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**US Army Corps
of Engineers**
Toxic and Hazardous
Materials Agency

USATHAMA

MILAN ARMY AMMUNITION PLANT

Remedial Investigation Report
VOLUME I

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A Remedial Investigation at the Milan Army Ammunition Plant, TN, was conducted for the U.S. Army Toxic and Hazardous Materials Agency, under the terms of an Interagency Agreement with the State of Tennessee and the U.S. Environmental Protection Agency. The study focused on the CERCLA site and selected RCRA-regulated units identified by previous studies as potential sources of contamination. A broad range of chemicals including metals, explosives, and other organic compounds were found in source areas and in groundwater. The results of a risk assessment indicate that unacceptable levels of human health risks potentially exist. Conceptual models of site and unit characteristics were formulated to explain major findings, and areas not contributing to the problem were identified. For many source areas, major unknowns exist regarding hydrology, extent of contamination, and current and future impacts to groundwater quality.

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FOR -- TASK ORDER NO. 4
MILAN ARMY AMMUNITION PLANT
REMEDIAL INVESTIGATION

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LIST OF ACRONYMS

ACGIH—American Council of Government Industrial Hygienists
ADA—Ammunition Destruction Area
AETs—apparent effects thresholds
ARARs—Applicable or Relevant and Appropriate Requirements
ASME—American Society of Mechanical Engineers
AWQC—ambient water quality criteria
BLU-63—bomb-loaded unit-63
BNA—base/neutral/acid extractable
BOD—biochemical oxygen demand
CALs—Contaminant Action Levels
CBR—chemical, biological, or radiological
CBU—cluster bomb unit
CDI—chronic daily intake
CERCLA—Comprehensive Environmental Response, Compensation and Liability Act
CLASS—Contract Laboratory Analytical Support Services
CL—clay
COR—Contracting Officer's Representative
CPFs—carcinogen potency factors
CRDL—certified reporting detection limit
CRLs—certified reporting limits
CRL—certified detection limit
CRQLs—contract required quantitation limits
CVAA—cold vapor atomic absorption
DNB—1,3,5-dinitrobenzene
DNT—dinitrotoluene
EOD—explosive ordnance disposal
EPA—U.S. Environmental Protection Agency
EP—Extraction Procedure
ESE—Environmental Science and Engineering, Inc.
FEMA—Flood Emergency Management Agency
GFAA—graphite furnace atomic absorption spectroscopy
GOCO—government-owned, contractor-operated
HAG—Health Assessment Group
HAs—health advisories
HA—health advisory
HEAs—Health Effects Assessments
HEAT—high explosive anti-tank
HMX—cyclotetramethylenetetranitramine
HSSWDS—Hydrologic Simulation on Solid Waste Disposal Sites
ICAP—inductively coupled argon emission plasma spectroscopy
ICF—ICF Technology, Incorporated
IRDMS—Installation Restoration Data Management System
IRIS—Integrated Risk Information System
IU/BK—Integrated Uptake/Biokinetic
K—Hydraulic conductivity
LAP—Load, Assembly and Production Lines
LOEC—lowest observed effect concentrations
MAAP—Milan Army Ammunition Plant
MCLG—Maximum Contaminant Level Goals
MCL—maximum contaminant level
MEV—million electron volt
MGD—million gallons per day

LIST OF ACRONYMS (Continued)

MOD—Milan Ordnance Depot
NAAQs—National Ambient Air Quality Standards
NAS—National Academy of Sciences
NB—nitrobenzene
NCP—National Contigency Plan
NEPA—National Environmental Policy Act
NOAA—National Oceanographic and Atmospheric Administration
NOEC—no observed effect concentrations
NPDES—National Pollutant Discharge Elimination System
NPDWS—National Primary Drinking Water Standards
NPL—National Priorities List
NPRM—Notice of Proposed Rulemaking
NSDWRs—National Secondary Drinking Water Regulations
OBG—Open Burning Ground
ORNL—Oak Ridge National Laboratories
OSWER—Office of Solid Waste and Emergency Response
PAHs—polycyclic aromatic hydrocarbons
PBSJ—Post, Buckley, Schuh, and Jernigan, Inc.
PCBs—polychlorinated biphenyls
PDWC—Permissible Drinking Water Criteria
PID—photoionization detector
PPE—personal protective equipment
PVC—polyvinyl chloride
PWTF—pink water treatment facilities
QA/QC—quality assurance/quality control
RCRA—Resource Conservation and Recovery Act
RDX—cyclotrimethylenetrinitramine
RfDs—Reference Doses
RI—Remedial Investigation
RME—reasonable maximum exposure
RPD—relative percent difference
SARA—Superfund Amendments and Reauthorization Act of 1986
SC and ML—sand, silt, and clay
SMCLs—Secondary Maximum Contaminant Levels
SPHEM—Superfund Public Health Evaluation Manual
SWMU—Solid Waste Management Unit
TAL/TCL—Target Analyte List/Target Compound List
TBCs—To-be-Considered materials
TCL/TAL—Target Compound List and Target Analyte List
TDC—Tennessee Department of Conservation
TDHE—Tennessee Department of Health and the Environment
TICs—tentatively identified compounds
TLVs—Threshold Limit Values
TNB—1,3,5-trinitrobenzene
TNT—2,4,6-trinitrotoluene
TSS—total suspended solids
TWA—time-weighted average
USABRDL—U.S. Army Biomedical Research and Development Laboratory
USACE—U.S. Army Corps of Engineers
USAEHA—U.S. Army Environmental Hygiene Agency
USATHAMA—U.S. Army Toxic and Hazardous Materials Agency

LIST OF ACRONYMS (Continued)

USCS—Unified Soil Classification System
USEPA—U.S. Environmental Protection Agency
USGS—United States Geological Survey
UXO—unexploded ordnance
VOC—volatile organic compound
WCOP—Wolf Creek Ordnance Plant
Weston—Roy F. Weston, Inc.

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MILAN ARMY AMMUNITION PLANT REMEDIAL INVESTIGATION REPORT
EXECUTIVE SUMMARY

A Remedial Investigation (RI) of the Milan Army Ammunition Plant in Milan, Tennessee, was conducted by ICF Technology Incorporated under contract to the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). The purpose of the RI was to investigate the extent of contamination at the suspected source areas identified by previous researchers, delineate the groundwater contamination plumes, and collect and analyze additional data to determine the geology underlying the site, the direction and rate of groundwater flow and contaminant transport, and the characteristics of the local surface water hydrology. In addition, a risk assessment of the site was performed to identify exposure pathways, estimate exposure point concentrations using both empirical data and deterministic computer models, and evaluate the level of risk posed to both human health and the environment.

Past environmental studies have determined that explosive waste emanating from the O-Line Ponds and other disposal areas has resulted in groundwater, surface water, and sediment contamination. The goal of the RI field work was to investigate the areas of potential concern identified by previous studies; namely, the O-Line Ponds area, Open Burning Ground, Ammunition Destruction Area, Former Ammunition Destruction Area, Former Burnout Area, 30 explosive wastewater sumps at the ammunition load lines, drainage ditches, Closed Sanitary Landfill, Present Sanitary Landfill, Former Borrow Pit, and Salvage Yard.

The field work for the project was performed between July and December, 1990. The investigation consisted of the installation of 26 monitoring wells to supplement data from 63 existing monitoring wells, collection of surface and subsurface soil samples to characterize suspected source strengths, collection of surface water and sediment samples in the on-site drainage ditch system and other surface water bodies to assess the potential for off-site transport of contaminants and impacts on aquatic life, performance of a series of pump tests to characterize aquifer behavior, and the installation of six surface water gaging stations in the drainage ditch system to characterize flow, drainage patterns, and surface water percolation.

Milan Army Ammunition Plant (MAAP) is a government-owned, contractor-operated facility whose primary mission includes the loading, assembling, and packaging of conventional ammunition items, as well as the maintenance, storage, and demilitarization of items as required. The MAAP facility was constructed in 1941 and with the exception of the period between 1945 and 1953 when the facility was in standby status, operations at MAAP have continued in an active status since that time. MAAP is currently under the jurisdiction of the U.S. Army Armament, Munitions, and Chemical Command. The operating contractor is Martin Marietta Ordnance Systems, Inc. and the current level of employment is 1,600 workers.

MAAP covers 22,436 acres and is located in both Carroll and Gibson Counties, Tennessee. The site lies approximately midway between the Tennessee and Mississippi Rivers in the west central part of the state. The City of Milan, population 8,000, lies to the immediate northwest of the site.

The topology of the site is flat to gently rolling. Numerous perennial and ephemeral surface water bodies drain the site; the largest of which are the Rutherford Fork of the Obion River and Wolf Creek. In the northern portion of the site, drainage ditches run roughly south to north and receive both surface runoff and discharge from MAAP treatment plant outfalls. The Rutherford Fork flows east to west and receives inflow from the major drainage ditches.

In the past, wastewater from production activities in the lines was discharged to concrete sumps or surface impoundments where settling of explosives occurred. From the sumps, wastewater flowed to the ditch system. Currently, MAAP treats all process water from the lines that generate explosives-contaminated wastewater in six pink water treatment facilities (PWTFs). The water is treated by an activated carbon adsorption system and discharged under the authority of a National Pollutant Discharge Elimination System (NPDES) permit.

The surface water studies conducted during the RI consisted of flow measurements at six locations in the ditch system during precipitation events. Analysis of the flow/precipitation data indicates that the ditches are losing bodies; that is, baseflow is zero, intermittent flow is due to PWTF discharge and surface runoff during precipitation events, and surface water recharges groundwater at these times. The estimated rate of surface water loss to groundwater is 90% of the water which enters the ditch system. The remaining 10% of the water flows to the Rutherford Fork via the major ditches or Wolf Creek.

MAAP lies in the Gulf Coastal Plain physiographic province. It is underlain by the Memphis Sand stratigraphic unit, which is part of the Claiborne group of Cretaceous age. The Claiborne and underlying Wilcox groups are the principal sources of groundwater in western Tennessee. The Memphis Sand is a thick body of non-marine sands that include subordinate lenses of clay and silt. Analysis of the boring logs developed during the field work shows that the clay and silt lenses, which range in thickness from 0.04 to 0.5 feet, cannot be correlated between wells and are therefore discontinuous across the site. The results of the aquifer testing indicate that the average horizontal hydraulic conductivity across the site is 27 feet/day. The stratified nature of the aquifer probably impedes the localized downward flow of groundwater without significant effect on horizontal movement or large-scale (regional) vertical migration.

The groundwater elevation contours obtained from the water level readings measured on December 3, 1990, indicate that the predominant flow direction is to the north-northwest. Groundwater is recharged primarily by precipitation infiltration in the southern portion of the site. Shallow groundwater in the northern portion of the site discharges to the Rutherford Fork, Wolf Creek, and Johns Creek on the eastern boundary of the site, but analysis of the potentiometric data from the well clusters indicates that much of the groundwater flows under these local discharge points and continues northwest to regional discharge points.

The small magnitude of the hydraulic gradient results in a low groundwater flow velocity, which is estimated to be 0.20 feet/day. This is an average value for the site, and some variation is expected for various areas of the MAAP facility.

From 1942 to 1978, MAAP has operated an ordnance demilitarization facility at O-Line. Wastewater from O-Line flowed into a series of earthen settling ponds and then into a drainage ditch, which flows north to the Rutherford Fork. Use of the ponds was discontinued in 1978 because of the discovery of groundwater contamination in three of the eleven production wells. The ponds were determined to be the most likely source of the contamination. In December 1984, the ponds were closed with a multilayered cap.

Previous investigators have determined that a groundwater contamination plume extends from the O-Line Ponds area toward the north-northwest. The collection and analysis of groundwater samples from existing and newly-installed wells during the RI field work confirmed that past use of the ponds has resulted in contamination by explosive compounds. The plume encompasses a relatively narrow region between the ponds and the northern facility boundary. The southern limit is the area around the O-Line Ponds, which is the location of the highest concentrations. The plumes for 2,4,6-TNT and HMX extend to the northern boundary as these compounds were detected in the northernmost cluster wells. The true northern extent of these contaminants cannot be determined from empirical evidence. However, the contaminant mass contained within the plume has been estimated and compared to the estimated loading rate of explosives in groundwater and the close agreement between these numbers indicates that the plume probably does not extend significantly further north of the facility boundary.

The extent of the plume compared to the calculated contaminant transport velocities for the contaminants indicate that the drainage ditches have been concurrent sources of contamination. Further evidence that this may have occurred is the results of the stream flow analysis, which shows that a significant fraction of the surface water in the ditches percolates downwards to the water table. It is also possible that residual contamination in the soil underlying the ditches is continuing to impact groundwater quality.

Approximately 370 acres at MAAP have been used for the destruction and disposal of out-of-specification ordnance items and explosive-contaminated wastes since about 1942. The area within this acreage where these wastes were destroyed is known as the Open Burning Ground (OBG) and the Ammunition Destruction Area (ADA). The ADA is further divided into the current ADA and the former ADA. The former ADA, which was abandoned in 1947, separates the current ADA from the 190 acres still used for open burning. Groundwater monitoring data collected by previous researchers have shown low but increasing levels of explosive contamination in groundwater from wells adjacent to the OBG. The analysis of groundwater samples collected during the RI show that high levels of explosives are present in the groundwater at depth.

Three categories of waste originating both on and off the MAAP site have been handled and/or continue to be handled at the OBG. They include bulk explosives; ordnance components, including defective ordnance items or components damaged during assembly at MAAP, and assemblies or components removed from inventory at storage depots; and wastes potentially contaminated with explosives, including boxes, crates, paper, rags, strapping, pallets, spent carbon from the PWTFs, precipitated explosives from settling sumps, and cleaning solvents that may have come into contact with explosive materials.

Bulk explosives, ordnance, and explosive-contaminated wastes were typically burned (as opposed to being detonated) at the OBG. Some explosive-contaminated liquid wastes, including paints and cleaning solvents, were disposed at the OBG without burning. Bulk explosives were burned on the ground surface. After a burn was completed, any combustion by-products were placed in natural gullies or excavated trenches.

The results of a trenching survey conducted in the OBG in 1988 indicated that two areas of highly contaminated soils exist in the northern area and a widespread area of lower contaminant levels exists in the southern portion of the OBG. Because the horizontal extent of contamination was not determined by the previous study, a fixed grid boring system was used in this study. The distance between each grid node was 800 feet. The grid was oriented so that nine of the nineteen boring locations were situated in the central portion of the OBG. One boring was located in each of the two areas identified in the previous study as being highly contaminated. The remaining borings are located around the perimeter of the OBG.

The chemical analytical results for soil samples collected from these borings show that contamination by explosives was detected at only three soil boring locations. Significant contamination by select metals (cadmium, chromium, mercury, and lead) was not detected. The vertical extent of soil contamination by explosives at these locations is limited to a depth of fifteen feet, with the concentrations of contaminants decreasing significantly at depths beyond 5 feet. It appears that the areas which are causing the observed groundwater contamination were not investigated during this study. Most of the boring locations do not correspond to the source areas identified by previous researchers. Therefore, it is likely that widespread subsurface contamination does not exist in the OBG, and that the groundwater contamination is caused by localized regions.

The Former Burn Out Area, located in the southern portion of the site, was investigated with five soil borings, the installation and sampling of a new monitoring well, and sampling of downgradient wells. The results of this investigation do not indicate that this area represents a significant source of contamination. Lead was detected in surface soil above the background level but was not detected in subsurface soil samples. Organic compounds associated with the production or packaging of explosives were detected in soil at very low concentrations. Explosives were not detected in soil samples. Therefore, the data indicate that this area is not a significant source of groundwater contamination.

The sumps at the load lines were investigated with horizontal and vertical soil borings to depths below the bottom of the sump. Surface and subsurface soil samples were collected to determine the extent of contamination and the potential for groundwater contamination at these locations. In general, the analytical data indicate that although surface and near-surface soil near some of the sumps is contaminated with explosives and heavy metals, the levels of contamination attenuate rapidly with depth.

The soil near sumps in Line B appears to be the most contaminated but it is not known if the observed soil contamination extends to the water table. Therefore, it cannot be determined, based on available data, if the cause of groundwater contamination is the soil near the sumps or the drainage ditches which received wastewater from the sumps.

Soil borings were installed in the Present Landfill, Closed Landfill, Former Borrow Pit, and Salvage Yard to determine the vertical and horizontal extent of contamination. The soil samples collected from the Present Landfill and Salvage Yard borings indicate that these areas are not significant sources of explosives or metals. Explosives and metals were detected in soil at depth in the Closed Landfill; however, the borehole was not extended to the water table so the vertical extent of contamination was not determined. In the Former Borrow Pit, lead and 2,4-DNT were detected in a surface soil sample but were not detected at a lower depth. Other organic contaminants were detected in soil samples collected down to 24 feet but were not detected in the downgradient monitoring wells. Therefore, the Former Borrow Pit does not appear to be a source of groundwater contamination.

A risk assessment was conducted to evaluate the human health and environmental risks associated with contamination of groundwater, surface soil, and sediment and to a lesser extent, contamination of subsurface soils and surface water by past activities at MAAP. In this assessment, a set of chemicals of potential concern was selected for detailed evaluation based on the RI sampling results. Using a conservative selection procedure, chemicals were selected for five media (groundwater, surface soil, subsurface soil, surface water and sediment). A variety of organic and inorganic chemicals have been detected at MAAP, in addition to the explosive compounds and the four metals that were the focus of the field investigation. The explosive chemicals and several organic chemicals most likely associated with manufacturing and production at the load lines were detected in each medium. Many inorganic chemicals also were detected in each medium. Because few background samples were collected in each of the sampled media, background levels of chemicals of concern have not been well characterized. Nevertheless, many of the inorganic chemicals detected at low concentrations were retained as chemicals of concern, although they could be well within background levels.

To evaluate the potential human health risks, several exposure pathways were selected for detailed evaluation. The exposure pathways that were quantitatively and qualitatively evaluated were:

- Residential drinking water exposures of future groundwater users at the northern and northwestern boundaries of MAAP, and of current users of off-site wells (quantitative);
- Residential inhalation and dermal exposures during in-home use of groundwater (qualitative);
- Inhalation exposures of workers and nearby residents of chemicals adsorbed onto wind-generated dust from surface soils at the OBG (quantitative); and
- Ingestion of deer killed at MAAP (quantitative).

Due to institutional controls at MAAP, drinking water ingestion exposures for potable water were not evaluated for those who work and live there. Several wells at MAAP are used for non-potable water, and dermal exposures and exposures from inhalation of chemicals that have volatilized during use could occur. These exposures are not expected to be significant, as few volatile chemicals were detected in groundwater, and those that were, were detected at low concentrations. Nevertheless, since these wells are not currently monitored, it is recommended that the water from non-potable wells be monitored on a somewhat consistent basis.

Exposure scenarios for each of the potential exposure pathways that was quantitatively evaluated were developed, and exposure point concentrations and chronic daily intakes (CDIs) of exposed populations were made. In this assessment, the reasonable maximum exposure (RME) case was evaluated in accordance with EPA guidance on conducting risk assessments at Superfund sites. For the pathways that were quantitatively evaluated, it was assumed that chemical concentrations in the environmental media sampled (or modeled) would remain constant over the duration of the exposure period assumed. In the absence of any site-specific information to the contrary, other exposure parameters used to estimate potential intakes for potentially exposed populations were based on EPA standard assumptions and/or professional judgement.

Quantitative risk assessment involves combining intakes for exposed populations with reference doses (RfDs, defined as acceptable daily doses for noncarcinogens) or slope factors (for carcinogens) to derive estimates of noncarcinogenic hazard, or excess lifetime cancer risks, of the potentially exposed populations. For carcinogens, potential risks are presented as the product of the CDI and slope factors. Risks were compared to EPA's target risk range of 10^{-4} to 10^{-6}. For noncarcinogens, potential hazards are presented as the ratio of the CDI to the reference dose (CDI:RfD), and the sum of the ratios is referred to as the hazard index. In general, hazard indices that are less than one are not likely to be associated with adverse health effects, and are therefore less likely to be regulatory concern than hazard indices greater than one. The risk estimates for each of the selected pathways are presented below.

For the receptor populations at the northern and northwestern boundaries of MAAP, risks exceeded the 10^{-6} risk level, primarily due to arsenic, RDX, and 2,4,6-TNT. However, it is important to note that RDX and 2,4,6-TNT are Class C carcinogens, and that carcinogenic risks could thus be over-estimated. In addition, arsenic was present in low concentrations and may well be within background levels, and so risks due to arsenic also could be over-estimated. The total hazard indices for groundwater ingestion exceed 1, primarily due to manganese, 1,3,5-TNB, 2,4,6-TNT, and vanadium. For current users of groundwater northwest of MAAP, the hazards associated with ingestion of groundwater exceeded one for cadmium. This could be due to problems in sampling, and therefore, there is uncertainty in the results.

Potential residents in the future could be exposed to organic chemicals of concern via inhalation of chemicals that have volatilized during use, and via dermal absorption. Relative to the risks associated with ingestion, inhalation and dermal exposures to chemicals in groundwater are not expected to be significant.

For the potential future drinking water exposures, it should be noted that it may not be appropriate to sum risks for all the chemicals of concern in the O-Line pond and OBG/ADA plumes of contamination, because the organic and inorganic chemicals are travelling at different rates (i.e., most inorganic chemicals are travelling at a slower rate than most organic chemicals). Therefore, it is unlikely that a potential receptor could be exposed to RME concentrations of all the chemicals at one time.

Inhalation risks were evaluated for workers at the OBG and for residents who live downwind from the OBG. The upper-bound excess lifetime cancer risks for workers was 1×10^{-5}, primarily due to chromium, while the risks for off-site residents was 2×10^{-6}, also due to chromium. As noted earlier, it was conservatively assumed that all chromium at the OBG was in the hexavalent form, a known inhalation carcinogen. However, it is more likely that most of the chromium in surface soil is in the trivalent (noncarcinogenic) form, as this form is readily adsorbed or complexed to soil particles, metal oxides, and organic matter.

The hazard index for the workers was one, due to chromium, while the hazard index for residents was less than one. Again, because it was assumed that all chromium was in the form Chromium VI, whose RfD is 200 times greater than the RfD for Chromium III, the hazards associated with inhalation exposures may be over-estimated.

Inhalation exposures of lead were not evaluated in the same manner as the other chemicals of potential concern. A comparison was made with the NAAQS for both worker and residential exposures, and with TLVs for worker exposures. According to modeled estimates of ambient air concentrations of lead on- and off-site, both worker and residential exposures would be well within acceptable levels.

Risks associated with ingestion of venison were calculated for those who consume deer killed at MAAP. Risks for ingestion of venison were 8×10^{-8}, while hazards were less than one, indicating that neither carcinogenic or noncarcinogenic effects are likely to occur.

In this assessment, potential ecological impacts associated with the chemicals of potential concern at the MAAP site were evaluated. Potential impacts on plants, terrestrial wildlife, and aquatic life were evaluated either qualitatively or quantitatively, depending upon the availability of exposure and toxicity information and the likelihood of significant exposure.

Potential impacts were evaluated for terrestrial wildlife exposed to chemicals of potential concern in soil, surface water and food. Impacts to deer, the indicator species for terrestrial wildlife, from ingestion of surface water are not predicted based on the available toxicity data. Exposure of terrestrial wildlife and livestock to chemicals in food also are not expected to result in significant impact due to the localized nature of the contamination at MAAP relative to the available foraging habitat.

Impacts to aquatic invertebrates and fish were evaluated by comparing surface water and sediment concentrations in various surface waters with ambient water quality criteria (AWQC), State water quality standards, and other toxicity data. Based on these comparisons it is apparent that aquatic life at MAAP may be adversely impacted by elevated concentrations of inorganic chemicals in surface water and sediment.

Conclusions

The major conclusions of this study are as follows:

- Groundwater contamination along a broad expanse and arising from several contributing sources is the problem of greatest concern at MAAP. The contaminated groundwater plumes extend toward off-site receptors, and the potential health threat is unacceptably large. Further data collection and/or an analysis of potentially feasible remedial or corrective measures is required. In order of decreasing availability to receptors with secondary consideration for chemical toxicity, known source strength, and release potential, the predominant source areas contributing to groundwater contamination are:
    - the ditches north of the O-line Ponds Area;
    - the closed O-line Ponds;
    - the OBG/ADA;
    - sumps, ditches, and wastewater ponds at several load lines;
    - the Closed Landfill;
    - the Former Borrow Pit; and
    - other areas investigated during this RI.
- Areas with relatively low or no observed problems and requiring no further action include:
    - the Former Burn Out Area;
    - the Present Landfill; and
    - the Salvage Yard.

- A significantly more complex set of hydrologic, chemical, and source identification questions were raised than can be resolved by available data. Many findings cannot be rationalized with the previously held concepts of release and transport from known sources at the site, and critical data for several areas are not available to isolate sources of concern. Many of these uncertainties are due to the inadequacy of available information toward understanding of hydrologic and transport processes, and to the presence of multiple contamination sources. Thus, for many of the areas, the site characterization phase has not progressed to the point where the feasibility of remedial options can be evaluated.

- The area where data are sufficient to proceed to a feasibility study phase, with concurrent additional data collection as necessary, is the O-Line Ponds Area, where additional data requirements can be related to needs for remedy selection and alternatives analysis.

Because the nature and extent of contamination and the resulting or potential human health and/or environmental risks were not fully characterized for each study area during this RI, further work at the site is planned by the Army and USATHAMA. At present, the following projects are being undertaken:

- A feasibility study for the O-Line Ponds area will be performed. The purpose of the feasibility study is to identify remedial options and treatment technologies which have the potential to mitigate the risks associated with contaminated media at the site. The identified technologies will be further researched, treatability tests will be conducted if needed, and the nine criteria listed in the NCP will be used to perform a detailed evaluation of each remedial option.

- Additional RI work will be performed to determine the extent to which the drainage ditches have contributed to groundwater contamination. The scope of work includes the installation of additional monitoring wells and the drilling of boreholes to collect subsurface soil samples.

- Negotiations between the Army and EPA are being conducted to evaluate whether the risk assessment performed as part of this study meets the requirements of a baseline risk assessment as defined under Section 430.30 (d) of the National Contingency Plan (40 CFR Part 300). If the risk assessment is not determined to be a baseline risk assessment, then a baseline risk assessment will be conducted for the facility or for specific areas within the facility.

In addition, further investigative work is planned for the OBG/ADA and other potential source areas identified in this RI.

As sufficient data are collected concerning each study area, a site-specific baseline risk assessment will be performed for each area. Should the potential risk associated with that area be determined to be unacceptably high, a feasibility study will be performed to identify remedial technologies which are capable of mitigating the risk.

SECTION 1.0

1.0 INTRODUCTION

ICF Technology Incorporated (ICF) has been contracted by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) to conduct a Remedial Investigation (RI) of the Milan Army Ammunition Plant (MAAP). This work was performed under Contract No. DAAA15-88-D-0009, Task Order No. 4. The RI field work and data evaluation procedures are in accordance with guidance documents for conducting activities performed under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). In addition, the procedures used in this investigation are consistent with the National Contingency Plan (NCP) and the Department of the Army's policy toward integrating the National Environmental Policy Act (NEPA) and CERCLA/SARA processes.

The RI was performed because the site is listed on the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL). The NPL is a list of those uncontrolled or abandoned hazardous waste sites which, in the estimation of EPA and based on available data, present the greatest risk to human health and the environment. The MAAP site was listed primarily because of contamination of groundwater by explosive compounds occurring at the O-Line Ponds Area and because of possible contamination of surface water by both explosives and toxic metals.

The purpose of this study is to determine the nature and extent of contamination associated with past disposal practices. In addition, the risks posed by conditions at the site to both human health and the environment are evaluated. The goal of this RI is to gather and present information which will allow appropriate risk management decisions to be made regarding evaluation and selection of remedial actions at the site.

This study was performed under the purview of USATHAMA, EPA Region IV, and the Tennessee Department of Conservation (TDC).

1.1 PURPOSE OF THE REPORT

This RI Report presents the results of background research performed at the site, field sampling procedures, the results of the investigation, an evaluation of the fate and transport of contaminants emanating from the site, and an assessment of risks posed by conditions at the site to human health and the environment. The purpose of the RI Report is to present a site-specific evaluation of the nature and level of risk so that an informed decision regarding the selection and evaluation of remedial actions can be made.

Past environmental assessments performed at MAAP have determined that explosive waste emanating from the O-Line Ponds and other on-site areas has resulted in groundwater, surface water, and sediment contamination. The goal of the field work conducted by ICF was to investigate all areas of potential concern identified by previous studies, including the O-Line Ponds area, Open Burning Ground (OBG), Current Ammunition Destruction Area (ADA), Former ADA, Former Burnout Area, loading, assembly, and production (LAP) lines which includes 30 explosive wastewater sumps, drainage ditches, Closed Sanitary Landfill, Present Sanitary Landfill, Former Borrow Pit, and the Salvage Yard. The field work was performed between August and December, 1990, and consisted of the following elements:

- installation of 26 monitoring wells to supplement data from 63 existing monitoring wells, to be used in determining the lateral and vertical extent of groundwater contamination;
- collection of surface and subsurface soil samples to characterize suspected source strengths;
- collection of surface water and sediment samples in the on-site drainage ditch system and other surface water bodies to assess the potential for off-site transport of contaminants and any impact on aquatic life;

- performance of a series of aquifer tests, including slug tests and drawdown and recovery pump tests to characterize aquifer behavior; and
- installation of six surface water gaging stations in the drainage ditch system to characterize flow, drainage patterns, and surface water percolation.

In addition to these data, historical data generated by studies performed by other researchers and information gathered during conversations and meetings with USATHAMA, the U.S. Army Corps of Engineers, MAAP, EPA Region IV, and TDC personnel were used in developing this report.

1.2 REPORT ORGANIZATION

The work presented in this report is divided into twelve sections as follows:

Section 1 - Introduction
Presents the purpose of the report and report organization.

Section 2 - Site Background
Presents information on the site location and physical setting, and also discusses the operational history of MAAP. This discussion focuses on the operations conducted at the suspected source areas at the facility. In addition, the results of previous environmental studies performed at the source areas under investigation are presented.

Section 3 - Previous Investigations and History of Response Actions
Presents a summary of previous investigations conducted at MAAP.

Section 4 - Technical Approach to Field Operations
Describes the field activities used to investigate the geology, hydrogeology, surface water hydrology, and extent of contamination at the site; the drilling of soil borings and soil sampling; installation of monitoring wells; collection of sediment, surface water and groundwater samples; aquifer testing; and stream gaging.

Section 5 - Results of Physical and Chemical Analyses
Presents the results of the physical testing of soils; water level survey results; aquifer test results; stream flow measurements, and the analytical results for soil, groundwater, surface water, and sediment samples.

Section 6 - Quality Assurance and Quality Control
Describes the quality control and quality assurance procedures and processes used during the remedial investigation.

Section 7 - Nature and Extent of Contamination
Describes the results of the chemical analysis of environmental samples in terms of characterizing the source areas and determining the extent of contamination in groundwater and surface water.

Section 8 - Contaminant Fate and Transport
Evaluates the environmental fate and transport of contaminants found at the site. This includes an assessment of potential routes of migration, the persistence and mobility of contaminants in the environment, and the potential for off-site migration of contaminants through affected media. A contaminant transport model was used to estimate the magnitude of groundwater contamination at the facility boundary in the future.

Section 9 - Baseline Risk Assessment

Identifies chemicals of potential concern and transport pathways which may result in human exposure. Characterizes the existing or potential human health risks that may be posed by conditions at the site. In addition, an environmental evaluation is described, in which concentrations of site-related chemicals in environmental media at exposure points are compared to toxicity-based criteria.

Section 10 - Identification of Potential Applicable or Relevant and Appropriate Requirements

Potential Applicable or Relevant and Appropriate Requirements (ARARs) are identified for use in evaluating proposed remedial actions.

Section 11 - Conclusions

Presents a summary of the remedial investigation findings. Discusses the nature and level of risk posed by conditions at the site. Data gaps are identified and recommendations are made for future work at the site.

Section 12 - References

2.0 SITE BACKGROUND

The following sections present known information regarding MAAP and specifically, the areas under investigation. This includes information on the site history, physical setting of the area, and a summary of potential environmental problems identified at the site by previous investigators.

2.1 PHYSICAL SETTING

MAAP currently covers 22,436 acres, and is situated in both Gibson and Carroll Counties as shown in Figure 2-1. The City of Milan lies 5 miles west of MAAP and has a population of 8,100; Humboldt lies 17 miles southwest with a population of 10,200; Trenton lies 18 miles northwest with a population of 4,600; and Jackson lies 28 miles south with a population of 50,000. The site is located approximately 50 miles east of the Mississippi River.

MAAP is serviced by two rail lines, two bus lines, several major truck lines, three US highways, and four state highways. Interstate 40 passes within 18 miles to the south of the plant. Air service is available through Jackson and Memphis, and there is a US Naval Air Station at Millington, Tennessee, near Memphis.

2.1.1 Climatology

The MAAP area is characterized by a temperate and continental climate. Rainfall averages about 50 inches per year, with an average minimum of 2.88 inches in October and an average maximum of 6.08 inches in January. There is no dry season, although the summer of 1990 was characterized by rainfall considerably below normal. Snowfall can be highly variable from year to year. The average annual evaporation is approximately 40 inches. Relative humidity averages 60-70%. The monthly mean temperature ranges from 40°F in winter to 80°F in July. The average frost free season is 215 days per year. The average depth of frost is 3 inches, with an extreme depth of 10 inches. Prevailing winds are from the south at an average velocity of 6-10 mph.

2.1.2 Site Physiography and Topography

MAAP is in the Gulf Coastal Plain Physiographic Province. Figure 2-2 is a relief map depicting the relationship of stratigraphic units to physiographic regions in Tennessee. MAAP lies within the coastal plain province of the Mississippi Embayment, west of the Western Valley of the Tennessee River and east of the Mississippi River Valley. The topography of the site and surrounding area is gently rolling to flat. It slopes regionally westward and contains numerous small streams, creeks, and drainage ditches. The elevation of the plant varies from a high of approximately 590 feet above mean sea level (ft-msl) on the south side, to a low of approximately 320 ft-msl on the north boundary of the plant.

2.1.3 Soil Types

The surface soils at MAAP consist chiefly of a reddish-brown to yellow mottled silty clay that grades into a clay unit with depth. The soil types include the Memphis, Loring, Grenada, Calloway, Henry, Falaya, and Waverly soil associations. Based on topography, the Memphis and Loring series occur on higher elevations and are well-drained soils. The Henry soil series is somewhat poorly drained and is usually associated with flat terrain while the Falaya and Waverly occur in the low areas and are poorly drained.

Drill logs from borings installed at the site indicate that the upper 12 to 15 feet of soil consists of reddish-brown to tan silty lean clay with some layers of sandy and fat clay. Below these depths, sands with varying amounts of silts and clays have been encountered. Occasional gravel, up to 3/8 inch in diameter, have been encountered during boring operations. A more sandy alluvium of lesser thickness

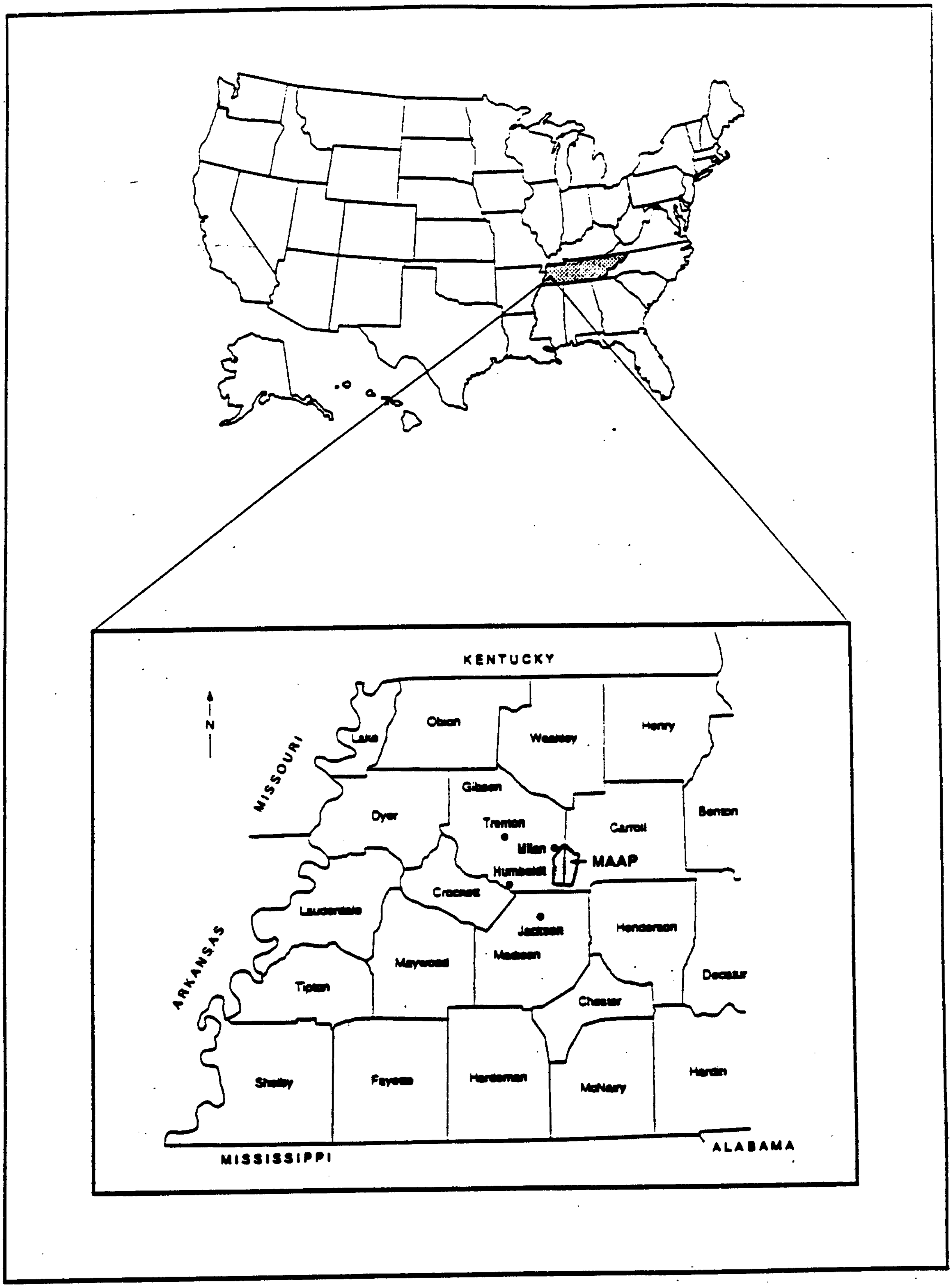
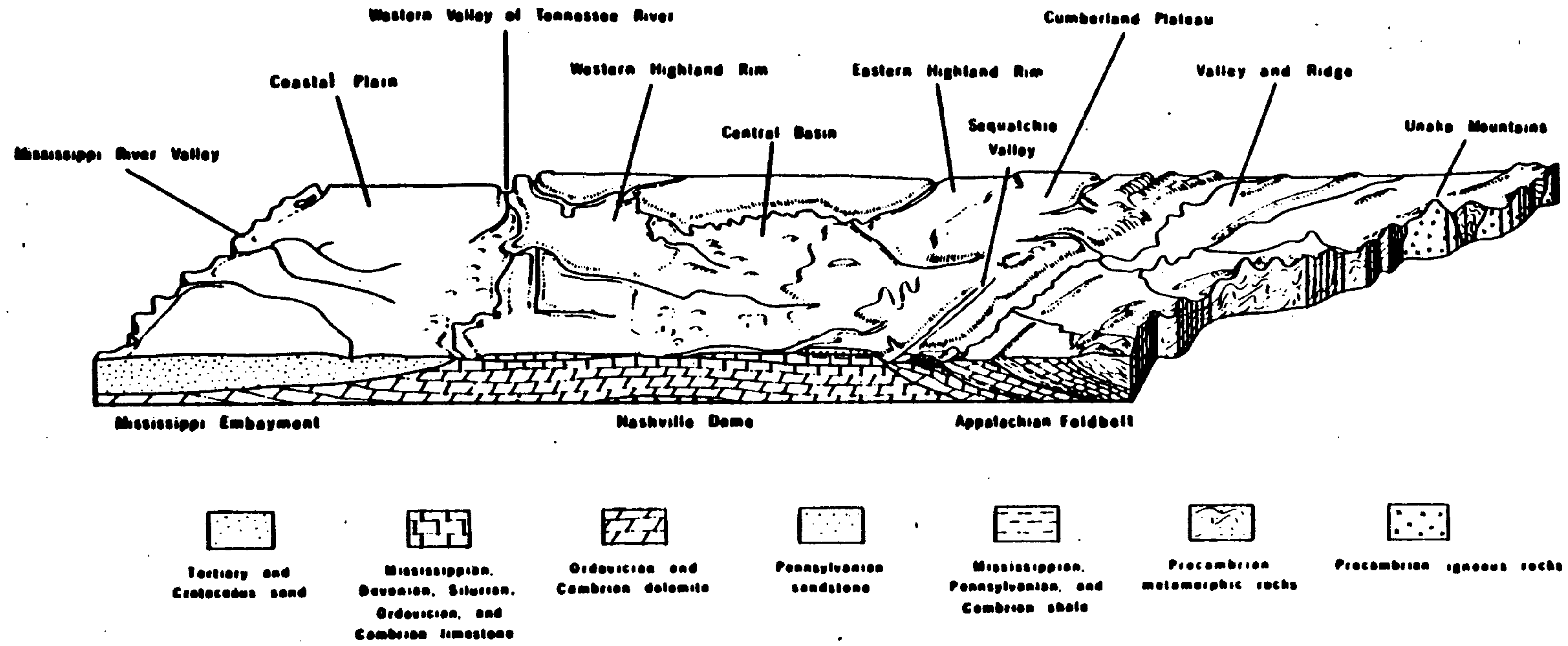


Figure 2-1
Location of MAAP in Western Tennessee



Source: Miller 1974

Figure 2-2
Relationship of Stratigraphic Units to
Physiographic Regions in Tennessee

(5-10 feet) was observed in several areas across the site. Natural and artificial drainage systems have incised into the alluvium in several locations.

2.1.4 Geology

Western Tennessee (including MAAP) lies on the eastern flank of the Upper Mississippi River Embayment. Structurally, the embayment is a downwarped, downfaulted trough whose axis approximates the present course of the Mississippi River. Sediments ranging in age from Cretaceous to Recent have been deposited in this trough during its complicated history which included advances and regressions of the sea. These sediments consist of sand, gravel, lignite, clay, chalk, and limestone units that vary in thickness.

MAAP is situated on the Memphis Sand of the Claiborne Group of Tertiary age in the Gulf Coastal Plain of western Tennessee. Figure 2-3 is a roughly east-west geologic cross section developed from lithologic and geophysical logs of observation wells in Dyer County (Dy:H-7, Dy:H-41), Gibson County (Gb:M-6; Gb:G-5), and Carroll County (Cr:F-15), as described in Parks and Carmichael (1990). The altitude and thicknesses of stratigraphic units beneath Milan, Tennessee are inferred from the data for observation wells in Gibson and Carroll Counties.

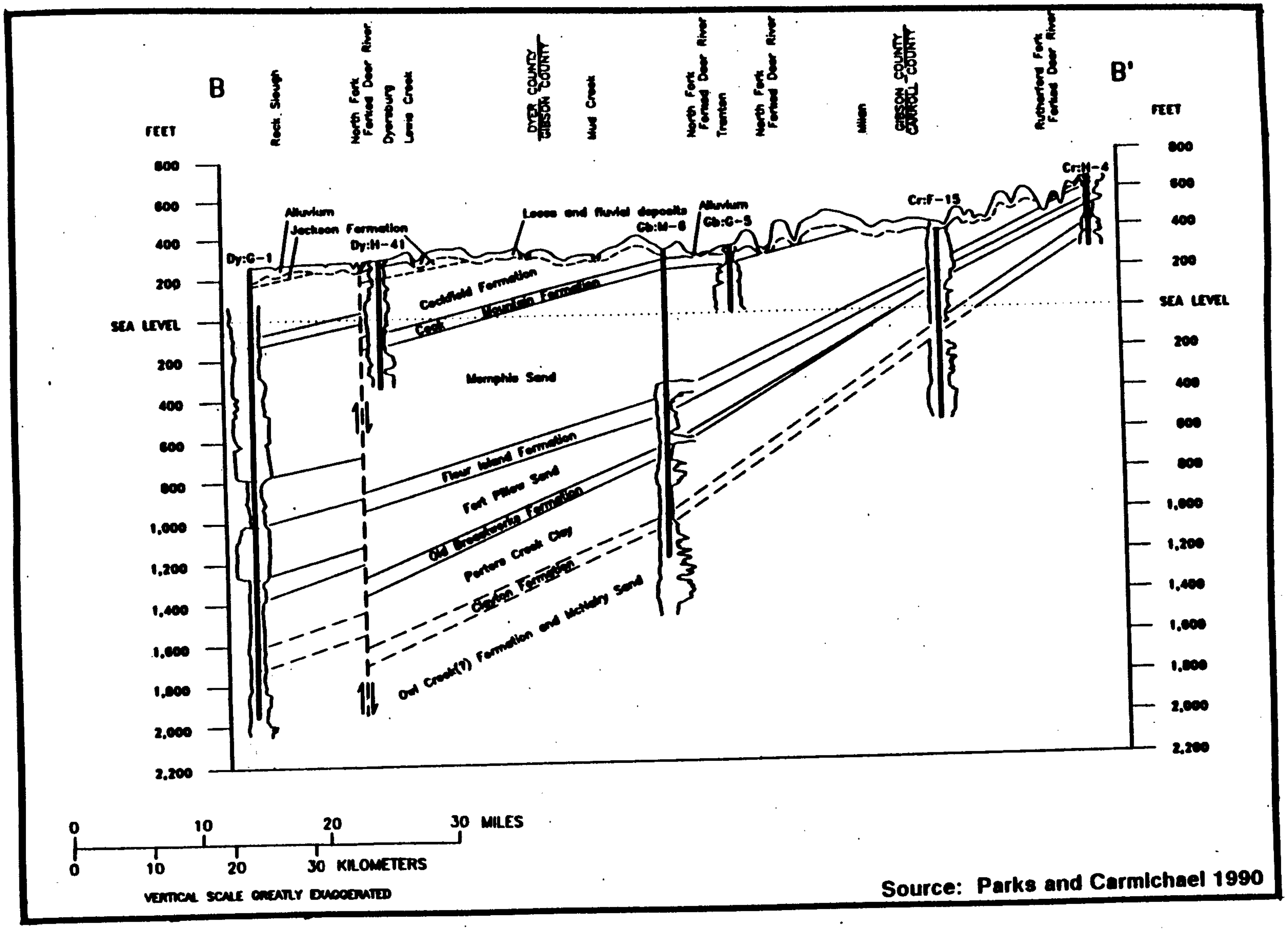
The Memphis Sand crops out in a broad belt across western Tennessee, but is covered in most places by fluvial deposits of Tertiary and Quaternary age and loess and alluvium of Quaternary age (Parks and Carmichael, 1990). The eastern boundary of the Memphis Sand was mapped by Parks and Russell (1975) as the contact between the Wilcox and Claiborne Formations. The Wilcox and Claiborne were mapped as formations because of the uncertainty of the equivalence of strata cropping out with the units that make up the Wilcox and Claiborne Groups in the subsurface, as subdivided by Moore and Brown (1969) (Parks and Carmichael, 1990). The western boundary of the outcrop belt is not well established because the contact between the Memphis Sand and the overlying Cook Mountain Formation is covered by fluvial deposits, loess or alluvium (Parks and Carmichael, 1990).

The Memphis Sand consists of a thick body of sand that includes subordinate lenses or beds of clay and silt at various horizons. The clay and silt locally are carbonaceous and lignitic; thin lenses of lignite also occur locally. Thick beds of clay and silt in the upper part of the Memphis Sand may, in some places, be confused with the overlying Cook Mountain Formation.

Sand in the Memphis Sand ranges from very fine to very coarse, but is commonly fine, fine to medium, or medium to coarse. The Memphis Sand ranges from 0 to 900 feet in thickness, and where the original thickness is preserved, it is about 400 to 900 feet thick (Parks and Carmichael, 1990). The formation is thinnest along the eastern limits of the outcrop belt in Hardeman, Madison, Carroll and Henry counties. In western Tennessee, the base of the Memphis Sand dips westward at rates of 20 to 50 feet per mile.

The Claiborne Group is underlain by the Wilcox Group which is about 60 feet thick. Figure 2-4 shows a north-south geologic cross section through MAAP and identifies the stratigraphic units underneath this area. There is no confining layer between the Wilcox and Claiborne Groups. Underlying the Wilcox is the Porters Creek Clay, which acts as a confining unit between the Fort Pillow Sand of the Wilcox Group and the McNairy Sand of Cretaceous age.

The exact depth to rock under MAAP is not known. A test well drilled to 1,289 feet about 20 miles south-southwest of MAAP near Jackson, Tennessee, was stopped in a sandy clay marl. It was estimated that rock (possibly limestone) would be encountered between 500 to 800 feet below the drilled depth of the test well.



Source: Parks and Carmichael 1990

Figure 2-3
E/W Geologic Cross-Section Through Dyer, Gibson and Carroll Counties, Tennessee

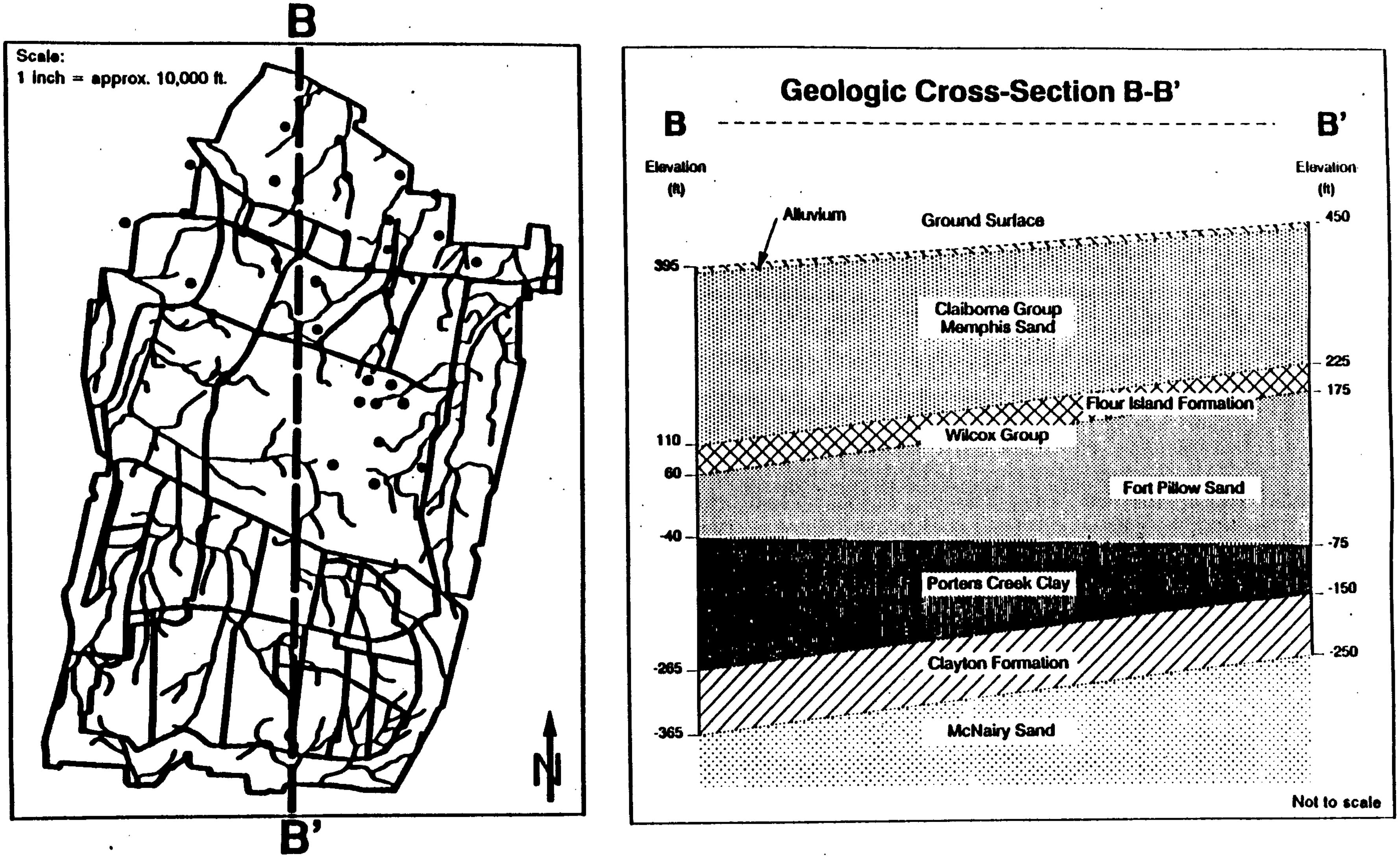


Figure 2-4

North/South Geologic Cross-Section of the MAAP Site

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2.1.5 Hydrology

2.1.5.1 Surface Water. Numerous perennial and ephemeral surface water features occur within the installation and flow to the north-northwest as depicted in Figure 2-5. Wolf Creek, the largest interior drainage body, originates at Pine Lake near the southeastern boundary and along with three tributaries (Dry Creek, East Fork of Wolf Creek, and West Fork of Wolf Creek) drains the southern and central portions of the installation. Wolf Creek exits along the northwest boundary and empties into the Rutherford Fork of the Obion River. The extreme southern portion of the installation drains south to the Middle Fork of the Forked Deer River (not depicted in Figure 2-5). The northeastern portion of the installation drains to Halls Branch, Johns Creek and then to the Rutherford Fork of the Obion River. The northern portions of MAAP contains several well-developed, ephemeral, natural drainage bodies (defined alphabetically and numerically as Ditches 1 through 10, B, and C in Figure 2-5) that join the Rutherford Fork along the northern boundary of the installation. The two parent streams, the Forked Deer River and Obion River, empty into the Mississippi River about 60 miles west of MAAP.

