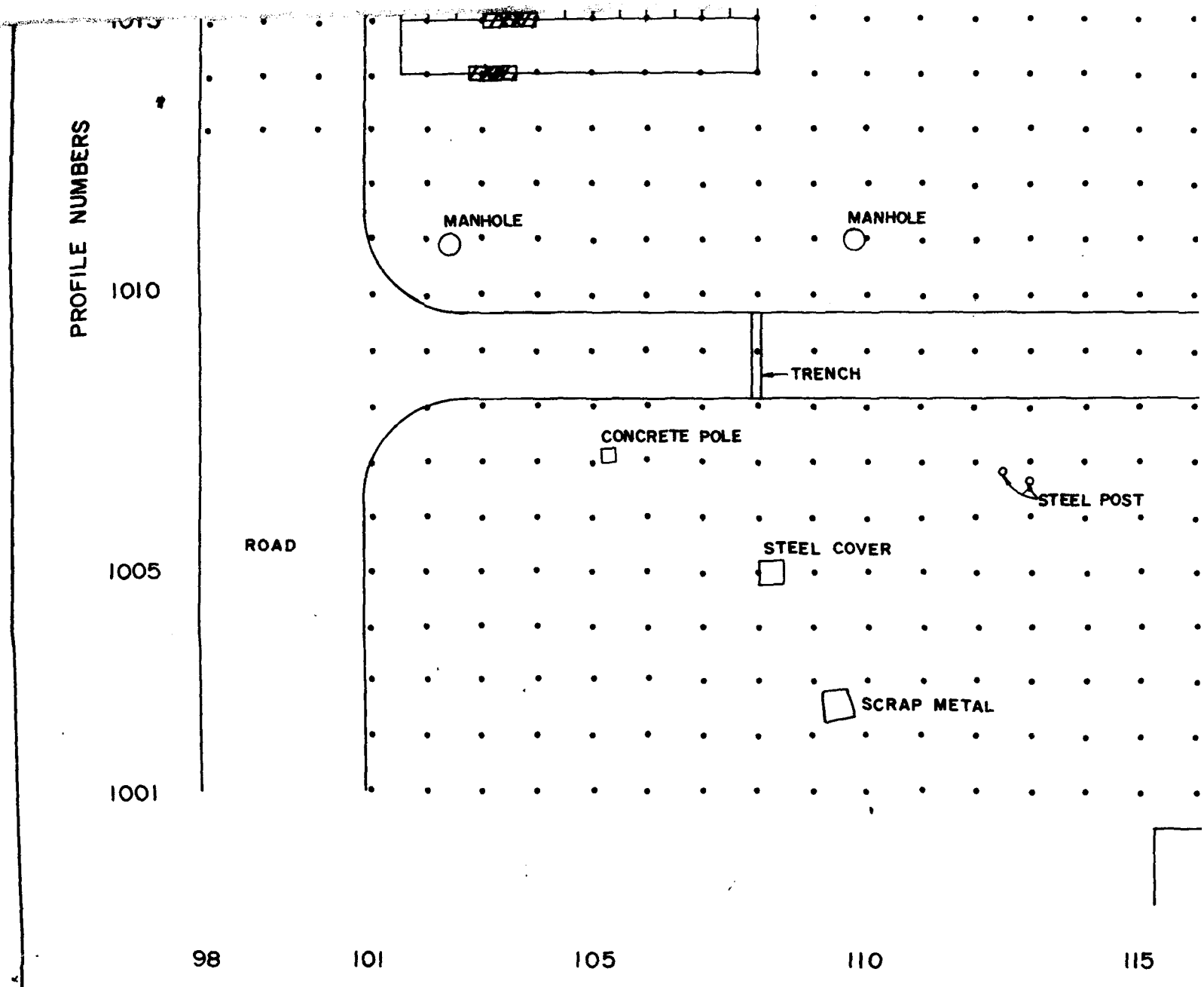
(4)

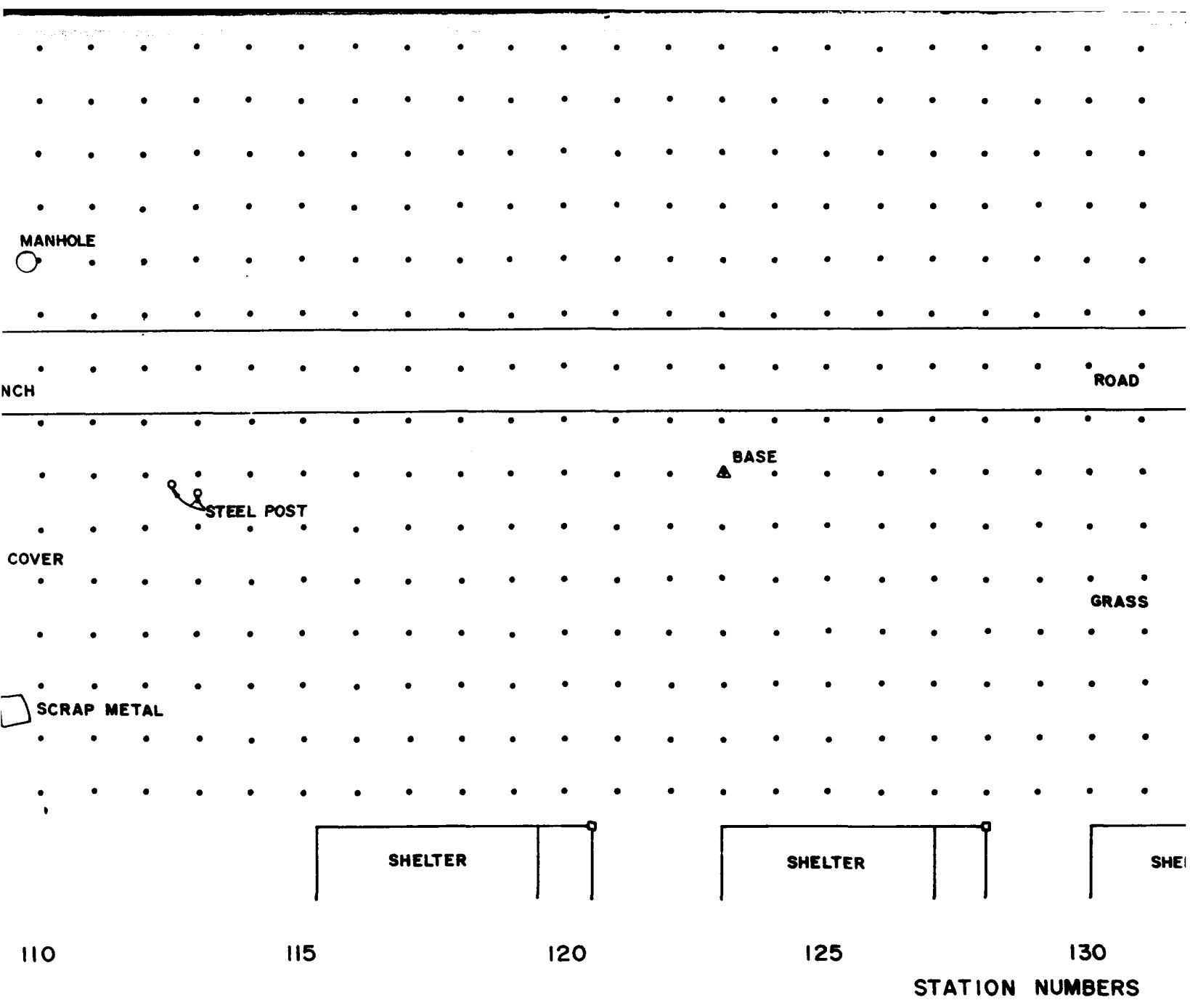
HYDRANT

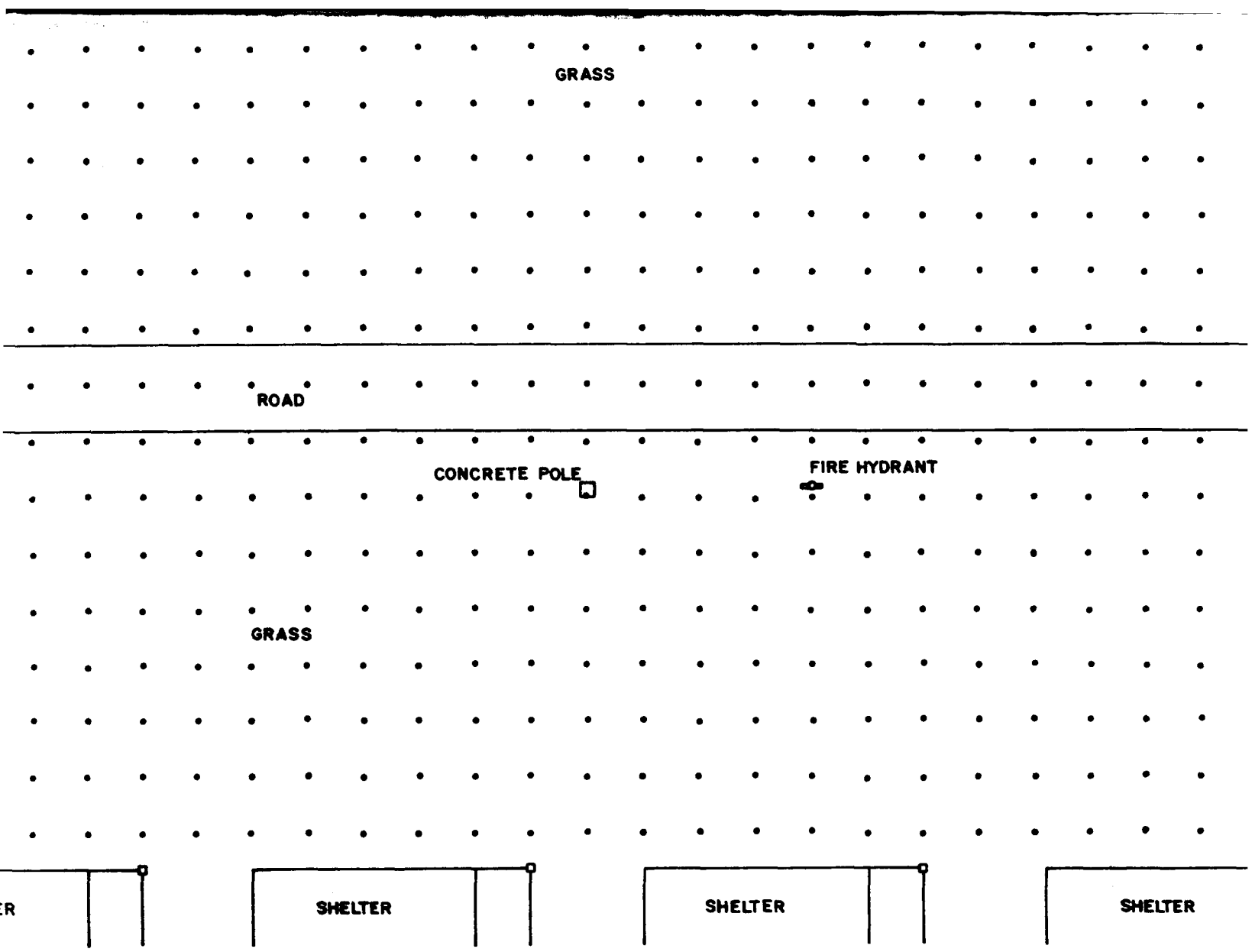
(4)

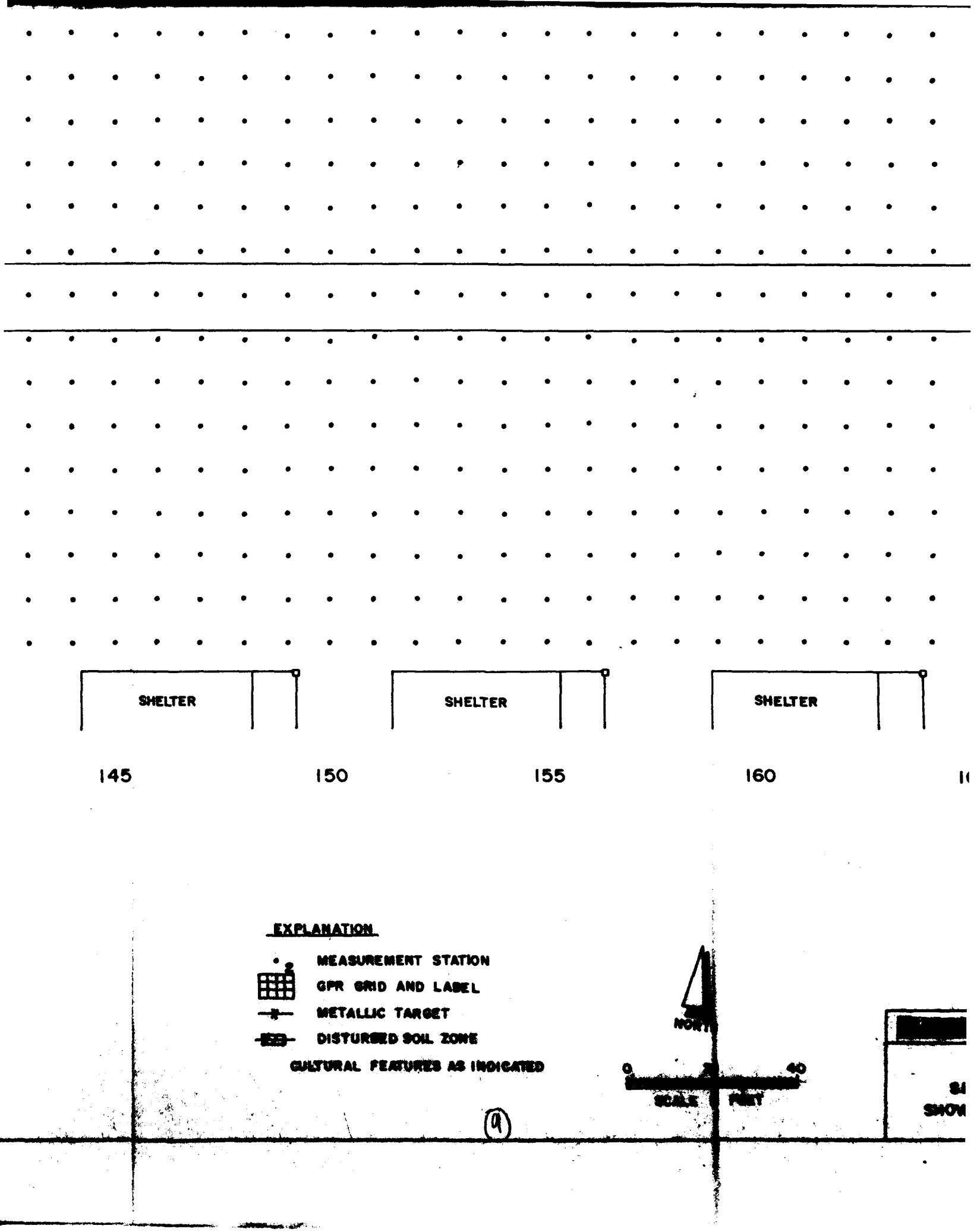
(5)

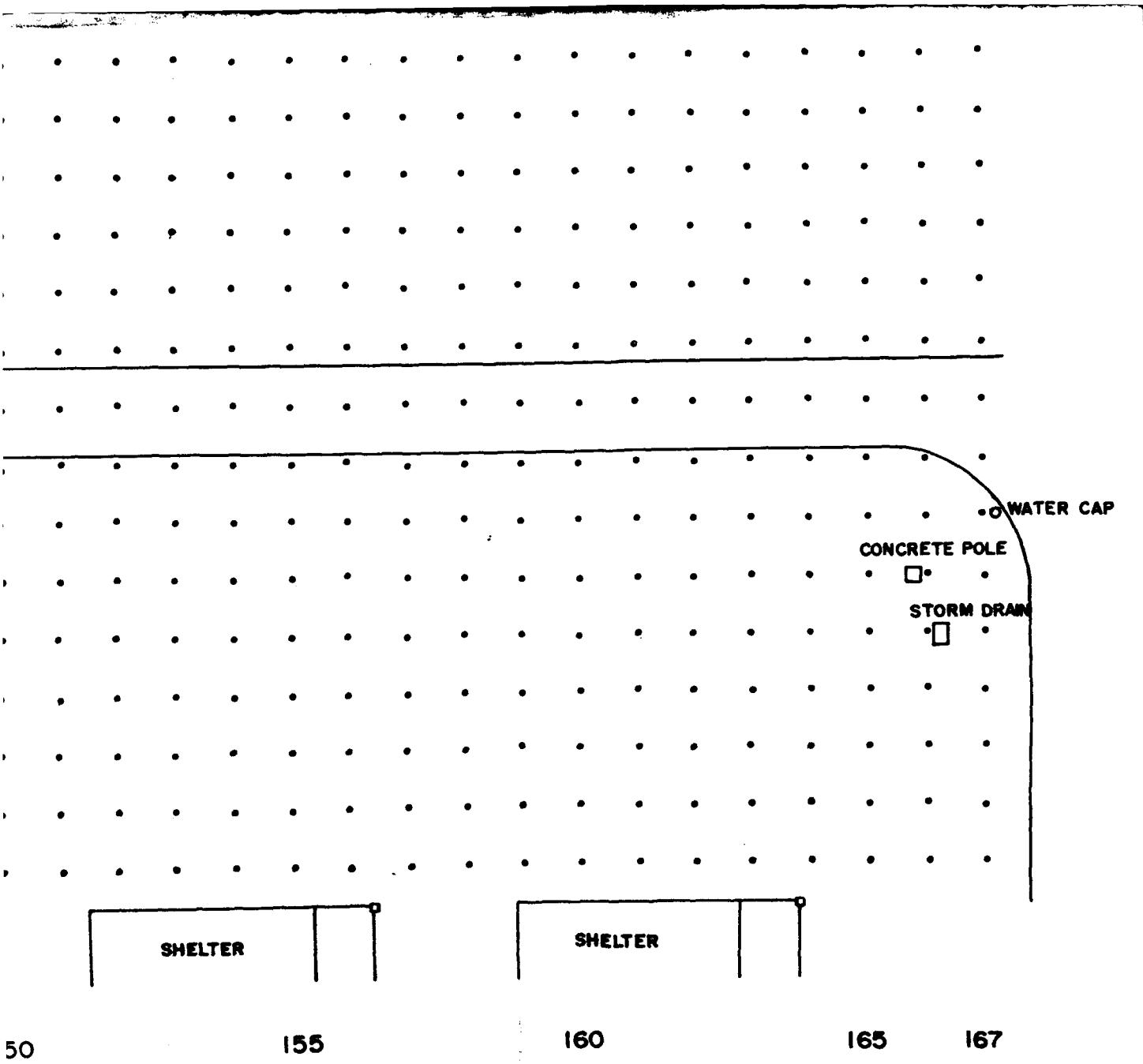



PROFILE NUMBERS
1010
1005
1001
MANHOLE
MANHOLE
TRENCH
CONCRETE POLE
STEEL POST
ROAD
STEEL COVER
SCRAP METAL
98
101
105
110
115


MANHOLE
NCH
ROAD
BASE
STEEL POST
COVER
GRASS
SCRAP METAL
SHELTER
SHELTER
SHE
110
115
120
125
130
STATION NUMBERS


GRASS
ROAD
CONCRETE POLE
FIRE HYDRANT
GRASS
ER
SHELTER
SHELTER
SHELTER
130
135
140
145
STATION NUMBERS


SHELTER
SHELTER
SHELTER
145
150
155
160
EXPLANATION
MEASUREMENT STATION
GPR GRID AND LABEL
METALLIC TARGET
DISTURBED SOIL ZONE
CULTURAL FEATURES AS INDICATED
NORTH
0
40
SCALE
FEET