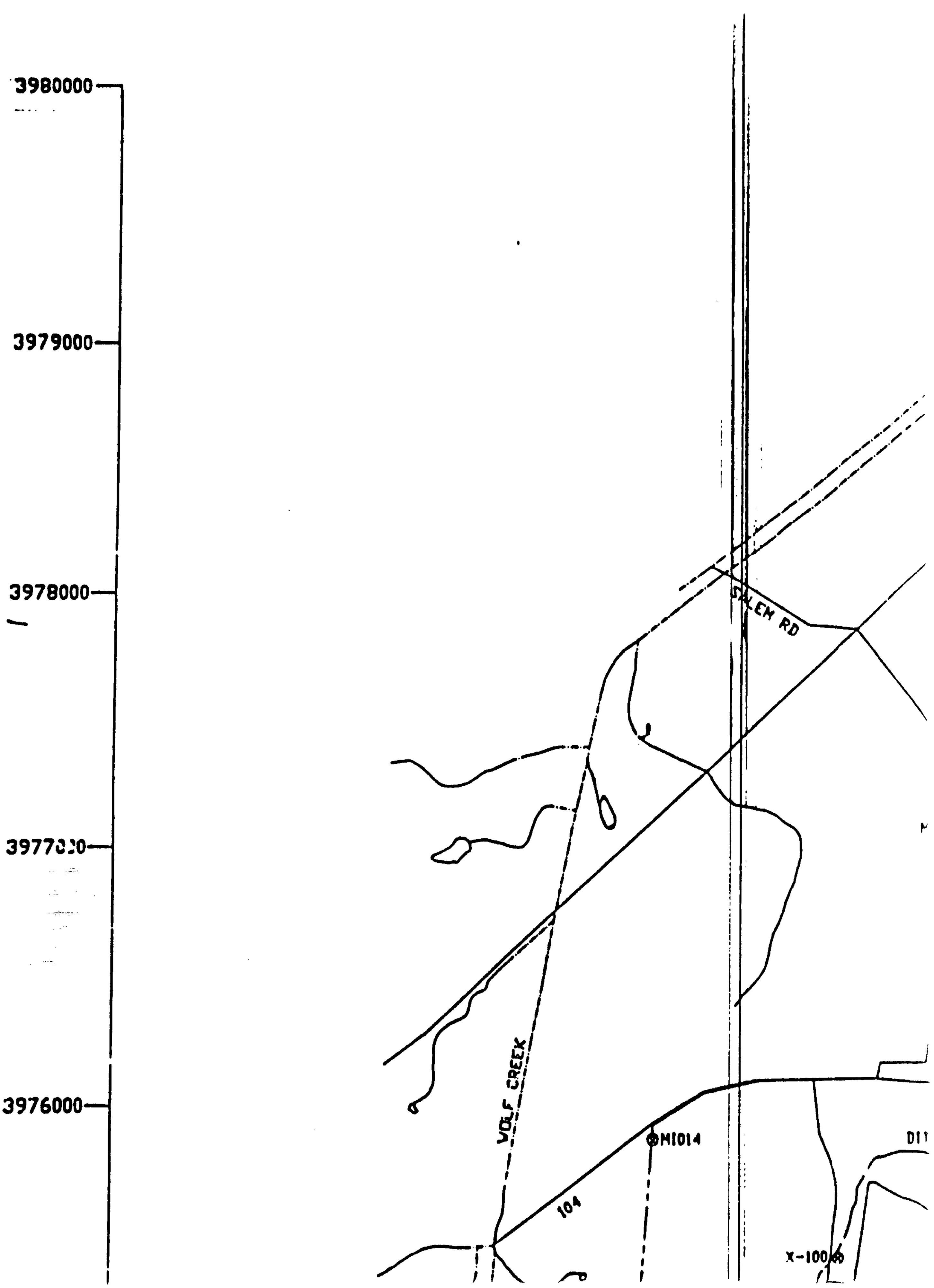
Under the authority of the Tennessee Water Quality Control Act, the Tennessee Water Quality Control Board has classified the three primary streams in and near MAAP (Rutherford Fork of the Obion River, the East Fork of Wolf Creek, and Wolf Creek) for the following uses: maintenance of healthy fish and aquatic life populations; human recreation; irrigation; and livestock and wildlife watering (TDHE, 1991).

2.1.5.2 Groundwater. Sands in the Claiborne and Wilcox Group are the principal sources of groundwater in western Tennessee. At MAAP, the Memphis Sand of the Claiborne Group is the major aquifer. Although groundwater is also abundant in the underlying Cretaceous sediments (i.e., McNairy Sands), it has not been necessary to tap these deeper sources in most areas. The major controls on groundwater movement in this unconfined aquifer are the dip of the sediments, surface topography, and surface recharge and discharge patterns. Groundwater flow in the MAAP area is generally to the west, in the direction of regional dip of these sands, and also trends northerly because of the topographic influence. The gradient of the sands is estimated to be about 20 feet/mile to the northwest. On a general scale, there are no abrupt hydrologic boundaries in the aquifer. The formation is recognized as sand with clay lenses and clay rich zones which may locally alter vertical groundwater flow, and stratification of the sediments tends to make vertical conductivities lower than horizontal conductivities. The sands range from fine to very coarse-grained, and the grain size may vary both horizontally and vertically over short distances.

The clay units that dominate the stratigraphic section below the Wilcox Group to the top of the Cretaceous McNairy Sand are known as the Porters Creek Clay, the Clayton Formation, and the Owl Creek Formation. Collectively, these formations constitute a stratigraphic unit which is approximately 425 feet thick and begins approximately 250 feet below the surface at MAAP. The McNairy Sand is the artesian aquifer that underlies the installation and begins approximately 500 feet below the Claiborne Group. The McNairy Sand is approximately 200 feet thick near the Tennessee-Mississippi state line and contains cross-bedded, variegated sands with lenses and interbeds of clay and lignite (Cushing et al., 1964). Clays are common in the McNairy Sand and relatively large clay bodies occur stratigraphically near the middle of the formation (Parks and Russell, 1975).

2.2 SITE HISTORY

The initial construction of the installation now known as MAAP was authorized on December 18, 1940, started in January 1941, and completed in January 1942. The H. K. Ferguson Engineering Company, Cleveland, Ohio, and the Oman Construction Company, Nashville, Tennessee, formed a company (The Ferguson-Oman Company) to design and construct the installation. The original land area contained 28,521.4 acres. Approximately 548 acres enclose the various production lines, and the storage areas total 7,930 acres. The field service portion includes approximately 9,897 acres, and approximately 1,395 acres are used for administrative, shop maintenance, housing, recreation and other functions.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104
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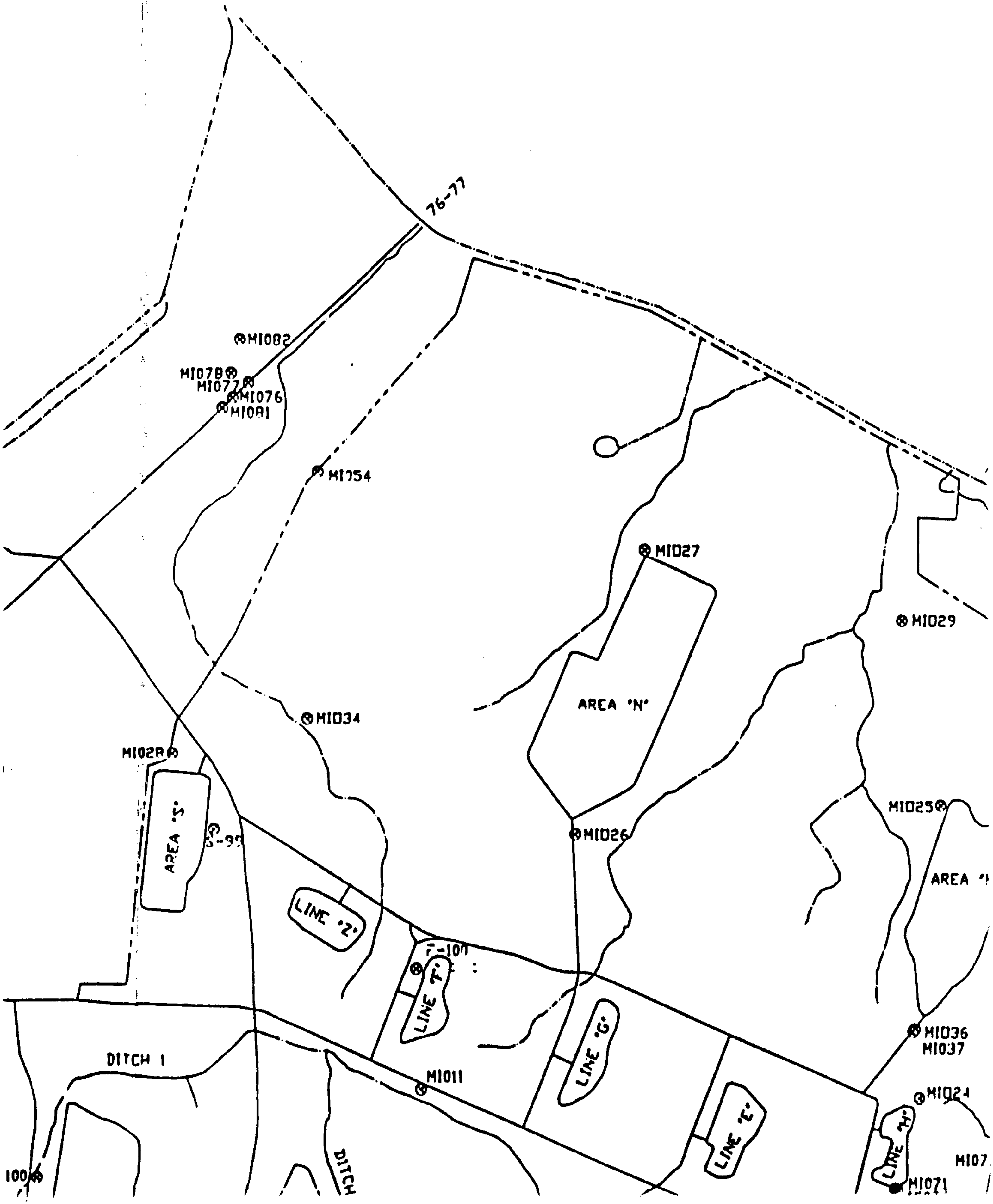

76-77
M1082
M1078
M1077
M1076
M1081
M1054
M1027
M1029
AREA 'N'
M1034
M1028
AREA 'S'
S-95
LINE 'Z'
F-100
LINE 'F'
M1026
M1025
AREA 'I
M1036
M1037
DITCH 1
M1011
LINE 'G'
LINE 'E'
LINE 'H'
M1024
DITCH
100
M107
M1071

ICF KAISER ENGINEERS

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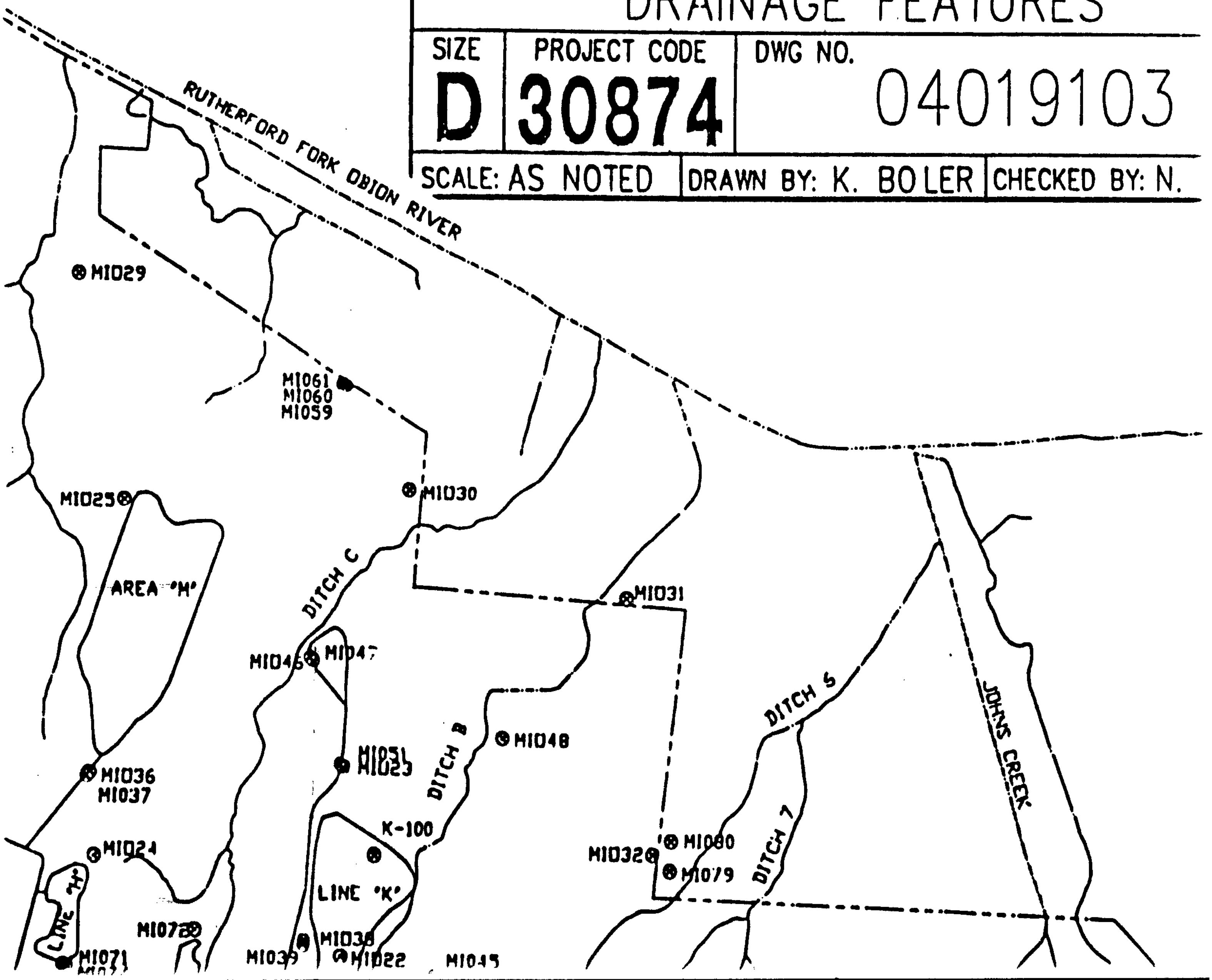
TITLE USATHAMA REMEDIAL INVESTIGATION

FIGURE 2-5
GENERAL SITE MAP AND
SIGNIFICANT SURFACE
DRAINAGE FEATURES

SIZE	PROJECT CODE	DWG NO.
D	30874	04019103

SCALE: AS NOTED	DRAWN BY: K. BOLER	CHECKED BY: N.



ICF KAISER
ENGINEERS

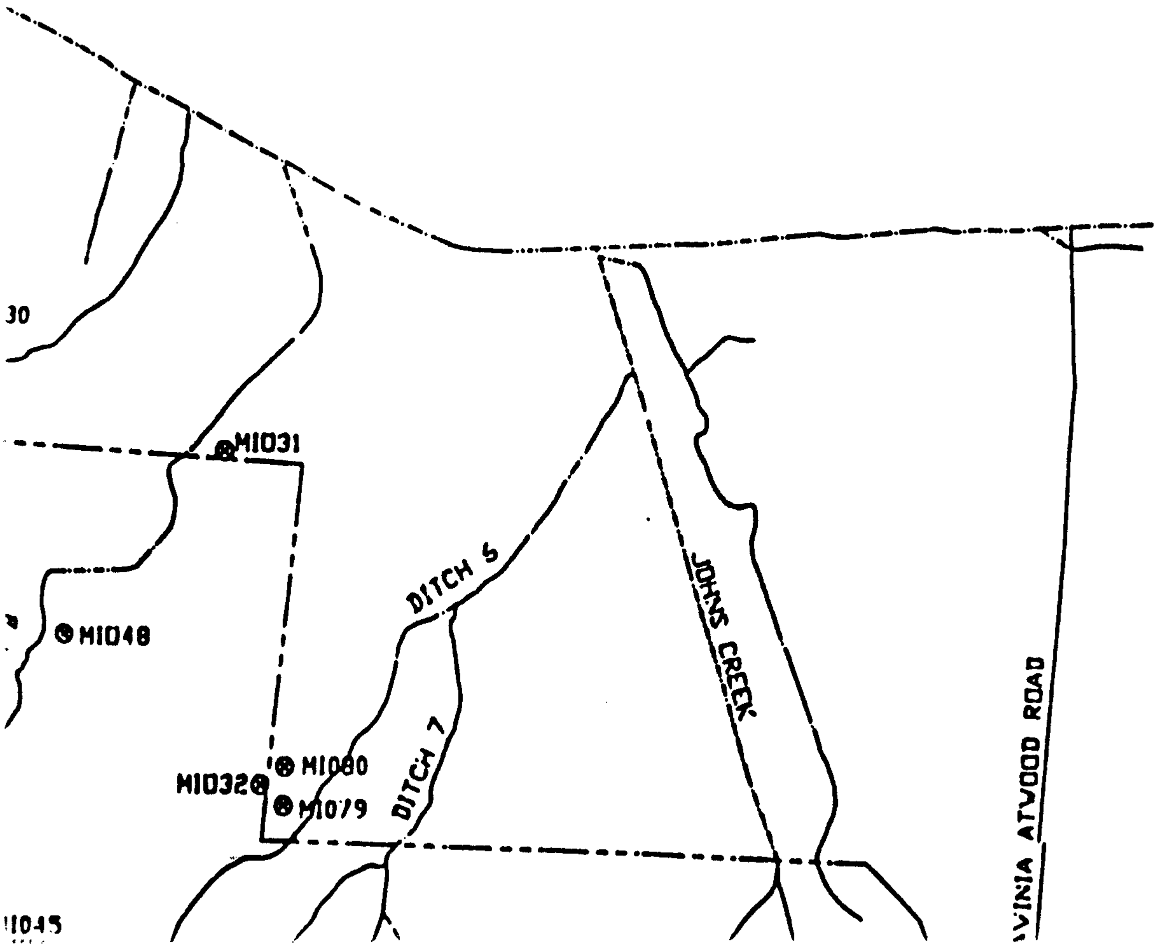
9300 LEE HIGHWAY
FAIRFAX, VIRGINIA
22031-1207

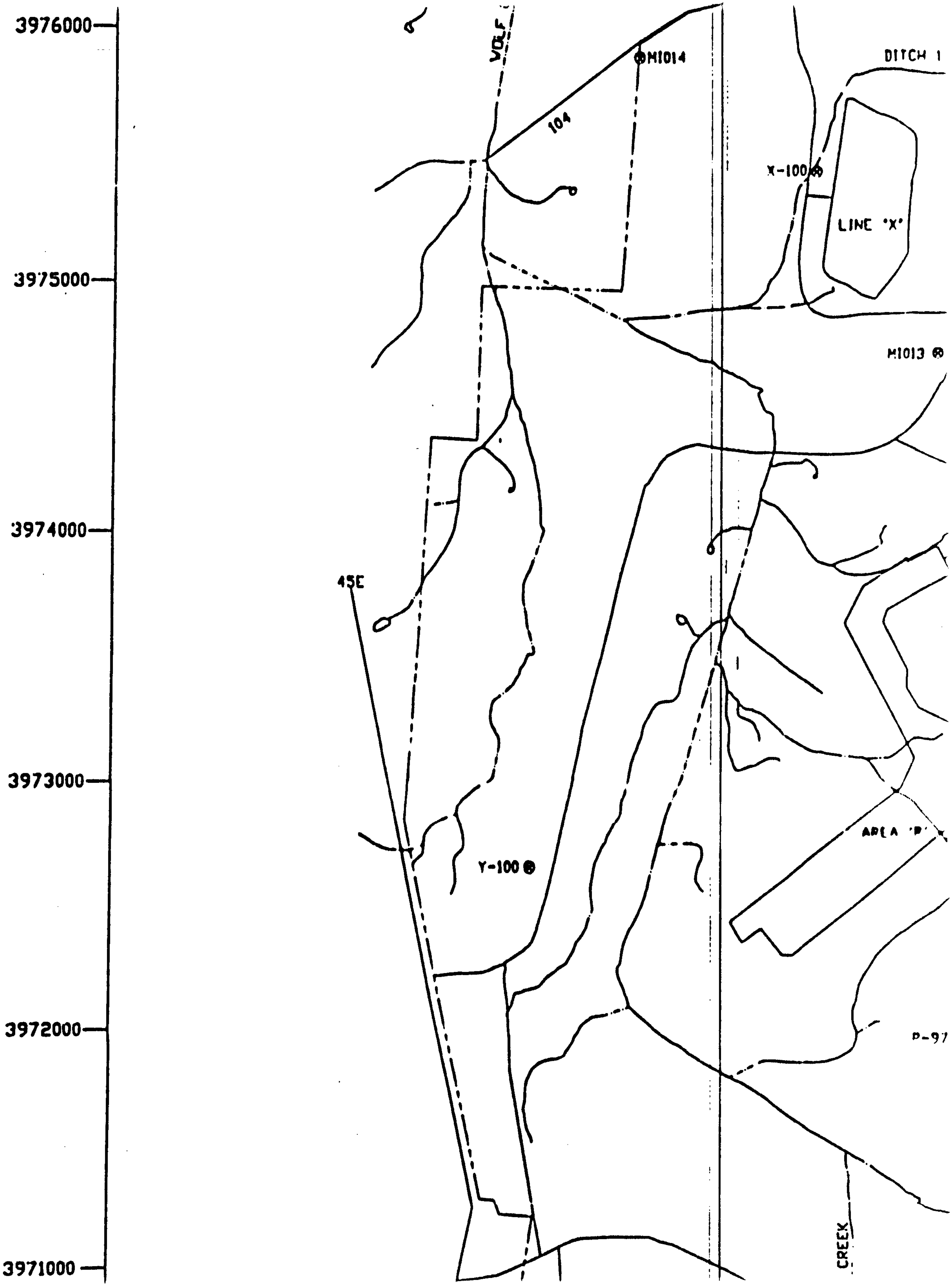
TLE USATHAMA REMEDIAL INVESTIGATION

FIGURE 2-5
GENERAL SITE MAP AND
SIGNIFICANT SURFACE
DRAINAGE FEATURES

ZE	PROJECT CODE	DWG NO.
)	30874	04019103

LE: AS NOTED	DRAWN BY: K. BOLER	CHECKED BY: N. OKUSU

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3974000
3973000
3972000
3971000
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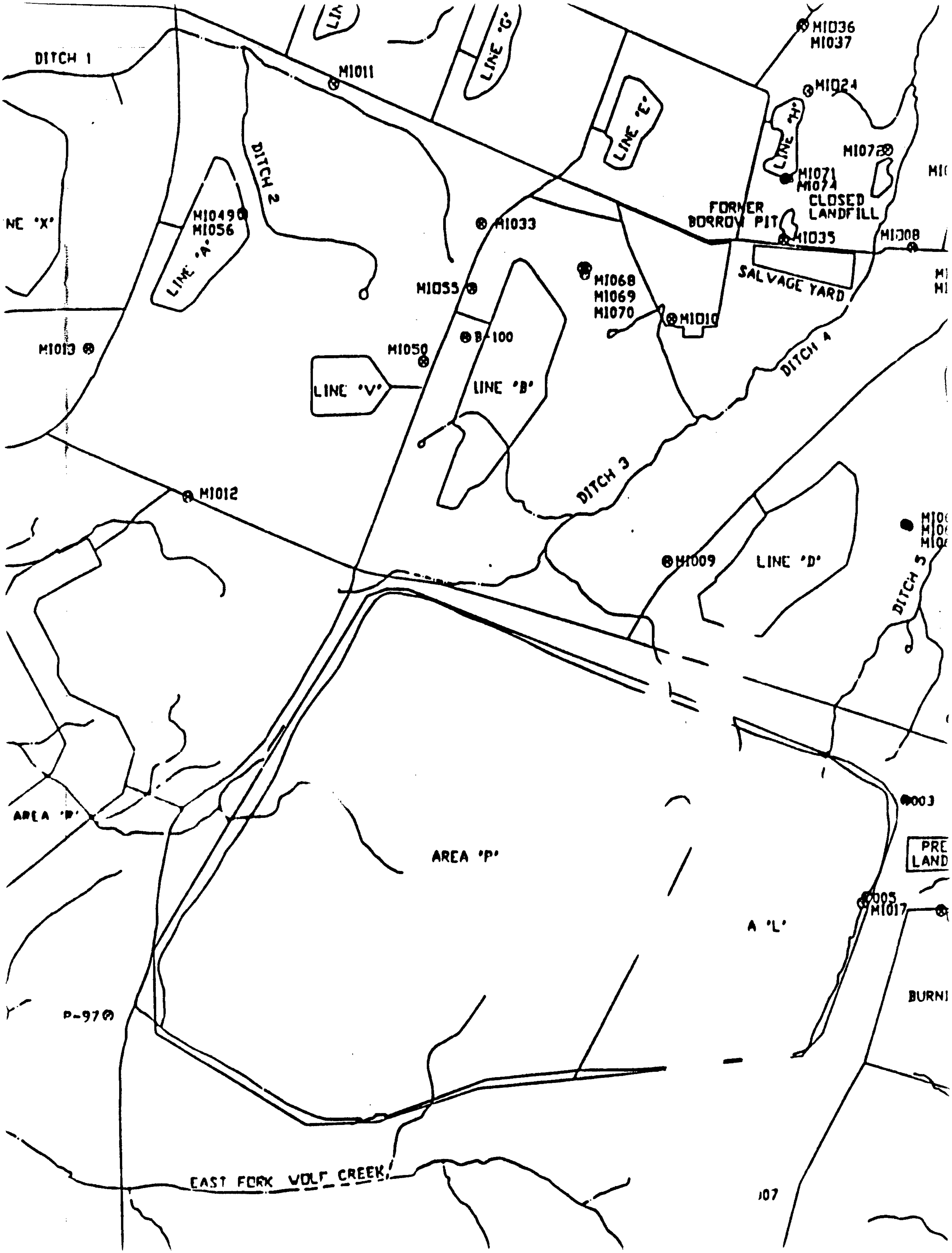
M1014
104
DITCH 1
X-100
LINE 'X'
M1013
45E
Y-100
AREA 'P'
P-97
CREEK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M1037
DITCH 1
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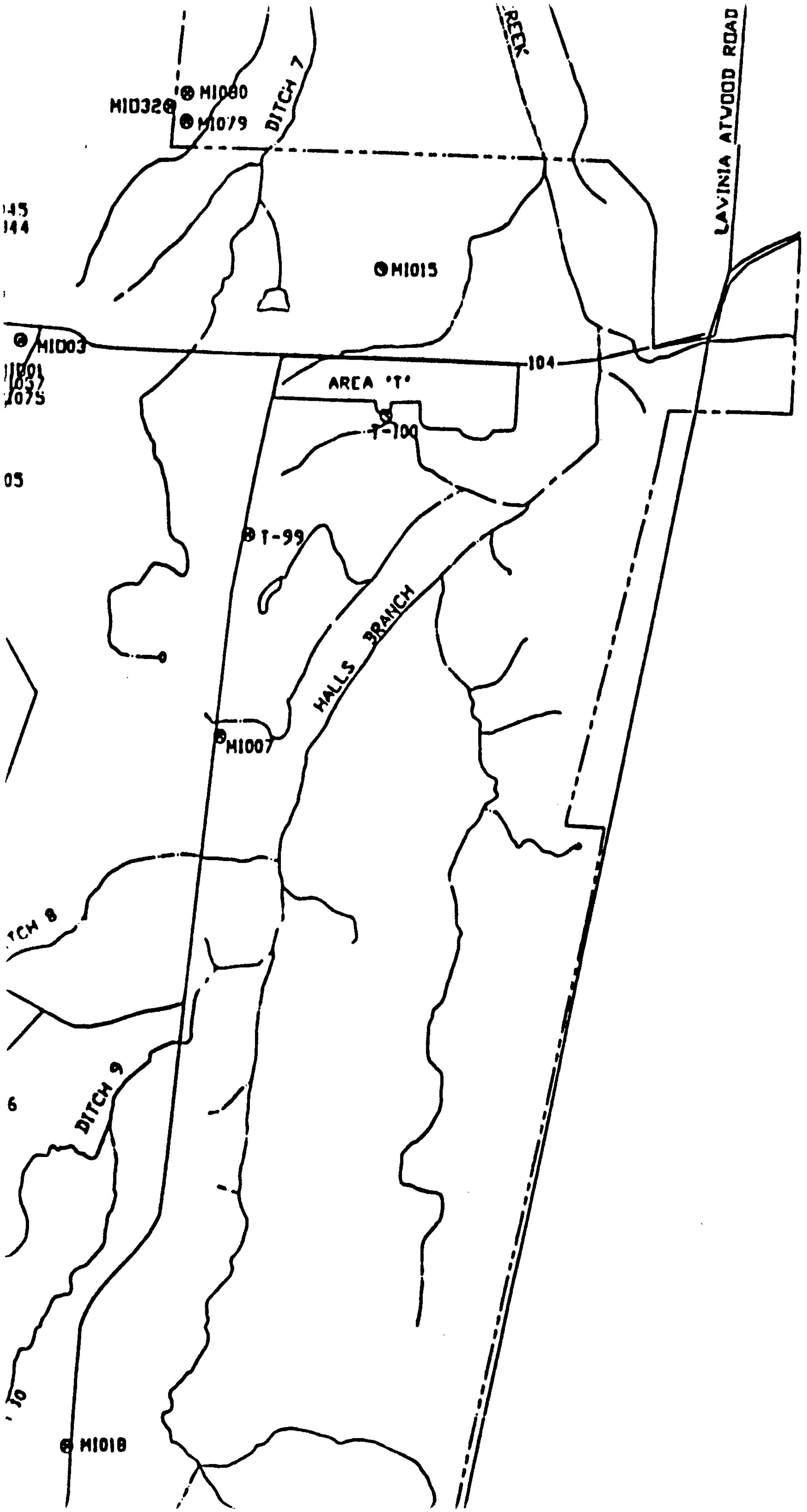
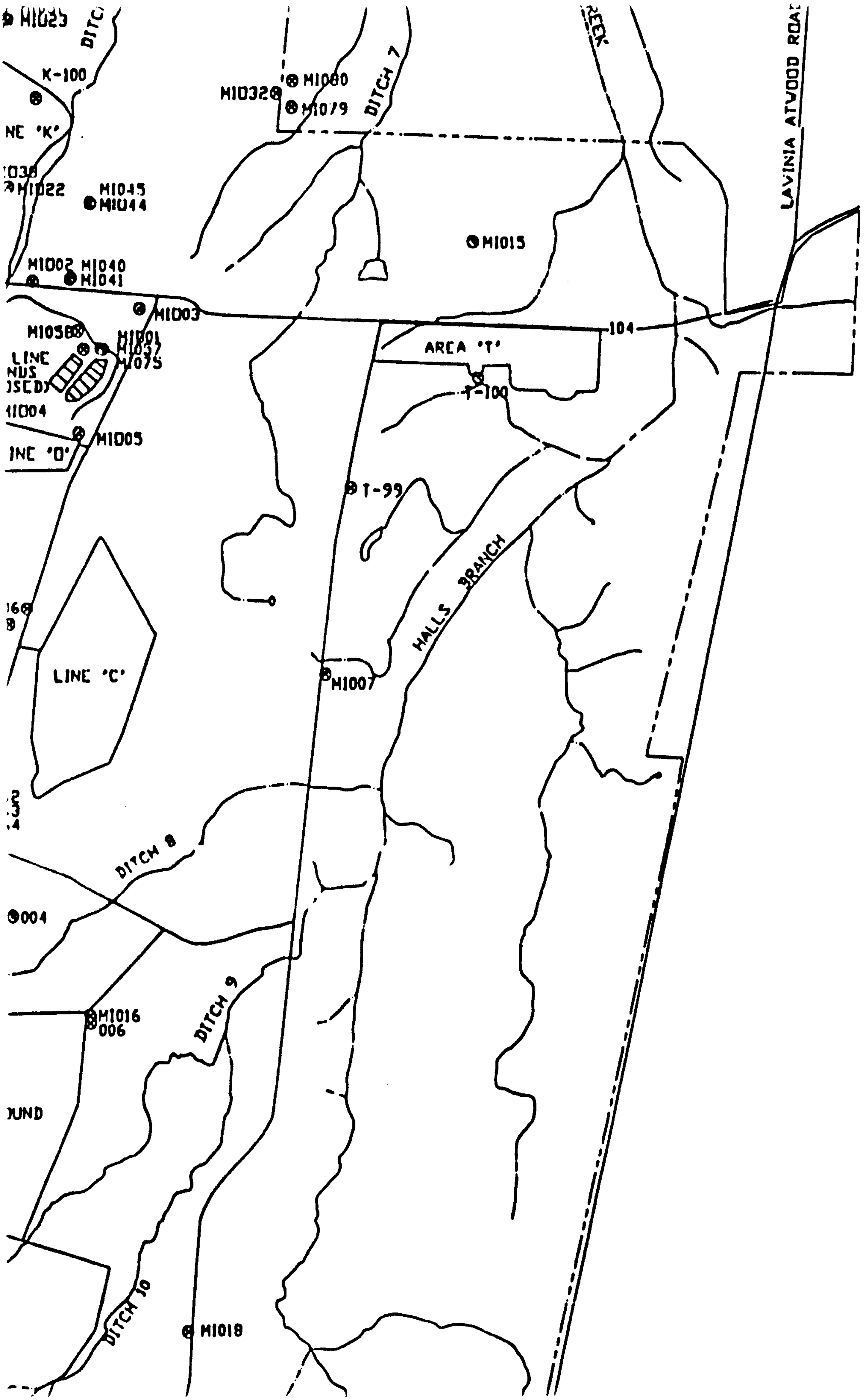
M1024
LINE 'E'
LINE 'H'
M1072
MI
DITCH 2
M1071
M1074
CLOSED
LANDFILL
FORMER
BORROW PIT
M1049
M1056
NE 'X'
M1033
M1035
M1008
LINE 'A'
SALVAGE YARD
MI
HI
M1068
M1069
M1070
M1055
M1010
M1013
B-100
M1050
DITCH A
LINE 'V'
LINE 'B'
DITCH 3
M1012
M10
M10
M10
M1009
LINE 'D'
DITCH 5
003
AREA 'P'
PRE
LAND
AREA 'P'
005
M1017
A 'L'
BURNI
P-97
EAST FORK WOLF CREEK
107


REEK
LAVINIA ATWOOD ROAD
M1080
M1032
M1079
DITCH 7
45
44
M1015
M1003
1001
1037
1075
104
AREA 'T'
T-100
05
T-99
HALLS BRANCH
M1007
TCH 8
DITCH 9
6
10
M1018



M1025
DITC
K-100
NE 'K'
1038
M1022
M1045
M1044
M1002
M1040
M1041
M1032
M1080
M1079
DITCH 7
REEK
LAVINIA ATWOOD ROAD
M1015
M1003
104
M1058
M1001
M1037
M1075
LINE
NDS
OSED)
M1004
M1005
INE 'O'
AREA 'T'
T-100
T-99
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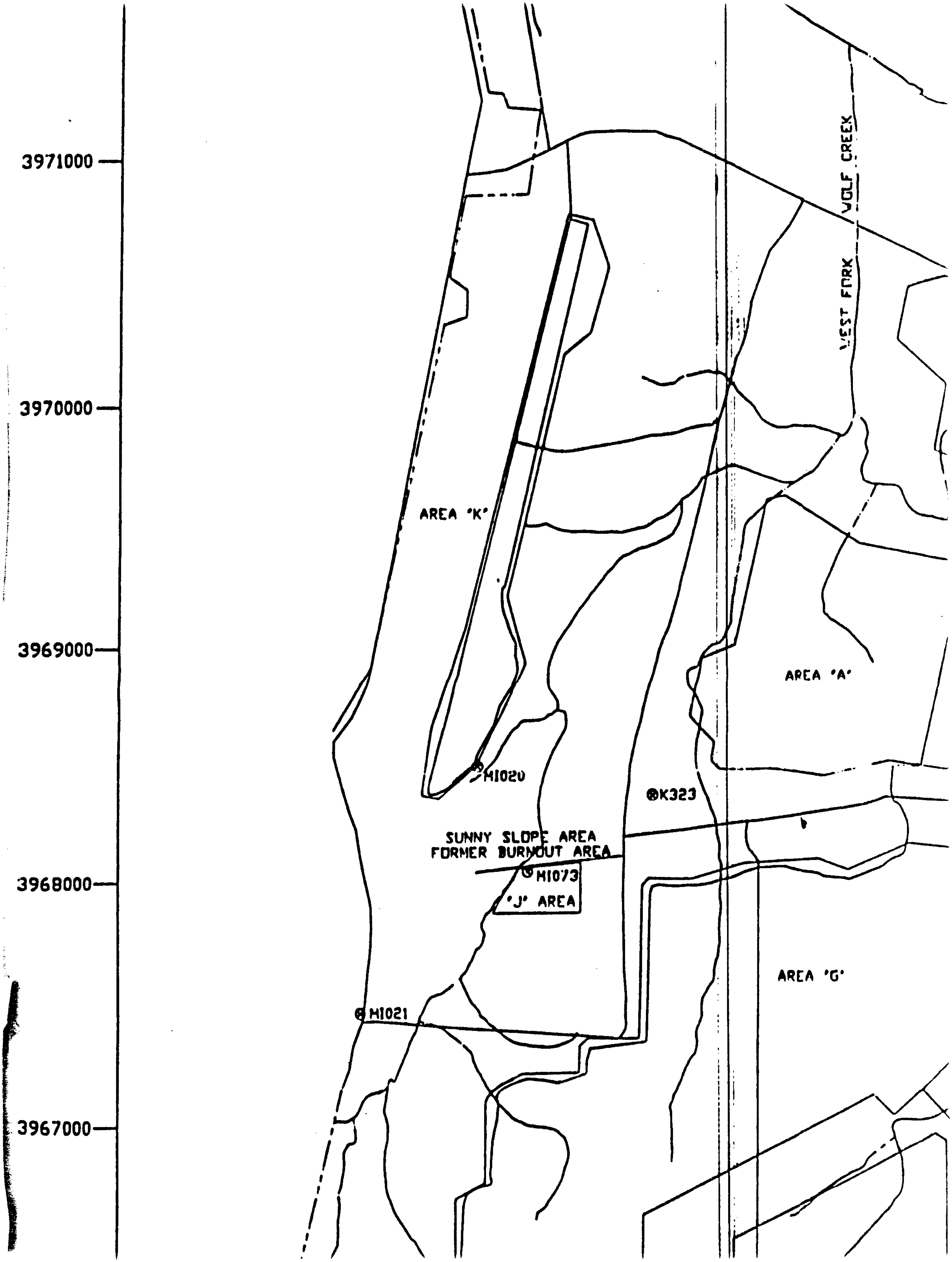
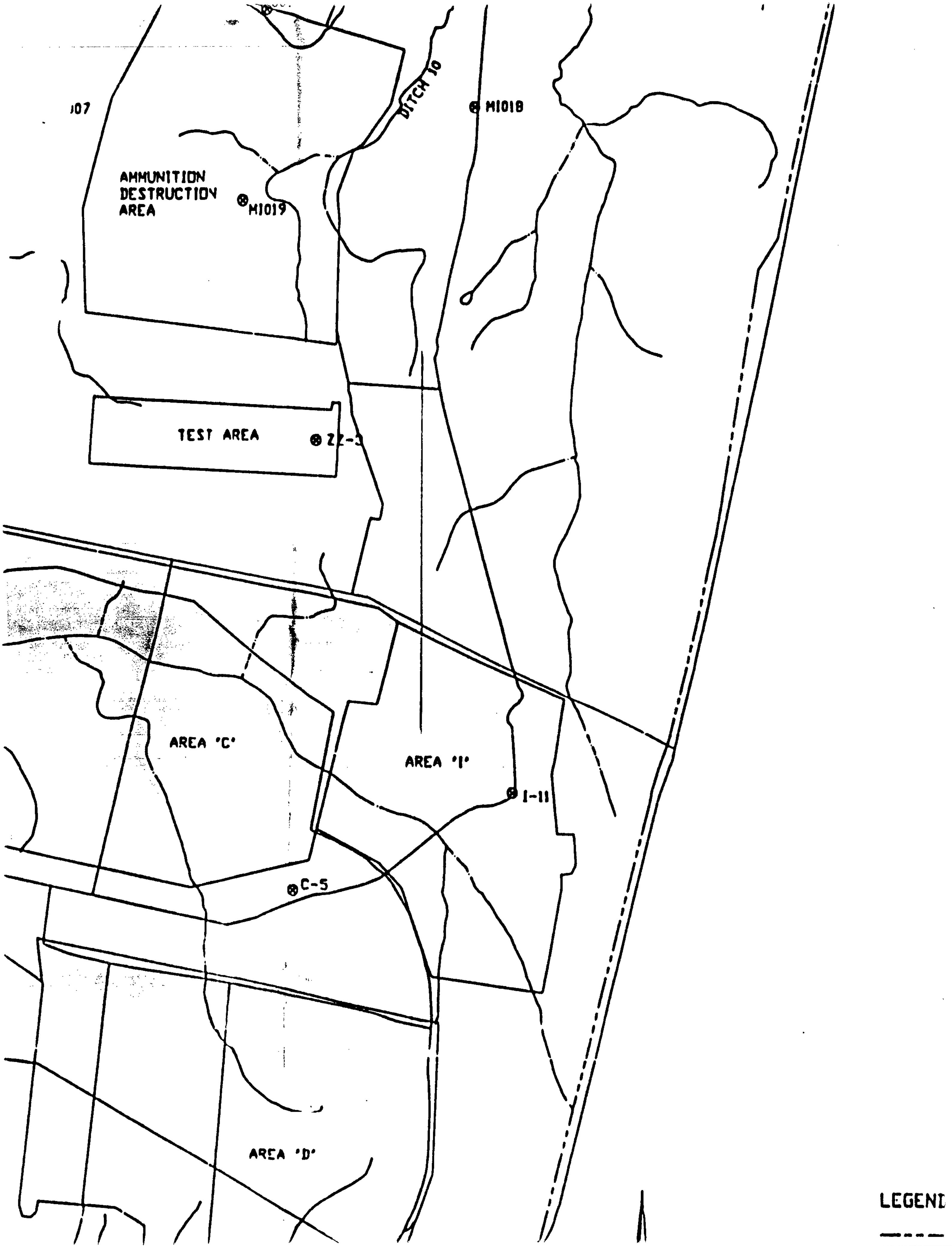
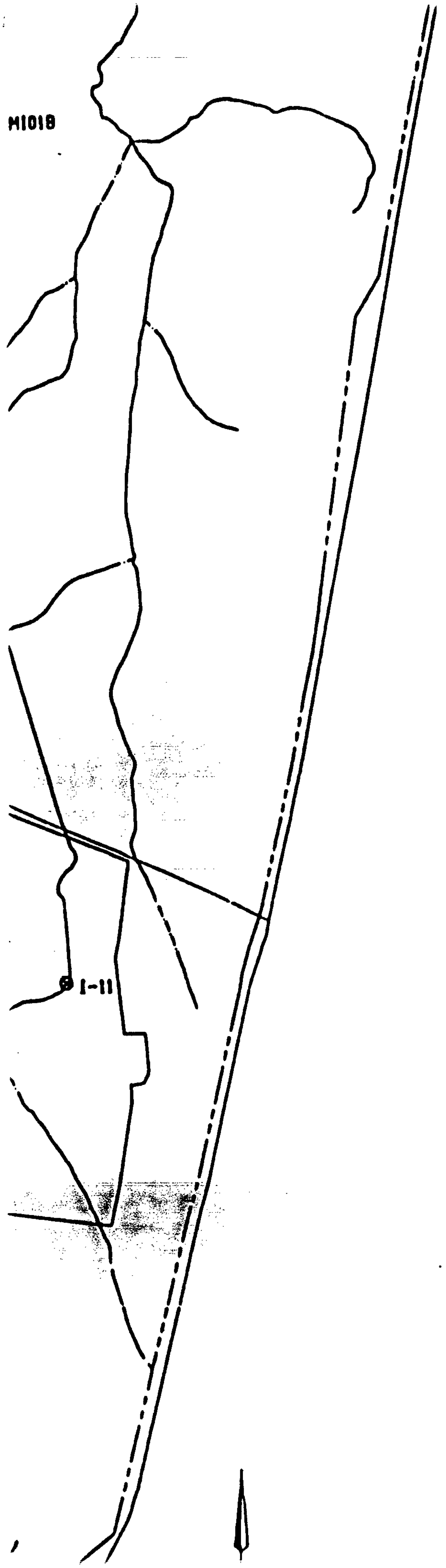
16
LINE 'C'
M1007
DITCH 8
004
M1016
006
DITCH 9
OUND
DITCH 10
M1018


3971000
3970000
3969000
3968000
3967000
WEST FORK WOLF CREEK
AREA 'K'
AREA 'A'
M1020
K323
SUNNY SLOPE AREA
FORMER BURNOUT AREA
M1073
'J' AREA
AREA 'G'
M1021

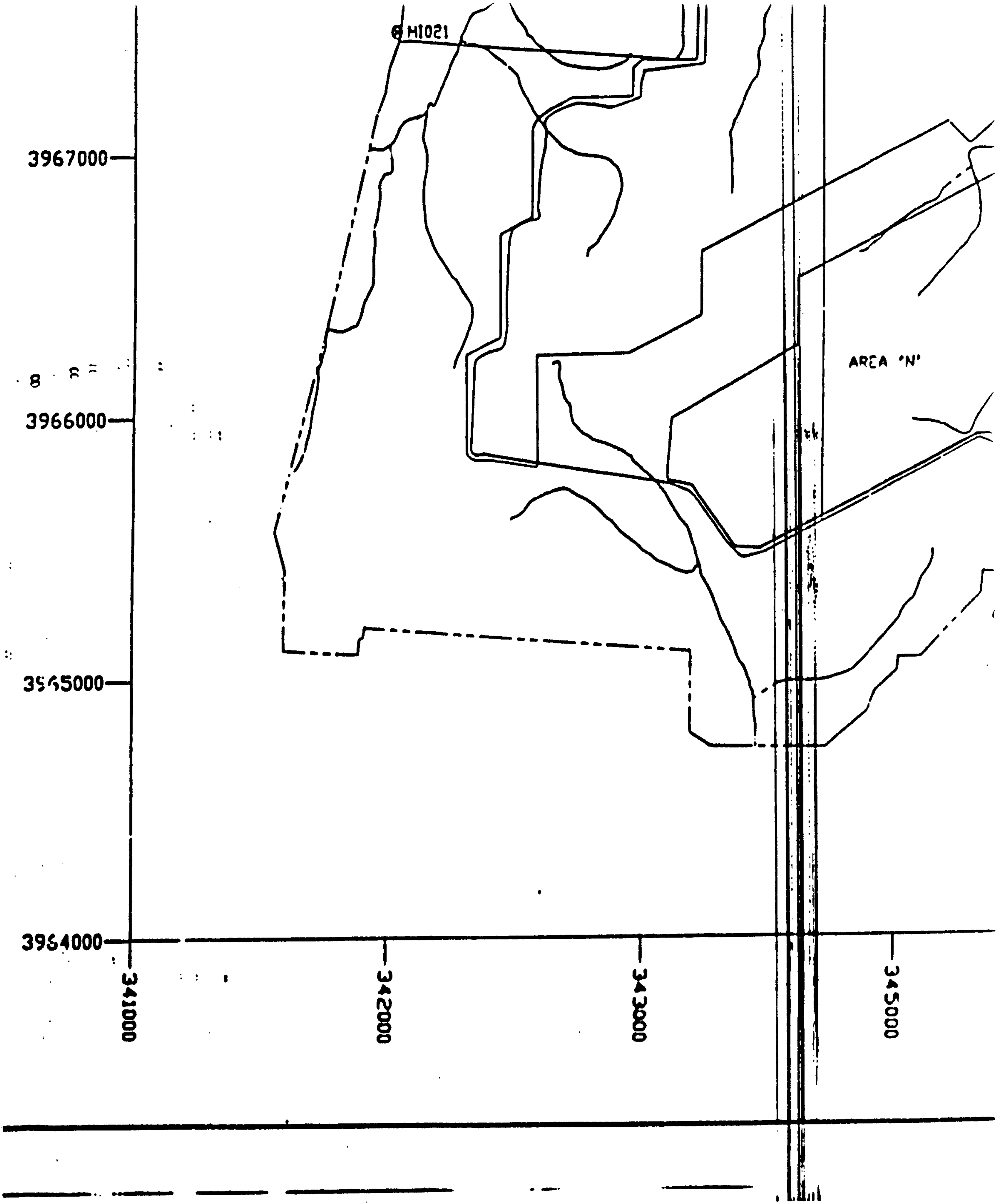

EAST FORK WOLF CREEK
WEST FORK WOLF CREEK
107
AMMU
DEST
AREA
AREA 'A'
AREA 'B'
E-67
AREA 'G'
AREA 'F'
AREA 'E'

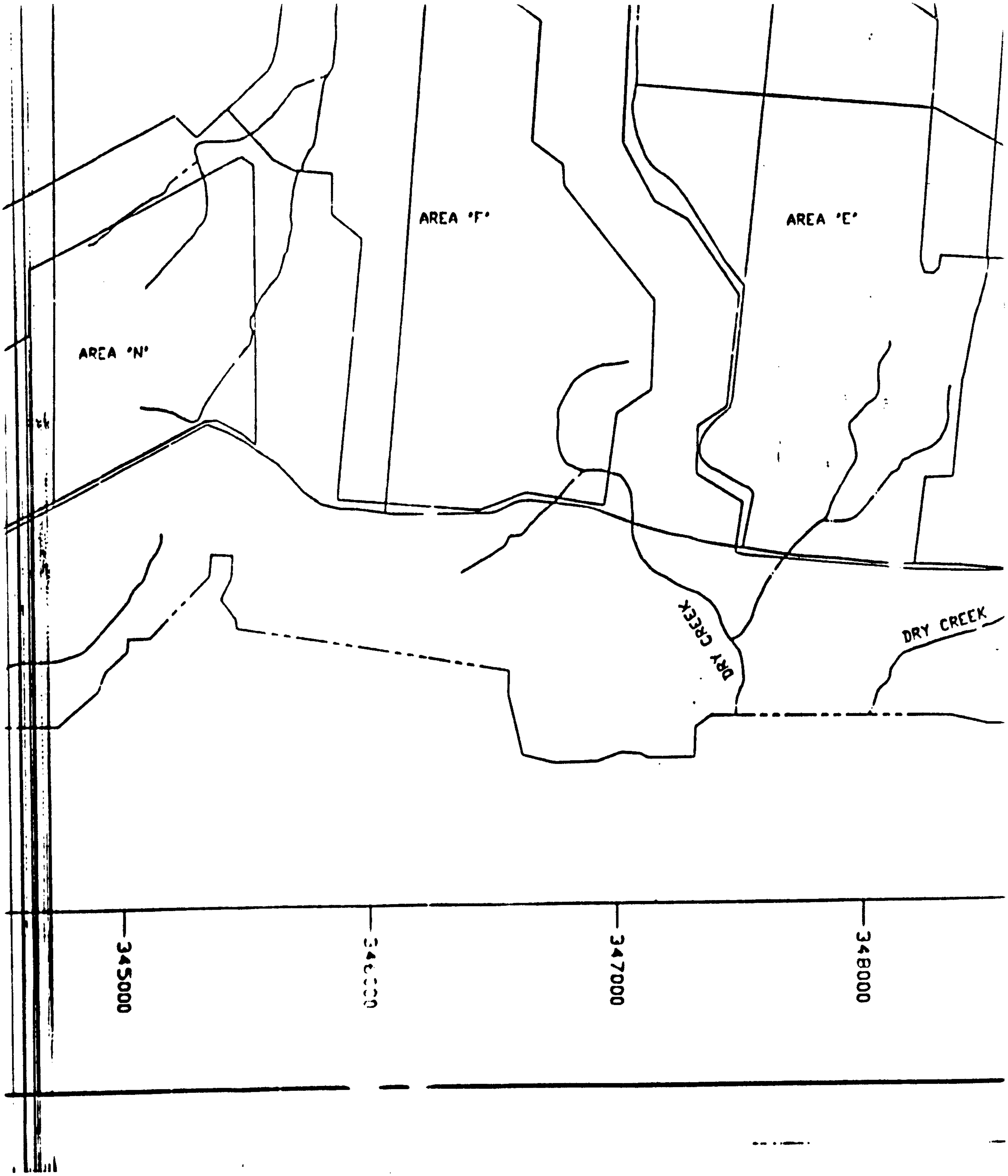

J07
AMMUNITION DESTRUCTION AREA
M1019
DITCH 10
M1018
TEST AREA
ZZ-3
AREA 'C'
AREA 'I'
I-11
C-5
AREA 'D'
LEGENI



LEGEND

---- FACILITY BOUNDARY


H1021
3967000
AREA 'N'
3966000
3965000
3964000
341000
342000
343000
345000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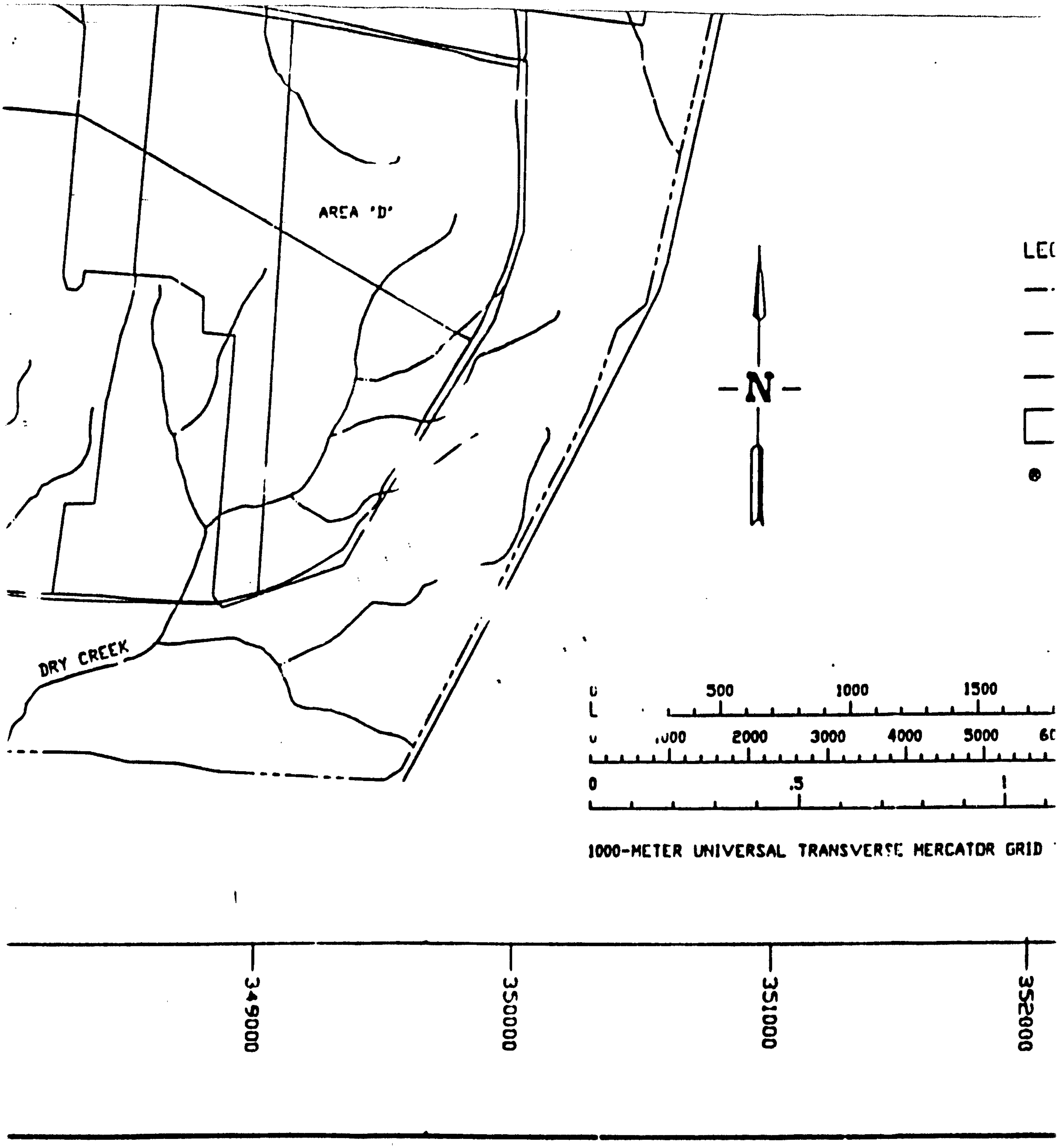
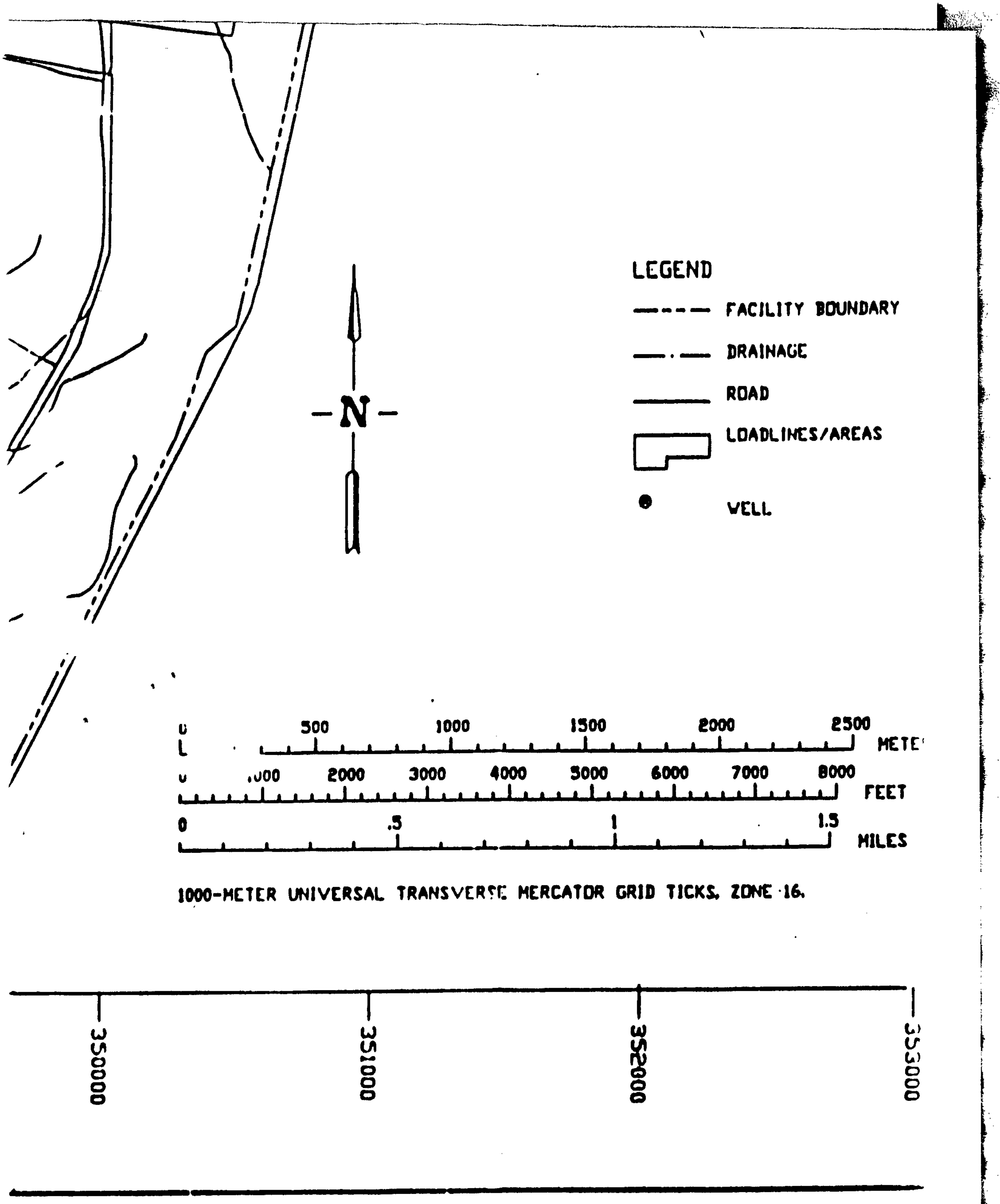
AREA 'E'
AREA 'N'
DRY CREEK
DRY CREEK
345000
346000
347000
348000


AREA 'D'
DRY CREEK
N
LE(
0
500
1000
1500
,000
2000
3000
4000
5000
6(
0
.5
1
1000-METER UNIVERSAL TRANSVERSE MERCATOR GRID
349000
350000
351000
352000


LEGEND
FACILITY BOUNDARY
DRAINAGE
ROAD
LOADLINES/AREAS
WELL
N
0
500
1000
1500
2000
2500
METE
0
1000
2000
3000
4000
5000
6000
7000
8000
FEET
0
.5
1
1.5
MILES
1000-METER UNIVERSAL TRANSVERSE MERCATOR GRID TICKS, ZONE 16.
350000
351000
352000
353000

Other acreage is necessary to allow safe distances between explosive areas. In 1946, Line G, containing approximately 42 acres, was sold to the United States Rubber Company. Other tracts have been sold; some deeded to the city of Milan and the University of Tennessee and leased and/or transferred to the Tennessee National Guard. The installation now contains 22,540 acres.

Initially, the plant was divided into two separate units: Wolf Creek Ordnance Plant, which was operated by the Proctor and Gamble Defense Corporation; and the Milan Ordnance Depot. In July 1943, the Ordnance Plant and Depot merged into a single integral ordnance facility (Milan Ordnance Center) and the Proctor and Gamble Defense Corporation became the operating contractor for the entire installation.

During World War II, the mission of the installation included: the production of fuzes, boosters, and complete rounds of both minor and major caliber ammunition; the operation of an ammonium nitrate plant; and the receiving, storage, and shipping of ammunition. The peak employment reached approximately 11,000 people.

Milan Ordnance Center was designated as Milan Arsenal on October 30, 1945, and the following month the plant changed to Government operation in a standby status. The mission at that time included extensive receipt, storage, and processing of ammunition returned from overseas; normal maintenance, surveillance, renovation and demilitarization; and a limited amount of new production.

During the early part of the Korean Emergency, the Proctor and Gamble Defense Corporation assumed operation of the installation. On April 29, 1953 the plant was placed in an active status. Employment reached approximately 8,000. The principal changes in the arsenal mission were the increased output of new ammunition, inclusion of experimental ammunition, and the Phase II Industrial Engineering Studies of all ordnance ammunition command loading plants.

Effective July 1, 1954, Milan Arsenal was designated a Permanent Installation. With sharp decreases in production schedules also in 1954, production lines were placed in layaway, and in 1955 two more lines were placed in standby. A revision of schedules necessitated cessation of production as of September 1957, leaving active only a small demilitarization program on B-Line.

Effective October 1, 1957 the industrial activity of Milan Arsenal was placed in an inactive status. An economy and austerity program was put into effect and remained until January 1, 1960, when the industrial portion of the Milan Arsenal returned to an active status. No change in status has been made since that time. However, later that same month (October 14, 1957), the Proctor and Gamble Defense Corporation terminated their contract with the Government. Harvey Aluminum Sales, Inc., with a home office in Torrence, California, became the operating contractor.

On November 2, 1961, the industrial portion of Milan Arsenal was designated as Milan Ordnance Plant and the field service portion as Milan Depot activity. The field service depot activities were discontinued on November 16, 1962. However, the field service mission is still being performed. On August 1, 1963, Milan Ordnance Plant became officially known as Milan Army Ammunition Plant, the present designation.

During the 1960s, necessary rehabilitation of existing facilities and some plant modernization was performed to carry out the production of the following items: fuzes, primers, delay plungers, delay elements, and boosters; 40mm, 60mm, 81mm, 90mm, 105mm, 106mm, and 155mm ammunition; mine, grenade, and cluster bomb unit dispensers; demolition kits; shell metal parts; pelleting explosives; and rework and renovation of various items.

On December 22, 1969 controlling interest in Harvey Aluminum Sales, Inc., was acquired by Martin Marietta, Inc.

During 1971, Lines E, F, and H were placed in layaway. Production of the items on these lines were transferred to other lines and equipment used to produce shell metal parts was transferred to private industry.

In December 1975, production of items on Line Z was canceled. Funds to layaway the line were received in 1976 and the line has now been placed in standby status. Production of items on Line Z were transferred to other lines. Likewise, the last item being produced on Line C was transferred to Line B in 1977 which then allowed Line C to be placed in a standby status.

Since 1963, 2,287 acres of the plant have been transferred to the United States Property and Fiscal Officer (State of Tennessee) for use by the Tennessee National Guard for weekend training purposes. Two large administration buildings, two duplexes, and one single family house were included in the transfer to the National Guard to support their training program.

In December 1977, a portion of Line H was reactivated to load, assemble, and pack M739 fuzes. This item required a humidity/temperature controlled atmosphere which was available at Line H.

An extensive modernization program began in 1978 and continued through 1985. Production Lines A, C, E, and Z were updated at this time. A project to automate the manufacture of 60mm and 81mm propellant increments was completed. This project led to the development of a melting system at MAAP. Prove out/production was completed in October 1983 and the line placed in layaway in August 1984. Limited production of 60mm and 81mm mortar rounds was transferred to a hand line at Line D.

The new x-ray facility at Line V was built to consolidate the plant's x-ray operations in one location. Previously, x-ray facilities existed at Lines C, D, and K. Line V contains an underground 4 million electron volt (MEV) x-ray unit, a 2 MEV unit, and a 0.420 MEV unit, plus a fluoroscope with video tape. This is the world's largest facility dedicated solely to non-destructive testing of ammunition.

Other upgrades to MAAP included the construction of pink water treatment facilities (PWTFs), built at six production lines under a contract issued by the U.S. Army Corps of Engineers (USACE). Construction began in October 1979 and was completed on March 13, 1981. These plants are used to remove explosive contaminants from process water before discharge using activated carbon filtration. These discharges are regularly monitored by a new environmental laboratory which was constructed in 1980.

The spent carbon generated by the PWTFs is a listed hazardous waste with the EPA Hazardous Waste Number K045. Spent carbon is presently being stored in the hazardous waste storage igloos in Area D. The facility stores spent carbon before transporting it to an off-site treatment, storage, and disposal facility.

Effective January 7, 1985, Martin Marietta Corporation sold its interest in the aluminum business and organized another company, Martin Marietta Ordnance Systems, Inc., to operate the Milan Army Ammunition Plant.

2.2.1 Current MAAP Mission

Currently, MAAP is a government-owned, contractor-operated (GOCO) military industrial installation under the jurisdiction of the Commanding General, Headquarters, United States Army Armament, Munitions and Chemical Command. Presently, MAAP is under the local command of the U.S. Army Ordnance Corps and is operated by Martin Marietta Ordnance Systems, Inc. The current level of employment at MAAP is 1,600 workers.

The general mission of MAAP currently includes:

a. The loading, assembling, and packaging (LAP) of conventional ammunition items as assigned;

b. Operation and maintenance, as directed, of active facilities in support of current operations;

c. Maintenance and/or layaway, in accordance with regulations for standby facilities, including any machinery and packaged items received from industry, in such condition as will permit rehabilitation and resumption of production within the time limitations prescribed;

d. Receipt, surveillance, maintenance, renovation, demilitarization, salvage, storage, and issue of assigned Field Service stocks and V and W Group items of industrial stocks as required or directed; and

e. Procurement, receipt, storage, and issue of necessary supplies, equipment, components, and essential materials.

2.3 MAAP RI SITE DESCRIPTIONS

This section describes the areas at MAAP which were investigated during the RI. The information presented in this section was collected from studies performed by previous investigators and information received from facility personnel. For some of these areas, contaminant concentration data is available from previous studies, and this information has been included in the site description. Other investigators of this facility have developed more general studies involving groundwater monitoring wells, etc., and these studies are discussed in Section 3.

MAAP facilities include 9 ammunition LAP Lines, one washout/rework line, one experimental line, one central x-ray facility, one test area, two shop maintenance areas, two magazine storage areas, 12 aboveground, earth-covered igloo magazine storage areas, a demolition and burning ground area, an administrative area, a family housing area, and recreational facilities. In addition, there are medical facilities, fire/ambulance stations, 10 high pressure heating/process steam plants, 16 low-pressure heating plants, and 6 PWTFs. There are two sewage treatment plants located on the facility: Wolf Creek Ordnance Plant (WCOP) treatment plant in the northern portion of the site and Milan Ordnance Depot (MOD) sewage treatment plant in the south. A laundry facility for clothing used by on-site personnel while working with explosives/propellants is located in Area J. Located in K-Line is a coal-fired steam plant, a coal pile, a storage pond, and a treatment plant for coal pile runoff.

Approximately 13,600 acres within the MAAP boundary are leased for agricultural use. Approximately 3,984 acres are used as cropland. Cotton, corn, and soybean are the main crops, and smaller amounts of grain sorghum and wheat are also grown. In 1990, there were 2,746 head of cattle grazing on the facility. The cattle graze between April and November on about 8,700 acres. In addition, MAAP has more than 6,000 acres of managed timberland.

MAAP has 15 supply wells that obtain water from the Memphis Sand. Four of the water-supply wells (C-5, I-11, S-99, and T-99) are currently in use as potable water sources. Wells C-5 and I-11 supply potable water to the southern portion of the site while T-99 and S-99, which are high-capacity, recently-installed wells, supply both potable water and production water to the northern portion of the site. All wells which supply potable water have water treatment equipment associated with them. The facility adds caustic soda to raise the pH of the water to 7 pH units (the pH of the groundwater underlying the site ranges from 5 to 6 pH units), phosphate for corrosion control, and chlorine for disinfection purposes. Typically, a primary well and a secondary well are designated within each well pair. The primary well is pumped for several months and the secondary well is used only when necessary to meet demand. For example, in December of 1990 and January of 1991, S-99 was the primary water supply well and was pumped at an average rate of 0.331 million gallons per day (MGD) with a maximum flow rate of 1.014 MGD. Well T-99 was the secondary well and was pumped at an average rate of 0.086 MGD with a maximum rate of 0.546 MGD. (Personal communication, Pat Brew, MAAP, January 24, 1991.)

Wells F-100 and T-100 are active but are not currently being used. These wells are maintained for usage should the plant's potable water demands increase in the future. Wells E-67, K-323, ZZ-3, and Y-100 are used for the following non-potable purposes: fire prevention, cooling water, production, and restrooms. Well P-97 is the non-potable water-supply well for an inactive building, so it is not currently used. Wells X-100, B-100, C-100, and K-100 are not used because the water is contaminated with explosives. (Personal communications, Mike Harris and Bill Blaylock, Martin Marietta, April 10 and April 19, 1991.) The depths of the above-listed water supply wells range from 141 to 292 feet.

Of the 14 process areas active by the end of World War II only 8 lines (A, B, D, H, I, O, V, and X) are in use today. In the past, wastewater from various production activities in the lines was discharged to open ditches that drained from sumps or surface impoundments into both intermittent and perennial streams and rivers. Currently, MAAP treats all process water from the lines that generate explosives-contaminated wastewater in the six PWTFs. This wastewater is processed by an activated carbon absorption system and discharged under the authority of a National Pollutant Discharge Elimination System (NPDES) permit.

The NPDES permit (identification number TN0000060) was issued in 1986 and expires on September 29, 1991. The permit identifies the receiving streams as being tributaries of John's Creek, Wolf Creek, and Rutherford Fork of the Obion River. These receiving streams are designated as Class III Waters, which are suitable for the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The outfalls are listed in Table 2-1, along with the wastewater source and the parameters which are regulated under the permit.

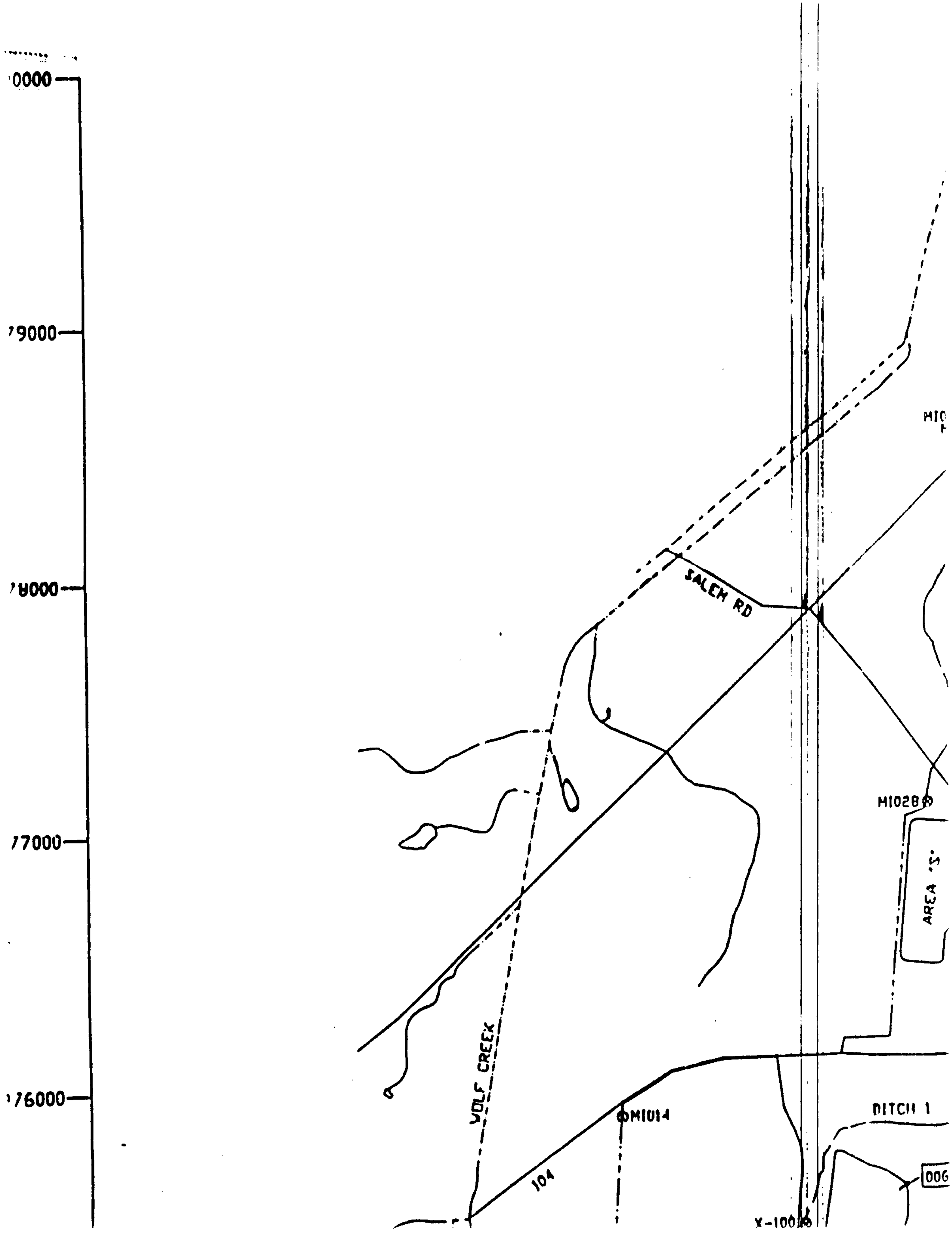
Outfall 001 discharges to Ditch 2, which flows to Wolf Creek. Discharge from Outfall 002 flows out the back of B-Line and joins Ditch 4, which converges with flow from D-line (Outfall 004), and continues north to Ditch C. Treated wastewater from the WCOP treatment plant (Outfall 009) is discharged into Ditch C south of the site boundary. Ditch C continues north to the Rutherford Fork. Outfall 003 from C-Line flows to Ditch 5 and converges with the discharge from 005 (O-Line). This ditch becomes Ditch B north of Route 104, and flows to the Rutherford Fork. Wastewater from Outfall 006 joins 001 discharge before flowing into Wolf Creek. Runoff from the coal pile (Outfall 007) flows into Ditch B, which flows into the Rutherford Fork. Discharge from the MOD sewage treatment plant in the southern area of the plant, designated as Outfall 008, flows into the East Fork of Wolf Creek. The locations of these outfalls are shown in Figure 2-6.

Other miscellaneous sources are covered in the permit, including potable and water treatment facilities, cooling systems, boilers, vehicle and equipment cleaning facilities, painting and corrosion control facilities, petroleum storage and handling areas, vehicle and equipment maintenance facilities, battery rework facilities, photographic laboratories, firefighter training areas, swimming pools, and storm sewers. A copy of the complete permit is provided in Appendix A of this report.

MAAP has a Resource Conservation and Recovery Act of 1976 (RCRA) Part B permit (Permit No. THNW-052) for permanent storage of hazardous waste. There are 15 storage units regulated under this permit: 14 igloos in Area D and a hazardous waste storage building in Area J. The material stored in the igloos includes spent carbon from the PWTFs and solvents contaminated with explosive compounds. The unit in Area J is used to store wastes such as PCB-containing materials, asbestos, uncontaminated solvents, and paint sludge. This Part B permit only allows the storage of hazardous wastes generated on site. In addition, the facility has applied for an interim Part B Permit for the open burning/open

Table 2-1
NPDES Outfalls, Sources, and Regulated Parameters

OUTFALL	SOURCE	REGULATED PARAMETERS
001	Production Line A	Total nitrobodies, total suspended solids (TSS)
002	Production Line B	Total nitrobodies, TSS
003	Production Line C	Total nitrobodies, TSS
004	Production Line D	Total nitrobodies, TSS
005	Production Line O	Total nitrobodies, TSS
006	Production Line X	Total nitrobodies, TSS
007	Coal Pile Runoff	TSS, heavy metals
008	MOD Sewage Treatment Plant	Biochemical oxygen demand (BOD, TSS, fecal coliform, ammonia nitrogen, dissolved oxygen, total residual chlorine
009	WCOP Sewage Treatment Plant	BOD, TSS, fecal coliform, ammonia nitrogen, dissolved oxygen, total residual chlorine, total nitrobodies
09A	Laundry Wastewater Treatment Facility	Total nitrobodies, TSS


0000
9000
8000
7000
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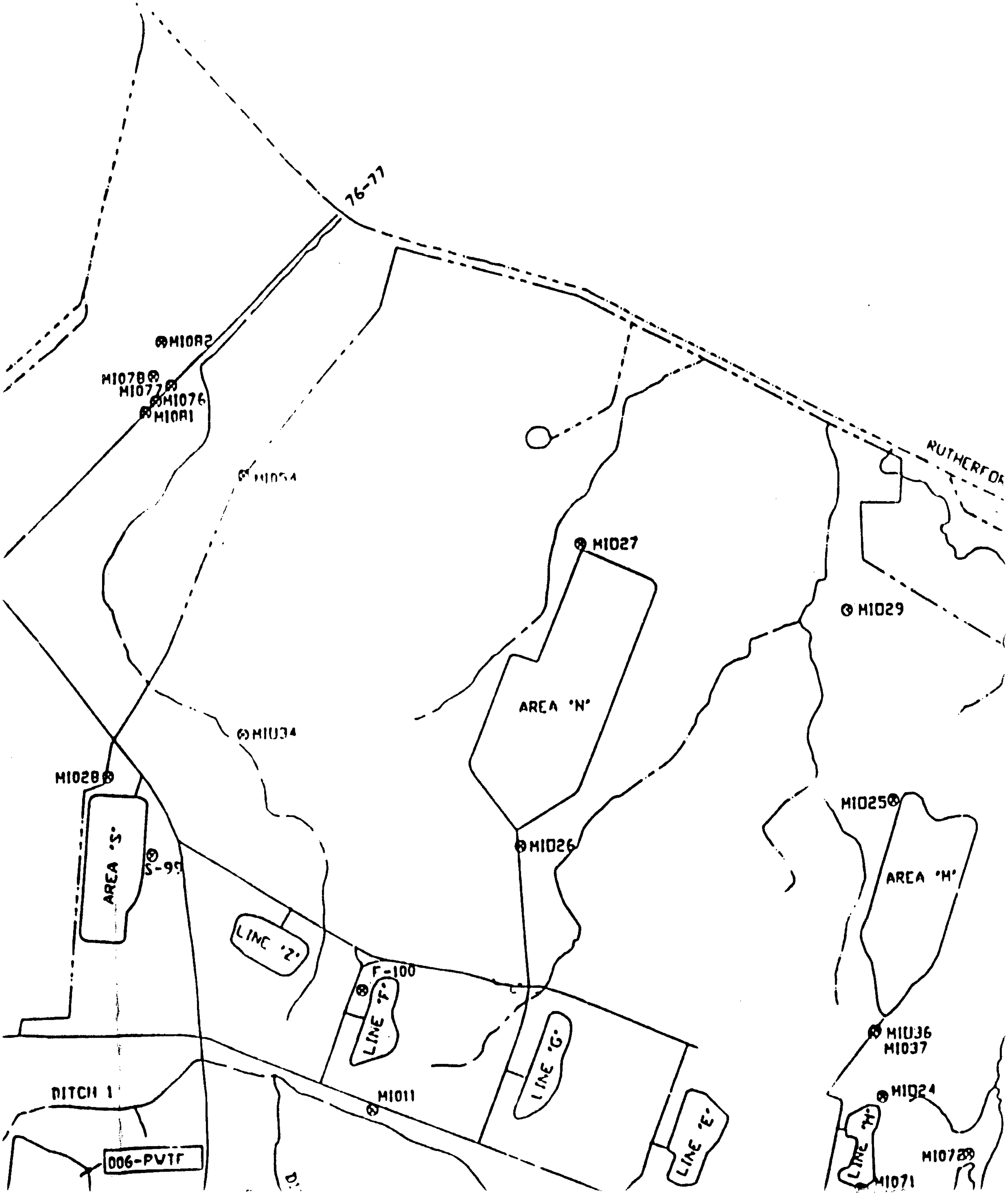
MIO
SALEM RD
M1028
AREA "S"
VOLF CREEK
M1014
DITCH 1
006
104
X-1001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RUTHERFOR
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M1034
M1028
AREA 'S'
S-99
M1025
M1026
AREA 'H'
LINE 'Z'
F-100
LINE 'F'
LINE 'G'
M1036
M1037
DITCH 1
M1011
M1024
LINE 'E'
006-PWTF
LINE 'H'
M1073
M1071

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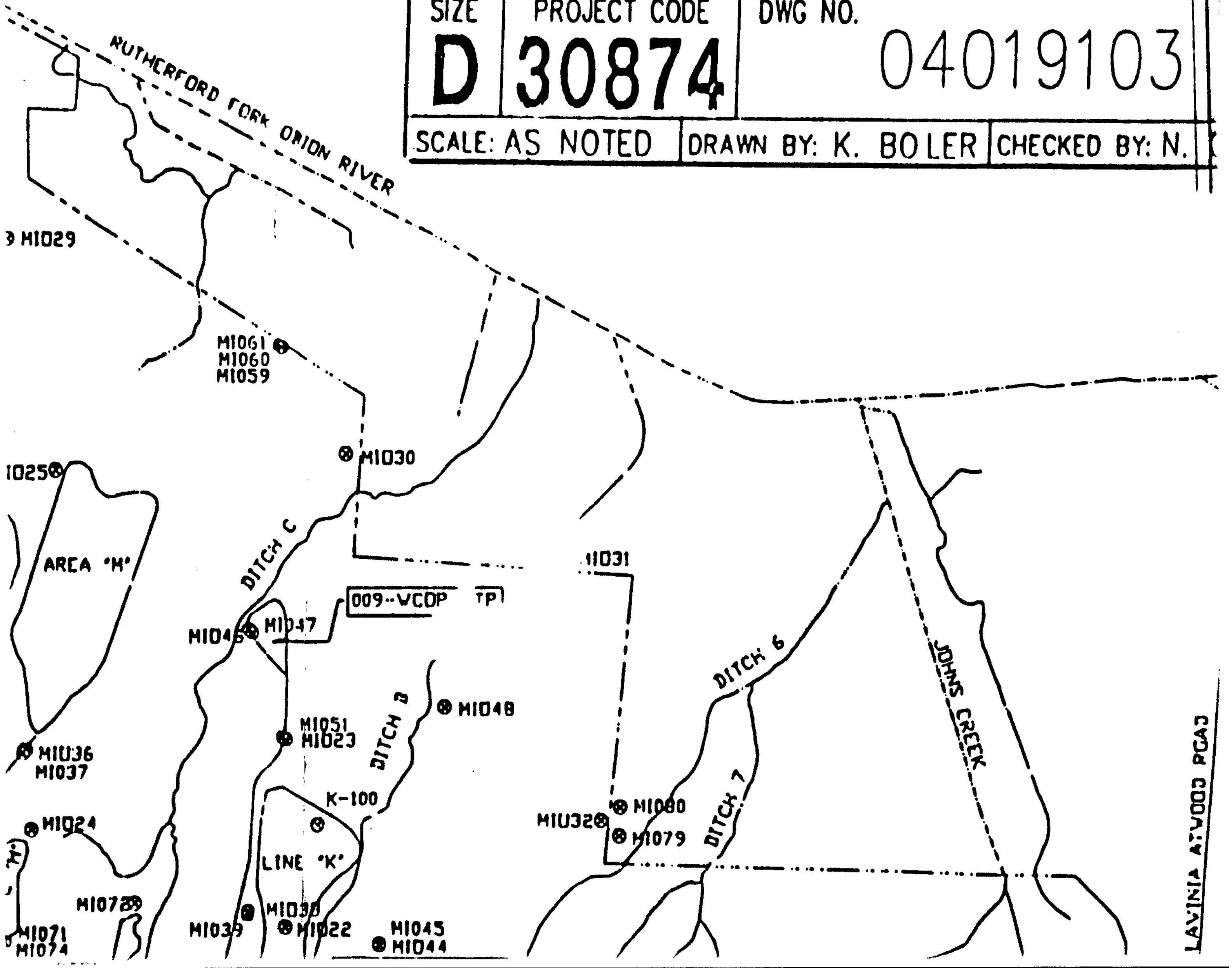
22031-1

TITLE USATHAMA REMEDIAL INVESTIGATION

FIGURE 2-6 LOCATIONS OF NPDES OUTFALLS

SIZE	PROJECT CODE	DWG NO.
D	30874	04019103

SCALE: AS NOTED | DRAWN BY: K. BOLER | CHECKED BY: N.



F KAISER
'GINEERS

9300 LEE HIGHWAY
FAIRFAX, VIRGINIA
22031-1207

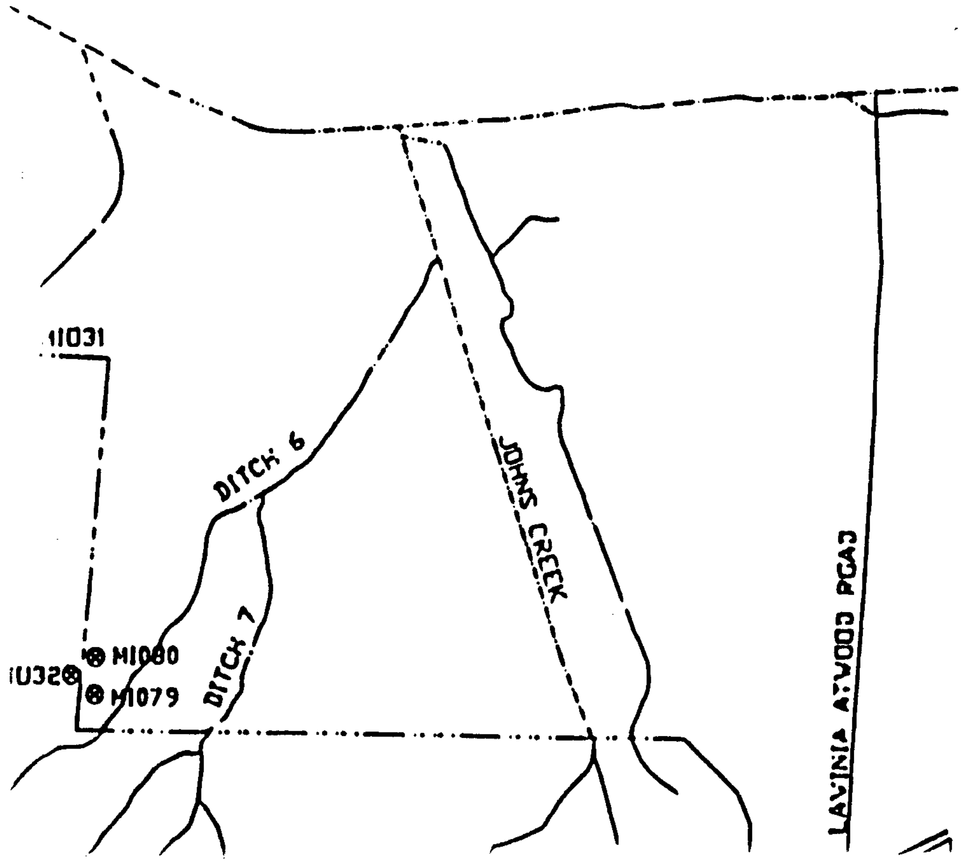
USATHAMA REMEDIAL INVESTIGATION

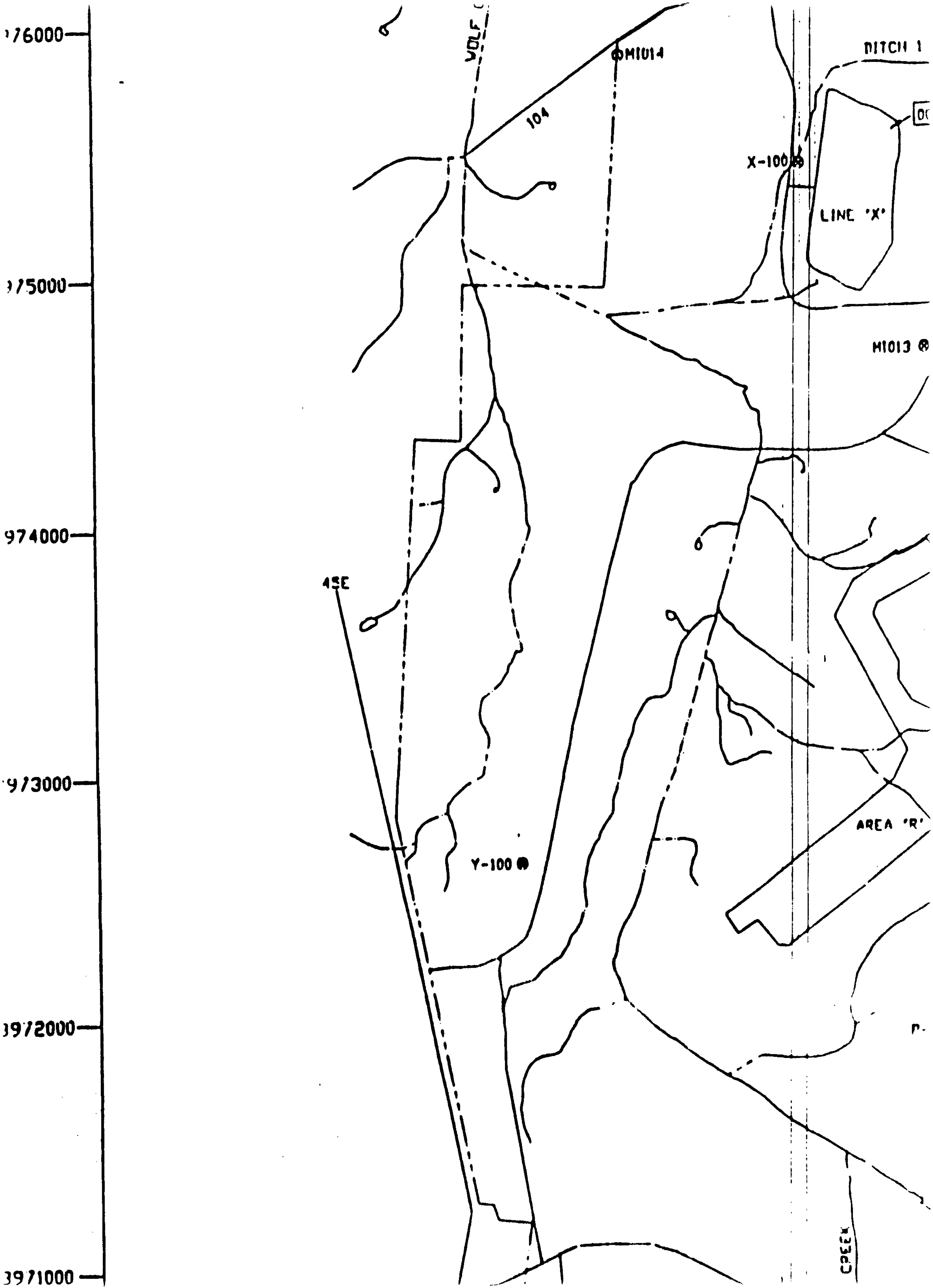
FIGURE 2-6
LOCATIONS
OF
NPDES OUTFALLS

ROJECT CODE 0874

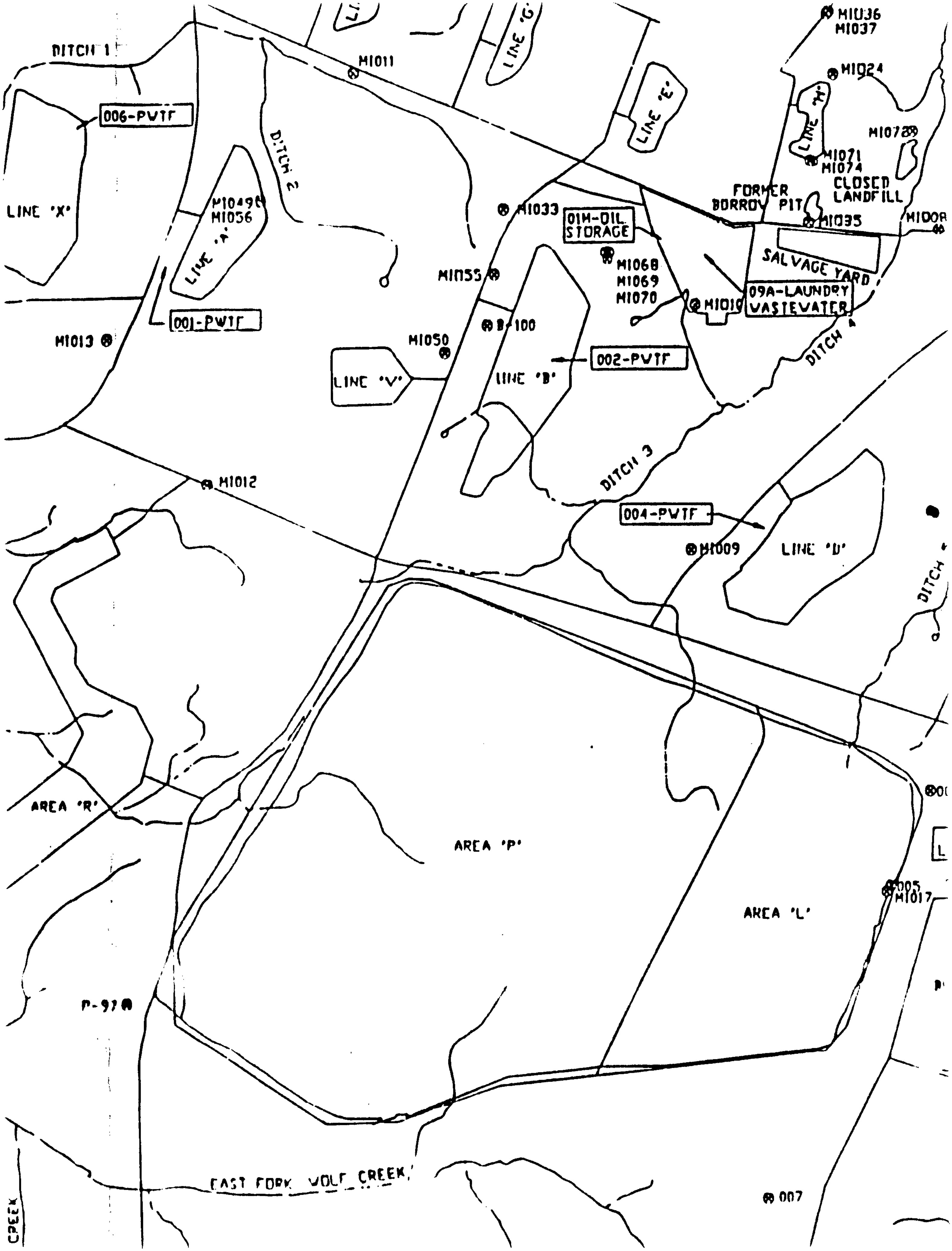
DWG NO. 04019103

NOTED | DRAWN BY: K. BOLER | CHECKED BY: N. OKUSU

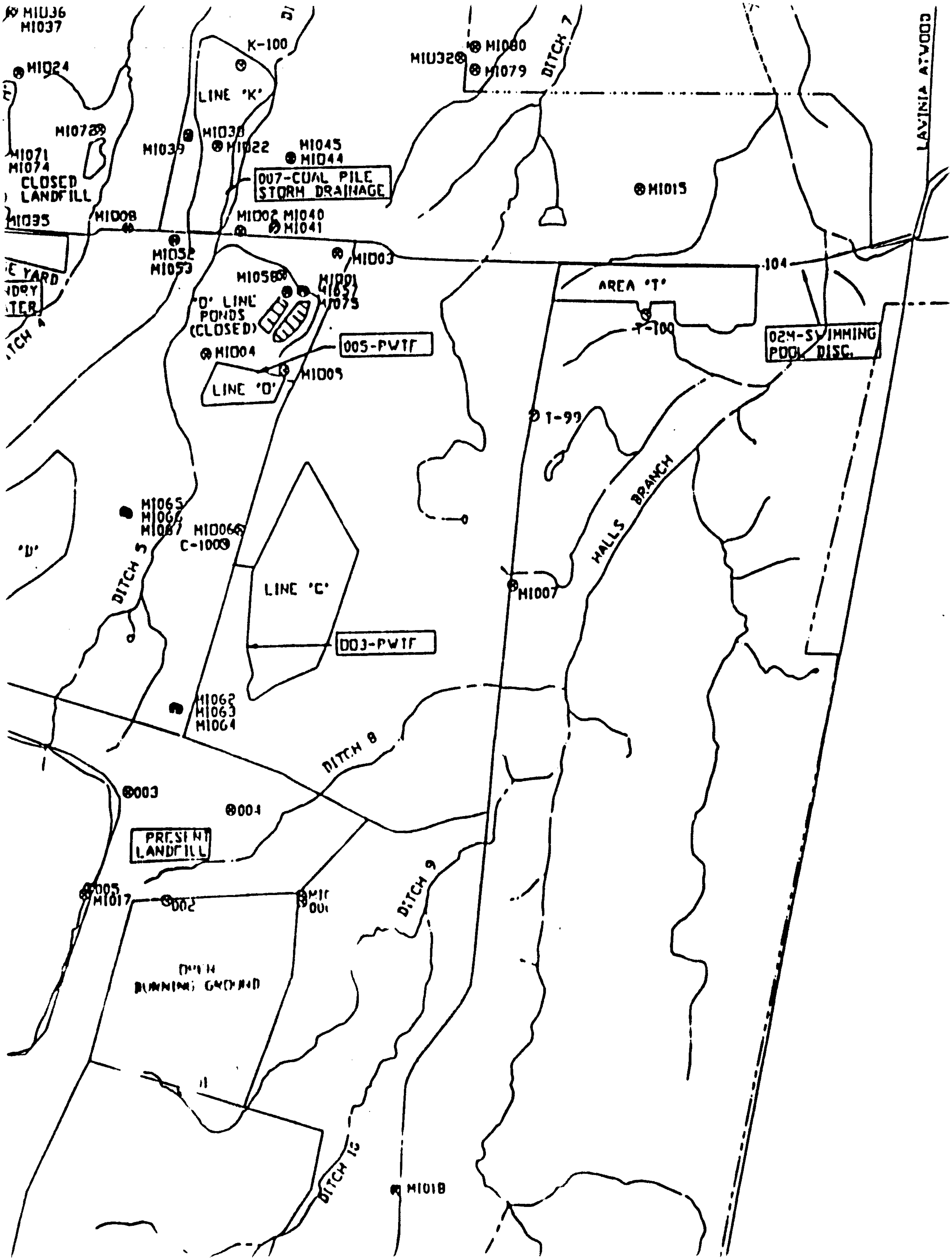




?76000
?75000
974000
973000
3972000
3971000
WOLF C
MI014
104
DITCH 1
00
X-100
LINE 'X'
MI013
4SE
Y-100
AREA 'R'
P.
CREEK



DITCH 1
006-PWTF
LINE 'X'
DITCH 2
M1049
M1056
LINE 'A'
001-PWTF
M1013
M1011
LINE 'G'
LINE 'E'
M1036
M1037
M1024
LINE 'H'
M1078
M1071
M1074
CLOSED LANDFILL
FORMER BORROW PIT
M1035
M100R
M1033
01H-OIL STORAGE
M1068
M1069
M1070
M1019
SALVAGE YARD
09A-LAUNDRY WASTEWATER
DITCH 4
M1055
B-100
M1050
LINE 'V'
LINE 'B'
002-PWTF
DITCH 3
M1012
004-PWTF
M1009
LINE 'D'
DITCH 4
AREA 'R'
AREA 'P'
AREA 'L'
005
M1017
P-97
EAST FORK WOLF CREEK
007
CREEK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DITCH 7
M1024
LINE 'K'
LAVINIA ATWOOD
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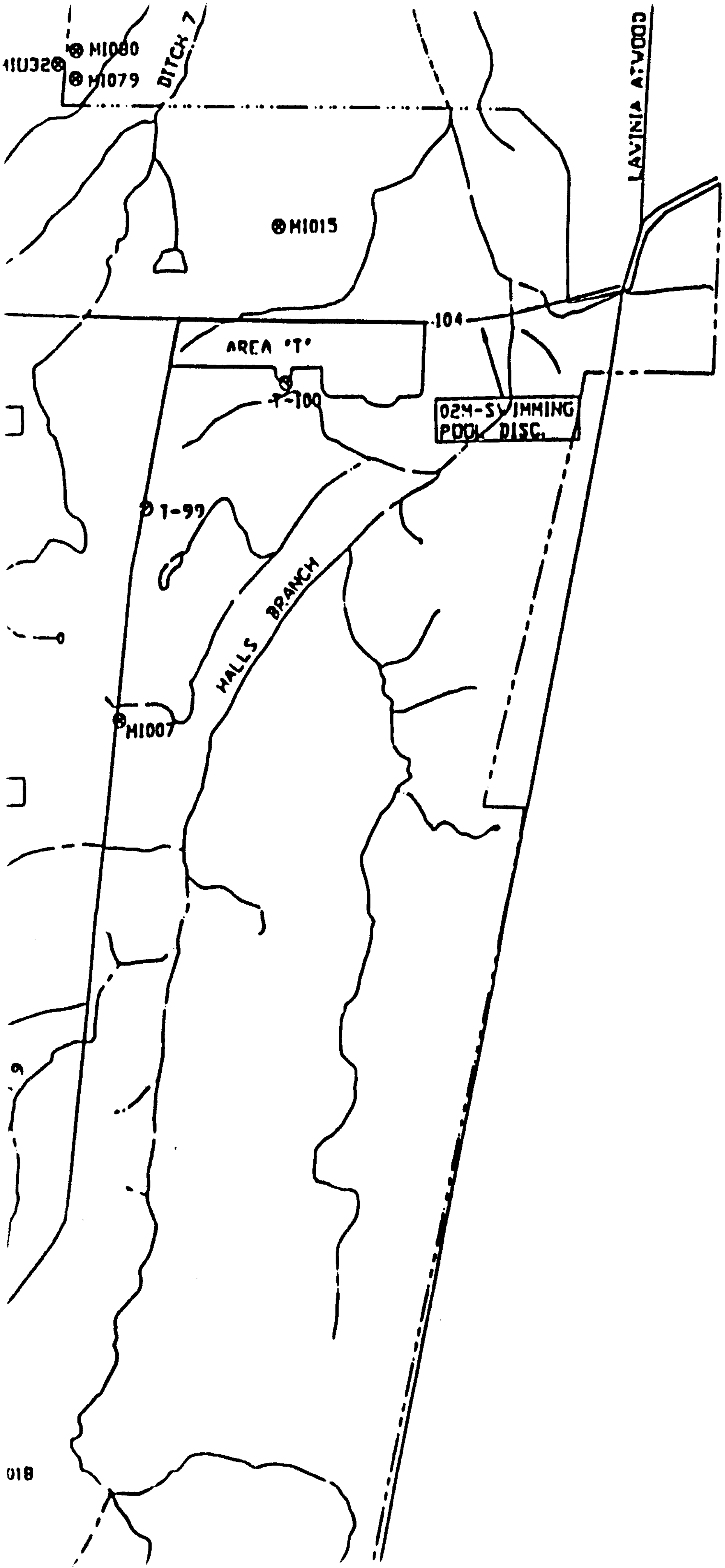
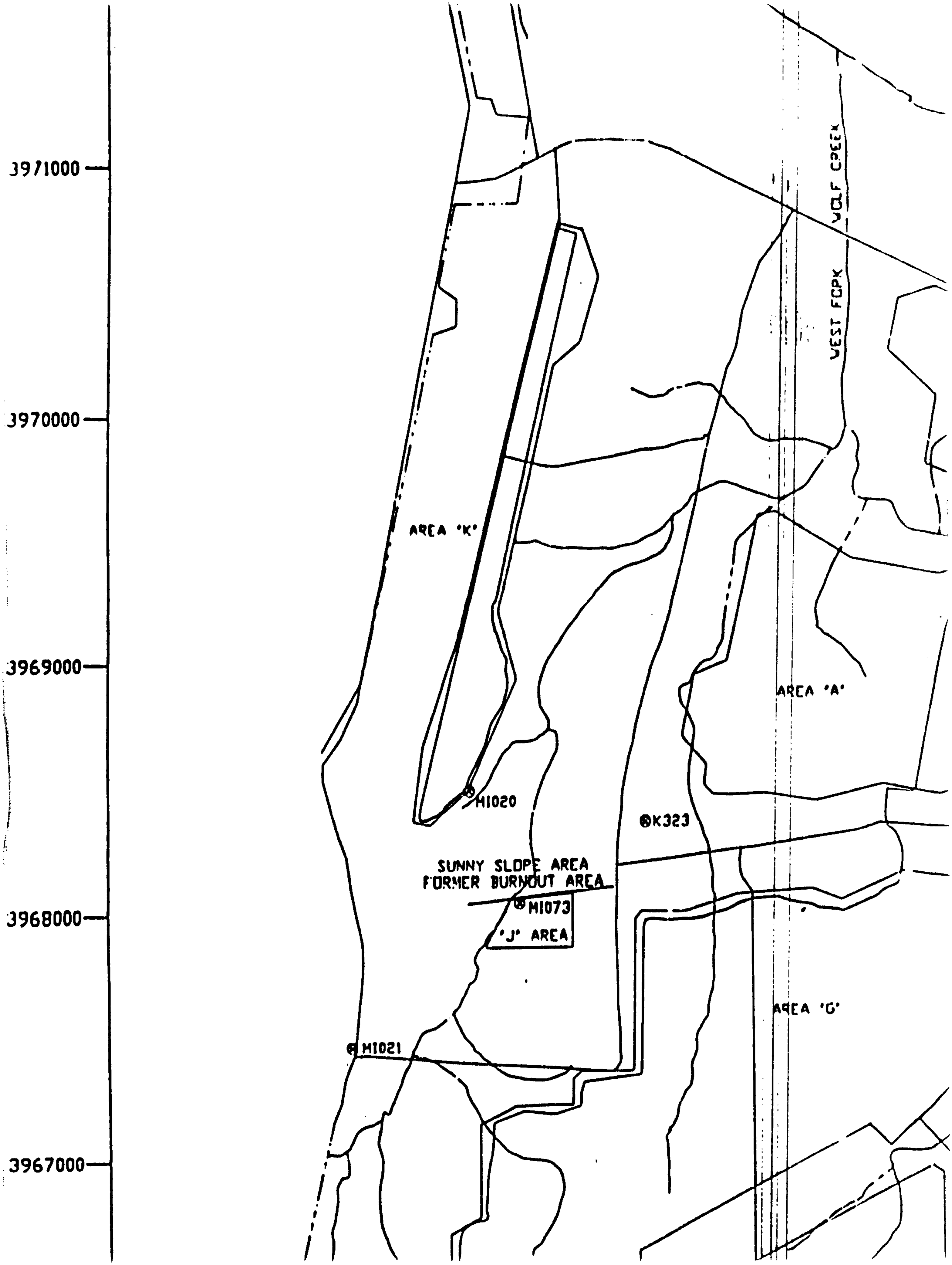
M1030
M1039
M1022
M1045
M1044
M1071
M1074
CLOSED
LANDFILL
007-COAL PILE
STORM DRAINAGE
M1015
M1035
M1008
M1002
M1040
M1041
M1052
M1053
M1003
104
M1058
M1001
M1057
M1075
'D' LINE
PONDS
(CLOSED)
AREA 'T'
T-100
024-SWIMMING
POOL DISC.
DITCH 4
M1004
005-PWTF
M1005
LINE 'D'
T-99
HALLS BRANCH
M1065
M1066
M1067
M1006
C-1000
'D'
DITCH 5
LINE 'C'
M1007
003-PWTF
M1062
M1063
M1064
DITCH 8
003
004
PRESENT
LANDFILL
005
M1017
002
DITCH 9
OPEN
BURNING GROUND
DITCH 10
M1018