IATION

IEASUREMENT STATION

PR GRID AND LABEL

IETALLIC TARGET

ISTURBED SOIL

URAL FEATURES AS INDICATED

NORTH

0 40

SCALE FEET

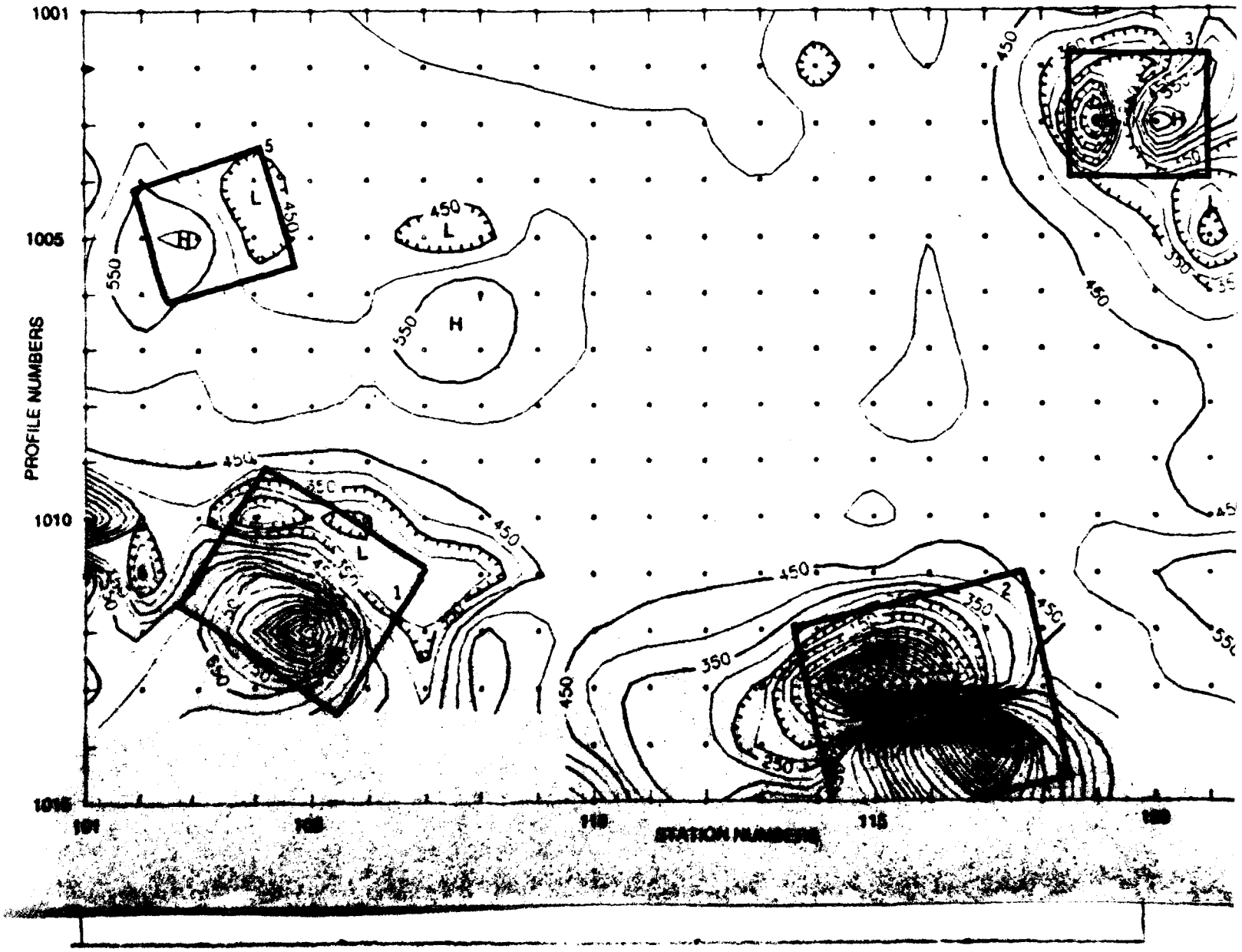
PLATE 3-4

GEOPHYSICAL SITE 4 BASE MAP SHOWING GPR RESULTS

(10)

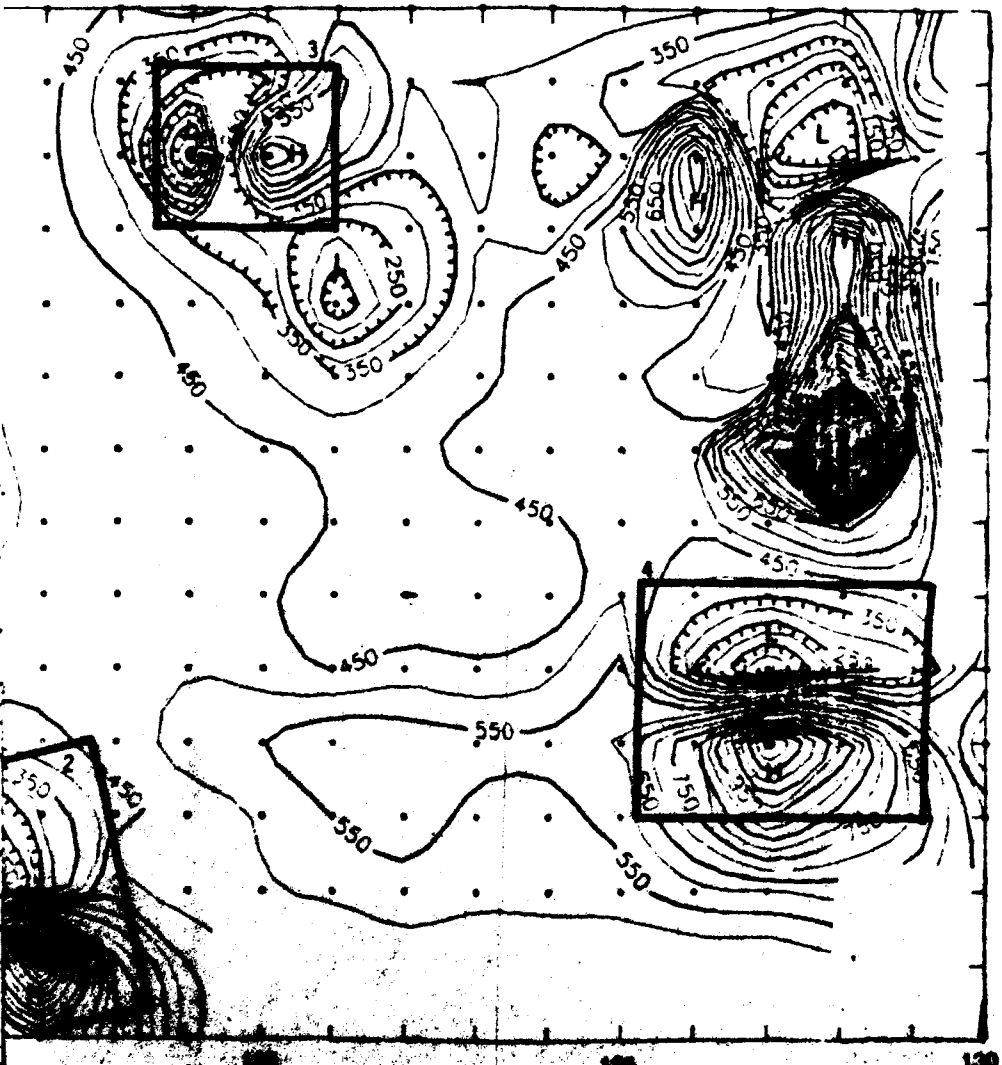
(1)

BOMARC SITE 1 TOTAL FIELD



(2)

TAL FIELD



NORTH

0 20 40 Feet

SCALE

EXPLANATION

0 MEASUREMENT STATION

~500~ CONTOUR LINE WITH MAGNETIC VALUE (TOTAL FIELD) IN GAMMAS, DRIFT CORRECTED

A CONSTANT VALUE OF 54,000 GAMMAS WAS SUBTRACTED FROM THE DATA

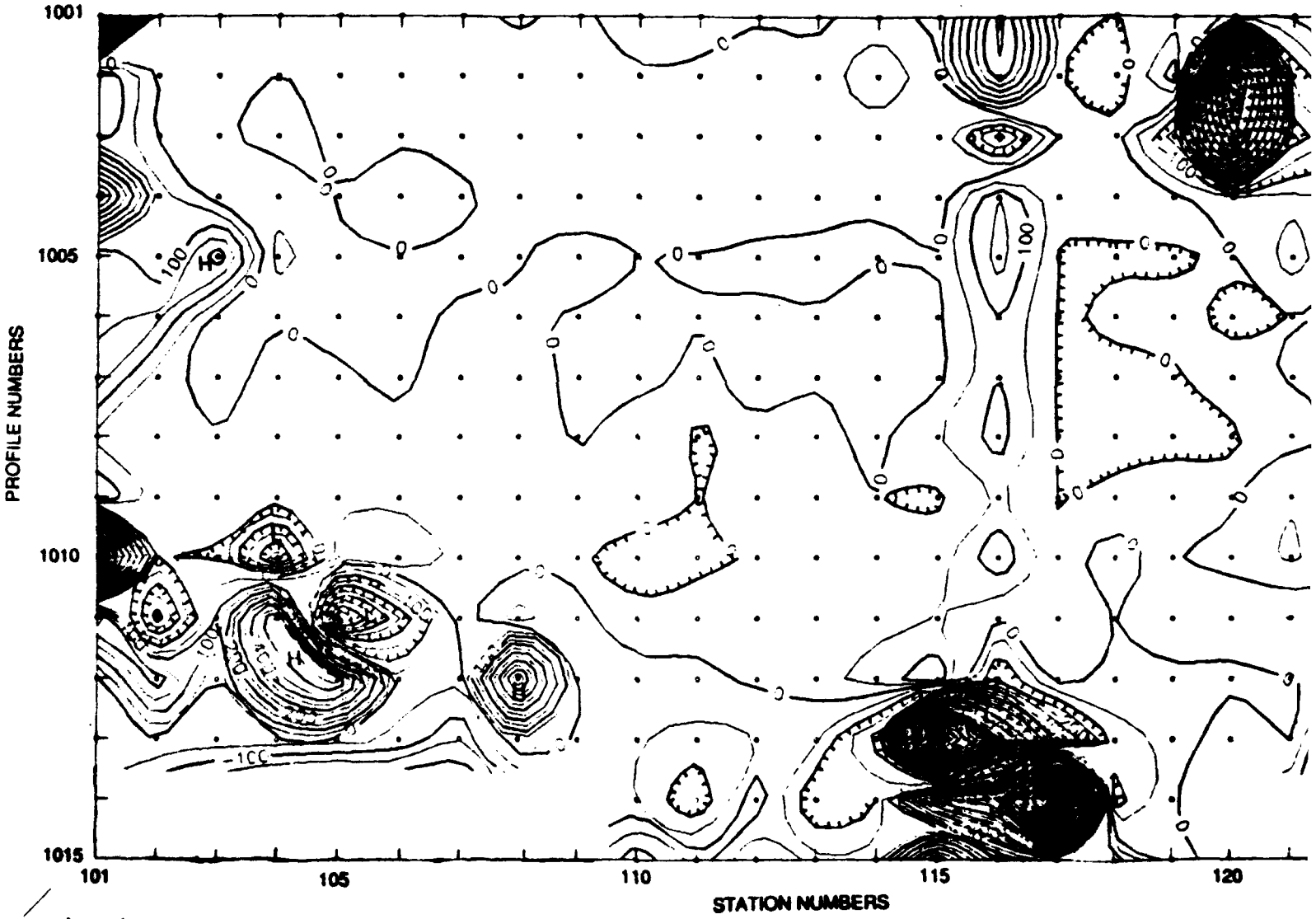
H/L HIGH/LOW VALUED CLOSED CONTOURS

CONTOUR INTERVAL = 50 GAMMAS

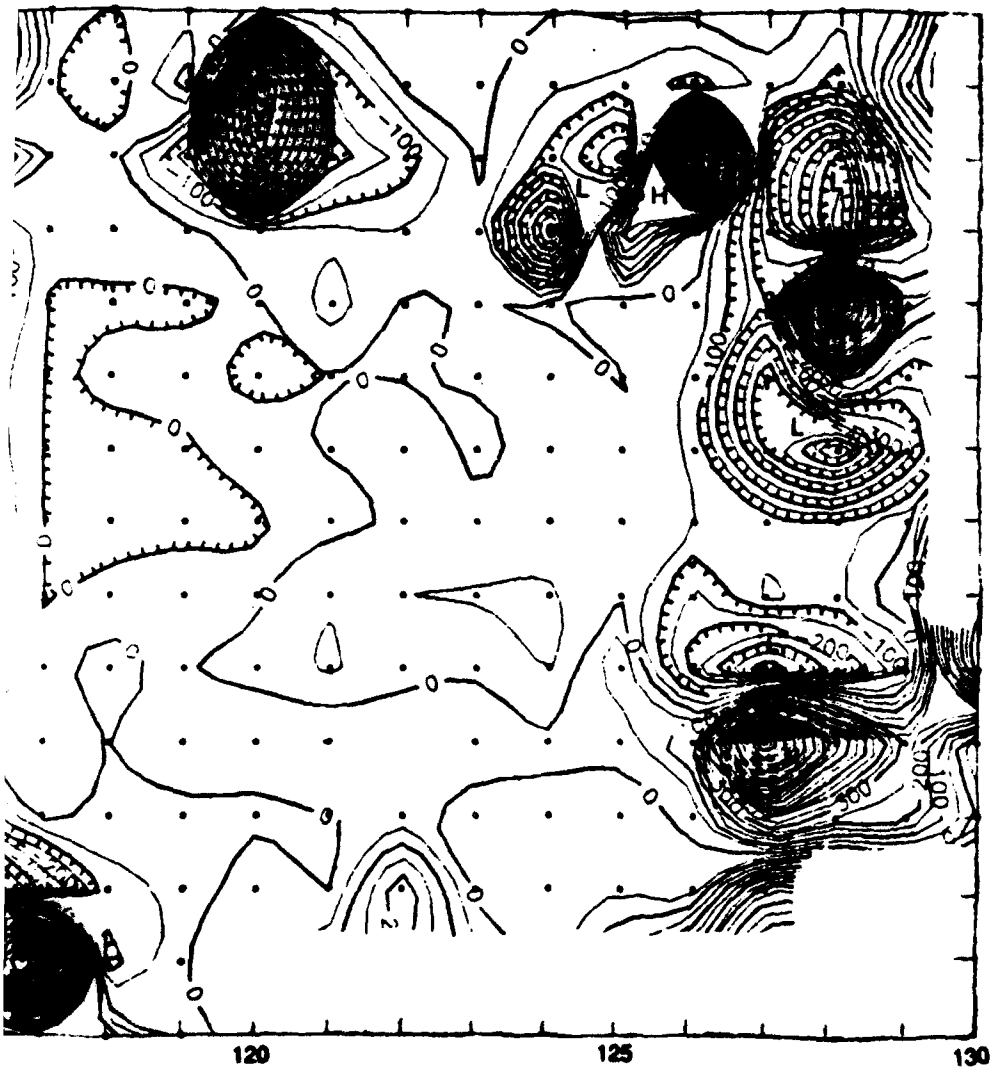
The Earth Technology Corporation	PLATE 3-5