1032
M1080
M1079
DITCH 7
LAVINIA ATWOOD
M1015
104
AREA 'T'
T-100
024-SWIMMING POOL DISC.
T-99
HALLS BRANCH
M1007
9
018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3970000
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3968000
3967000
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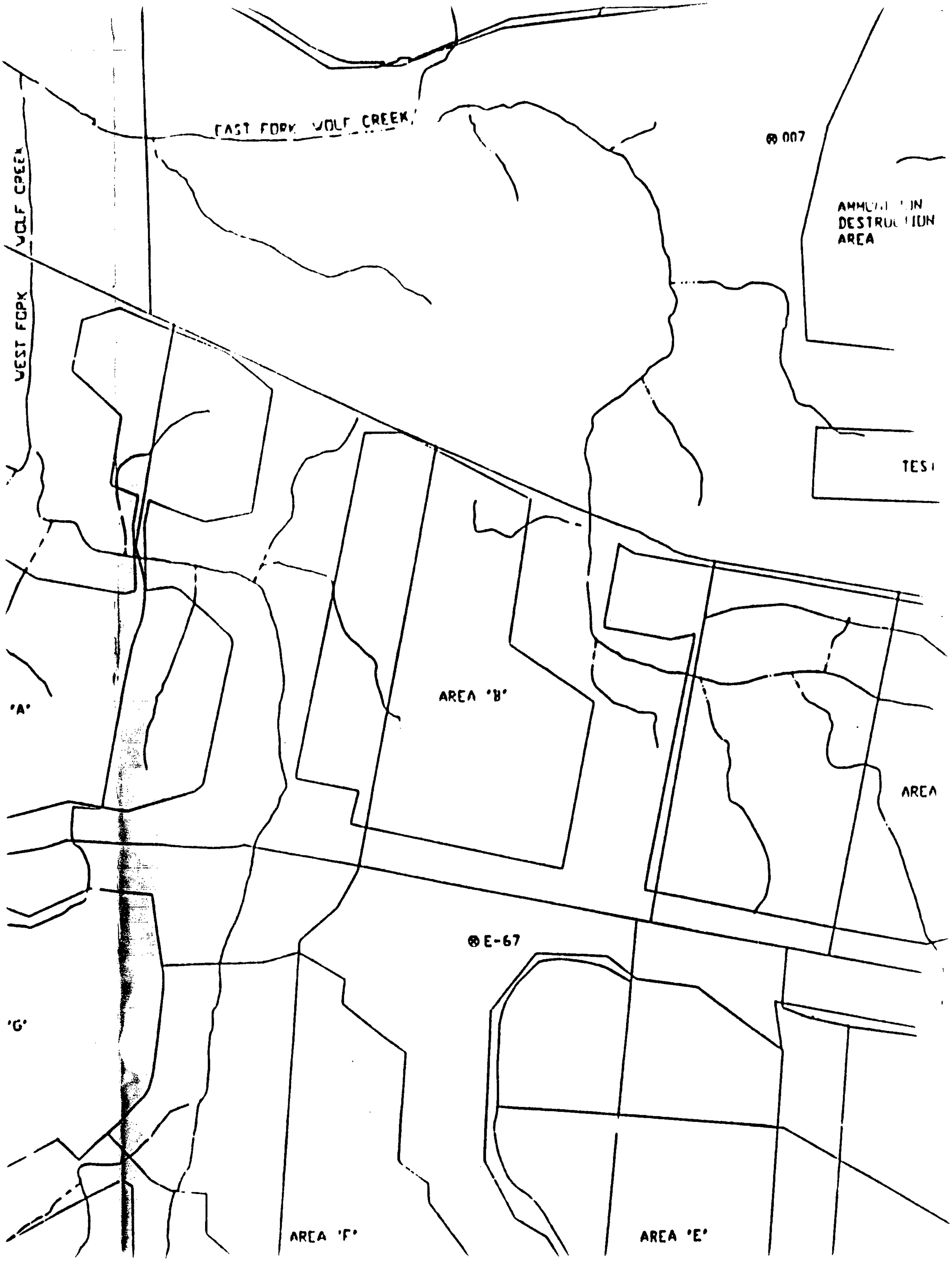
WEST FORK
AREA 'K'
AREA 'A'
M1020
K323
SUNNY SLOPE AREA
FORMER BURNOUT AREA
M1073
'J' AREA
AREA 'G'
M1021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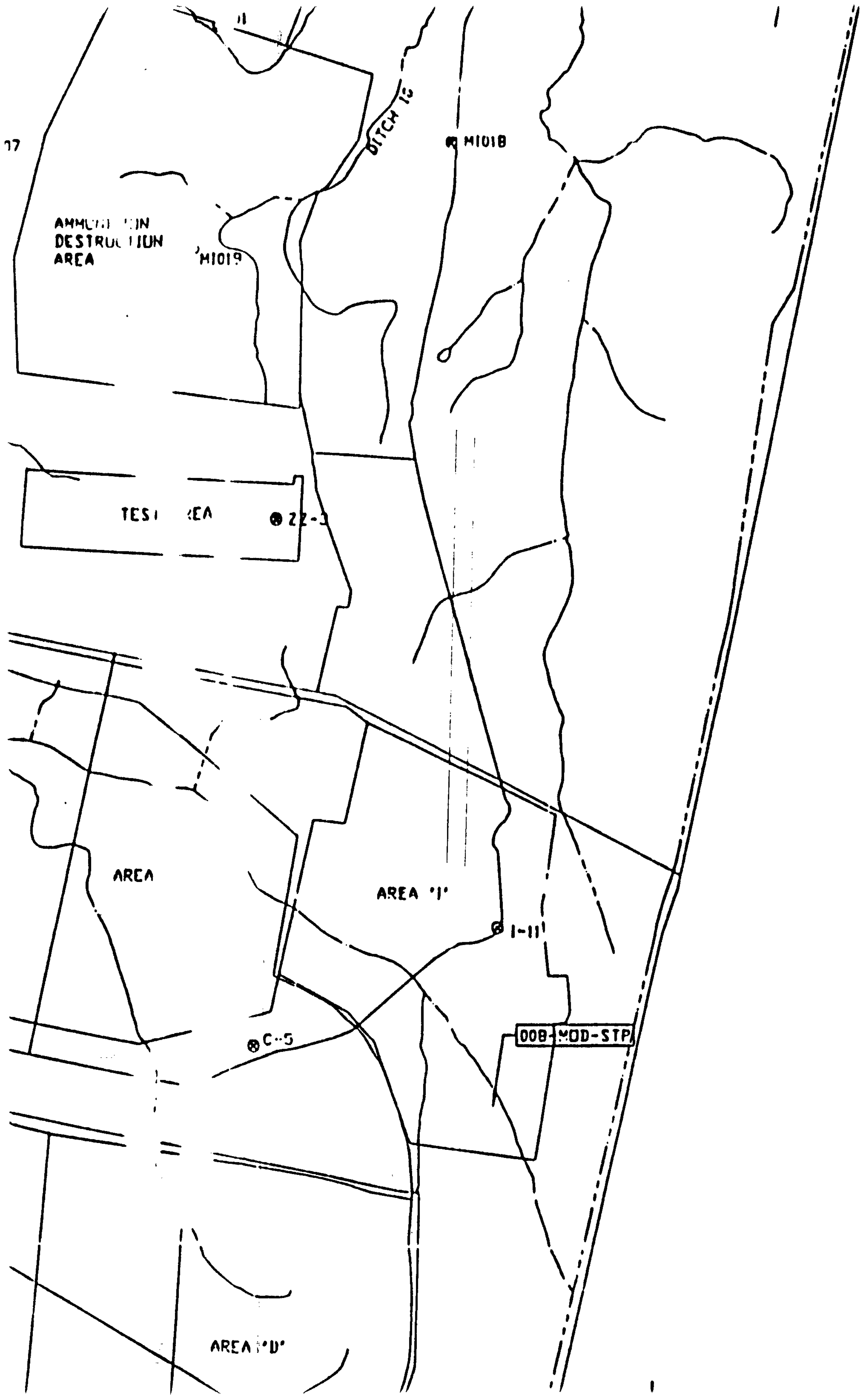
WEST FORK WOLF CREEK
⊗ 007
AMMUNITION DESTRUCTION AREA
TES
AREA 'B'
'A'
AREA
⊗ E-67
'G'
AREA 'F'
AREA 'E'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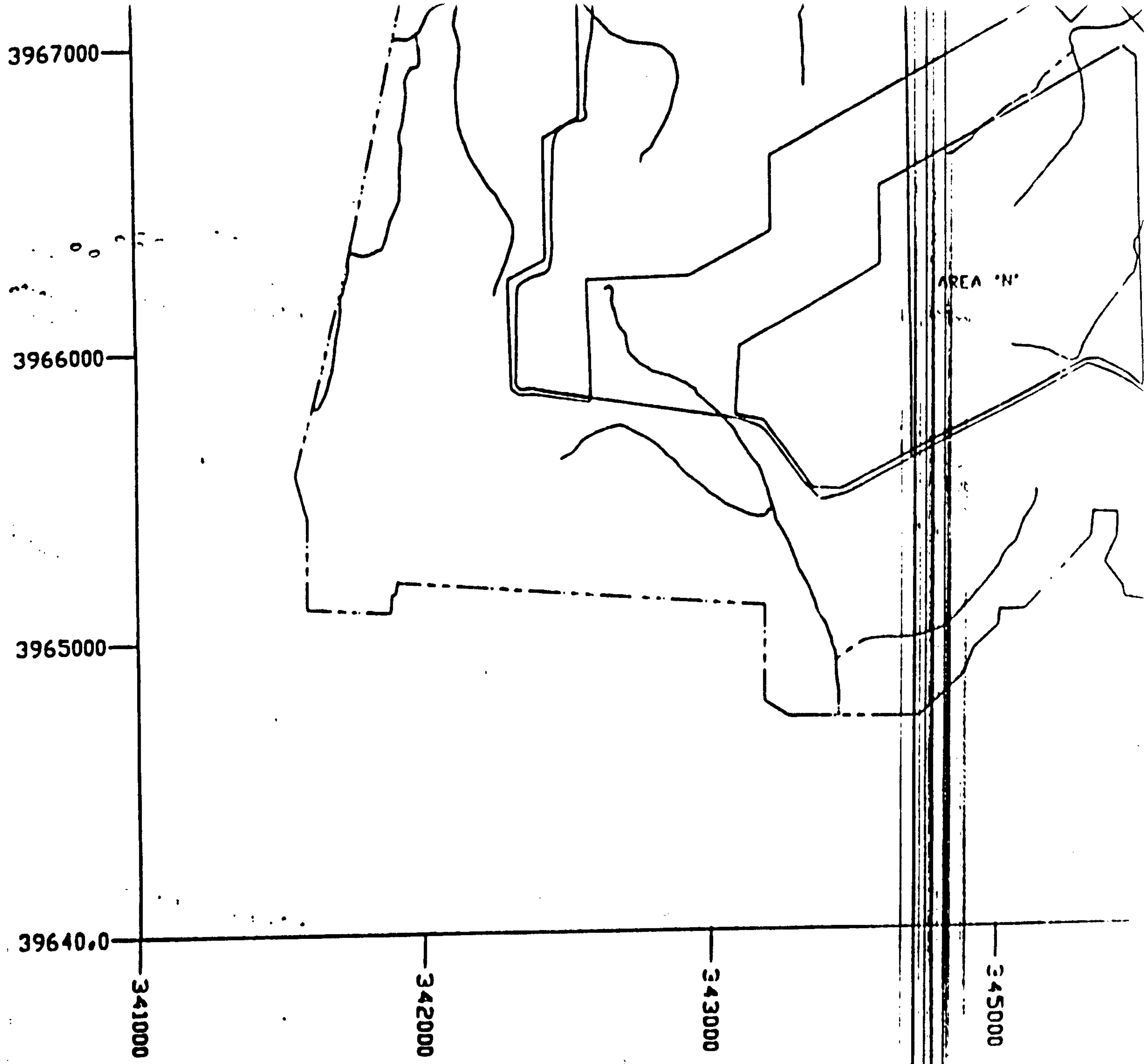
AMMUNITION
DESTRUCTION
AREA
M1019
DITCH 13
M1018
TEST AREA
22-3
AREA
AREA 'I'
I-11
C-5
008-MOD-STP
AREA 'D'

LEGEND


MOD-STP
LEGEND
FACILITY BOUNDARY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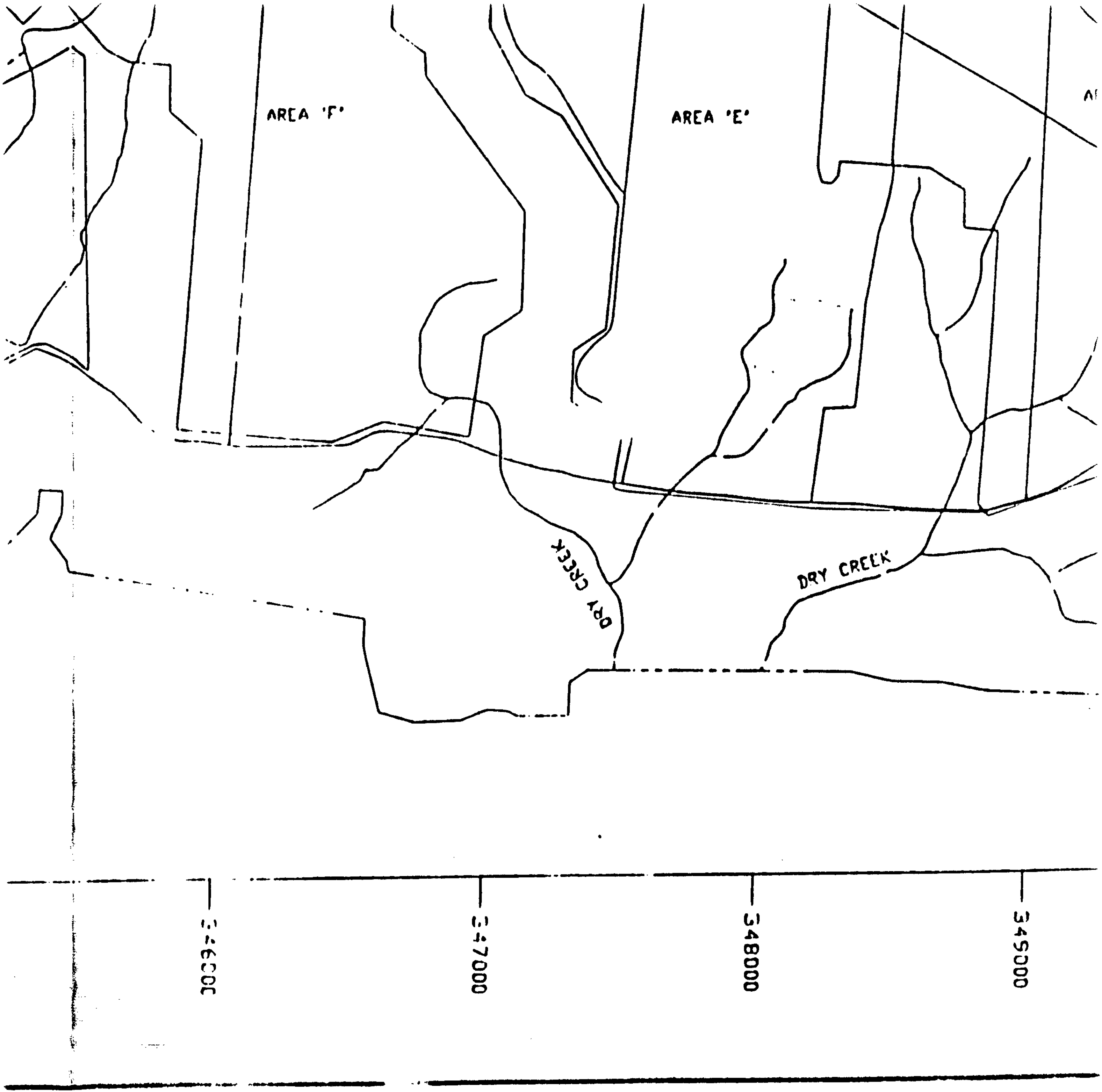
345000
AREA 'N'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AREA 'E'
DRY CREEK
DRY CREEK
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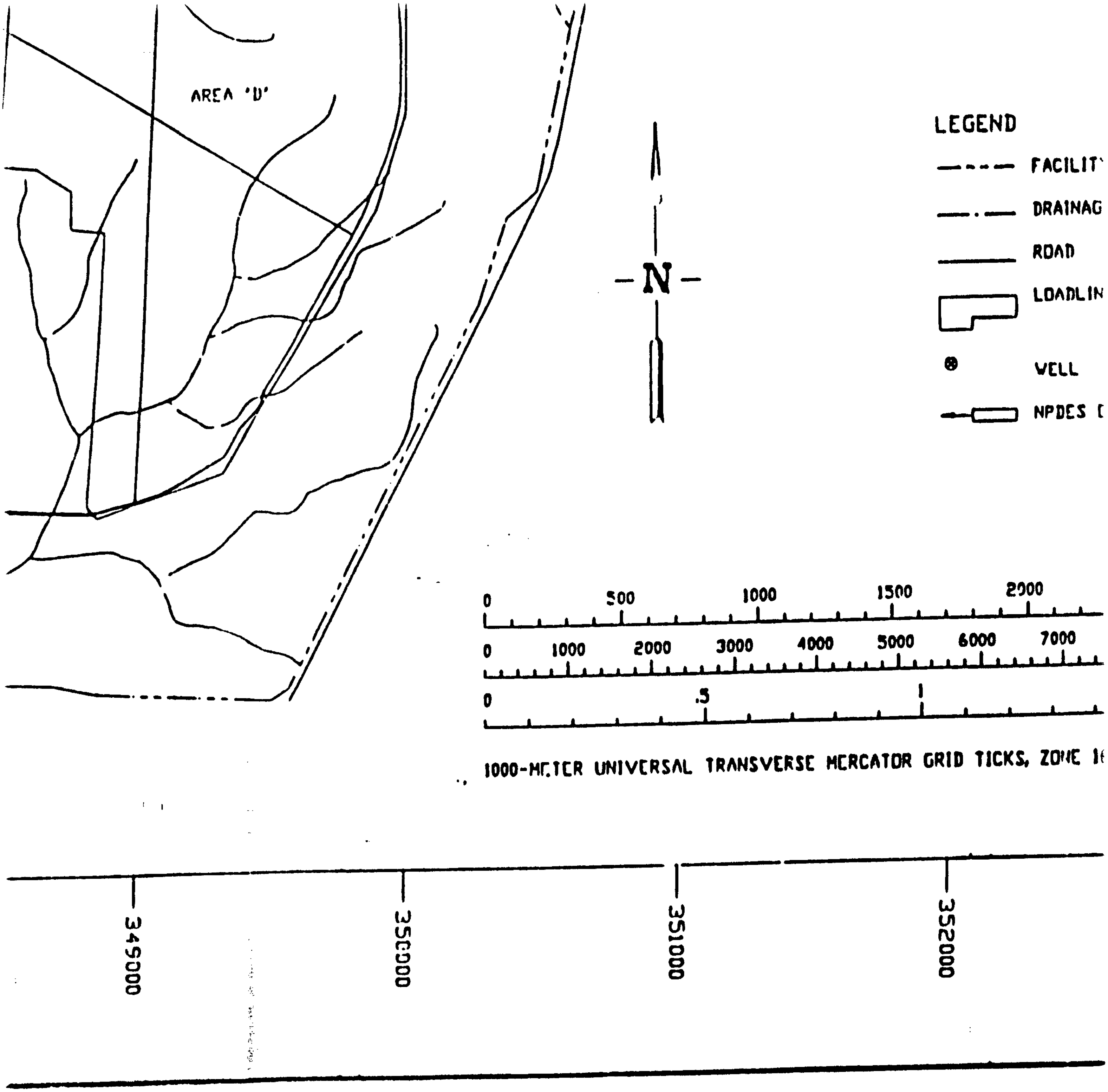
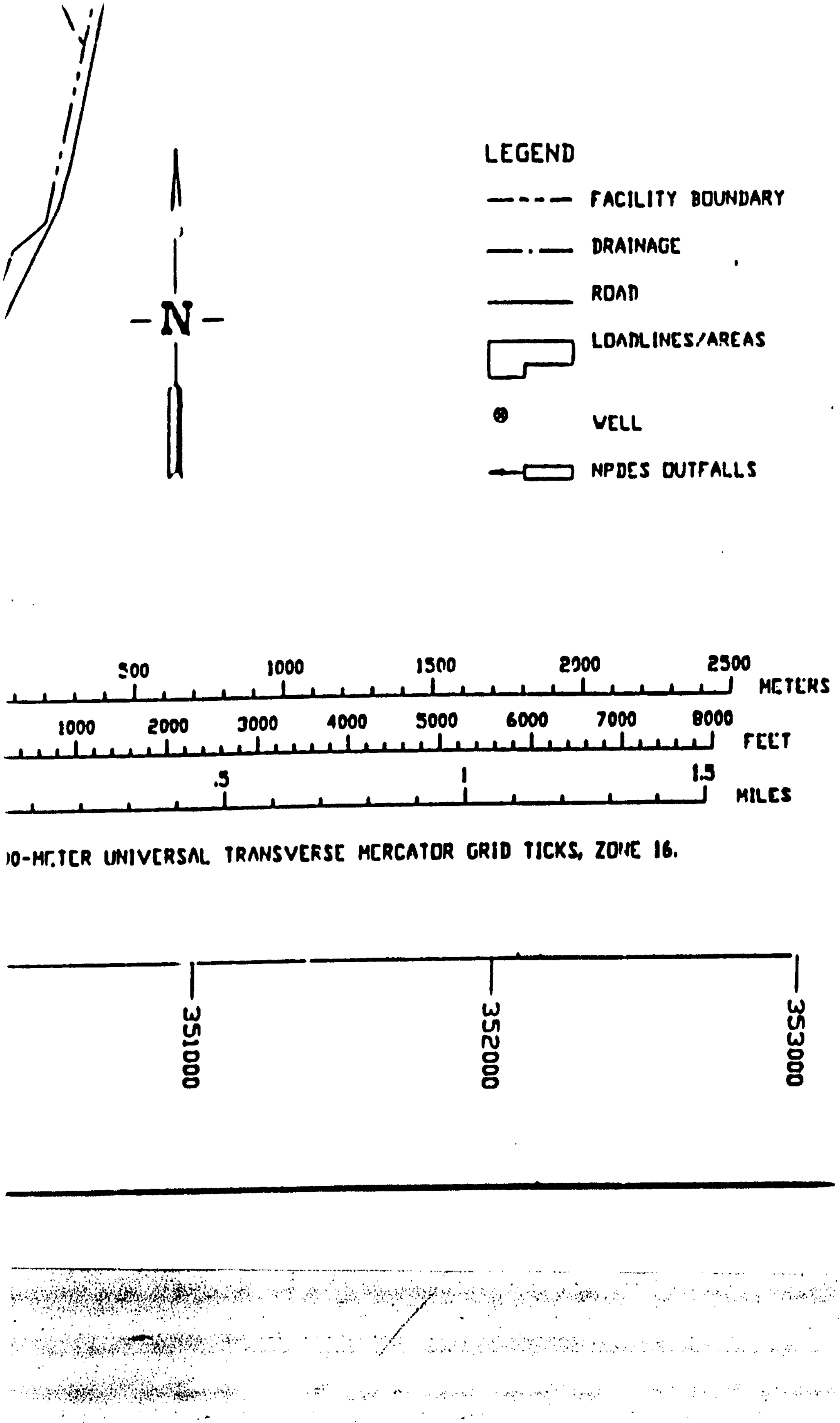
347000
348000
349000


AREA 'D'
N
LEGEND
FACILIT
DRAINAG
ROAD
LOADLIN
WELL
NPDES
0
500
1000
1500
2000
0
1000
2000
3000
4000
5000
6000
7000
0
.5
1
1000-METER UNIVERSAL TRANSVERSE MERCATOR GRID TICKS, ZONE 1
349000
350000
351000
352000



0-METER UNIVERSAL TRANSVERSE MERCATOR GRID TICKS, ZONE 16.

detonation of ordnance in the OBG and ADA areas. This application is pending with the TDC. The facility holds the EPA hazardous waste ID No. TN0210020582. (Personal communication, Paul Higgs, MAAP, March 22, 1991).

From about 1942 until 1978, wastewater from a munitions demilitarization facility (O-Line) was discharged to 11 unlined settling ponds. In December 1984, the O-Line Ponds were closed with a multilayered cap. However, in May 1984, because of the level of contamination in the groundwater, the facility was proposed for listing on the National Priorities List (NPL). Final listing on the NPL took place in August 1987.

In addition, MAAP has used a burning ground to treat or dispose of some of its waste. The burning ground has been reportedly used for the burning of ammunition and propellant, the disposal of spent ordnance and solvents contaminated with reactive wastes, and the burning of wastewater treatment residuals generated from various LAP Lines at MAAP. The past practice had been to conduct these activities on the open ground or in shallow pits. Currently, such wastes are burned in above ground containment pans. Explosive-contaminated material and non-contaminated wastes (wooden pallets, cardboard boxes, etc.) are also disposed of separately in this area by open burning.

Included in the scope of this RI are: the O-Line Ponds area; the OBG; the Former Burnout Area; the former and current ADAs; LAP Lines A through E, O, X, and Z; the Closed Landfill; the Present Landfill; the Former Borrow Pit; the Salvage Yard; and a series of ditches that drain the LAP Lines. All of these areas were designated as solid waste management units (SWMU) in a RCRA Facility Assessment performed in 1986 by A.T. Kearney and Geo/Resource Consultants (USEPA, 1986d). The locations of these units are shown in Figure 2-5.

The following paragraphs provide general descriptions of each site on which the RI focused, as well as a historical review of past operations and practices which may have led to environmental contamination.

2.3.1 O-Line Ponds Area

The O-Line area (Figure 2-7) at MAAP was built as part of the initial plant construction activity in 1941. It has operated since 1942 as an ordnance demilitarization facility. From the start, the major function of the line has been to remove explosives from bombs and projectiles by injecting a high-pressure stream of hot water and steam into the steel shell of the munitions. The types of explosives handled in the facility included TNT and RDX.

Wastewater contaminated with explosives was discharged from the O-Line washout operations through a series of baffled concrete sumps where cooling caused significant amounts of explosives to precipitate out of the waste stream. The collected explosives were periodically removed from the sumps and burned at the burning ground. Effluent from the sumps was initially discharged to an open ditch known as Ditch B (Figure 2-5), which ran through the O-Line area. At an as yet undetermined date in 1942, 11 individual surface impoundments were excavated to receive the O-Line effluent before discharge to the open ditch. The ponds (Figure 2-8) reportedly were excavated into native soil and the excavation material was used to form the pond dikes.

The ponds were 3-5 feet deep, had a total capacity of 5.5 million gallons, and covered an area of about 280,000 square feet. The ponds were interconnected with a series of spillways, open ditches, and distribution boxes allowing several pond configurations to be used in series. Effluent from the last pond flowed through a bank of sawdust-filled tanks before discharge to Ditch B. The sawdust from the tanks was periodically removed and burned in the OBG. The ponds were designed to allow explosives to settle out of the effluent before it was discharged to surface waters. The drainage ditch that received effluent from the final pond discharged to the Rutherford Fork of the Obion River which runs along the northern boundary of MAAP as shown in Figure 2-5.

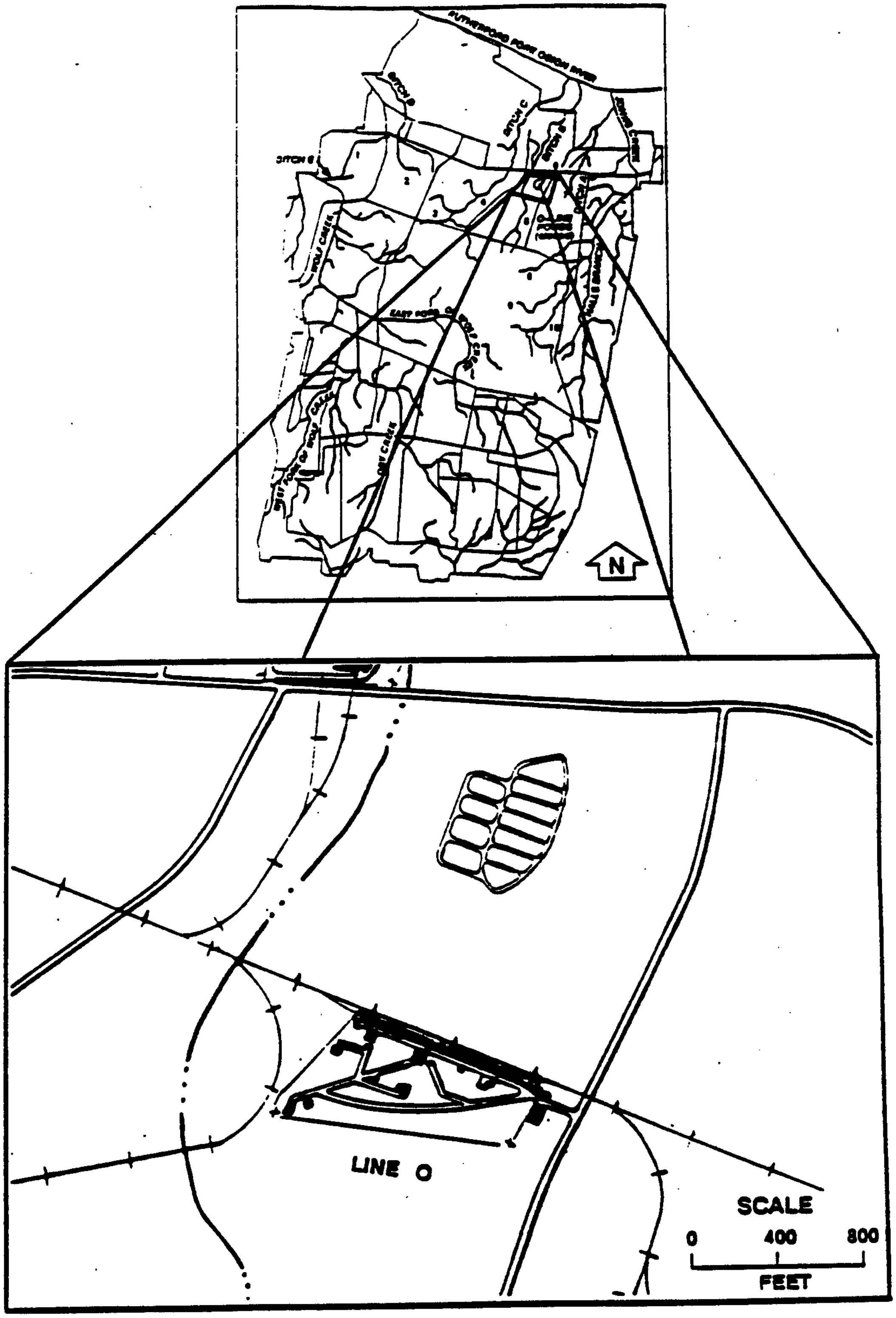


Figure 2-7
O-Line and O-Line Ponds Location

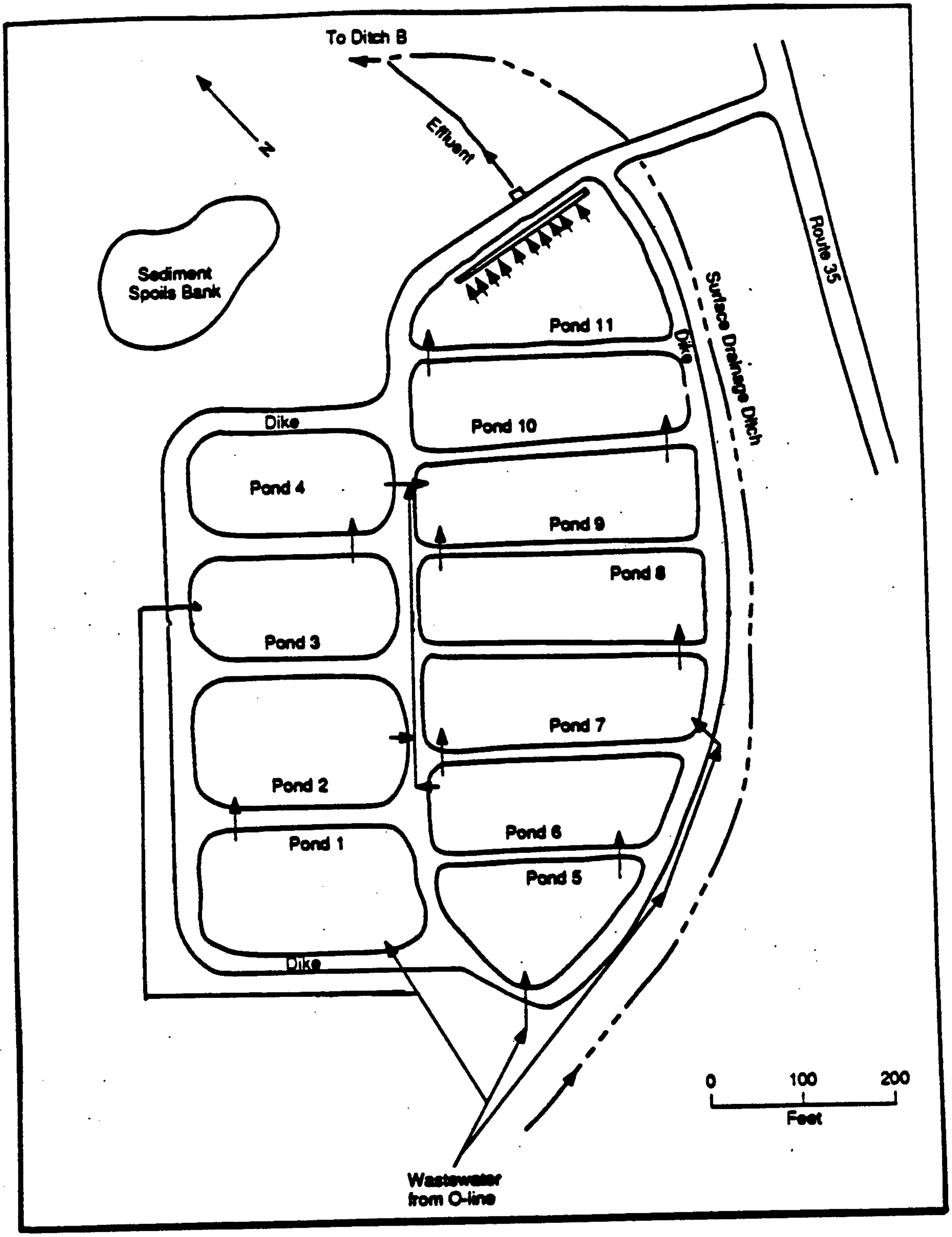


Figure 2-8
O-Line Ponds Area

Operations continued unchanged until 1978 with one exception. In 1971, solids in the ponds were dredged and placed in the northwestern corner of the pond area. In 1978, the U.S. Army Environmental Hygiene Agency's (USAEHA) water well sampling program (USAEHA, 1978) revealed that three of MAAP's 11 water supply wells at MAAP were contaminated with explosive constituents. The affected wells were near a number of production areas, including O-Line. MAAP facility personnel elected to cease using the O-Line Ponds since they were determined to be the most likely source of the groundwater contamination. As a result, the O-Line operation was placed in a standby status in December 1978, and effluent has not been discharged to the ponds since that time. The impounded effluent remained in the ponds until 1981, when the supernatant was pumped out and treated in a newly constructed PWTF, consisting primarily of carbon adsorption units and fabric filtration units. The effluent from the PWTF was discharged to the open ditch under the facility's NPDES permit. A vinyl liner was placed on top of the pond sediments and the liner was filled with fresh water to stabilize it until final closure in 1984.

MAAP subsequently prepared and submitted a RCRA closure plan for the pond site (USATHAMA, 1982b). The closure plan was approved by the Tennessee Department of Health and the Environment (TDHE) and implemented in 1984. The closure plan called for the construction of a multilayered cover system for the ponds. The water in the ponds was tested and discharged under the MAAP NPDES permit, and the material dredged in 1971 was placed on top of the previously installed liner. The ponds were then filled with clean inorganic fill from an on-site borrow pit. The fill was placed in 2 foot lifts and compacted. The pond berms were graded to accommodate the final grade, and the perimeter of the fill material was extended to the outer boundary of the O-Line Pond berms. A clay layer was placed in 6 inch lifts and compacted under optimum moisture conditions to achieve maximum soil density. The clay layer consisted of five lifts for a total of 30 inches. The perimeter of the clay layer was keyed into the existing subsurface by tying into a 3 feet wide by 8 feet deep trench of clay compacted in 2 foot lifts up to ground level. The clay layer was topped with an 8 inch gravel layer that contained a 4 inch perforated PVC pipe perimeter drainage system. The gravel layer was covered with 12 inches of clay and 6 inches of topsoil consistent with the final grade. A vegetative cover was then established. A cross section (Line A--A') of the multilayered cover system is depicted in Figure 2-9. The rationale for taking the ponds out of service in 1984 and placing the liner on top of the contaminated soil was to decrease hydraulic loading onto the contamination source. The cap was designed to further minimize hydraulic loading on the contamination source by providing a multilayered system. Rates of percolation through the upper soils of the cap were determined using the Hydrologic Simulation on Solid Waste Disposal Sites (HSSWDS) Model developed by the Corps of Engineers. The thickness of the drain layer was determined by calculating the maximum height of water expected in the layer with a final grade slope of 3%. The maximum height of water expected is 2.63 inches. To be conservatively safe, an 8 inch drain layer was chosen.

A 30 inch clay layer was selected in the final design of the cap. The permeability of the clay ranges from 10^{-6} to 10^{-7} cm/s, with a linearized diffusivity ranging from 3×10^{-6} to 3×10^{-7} cm/s. Breakthrough was determined to be 480 years, with a leachate rate following breakthrough ranging from 10^{-6} to 10^{-7} cm/second per square cm.

The post-closure measures that have been performed since cap installation are summarized as follows:

- Periodic cutting of grass and spraying of turf to prevent excessive vegetation and deep root growth that may adversely affect cover performance; and
- Maintenance of fences that limit access to the site.

In addition, the facility has performed semiannual and then annual sampling of 11 existing wells downgradient of the O-Line Ponds area to monitor groundwater quality. These data are further discussed in Section 3.0.

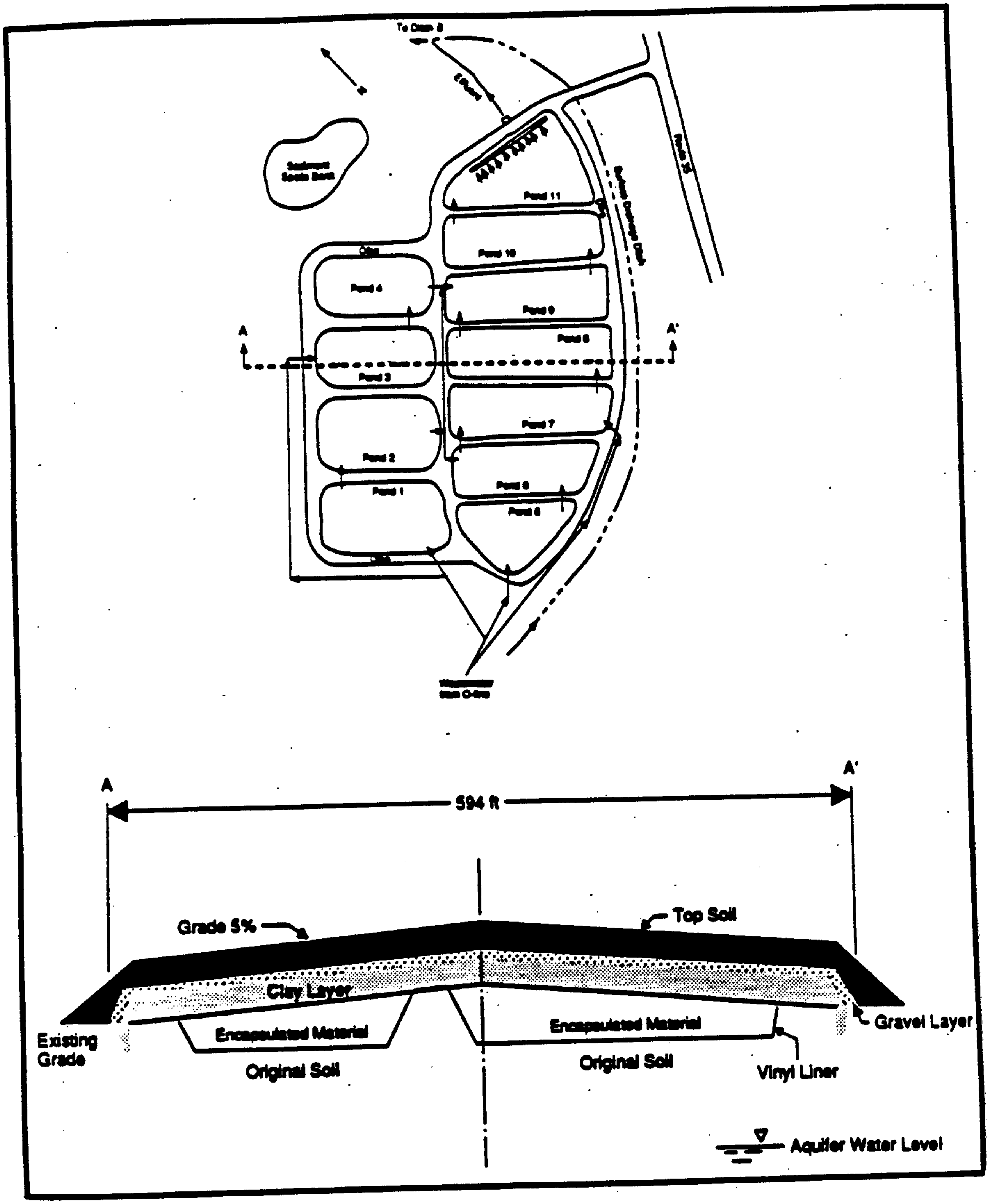


Figure 2-9
Cross-Sectional Sketch of the Multilayered Cover System Used for the O-Line Ponds

2.3.1.1 Summary of Existing Data. Only limited monitoring data are available for the effluent that was discharged from the O-Line operations area into the O-Line Ponds, but the characteristics can be inferred from present operations. Approximately 17,000 gallons per week of treated O-Line effluent is currently discharged to the O-Line ditch. MAAP representatives reported that in the past, 34,000 gallons per day of O-Line effluent was discharged. It was also indicated that before they were closed, the O-Line Ponds had received effluent containing up to 800 mg/L of total nitrobodies (personal communication, Bill Blaylock, Martin Marietta, November 1987). Nitrobodies are nitrogen-containing, explosives-related chemicals such as 2,4,6-trinitrotoluene (TNT), 2,4- and 2,6-dinitrotoluene (DNT), cyclotrimethylenetrinitramine (RDX), and cyclotetramethylenetetranitramine (HMX).

The contaminant burden of the effluent that was discharged to the O-Line Ponds can also be inferred from present operations at O-Line. MAAP representatives have indicated to Argonne National Laboratory staff that analytical results for effluent from this location in the treatment plant are generally representative of effluent quality discharged to the O-Line Ponds before the PWTF was constructed (personal communication, Bill Blaylock, Martin Marietta, January 1988; reported by USATHAMA, 1988). Assuming that O-Line operations have remained generally unchanged since the installation of the PWTF, effluent water quality prior to treatment in the PWTF should be fairly representative of the effluent discharged to the O-Line Ponds in the past. Table 2-2 summarizes the nitrobody concentrations of O-Line effluent after a fabric filtration step in the PWTF for the period from October 14, 1985, through December 16, 1986. As indicated in this table, the total nitrobody concentration of effluent for the period of record ranged from 1.92 to 10.82 mg/L. This information suggests that the 800 mg/L total nitrobody content reported for the O-Line effluent was the exception rather than the rule.

The sediment and supernatant in the O-Line Ponds were sampled and analyzed before the ponds were closed (USATHAMA 1982a, 1981). Relevant results are briefly described below.

Pond and spoil-bank samples collected in the 1982 study were analyzed for priority pollutant inorganic compounds and explosive contaminants, including TNT, RDX, 2,6-DNT and 2,4-DNT. Pond supernatant samples were also analyzed for priority pollutant extractable compounds and volatile compounds while pond sediment samples were analyzed for priority pollutant extractable compounds only. The samples for both supernatant and sediment were collected from the approximate centers of Ponds 1,3,5,8, and 11.

Results indicated that the inorganic materials in the pond samples were below concentrations of regulatory concern. Because a variety of priority pollutants (phthalate esters, dinitrotoluenes, and methylene chloride) were detected at low levels, organic priority pollutants may be contaminants of concern in the O-Line Ponds. The most commonly detected contaminants, and those detected at the highest concentrations, were explosives-related compounds. These data are shown in Table 2-3. Of the 5 ponds sampled, Pond 5 contained the highest concentrations of total nitrobodies (4,820.4 µg/L in the supernatant and 49.5 mg/kg in the sediment). All pond samples contained detectable concentrations of each of the explosive constituents RDX, 2,4,6-TNT, 2,4-DNT, and 2,6-DNT.

In 1981, extensive pond sampling and analysis efforts were conducted as part of a leaching test study on the O-Line Pond sediments (USATHAMA, 1981). Surficial and core sediment samples were collected from multiple locations in each of the 11 ponds (Figure 2-10). A subset of the samples was analyzed for 2,4,6-TNT, DNT, RDX, lead, chromium, mercury, cadmium, and reactivity. Additional sediment samples were subjected to a leachate generation test. The leachate was subsequently analyzed for the principal explosive constituents.

Table 2-4 presents the data from analysis of the surficial pond sediment samples. The two DNT compounds were not detected or were present only in trace concentrations in these samples. RDX and TNT were detected in nearly all of the samples collected. Concentrations of RDX range from 1.18 to 1,340 mg/kg, and TNT concentrations ranged from undetected to 75,100 mg/kg. The most elevated concentrations of RDX and TNT were in samples from Ponds 1, 3, 5, 6, and 7.

TABLE 2-3
CONCENTRATIONS OF EXPLOSIVES AND INORGANICS IN O-LINE PONDS MEASURED IN 1980

Lagoon		Concentrations in Micrograms Per Liter (Water) and Milligrams Per Kilogram (Sediment)										
		TNT	2,4-DNT	2,6-DNT	RDX	Lead	Chromium	Mercury	Nitrate	Nitrite	Phosphate	Sulfate
1	Water	+	+	+	850	ND	ND	ND	2,000	68	280	+
	Sediment	13.00	.037	.085	26.0	7.1	27.5	ND	10.1	0.12	ND	31.0
3	Water	0.7	ND	+	+	ND	ND	ND	ND	7	280	+
	Sediment	11.00	.310	.083	4.70	20.2	22.5	ND	10.7	0.19	0.30	29.0
5	Water	65	ND	5.4	4,750	ND	ND	ND	2,600	30	40	+
	Sediment	10.50	.825	.023	38.0	22.6	22.5	ND	12.0	0.73	ND	72.0
8	Water	4.3	ND	+	+	ND	ND	ND	180	15	100	+
	Sediment	1.34	.022	.002	6.5	8.6	18.7	ND	11.6	0.19	ND	24.3
11	Water	0.3	ND	ND	+	ND	ND	ND	ND	7	70	+
	Sediment	0.50	.054	.006	3.6	8.6	21.3	ND	ND	0.19	0.30	21.1
Spoils Bank	Sediment	7.5	.031	.017	36.1	11.1	21.9	ND	22.1	0.57	ND	67.1
Detection Limits	Water	*	*	*	*	116	133	0.117	90.9	7	160	*
	Sediment	*	*	*	*	3.4	4.8	0.067	0.28	0.04	0.30	11.6

NOTES: Explosives determinations by GC-EC. RDX determinations in sediment not corrected for method recovery efficiency.

* Explosives detection limits are variable depending on sample source.
ND Analyte not detected.
\+ Analyte observed at a level below the calculated detection limit at the 90% confidence level.

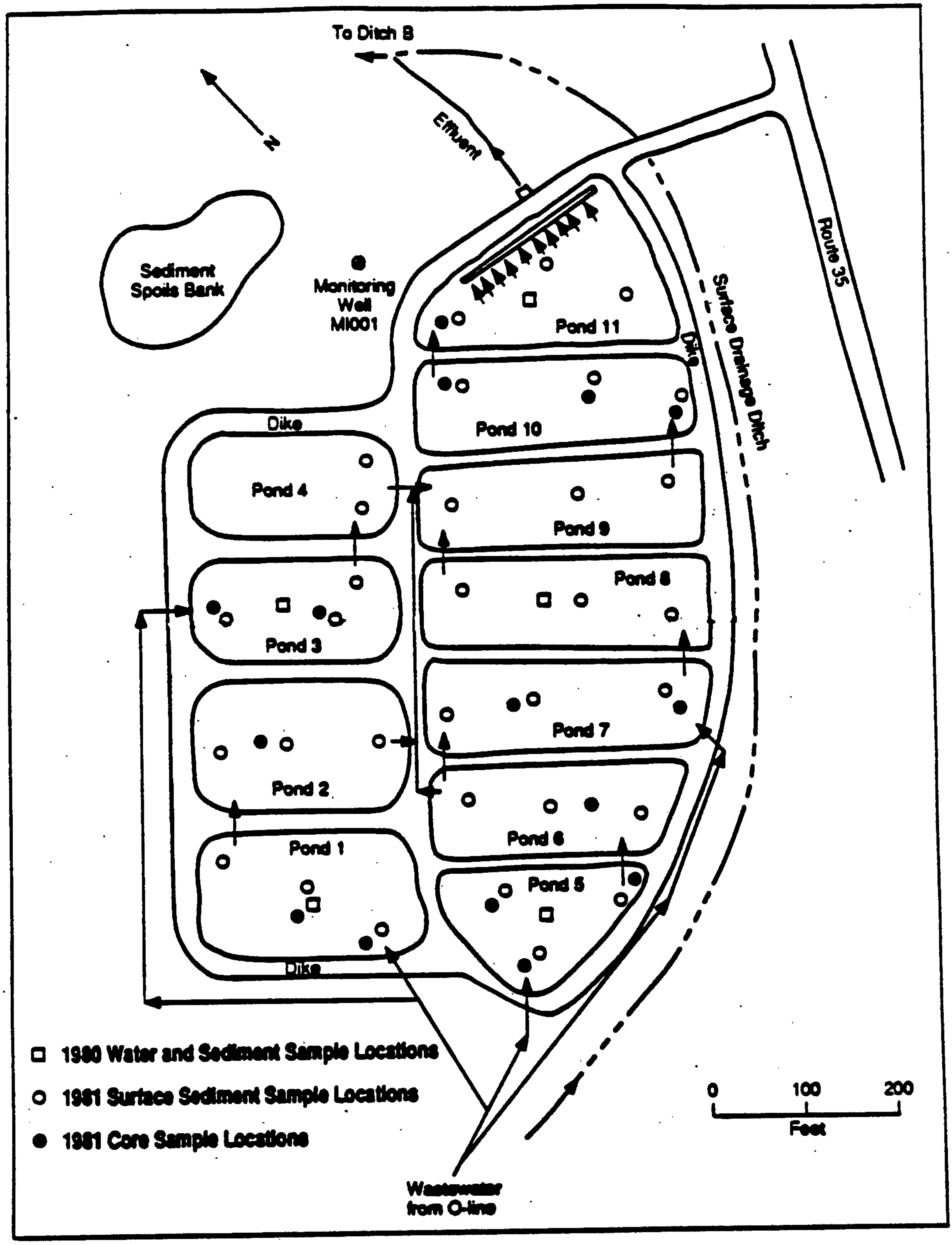
SOURCE: USATHAMA, 1982a

TABLE 2-2
NITROBODY[a] CONCENTRATIONS IN O-LINE EFFLUENT AFTER FABRIC FILTRATION

Sample Date	Concentration (mg/L)	Sample Date	Concentration (mg/L)
1985		1986 (Cont'd)	
Oct. 14	4.21	Sept. 19	3.59
Oct. 16	4.19	Sept. 22	3.61
Oct. 17	4.0	Sept. 26	3.46
Oct. 18	10.45	Oct. 2	3.36
Oct. 23	4.1	Oct. 8	7.04
Oct. 28	5.24	Oct. 10	3.75
Nov. 12	4.0	Oct. 13	3.48
		Oct. 14	3.92
1986		Oct. 15	3.17
June 4	5.31	Oct. 20	1.92
June 11	5.20	Oct. 22	4.70
June 23	7.31	Oct. 30	5.88
June 27	8.66	Nov. 3	6.98
July 7	7.18	Nov. 6	6.65
July 18	7.16	Nov. 10	3.34
July 28	5.40	Nov. 11	4.65
Aug. 1	6.0	Nov. 14	4.64
Aug. 6	4.07	Nov. 17	5.24
Aug. 11	4.16	Nov. 18	4.89
Aug. 21	4.09	Nov. 24	4.87
Aug. 25	3.4	Dec. 1	3.00
Sept. 4	3.22	Dec. 12	9.72
Sept. 12	3.25	Dec. 16	10.82
Sept. 17	5.37		

[a] Nitrobodies are nitrogen-containing, explosives-related chemicals such as TNT, DNT, RDX, and HMX.

Source: USATHAMA, 1988



Sources: USATHAMA, 1981; USATHAMA, 1982a; USATHAMA, 1982b

Figure 2-10
Sample Locations in the O-Line Ponds

TABLE 2-4
ANALYSES OF SURFICIAL SEDIMENT SAMPLES FROM O-LINE PONDS IN 1981 (mg/kg)

Pond	Sample Location	2,4,6-TNT	RDX	Pb	Cr	Cd	Hg	2,4-DNT	2,6-DNT	Moisture Content (% wet. wt.)
1	Inlet	38,500	510	21	9	4.20	<0.18	<40.1	<73.3	38
	Outlet	28,200	504	28	14	<3.50	<0.21	<35.7	<65.2	31
2	Inlet	46.8	320	33	15	<3.50	<0.13	<3.10	<5.67	21
	Middle	42.7	531	24	16	<3.50	<0.12	<3.07	<5.60	20
	Outlet	10.5	259	16	13	<3.50	<0.12	<0.288	<0.527	15
3	Inlet	75,100	1,340	34	14	11.3	<0.17	<40.9	<74.7	40
	Middle	249	127	21	14	<3.50	<0.12	<2.47	<4.51	<0.7
	Outlet	114	303	26	17	<3.50	<0.12	<0.316	<0.578	20
4	Inlet	42.3	406	26	16	<3.50	<0.12	<3.08	<5.63	20
	Middle	11.2	424	31	18	<3.50	<0.13	<0.310	<0.567	21
	Outlet	17.1	384	27	17	<3.50	<0.12	<0.303	<0.553	19
5	Inlet	12,700	697	30	14	<3.50	<0.16	<34.3	<62.7	26
	Middle	2,080	624	24	19	<3.50	<0.15	<31.5	<57.6	21
	Outlet	305	427	20	12	<3.50	<0.16	<3.10	<5.67	21
6	Inlet	1,290	976	26	14	<3.50	<0.13	<33.6	<61.3	25
	Middle	74.2	437	37	21	<3.50	<0.13	<3.31	<6.05	26
	Outlet	16.4	612	30	15	<3.50	<0.13	<0.327	<0.597	25
	Inlet	8.43	420	31	15	<3.50	<0.15	<0.299	<0.546	18
7	Middle	736	424	36	18	<3.50	<0.14	<3.07	<5.60	20
	Outlet	2,320	430	23	12	<3.50	<0.15	<31.8	<58.2	23
8	Inlet	716	460	17	9	<3.50	<0.12	<3.03	<5.53	19
	Middle	12.8	178	34	18	<3.50	<0.12	<0.292	<0.533	16
	Outlet	3.40	331	39	17	<3.50	<0.13	<0.311	<0.568	20
9	Inlet	28.8	439	37	18	<3.50	<0.13	<3.18	<5.82	23
	Middle	6.54	325	35	16	<3.50	<0.12	<0.301	<0.549	18
	Outlet	15.7	454	28	15	<3.50	<0.12	<0.299	<0.546	18

TABLE 2-4 (Continued)
ANALYSES OF SURFICIAL SEDIMENT SAMPLES FROM O-LINE PONDS IN 1981 (mg/kg)

Pond	Sample Location	2,4,6-TNT	RDX	Pb	Cr	Cd	Hg	2,4-DNT	2,6-DNT	Moisture Content (% wet. wt.)
10	Inlet	9.98	380	34	17	<3.50	<0.12	<0.331	<0.605	20
	Middle	12.0	64.9	23	11	<3.50	<0.12	<0.322	<0.588	19
	Outlet	7.53	462	29	15	<3.50	<0.12	<0.307	<0.560	20
11	Inlet	<0.123	1.48	25	13	<3.50	<0.20	<0.288	<0.527	15
	Middle	0.250	1.18	27	12	<3.50	<0.13	<0.314	<0.574	22
	Outlet	0.167	67.3	33	16	<3.50	<0.12	<0.310	<0.567	21
Drainage Ditch	Surface	<0.134	2.80	42	17	<3.50	<0.12	<0.314	<0.574	22
	4-ft depth	13.2	16.9	24	10	<3.50	<0.12	<0.302	<0.552	18

[a] "Less than" symbol (<) indicates that the concentration was below the analytical detection limit shown; except for drainage ditch samples, each sample consisted of a core of the top 6 in. of the pond sediment.

Source: USATHAMA, 1981.

Table 2-5 summarizes the analyses of core sediment samples. Concentrations of RDX and TNT generally decrease with depth for all sample locations except in the case of the outlet location in Pond 5, where concentrations increased with depth.

Many of the same samples listed in Table 2-5 were also used for the simulated leachate test. Deionized, organic-free water 10 times the volume of the sediment sample was continuously mixed with the sediment for 24 hours. The investigators determined that explosive contaminant levels in the leachate were relatively independent of pH. As a result, it was decided to focus on generating leachate under naturally occurring pH conditions with no pH control or adjustment. In the resulting tests, trace metals were present in the leachate but were below concentrations of regulatory concern. The two DNT compounds were not detected. Concentrations of RDX and TNT in the leachate samples generally corresponded to the total constituent analytical results for the sediments. Concentrations of TNT in the leachate ranged from 0.233 to 55.8 mg/L, and RDX concentrations ranged from 2.3 to 50.1 mg/L. Core samples from depths of 30-36 inches generated significant levels of explosives in the simulated leachate. These results suggest that although the ponds were drained before closure, the residual pond sediments represent a relatively significant source of contamination.

2.3.2 Open Burning Ground

Approximately 370 acres at MAAP have been used for the destruction and disposal of out-of-specification ordnance items and explosive-contaminated wastes since about 1942. The area within this acreage where these wastes were destroyed is known as the Open Burning Ground (OBG) and the Ammunition Destruction Area (ADA) (Figure 2-11). The ADA is further divided into the current ADA and the former ADA. The former ADA, which was abandoned in 1947, separates the current ADA from the 190 acres still used for open burning. Groundwater monitoring data have shown low but increasing levels of explosive contamination in groundwater from wells adjacent to the OBG. Because of these results, an investigation and engineering analysis for remedial action was conducted in 1987. Only soil sampling to a total depth of 20 feet was conducted during that investigation. The data indicated that approximately 22 acres of the OBG posed a significant threat to groundwater quality. The chemicals of concern were identified as being explosive compounds and heavy metals. The 22 acres are divided among 7 sections of the OBG designated as A, B, C, D, F, G, and H. A more detailed description of this study, performed by Post, Buckley, Schuh, and Jernigan, Inc. (PBSJ, 1988), is given at the end of this section.

Three categories of waste originating both on and off the MAAP site have been handled and/or continue to be handled at the OBG. They include bulk explosives; ordnance components, including defective ordnance items or components damaged during assembly at MAAP, and assemblies or components removed from inventory at storage depots; and wastes potentially contaminated with explosives, including boxes, crates, paper, rags, strapping, pallets, activated carbon from the PWTFs, precipitated explosives from settling sumps, and cleaning solvents that may have come into contact with explosive materials.

Bulk explosives, ordnance, and explosive-contaminated wastes were typically burned (as opposed to being detonated) at the OBG. Some explosive-contaminated liquid wastes, including paints and cleaning solvents, were disposed at the OBG without burning. Bulk explosives were burned on the ground surface. After a burn was completed, any combustion by-products were placed in natural gullies or excavated trenches.

The excavation of the trenches followed no specific design criteria but was based on site access and topography. In general, trenches were excavated into hillsides by a bulldozer, with the entrance to the trench at the toe of the hillside. The trenches were usually about 15 feet deep and about one bulldozer blade in width. Debris, ordnance components, and ash from the bulk explosive burn operation were dumped from trucks into the excavated trenches. The trench contents then were burned periodically. Once the residuals from the dumping and burning filled the trench, the excavation was covered with soil.

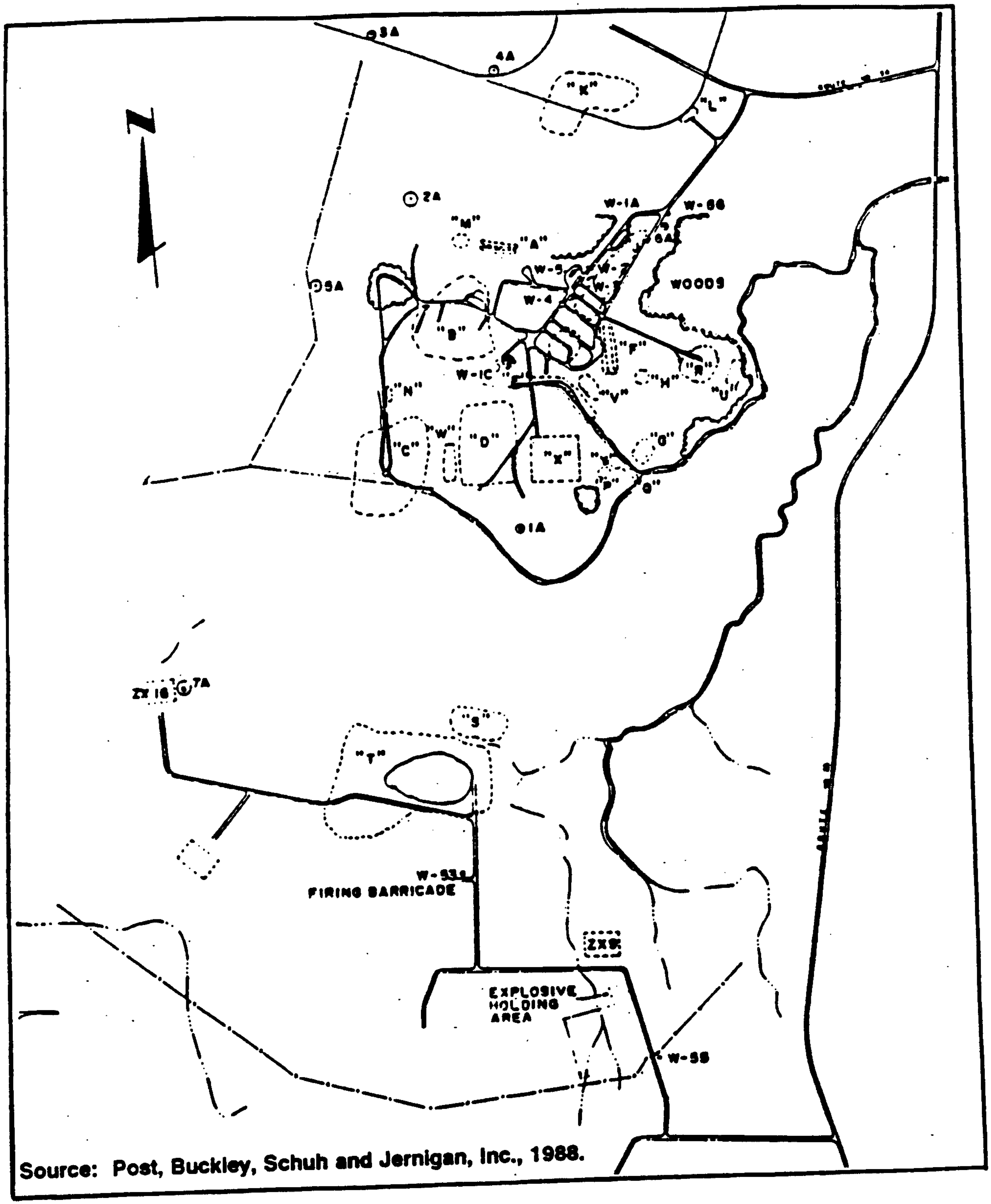
Table 2-5
Analyses of Selected Core Sediment Samples from O-Line Ponds in 1981

Pond	Sample Location	Depth (in.)	Concentration (mg/kg)								Moisture Content (% wet wt.)
			2,4,6-TNT	RDX	Pb	Cr	Cd	Hg	2,4-DNT	2,6-DNT	
3	Middle	0-6	176	572	22	15	<4	<0.2	<3.070	<5.60	20
	Middle	30-36	109	131	16	10	<4	<0.2	<0.295	<0.540	17
	Inlet	0-6	38,800	734	24	10	5	<0.2	<43.0	<78.6	43
	Inlet	6-12	41,300	715	24	5	6	<0.2	<35.5	<64.9	31
	Inlet	18-24	691	263	18	9	<4	<0.2	<31.4	<57.4	22
	Inlet	30-36	534	80.7	20	9	<4	<0.6	<31.4	<57.4	21
5	Outlet	0-6	101	22.8	21	12	<4	<0.1	<0.303	<0.553	19
	Outlet	30-36	715	363	20	10	<4	<0.1	<24.7	<45.2	0.8
	Inlet	0-6	9,830	476	29	12	<4	<0.2	<33.1	<60.5	26
	Inlet	6-12	463	75.8	20	14	<4	<0.2	<3.17	<5.78	21
	Inlet	18-24	406	181	20	12	<4	<0.2	<3.06	<5.59	19
	Inlet	30-36	307	117	21	11	<4	<0.2	<3.02	<5.52	18
	Middle	0-6	449	498	19	10	<4	<0.3	<3.10	<5.67	21
	Middle	30-36	49.6	98.7	19	11	<4	<0.2	<0.295	<0.540	17
6	Middle	0-6	91.7	40.9	23	9	<4	<0.2	<0.345	<0.631	29
	Middle	24-30	12.9	34.2	22	12	<4	<0.2	<0.307	<0.561	17
7	Inlet	0-6	101	508	20	10	<4	<0.2	<0.318	<0.582	23
	Inlet	6-12	51.9	123	23	10	<4	<0.2	<0.310	<0.567	21
	Inlet	18-24	93.1	84.2	24	11	<4	<0.2	<0.303	<0.553	19
	Inlet	30-36	43.9	132	20	10	<4	<0.1	<0.302	<0.552	18
	Middle	0-6	7.64	324	24	10	<4	<0.1	<0.316	<0.578	17
	Middle	30-36	6.24	49.1	18	8	<4	<0.1	<0.295	<0.539	16

Note: "Less than" symbol (<) indicates that the concentration was below the analytical detection limits shown.

1832177

Source: USATHAMA, 1981



Source: Post, Buckley, Schuh and Jernigan, Inc., 1988.

Figure 2-11
Areas in the OBG and ADA

Operations continued unchanged until late 1983, when the TDHE determined that operations at the OBG should comply with RCRA and Tennessee hazardous waste rules. MAAP agreed to alter practices at the OBG by prohibiting placement and treatment of reactive wastes on the ground. Such wastes are currently burned in large flash pans that are elevated off the ground. In addition, MAAP agreed to remove wastes and contaminated soil from a disposal trench that was active at that time. More than 2,200 55-gal drums of waste and soil were removed from the trench in 1983. The trench was subsequently backfilled and the drums were manifested for off-site disposal by Chemical Waste Management, Inc., under contract to the Defense Reutilization and Marketing Office.

In 1981, the USAEHA installed additional monitoring wells near the OBG which have revealed that explosive constituents (RDX and TNT) are increasing in several of the downgradient wells. In addition, high concentrations of TNT have been noted in the surface soils at the OBG along with significant levels of 2,4-DNT and 2,6-DNT. Because materials are now burned in pans rather than on the ground surface, the potential for releases to soil has been minimized. However, the potential for releases to air still exists by virtue of the open burning operation.

2.3.2.1 Summary of Existing Data. The PBSJ study utilized a records search, interviews of current and former MAAP employees, aerial photograph interpretation, geophysics, and exploratory pit excavation and soil sampling to a depth of 20 feet. Their findings are summarized, by area (see Figure 2-11), in this section. In addition, information obtained from MAAP is used to describe the area and the dates when the areas were active.

Contaminant Action Levels (CALs) were calculated by PBSJ as a means of determining when levels of contaminants in soil indicate that corrective response is necessary. A conservative model was used to develop CALs for organic contaminants which also have drinking water standards. The drinking water standards have changed since the report was written in 1988. For the inorganics, an upper limit of 95% confidence interval for the mean background concentration was used. These CALs are shown in Table 2-6. A summary of the chemical analysis of soil samples collected by PBSJ is given in Appendix B.

Area A - Waste Disposal Trenches

This area was used between the mid-1960s to the mid-1970s and is currently inactive. Two disposal trenches were identified in this area. The trenches were determined to be approximately 200 feet long and 15 feet wide with depths ranging to 8 feet. Analytical data from samples collected in each of the trenches indicate that both trenches are contaminated with cadmium, chromium, and lead. Contamination was observed to extend below the bottom of the trench to at least 13 feet but less than 19 feet.

Concentrations of heavy metals have regulatory significance. The report concluded that using the Extraction Procedure (EP) Toxicity method, as required under RCRA, the trench contents and underlying soil may constitute hazardous waste by virtue of the concentrations of cadmium, chromium, and lead.

Detectable concentrations of RDX, TNB, 2,6-DNT, and TNT were also observed in the southernmost trench. The highest levels detected were: RDX, 596 μg/kg; 1,3,5-TNB, 1,627 μg/kg; 2,6-DNT, 230 μg/kg; and 2,4,6-TNT, 259 μg/kg. These contaminants may have been associated with the free water in the trench and may not represent soil beyond the 8 foot trench depth.

In excavating the sample pits in the two trenches, a considerable variety of inert ordnance items were recovered. These components include 105mm high explosive anti-tank (HEAT) rounds, bomb-loaded unit-63 (BLU-63) bomblet casings, cluster bomb unit (CBU) hemispheres, empty initiator tubes, 105mm beehive rounds, 105mm armor piercing fin stabilized discarding sabot rounds, tungsten alloy kinetic penetrators, 40mm grenade bodies, 105mm high explosive plasticized rounds, 105mm white phosphorus shell casing, and assorted fuse/triggering mechanisms. All items appeared to be inert. Contaminant levels in Area A exceeded CALs for several contaminants and the report recommended that corrective action be considered.

Table 2-6
Contaminant Action Levels

PARAMETER	DRINKING WATER STANDARD$^{(a)}$		UPPER LIMIT OF 95% CONFIDENCE INTERVAL FOR MEAN BACKGROUND CONCENTRATION (µg/kg)	CONTAMINANT ACTION LEVEL (µg/kg)
	U.S. EPA^1 (mg/L)	OTSG^2 (mg/L		
HMX	-		NA	-
RDX	-	0.035	NA	5,300
1,3,5-Trinitrobenzene (TNB)	-	0.2	NA	30,000
1,3-Dinitrobenzene (DNB)	-	-	NA	-
Nitrobenzene	14.8	-	NA	3,000,000
Tetryl	-	-	NA	-
2,4,6-Trinitrotoluene (TNT)	-	0.044	NA	6,600
2,4-Dinitrotoluene (2,4-DNT)	0.0011	-	NA	170
2,6-Dinitrotoluene (2,6-DNT)	-	-	NA	-
Cadmium	NA	NA	560	560
Chromium	NA	NA	20,700	20,700
Lead	NA	NA	15,800	15,800

Notes:

(a)	The drinking water standards have changed since the report was written in 1988.
1	U.S. EPA water quality criteria for the protection of human health (as used by PBSJ).
2	U.S. Army Office of the Surgeon General guidelines for permissible levels in drinking water (as used by PBSJ).
-	No drinking water standard available.
NA	Not Applicable.

Source: Post, Buckley, Schuh, and Jernigan (1988)

Area B - Bulk Explosive/Propellant Burning Area, Current Location of Burn Pans

This area includes approximately 9.4 acres of open, gently rolling terrain used from 1942 to 1983 for surface burning of explosive and propellant trains. Since 1983, the area has been used for the open burning of propellants in above-ground burning pans. Three soil samples were analyzed from the single sample pit excavated in this area.

Chemical data from soils indicated contamination at concentrations of 335 µg/kg for 2,6-DNT and 250 µg/kg for tetryl. Cadmium, chromium, and lead were also detected at maximum concentrations of 227 mg/kg, 19.9 mg/kg, and 23.0 mg/kg, respectively.

Area D - Bulk Explosive/Propellant Burning Area

This area was used between the early 1950s and the mid 1970s and is currently inactive. Area D has approximately 10.3 acres that was reportedly used from the early 1950s to the mid-1970s for surface burning of explosive and propellant trains. Data from the 5 sample pits excavated in this area supported a finding that Area D had been used for surface burning.

Cadmium, chromium, and lead were uniformly found in the uppermost 2 feet of the sample pits. With one exception, metals were not found deeper than 2 feet. The concentrations of inorganics detected exceeded the CALs.

HMX, RDX, TNT, 2,4-DNT, 2,6-DNT, and 2,4,6-TNT were also found in the sample pits to a depth of 4 feet. The maximum detected concentrations of these contaminants are 476 µg/kg, 1,739 µg/kg, 244 µg/kg, and 230 µg/kg, respectively. Tetryl was found uniformly within the sample pits to depths of 19 feet and nominal concentrations of 300 µg/kg. Cadmium, chromium, and lead were also detected at maximum concentrations of 22.9 mg/kg, 36.5 mg/kg, and 288 mg/kg, respectively. Burial activities have not been reported in Area D, thus the contaminant distribution may have resulted from migration due to infiltration of rainfall, or systematic error in the data.

Area E - Ash Disposal Area

Analytical data from two soil samples taken from a single sample pit did not indicate any contamination in this area. Therefore, Area E was not considered for corrective action.

Area F - Waste Disposal Trenches

The trenches in this area were used between the mid-1970s and 1983. Two trenches were then abandoned, and a third was remediated in 1983. The two inactive disposal trenches and one former trench disposal area were identified through sample pit excavation. The two trenches were estimated to be 200 feet long and 15 feet wide with depths ranging to 6 feet. Analytical data from samples collected in the trenches indicated that both were contaminated with cadmium, chromium, and lead throughout their cross-sections. The zone of contamination appears to extend to a depth of at least 15 feet.

Detectable concentrations of several explosive compounds including HMX, RDX, 2,4-DNT, and TNT were found in samples from the trenches. The compounds were not detected beyond a depth of 8 feet. The highest concentrations were detected in samples taken from the middle and west trenches. The maximum concentrations detected are: HMX, 46,711 µg/kg; RDX, 301,591 µg/kg; 2,4-DNT, 2,457 µg/kg; 2,4,6-TNT, 13,955 µg/kg; and tetryl, 476 µg/kg.

Materials recovered from the trenches indicate that they were used for the disposal of burned debris, metals scrap, plastic bags, and miscellaneous ordnance items. Items recovered included 105mm HEAT rounds, CBU hemispheres, BLU 63 casings, complete 81mm mortar shells, complete 40mm aerially dispersed grenades, 105mm tungsten alloy penetrators, warhead casings from target optically wire guided anti-tank missiles, and miscellaneous triggering mechanisms and detonators. In all cases, recovered ordnance items were determined to be inert.

Results of the investigation indicated that a third trench located east of the other trenches had been constructed, used for disposal, and then excavated as part of a clean-up effort. General widespread contamination by heavy metals was observed in a 300 foot long by 100 foot wide area surrounding the former trench disposal area. Contamination by cadmium, chromium, and lead was observed to extend to depths between 4 and 8 feet. TNT and RDX were also detected at low levels. Contaminant levels in Area F exceeded CALs for both organic and inorganic contaminants, and the report recommended that corrective action be considered.

Area G - Paint/Rags/Garbage Disposal Trenches

This area was used from the late 1950s to the mid 1970s and is currently inactive. The preliminary investigation performed by PBSJ indicated that between 4 and 6 trenches existed in Area G, each 60 feet long and 20 feet wide with depths of 5 feet. However, the field excavation and sampling efforts identified only two disposal trenches with depths of 2 to 2.5 feet. Recent grading operations in the area could account for the difference in depth. Analytical data from samples collected in and around these trenches indicated that both were contaminated with cadmium, chromium, and lead to depths of approximately 4 to 7 feet. Contamination by RDX, nitrobenzene, 1,3,5-TNB, 2,4-DNT, 2,6-DNT, 2,4,6-TNT and tetryl was also observed in the top 4 feet of the cross-section.

If it is assumed that the background data are correct and the sample pits are located along the edge of the two trenches discovered, then the 6 trenches could include approximately 2,900 cubic yards of soil and waste material potentially contributing nearly 100 lbs of TNT to the groundwater. Contaminant levels in this area exceeded the CALs, and the report recommended that corrective action in this area be considered.

Area H - 40mm Destruction Area

Activities in this area began in the 1940s and are currently ongoing. A single sample pit was excavated along the southern boundary of Area H where 40mm grenades had been previously burned. Analytical data from this pit indicates that only cadmium and lead concentrations in the top 4 to 6 feet exceeded the CALs. Detectable concentrations of RDX, TNB, and TNT were found at greater depths in this sample pit as well.

Area South of Area H (SH)

Analytical data from 3 sample pits (7 soil samples) located 150 feet south of Area H indicated that two of the three locations had apparently been used for surface burning/flashing of laboratory waste and ordnance. The residues were covered with 1 foot of soil. Both locations exhibited contamination by heavy metals at depths from 4 to at least 12 feet.

The site used for ordnance flashing also exhibited concentrations of 150 to 200 mg/kg of TNT at depths of 4 to 12 feet. In addition, detectable concentrations of HMX, RDX, and TNB were found at depths of 12 feet. No buried ordnance items were found, but inert 90mm and 106mm recoilless rifle casings littered the surface at that location. This area exceeded the CALs and corrective action was recommended.

Area J - Metal Flashing/Bulk Explosive Burning Area

This area was used between the mid 1940s to the late 1950s and is currently inactive. Significant surface burning activities occurred in this area from the mid-1940s to the late 1950s. No disposal activities are known to have occurred since that time. Three sampling pits were excavated generally along the north-south axis of Area J. None of the analytical data indicated concentrations in excess of the CALs within Area J. However, two of the sample pits indicated the presence of relatively high concentrations of TNT and, to a lesser degree, TNB from the surface down to at least 12 feet. It was concluded that potential masses of TNB and TNT in Area J represent sources that could impact groundwater quality.

Area K - Contaminated Paper Burning

This area was used from the mid 1950s to the late 1960s and is currently inactive. One of the two soil samples from Area K indicated a concentration of chromium (22.1 mg/kg) which slightly exceeded the CAL of 20.7 mg/kg. The significance of this value with respect to the contamination assessment was considered questionable. Therefore, the report recommended no corrective action in this area.

Area L - Old Incinerator Site

Analytical data from Area L indicated that chromium (31.9 mg/kg) and 2,4-DNT (250 μg/kg) concentrations exceeded the CALs. The significance of this value with respect to the contamination assessment was considered questionable. Therefore, the report recommended no corrective action in this area.

Area M - O Line Sludge Disposal Area

No visible signs of residual sludge were observed at the O-Line sludge disposal area. However, chromium and lead contamination were detected in the top 2 feet. Detectable amounts of 2,6-DNT and tetryl occurred to depths of 12 feet. The report suggests that other organic compounds may possibly have migrated beyond the depth of investigation. Therefore, the report recommended that possible corrective action be considered for this area.

Area N - Spent Activated Carbon Disposal Site

This area, as identified in the PBSJ report, is approximately 10 feet by 20 feet and is located on the east side of the former ADA road, about 150 feet north of the former ADA boundary. Spent activated carbon from the facility's PWTFs had been disposed of in this area by dumping. In 1983, the carbon was excavated and disposed of off-site. This area was not investigated by PBSJ.

Area P - Explosive Pouring Machine Burial Site

An explosive pouring machine, which was partially decontaminated in the OBG, is buried in this area. The depth of the machine is approximately 5 feet. This area was not investigated by PBSJ.

Area Q - Ammonium Nitrate Disposal Site

Approximately 40,000 to 50,000 lbs of ammonium nitrate was buried in this area. The ammonium nitrate was in 100-lb double-layer paper sacks and was buried in two pits approximately 300 feet east-southeast of the current explosive-contaminated waste burning area. The larger pit ran in a northwest-southeast direction, and its approximate dimensions were 75 feet long by 18 feet wide by 15 feet deep. The smaller pit was adjacent to the larger pit to the southwest. The disposal took place around 1955. This area was not investigated by PBSJ.

Area R - Old Hopper Area

This area is approximately 125 square feet and is the location where waste munitions casings, etc. were flashed in hoppers and on tables from the mid-1940s to the mid-1970s. The ashes from this flashing were disposed of in a trench and the casings were sent to salvage. This area is currently the location of the uncontaminated waste burning area. PBSJ did not investigate this area.

Area S - White Phosphorus-Containing Ordnance Destruction Area

This area is approximately 200 feet by 500 feet. From the mid-1940s to the early 1950s, white phosphorus-containing ordnance were destroyed in this area. This area was not investigated by PBSJ.

Areas U, V, and Y - Flashing of Materials

The dimensions and dates of operation of these areas are unknown. Area U was reportedly used for the flashing of potentially contaminated materials. Area V was used for flashing fuel tanks and light poles. Area Y was used for flashing metal components. PBSJ did not investigate these areas.

Area W - Potential Ammunition Destruction Area

This area was active between the late 1960s to the early 1970s and is currently inactive. Area W is a 1.7 acre area which was identified as having been used for both surface detonation of white phosphorus ordnance and surface burning/flashing of explosive and propellant trains. Tetryl appeared to be uniformly distributed within the soil column at concentrations of 300 to 400 μg/kg. 2,6-DNT was also detected in a sample collected at 12 feet at a concentration of 257 μg/kg. The report concluded that Area W does not pose a potential threat to groundwater quality and, therefore, corrective action was not recommended.

Area X - Flashing Area for Explosive Contaminated Material

This area was active from the mid-1950s to the present. Analytical data from the two sample pits located within Area X indicated a general absence of contamination. Lead was detected at a concentration that exceeds the CAL in one sample at a depth of 1 foot. The report recommended that this area not be considered for corrective action.

Area Z - Burning Pans

The burning pans in this area were used from the early 1960s to the mid 1970s. Heavy metal contamination was not detected in the single sample pit located in Area Z. Further, no detectable concentrations of explosive compounds were found. The report recommended corrective action not be considered for this area.

2.3.2.2 Current Ammunition Destruction Area. At the current ADA, disposal of ordnance items is accomplished by below ground level detonation of approximately 500 lbs of material at once. MAAP personnel then police the area for combustion by-products. A total of 10 samples were collected by PBSJ both within and adjacent to this area. Explosive compounds were detected at the following maximum levels: HMX, 367 μg/kg; RDX, 1,436 μg/kg; 2,4-DNT, 276 μg/kg; 2,6-DNT, 488 μg/kg; 2,4,6-TNT, 341 μg/kg; and tetryl, 294 μg/kg. The levels of cadmium, chromium, and lead exceeded the CALs.

2.3.2.3 Former Ammunition Destruction Area. The former ADA, identified as Area C in Figure 2-11, was abandoned in 1947. According to the PBSJ report, Area C comprises an estimated 8 acres of the OBG which was used in the 1940s for surface detonation of live ordnance. In addition to destruction of ordnance, "problem" ordnance was buried at the former ADA without detonation. In 1984, the surface was cleared by hand, regraded by bulldozer to improve drainage, and seeded to reduce erosion. During the regrading operation, components suspected of containing white phosphorus self-ignited after being uncovered and/or struck by heavy equipment.

The extensive cleanup and regrading activities drastically modified the physical character of the site. As a result, the randomly located sample pits dug by PBSJ were not successful in defining the general physical characteristics of the area.

Analytical data indicated minimal and apparently unrelated levels of contamination within Area C. Contamination by cadmium and lead occurs in discrete portions of Area C at depths down to 1 foot. 2,4-DNT was detected at 2 locations in Area C at depths ranging from 1 to 6 feet. The CALs were exceeded for these contaminants, and therefore, corrective action was recommended for this area.

2.3.3 Former Burnout Area

The Former Burnout Area is located in the southwestern portion of MAAP directly west of the explosives storage area (Figure 2-11). The Former Burnout Area was used in the 1940s and 1950s to dispose of a wide range of conventional munitions. All disposal activities have been terminated and it is presently used as a pistol range.

Disposal included above ground burn-out of large projectiles within a cement containment area. Reportedly, all combustion by-products were removed from the site. Analyses of five clusters of shallow soil samples indicated insignificant levels of TNT and 2,6-DNT and no detectable 2,4-DNT. However, RDX was found at relatively high average concentrations.

2.3.4 LAP Line Areas

This section summarizes the known information about the operational histories and disposal practices of the LAP Line areas. The source of the information presented in this section is a report describing SWMUs performed by A.T. Kearney and Geo/Resource Consultants (USEPA, 1986d); a personal communication with Bill Blaylock, Martin Marietta, on April 10, 1991; and a reference manual on military explosives (U.S. Department of the Army, 1984).

2.3.4.1 Line A. LAP Line A has been operated since 1941. Past activities included the renovation of 60mm mortars rounds, loading fuzes, press loading of 60mm mortars rounds, and rocket assembly. The explosives handled at this line include Amatol (a mixture of TNT and ammonium nitrate), Composition B (a mixture of TNT and RDX), and tetryl. Past practices include wastewater discharges to sumps and from the sumps to surface drainage ways. Also included was occasional wash down of the entire assembly line with water. Line wastewater is presently discharged to a PWTF. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are four sumps at Line A.

2.3.4.2 Line B. The Line B area has been in operation since 1941. Past activities have included: the renovation of high explosive rocket and artillery rounds; demilitarization of high explosive 37mm, 40mm and 75mm rounds; disassembly of 40mm shells and 4.5-inch rockets; assembly and loading of various artillery shells; production of 4.5-inch rockets; and segregation and handling of cordite. The explosives loaded at this line include Composition A (a mixture of RDX and a desensitizer, such as beeswax or a synthetic wax) and Composition B. Currently, plastic-bonded explosives are extruded and dried at Line B. These explosives are mixtures of RDX, polystyrene, and Di-N-octyl phthalate. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. Line wastewater is presently discharged to a PWTF. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are three sumps currently in place and an additional sump which has been closed.

2.3.4.3 Line C. The Line C area operated from 1941 until the 1970s. Past activities included the use of a melt/pour operation, renovation of rockets, the loading of mortar and rockets, and the disassembly of howitzer shells. Amatol and Composition B were loaded at this line. It is possible that Composition A was also used. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. If the line is reactivated, wastewater will be discharged to the PWTF. An x-ray facility existed previously at this line. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are 7 sumps at Line C.

2.3.4.4 Line D. The Line D area operated from 1941 until the 1970s. Past activities included use of a melt/pour operation, the renovation of howitzer and mortar shells, and the loading of howitzer shells. Amatol and Composition B were loaded at this line. It is possible that Composition A was also used. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. If the line is reactivated, wastewater will be discharged to a PWTF. The melt/pour portion of the site is on standby. Some conventional munitions are being assembled in the D-Line area and Dupont sheeting, a plastic-bonded explosive, is currently being cut into sheets. A former photographic lab and x-ray facility may have discharged spent solutions to surface drainage ditches. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are four sumps at Line D.

2.3.4.5 Line E. The Line E area operated from 1941 until the 1970s. Past activities included the assembly of fuzes, booster leads, and the blending and pelletizing of tetryl. Prior to the Vietnam War, the fuzes were made of tetryl. After the Vietnam War, Composition A5 was used, which is a mixture of RDX and barium stearate. The facility was operated as a dry line, although past practices may have included discharges to a sump or drainage ditch. The site is presently on standby status. Investigation of the one sump at Line E was included in this RI.

2.3.4.6 Line K. Although the Line K area was not investigated during the RI, groundwater sampling and analysis of wells downgradient from this area indicated that Line K may be a source of metal contamination. To determine if Line K is a source of groundwater contamination, facility personnel were interviewed to determine what operations had been performed in this area. The information gathered from these interviews is presented in this section.

The Line K area has been used for both metal parts production and munitions production. Both activities are currently inactive and K-Line is being used as a storage area. According to Thomas Allen (personal communication, 1991), a current MAAP employee who previously supervised the work at K-Line, metal plating operations were performed in Building K-50. These plating operations continued until about 10 or 15 years ago. Both zinc chromate electrolytic plating and cadmium electrolytic plating processes were used, and both of these processes were cyanide-based. The main plating tank had a capacity of 33,000 gallons, so it appears that metal plating was a large-scale operation.

Wastewater from the plating processes was treated to convert hexavalent chromium to trivalent chromium. The pH was adjusted with sulfuric acid and the cyanide was neutralized to reduce the toxicity of the wastewater. The water was then discharged to the nearby drainage ditch. A pond located in K-Line was used as part of the treatment system, and probably provided the volume needed for settling of solids and neutralization. This pond was closed a number of years ago. According to Bill Blaylock of MAAP (personal communication, 1991a), the soil was tested for contamination and then disposed of at an unknown location. There are no written records of sampling data.

Sludge from the plating process were generated periodically when the process tanks were cleaned. These sludge were loaded onto rail cars. Mr. Allen does not know where the sludge were taken for disposal, but it is likely that the sludge were disposed of on site. Possibly, this occurred in the OBG/ADA areas where other types of disposal and burial of waste were common.

Prior to 1946, ammonium nitrate was manufactured by facility personnel at K-Line for use in agricultural fertilizers. In 1946, a large explosion occurred which destroyed a building and killed several people. A release of ammonium nitrate occurred at this time. The production of ammonium nitrate was discontinued following the accident.

In addition, an x-ray facility previously existed at Line K.

2.3.4.7 Line O. As discussed in the description of the O-Line Ponds Area in Section 2.3.1, this area has been in operation since 1941. O-Line is a conventional demilitarization facility constructed to remove explosives from bombs and projectiles by injecting a high pressure stream of hot water and steam into the open cavity of the munitions to melt and wash out the explosive fill. Past practices included wastewater discharges from concrete sumps to the O-Line Ponds. Wastewater is presently piped from steel tanks set in concrete pits to the O-Line PWTF. There are three sumps at Line O.

2.3.4.8 Line X. The Line X area has been in operation since 1941. Past and present activities include the loading of mortar rounds, rockets, and fuzes; demilitarization of 20mm and 37mm munitions; renovation of fuzes; and production of mortar and artillery shells. Explosives loaded at this line include Amatol, Composition A5, Composition B, and possibly tetryl. Currently, plastic-bonded explosives are being handled at this line. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are six sump locations at Line X. Two sumps have been closed.

2.3.4.9 Line Z. The Line Z area operated from 1941 until the 1970s. Past production activities included the loading of fuzes. Both tetryl and Composition A5 have been used at this line. Past practices included wastewater discharges to sumps and from sumps to surface drainage ways. Also included was occasional wash down of the entire facility with water. This area was investigated because past practices may have caused soil, drainage way, and groundwater contamination. There are two sumps at Line Z.

2.3.5 Drainage Ditches

In the past, wastewater from various production activities in the lines was discharged to open ditches that drained from sumps or surface impoundments into both intermittent and perennial streams. Currently, MAAP treats all process water from the lines that generate explosives-contaminated wastewater in six PWTFs. However, several of the ditches were possibly affected by past activities. The ditches which were investigated as part of this study are designated as Ditches 1 through 10 and Ditches B and C in Figure 2-5.

Ditches 1 and 2 receive treated effluent from Lines A and X. Ditch 2 drains into Ditch 1, which flows into Wolf Creek near the facility's western boundary. Ditch 3 receives treated effluent from Lines B and D, flows north into Ditch 4, continues to Ditch C, and finally drains into the Rutherford Fork of the Obion River. Ditch C also receives discharge from the WCOP sewage treatment plant. Ditch 5 receives treated effluent from Line O and Line C, if it is reactivated. This ditch flows into Ditch B, which also receives coal pile runoff, and continues to the Rutherford Fork. Ditches 7 and 8 are not known to have received wastewater from the facility. Ditches 8, 9, and 10 drain areas within the OBG, ADA, and the Present Landfill. These ditches flow into Halls Branch, which converges with Johns Creek near the facility's eastern boundary, and flows into the Rutherford Fork.

In addition to the ditches listed above, an unnamed ditch running north from Highway 104 to the Rutherford Fork exists between Line Z and Line F. This ditch may have received wastewater discharged from either or both of these lines (personal communication, Bill Blaylock, Martin Marietta, April 10, 1991). Both of these lines used tetryl from World War II to the Vietnam War, and a mixture of RDX and barium stearate from the Vietnam War until the lines were put on standby status. Because this ditch begins near these fuze lines and is upgradient from the off-site residential wells which have shown evidence of RDX contamination in the past, it is possible that this ditch has contributed to the observed off-site groundwater contamination.

2.3.6 MAAP Landfills

Throughout its history MAAP has operated sanitary landfills for the disposal of reportedly non-hazardous material. The original landfill is located west of Area W and Highway 23 and was used from the 1940s until the late 1950s. The second landfill, now classified as the closed landfill, was operated from the 1960s until 1974 when it was closed. Currently, all debris and trash designated for disposal is transported to the sanitary landfill located just northwest of Area W.

This RI effort addresses the closed landfill and the present landfill. Descriptions of both of these sites and a summary of disposal practices at each are provided in the following paragraphs.

2.3.6.1 Closed Sanitary Landfill. MAAP operated a landfill located between H-Line and K-Line north of Highway 104 from the late 1960s until 1974. This landfill was reportedly used as a general purpose disposal area for paper, construction material, and miscellaneous items including RDX-contaminated packing material. Disposal procedures included the excavation of trenches 8-10 feet deep, 15 feet wide, and 50-75 feet long. These trenches were then filled with inert material, compacted, then covered with soil. Natural topographic lows were utilized where possible. The RCRA Facility Assessment reported that leachate from this landfill may enter a drainage ditch that flows northward, passing a sanitary sewage treatment plant then leaving the installation area on the north. Trace levels of TNT and 2,6-DNT and an unusually high level of RDX were detected in the soil during a contamination survey conducted by USATHAMA in 1982 (USATHAMA, 1982a).

2.3.6.2 Present Sanitary Landfill. The present landfill is located just northwest of area W. Rubbish and debris from industrial operations consisting mainly of paper, shipping containers, cardboard boxes, filter pads, etc. are placed in trenches, compacted and covered with soil. The trenches are excavated down to a clay material which may retard leachate migration.

2.3.7 Former Borrow Pit (Construction Debris Pit)

The former borrow pit is located directly south of H-Line and immediately north of Highway 104. The pit is a former borrow area used to excavate sand for construction activities. MAAP has allowed the disposal of discarded building materials from base construction and renovation activities to occur in this pit. This activity has been stopped pending the outcome of the RI. Currently, the sand pit contains ponded water.

2.3.8 Salvage Yard

The salvage yard is on the east side of Area J and immediately south of Highway 104. This area is completely enclosed by a fence. The date on which the Salvage Yard was first used is not known. All salvaged, non-hazardous scrap, including casings, machinery, and wood, is stored at this location in bins or in piles until sold to a scrap dealer.

In the past, the metal was stored on the ground. It was later discovered that lead was leaching into the soil. Since that time, the lead materials have been stored under roof. (Personal communication, Mike Harris, April 19, 1991).

Following the groundwater sampling of the O-Line Ponds, a closure plan for the ponds was published by USATHAMA (1982b). Based on the finding that the sediments were non-reactive, capping the lagoons with maintenance and monitoring of the cap and groundwater wells for a period of 30 years was selected as the remedial alternative. Construction work for the remedial action was completed in December 1984 and the monitoring program was initiated in 1985. A Remedial Action Decision Document for the O-Line Ponds (USATHAMA, 1987) was issued in November, 1987 which summarized the remedial action selection.

In 1983, Roy F. Weston, Inc. (Weston) performed an assessment of groundwater contamination at MAAP (USATHAMA, 1983a, 1983b, and 1983c). The report concluded that the principal source of groundwater contamination is the O-Line Ponds area, which have released contaminants to both the upper and middle depths of the Claiborne aquifer. Specific conclusions drawn by the authors of the report are as follows:

- The authors' analysis of gamma log data was that two distinct intervals of high gamma emissions exist in the saturated zone. The intervals appeared to be continuous between wells that were logged. These intervals of high gamma emissions were interpreted as clay-rich zones in two major sedimentary cycles. One interval is located at the groundwater surface; the other divides the aquifer in two, horizontally. Hydrologic evidence and lithologic logs indicated that these intervals are not major confining zones and are lithologically very variable. However, they do indicate distinct intervals of relatively low hydraulic conductivity in the vertical column. This variability in sediment types would indicate that a continuous barrier to vertical contaminant migration is not assured.

- Four well pumping and recovery tests completed north of O-Line produced values for hydraulic conductivity from 0.5 to 167 feet/day. The highest value was obtained from recovery of production well K-100 after extended pumping and represents an average value for a large portion of the aquifer. Using an average hydraulic conductivity of 167 feet/day for the site yields a horizontal groundwater flow velocity of approximately 150 feet/year. Determination of hydraulic conductivity based on grain size analysis of sediment samples indicates that groundwater flow velocity through discrete layers of clean fine sands can be 2 to 3 orders of magnitude higher than this estimate; thus, the potential exists for migration of contaminants through discrete sandy layers at a much higher rate than the average flow velocities would suggest.

- Average hydraulic conductivities in the vertical direction at the site were not directly measured. However, the presence of stratified clays and silts indicate that vertical conductivities may be several orders of magnitude lower than the horizontal hydraulic conductivities. Local variations in vertical hydraulic conductivity and hydraulic gradient are greater than that for the horizontal components.

- The principal source of explosives contamination to groundwater at MAAP are the O-Line Ponds. Groundwater samples from wells near the ponds contained higher concentrations (>1,000 μg/L) of RDX, TNT, and HMX and lesser amounts of TNB, DNB, and 2,4-DNT. Contaminants have migrated along a narrow front in a north-northwesterly direction.

- Of the wells along the installation boundary, north of O-line, only MI032 contained explosive contaminants. Of these, only RDX was slightly above maximum allowable concentrations. Well MI032 is not hydrologically downgradient from the O-line area and is screened in sediments with a relatively low hydraulic conductivity estimated to be two orders of magnitude lower than average values for the aquifer. Since explosive contaminants were detected at low concentrations, it was speculated that there was little chance for migration of contamination off the installation at levels of concern. A recommendation was made, later in the report, to continue monitoring this well.

3.0 PREVIOUS INVESTIGATIONS AND HISTORY OF RESPONSE ACTIONS

Prior work performed at MAAP includes the Installation Assessment (USATHAMA, 1978), MAAP Contamination Survey performed by Envirodyne Engineers (USATHAMA, 1982a), Leaching Test of Milan Army Ammunition Plant Lagoon Sediment performed by Environmental Science and Engineering (USATHAMA, 1981), Installation Restoration Program Support and Services, MAAP, performed by Roy F. Weston (USATHAMA, 1983a, 1983b, and 1983c), RCRA Facility Assessment performed by A.T. Kearney (USATHAMA, 1986), and the Investigation and Engineering Analysis for Remedial Actions (PBSJ, 1988). The Environmental Science and Engineering, A.T. Kearney and Geo/Resource Consultants, and PBSJ studies were described in detail in Section 2. The other studies, which are less site-specific in nature, are described in this section.

An Installation Assessment of MAAP was conducted in March, 1978, by USATHAMA. The purpose of this investigation was to identify and assess actual or potential chemical, biological, or radiological (CBR) contaminant migration at MAAP. The review indicated that there was a potential for on-site contamination, as well as off-site migration, at hazardous concentrations. However, it was not determined if off-site migration was a function of current activities or past operation. It was recommended that a program be established to determine the extent of the migration hazard.