OEHL-BOMARC
SITE 1
MAGNETIC CONTOUR MAP
TOTAL FIELD

BOMARC SITE 1 VERTICAL GRADIENT



AL GRADIENT



NORTH

0 20 40 Feet

SCALE

EXPLANATION

0 - MEASUREMENT STATION

~50~ - CONTOUR LINE WITH MAGNETIC VALUE (VERTICAL GRADIENT) IN GAMMAS/METER

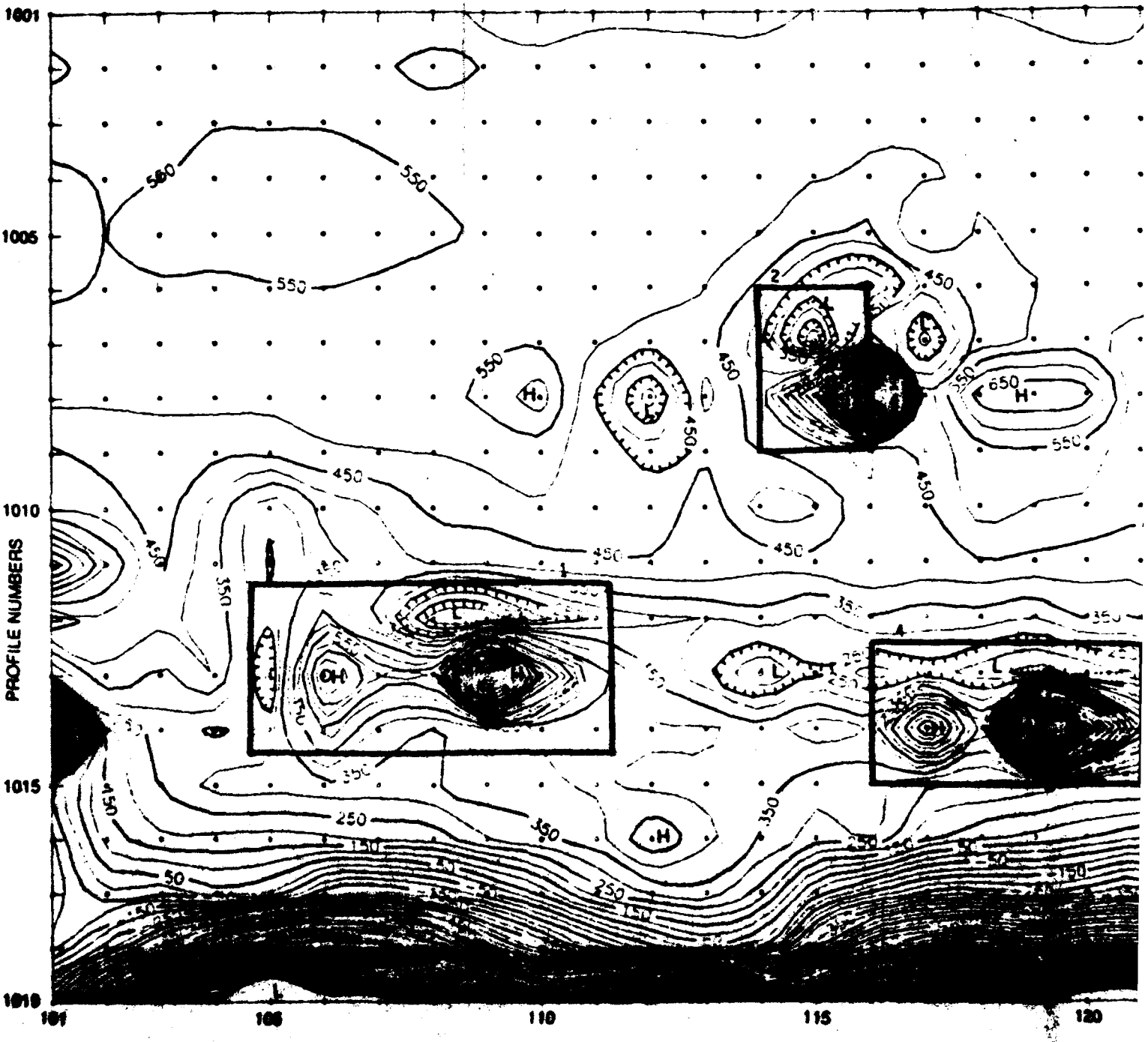
H/L - HIGH/LOW VALUED CLOSED CONTOURS

CONTOUR INTERVAL = 50 GAMMAS/METER

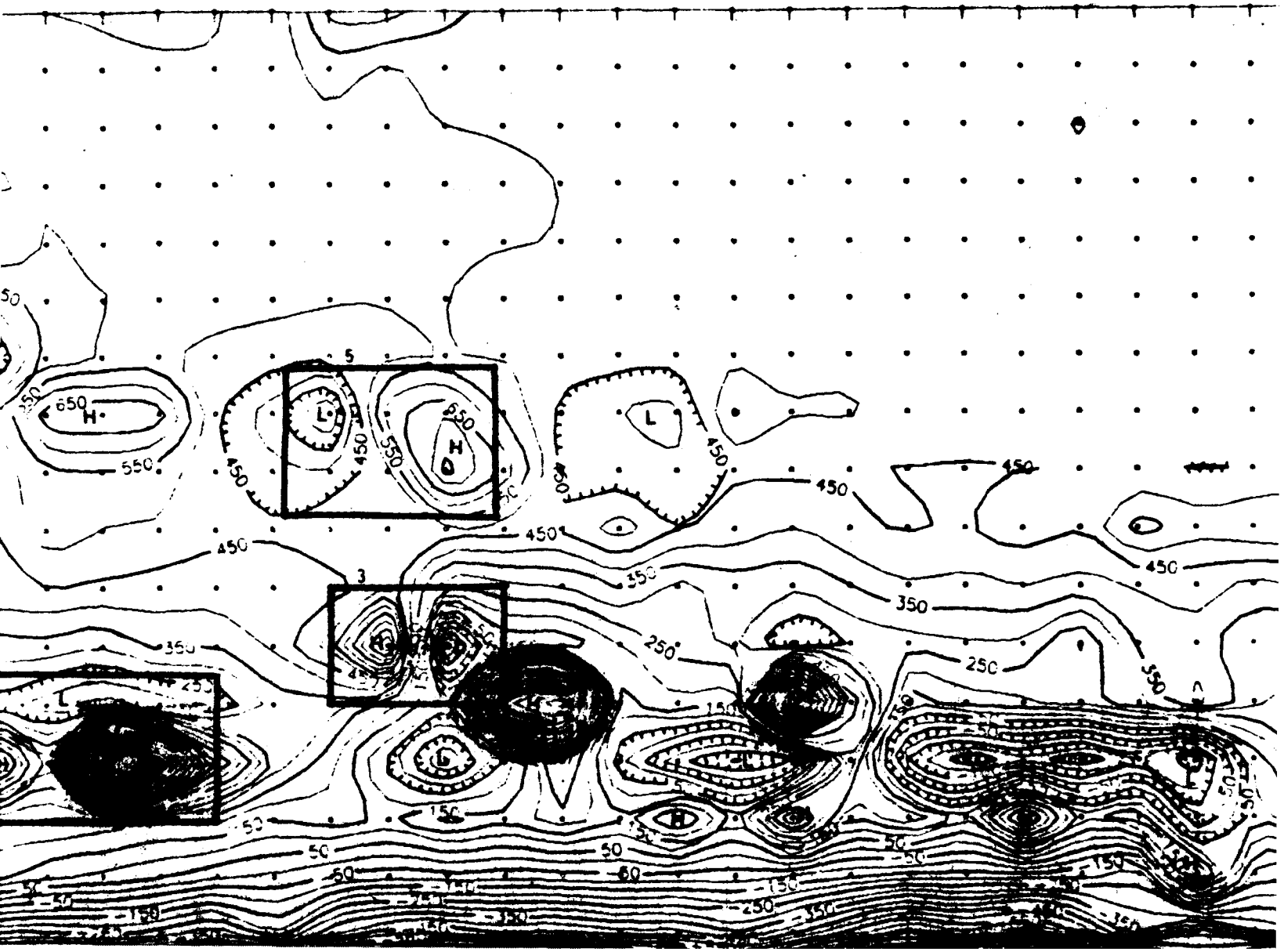
The Earth Technology Corporation

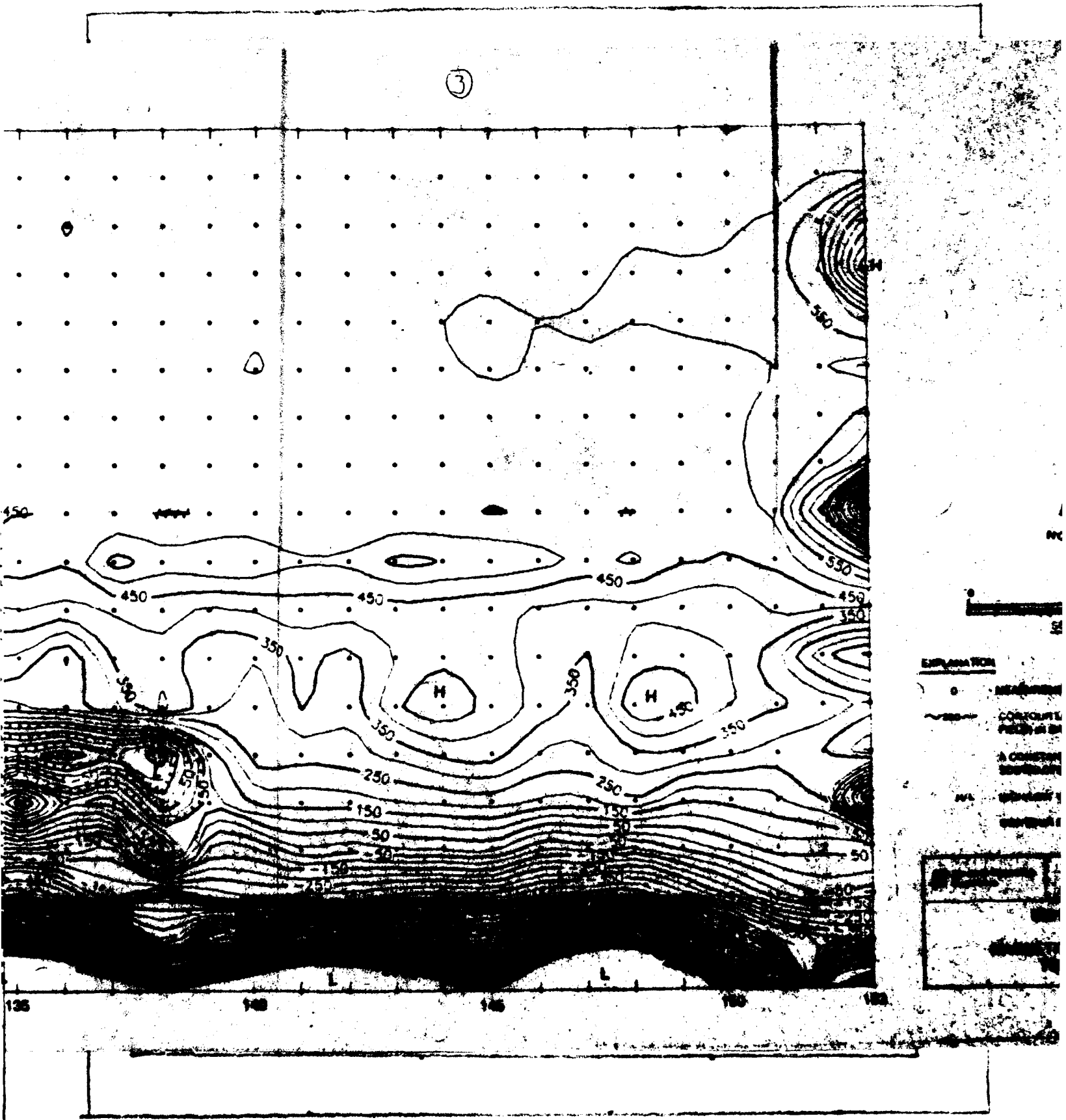
PLATE 3-6

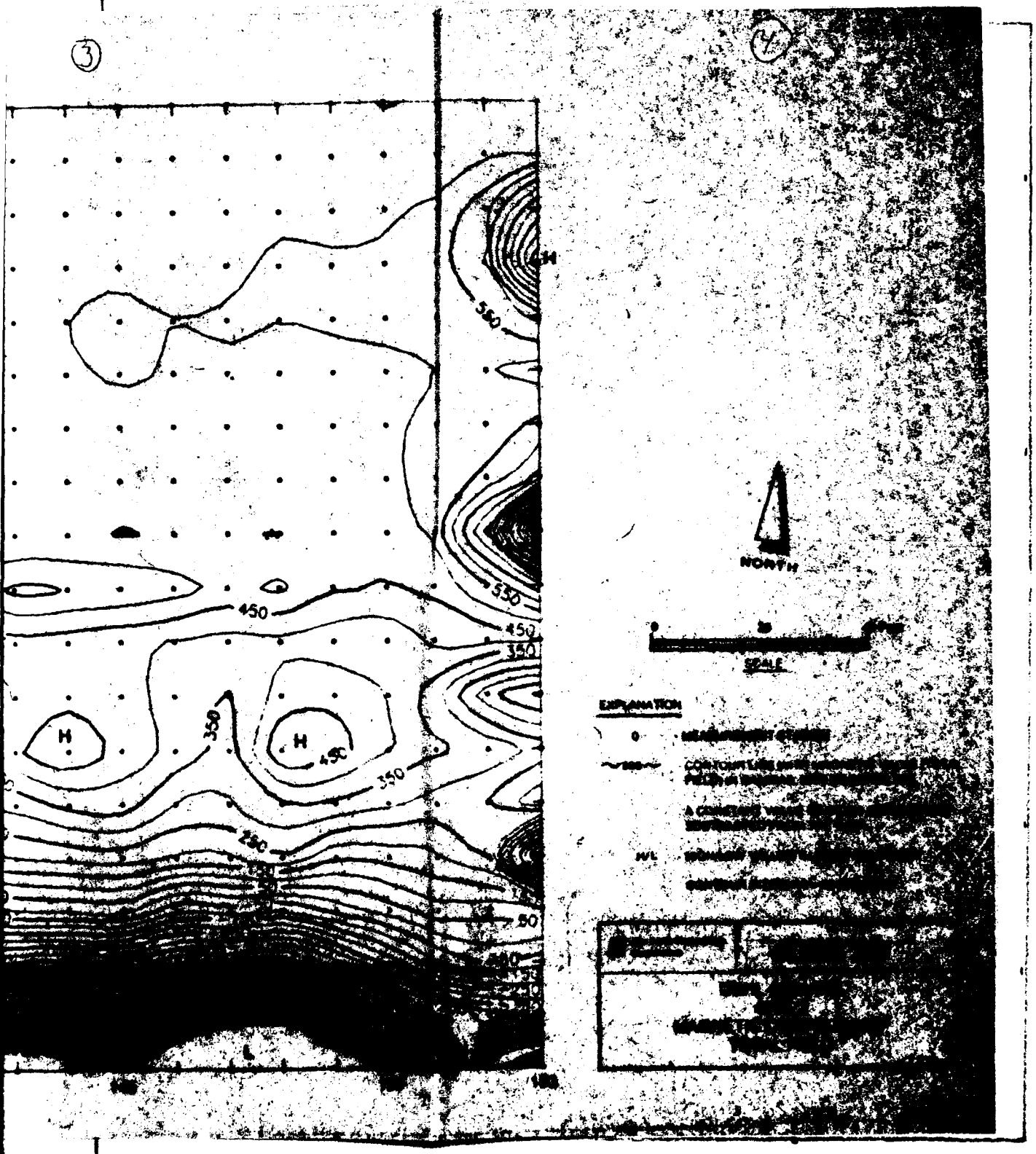
OEHL-BOMARC
SITE 1
MAGNETIC CONTOUR MAP
VERTICAL GRADIENT

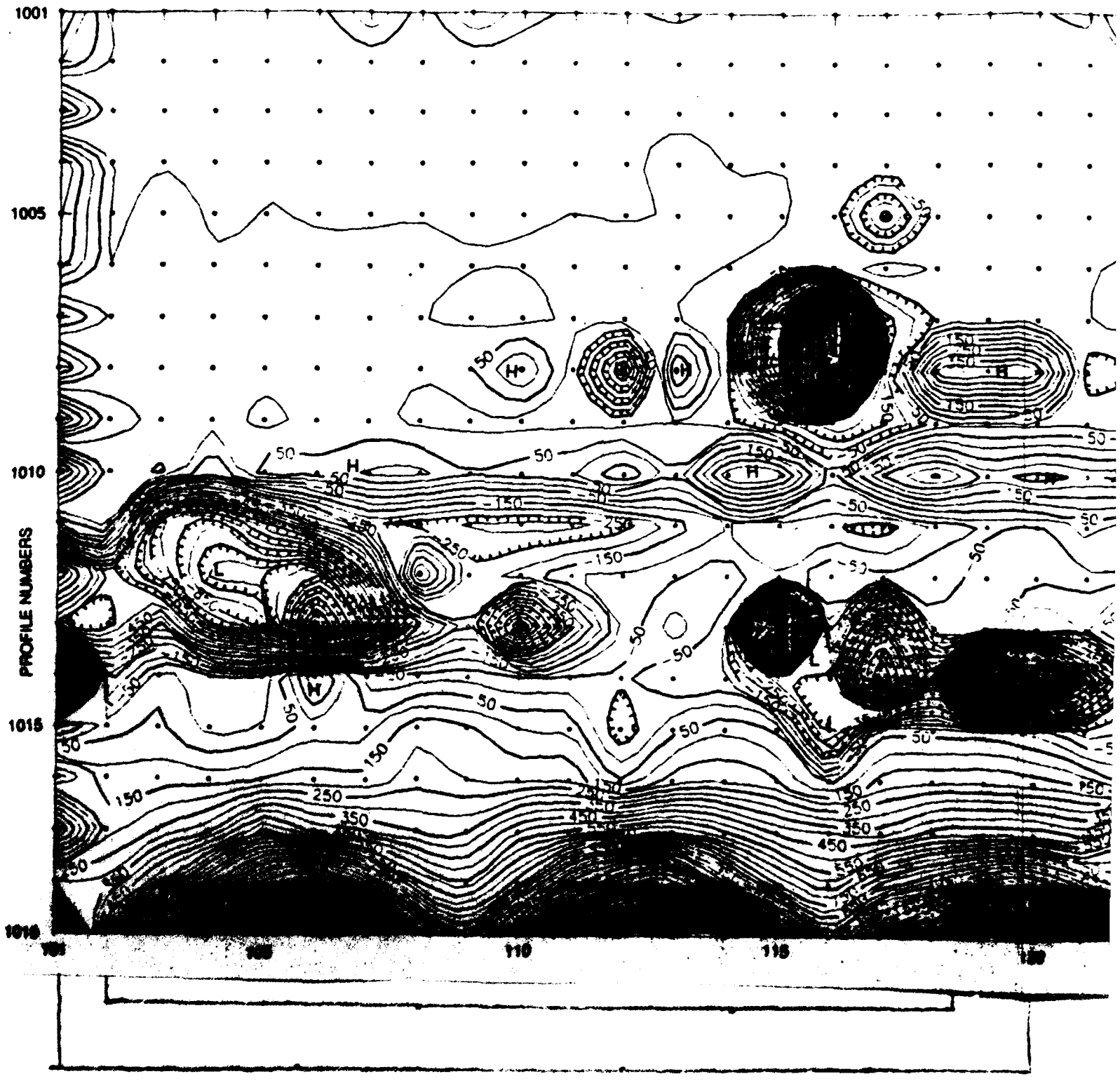

1001
1005
1010
1015
1019
PROFILE NUMBERS
101
105
110
115
120
560
550
450
350
250
150
50
650
H
L

BOMARC SITE 2 TOTAL (Z) FIELD



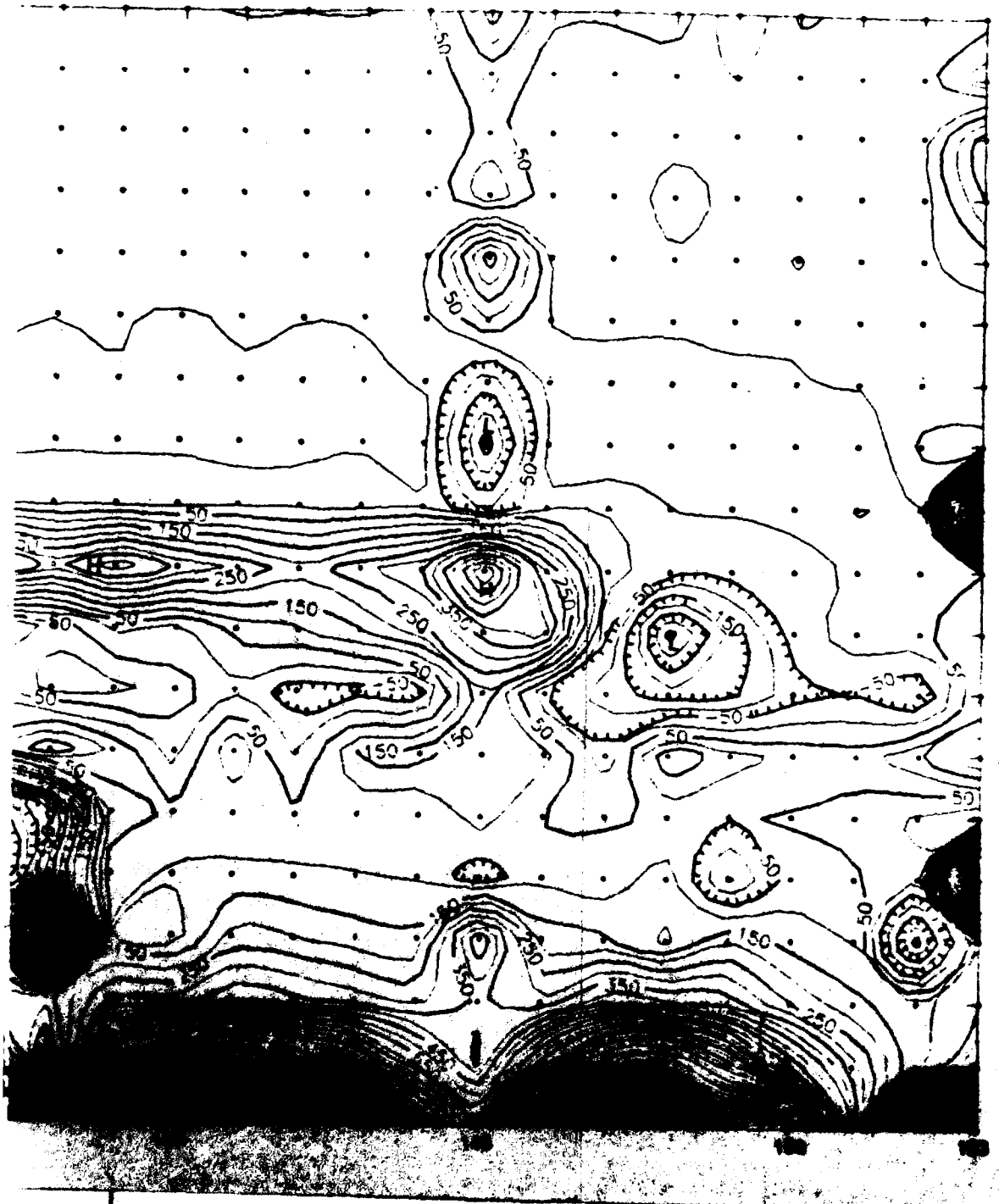

③
H
H
L
L
450
350
250
150
50
-50
-150
135
140
145
150
155
EXPLANATION


3
4
H
560
530
450
350
250
NORTH
SCALE
EXPLANATION


1001
1005
1010
1015
1016
PROFILE NUMBERS
110
115
H
50
150
250
350
450
550

BOMARC SITE 2 VERTICAL GRADIENT

(3)



EXPLANATION

- 0 · MEASUREMENT STATION
- ~50~ · CONTOUR LINE WITH MAGNETIC VALUE (VERTICAL GRADIENT) IN GAMMAS
- H/L · HIGH/LOW VALUED CLOSED CONTOURS

CONTOUR INTERVAL = 50 GAMMAS/METER

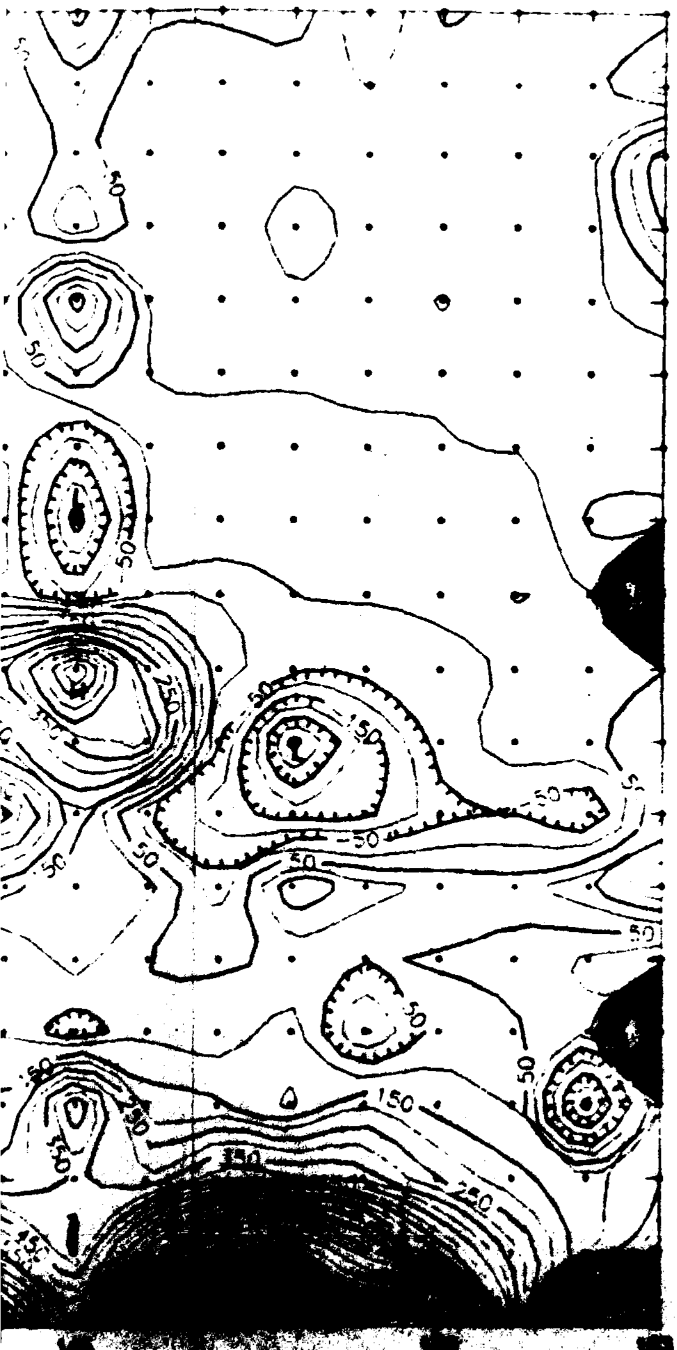
The Earth Technology Corporation

PLATE 3-8

OEHL-BOMARC
SITE 2
MAGNETIC CONTOUR MAP
VERTICAL GRADIENT

(3)

(4)



NORTH

0 20 40 Feet

SCALE

EXPLANATION

- MEASUREMENT STATION
~50~ · CONTOUR LINE WITH MAGNETIC VALUE (VERTICAL GRADIENT) IN GAMMAS/METER
H/L · HIGH/LOW VALUED CLOSED CONTOURS

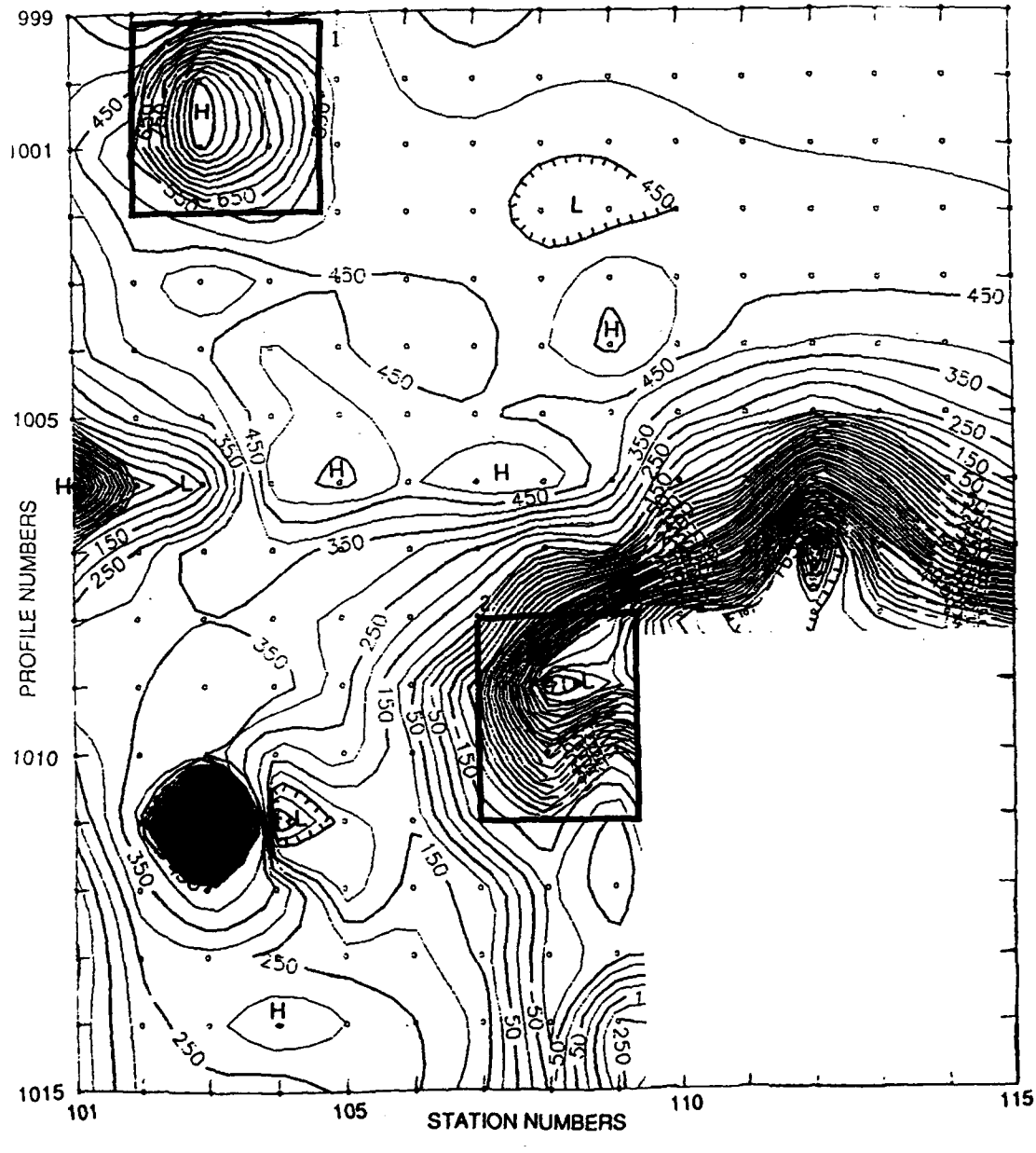
CONTOUR INTERVAL = 50 GAMMAS/METER

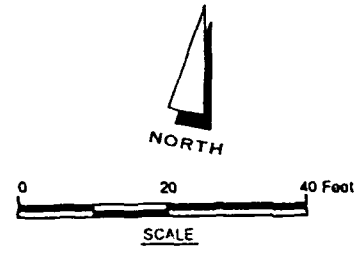
The Earth Technology Corporation

PLATE 3-8

OEHL-BOMARC
SITE 2
MAGNETIC CONTOUR MAP
VERTICAL GRADIENT

BOMARC SITE 3 TOTAL FIELD





EXPLANATION

0 - MEASUREMENT STATION

~500~ - CONTOUR LINE WITH MAGNETIC VALUE (TOTAL FIELD) IN GAMMAS, DRIFT CORRECTED.