In 1979, USATHAMA initiated a two-phased program to characterize the state of environmental contamination at MAAP. The first phase, consisting of analysis of water samples from 11 private wells and 3 municipal wells outside MAAP boundaries, was completed in August 1979. It was concluded that there was no significant off-site contamination hazard from explosive waste in subsurface waters originating at MAAP (USATHAMA, 1982a).

The second phase of the program involved an extensive environmental contamination survey of groundwater, surface streams, and ditches passing through MAAP, and known or suspected areas of surface contamination. The survey included installation of 33 shallow groundwater monitoring wells. The results suggested that off-site water supplies were not contaminated by explosive or organic contaminants originating at MAAP. However, groundwater and surface water within MAAP were contaminated with TNT, DNT, and RDX; and the contamination was shown to be moving slowly toward the plant boundaries at low concentrations. Furthermore, surface water within MAAP and at the plant boundaries was found to contain mercury at concentrations that exceed the Federal ambient water quality criteria at both upstream and downstream locations. The results of the groundwater investigation show that the drinking water standard for mercury was exceeded in one instance.

In addition, the survey also found that lead and chromium exist in groundwater and surface water at MAAP. Migration in groundwater is inconclusive, and migration in surface streams and ditches is slight. The potential for surface migration of lead, chromium, and TNT beyond MAAP boundaries exists in the form of low level contamination in stream sediments. Other substances such as nitrate, nitrite, phosphate and sulfate anions exist in surface and/or subsurface waters within MAAP, but migration was not environmentally significant. Major sources of contaminant migration at MAAP identified include the wastewater lagoons at O-Line, the OBG and ADA, and drainage ditches from these areas. It was recommended that additional surface and subsurface testing be conducted to identify secondary sources of groundwater contamination at MAAP and to develop comprehensive contamination abatement measures. Also during this time, a program for cleanup of the O-Line Ponds had been initiated. The final report for this environmental survey program was prepared and published by USATHAMA (1982).

Groundwater sampling near the O-Line settling ponds was conducted from October through December 1981 by Environmental Science and Engineering, Inc., (USATHAMA, 1981). Sediments from 11 ponds in addition to simulated leachate from the sediments were analyzed. In all samples of sediment or simulated leachate, 2,4,6-TNT and RDX were identified as the compounds of greatest concern in each of the ponds, and the most contaminated ponds were 1, 3, 5, and 6. The results of this study are discussed in more detail in Section 2.0.

- Explosive contaminants were also found in wells in the B-line area, west (and not hydrologically downgradient) of the O-line. These contaminants were deemed to be related to past discharge of production wastewater to drainage ditches in the B-line area.

- Groundwater samples from wells in the burning grounds and ammunition destruction areas contained RDX and TNT above maximum acceptable concentrations. Only RDX was found in nearby wells hydrologically downgradient from the site at concentrations less than 18 μg/L. Migration of explosive contaminants was therefore determined to be minimal from these areas. A recommendation was made to continue monitoring these wells.

- Only one well sampled in the northwest boundary area (MI028) contained explosives, i.e., TNT at a concentration of 1.6 μg/L. Contaminant migration from the major source of explosives, the O-line ponds, was found to be moving more directly to the north and it was considered unlikely that the explosives contamination would affect the northwest boundary area. A recommendation was made to continue monitoring the two wells in this area.

- Of the two wells in the closed burning ground area, neither contained explosives. Also, because the direction of groundwater flow in this area is northeast toward the center of the installation, there is no apparent risk of off-site migration of contaminants in the groundwater from the closed burning grounds.

- Nitrates and nitrites were found in groundwater throughout the site in concentrations well below 10 mg/L. Although some elevated levels (up to 16.8 mg/L for nitrates) were observed in wells near the O-line ponds, there is evidently a background level of nitrates and nitrites in the groundwater independent of sources from manufacturing. Any contamination from manufacturing activities is not generally distinguishable from background contamination, except very near the O-line ponds. Migration of nitrates and nitrites were determined not to be a matter of concern.

- Lead was found in two wells in the burning ground and ammunition destruction areas and in both wells in the closed burning grounds. Concentrations ranged from 6.5 to 17.6 μg/L, which are well below the EPA primary drinking water standard of 50 μg/L. Chromium was found in both deep and shallow wells downgradient from the O-line ponds. Highest concentrations (22-55 μg/L) were found in three deep wells, MI041, MI047 and MI053. However, no plume was identified. Only well MI041 exceeded the EPA drinking water standard for chromium of 50 μg/L. Lesser concentrations of chromium were also found in wells in the northwest boundary area, ammunition destruction area and closed burning grounds. None of these wells had cadmium concentrations exceeding 10 μg/L, the EPA primary drinking water standard for cadmium. The only well to exceed these limits was well MI035, adjacent to an abandoned sand pit, which contained concentrations of cadmium at 41 μg/L. A recommendation was made, later in the report, regarding monitoring of this well.

A RCRA Facility Assessment Report for MAAP performed by A.T. Kearney and Geo/Resource Consultants was prepared for the USEPA (USEPA, 1986d). The purpose of this assessment was to identify all SWMUs that have operated on the site, evaluate all available information pertaining to each SWMU, and assess the likelihood of releases of hazardous wastes or constituents from each. It was concluded that sound waste management practices were being applied and the potential for releases of hazardous constituents was primarily from the closed areas and past operations.

In 1987, an Investigation and Engineering Analysis for Remedial Actions report for MAAP was initiated by the USACE (PBSJ, 1988). Due to the suspected groundwater contamination at MAAP, this project was authorized to identify explosive/ordnance waste burial sites within the OBG and to identify alternative corrective actions. An engineering investigation of the site included the excavation of 58 sample pits and exploratory ditches in the OBG. In addition, 227 discrete soil samples were collected from areas within the sample pits representing the greatest potential for contamination. The results, as described in detail in Section 2.3, indicated that 3 burial trench areas found in the OBG were potential sources of groundwater contamination and 6 areas within the OBG, representing approximately 22 acres, posed potential threats to groundwater quality. It was estimated that the trench disposal areas represented approximately 50% to 80% of the contamination due to heavy metals and organic compounds found in the study area. The selected corrective action alternative was to regrade, cap, and revegetate the problem areas. Additional work was recommended to fully define the extent of contamination and relative contributions to potential groundwater contamination.

A Groundwater Contamination Survey (USAEHA, 1988) was conducted in February 1988. The purpose of the survey was to identify and evaluate all SWMUs as part of a pending RCRA Part B permit application, and to delineate those units requiring further sampling, investigation, and corrective action. It was concluded that additional environmental investigations are needed at four SWMUs (Line B, the Former Burnout Area, the Present Landfill, and the Former Borrow Pit), and no further environmental investigation is needed at the remaining SWMUs due to either the very low potential for release or the demonstrated lack of a release by environmental investigation. At the time of the survey, investigation of two SWMUs (O-Line Ponds and OBG) were already in progress. It was also recommended that as a precautionary measure, groundwater sampling of all existing monitoring and supply wells be conducted for explosives contamination at MAAP.

The facility has conducted regular sampling and analysis of groundwater from selected production and monitoring wells for the purpose of monitoring the extent of the contaminant plume. The wells in the vicinity of and downgradient from the O-Line Ponds area have been sampled annually since 1986. The RCRA wells (001 through 007) and production well I-11 have been sampled semi-annually since 1982. The RCRA wells were installed by AEHA to monitor the quality of groundwater emanating from the OBG/ADA areas. The analytical data from the RCRA wells and I-11 are presented in tabular format in Appendix C. The analytical data from the O-Line Ponds area wells are available in the IRDMS database and therefore are not included in this report.

The TDHE has conducted regular sampling of 18 off-post residential drinking water wells and 3 City of Milan public water supply wells. This activity has been performed by both the Division of Solid Waste and the Division of Water Pollution Control. The analytical data from 1982 to 1990 are presented at the end of Appendix C. The sample results indicate that of the wells tested, only the Bledsoe residence and New Hope Baptist Church wells have shown evidence of contamination by explosive compounds. In 1982, RDX was detected at a concentration of 36.4 μg/L in the Bledsoe well. The concentration has decreased over time until in 1988, the levels of explosives were below detection in this well. RDX was detected in the well near the New Hope Baptist Church at 3.84 μg/L in 1982. The concentrations of explosive compounds decreased from 1982 to 1988. In 1988, the concentration of RDX in the New Hope Baptist Church was 0.68 μg/L. In 1990, EPA, Martin-Marietta, and the TDHE sampled these wells and the levels of explosive contaminants were below the detection limits.

4.0 TECHNICAL APPROACH TO FIELD OPERATIONS

The following sections present the technical rationale, procedures, methods, and protocols used during the field activities conducted at MAAP during the months of July through December, 1990. These activities included sampling support operations, unexploded ordnance (UXO) clearance, soil boring and sampling, monitoring well installation, groundwater and domestic drinking water sampling, aquifer testing, surface water and sediment sampling and stream gage installation. The technical approach for field activities was previously defined in the Sampling and Analysis Plan (July 1990) and the addenda submitted to USATHAMA on September 20, 1990 and November 6, 1990. These documents outline the proposed approach for conducting the MAAP Remedial Investigation. Modifications to the Sampling Plan necessitated by field conditions were made only after approval by USATHAMA, and documentation is provided in Appendix D.

The methodology for conducting the RI field work complies with all USATHAMA and USEPA geotechnical and QA/QC requirements, except where noted, and fully complies with the Accident Prevention and Safety Plan developed for the site.

4.1 SAMPLING SUPPORT ACTIVITIES

The activities described in this section include the construction of the decontamination pad, generation of deionized, organic-free water for equipment decontamination, and containerization and disposal of investigation-derived waste.

4.1.1 Decontamination Pad Construction

A 30 by 50 foot decontamination (decon) pad was constructed in July of 1990, prior to the start of field work. It was located near the northeast corner of Line O. The decon pad consisted of a ramped floor which was level with the ground surface and elevated sides constructed of stacked 6-inch by 6-inch lumber. The entire pad, including the sides, was lined with two layers of 5-mm polyethylene sheeting to make a watertight sump for the collection of washing and rinsing solutions. A centrifugal pump was used to pump the accumulated decon water from the pad into a 2,000-gallon polyethylene storage tank located outside of the decon pad.

The decon pad was used to contain the water from decontamination of the drill rigs, auger flights, and all sampling equipment. The drill rigs were backed into the decon pad and cleaned using the procedures outlined in Section 4.3. Decontamination of augers took place on metal sawhorses, and sampling equipment was decontaminated on a wooden table covered with plastic sheeting.

4.1.2 Generation of Deionized, Organic-Free Water for Equipment Decontamination

The approved water source for this project was production well T-99. Only water from this well was used for equipment decontamination, mixing of grout, and mixing of drilling fluid. The water was not chlorinated before use.

A system for making deionized, organic-free water was set up next to the decon pad for use in equipment decontamination. The system consisted of a 500-gallon polyethylene tank for storing water from T-99, a system of canisters for water treatment, and a small centrifugal pump. The T-99 water in the tank was pumped through a pre-filter canister, then cation exchange, anion exchange, and activated carbon filter canisters. These canisters were monitored regularly for breakthrough of contaminants.

4.1.3 Containerization and Treatment of Investigation-Derived Waste

All soil cuttings and drilling mud generated as a result of drilling activities at MAAP were drummed, labeled, and transported to a designated temporary storage area in the OBG. Materials derived from individual wells and boreholes were drummed separately so that the results of the chemical analysis could be used to determine the ultimate disposal of those drums. The drums will be disposed in accordance with RCRA requirements and with the approval of the TDC. Decisions regarding the disposal of the drums have not yet been made. At the close of the field investigation in December 1990, a total of 712 55-gallon drums were present in the temporary storage area in the OBG.

The water pumped out of the decon pad into the 2,000-gallon tank was disposed of through the O-Line PWTF. While the water was stored in the 2,000-gallon tank, the solids were allowed to settle to the bottom of the tank. A flocculating agent such as sodium chloride or sodium hypochlorite was added to the tank to accelerate flocculation and clarification of the water. Flocculation was necessary to reduce the loading of solids into the PWTF because if the solids burden was too great, the fabric filter system in the treatment facility would become clogged. Periodically, the clarified water in the 2,000-gallon tank was pumped into a truck-mounted tank for transport to the O-Line PWTF. The water was emptied into the PWTF holding tank, treated, and disposed under the facility's current NPDES permit. The solids at the bottom of the holding tank were containerized in 55-gallon drums and transported to the OBG for storage pending a disposal decision.

Groundwater derived from both well development and pre-sample purging was treated in the same manner. Turbid water resulting from well development was transferred into holding tanks for flocculation and settlement prior to discharge into the O-Line PWTF. Pre-sample purge water was generally clear enough to be disposed of at O-Line without settling.

All used personal protective equipment (PPE) was securely contained in plastic bags and placed in a drum. Approximately once a week, personnel from the OBG would pick up the PPE and dispose of it, along with contaminated waste generated by the facility, by open burning.

4.2 UXO CLEARANCE

Explosive ordnance disposal (EOD) support for this investigation was provided by UXB International, Inc., headquartered in Chantilly, VA. Only qualified UXO technicians from UXB International, Inc. were authorized to inspect an area or borehole for explosive hazards and to declare an area or borehole free of ordnance hazards.

The EOD aspect of the MAAP investigation was divided into two parts: the UXO clearance and safety survey and the borehole geophysical survey. The purpose of the UXO clearance and safety survey was to clear the surface and near-surface area used by the drilling crews of unexploded ordnance. The geophysical survey consisted of periodically inserting a magnetometer in the borehole during drilling operations to detect the presence of ordnance ahead of the drill bit.

Numerous projectiles, casings, fragments, and fuzes were recovered during the UXO clearance and safety survey conducted in the OBG and ADAs. These recovered items include 37mm anti-personnel rounds, 60mm and 81mm mortar rounds, 40mm anti-aircraft casings, M83 butterfly bomb fuzes, etc. The UXB International Project Leader's daily log (included in this report as Appendix E) lists the items recovered in each area. All recovered ordnance items were disposed of through proper channels.

4.2.1 UXO Clearance and Safety Survey

During this phase, both the specified soil boring site and a 25-foot wide pathway to the site were cleared of unexploded ordnance. UXB personnel clearly marked the drill site and pathway boundaries. The following paragraphs describe the general procedures that were followed by UXB personnel at the individual drilling sites.

A clearance team, consisting of two UXB personnel, conducted a surface visual sweep of the proposed route the drilling rig would take from the road to the drilling site and cleared a path 25 feet wide.

They maintained a line of sight with each other at all times and maintained communication with other field crew members.

If unexploded ordnance was encountered, they attempted to find a clear route around the hazardous item. If this could not be done, because of rough terrain or an abundance of hazardous items in the area, unexploded ordnance that could be moved safely was placed outside of the area to be cleared. If unexploded ordnance encountered was not safe to be moved, the UXB team leader marked the location of the item and contacted MAAP personnel. Procedures were then followed to blow up the item in place.

The outer perimeter of the cleared area was defined using marking stakes and lines. UXB personnel then conducted a geophysical survey of the area, using the Forrester Electromagnetic Detector to locate metallic items to a minimum depth of two feet. All metallic contacts were marked with stakes and were then hand-excavated by UXB personnel to a depth of two feet and buried ordnance was identified and handled as described above.

The area thus cleared and marked was then surface scraped with heavy equipment, operated by MAAP personnel, to a depth of 12 inches to remove the majority of non-hazardous metallic items and to facilitate passage of the drilling equipment to the sampling site. Because the surface soil at the borehole location was disturbed by these activities, the surface soil samples were collected in an undisturbed area near the boring location. This is further discussed in Section 4.3.2. UXB personnel then used stakes to mark the exact location of the sampling sites as directed by the ICF Field Operations leader.

4.2.2 Geophysical Survey

A borehole geophysical survey using the Forrester Electromagnetic Detector (MK 26 Ordnance Locator) was conducted by UXB personnel at all wells and test borings drilled at the former ADA, new ADA, OBG, and Former Burn Out Area. The MK 26 is the most recently-approved military locator and is used by U.S. military EOD forces for detecting subsurface ordnance items.

The downhole geophysical survey was conducted by UXB personnel within the top 20 feet of each test boring and within the top 25 feet of the borehole drilled for the installation of monitoring well MI073 (in the Former Burn Out Area). A surface scan for UXO was first performed. Then the first 5 feet of the soil boring was drilled. The auger was removed from the borehole and a temporary PVC casing was inserted into the hole. The drill rig was then moved forward approximately 10 feet to prevent signal interference during the downhole survey. The electromagnetic detector was inserted into the PVC casing and lowered to scan the entire length of the borehole. After the UXB personnel determined that the hole and the next interval to be drilled were free of ordnance, the PVC casing was removed and the drill rig was repositioned over the hole. The auger was then reinserted into the borehole and the borehole was advanced by five feet. The survey equipment and PVC casing was decontaminated between each downhole scan according to the procedures outlined in Section 4.3.2.

4.3 SOIL BORING/SAMPLING PROGRAM

The objectives of the soil boring and sampling program at MAAP were to identify potential sources of contamination and to assess the potential for contaminant migration from these sources. The areas investigated include the OBG, ADAs, 30 LAP line explosive wastewater sumps, the Former Burn Out Area, Former Borrow Pit (Construction Debris Pit), Closed Landfill, Present Landfill, and the Salvage Yard. Specific activities undertaken and the objective of each are described as follows:

a. Collect and perform chemical analyses on soil samples to construct a three-dimensional definition of contaminant sources and to assess the extent of contamination in soils at each suspected source location; and

b. Describe soil samples and lithology in detail to define the geologic nature of each area and to assess stratigraphic continuity, in order to evaluate the rate of contaminant migration in the soils.

4.3.1 Boring Location Rationale

Soil borings were drilled at the OBG, the ADAs, the Closed and Present Landfills, Former Borrow Pit, Salvage Yard, the Former Burn Out Area, and at each of the 30 explosive wastewater sumps at MAAP. The data gathered by chemical analysis of soil samples were used to assess each site as a potential source for groundwater contamination at MAAP.

4.3.1.1 Open Burning Grounds (OBGs) and Ammunition Demolition Areas (ADAs). The results of a trenching survey (PBSJ, 1988) conducted in the OBG indicated that two areas of highly contaminated soils exist in the northern area and a widespread area of lower contaminant levels exists in the southern portion. Because the horizontal extent of contamination was not determined by the previous study, a gridded boring system was used in the present study. The distance between each grid node is 800 feet. The grid is oriented so that nine of the nineteen boring locations were situated in the central portion of the OBG. One boring each is located in the two areas identified by PBSJ as being highly contaminated. The remaining borings are located around the perimeter of the OBG as shown in Figure 4-1. Of the remaining borings, two were drilled in the new ADA and one in the former ADA (see Figure 4-1 for boring locations) to evaluate soil contamination in these areas.

The sampling pits dug by PBSJ extended to a depth of only 20 feet. In some of these test pits, contamination of soil by explosives and heavy metals was detected at the deepest part of the pit, which indicates that the vertical extent of contamination was not fully delineated during this previous study. Therefore, the borings installed during this present study extended down to the depth of groundwater or to a maximum depth of 114 feet. If groundwater was encountered shallower than 114 feet, then two additional split spoon samples were collected to assess soil contamination at the depth of groundwater and to confirm the depth to groundwater. As shown in Table 4-1, the borings in the OBG and ADAs ranged in depth from 15 to 114 feet. The average depth of a boring in these areas is 66 feet.

4.3.1.2 Sump Borings in LAP Line Areas. A total of 30 wastewater sumps were identified at MAAP. Thirty-four borings were drilled and sampled in the vicinity of these sumps to help characterize the sumps as potential sources of explosive contamination. Information regarding the explosive wastewater sump sampling activities at MAAP is presented in Table 4-2. The boring designation, depth of boring and hand-augured samples, depth to the bottom of the sumps, depth interval of the soil sample, chemical analyses performed, and date completed, are outlined for each sump that was investigated. Because access to some of the sumps was restricted, the angled boring technique originally proposed in the Sampling and Analysis Plan was performed at only four locations. Therefore, each of the 30 explosive wastewater sumps were investigated with one vertical soil boring, and four sumps were investigated with an angled as well as vertical soil boring. Vertical soil boring locations inaccessible by a drill rig were hand-augured for collection of soil samples.

The sumps were designed to allow wastewater to enter into one side and pass through a bag filter which caught floating particulate matter. Solids were allowed to settle out in the sump bottom. The wastewater would then be discharged from an outfall on the opposite side of the sump into a surface water drainage ditch which flowed away from the load line. Samples collected from these borings characterized the sumps as potential sources of explosive contamination. The following discussion of sump boring activities is subdivided by area investigated at each LAP Line.

Line A. Four sumps were investigated at Line A. The soil borings designated for each sump are SA-4, SA-7, SA-40, and SA-44 (both vertical and angled borings were installed) and are shown in Figure 4-2. SA-4 was located in a culvert adjacent to sump A-4. This sump is an aboveground concrete structure surrounded by a concrete pad. Discharge from the settling tanks was piped through to a

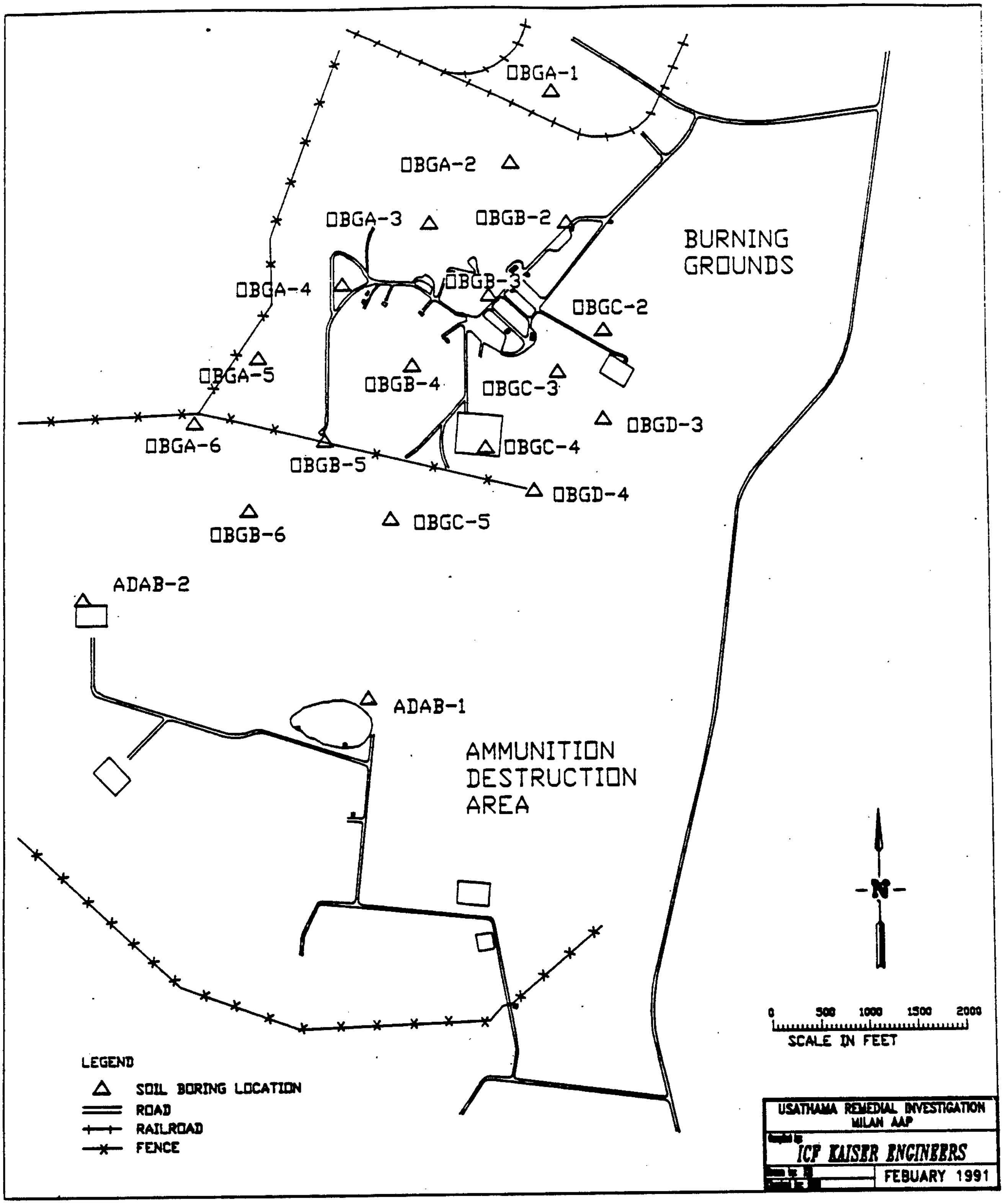


Figure 4-1
OBG and ADA Soil Boring Locations

TABLE 4-1
Soil Samples Collected in the OBG and ADA

Boring Designation	Depth of Boring (feet)	Depth to H_2O from Surface	Boring Method	Chemical Sample Interval and Analysis		Date Com-pleted
OPEN BURNING GROUND, 17 BORINGS						
OBGA-1	55	46.9	Rig	0–1	SM&E	09-09-90
				5–7	EPA TAL TCL&E	
				10–12	SM&E	
				20–22	SM&E	
				25–27	SM&E	
				50–52	SM&E	
OBGA-2	62	58.5	Rig	0–1	SM&E	09-08-90
				5–9	EPA TAL TCL&E	
				5–9	EPA TAL TCL&E duplicate	
				10–14	SM&E	
				10–14	SM&E duplicate	
				30–32	SM&E	
				60–62	SM&E	
OBGA-3	90	85	Rig	0–1	SM&E	08-12-90
				5–7	SM&E	
				20–22	EPA TAL TCL&E	
				45–47	SM&E	
				90–92	SM&E	
OBGA-4	114	111.3	Rig	0–1	SM&E	09-06-90
				0–1	EPA TAL TCL&E	
				0–1	EPA TAL TCL&E duplicate	
				5–9	EPA TAL TCL&E	
				5–9	EPA TAL TCL&E duplicate	
				15–17	SM&E	
				30–32	SM&E	
				100–102	SM&E	
				110–114	SM&E	
				110–114	SM&E duplicate	
OBGA-5	15	11.9	Rig	0–1	SM&E	07-31-90
				5–7	EPA TAL TCL&E	
				15–17	SM&E	
OBGA-6	40	29	Rig	0–1	SM&E	07-27-90
				5–7	SM&E	
				30–32	SM&E	
				35–37	SM&E	
				40–42	SM&E	
OBGB-2	42	30.82	Rig	0–1	SM&E	08-28-90
				5–9	EPA TAL TCL&E	
				25–27	SM&E	
				35–37	SM&E	
				40–42	SM&E	
OBGB-3	42	21.4	Rig	0–1	SM&E	08-28-90
				5–9	EPA TAL TCL&E	
				20–22	SM&E	
				35–37	SM&E	
				35–37	SM&E duplicate	
				40–42	SM&E	

TABLE 4-1 (Continued)

Boring Designation	Depth of Boring (feet)	Depth to H_2O from Surface	Boring Method	Chemical Sample Interval and Analysis		Date Completed
OBGB-4	87	86.2	Rig	0–1	SM&E	08-24-90
				5–7	EPA TAL TCL&E	
				15–17	SM&E	
				45–49	SM&E	
				45–49	SM&E duplicate	
				85–87	SM&E	
OBGB-5	105	100	Rig	0–1	SM&E	08-22-90
				5–9	SM&E	
				5–9	SM&E duplicate	
				25–27	SM&E	
				45–47	SM&E	
				105–107	EPA TAL TCL&E	
OBGC-2	75	72-75	Rig	0–1	SM&E	08-06-90
				5–7	EPA TAL TCL&E	
OBGC-3	80	76.8	Rig	0–1	SM&E	08-09-90
				5–7	SM&E	
				15–17	EPA TAL TCL&E	
				30–34	SM&E	
				30–34	SM&E duplicate	
				80–82	SM&E	
OBGC-4	70	65	Rig	0–1	SM&E	08-20-90
				5–7	SM&E	
				15–17	SM&E	
				65–67	SM&E	
				70–72	EPA TAL TCL&E	
OBGC-5	70	65	Rig	0–1	SM&E	08-14-90
				5–7	SM&E	
				15–17	EPA TAL TCL&E	
				45–47	SM&E	
				70–72	SM&E	
OBGD-3	35	22-25	Rig	0–1	SM&E	08-08-90
				5–7	EPA TAL TCL&E	
				25–27	SM&E	
				35–37	SM&E	
OBGD-4	15	11	Rig	0–1	EPA TAL TCL&E	08-08-90
				5–7	SM&E	
				15–17	SM&E	
FORMER ADA, 1 BORING						
OBGB-6	110	105.1	Rig	0–1	SM&E	07-30-90
				5–7	EPA TAL TCL&E	
				20–22	SM&E	
				60–62	SM&E	
				103–105	SM&E	
AMMUNITION DEMOLITION AREA, 2 BORINGS						
ADAB-1	82	71.2	Rig	0–1	SM&E	08-26-90
				5–9	EPA TAL TCL&E	
				25–27	SM&E	
				30–32	SM&E	
				60–64	SM&E	
				60–64	SM&E duplicate	

TABLE 4-1 (Continued)

Boring Designation	Depth of Boring (feet)	Depth to H_2O from Surface	Boring Method	Chemical Sample Interval and Analysis		Date Completed
ADAB-2	67	55	Rig	0.5–1	SM&E	08-27-90
				5–9	SM&E	
				5–9	SM&E duplicate	
				15–19	EPA TAL TCL&E	
				50–52	SM&E	
				60–62	SM&E	

SM&E	Select metals and explosives.
EPA TAL TCL&E	EPA Target Analyte List/Target Compound List and Explosives.

Table 4-2
Soil Samples Collected Near the LAP Line Wastewater Sumps

Load Line	Boring Designation	Depth of Boring (feet)	Depth of Sump (feet)	Boring Method	Chemical Sample Interval and Analysis		Date Completed
A	SA-7	10	8	Rig	0–2	SM&E	11-04-90
					5–7	EPA TAL TCL&E	
					5–7	EPA TCL duplicate	
					10–12	SM&E	
A	SA-44	10	7.5	Rig	0–2	SM&E	10-04-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
A	SA-A44 (angle)	14 vertical 20 angle	7.5	Rig	10.5–14	EPA TAL TCL&E	10-09-90
A	SA-40	6.5	5.5	Hand auger	0–1	SM&E	10-05-90
					2.5–3.5	EPA TAL TCL&E	
					5.5–6.5	SM&E	
A	SA-4 (sample down slope of sump)	3	8	Hand auger	0–1	SM&E	11-08-90
					1–2	EPA TAL TCL&E	
					2–3	SM&E	
B	SB-18	10	9	Rig	0–2	SM&E	09-25-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
					10–12	SM&E duplicate	
B	SB-12	10	8	Hand auger	0–1	SM&E	11-02-90
					4–5	SM&E	
					9–10	EPA TAL TCL&E	
B	SB-273	10	8	Hand auger	0–1	SM&E	09-26-90
					4.5–5.5	EPA TAL TCL&E	
					9–10	SM&E	
B	SB-A10 (angle)	17.5 vertical 25 angle	7	Rig	14–17.5	EPA TAL TCL&E	10-07-90
B	SB-10	10	7	Rig	0–2	SM&E	10-05-90
					5–7	SM&E	
					10–12	EPA TAL TCL&E	
B	SB-2	10	8	Rig	0–2	SM&E	10-05-90
					5–7	SM&E	
					10–12	EPA TAL TCL&E	
C	SC-A42E (angle)	10.5 vertical 15 angle	4	Rig	7–10.5	EPA TAL TCL&E	10-08-90
C	SC-42	10	8.5	Rig	0–2	EPA TAL TCL&E	09-13-90
					5–7	SM&E	
					10–12	SM&E	
C	SC-12	10	8	Rig	0–2	SM&E	09-19-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	

TABLE 4-2 (Continued)

Load Line	Boring Designation	Depth of Boring (feet)	Depth of Sump (feet)	Boring Method	Chemical Sample Interval and Analysis		Date Completed
C	SC-5	10	9	Rig	0–2	SM&E	09-19-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
					10–12	SM&E duplicate	
C	SC-42E	10	4	Rig	0–2	SM&E	09-20-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
					5–7	EPA TAL TCL&E duplicate	
C	SC-1	10	8	Rig	0–2	SM&E	09-20-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
C	SC-6	10	8	Rig	0–2	EPA TAL TCL&E	09-14-90
					5–7	SM&E	
					10–12	SM&E	
D	SD-10	10	8	Rig	0–2	SM&E	09-22-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
D	SD-42B	6	4.5	Hand auger	0–2	EPA TAL TCL&E	10-09-90
					3.5–4.5	SM&E	
					5–6	SM&E	
D	SD-41	6.5	5.5	Hand auger	0–2	EPA TAL TCL&E	10-10-90
					3–5	SM&E	
					5.5–6.5	SM&E	
D	SD-42	6	4.5	Hand auger	0–2	EPA TAL TCL&E	10-11-90
					0–2	EPA TAL TCL&E duplicate	
					3–4.5	SM&E	
					5–6	SM&E	
E	SE-4	10	8	Rig	0–2	SM&E	09-26-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
					10–12	SM&E duplicate	
O	SO-3	10	9	Rig	0–2	SM&E	10-11-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
O	SO-14	10	9	Rig	0–2	SM&E	09-25-90
					5–7	EPA TAL TCL&E	
					5–7	EPA TAL TCL&E duplicate	
					10–12	SM&E	
X	SX-8	9	7	Hand auger	0–2	SM&E	10-03-90
					5–7	EPA TAL TCL&E	
					8–9	SM&E	

TABLE 4-2 (Continued)

Load Line	Boring Designation	Depth of Boring (feet)	Depth of Sump (feet)	Boring Method	Chemical Sample Interval and Analysis		Date Completed
X	SX-313	7.5	6.5	Hand auger	0–1	EPA TAL TCL&E	10-25-90
					3.5–4	SM&E	
					4–4.5	SM&E	
					6.5–7.5	SM&E	
X	SX-103	6.5	5.5	Hand auger	0–1	SM&E	10-26-90
					2.5–3.5	SM&E	
					5.5–6.5	EPA TAL TCL&E	
X	SX-41	5.5	4	Hand auger	0–1	SM&E	11-05-90
					2.5–3	SM&E	
					4.5–5.5	EPA TAL TCL&E	
X	SX-26	5	4	Hand auger	0–1	SM&E	11-09-90
					2–3	EPA TAL TCL&E	
					2–3	EPA TCL duplicate	
					4–5	SM&E	
Z	SZ-4	10	5	Rig	0–2	SM&E	09-20-90
					5–7	EPA TAL TCL&E	
					10–12	SM&E	
Z	SZ-4W	10	7	Rig	0–2	SM&E	09-22-90
					5–7	SM&E	
					10–12	EPA TAL TCL&E	
					10–12	EPA TCL duplicate	
Z	SZ-2	10	7	Rig	0–2	EPA TAL TCL&E	09-22-90
					5–7	SM&E	
					10–12	SM&E	
					10–12	SM&E	
Z	SZ-A4 (angle)	10.5 vertical 15 angle	5	Rig	7–10.6	EPA TAL TCL&E	10-08-90

SM&E	Select metals and explosives.
EPA TAL TCL&E	EPA Target Analyte List/Target Compound List and Explosives.

second concrete sump. This piping extends over a concrete culvert which directs surface drainage under a ramp and into a ditch. The ditch is located downgradient of the sump system and is considered the area of most probable contamination from the sump system. Boring SA-4 was located at the discharge point of the concrete culvert. Soil samples were obtained using a hand auger because access to the area by drill rig was not possible. Three soil samples were collected from a depth of 0-3 feet below ground surface.

Sumps A-7, A-44, and A-40 are all new sumps. The soil boring at sump A-7 was located adjacent to the southwest corner of the sump. The boring was completed to a depth of 10 feet and four samples were collected for chemical analysis.

Sump A-40 was not accessible by a drill rig; however, samples were obtained by hand-augering to a depth of 6.5 feet. Three samples were collected at location SA-40.

Sump A-44 was investigated with both a vertical and angled soil boring. The vertical soil boring (SA-44) was located on the northeast side of the tank and three samples were collected for chemical analysis. The angled boring (SA-A44) was located 10.5 feet from the north end of the sump. A 20 degree angle on the boring provided access to soil at a depth of 14 feet below ground surface and below the bottom of the sump. During drilling of the angled borehole, a section of PVC conduit was brought up in the cuttings. The boring was terminated at the intended depth of sampling and a soil sample was collected for chemical analysis. The MAAP Safety Officer was notified of the situation and subsequently investigated the incident. The investigators determined that the electrical conduit contained an abandoned 440-volt line (personal communication, Jerry Mangrum, Martin Marietta, May 30, 1991).

Line B. Five sumps were investigated at Line B. The soil borings are designated SB-18, SB-12, SB-273, SB-2, SB-10 (vertical) and SB-A10 (angled) (See Figure 4-3). Sump B-18 was an aboveground metal structure constructed on a concrete pad. This sump was closed in the late 1960s, and according to MAAP personnel the sump discharge was from a melt-kettle process. The soil boring was located on the northeast side of Building B-18, adjacent to the effluent ditch.

The vertical soil boring corresponding to sump SB-2 was located at the northern end of the sump. The soil boring was drilled to a depth of 10 feet, and three soil samples were collected.

A vertical soil boring was installed at sump SB-10, located at the northeast end of the sump. The soil boring was drilled to a depth of 10 feet, and three soil samples were collected from this location. An angled boring was also installed at sump B-10. The borehole was located 13 feet from the northeast corner of the sump. A 25 degree angle on the drill rig allowed access to soil beneath the bottom of the sump at a vertical depth of 17.5 feet below ground surface.

Sump B-273 was not accessible to the drill rig, so soil samples were collected by hand-augering to a depth of 10 feet. Building 273 contained nine sumps that were approximately eight feet deep. The boring location was adjacent to the north side of Building 273.

Sump B-12 is a new sump which was inaccessible by drill rig. A hand-augured soil boring was installed 6 feet west of the northwest corner of the sump. The soil boring was completed at a depth of 10 feet and three soil samples were collected.

Line C. Six sumps were investigated at Line C and the designated soil borings for these sumps are SC-42, SC-42E, SC-12, SC-5, SC-1 and SC-6 (see Figure 4-4). All sumps were accessible by the drill rig and an angled boring was installed by sump C-42E (designated SC-A42E), as indicated in Table 4-2.

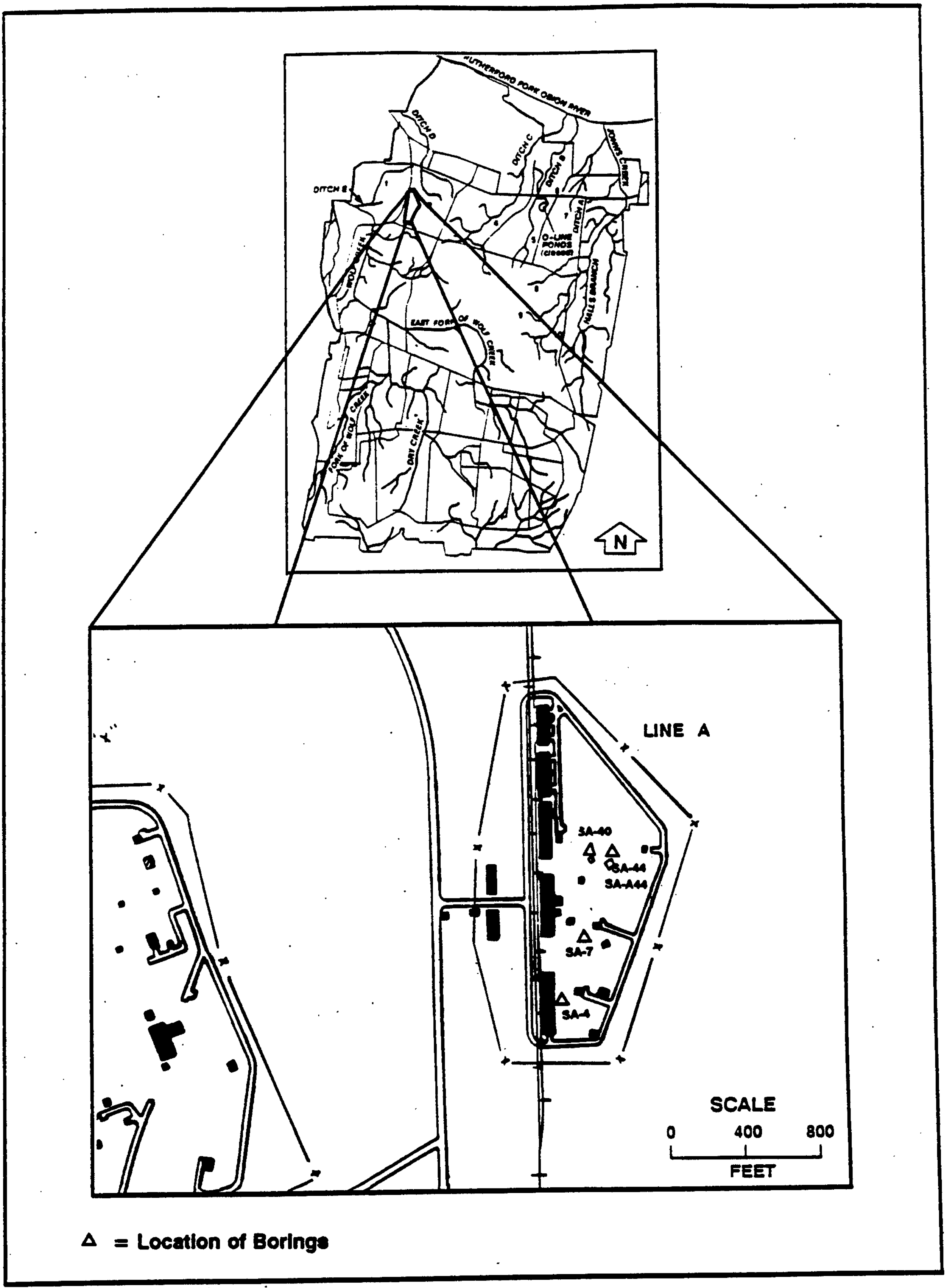


Figure 4-2
Location of Borings at Line A

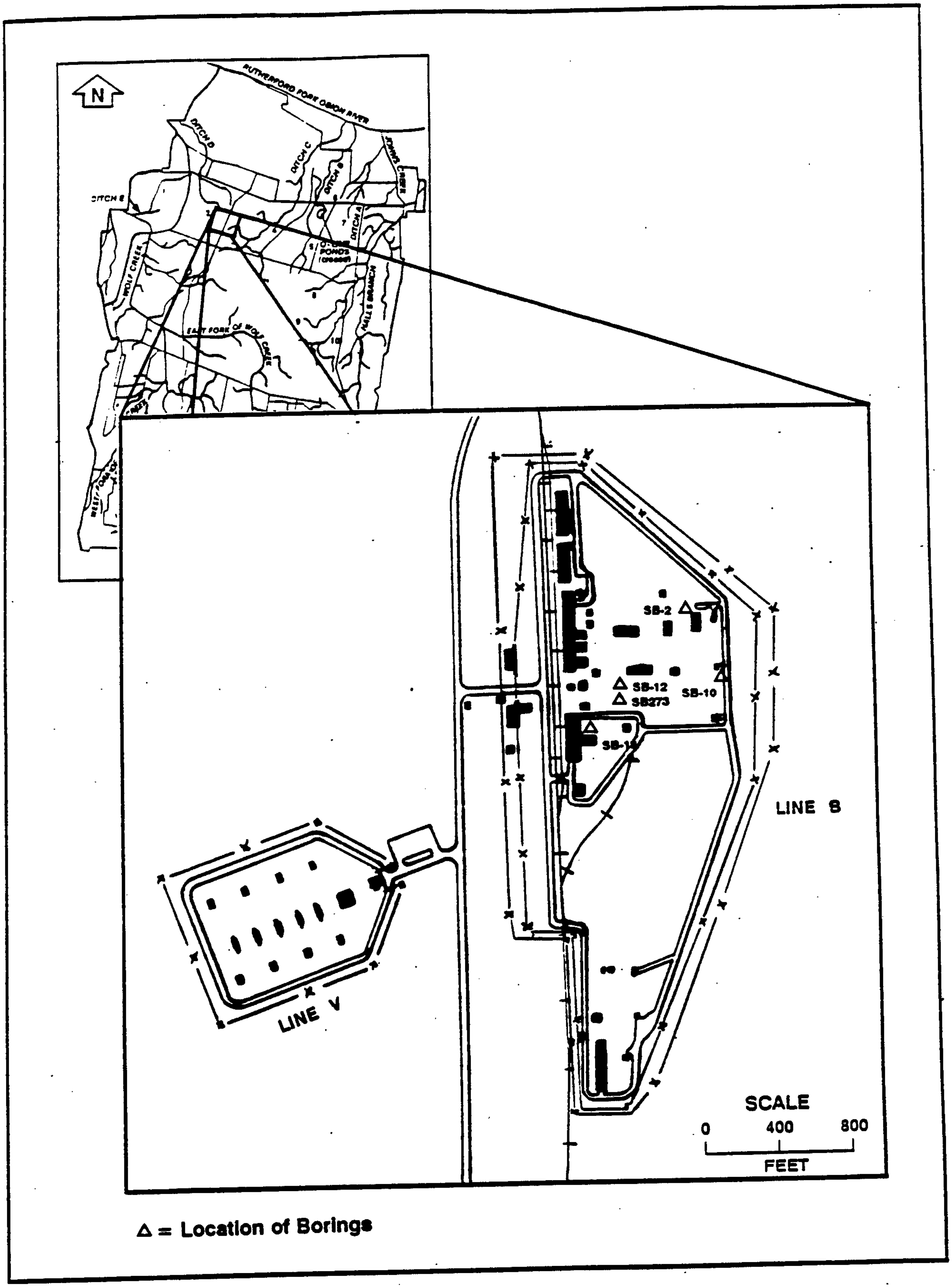


Figure 4-3
Location of Borings at Line B

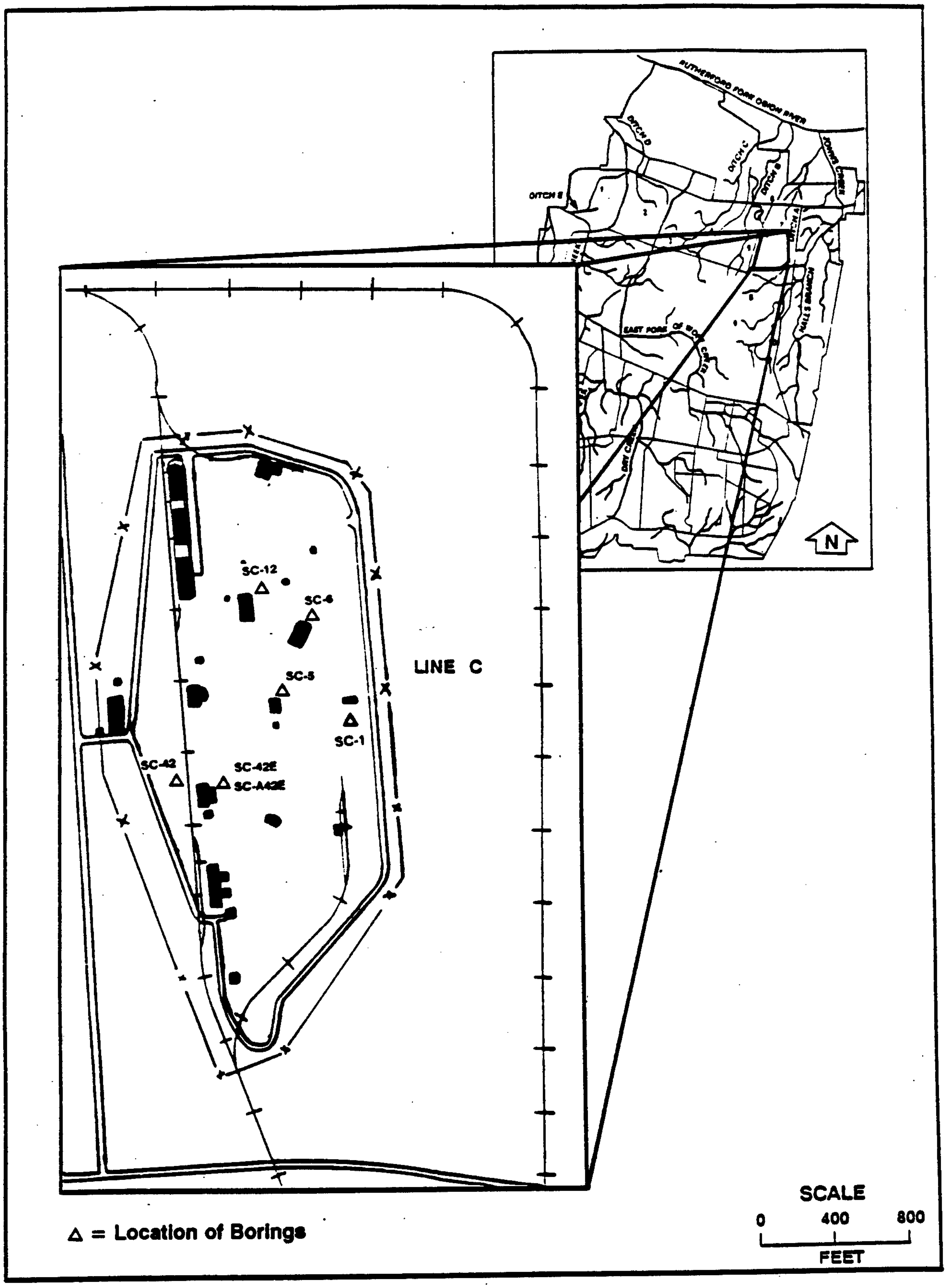


Figure 4-4
Location of Borings at Line C

Sump C-42E is an old concrete sump in a deteriorated condition. Cracks and holes in the concrete indicated that the sump would not hold water and was observed to be dry at the time of sampling. The sump was constructed with three baffled settling chambers. The shallowest chamber, located adjacent to the building, was approximately 3 feet deep and the third chamber, furthest from the building, was 7 feet deep. A concrete drainage spillway allowed effluent to drain from the third chamber into a ditch that flowed east away from the building. A vertical soil boring was located at the end of the concrete drainage spillway and drilled to a depth of 10 feet. Three soil samples were collected at this location (SC-42E). An angled boring was installed 8 feet north of the northeast corner of the sump (SC-A42E). An angle of 15 degrees on the drill rig allowed access to soil beneath the sump at a vertical distance of 10.5 feet below ground surface.

Sump C-42 is a new three-chambered sump, constructed of metal and inset into a concrete pad. A soil boring (SC-42) was installed adjacent to the northeast corner of the sump and drilled to a depth of 10 feet. The soil boring was drilled in an area adjacent to the overflow pipe that protrudes from the north end of the sump.

Sump C-12 is similar in configuration to sump C-42; however, the age of the sump is unknown. A vertical soil boring (SC-12) was installed adjacent to the northeast corner of the sump. An overflow pipe protrudes from the northeast corner of the sump and the soil boring was drilled into a depressed spillway probably formed by overflow from the tank.