A CONSTANT VALUE OF 54,000 GAMMAS WAS SUBTRACTED FROM THE DATA.

H/L - HIGH/LOW VALUED CLOSED CONTOURS

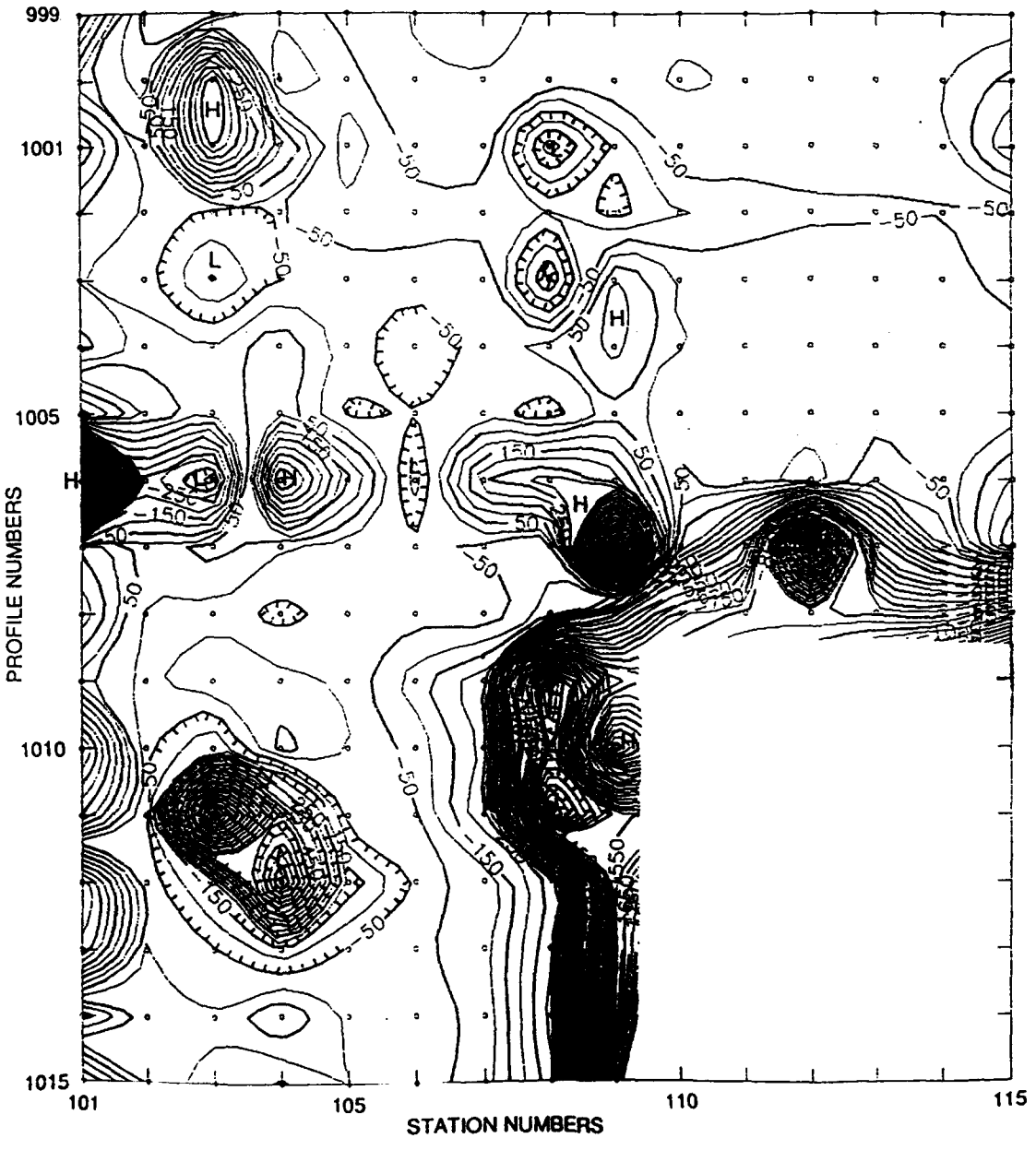
CONTOUR INTERVAL = 50 GAMMAS

The Earth Technology Corporation

PLATE 3-9

OEHL-BOMARC
SITE 3
MAGNETIC CONTOUR MAP
TOTAL FIELD

BOMARC SITE 3 VERTICAL GRADIENT



NORTH

0 20

SCALE

EXPLANATION

0 - MEASUREMENT STA

~50~ - CONTOUR LINE WITH VALUE (VERTICAL C

H/L - HIGH/LOW VALUED

CONTOUR INTERVA

The Earth Technology Corporation

PLA

OEHL-BOMA
SITE 3
MAGNETIC CONTO
VERTICAL GRA

E 3 VERTICAL GRADIENT

STATION NUMBERS

NORTH

0 20 40 Feet

SCALE

EXPLANATION

0 - MEASUREMENT STATION

~50~ - CONTOUR LINE WITH MAGNETIC VALUE (VERTICAL GRADIENT) IN GAMMAS/METER

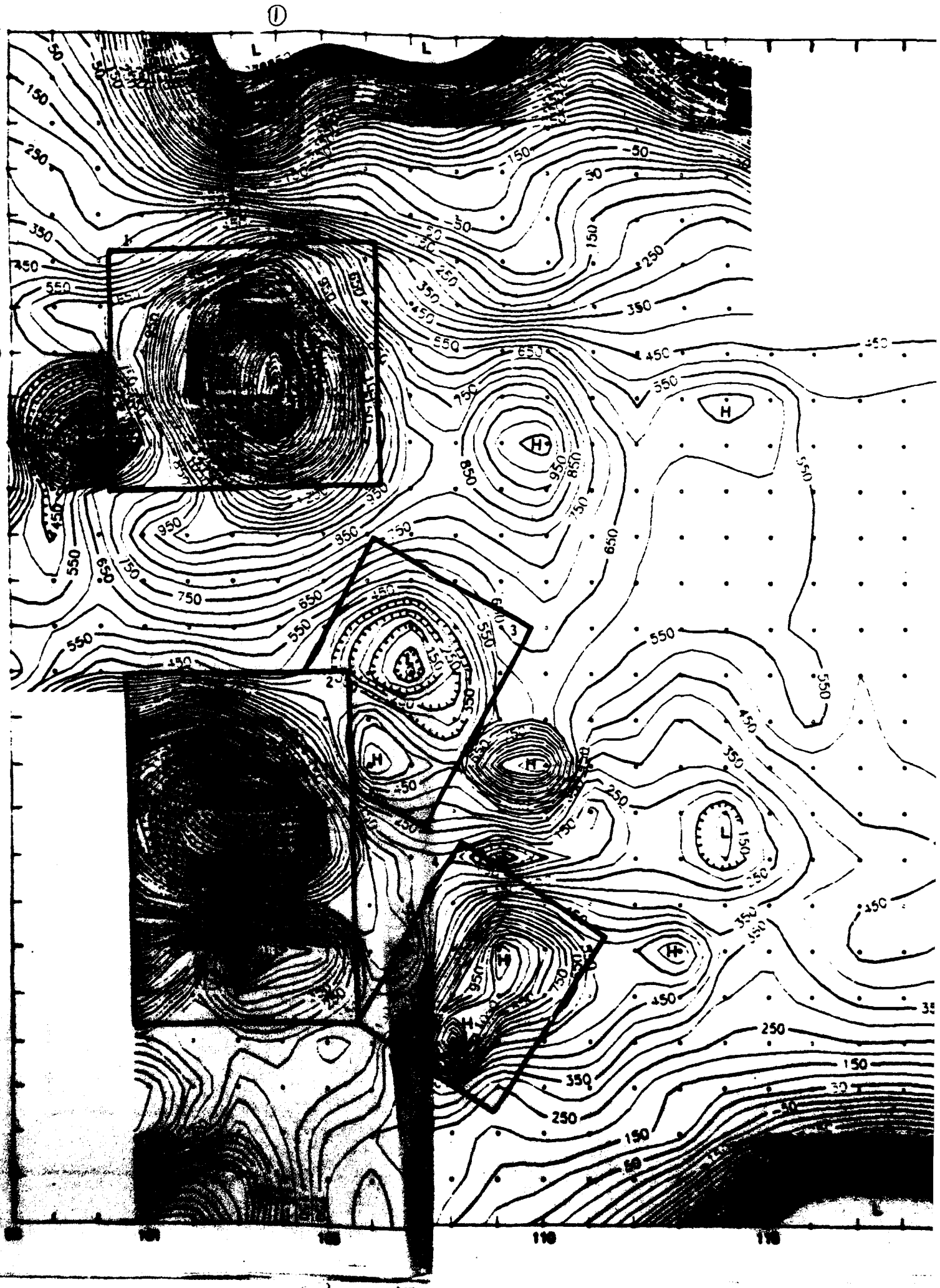
H/L - HIGH/LOW VALUED CLOSED CONTOURS

CONTOUR INTERVAL = 50 GAMMAS/METER

The Earth Technology Corporation

PLATE 3-10

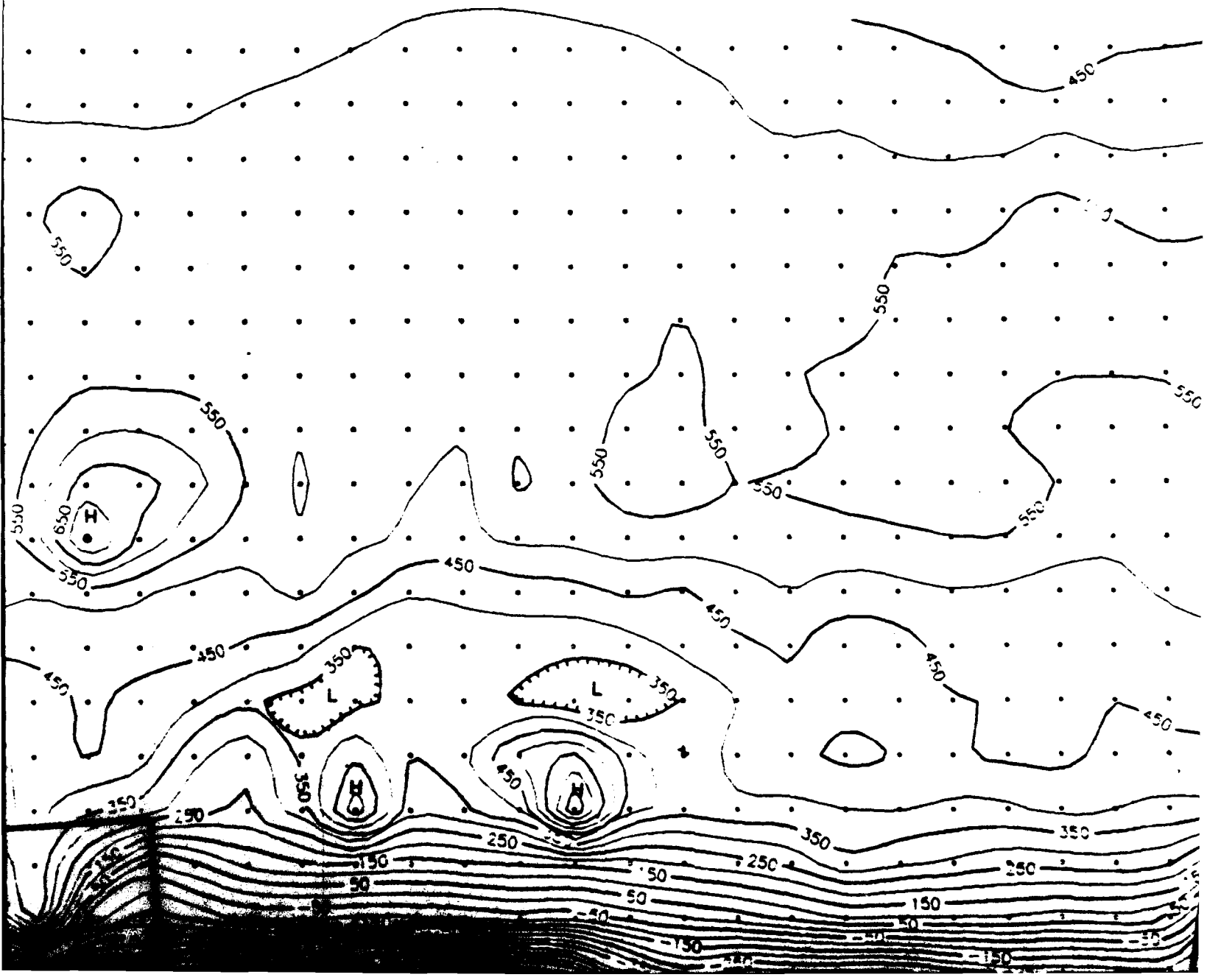
OEHL-BOMARC
SITE 3
MAGNETIC CONTOUR MAP
VERTICAL GRADIENT

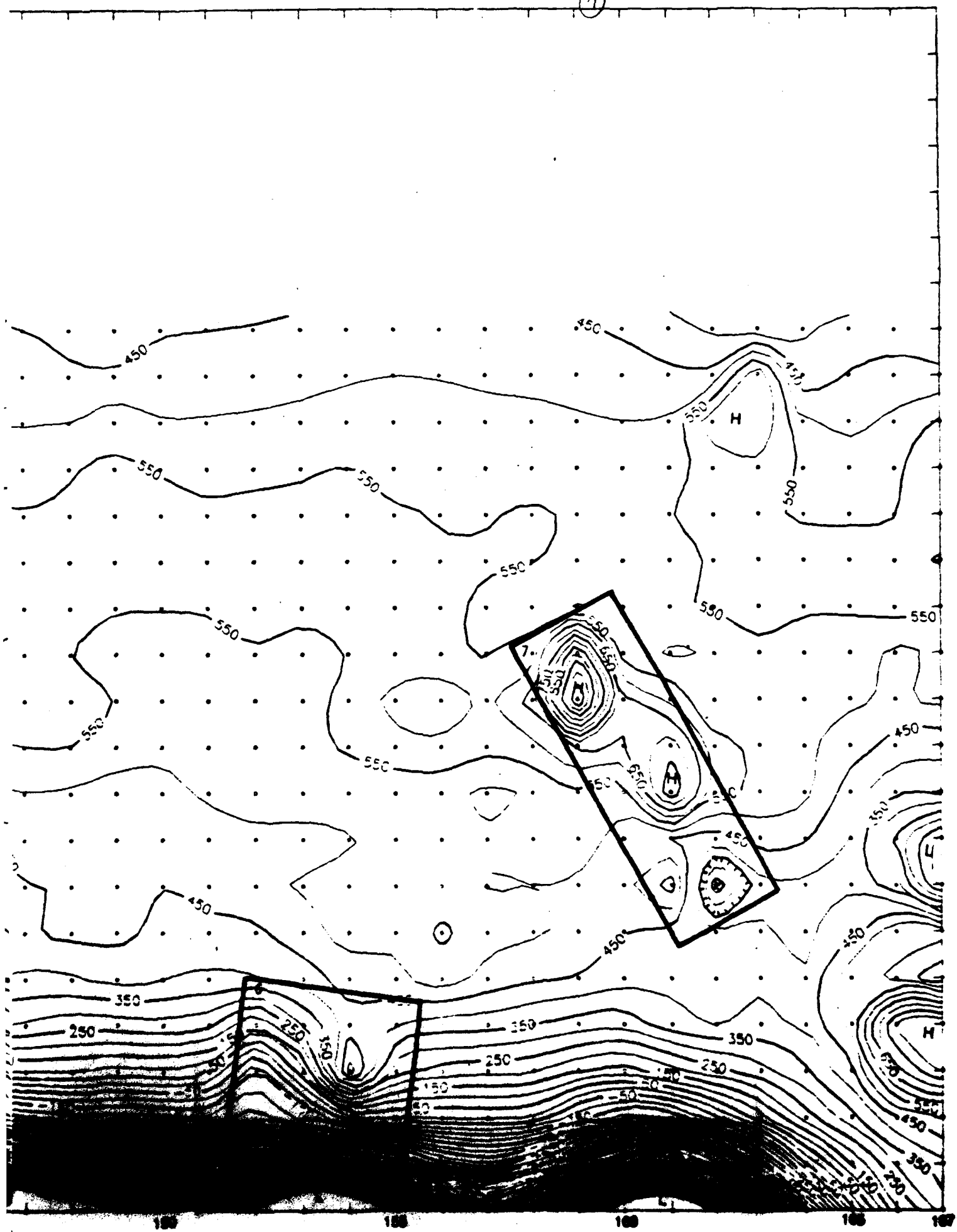

1027
1025
1020
1015
1010
1005
PROFILE NUMBERS
L
H
950
850
750
650
550
450
350
250
150
50
-50
-150

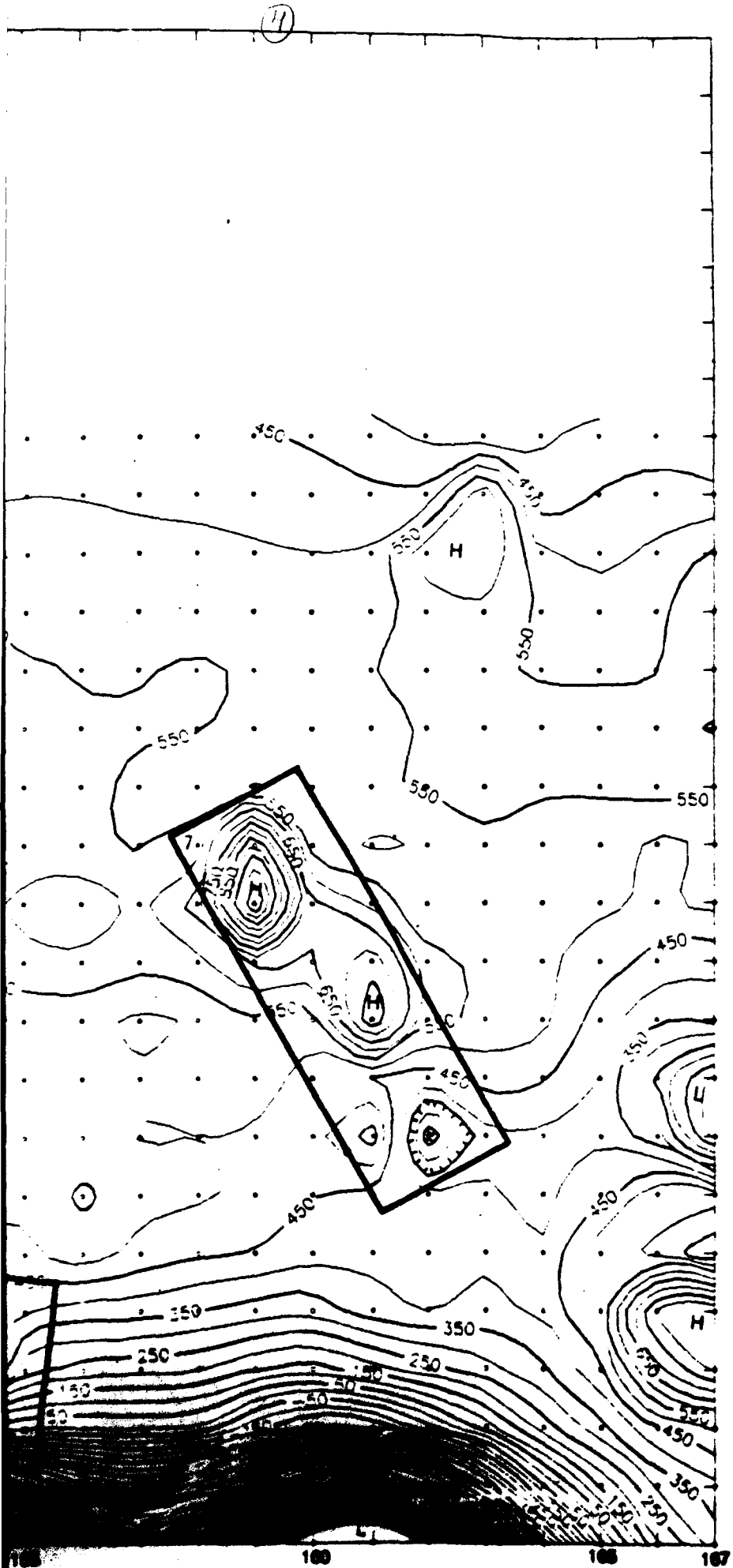
BOMARC SITE 4 TOTAL FIELD

SITE 4 TOTAL FIELD

(3)




450
550
H
350
250
150
EXPLANATI
0
HWL
100
105
107



NORTH

0 20 40 Feet

SCALE

EXPLANATION

0 - MEASUREMENT STATION

~800~ - CONTOUR LINE WITH MAGNETIC VALUE (TOTAL FIELD) IN GAMMAS, DRIFT CORRECTED

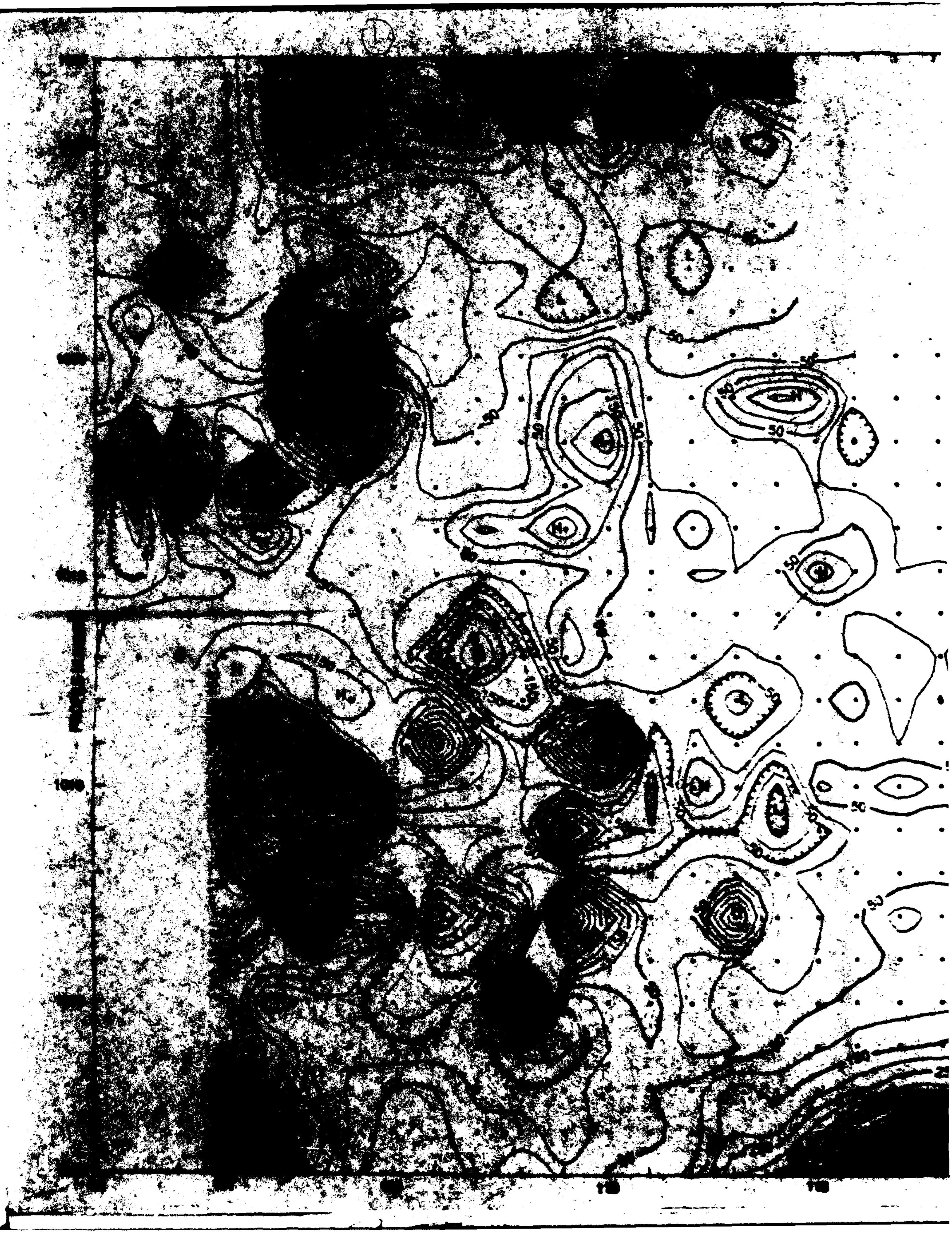
A CONSTANT VALUE OF 54,000 GAMMAS WAS SUBTRACTED FROM THE DATA

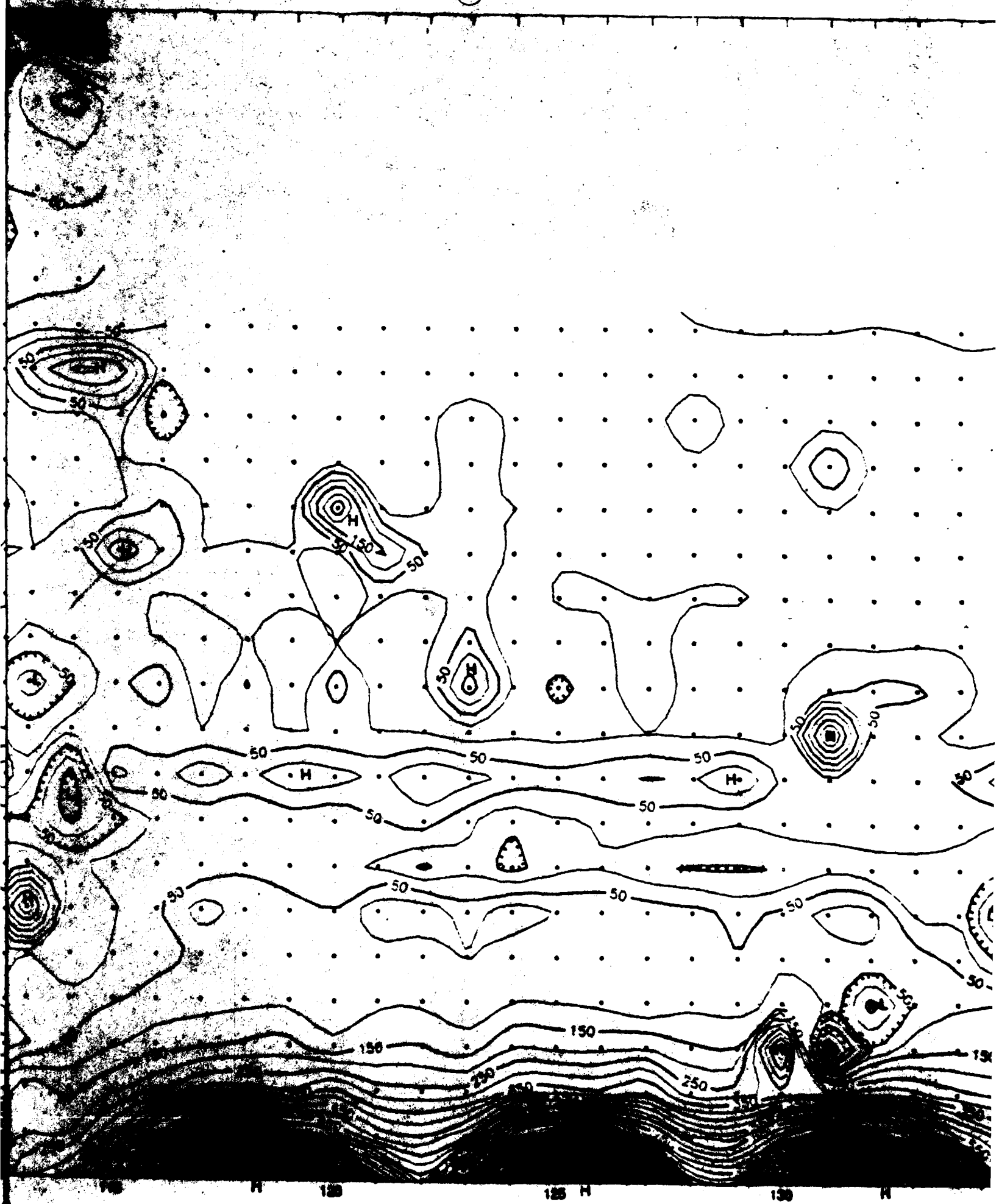
H/L - HIGH/LOW VALUED CLOSED CONTOURS

CONTOUR INTERVAL = 50 GAMMAS

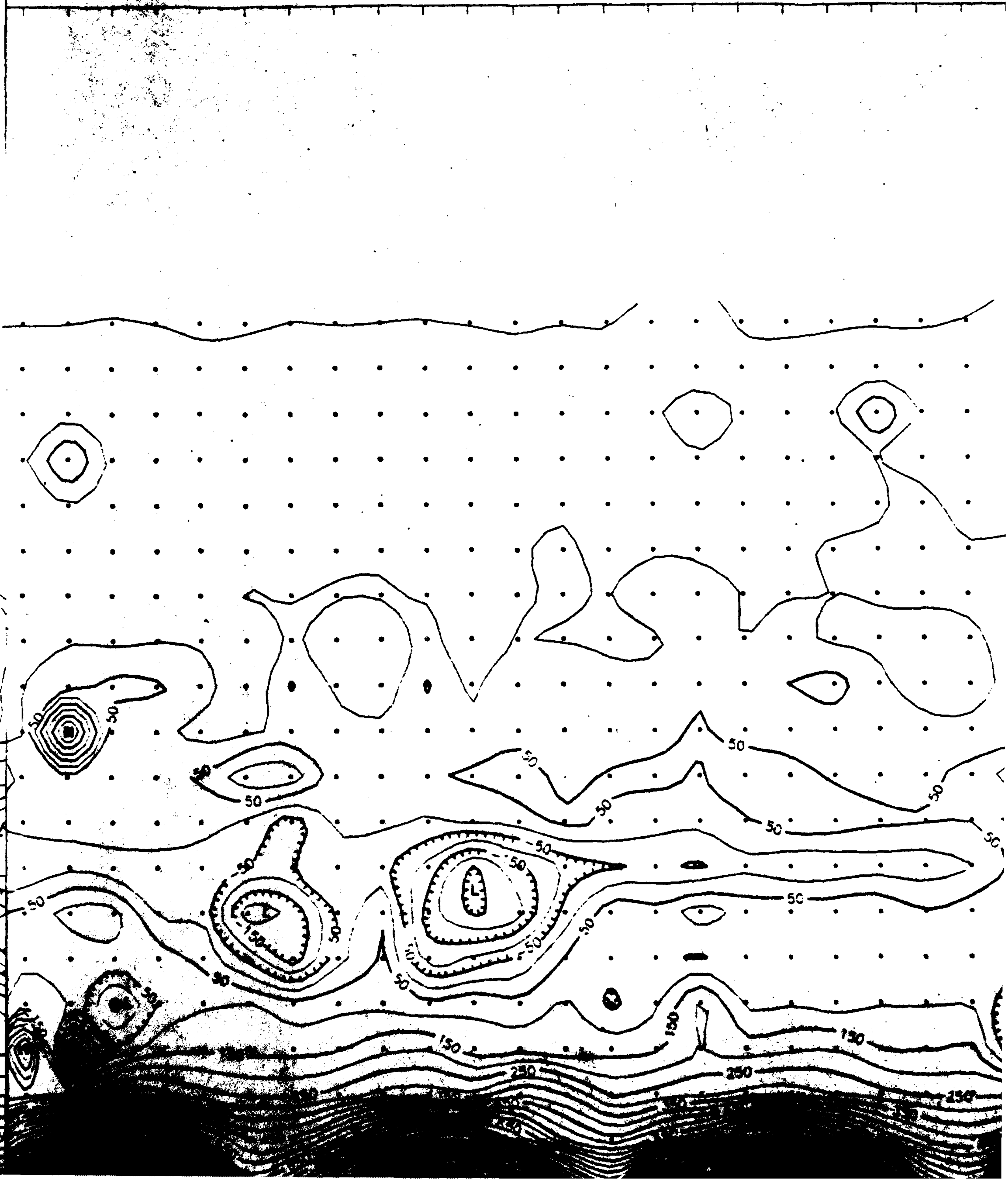
The Earth Technology Corporation	PLATE 3-11

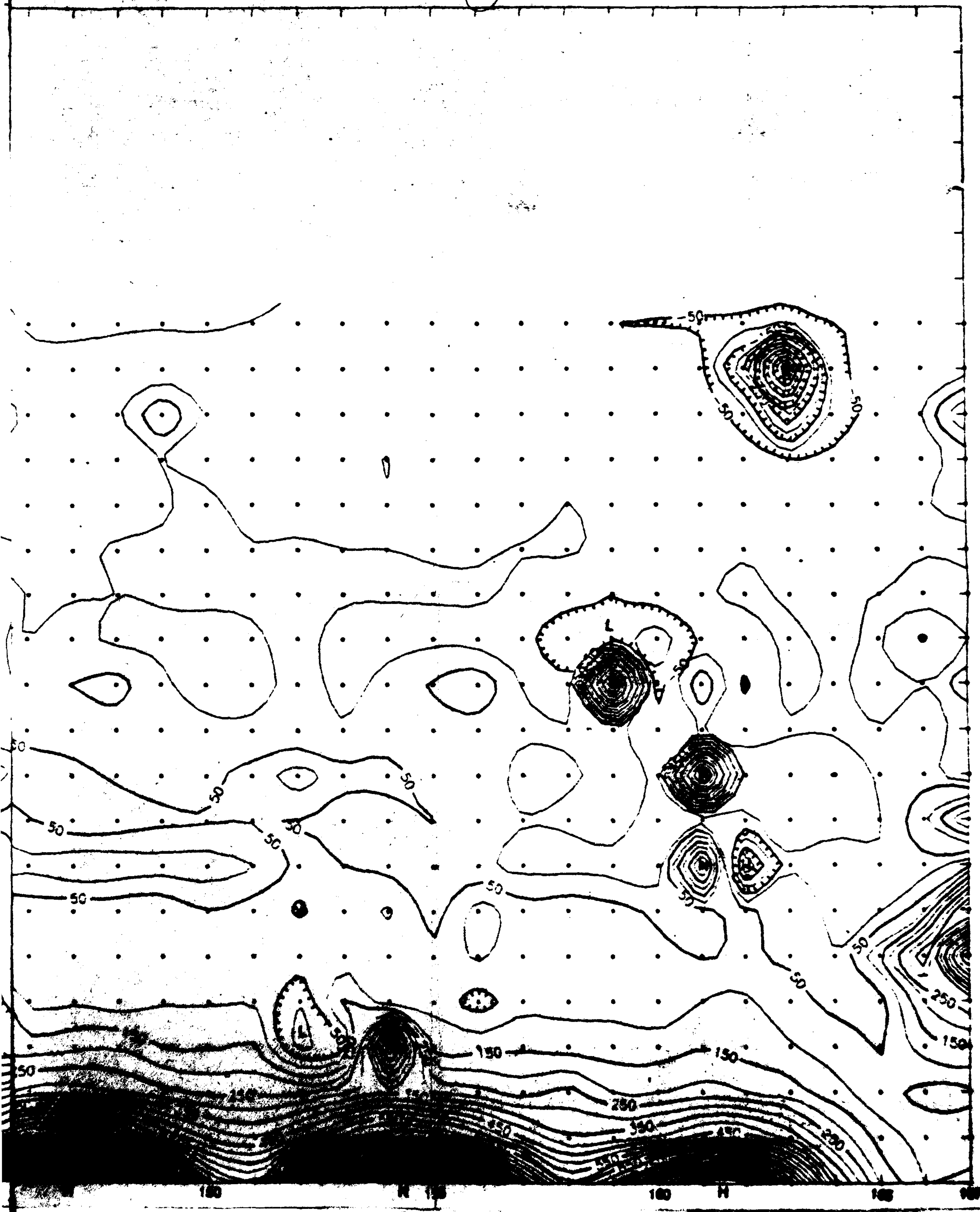
OEHL-BOMARC
SITE 4
MAGNETIC CONTOUR MAP
TOTAL FIELD




50
H
150
250
H
H
H
H
H

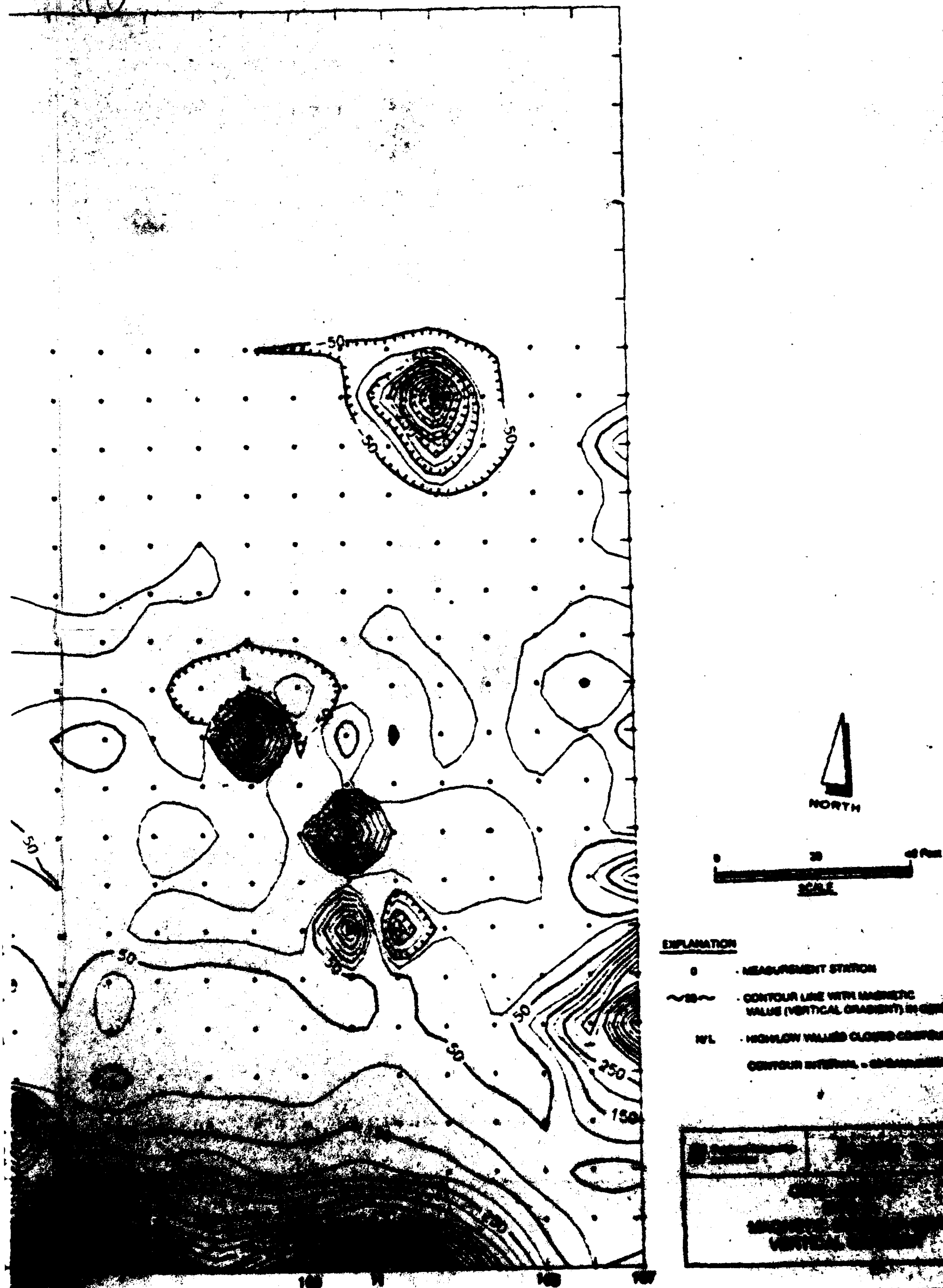
BOMARC SITE 4 VERTICAL GRADIENT (3)




50
150
250
350
L
H

(7)

(5)