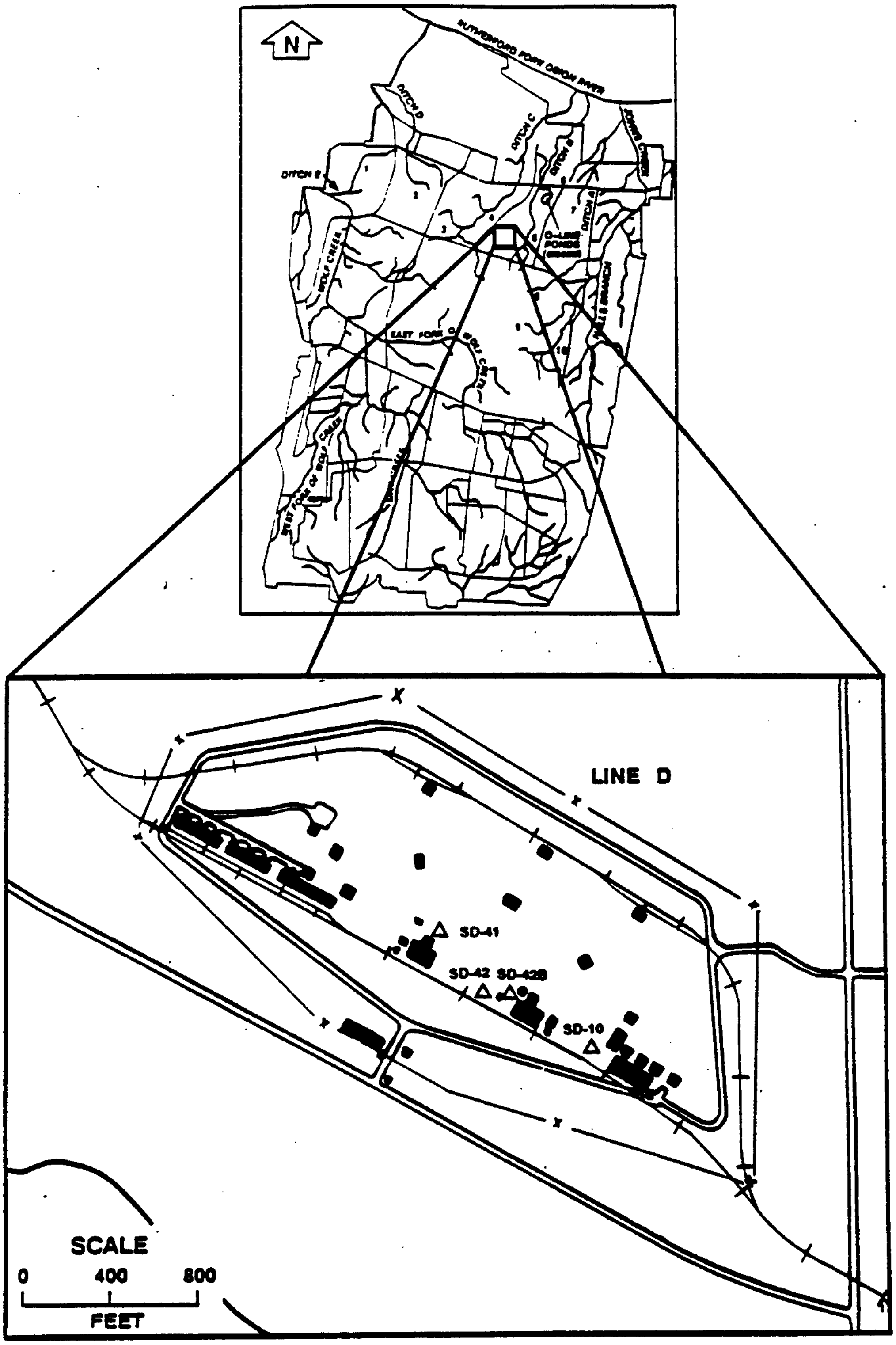
Sumps C-1, C-5, and C-6 are all of similar configuration. Each sump is a five-chambered metal structure set into a concrete pad. Sump C-1 is new and sumps C-5 and C-6 are of unknown age. Except for C-6, each sump has an overflow pipe that discharges directly to the ground adjacent to the sump. At sump C-6, the overflow pipe conveyed effluent to a buried PVC pipe that discharged to a ditch 50 feet northeast of the sump. Soil boring SC-6 was located at the discharge point of the subsurface PVC pipe. Soil boring SC-1 was located at the northeast end of the sump adjacent to the discharge area of the overflow pipe. Soil boring SC-5 was located in a drainage ditch approximately 12 feet south of the sump. The location of this soil boring with respect to the sump was restricted due to buried electrical lines in the vicinity of the sump.

Line D. Four sumps were investigated at Line D and the designated soil borings are SD-10, SD-42B, SD-41, and SD-42 (see Figure 4-5). Only one sump, D-10, was accessible by a drill rig. Sump D-10 is new, and the soil boring (SD-10) was located in a topographically low area approximately 5 feet west of the concrete pad that contains the sump system. The remainder of the soil borings at D Line were hand-augured.

Sump D-41 was constructed of concrete and metal settling chambers, and contained water at the time the soil samples were collected. According to MAAP personnel, the sump has been refurbished. The soil boring was located approximately 25 feet south of the outlet pipe, which at some time discharged to the ground surface. The soil boring was hand-augured to a depth of 6.5 feet and three samples were collected.

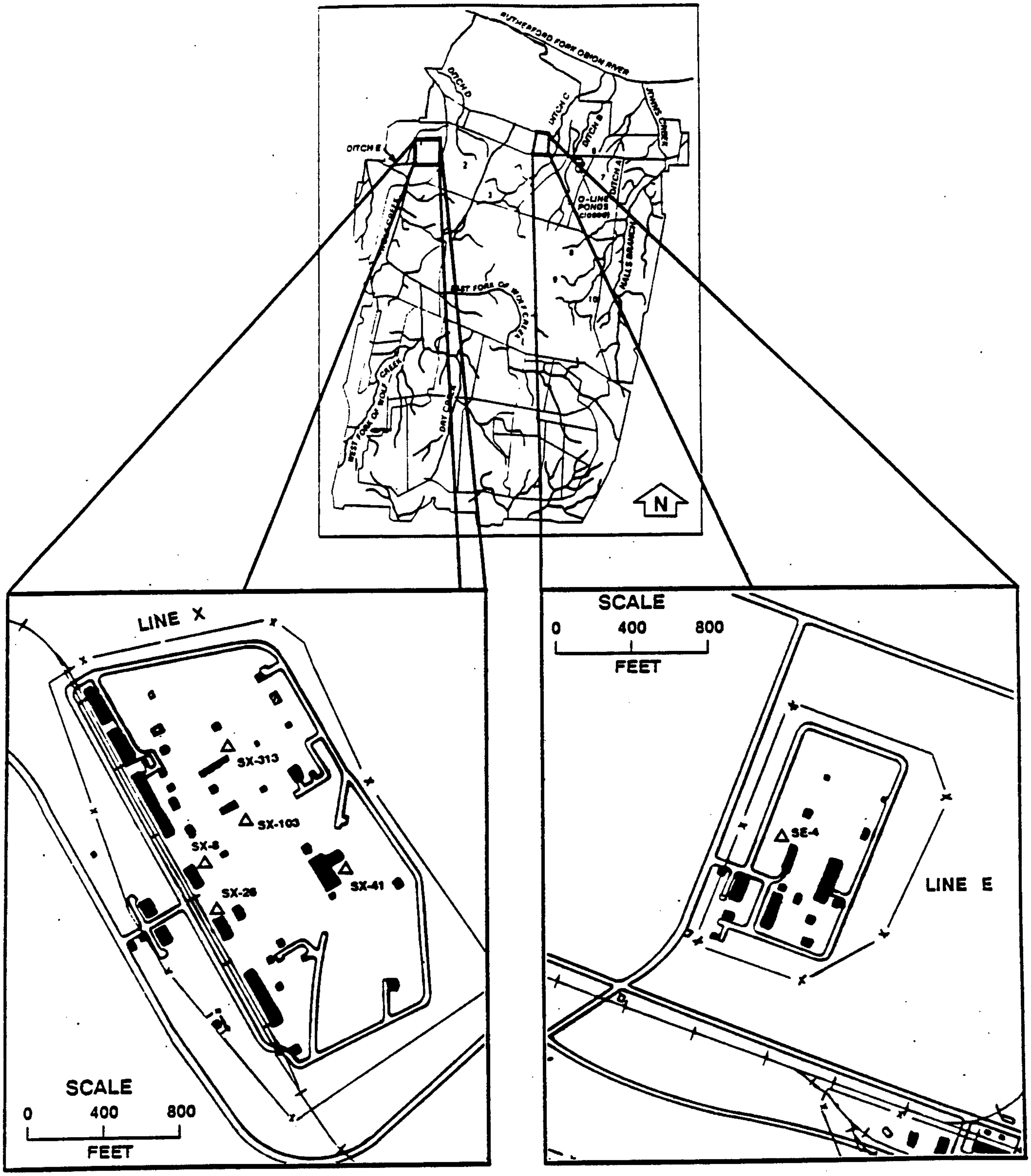
There are two sumps located north of Building D-42. According to MAAP personnel, both of these sumps were refurbished in 1981. At the time of sampling, these two sumps contained water. Soil boring SD-42 was located five feet north of the northwest corner of the sump and was hand-augured to a depth of 6 feet. Soil boring SD-42B was located adjacent to a covered concrete surface drainage system south of the sump. This boring was hand-augured to a depth of 6 feet and three soil samples were collected.

Line E. One sump was investigated at Line E and the designated soil boring is SE-4 (see Figure 4-6). According to MAAP personnel, the sump at Line E was closed and removed. The sump was located at the north end of Building E-4. The soil boring was located in an area of stressed vegetation on the effluent side of the sump, approximately 40 feet west of the northwest corner of Building E-4.



△ = Location of Borings

Figure 4-5
Location of Borings at Line D



△ = Location of Borings

Figure 4-6
Location of Borings at Lines E and X

Line O. Two sumps were investigated at Line O and the designated soil borings are SO-3 and SO-14 (see Figure 4-7). According to MAAP personnel, sump O-3 is an old structure which had been filled with sand and capped with a concrete pad. The concrete pad appeared to be in good condition at the time of sampling. The refurbished sumps at this location are constructed of metal and set in a concrete pad adjacent to the closed sump. The soil boring was located approximately 60 feet north of Building O-3, in a fenced area north of the railroad tracks. Because access to the sump was restricted by power lines, the soil boring was located on the downgradient side of the sump at the discharge point of a concrete-lined drainage ditch.

SO-14 was located eight feet south of the sump system and 6 feet east of Building O-14. The sump is a two-chambered metal structure set into a concrete pad. The soil boring was drilled to a depth of 10 feet and three soil samples were collected.

Line X. Five sumps were investigated at Line X and the designated soil borings are SX-8, SX-313, SX-103, SX-41, and SX-26 (see Figure 4-6). All sumps were inaccessible to a drill rig. Therefore, hand-augured soil samples were collected for chemical analysis.

According to MAAP personnel, sump X-8 has been closed and removed. An attempt to drill the soil boring with a motorized post-hole auger machine was not successful below a depth of five feet. The soil boring was completed by hand-augering to a depth of nine feet. Three soil samples were collected for chemical analysis.

Sump X-313 is located north of Building X-313. The structure contained three old sumps that have been closed and one new sump. The soil boring was located adjacent to the west corner, and on the effluent side, of the existing sump. The soil boring was hand-augured to a depth of 7.5 feet and four soil samples were collected for chemical analysis.

Sump X-103 is a new, one-chambered, aboveground concrete structure that currently contains water. The soil boring was located at the northern end of the sump and hand-augured to a depth of 6.5 feet. Three soil samples were collected.

Sump X-41 is an old sump system that had been refurbished and currently contains water. According to MAAP personnel, this sump was originally part of an old melt-pour operation that apparently discharged to Wolf Creek. Explosives-contaminated wastewater was discharged to Wolf Creek and reportedly turned the creek water red due to the quantities of explosives carried in the sump effluent. The soil boring was located adjacent to the southwest corner of the sump. The sump is a two-chambered, metal structure set in concrete at ground level. Soil boring SC-41 was located adjacent to the southwest corner of the sump and hand-augured to a depth of 5.5 feet. Three soil samples were collected for chemical analysis.

According to MAAP personnel sump X-26 has been closed and removed. The soil boring was located 6 feet northwest of Building X-26. The soil boring was hand-augured to a depth of 5 feet and three soil samples were collected for chemical analysis.

Line Z. Three sumps were investigated at Line Z and the soil boring designations are SZ-4, SZ-2, SZ-4W (vertical) and SZ-A4 (angled). These boring locations are shown in Figure 4-8. All sumps at Line Z were accessible by the drill rig.

Sump Z-4W is located at the western end of Building Z-4 and is constructed of concrete. An open concrete spillway adjacent to the building conveyed effluent to the southern end of the sump that is covered by a metal plate. Soil boring SZ-4W was located at the discharge point of a concrete drainage spillway at the southern end of the sump. The soil boring was drilled to a depth of ten feet and four soil samples were collected for chemical analysis. An angled boring was installed eight feet southwest of the

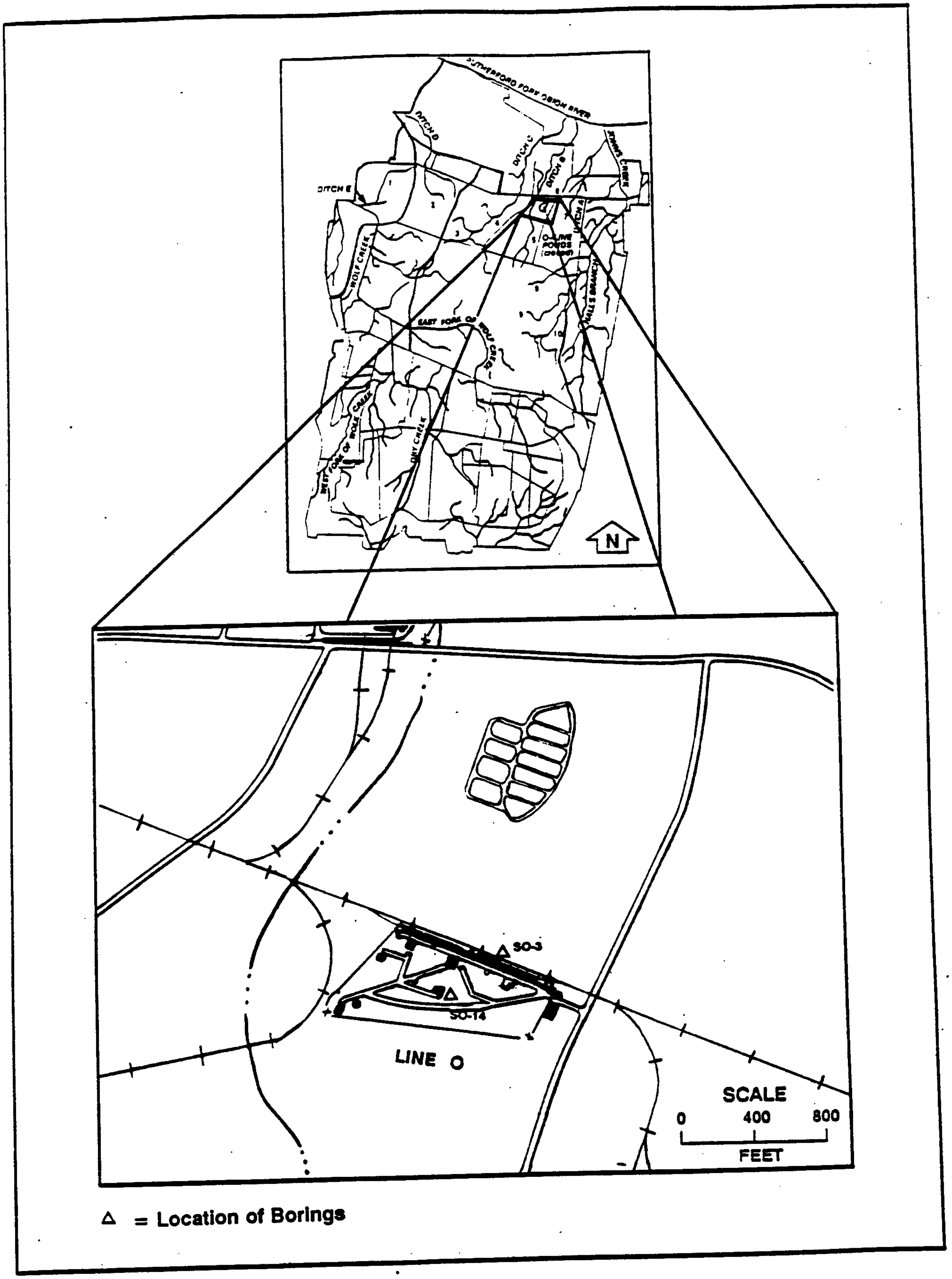


Figure 4-7
Location of Borings at O-Line

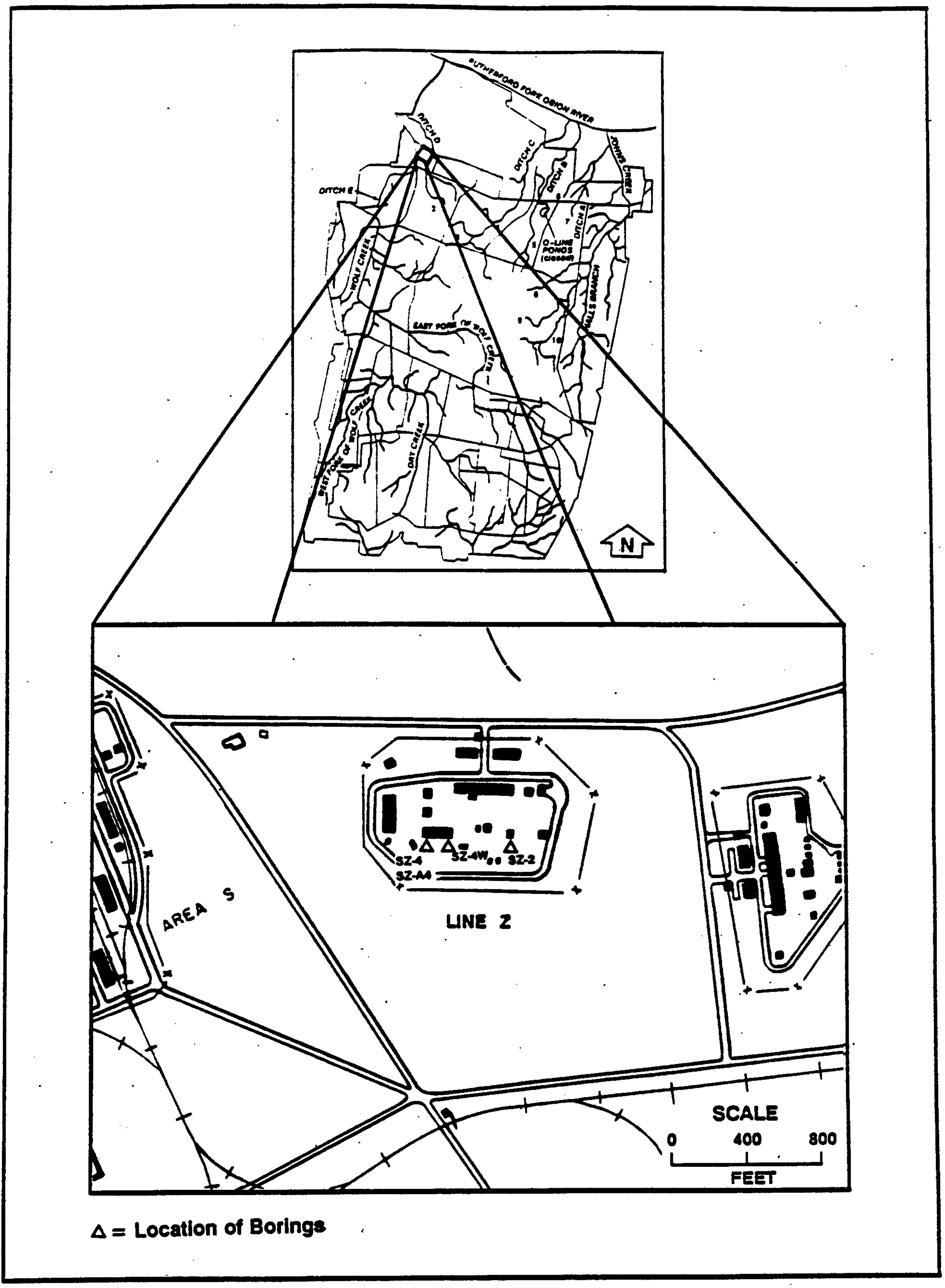


Figure 4-8
Location of Borings at Line Z

sump system (SZ-A4). An angle of 15 degrees on the drill rig allowed access to soil at a vertical depth of 10.5 feet below ground surface and beneath the sump structure.

Sump Z-4 is located at the eastern end of Building Z-4 and is of the same configuration as sump Z-4W. Soil boring SZ-4 was located at the discharge point of the drainage spillway at the southern end of the sump. The soil boring was drilled to a depth of ten feet and three soil samples were collected for chemical analysis.

Sump Z-2 is an old metal sump system located on the south side of Building Z-2. The sump is an aboveground structure on a concrete pad with a metal drainage chute that discharged effluent to the ground surface. Soil boring SZ-2 was located in the discharge area south of the sump. The soil boring was completed to a depth of ten feet and four soil samples were collected for chemical analysis.

4.3.1.3 Former Burn Out Area. Five soil borings designated CBG-1 to CBG-5 were installed at the Former Burn Out Area (Closed Burning Ground) to investigate soil contamination from past burn activities in this area. (See Figure 4-9 for soil boring locations). All soil boring sites were accessible by a drill rig and were completed at a depth of 10 feet below ground surface. Table 4-3 lists the soil samples collected at the Former Burn Out Area.

4.3.1.4 Former Borrow Pit. Three soil borings were installed at the Former Borrow Pit (Construction Debris Pit) to investigate soil contamination resulting from disposal activities that reportedly occurred in this area (Figure 4-10). The soil borings are designated CDP-1 to CDP-3. Table 4-3 presents sampling information for each borehole. The sampling design for this area was modified by USATHAMA to include deeper soil borings in order to assess soil contamination at and below the level of groundwater and ponded water at the site. The soil borings were located around the perimeter of the pit, on a topographically high area, north and east of the pond. CDP-1 and CDP-2 were drilled to a depth of 32 feet below ground surface, which was below the estimated depth of the ponded water surface at these sites. CDP-3 was drilled to a depth of 35 feet below ground surface and six samples were collected for chemical analysis.

4.3.1.5 Closed Landfill. Five soil borings were installed at the Closed Landfill, as shown in Figure 4-11. These soil borings (designated CLF-1 to CLF-5) were installed to investigate explosives contamination in the fill material at the site. Table 4-4 presents information regarding the soil borings installed at the Closed Landfill which includes the depth of the soil boring, sample depths and chemical analyses performed on the samples and date the boring was completed. The soil borings were located just inside of the landfill boundary. All borings, except CLF-4, were drilled to a depth of ten feet. During drilling of CLF-4, a thick zone of cardboard and plastic debris was encountered. An attempt to sample the interval with the split spoon yielded only partial recovery of cardboard and plastic debris. Additional footage was drilled to bypass this zone and obtain a soil sample.

4.3.1.6 Present Landfill. Two soil borings were installed at the Present Landfill (see Figure 4-12) to investigate soil contamination resulting from disposal activities currently conducted at MAAP. These soil borings were located on the downgradient side of the landfill near the outer perimeter. Table 4-4 presents information on the soil borings and samples collected at this site. Soil boring LF-1 was drilled to a depth of 12 feet below ground surface and four soil samples were collected for chemical analysis. LF-2 was drilled to a depth of ten feet below ground surface and three soil samples were collected for chemical analysis.

4.3.1.7 Salvage Yard. The Sampling and Analysis Plan called for a soil boring on either side of the lead bin. A boring could not be installed upgradient from the lead bin because a railroad track exists on that side of the bin. Consequently, one boring (SYD-1) was installed downgradient from the lead bin and the second soil boring (SYD-2) was installed on the downgradient side of the metal scrap pile, as shown in Figure 4-13. (Approval for this deviation was later obtained from USATHAMA, as documented in

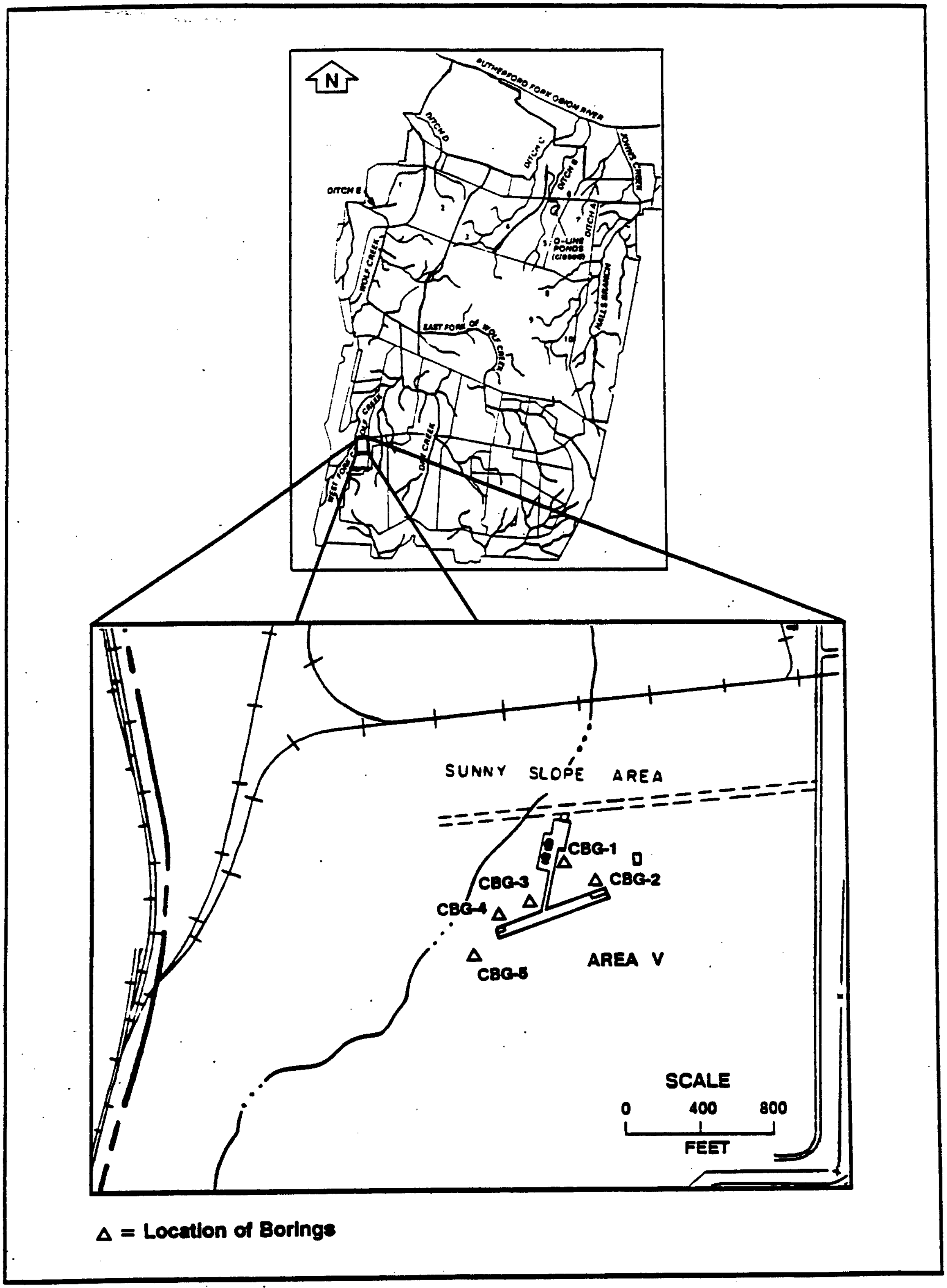


Figure 4-9
Former Burn Out Area Boring Locations

Table 4-3
Soil Samples Collected from the Former Burn Out Area and Former Borrow Pit

Boring Designation	Depth of Boring (feet)	Depth to H_2O from Surface	Boring Method	Chemical Sample Interval and Analysis		Date Com-pleted
			Former Burn Out Area			
CBG-1	10	N/A	Rig	0–2 5–7 10–12	EPA TAL TCL&E SM&E SM&E	09-08-90
CBG-2	10	N/A	Rig	0–2 5–7 10–12	SM&E SM&E EPA TAL TCL&E	09-08-90
CBG-3	10	N/A	Rig	0–2 5–7 10–12 10–12	SM&E SM&E EPA TAL TCL&E EPA TCL duplicate	09-09-90
CBG-4	10	N/A	Rig	0–2 5–7 10–12 10–12	SM&E EPA TAL TCL&E SM&E SM&E duplicate	09-09-90
CBG-5	10	N/A	Rig	0–2 5–7 10–12	SM&E SM&E EPA TAL TCL&E	09-09-90
			Former Borrow Pit			
CDP-1	32	13.9	Rig	0–1 10–14 10–14 15–19 15–19 20–22 30–32	SM&E SM&E SM&E duplicate EPA TAL TCL&E EPA TAL TCL&E duplicate SM&E SM&E	09-11-90
CDP-2	32	23.5	Rig	0–1 12–14 22–24 24–26 30–32	SM&E SM&E EPA TAL TCL&E SM&E SM&E	09-09-90
CDP-3	35	10	Rig	0–1 10–12 15–17 20–22 25–27 35–37	SM&E SM&E EPA TAL TCL&E SM&E EPA TAL TCL&E SM&E	09-12-90

SM&E	Select metals and explosives.
EPA TAL TCL&E	EPA Target Analyte List/Target Compound List and Explosives.
N/A	Not applicable; no groundwater was hit.

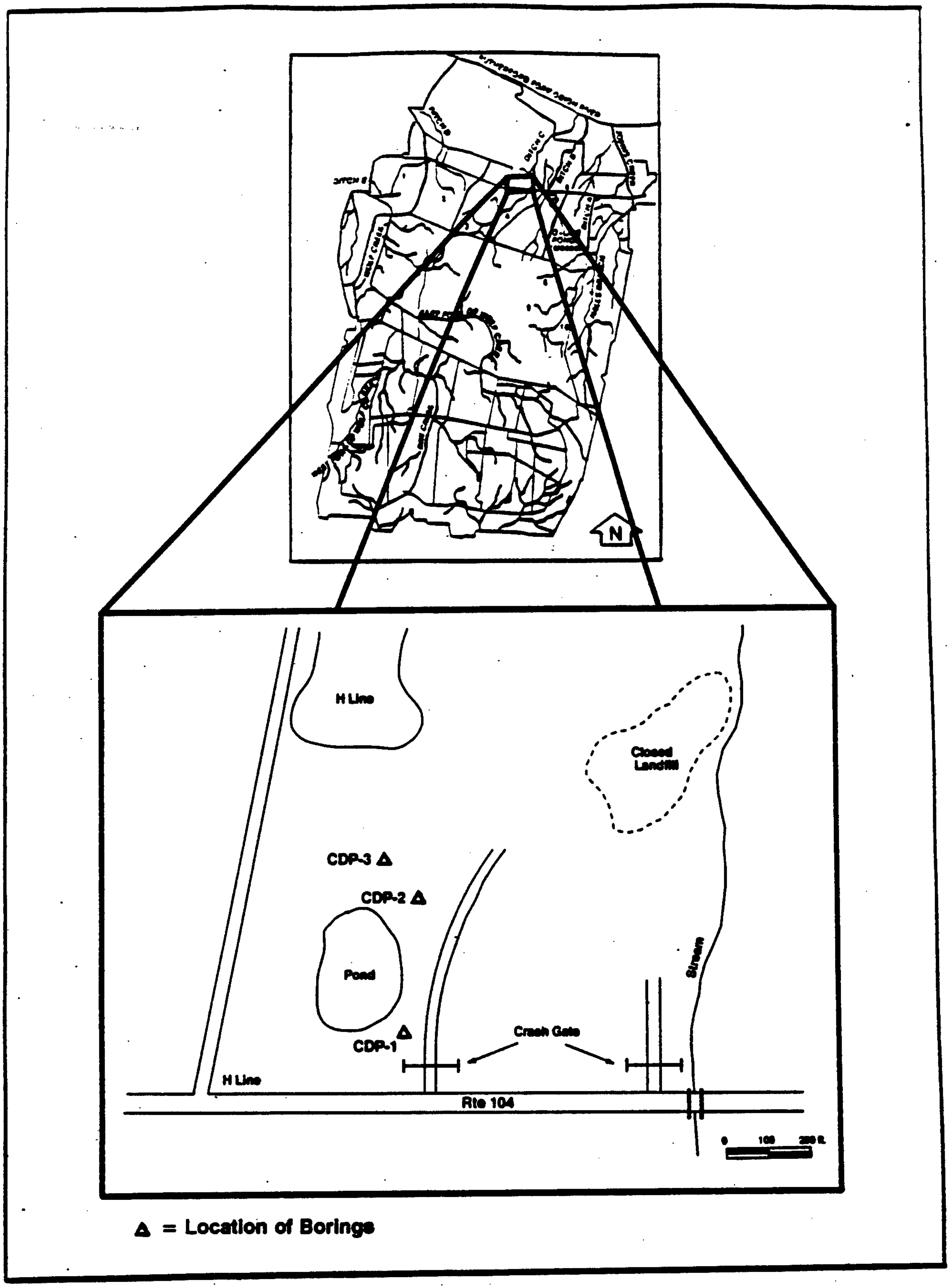


Figure 4-10
Former Borrow Pit Boring Locations

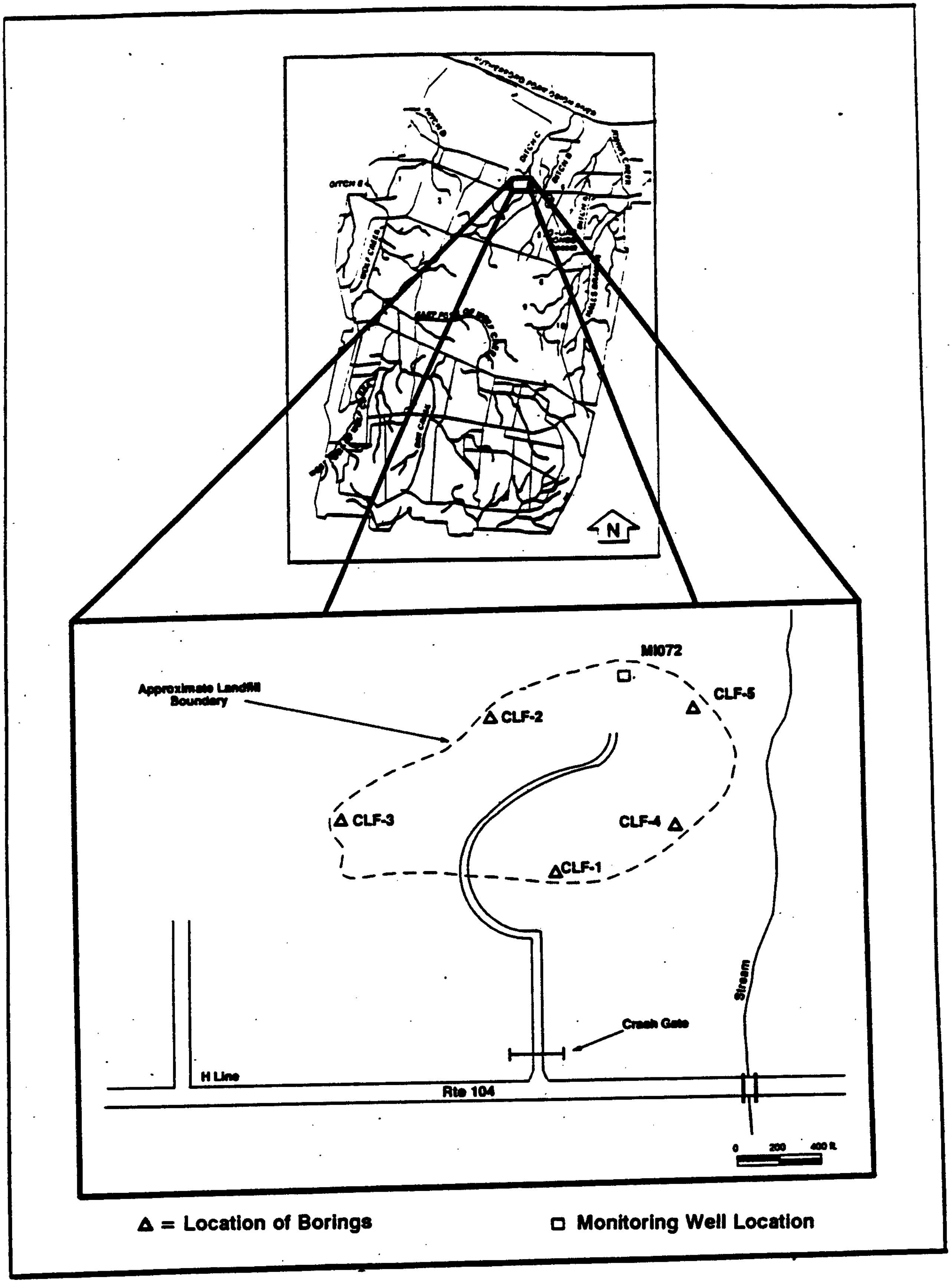


Figure 4-11
Closed Landfill Boring Locations

Table 4-4
Soil Samples Collected from the Former Landfill, Present Landfill, and Salvage Yard

Boring Designation	Depth of Boring (feet)	Depth to H_2O from Surface	Boring Method	Chemical Sample Interval and Analysis		Date Completed
			Former Landfill			
CLF-1	10	N/A	Rig	0–2	SM&E	09-11-90
				5–7	SM&E	
				10–12	EPA TAL TCL&E	
CLF-2	10	N/A	Rig	0–2	SM&E	09-11-90
				5–7	EPA TAL TCL&E	
				10–12	SM&E	
CLF-3	10	N/A	Rig	0–2	SM&E	09/12/90
				5–7	SM&E	
				10–12	EPA TAL TCL&E	
				10–12	EPA TAL TCL&E duplicate	
CLF-4	15	N/A	Rig	0–2	SM&E	09-13-90
				5–9	SM&E	
				5–9	SM&E duplicate	
				12–14	EPA TAL TCL&E	
CLF-5	10	N/A	Rig	0–2	EPA TAL TCL&E	09-13-90
				5–7	SM&E	
				10–12	SM&E	
			Present Landfill			
LF-1	12	N/A	Rig	0–1	SM&E	09-13-90
				5–9	EPA TAL TCL&E	
				5–9	EPA TAL TCL&E duplicate	
				10–12	SM&E	
LF-2	10	N/A	Rig	0–7	SM&E	09-13-90
				0–7	SM&E duplicate	
				10–12	EPA TAL TCL&E	
			SALVAGE YARD			
SYD-1	10	N/A	Rig	5–7	EPA TAL TCL&E	09-12-90
				5–7	EPA TAL TCL&E duplicate	
SYD-2	10	N/A	Rig	5–7	EPA TAL TCL&E	09-12-90

SM&E	Select metals and explosives.
EPA TAL TCL&E	EPA Target Analyte List/Target Compound List and Explosives.
N/A	Not applicable; no groundwater was hit.

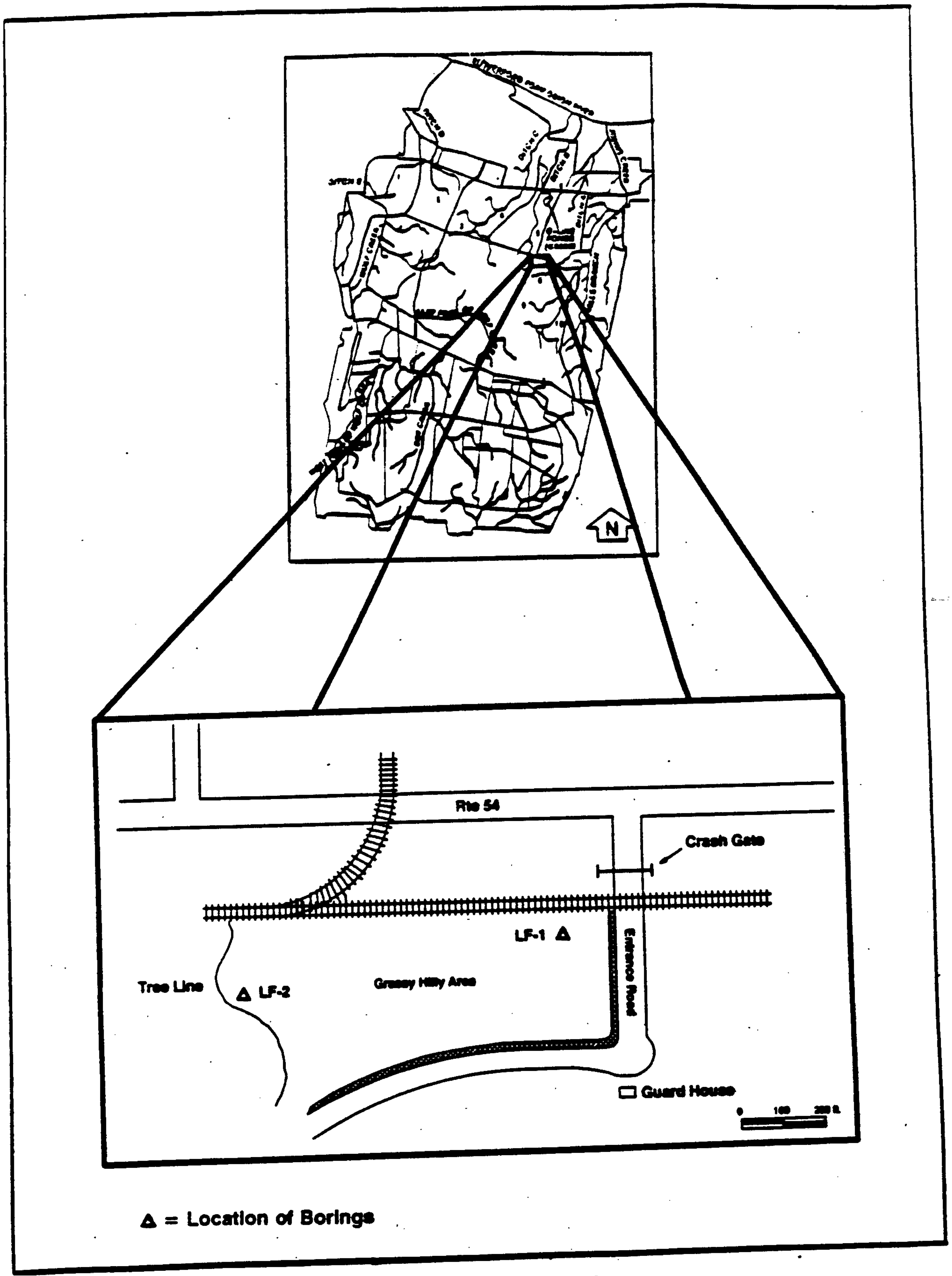


Figure 4-12
Present Landfill Boring Locations

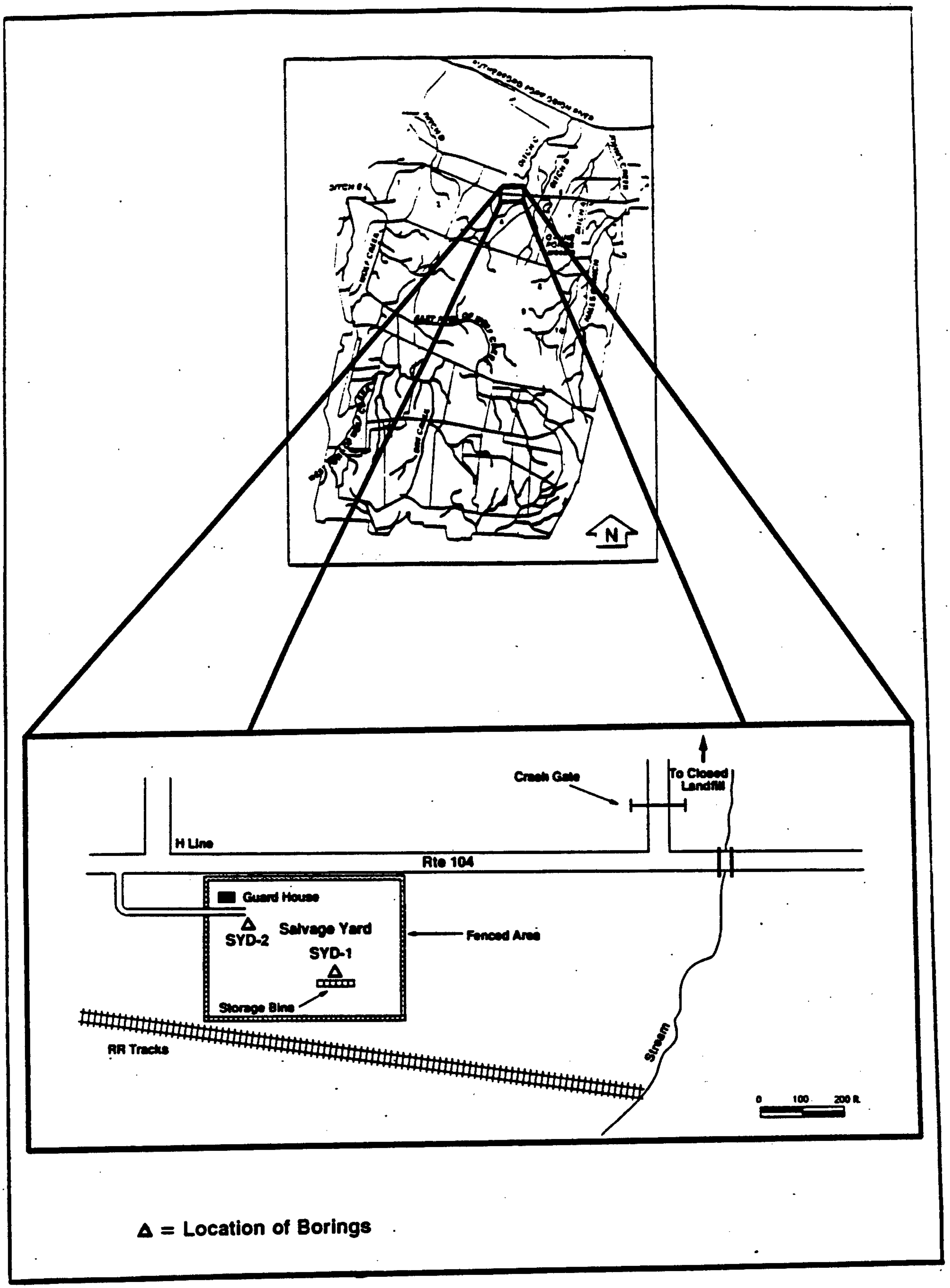


Figure 4-13
Salvage Yard Boring Locations

Appendix D.) Each boring was drilled to a depth of ten feet and three soil samples were collected for chemical analysis (see Table 4-4).

4.3.2 Soil Sampling Procedures

The methods used in drilling the borings and collecting soil samples are described in this section. Hollow-stem auger vertical drilling, angled drilling, and hand-augering techniques were all used at MAAP to obtain soil samples and lithologic information. Detailed boring logs were prepared by the Site Geologist overseeing the drilling which describe the soil samples and the manner in which they were obtained. The procedures used in decontamination of the drilling equipment are also described in this section.

4.3.2.1 Hollow-Stem Auger Vertical Drilling and Sampling. The hollow-stem augers used to drill the vertical borings have an inside diameter of 4.25 inches. As the augers were advanced, split spoon samples were collected at 5-foot intervals, or at each change in lithology. The soil samples were collected with either a 2-foot or 18-inch long, stainless steel, split spoon sampler driven into the soils beyond the end of the augers. The soils were checked with a photoionization detector (PID) and then samples to be analyzed for volatile organic compounds (VOC) were transferred from the spoon into sample bottles using a stainless steel spatula. Latex gloves were worn by all sampling personnel to eliminate the introduction of contaminants during sample handling. The VOC samples were collected from all portions of the split spoon. The remainder of the sample was then mixed in a decontaminated glass bowl using a stainless steel spatula, to insure homogeneity, prior to being placed in sample containers. All samples were immediately placed in plastic ice chests and maintained at 4° C from the time of sample collection until analysis. VOC samples were not mixed, but placed directly in the sample containers as quickly as possible to reduce the risk of losing volatile constituents to the air.

In the OBG/ADA area, the surface soil was scraped by heavy equipment to a depth of 12 inches. In order to obtain an undisturbed surface soil sample which is representative of the area, a sample was collected from an undisturbed area near the borehole.

Once the desired completion depth for the soil boring was reached and all samples were collected, the borehole was sealed by grouting with a mixture of 20:1 cement and bentonite with the approved water, as required by the USATHAMA Geotechnical Requirements (1987a). At the completion of the boring program in a given area, each soil boring site was checked every 24 hours for grout settlement, and additional grout was added if necessary until the borehole was filled.

The samples and drill cuttings from each borehole were visually inspected and checked with a PID for contaminants. The cuttings were collected in drums and labeled with weatherproof markings showing well or boring number, date, location, and appropriate depth range of the contents. The drums were then sealed and transported to a secure area at the OBG where they are stored pending a final disposal decision.

4.3.2.2 Hollow-Stem Auger Angled Drilling and Sampling. A CME 75 drill rig with 4.25-inch inside diameter hollow stem augers was configured to bore an angled hole. The surface entry points of the boreholes were located 8 to 15 feet from the sumps, which allowed the augers 3 to 5 feet of clearance below the bottom of each sump. The borehole was drilled with augers to the desired sampling depth. A five-foot sampling barrel was attached to the drill rods and inserted into the augers. The augers were then advanced five feet. The sampling barrel was removed from the augers with the cuttings intact. The soil was scanned with a Photoionization Detector and samples were collected according to the procedures previously outlined. Only the soil from the final 2 feet of the sampling barrel were collected for analysis because these soils originated from directly beneath the sump. The angled boreholes were abandoned according to the procedures outlined for the vertical soil borings.

Angled boreholes were installed outside of sumps and soil samples were collected from beneath these structures without incurring structural damage and with minimal disruption of normal operations. At sumps A-44, B-10, C-42E, and Z-4 soil samples were collected from directly beneath the sumps via angled borings and were analyzed for Target Analyte List/Target Compound List (TAL/TCL) and explosive constituents. These samples were collected in addition to, and for comparison with, soil samples collected adjacent to these sumps from conventional vertical soil borings.

4.3.2.3 Hand Augering and Sampling Procedures. Hand-augured soil borings were installed in areas inaccessible by a drill rig. The borings were installed using a 2-inch inside diameter, 6-inch long stainless steel auger; stainless steel extensions were used to reach the required depth. Latex gloves were worn by all sampling personnel to eliminate introduction of contaminants during sample handling. The soils collected in the auger were removed with a stainless steel spatula and collected in a decontaminated glass mixing bowl. Soil sampling followed the same procedures outlined for split spoon sampling.

4.3.2.4 Boring Logs. During the drilling and sampling operations, the Site Geologists recorded all activities in the field boring logs. Upon completion of each boring or well, information from the boring logs was transferred to the Field Drilling or Well Construction File form, and original boring logs were submitted to USATHAMA following completion of the boring or well. The following data were recorded in the boring logs in real-time at the drill site:

a. Depths in feet and fractions thereof (tenths of inches). Measurements were entered on the data entry forms.

b. Soil descriptions, in accordance with the Unified Soil Classification System (USCS), including the following items:

    1. Classification
    2. USCS symbol
    3. Secondary components and estimated percentage
    4. Color (using Munsell Soil Color Chart)
    5. Plasticity
    6. Consistency (cohesive soil) or density (noncohesive soil)
    7. Moisture content
    8. Texture/fabric/bedding
    9. Depositional environment

c. Cutting descriptions, including basic classification, secondary components, and other apparent parameters.

d. Numerical, visual estimates of secondary soil constituents (If terms such as "trace," "some," or "several" are used, their quantitative meanings were defined in a general legend)

e. Length of sample recovered for each sampled interval for driven (split-spoon) samples.

f. Blow counts, hammer weight, and length of fall for split-spoon samples.

g. Estimated interval for each sample.

h. Depth to water first-encountered during drilling and the method of determination (Any distinct water-bearing zones below the first zone also were noted).

i. When drilling fluid was used, fluid losses, quantities lost, and the intervals over which they occurred.

j. General description of the drilling equipment used, including the rod size, bit type, pump type, rig manufacturer, model, and drilling personnel.

k. Drilling sequence.

l. Any unusual problems.

m. Start and completion dates of all borings, and a chronological time-sequence of all events.

n. Lithologic boundaries.

The boring logs were submitted directly from the field to the Contracting Officer's Representative. In cases where a monitoring well was installed in the borehole, both the log for that boring and the well installation sketch were submitted.

4.3.2.5 Equipment Decontamination. At the conclusion of all borings/drilling activities, all downhole drilling equipment and sampling tools, including the rig, were decontaminated using the methods outlined by EPA Region IV prior to moving to the next location. All decontamination activities were performed in the leak-proof decontamination pad described in Section 4.1.1. The decontamination process was conducted according to the following procedures:

a. Steam cleaning using unchlorinated water from the approved source (Production well T-99).

b. Brush cleaning with unchlorinated water and EPA approved laboratory detergent (Alconox).

c. Rinse with unchlorinated water.

d. Rinse with deionized, organic-free water.