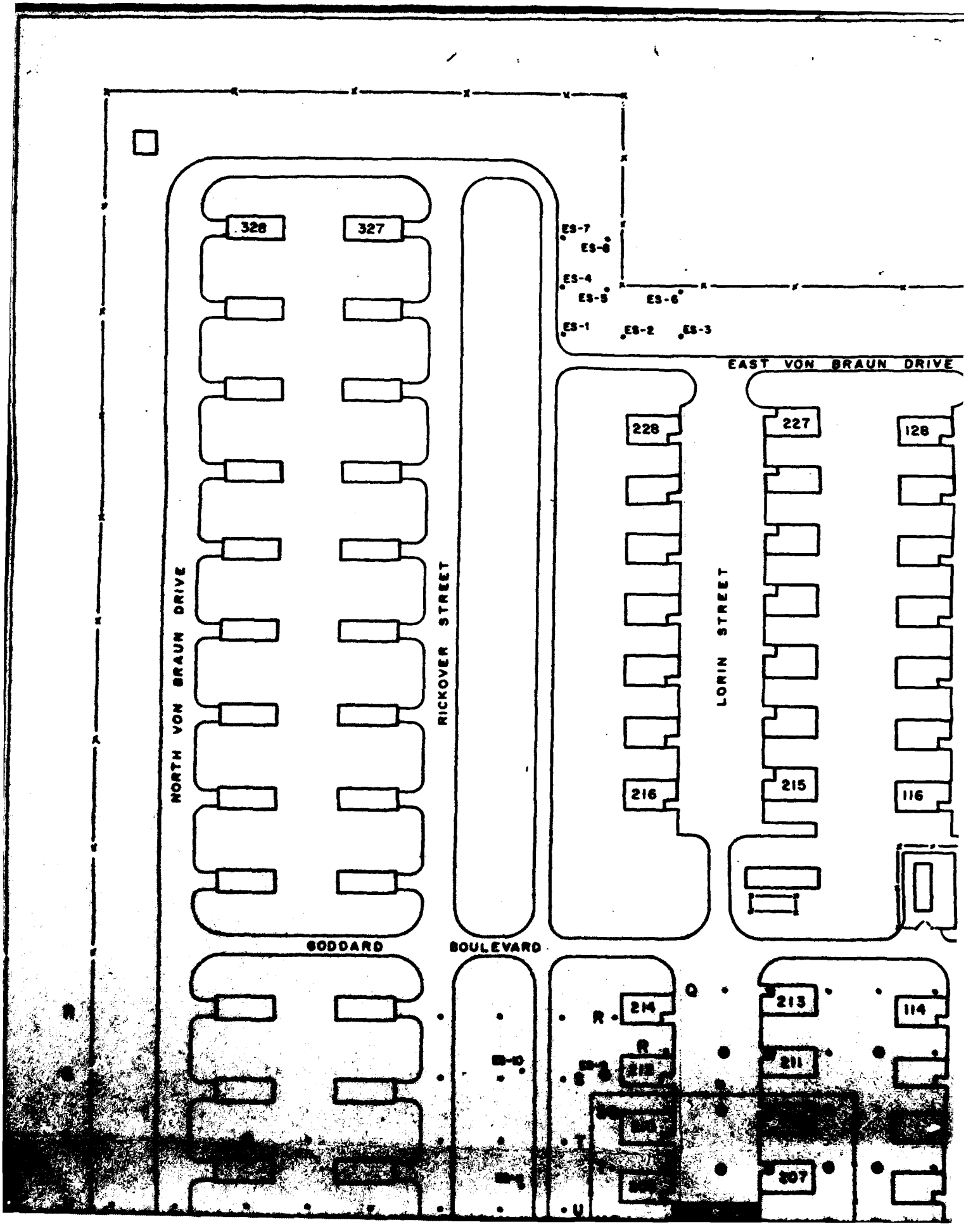
EXPLANATION

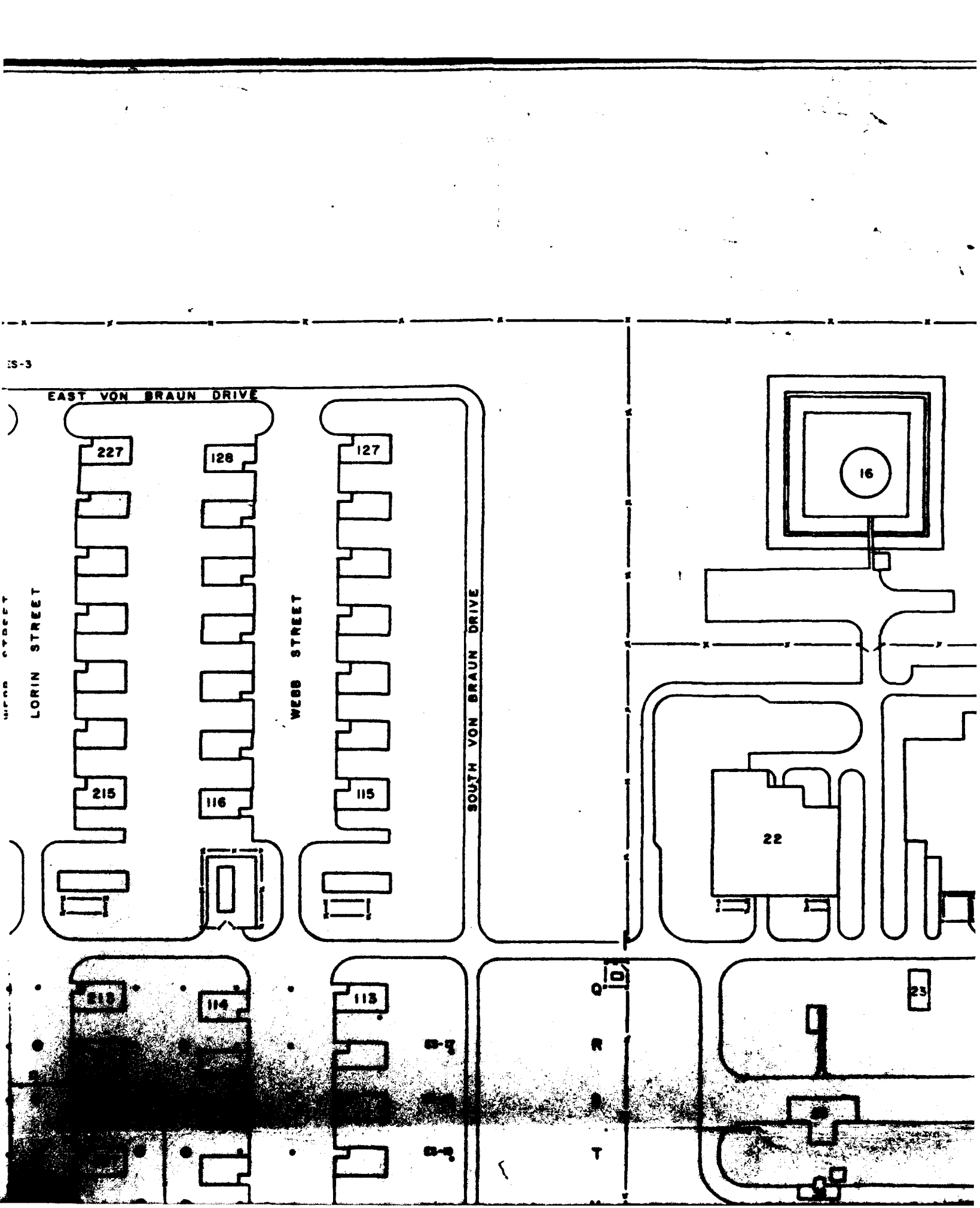
MEASUREMENT STATION

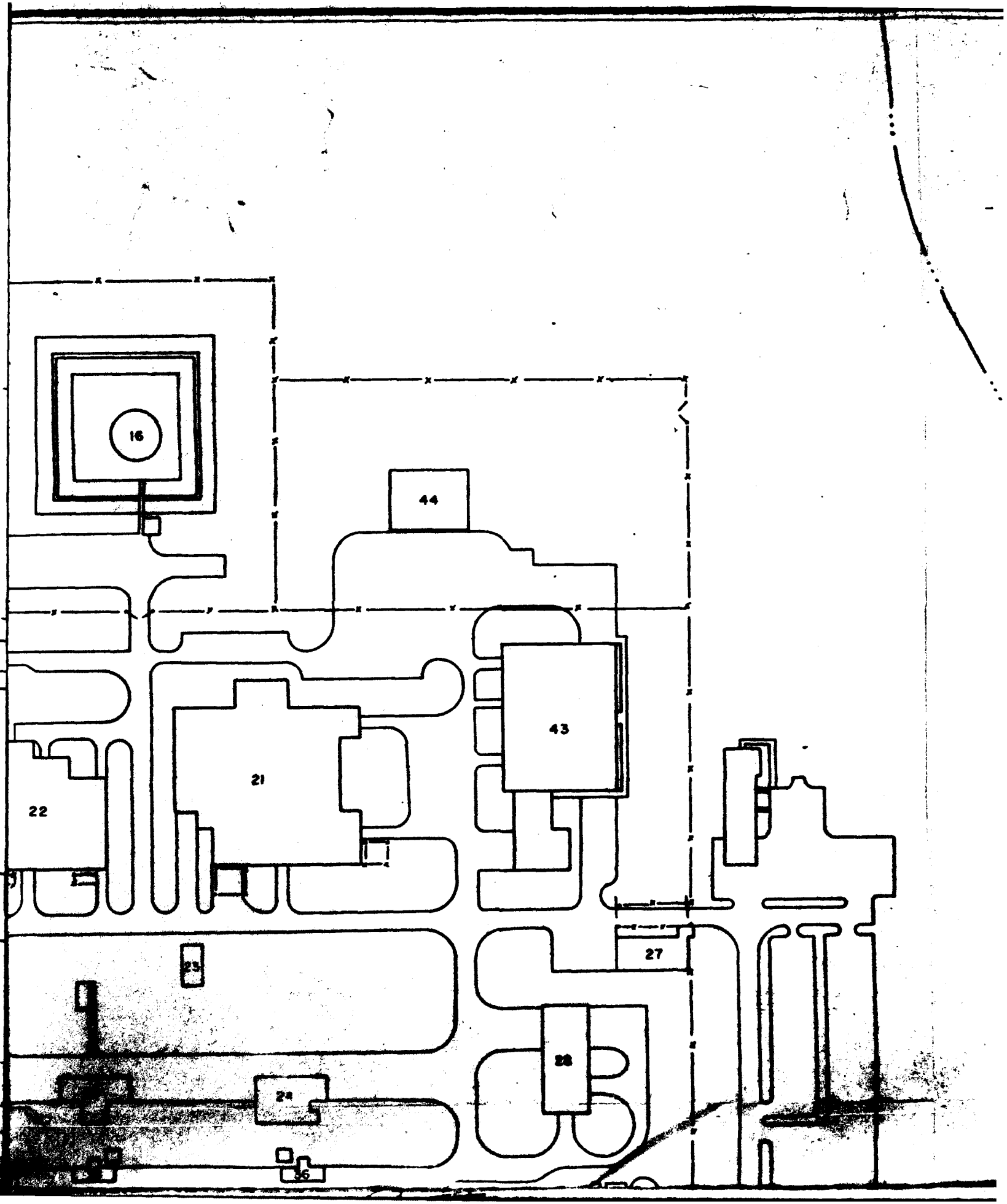
CONTOUR LINE WITH MAGNETIC VALUE (VERTICAL GRADIENT) IN

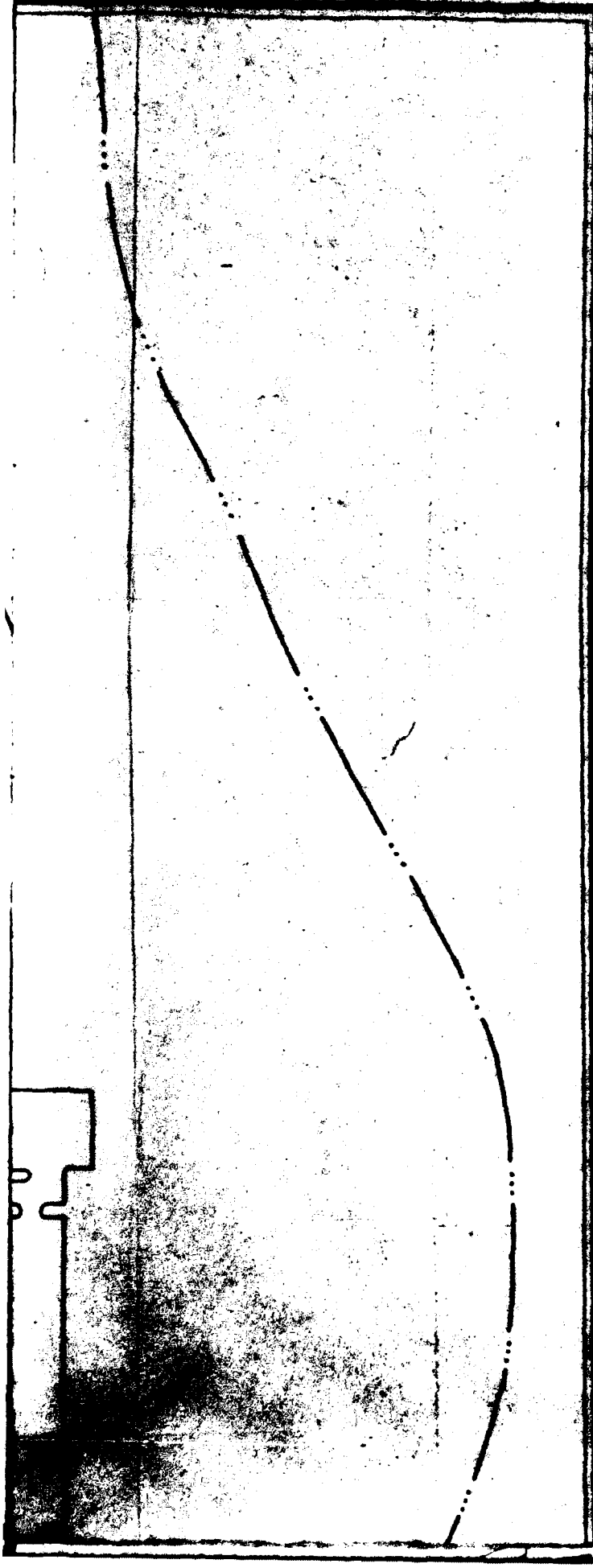
H/L HIGH/LOW VALUED CLOSED CONTOURS

CONTOUR INTERVAL =


328
327
ES-7
ES-8
ES-4
ES-5
ES-6
ES-1
ES-2
ES-3
EAST VON BRAUN DRIVE
228
227
128
NORTH VON BRAUN DRIVE
RICKOVER STREET
LORIN STREET
216
215
116
GODDARD
BOULEVARD
214
213
114
211
207

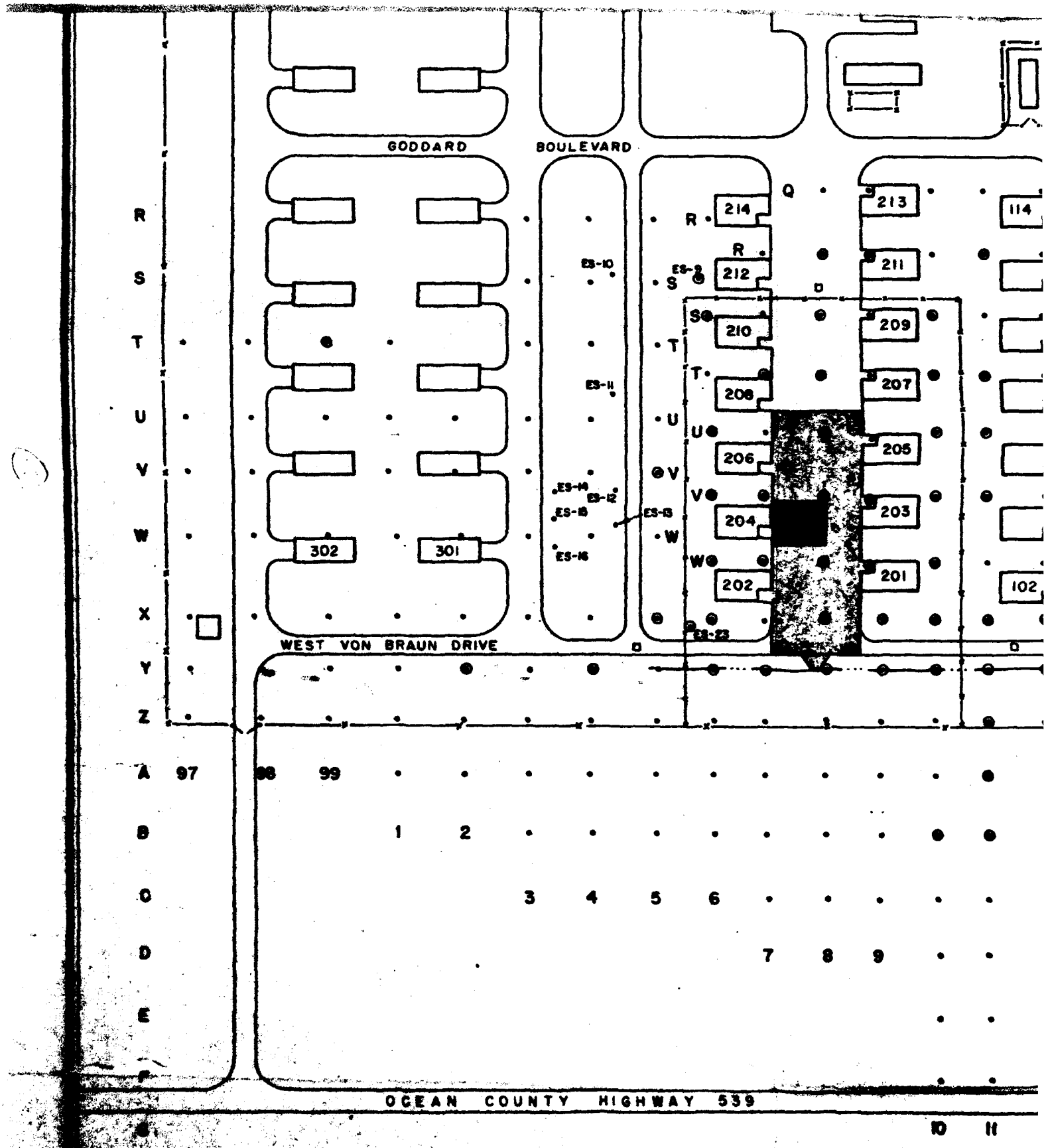

ES-3
EAST VON BRAUN DRIVE
227
128
127
16
LORIN STREET
WEBB STREET
SOUTH VON BRAUN DRIVE
215
116
115
22
213
114
113
23
Q
R
T


16
44
43
21
22
27
23
28
24
36



EXPLANATION

- HPG STATION LOCATION (Letters and numbers at margins denote row and column number)
- ES-22 — HPG POINTS NOT PART OF MAIN GRID
- GRID POINT WITH MEASURABLE AMERICIUM-241 ACTIVITY
- AIR SAMPLING STATION
- FENCE
- DRAINAGE
- CULVERT
- PONDING AREA
- 44 — BUILDING AND NUMBER
- 4-INCH CONCRETE POUR OVER ASPHALT SURFACE
- ADDITIONAL 2-INCH CONCRETE POUR OVER 4-INCH CONCRETE POUR AND ASPHALT SURFACE


GODDARD
BOULEVARD
WEST VON BRAUN DRIVE
OCEAN COUNTY HIGHWAY 539
214
213
212
211
210
209
208
207
206
205
204
203
202
201
302
301
114
102
ES-10
ES-9
ES-11
ES-14
ES-12
ES-13
ES-15
ES-16
ES-22
R
S
T
U
V
W
Q
X
Y
Z
A
B
C
D
E
F
97
98
99
1
2
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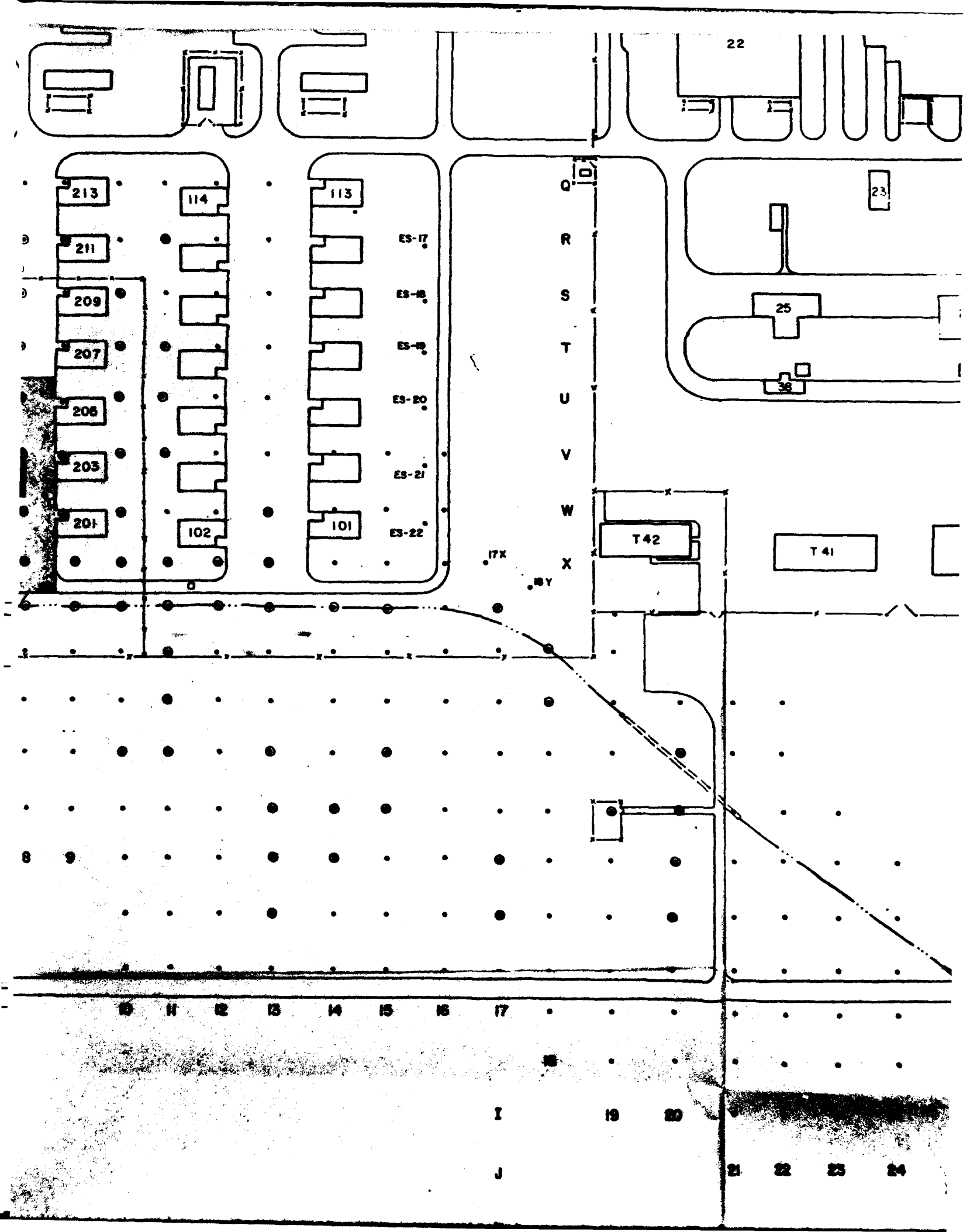
4
5
6
7
8
9
10
11


22
213
114
113
211
209
207
206
203
201
102
101
ES-17
ES-18
ES-19
ES-20
ES-21
ES-22
Q
R
S
T
U
V
W
X
23
25
38
T42
T41
17X
18Y
10
11
12
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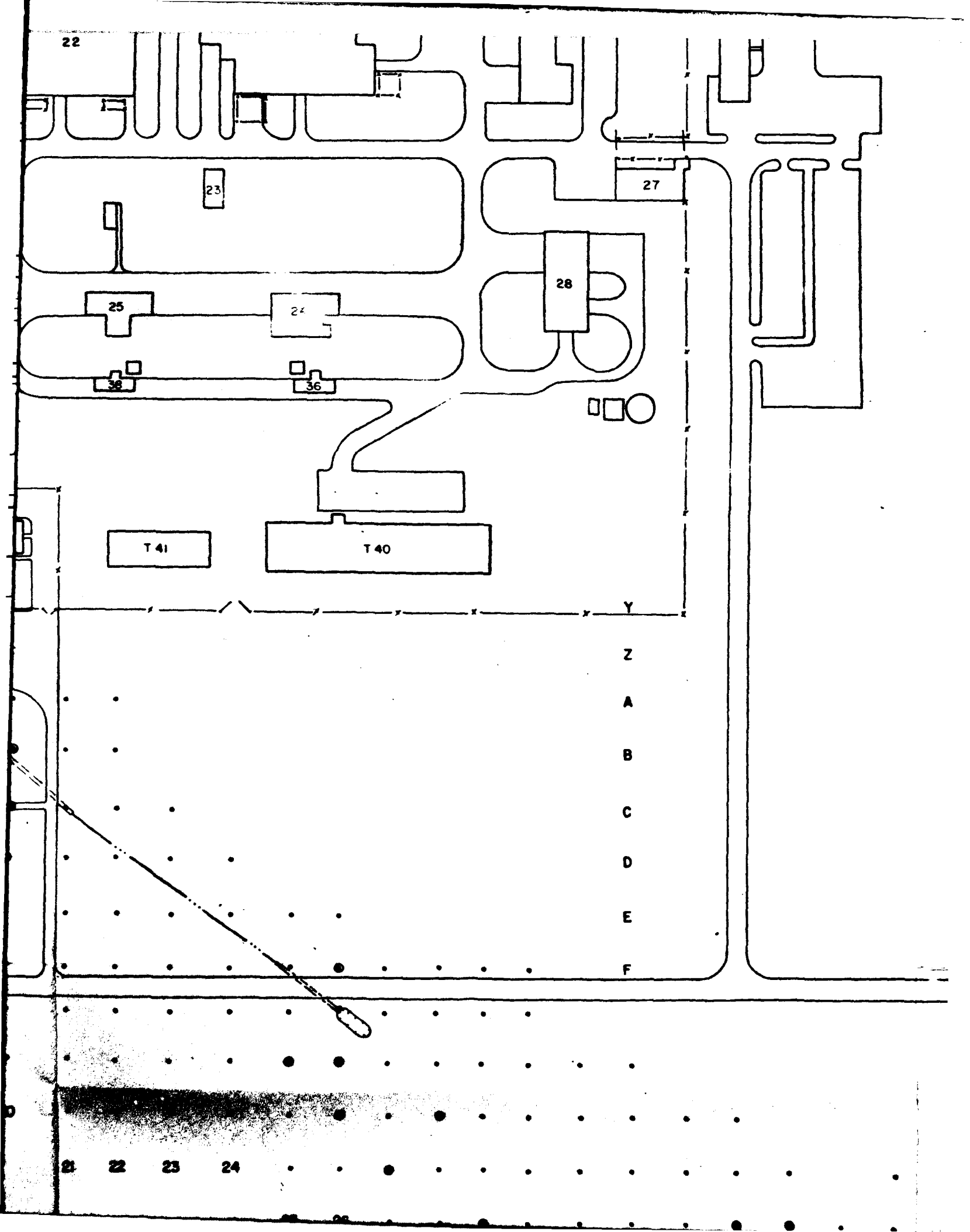
24
I
J
8
9


22
23
27
28
25
24
38
36
T 41
T 40
Y
Z
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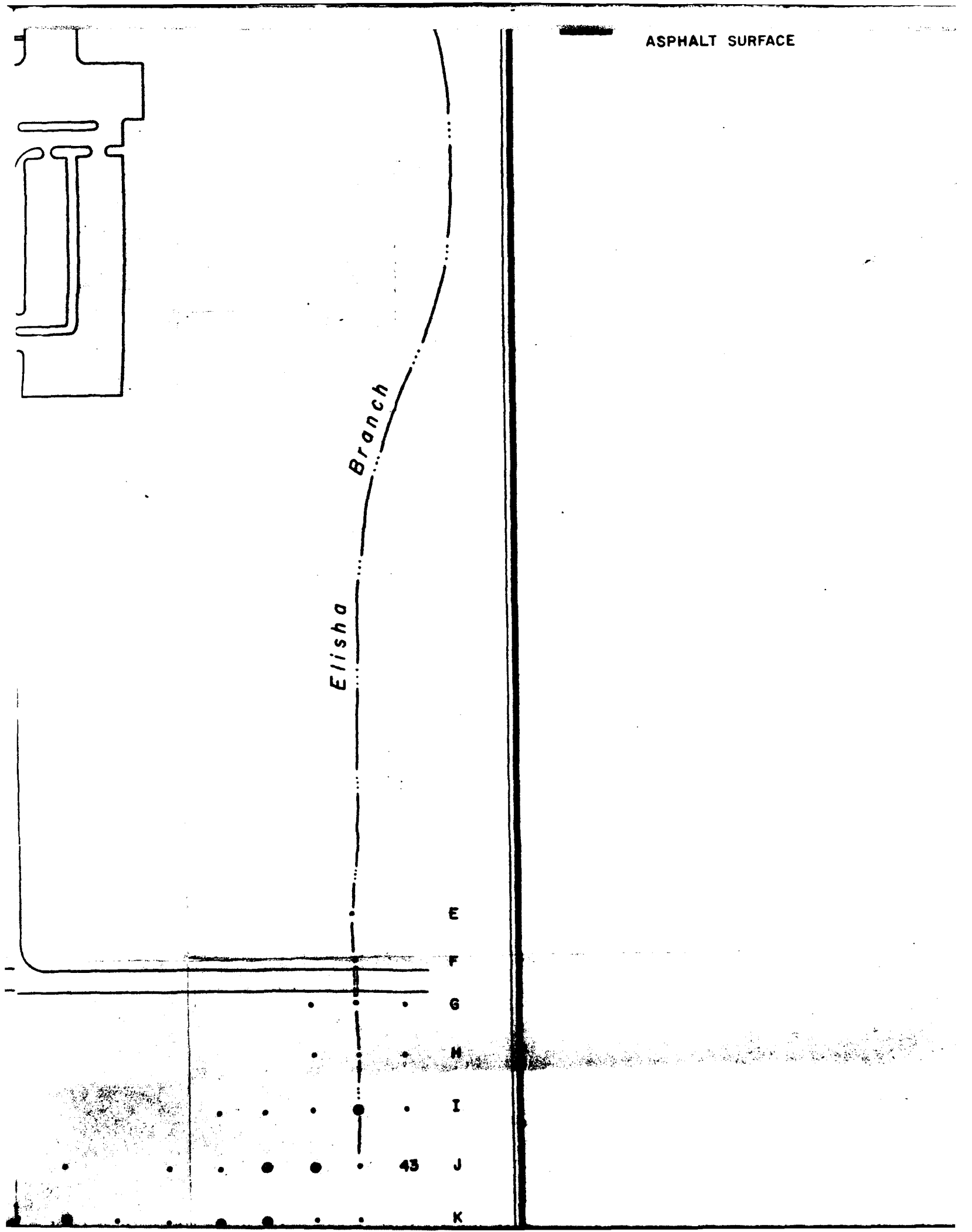
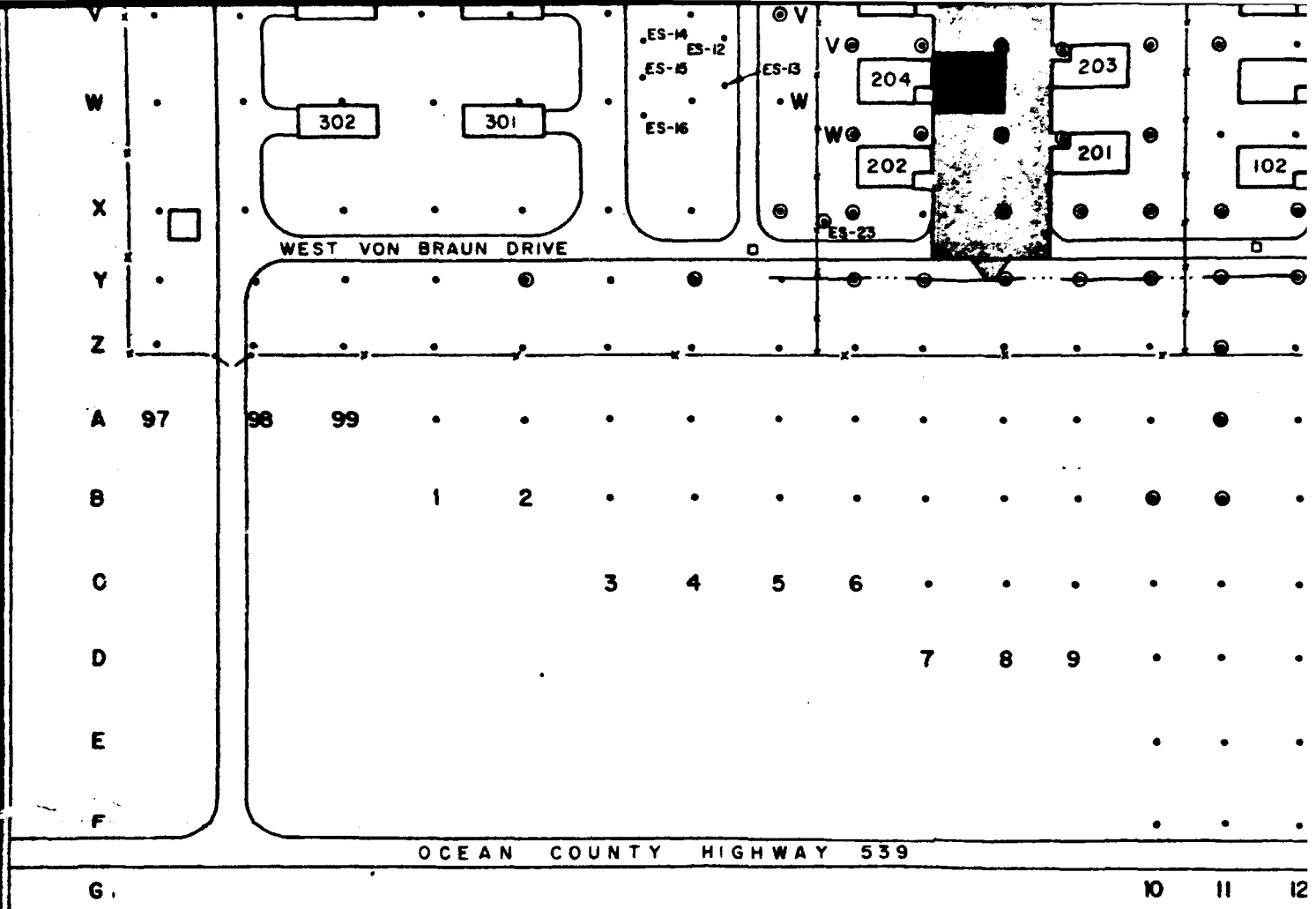
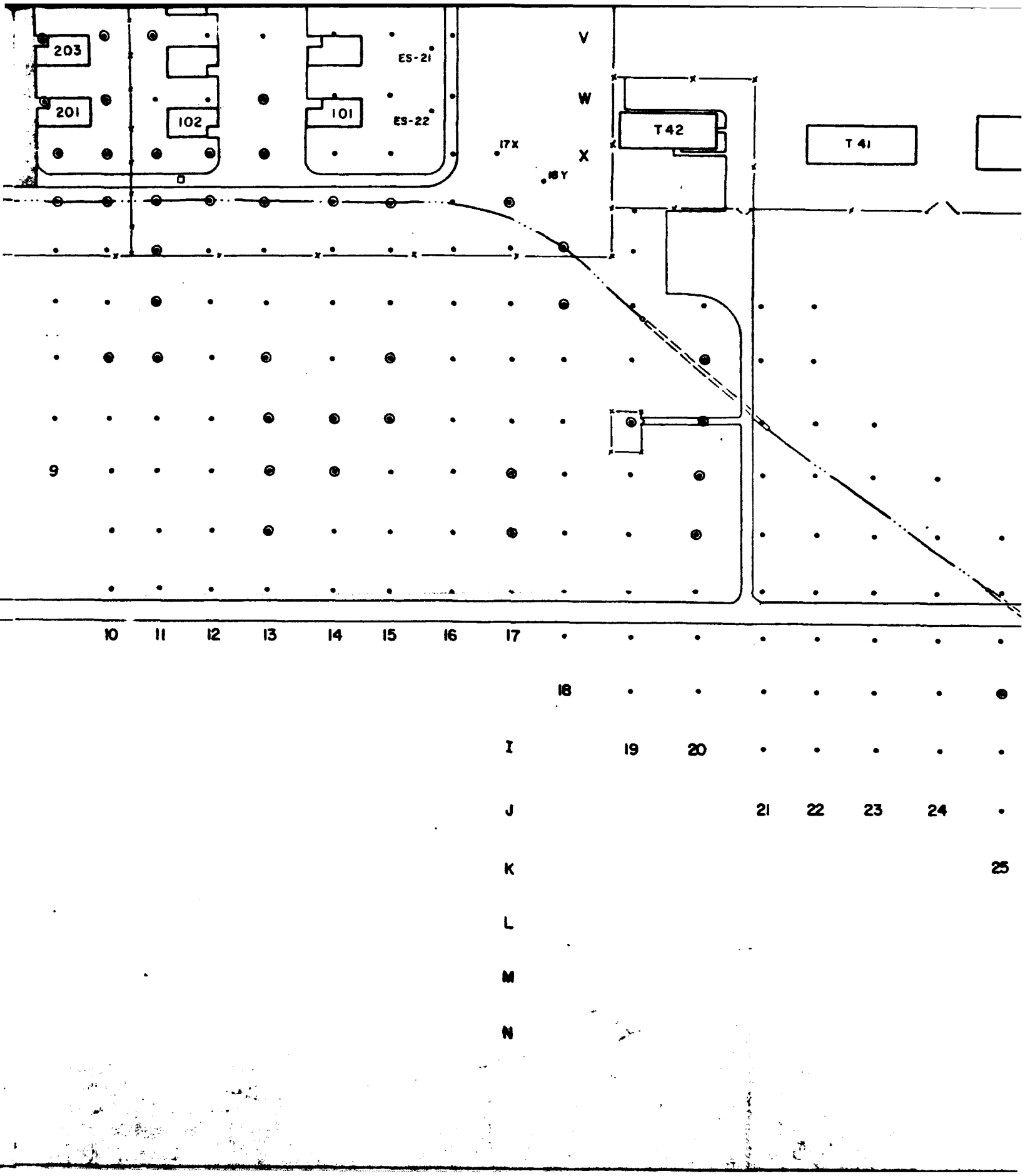
C
D
E
F
21
22
23
24


ASPHALT SURFACE
Elisha Branch
E
F
G
H
I
43
J
K


V
W
X
Y
Z
A
B
C
D
E
F
G
H
302
301
ES-14
ES-12
ES-15
ES-13
ES-16
204
203
202
201
102
ES-23
WEST VON BRAUN DRIVE
97
98
99
1
2
3
4
5
6
7
8
9
10
11
12
OCEAN COUNTY HIGHWAY 539


203
201
102
101
ES-21
ES-22
17X
18Y
V
W
X
T42
T41
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M
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T 41
T 40
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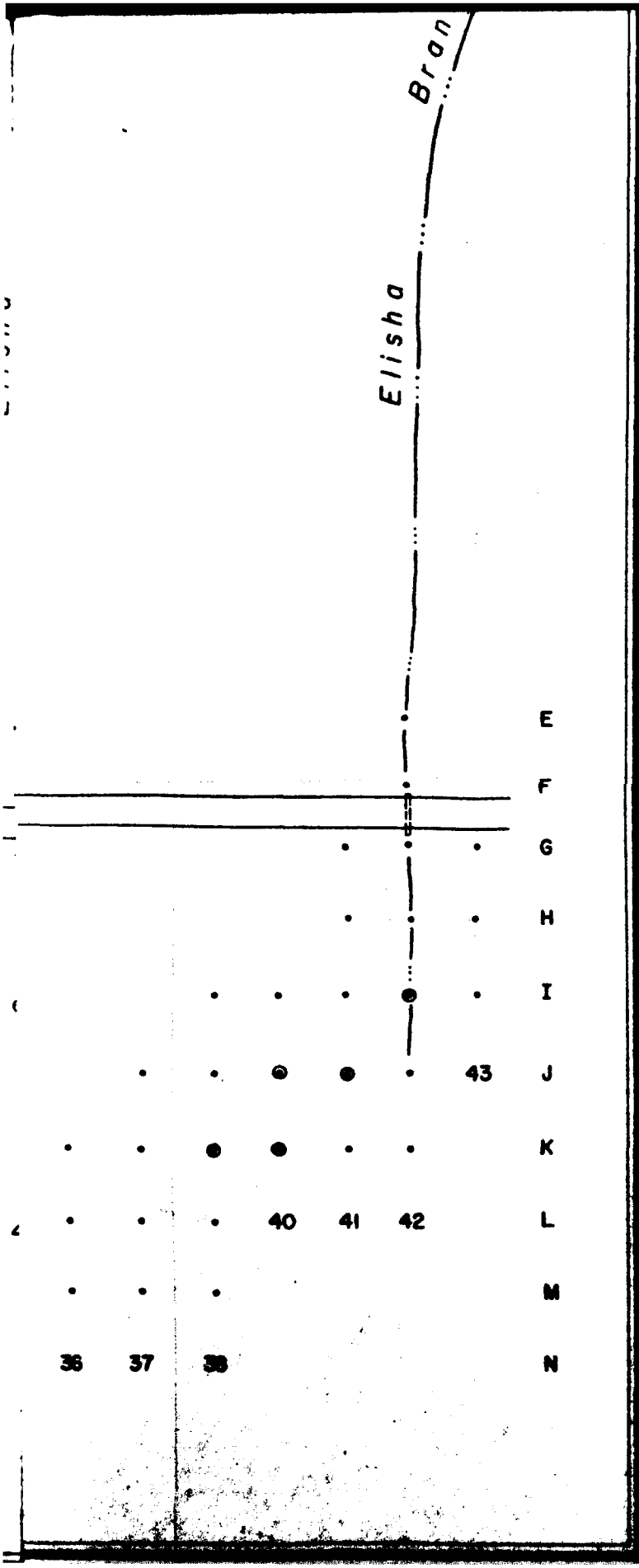

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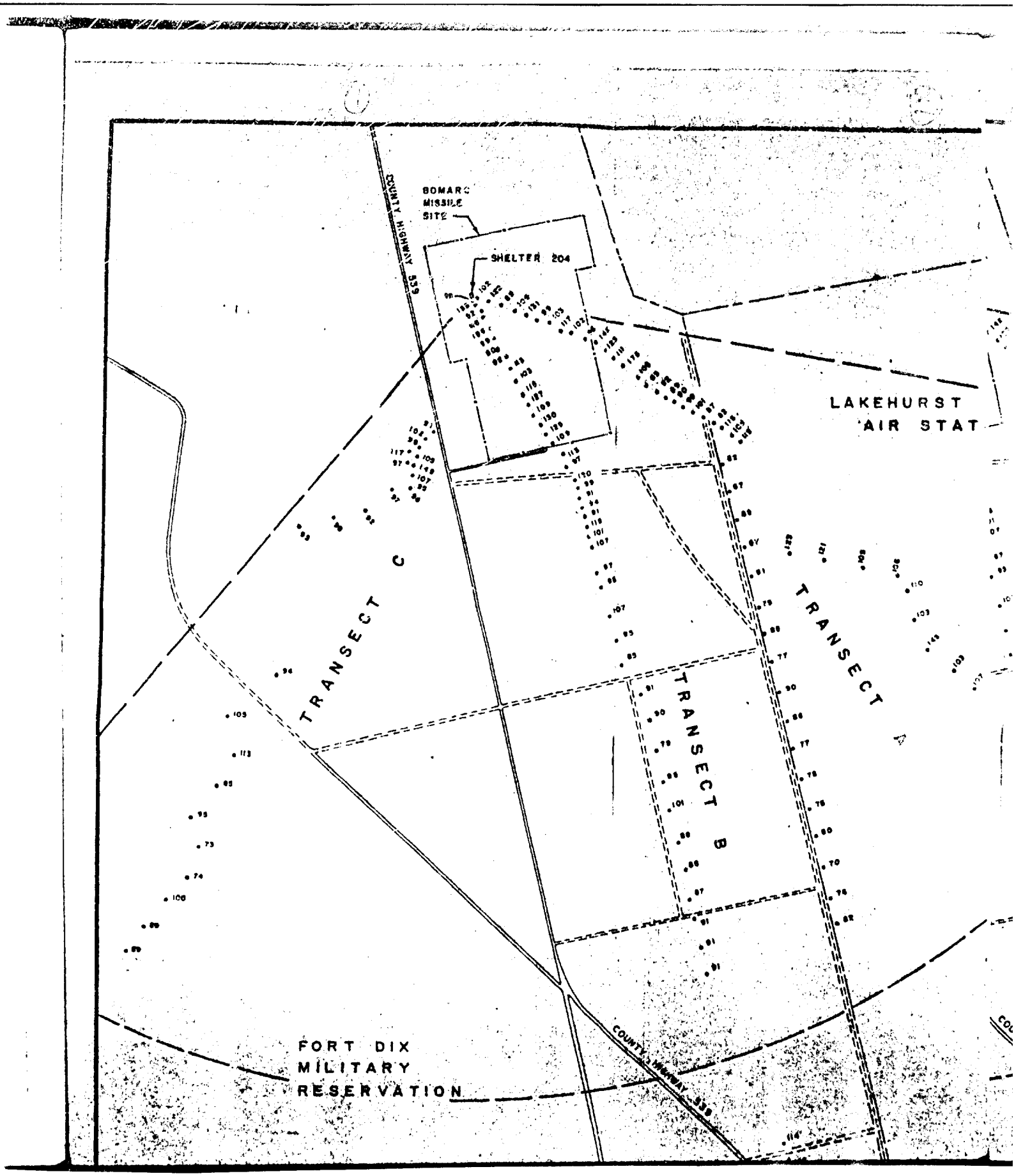
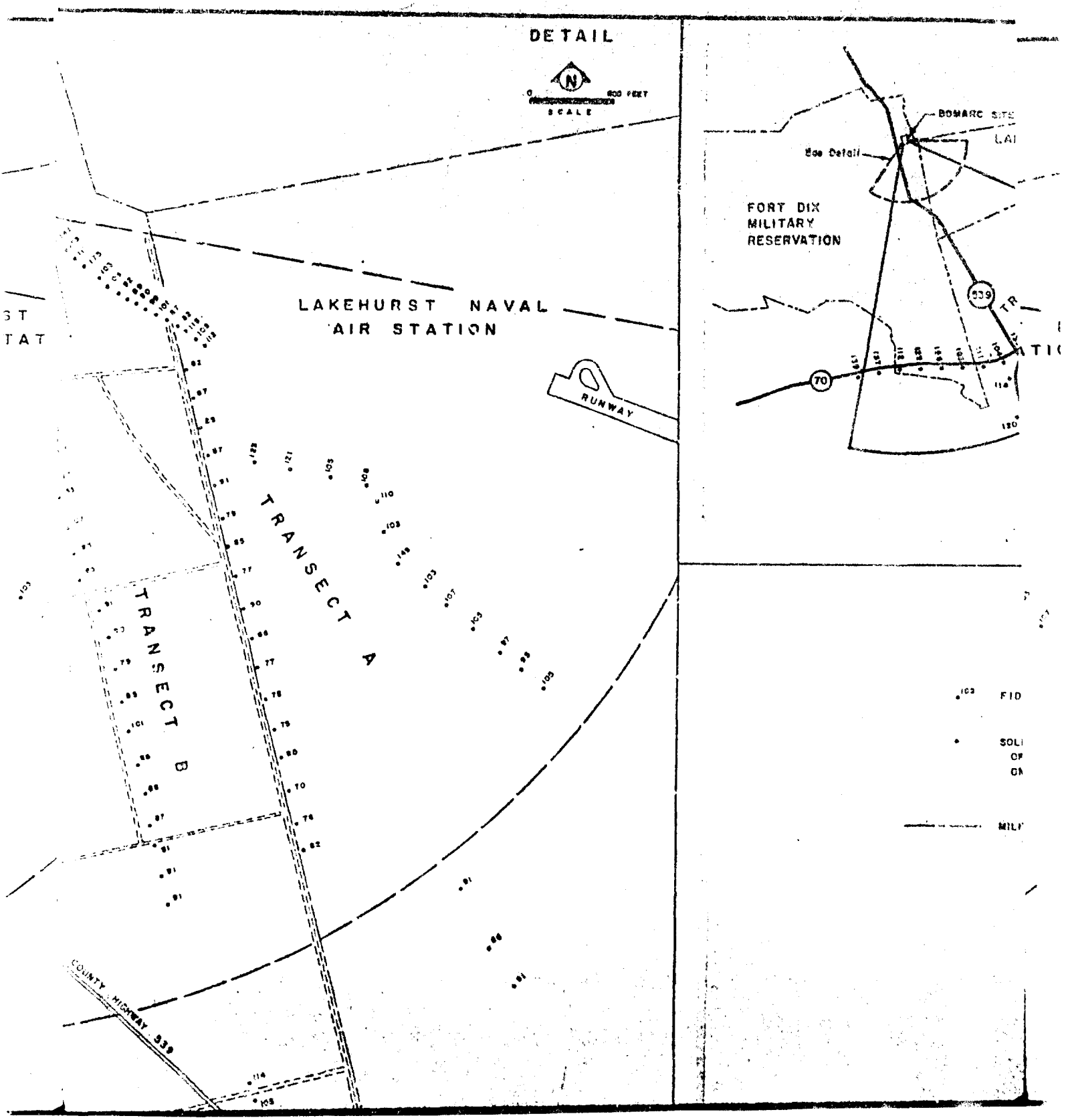
PLATE 4-1

IN-SITU SURVEY SAMPLING STATIONS


BOMARC
MISSILE
SITE
SHELTER 204
COUNTY HIGHWAY 539
LAKEHURST
AIR STAT
TRANSECT C
TRANSECT B
TRANSECT A
FORT DIX
MILITARY
RESERVATION
COUNTY HIGHWAY 539


DETAIL
N
0
800 FEET
SCALE
LAKEHURST NAVAL
AIR STATION
RUNWAY
TRANSECT A
TRANSECT B
COUNTY HIGHWAY 539
BOMARC SITE
See Detail
FORT DIX
MILITARY
RESERVATION
539
70

DETAIL

N

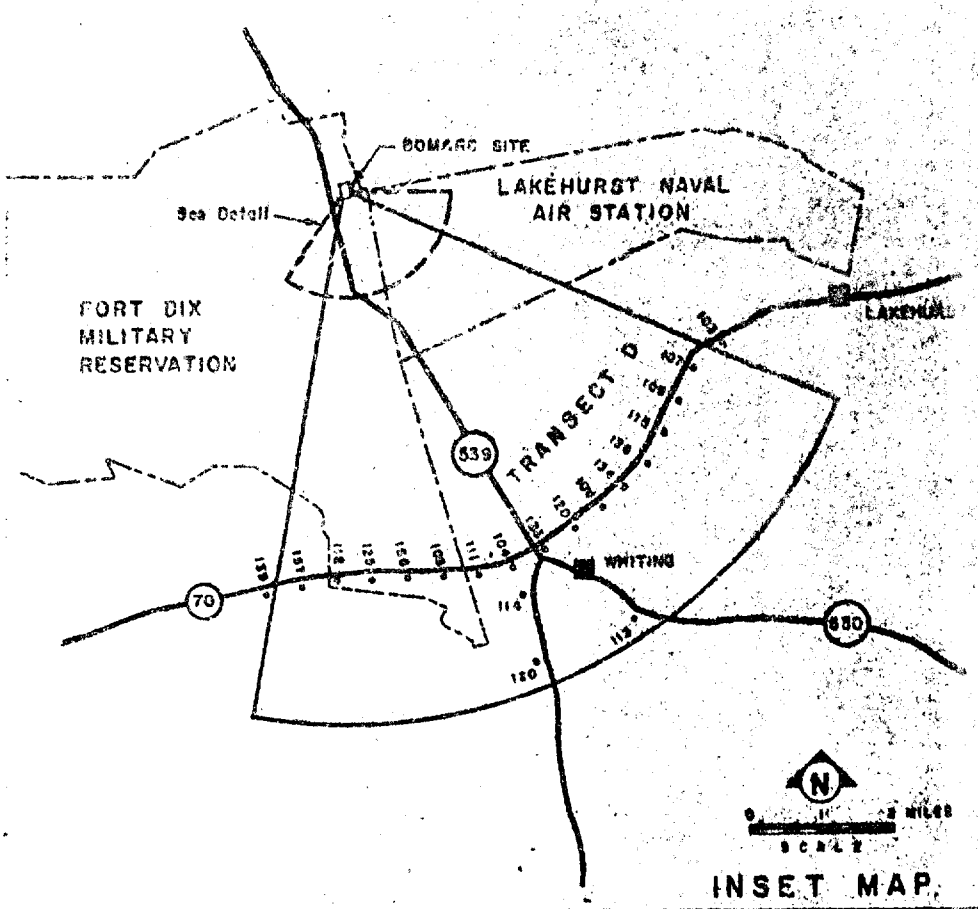
0 600 FEET

SCALE

N..VAL

..ION

RUNWAY



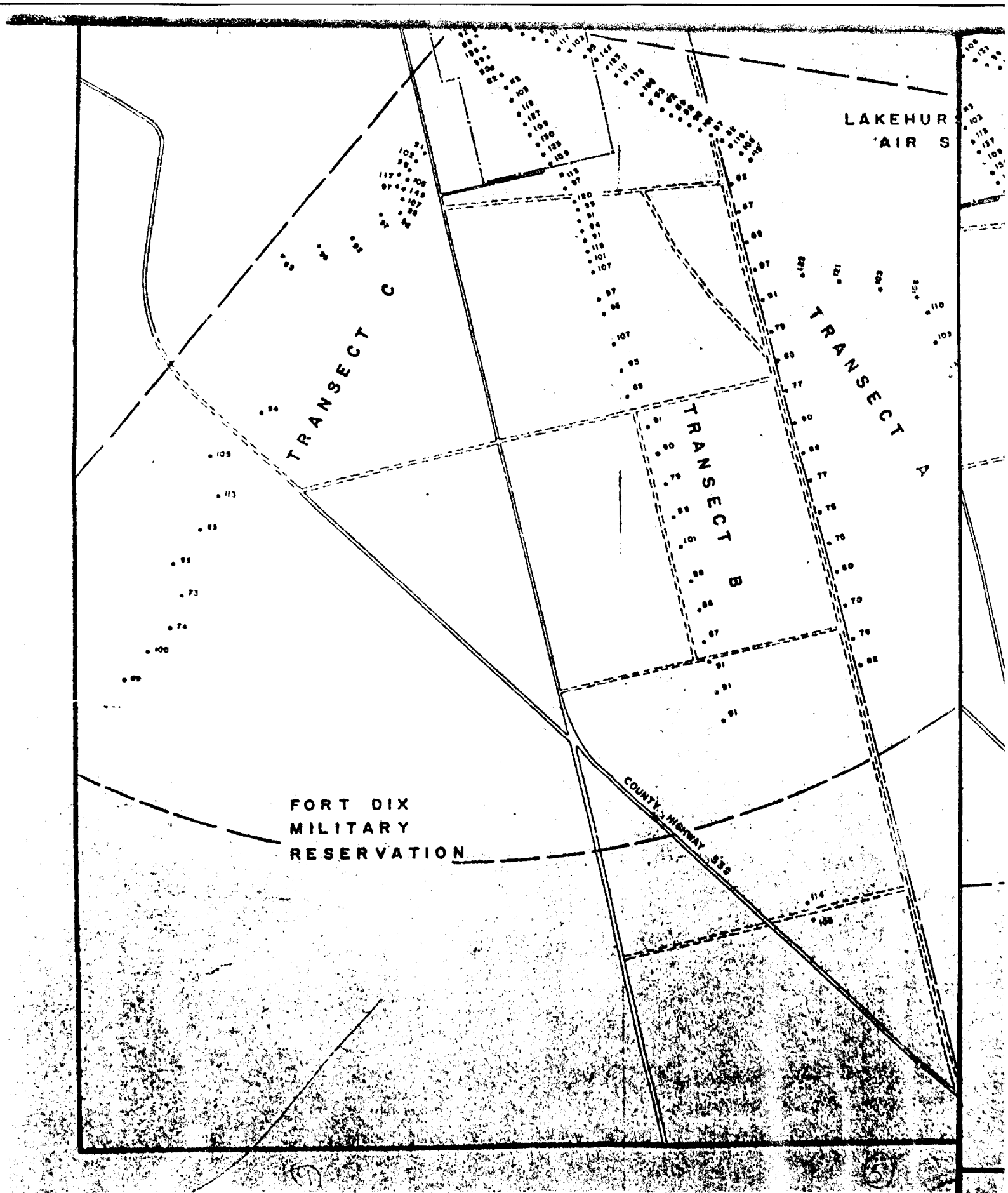
INSET MAP.

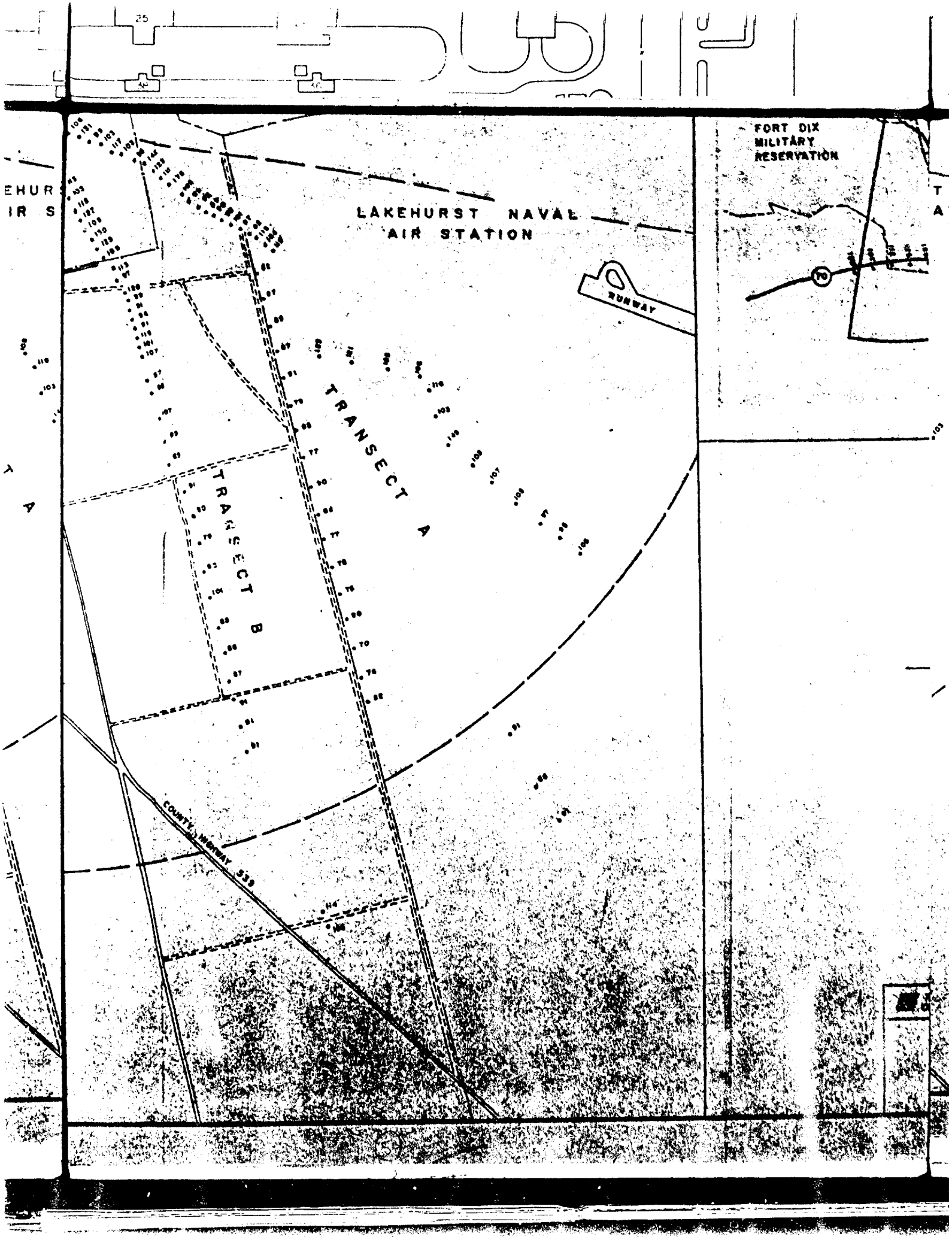
EXPLANATION

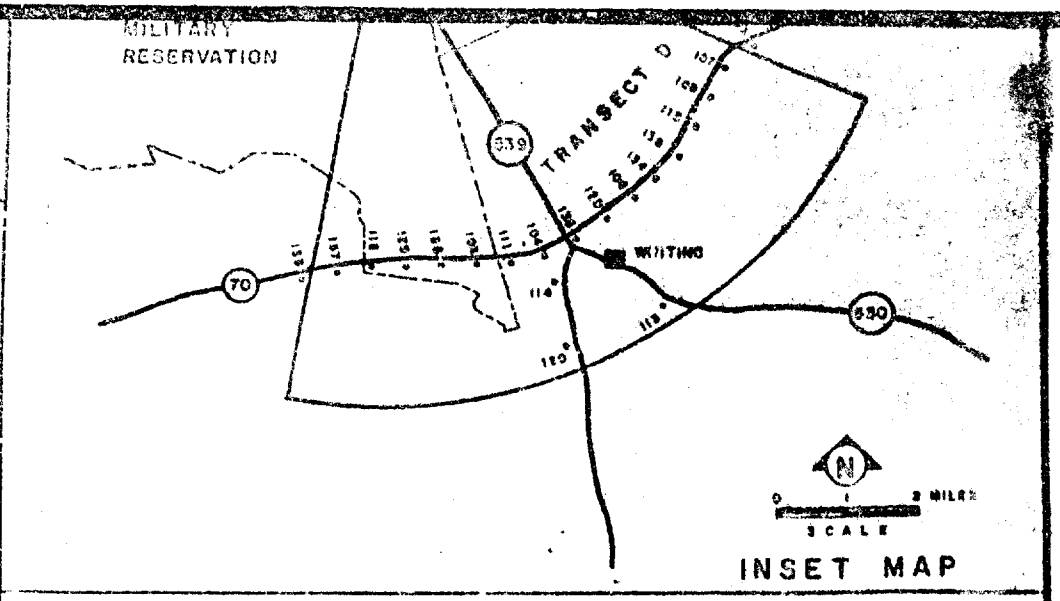
•[103] FIDLER READING IN COUNTS PER MINUTE

• SOLID POINT INDICATES SOIL SAMPLE TAKEN. OPEN POINT INDICATES FIDLER READING ONLY.

——— MILITARY RESERVATION BOUNDARY


LAKEHUR
AIR S
TRANSECT C
TRANSECT B
TRANSECT A
FORT DIX
MILITARY
RESERVATION
COUNTY HIGHWAY 532


LAKEHURST NAVAL
AIR STATION
RUNWAY
TRANSECT A
TRANSECT B
COUNTY HIGHWAY 539
FORT DIX
MILITARY
RESERVATION



INSET MAP

EXPLANATION

^{105} FIDLER READING IN COUNTS PER MINUTE

• SOLID POINT INDICATES SOIL SAMPLE TAKEN, OPEN POINT INDICATES FIDLER READING ONLY.

——— MILITARY RESERVATION BOUNDARY

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PLATE 4-2

LOCATIONS AND VALUES OF FIDLER READINGS TAKEN TO VALIDATE AIR MODELING