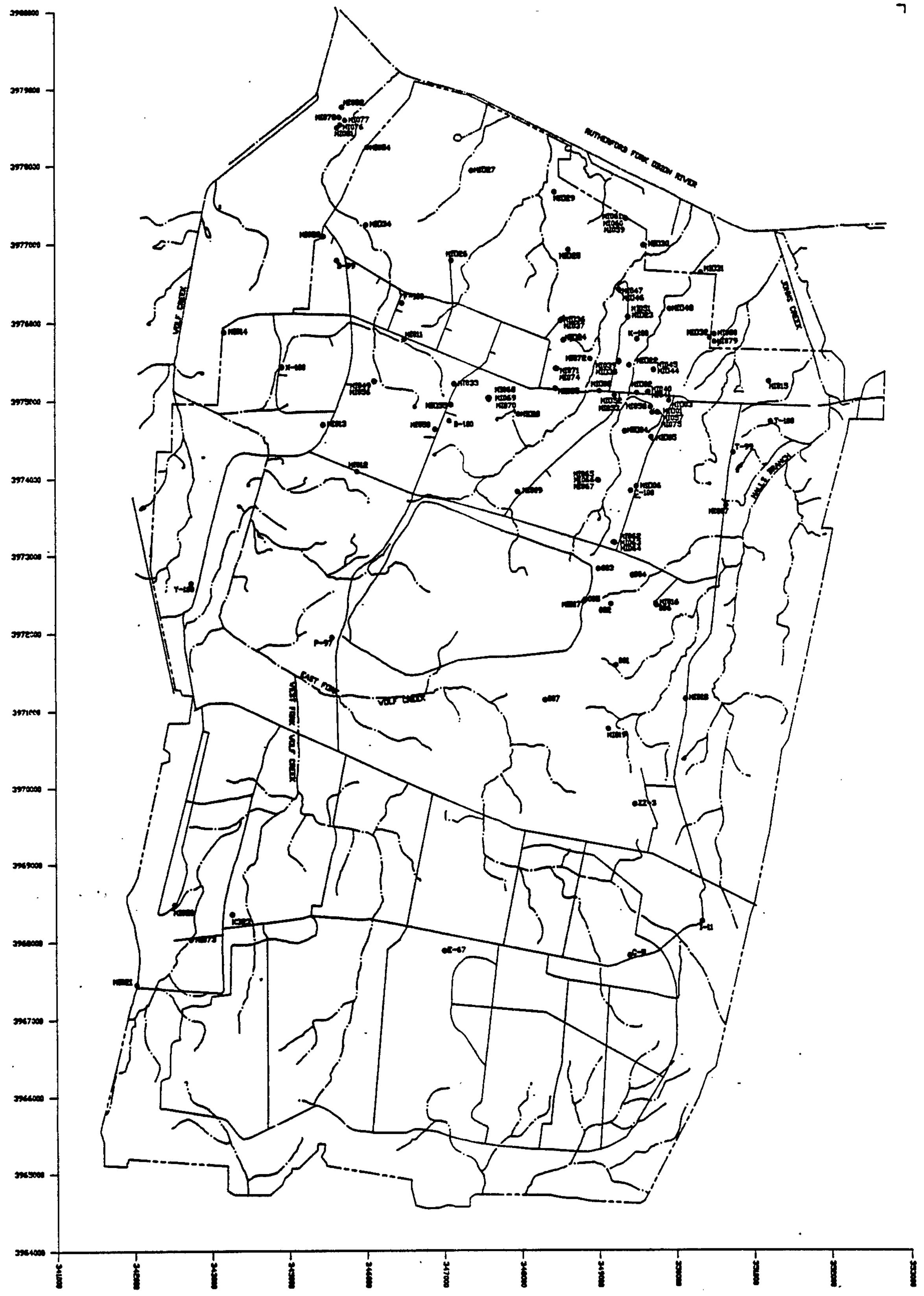
e. Rinse with isopropanol.

f. Final rinse with deionized, organic-free water.

The portion of the drill rig that was over the hole was steam cleaned using approved, unchlorinated water and scrubbed with a wire brush prior to moving to the next location. Water generated during this process was pumped from the decon pad into a holding tank to allow solids to settle to the bottom of the tank. The water was then transported to O-Line, treated by the PWTF, and discharged into the drainage ditch system. Split spoons were decontaminated at the drill sites following the above steps with the exception of steam cleaning. All water generated during the decontamination of split spoons at the boring sites was containerized in 55-gallon drums, transported to O-Line, and discharged to the wastewater treatment system. Sediment accumulated in the holding tank at the decon pad was transferred into labeled 55-gallon drums and transported to the temporary storage area at the OBG. Decontamination rinse blanks for sampling equipment were collected periodically between sampling sites to determine if cross-contamination was occurring. The stainless steel split spoon samplers and all sample handling equipment were wrapped with aluminum foil after cleaning to prevent them from becoming contaminated while moving to the next sampling site. In addition, all drill rods and augers were wrapped in plastic sheeting to prevent contamination while moving.

4.4 MONITORING WELL PROGRAM

Twenty-six groundwater monitoring wells were installed to define the presence and extent of groundwater contamination beneath the site and in off-post areas to the northeast and northwest of MAAP. These wells are designated as MI057 to MI082 in Figure 4-14. The wells were installed to



LEGEND
- —·— STREAM/DRAINAGE
- —-— PROPERTY LINE
- ● MONITORING WELL
- —— GROUNDWATER CONTOUR
- APPARENT SURVEY ERROR

0 500 1000 1500 METERS
0 1000 2000 3000 4000 5000 FEET
0 .5 1 MILES
1000 M UTM GRID TICKS, ZONE 16

-N-

ICF KAISER ENGINEERS
9300 LEE HIGHWAY
FAIRFAX, VIRGINIA
22031-1207

TITLE USATHAMA REMEDIAL INVESTIGATION

FIGURE 4-14
LOCATIONS OF GROUNDWATER
MONITORING WELLS AND
PRODUCTION WELLS

SIZE	PROJECT CODE	DWG NO.
B	30874	04019104

SCALE: AS NOTED | DRAWN BY: K. BOLER | CHECKED BY: N. OKUSU supplement the information from the existing 63 on-site monitoring wells and 15 production wells. This monitoring well system was used to define the extent of groundwater contamination and to determine if the suspected source areas (the O-Line Ponds area, the OBG and ADA areas, Former Burn Out Area, Former Borrow Pit, Closed Landfill, LAP lines, and drainage ditches) are continuing to impact groundwater quality. The rationale for the location of the groundwater monitoring wells is described in Section 4.4.1. The well installation procedures are described in Sections 4.4.2 to 4.4.4.

4.4.1 Monitoring Well Location Rationale

Twelve of the twenty-six monitoring wells are grouped together in units of three wells each and are referred to as cluster wells. Each cluster contains a shallow, intermediate, and deep well which allows sampling of the water in the upper, middle and lower portions of the aquifer. Because the wells in a cluster are close to each other (within a 40-foot radius of the center well), the vertical distribution of groundwater contamination can be determined.

In addition to these cluster wells, four of the newly-installed monitoring wells are grouped as paired wells. In each pair, one monitoring well is constructed of stainless steel and the other is constructed of PVC. The well installation and construction, with the exception of the casing material, is identical for the well pair. Data from the well pairs were used to evaluate the effects of casing composition, if any, on sampling results.

The remaining ten newly-installed wells were installed to investigate contamination on-site and in off-post residential and agricultural areas downgradient from the O-Line Ponds and OBG. To eliminate any doubt about the validity of the chemical analysis of samples from off-post areas, all off-post wells installed during this investigation are constructed of stainless steel.

The location, depth, and rationale for each newly-installed monitoring well is listed in Table 4-5. Other information contained in this table includes well construction materials and well completion date.

4.4.1.1 Open Burning Ground. Two sets of cluster wells are located directly downgradient of the OBG and the ADAs to determine the vertical and lateral extent of contaminant migration in the groundwater. Wells MI062, MI063, and MI064 are located north of and immediately adjacent to the OBG; wells MI065, MI066, and MI067 are located farther north of the OBG, at a point to the east of LAP Line D.

Previous studies have shown that the groundwater downgradient from the OBG and ADA area is contaminated with explosives (USATHAMA, 1983a, and RCRA data in Appendix C). An investigation conducted in late 1987 (PBSJ, 1988) indicated that several areas with explosive-contaminated soils exist at the OBG. Because of the age of the OBG and the relatively permeable soils characteristic of the MAAP site, there is a moderate to high potential for groundwater contamination to occur from these sources.

4.4.1.2 O-Line Ponds. Explosive compounds have been detected in the shallow groundwater directly beneath the O-Line Ponds and in deeper wells located north of the O-Line Ponds area. Sampling conducted since the ponds were filled in and capped has detected contaminants at nearly constant concentrations throughout the monitoring period (IRDMS data). The purpose of the well installations in the immediate area of the O-Line Ponds is to determine if the groundwater at an intermediate depth is contaminated beneath the ponds and also to determine the magnitude of shallow groundwater contamination northwest of the ponds. Monitoring well MI057, an intermediate well, is located next to existing well MI001, a shallow well. Well MI058, a shallow well, is located approximately 500 feet west of the O-Line Ponds. This well is located near Ditch 5 which is the drainage ditch that receives runoff from the historic O-Line Ponds operation and the current O-Line wastewater treatment plant effluent.

One well cluster is also located north of the O-Line Ponds between Area M and the northern boundary of the facility, approximately 1.5 miles downgradient of the O-Line Ponds. Historic well sampling data showed trace amounts of explosives 10 years ago on the northern boundary of MAAP. Subsequent

TABLE 4-5

LOCATION AND DEPTH OF GROUNDWATER MONITORING WELLS AND LOCATION RATIONALE

Monitoring Well No.	Casing Type (schedule 40 or 80 PVC, or stainless steel)	Portion of Water Table Aquifer to be Monitored	Depth of Saturated Water Table (ft below ground surface)	Depth of Well Screened Interval (ft below ground surface)	Total Well Depth Drilled (ft)	Description of Location and Rationale Used to Justify Monitoring Well Placement	Completion Date
MI057	PVC-40	Middle	46	160-170	172	Approximately 50 ft north of the O-Line Ponds on the downgradient side. To be paired with well MI001 (upper). Together they will define the vertical extent of contamination to a depth of 170 feet beneath the O-Line Ponds.	11-4-90
MI058	PVC-40	Upper	52	64.5-74.5	75	West of the O-Line Ponds, approximately 500 ft, to define the western extent of contamination in the upper portion of the aquifer.	8-27-90
MI059 MI060 MI061	PVC-40 PVC-40 PVC-40	Upper Middle Lower	16 16 14	18-28 139.5-149.5 234.5-244.5	30 152 247	Northeast of Igloo area "M." Placed downgradient of the O-Line Ponds approximately 1.5 miles to determine the presence/extent of contamination emanating from the O-line Ponds in the upper, middle, and lower portions of the aquifer as they reach MAAP's northern boundary.	9-22-90 9-26-90 8-29-90
MI062 MI063 MI064	PVC-40 PVC-40 PVC-80	Upper Middle Lower	91 95 90	89-99 149.5-159.5 236-246	100 160 246.5	North of the OBG, placed downgradient at a distance of about 3000 ft, to detect the presence of contamination migrating from the OBG in the upper, middle, and lower portion of the aquifer.	8-1-90 10-8-90 9-20-90
MI065 MI066 MI067	PVC-40 PVC-40 PVC-80	Upper Middle Lower	95 83 79	99-109 160-170 241-251	109.5 172 252	Placed along the same direction from the OBG as MI062, 063, and 064, located an additional 2500 ft downgradient, to detect the presence/extent of contamination migrating from the OBG in the upper, middle, and lower portion of the aquifer.	8-9-90 10-12-90 10-9-90
MI068 MI069 MI070	PVC-40 PVC-40 PVC-80	Upper Middle Lower	82 68	88-98 161-171 240-250	100 175 252	Northeast of LAP Line B, approximately 800 ft downgradient, to detect the presence of contamination migrating from LAP Line B in the upper, middle, and lower portion of the aquifer.	8-11-90 10-24-90 10-23-90
MI071	PVC-40	Upper	50	54-64	65	North of the construction debris pit, approximately 500 ft, downgradient, to detect the presence of contamination migrating from the pit.	8-22-90

TABLE 4-5 (Continued)

LOCATION AND DEPTH OF GROUNDWATER MONITORING WELLS AND LOCATION RATIONALE

Monitoring Well No.	Casing Type (schedule 40 or 80 PVC, or stainless steel)	Portion of Water Table Aquifer to be Monitored	Depth of Saturated Water Table (ft below ground surface)	Depth of Well Screened Interval (ft below ground surface)	Total Well Depth Drilled (ft)	Description of Location and Rationale Used to Justify Monitoring Well Placement	Completion Date
MI072	PVC-40	Upper	25	34-44	45	North of the closed landfill, approximately 20 to 50 ft from its boundary, to detect the presence of contamination migrating from the landfill.	8-26-90
MI073	PVC-40	Upper	80	83-93	93.5	North of Area "A" (former burn-out area), approximately 50 ft downgradient, to detect the presence of contaminations migrating from the area.	8-21-90
MIO74	Stainless Steel	Upper	46	54-64	65	North of construction debris pit and downgradient, to detect contamination migrating from pit and assess data quality from MI071.	9-6-90
MIO75	Stainless Steel	Middle	49	160-170	170.5	Approximately 50 feet north of the O-Line Ponds on the downgradient side. Paired with PVC well MI057 to assess data quality.	11-7-90
MIO76	Stainless Steel	Upper	28	33-43	45	Approximately 1,600 feet northwest of MAAP boundary on east side of Tennessee State Highway 79. Installed to sample and assess contamination off-post and downgradient from O-Line and OBG. Located near the Bledsoe well.	10-19-90
MIO77	Stainless Steel	Upper	28	44.5-54.5	55	Same as MI076.	10-22-90
MIO78	Stainless Steel	Upper	21	29-39	40	Approximately 1,800 feet northwest of MAAP boundary on west side of Tennessee State Highway 79. Installed to assess off-post contamination downgradient from O-Line and OBG.	10-24-90
MIO79	Stainless Steel	Upper	25	45-55	57.5	Approximately 200 yards east of MI032, near the National Guard property, northeast of the facility. Installed to assess off-post contamination.	11-2-90

TABLE 4-5 (Continued)

LOCATION AND DEPTH OF GROUNDWATER MONITORING WELLS AND LOCATION RATIONALE

Monitoring Well No.	Casing Type (schedule 40 or 80 PVC, or stainless steel)	Portion of Water Table Aquifer to be Monitored	Depth of Saturated Water Table (ft below ground surface)	Depth of Well Screened Interval (ft below ground surface)	Total Well Depth Drilled (ft)	Description of Location and Rationale Used to Justify Monitoring Well Placement	Completion Date
MIO80	Stainless Steel	Upper	26	44.5-54.5	55	Same as MI079.	11-2-90
MIO81	Stainless Steel	Upper	28	35-45	47.5	Same as MI076.	11-4-90
MIO82	Stainless Steel	Upper	20	34-44	45	Same as MI078. Located northwest of the New Hope Baptist Church.	11-5-90

sampling in 1983 did not detect any of these contaminants; however, all of the northern boundary wells are upper (shallow) wells. Additionally, 1988 and 1989 sampling results for monitoring well MI046, located approximately 1/2 mile south of the plant boundary, showed significant amounts of explosive contamination in the groundwater. This particular well is screened at a deeper depth (the middle of the aquifer) than the boundary wells. Cluster wells MI059, MI060, and MI061 are screened in the upper, middle, and lower portion of the aquifer in this area and were used to determine if contaminants are migrating at greater depths than can be detected in the shallow boundary wells.

4.4.1.3 Line B. Since 1979, explosives have been detected in groundwater samples collected from an upper groundwater monitoring well located downgradient of LAP Line B (IRDMS data). However, this well (MI010) is also located close to Area J. There are also reports of historical pooling of wash-down water in a swampy area behind LAP Line B. For these reasons, a set of cluster wells is located north of Line B, between the line and Area J. Sampling results from this cluster were used to determine the presence and vertical distribution of potential explosives contamination emanating from Line B.

4.4.1.4 Other Solid Waste Management Units (SWMUs) and Off-Post Wells. Monitoring wells were installed to determine the quality of groundwater in the vicinity of specific SWMUs and assess off-post groundwater contamination migration. Two wells (MI071 and MI074) are located directly downgradient of the Former Borrow Pit. These wells form a stainless steel/PVC pair to determine if there is interference between the contaminants and the PVC. Two other wells are single upper monitoring wells designed to investigate releases from SWMUs, specifically the Former Burn Out Area (MI073), and the Closed Landfill (MI072).

In addition to the on-post monitoring wells, seven new off-post monitoring wells were installed during the RI at the request of USATHAMA: five shallow wells on the northwest side of the facility and 2 wells on the northeast side of the facility. The five northwest wells were installed near the existing Bledsoe and New Hope Baptist Church residential wells. Three wells (MI076, MI077, and MI081) are located on the east side of Highway 79 (on the University of Tennessee property) and two wells (MI078 and MI082) are located on the west side of the highway. These wells were installed to evaluate groundwater quality in a 200 yard radius around the existing residential wells. Between 1982 and 1988, sampling conducted by the TDHE indicated that these wells were contaminated by explosive compounds (TDHE data, Appendix C). The depths of the existing residential wells are not known, but are presumed to be between 40 to 60 feet deep. The existing hand-dug well on the Bledsoe property, which is not used for drinking water, is 36 feet deep.

The other two off-post wells were installed near the National Guard property. One well (MI079) is located approximately 200 feet to the east of MI032, which is an existing monitoring well installed by USATHAMA in 1982. The second well (MI080) is located approximately 250 feet to the northeast of MI032, placing it almost directly north of MI080. Both of these newly-installed wells are screened just below the water table.

4.4.2 Drilling of Boreholes for Groundwater Monitoring Wells

Both hollow-stem and mud rotary drilling techniques were used to drill the boreholes for monitoring well installation. Shallow wells were drilled using hollow-stem augers to allow better determination of the depth to groundwater.

The total depth of each monitoring well was based on an evaluation of all geologic data obtained during drilling. At each of the well cluster locations the shallow, or upper, groundwater monitoring well was drilled first using hollow-stem augers. The well screen for the upper monitoring well was placed to intersect the water table or at an interval 2-20 feet below the water table. Once direct measurement of the depth to the groundwater surface had been determined, the probable depths for the intermediate and lower monitoring well screened intervals were estimated. The deep well of the cluster was installed next. Split-spoon samples were not collected during drilling of the deep borehole until the depth of the hole equaled the depth of the shallow well. After that point, split-spoon samples were collected at five foot intervals down to the final depth of the deep well. The lithology information gained during drilling the deep well was used to select a completion horizon for the intermediate well. Split spoon samples were not collected while drilling the intermediate well borehole, with the exception that a sample was taken at the selected depth of the screened interval. If the sample collected from this interval did not exhibit the desired lithology, the bore was advanced and another soil sample was collected.

4.4.2.1 Hollow-Stem Auger Drilling/Sampling. A truck-mounted hollow-stem auger drill rig (CME-75, Mobile B-61) was used to drill the shallow monitoring wells at MAAP. The hollow stem augers had an inside diameter of 6.25 inches. As the augers were advanced, split spoon samples were collected at 5-foot intervals, or at each change in lithology. The soil samples were collected with either a 2-foot or 18-inch long, stainless steel split spoon sampler driven into the soils beyond the end of the augers. Sample collection for the purposes of lithologic description and physical testing followed the same procedures outlined for soil borings (Section 4.3.2). In addition, a portion of the sample in each split spoon was collected and composited for chemical analysis. These samples were collected to assess levels of contamination present in the drummed cuttings from each well.

Heaving sands were often encountered during drilling, at the depth of groundwater. When heaving sands were encountered water or a dilute mixture of water and bentonite were added to the interior of the auger to equalize pressures and prevent additional sand from being injected up into the augers. For additional details on problems encountered during drilling see Appendix F. Boring logs and well construction sketches for monitoring wells installed during the RI investigation are presented in Appendix G.

4.4.2.2 Mud Rotary Drilling/Sampling. Failing 1250 and 1500 drill rigs were used to install the intermediate and deep wells using the mud rotary technique. Each drill rig was equipped with a retractable rotary table, mud pump, drill pipes, 1-3/4 inch sampling rods, and portable mud pits. Prior to arriving at a monitoring well site, all equipment was decontaminated according to the procedures outlined in Section 4.3.2. The decontaminated drill pipes, sampling rods, and other down-hole equipment were then wrapped in plastic and transported to the site. The drill rig was positioned over the staked boring location and plumbness was obtained by careful leveling of the drill rig prior to commencement of drilling. In addition, drilling proceeded in an efficient and controlled manner to eliminate wobble/chatter in the drill stem. The following setup procedures were conducted in preparation for drilling of the monitoring well borehole.

a. The surface casing was positioned and hammered approximately 2-3 feet into the ground surface with a 300-lb hammer.

b. Bentonite pellets were placed around the surface casing on the ground surface and wetted to seal the casing and prevent mud seepage during drilling.

c. The mud pit was set in place and leveled. The capacity of the mud pit was calculated by the Site Geologist and fluid losses/additions were recorded during drilling operations.

d. The mud pit was filled with water and Baroid Quik-gel bentonite was added to the water while circulating the mixture through the mud pump to ensure thorough mixing. A sample of the mud was collected prior to drilling and analyzed for TAL/TCL and explosive constituents to ensure that decontamination procedures were effective. Results of the chemical analyses indicated that cross-contamination did not occur between mud rotary drilling sites, and that the materials used were of consistent quality.

Following these initial setup procedures, a 9 7/8-inch drag bit was attached to 2-inch diameter drill pipe and inserted into the surface casing area. All drilling mud which circulated to the surface during the drilling operations was contained in a steel mud pit. The mud pit contained three baffled chambers. Two chambers allowed settling of the sediments from the mud and the third chamber was a suction pit where the pump recirculated the fluid back through the drill pipe. Cuttings which washed up during drilling were removed from the mud pit and containerized in 55-gallon drums. The drums were labeled with the monitoring well site designation, date, identification of contents, and depth interval of origination for the cuttings.

All borings drilled with the mud rotary technique were drilled following the same procedures as previously outlined with the exception of borings for monitoring wells MI061 and MI064. These borings were initially drilled with a 6 1/2-inch diameter drag bit and reamed with a 9 7/8-inch drag bit. The smaller bit was initially used because the unconsolidated sediments underlying MAAP were considered unstable and it was thought that they would easily collapse during drilling of a large diameter borehole. The drilling procedure was subsequently modified to use a 9 7/8-inch drag bit after determining that hole stability was not a problem. The design of the 9 7/8-inch drag bit was modified to allow split spoon sampling through the bit.

Split spoon sampling was conducted in the deep borings at five-foot intervals starting below the depth of the last sample interval from the shallow well. Split spoon samples were collected by inserting the split spoon attached to 1 3/4-inch sampling rods inside of the drill pipe. Either a 2-foot or 18-inch long, stainless steel split spoon sampler was driven into the formation beyond the head of the bit using a 140-lb hammer. The Site Geologist determined the final depth of the borehole by examining the split spoon samples and identifying an interval appropriate for installation of the well screen. At all well locations, the well screen was installed in a lithologic interval which does not contain clay.

After drilling was completed and prior to the installation of well casing, the mud was thinned/displaced by pumping water down the drill pipe. All displaced drilling mud was then containerized in 55-gallon drums. These drums were labeled with the identification of contents, boring site, and date. All drums at the monitoring well sites were sealed and transported to the drum storage area at the OBG following completion of the monitoring well installation.

Intermediate wells drilled at cluster well sites were only sampled within the screened interval of the well, as previously discussed. The only exception was intermediate well MI057, which was sampled from the top to the bottom of the boring.

During sampling and well installation procedures, all personnel handling the sampling rods, spit spoon and sampling equipment wore clean latex or polyethylene gloves to prevent the introduction of contaminants during equipment and sample handling.

4.4.3 Groundwater Monitoring Well Design and Construction

A diagram of monitoring well construction is shown in Figure 4-15. The shallow monitoring wells are constructed of flush-threaded Schedule 40, 4-inch diameter PVC casing and screens or flush-threaded, 4-inch diameter, stainless steel casing with wire wrapped screens. The intermediate wells are constructed of Schedule 40, 4-inch diameter PVC casing and screens. The deep wells are constructed of flush-threaded Schedule 80, 3.8-inch diameter PVC casing for added wall strength. All well screens have a solid bottom and were factory slotted, with a slot width of 0.010-inch. Solid casing extends from the screen to approximately 2.5-feet above land surface. A loose-fitting cap was placed on top of the riser. The PVC materials used for well construction at MAAP conform to National Sanitation Foundation Standard 14 for potable water usage or American Society for Testing and Materials equivalent. All PVC and stainless steel screens and casing were precleaned and wrapped in plastic prior to arrival on-site. No plastic solvents or glues were used on any of the well materials, including the stainless steel centralizers installed on monitoring well MI061.

The grout used in well construction was composed by weight of 20 parts Type II Portland cement to one part Baroid Quik-gel bentonite, with a maximum of 8 gallons of approved water per 94-pound bag

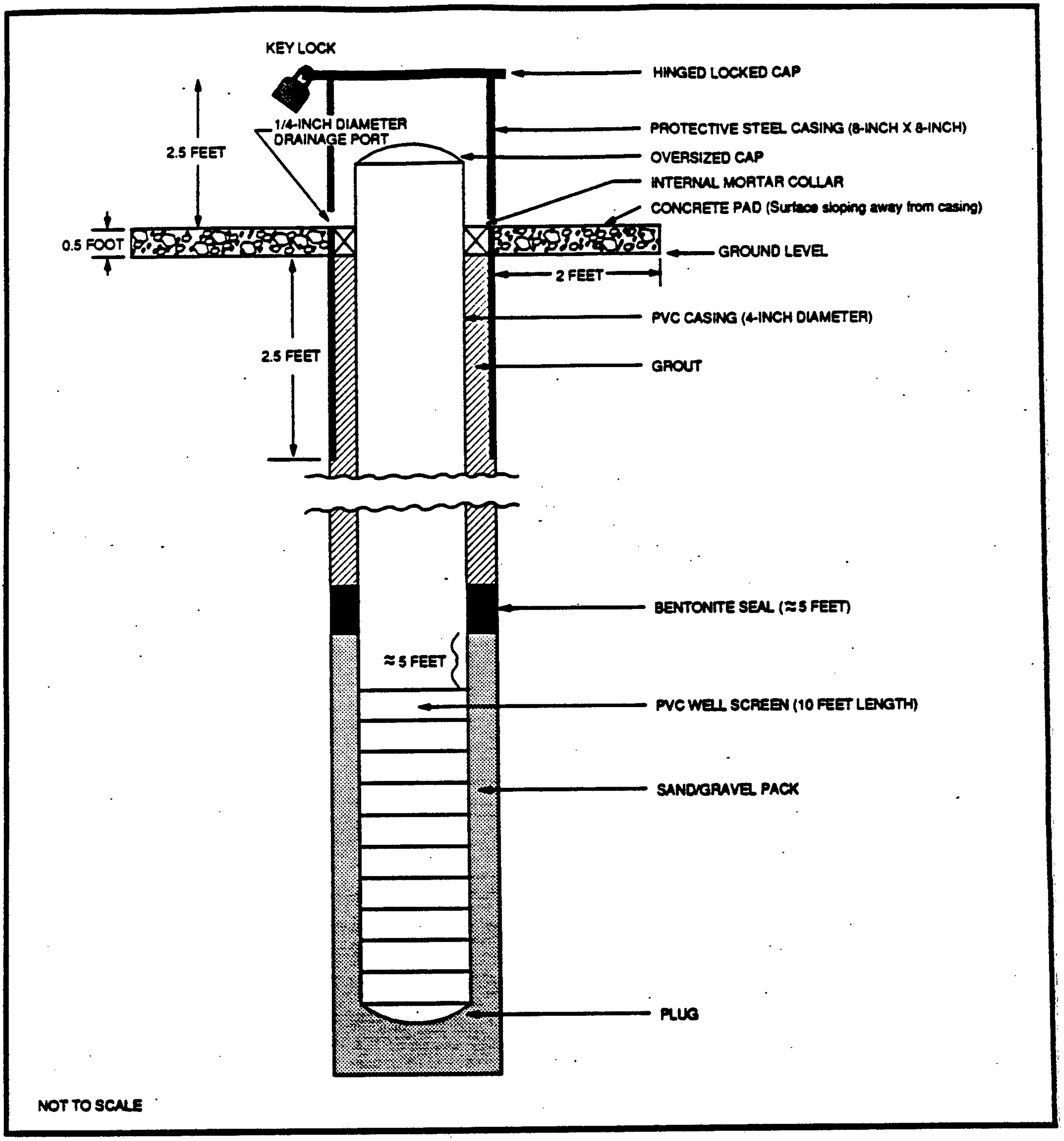


Figure 4-15
Groundwater Monitor Well Construction

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of cement. Bentonite was added after mixing of the cement and water. Specifications and a sample of bentonite were submitted to USATHAMA for approval prior to use.

The sand pack filter material consisted of Colorado 20/40 silica sand. This size is compatible with both the screen slot size and aquifer materials. A jar of the material was submitted to USATHAMA for approval, along with information on the lithology, grain-size distribution, and source of the material prior to use.

An 8-inch by 8-inch protective iron casing was installed over the top of the PVC or stainless steel riser. This casing extends approximately 2.5 feet above land surface and is seated 2.5 feet into the well seal grout. The iron casing includes a padlocked, hinged cap. The well was vented to the atmosphere via a loose-fitting PVC cap, which will prevent entry of water but is not airtight. This design allows the well to be open to the atmosphere and allows for groundwater level stabilization. In accordance with the Geotechnical Requirements, a 1/4-inch diameter drainage port was installed, centered 1/8-inch above the level of the internal mortar collar. The same key is used for all padlocks at the site.

A protective concrete pad was installed around each well. The pad consists of a 4'x4'x6" thick concrete pad which slopes away from the protective casing and extends 2 feet below the ground surface around the area of the riser.

The exterior of the protective casing is painted orange and the well designation was hand painted with a brush on the top and side of the protective casing with white paint. Four steel pickets, each radially located within four feet of the well, and placed two to three feet below ground and extending 3 feet above ground are cemented into the surrounding protective concrete pad. These pickets are also painted in order to facilitate observation from a distance and flagged in areas that are overgrown by vegetation. Each of these activities was completed prior to ground water sampling.

4.4.4 Groundwater Monitoring Well Installation Procedures

When a boring was completed, the Site Geologist visually inspected the hole before the monitoring well was installed. All well installations occurred within 12 hours of boring completion, and, once begun, continued uninterrupted until well installation was complete or until the bentonite seal was installed.

The well screen and casing arrived on-site from the factory pre-cleaned and wrapped in plastic by the manufacturer and were carefully decontaminated using the procedures outlined in Section 4.3.2. The well casing was then wrapped in clean plastic sheeting and transported to the drill site. The screen and casing were then lowered into the borehole by 30 foot sections using a gin line on the drill rig. In those cases where mud rotary drilling was used, all drilling mud remaining in the borehole was displaced with water prior to the insertion of the well casing. Clean latex gloves were worn at all times during the handling of well screens and casing.

Following the placement of the casing into the borehole, the sand pack was installed through a tremie pipe around the well screen to a height of approximately 5 feet above the well screen. A 5-foot bentonite slurry seal was pumped in place on top of the filter material through the tremie pipe, and unchlorinated water from the approved source was added after the slurry to assure complete ejection of the bentonite slurry from the tremie pipe. The bentonite seal was allowed to harden for a minimum of one hour. The thickness of the sand pack and bentonite seal were verified using a cable and tag method.

A gel-cement grout seal consisting of Type II Portland cement and bentonite was installed from the top of the bentonite seal to two feet below the land surface. Grouting was performed in a continuous operation in the presence of the Site Geologist. The grout was pumped into the annular space under pressure using a tremie pipe. Sections of tremie pipe were periodically removed during the grouting process; however, the bottom of the tremie pipe remained within the grout mixture to ensure a continuous grout seal. The grout was allowed to set for a minimum of 12 hours, and generally for 24 hours or more. After the grout seal set, it was checked for settlement, and additional grout was added when necessary to fill any depressions. An 8-inch diameter steel protective casing was then placed over the well to ensure protection of the well. The protective casing was sealed in the grout to a depth of at least 2-1/2 feet. Protective posts were installed around the well to prevent damage to the wells by vehicular operation.

Appendix G contains the boring logs and well construction sketches which illustrate by depth, the bottom of the boring, screen location, coupling location, granular backfill, seals, grout, and height of riser above ground surface. Well sketches also include details about the protective casing.

4.4.4.1 Problems Encountered During Monitoring Well Installation. During the installation of monitoring wells, difficulties were encountered during drilling and well installation. The following problems have affected the intended design of the monitoring well construction and in one case impacted groundwater flow to the well.

Heaving sands were frequently encountered during shallow monitoring well installations. Heaving sands are an inherent physical characteristic of this geologic formation, where water-saturated sand is pushed upward into the hollow-stem augers by subsurface pressures. While drilling the borehole for MI059, heaving sands ultimately necessitated abandonment of the first borehole (See Appendix D-Technical Memoranda on Field Activities). This well was later successfully installed.

Heaving sands were also encountered at a depth of 45 feet during the installation of monitoring well MI081. The pressure in the auger was equalized with the formation pressure by adding a dilute slurry of water and bentonite inside the augers. During the installation of the granular filter pack, the tremie pipe repeatedly jammed between the stainless steel casing and augers. The casing was removed and reinstalled several times. During each successive attempt to install the well casing, heaving sands were forced into the augers. The pressure in the augers was eventually stabilized by adding water to the augers. The hole then required redrilling inside of the augers utilizing a 5 3/4-inch roller bit in an attempt to remove all sand from the interior of the augers and prevent jamming of the tremie pipe between the well casing and the augers. The monitoring well was then successfully installed with a fluid loss of 850 gallons of water and 1 bag (50 lbs) of bentonite to the formation. During well development, this well sustained a minimal flow rate of 2 gallons per minute (gpm), which was probably due to the well installation procedures. The porosity of the formation was apparently reduced due to the quantities of water and bentonite injected through the augers and lost to the formation during well installation.

Difficulties were encountered during development of monitoring well MI069. Attempts to introduce a 3 6/8-inch F&W pump to the well failed due to a restricted zone that was encountered at a depth of 21.9 feet. A 3-inch Trico pump was inserted into the casing, which cleared the restricted zone. The restricted zone in the PVC casing is located 0.9 feet below a joint and is not considered an artifact of the well construction or materials. The constricted zone is probably the result of warping caused by heat generated from setting grout. Collapse of formation sands during drilling probably washed sands out of this area, which resulted in a large void space in the borehole. The volume of grout pumped into the annular space exceeded the calculated volume, which indicates that additional grout was needed to fill this void space.

4.4.5 Monitoring Well Development

The newly-installed wells were developed according to USATHAMA protocol and the development records are included in Appendix H. The development was performed no less than two days after well installation was completed, as shown in the schedule outlined in Table 4-6. Well development did not always occur within the time frame established in the work plan. Failure to meet the established well development goals of up to seven days after well installation occurred for several reasons. Equipment problems were encountered during the initial phase of the well development process that resulted in schedule delays. Additional schedule delays were encountered due to site access difficulties. Access

TABLE 4-6

MAAP MONITORING WELL DEVELOPMENT SCHEDULE

WELL I.D.	DATE COMPLETE	DATE DEVELOPED (1990)	STATIC WATER LEVEL	CASING TYPE	FLUIDS LOST DURING DRILLING (GAL)	VOLUME REMOVED (GAL)
NORTH OF O LINE						
MI057	11/04/90	11/10-11/12	48.24	SCH 40 PVC	1,088	6,100
MI058	08/27/90	09/06	47.15	SCH 40 PVC	350	2,100
MI075	11/07/90	11/12-11/14	49.24	Stainless steel	1,093	6,150
NORTHEAST OF IGLOO AREA M						
MI059	09/22/90	09/25	15.3	SCH 40 PVC	20	250
MI060	09/26/90	10/17-10/19	16	SCH 40 PVC	2,508	5,400
MI061	08/29/90	09/19	16	SCH 80 PVC	2,000	5,000
NORTH OF OPEN BURING GROUND						
MI062	08/01/90	08/14-08/15	93.5	SCH 40 PVC	120	2,015
MI063	10/08/90	10/11-10/12	94.4	SCH 40 PVC	2,800	5,550
MI064	09/20/90	10/07-10/10	104.1	SCH 80 PVC	2,582	5,200
NORTH OF OPEN BURNING GROUND (EAST OF D LINE)						
MI065	08/09/90	08/15	79.1	SCH 40 PVC	150	1,020
MI066	10/12/90	11/01-11/02	82.68	SCH 40 PVC	1,617	5,500
MI067	10/09/90	10/21-10/24	78.9	SCH 80 PVC	870	6,200
NORTH EAST OF LINE B						
MI068	08/11/90	08/21	84.6	SCH 40 PVC	325	1,870
MI069	10/24/90	11/03-11/06	70.58	SCH 40 PVC	4,700	6,255
MI070	10/23/90	11/07-11/10	81.6	SCH 80 PVC	2,000	5,000
NORTH OF CONSTRUCTION DEBRIS PIT (H LINE)						
MI071	08/24/90	08/29/90	48.8	SCH 40 PVC	100	800
MI074	09/06/90	09/11-09/12	48.8	Stainless steel	400	2,200
NORTH OF CLOSED LANDFILL						
MI072	08/26/90	09/09-09/13	28.46	SCH 40 PVC	270	1,500
NORTH OF FORMER BURNING GROUND (SUNNY SLOPE)						
MI073	08/21/90	08/27	67.6	SCH 40 PVC	305	1,780

TABLE 4-6 (Continued)

MAAP MONITORING WELL DEVELOPMENT SCHEDULE

WELL I.D.	DATE COMPLETE	DATE DEVELOPED (1990)	STATIC WATER LEVEL	CASING TYPE	FLUIDS LOST DURING DRILLING (GAL)	VOLUME REMOVED (GAL)
OFF POST NORTHWEST OF FACILITY						
MI076	10/19/90	10/24	30	Stainless steel	145	1,000
MI077	10/22/90	10/25	29.4	Stainless steel	205	1,600
MI078	10/24/90	10/27	24.58	Stainless steel	250	1,440
MI081	11/04/90	11/15-11/17	32.8	Stainless steel	783	2,058
MI082	11/05/90	11/14	11.97	Stainless steel	330	2,050
OFF POST NORTH OF AREA Q (TN NATIONAL GUARD)						
MI079	11/02/90	11/13	31.9	Stainless steel	275	1,730
MI080	11/02/90	11/13	28.2	Stainless steel	210	1,250

to monitoring well sites was restricted on several occasions due to inclement weather degrading routes to the sites and preventing vehicular access.

The following data were recorded for development, as required in the geotechnical requirements:

a. Well designation.

b. Date of well installation.

c. Date of development.

d. Static water level before and 24 hours after development.

e. Quantity of water lost during drilling and fluid purging, if water was used.

f. Quantity of standing water in well and annulus (30 percent porosity assumed for calculation) prior to development.

g. Specific conductivity, temperature, and pH measurements taken and recorded at approximately 15 minute intervals throughout the development process. Calibration standards were run prior to and after each day's operation in the field.

h. Depth from top of well casing to bottom of well.

i. Screen length.

j. Depth from top of well casing to top of sediment inside well, before and after development.

k. Physical character of removed water, including changes during development in clarity, color, particulates, and odor.

m. Type and size/capacity of pump and/or bailer used.

n. Description of surge technique, if used

o. Height of well casing above ground surface.

p. Quantity of water removed and removal time.

Development of wells was accomplished by pumping the groundwater with an electric-powered submersible pump until the water was clear and the well sediment free to the fullest extent practical. Groundwater was removed from the upper portion of the water table. Periodically during development, the well was surged (the power to the pump was turned off and the water in the pump pipe flowed back down the pipe) and swabbed (the pump, which fit tightly inside the well casing, was lifted up and down inside the well screen while the pump was operating). The four-inch Schedule 40 PVC wells were developed with either a 3-6/8 inch diameter F&W pump or a 3.9-inch diameter Grundfos pump, and a 3-inch Trico pump was used in the 3.8-inch Schedule 80 wells. Water was not added to the wells to aid in development, nor were any type of air-lift techniques used. The pump was decontaminated according to the procedures outlined in Section 4.2.2 and allowed to air dry before it was used in the next well.

A total of 81,018 gallons of well development water was containerized over the course of the well development activities at MAAP. The well development water was initially containerized in a portable tank at the well site then transferred to a holding tank at the decontamination pad where the turbid water was flocculated prior to transport and discharge to the Army's activated carbon treatment system at O-Line.

Well development commenced no sooner than 48 hours after completion of the mortar collar placement. Development proceeded until the following conditions were met:

a. The well water is clear to the unaided eye;

b. The sediment thickness remaining in the well is less than 5 percent of the screen length (the depth to the water/sediment interface was measured with a weighted tape and the percentage of sediment height to screen length was calculated);

c. At least five well volumes (including the saturated filter material in the annulus) plus five times the volume of water added during the drilling process have been removed from the well;

d. Until three unchanged successive readings are obtained for the specific conductivity, temperature, and pH of the development water;

e. A 1-pint sample of the test water obtained during the development process from each well had been collected and stored so as not to freeze; and

f. The cap and all internal components of the well casing above the water table have been rinsed with well water to remove all traces of soil/sediment/cuttings. Washing was conducted before and/or during development.

During the development of monitoring wells at MAAP it became apparent that the development goals for each well were met prior to removing the five well volumes plus the volume of fluid losses recorded during drilling, established under the USATHAMA geotechnical guidelines for well development (USATHAMA, 1987a). Recommendations made by ICF to the COR resulted in USATHAMA approval to modify the monitoring well development requirements and reduce the volume of water removed from each well as long as all other conditions listed in a through f above (except for condition c) were met. The following case is one example that resulted in modification of the well development requirements.

Development of monitoring well MI061 required removal of approximately 11,000 gallons of water according to USATHAMA guidelines for well development. During the early stages of development, it was established that water retrieved from MI061 had stabilized in appearance, temperature, pH, and conductivity. The well sustained an average discharge rate of 8.3 gpm with approximately 10 feet of drawdown. The drawdown stabilized very quickly, which suggested that the well and aquifer could easily produce 10 gpm. These factors indicated that monitoring well MI061 was fully developed after withdrawal of five times the well bore and annulus storage volumes, or approximately 1,000 gallons. Pumping continued with no change in the hydrogeologic parameters after the withdrawal of 2,500 gallons of water. At this time, consultation with the COR resulted in revision of the development requirement and a total of 5,000 gallons of water was ultimately withdrawn from this well. Eight monitoring wells were developed under similar conditions where the required volume of water withdrawn from the well was reduced after the hydrogeologic goals of well development were achieved.

During development of monitoring well MI081, the well was pumped dry almost immediately during the initial phase of the process. A surge block technique was used to scrub the screened interval after the well recharged. The swabbing continued until the well sustained a pumping rate of 2 gpm. The minimal flow rate of groundwater to the well is probably the result of well installation procedures as discussed in Section 4.3.3.1.

4.5 SURVEYING OF WELLS

The newly-installed wells were surveyed between the time period of October 30 to December 4, 1990. The surveying was performed by the David Hall Land Surveying Co. of Jackson, TN. The elevation of average ground surface at the wellhead, elevation of the top of casing, and well location in State Planar Coordinates were calculated. A description of the surveying method is included in Appendix I. The reference points used in establishing the survey coordinates are benchmarks installed by the USACE. The locations and elevations of the wells are provided in Appendix I, as well as a copy of the surveyor's field log.

4.6 GROUNDWATER SAMPLING

Sampling of all existing and newly installed wells occurred during the period of October 13 to December 12, 1990.

4.6.1 Wells Sampled

The set of wells sampled in this program consists of the 32 wells installed by the U.S. Army Toxic and Hazardous Materials Agency in 1981, 24 wells installed by Weston in 1983, 26 wells installed by ICF in 1990, 7 RCRA wells in the OBG and ADA installed by AEHA, 13 of the 15 plant production wells, and 2 off-post domestic drinking water wells. A total of 104 wells were sampled. Table 4-7 shows the well name, laboratory analysis requested, QA samples associated with that well sample, and date of sampling. The samples were either analyzed for the full Target Compound List and Target Analyte List plus explosives or for select metals (cadmium, chromium, mercury, and lead) and explosives. The groundwater wells sampling forms, which provide information on the volume of pre-sample purge water removed from each well and the stabilization readings measured during purging, are included in this report as Appendix J.

All of the USATHAMA and RCRA wells were successfully sampled and these samples were analyzed for the requested parameters. The sample from well MI040 was not logged in correctly by the laboratory and the unfiltered metal sample was not analyzed for mercury. The sample taken from well MI046 was not analyzed for explosives due to laboratory error, so the well was resampled on February 6, 1991, by Martin Marietta personnel. The sample was shipped to ESE for explosives analysis.

All of the newly-installed wells were sampled and these samples were analyzed appropriately. The wells were sampled more than 14 days after well development to allow the conditions in the well to fully stabilize.

Two of the plant production wells could not be sampled. It was found that well B-100 has not been used for years and no longer has a pump. Well C-100 was undergoing electrical transformer replacement during the time period in which well sampling was conducted. After the transformer was replaced, an effort was made to start the pump, but electrical current surges caused a fuse to blow repeatedly and the operation was halted. Production wells C-5, E-67, F-100, I-11, K-100, K-323, P-97, S-99, T-99, T-100, X-100, Y-100, and ZZ-3 were sampled for select metals and explosives analysis only.

4.6.2 Groundwater Sampling Procedures

The following procedure was used in sampling the groundwater monitoring wells:

- A clean sheet of polyethylene was placed on the ground surface around the well and was taped securely to the steel casing to prevent any spilled water from infiltrating directly at the wellhead.

Table 4-7
Groundwater Samples Collected

Site ID	Analysis	Duplicate	Rinse Blank	Date
MI001	SM+E			10/21/90
MI002	SM+E			10/30/90
MI003	SM+E			10/17/90
MI004	SM+E			11/12/90
MI005	SM+E			10/16/90
MI006	TAL/TCL+E			10/16/90
MI007	SM+E			11/1/90
MI008	SM+E			10/31/90
MI009	TAL/TCL+E		X	11/3/90
MI010	SM+E			11/10/90
MI011	SM+E			11/1/90
MI012	SM+E			11/4/90
MI013	SM+E			11/5/90
MI014	TAL/TCL+E	X		11/11/90
MI015	SM+E			11/10/90
MI016	SM+E	X		11/1/90
MI017	TAL/TCL+E			11/7/90
MI018	SM+E	X		11/5/90
MI019	SM+E			11/6/90
MI020	SM+E			11/10/90
MI021	SM+E	X	X	11/13/90
MI022	SM+E			11/9/90
MI023	SM+E			10/31/90
MI024	SM+E			11/9/90
MI025	SM+E	X		11/8/90
MI026	SM+E			11/4/90
MI027	SM+E			11/9/90
MI028	SM+E			11/7/90
MI029	SM+E			11/11/90
MI030	TAL/TCL+E	X		11/11/90
MI031	SM+E			11/12/90
MI032	SM+E			11/12/90
MI033	SM+E			11/7/90

Table 4-7 (continued)
Groundwater Samples Collected

Site ID	Analysis	Duplicate	Rinse Blank	Date
MI034	TAL/TCL+E			10/15/90
MI035	TAL/TCL+E			10/28/90
MI036	SM+E		X	10/28/90
MI037	SM+E			10/30/90
MI038	SM+E			10/25/90
MI039	SM+E			10/24/90
MI040*	SM+E			10/26/90
MI041	SM+E			10/27/90
MI044	SM+E			11/2/90
MI045	SM+E			11/2/90
MI046	SM+E			10/21/90
MI047	SM+E			10/23/90
MI048	SM+E			10/30/90
MI049	TAL/TCL+E	X		11/5/90
MI050	TAL/TCL+E			11/1/90
MI051	TAL/TCL+E			10/21/90
MI052	SM+E			10/31/90
MI053	SM+E			10/31/90
MI054	TAL/TCL+E			10/29/90
MI055	TAL/TCL+E			10/22/90
MI056	SM+E	X		11/5/90
MI057	TAL/TCL+E			11/29/90
MI058	SM+E			11/2/90
MI059	SM+E			11/4/90
MI060	TAL/TCL+E	X		11/30/90
MI061	SM+E			11/8/90
MI062	SM+E			11/3/90
MI063	TAL/TCL+E			11/3/90
MI064	SM+E			11/6/90
MI065	SM+E			11/4/90
MI066	SM+E		X	12/12/90
MI067	SM+E			12/12/90

*Not analyzed for Mercury due to laboratory error.

Table 4-7 (continued)
Groundwater Samples Collected

Site ID	Analysis	Duplicate	Rinse Blank	Date
MI068	SM+E	X	X	11/6/90
MI069	SM+E		X	11/29/90
MI070	SM+E		X	12/2/90
MI071	TAL/TCL+E	X	X	11/1/90
MI072	TAL/TCL+E			11/3/90
MI073	TAL/TCL+E			11/2/90
MI074	SM+E			11/3/90
MI075	SM+E		X	11/30/90
MI076	SM+E			11/8/90
MI077	SM+E		X	11/9/90
MI078	SM+E			11/9/90
MI079	SM+E			11/29/90
MI080	SM+E			11/29/90
MI081	SM+E	X	X	11/28/90
MI082	SM+E	X		11/28/90

Domestic Wells

DW001 (Bledsoe Residence	SM+E			11/27/90
DW002 New Hope Baptist Church	SM+E			11/27/90

Production Wells

Site ID	Analysis	Duplicate	Rinse Blank	Date
K-100	SM+E			10/18/90
T-100	SM+E			10/18/90
F-100	SM+E			10/19/90
X-100	SM+E			10/19/90
Y-100	SM+E			10/19/90
P-97	SM+E			10/19/90
ZZ-3	SM+E			10/19/90
K-323	SM+E			10/19/90
E-67	SM+E			10/18/90
C-5	SM+E			10/18/90
I-11	SM+E			10/18/90

Table 4-7 (continued)
Groundwater Samples Collected

Site ID	Analysis	Duplicate	Rinse Blank	Date
T-99	SM+E			10/18/90
S-99	SM+E			10/19/90
RCRA Wells				
001	SM+E			11/6/90
002	SM+E			11/6/90
003	SM+E		X	11/7/90
004	SM+E			11/4/90
005	SM+E			11/7/90
006	SM+E			11/4/90
007	SM+E			11/8/90

SM+E	Select Metals and Explosives.
TAL/TCL+E	Target Analyte List/Target Compound List and Explosives.

- A respirator was worn while opening the well cap and a PID reading was taken both upon well opening and periodically during purging.

- All purge water was containerized at the site, transported to a holding tank located near the O-line PWTF, flocculated if the solids content was high, and then discharged into the treatment plant. For wells which required a large purge volume, several trips had to be made to the holding tank and consequently the purging was occasionally interrupted.

- The depth to groundwater was then measured with an electric water level meter. A weighted tape was used to measure the depth to groundwater and to the bottom of the well. Using these depths, the total extraction volume was calculated. This volume is equal to 5 times the sum of the well volume and saturated filter pack volume. For the existing wells, the well diameter, borehole diameter, and filter pack height information was obtained from previous reports.

- The wells were then purged using either a submersible pump or a bailer. Only 5 of the wells were purged with a bailer; these are MI001, MI003, MI034, MI035, and MI054. The water in these wells was very sandy and caused the submersible pumps to lock.

- The wells were purged according to a procedure outlined by the USATHAMA Geotechnical Requirements (1987a). The pump was lowered to a depth of 10 feet below the static water level. The pump was run at a rate of approximately 5 gpm. If the water level dropped to the pump level, the well was allowed to recharge, and the time needed to recharge was measured. If the recharge rate indicated that the time needed for the entire water column to recharge was greater than 1 hour, then the pump was dropped to within 5 feet of the well bottom and purging continued until the well went dry. This procedure was repeated until a total of 3 well evacuations were completed. When the well recharged a fourth time, it was sampled. However, if the recharge rate indicated that the time needed for the entire water column to recharge was less than 1 hour, then the pump was lowered as the water level dropped and the pump was turned on and off as needed until 5 complete equivalent volumes were evacuated. If the water level stabilized, the pump was slowly raised to the point of exposure. At no time did the distance between the water level and the pump intake exceed 10 feet. However, if the recharge rate indicated that the time needed for the water column to recharge was slightly less than one hour, but the time needed to evacuate 5 equivalent volumes was greater than 5 hours, then if after evacuating 3 equivalent volumes the parameters of pH, temperature, and conductivity had stabilized, well sampling was permitted. For most of the wells, the pumping rate could be matched to the recharge rate so the pump was allowed to run continuously.

- At the beginning of purging and every 10 or 15 minutes while pumping, a sample was collected for readings of pH, temperature, and conductivity were obtained by triple-rinsing a glass beaker and then filling it with water from the pump or bailer. These readings were used to determine if conditions in the well had stabilized. The readings were recorded on the groundwater sample form along with the time of the reading, the water level reading, and the cumulative volume extracted.

- After the well was purged, a teflon bailer was used to extract the sample. The teflon bailers have a 3-foot long leader constructed of teflon-coated stainless steel. Disposable nylon rope was tied onto this leader and was not permitted to come into contact with the water. The sample bottles were first triple-rinsed. Then the bottles were filled in order of decreasing volatility of the analytes. In the case of a TAL/TCL and explosives sample, the VOC vials were preserved with 6 drops of hydrochloric acid and then the sample was poured slowly into the vials to prevent excessive agitation. The vials were inspected to ensure that air bubbles were not present in the vials. Then the BNA/pesticide/PCB and explosives bottles were filled, leaving about 10% headspace. The unfiltered metals bottle was filled next, again leaving 10% headspace. Finally, a filtered metals sample was obtained using a peristaltic pump, disposable tubing, and a disposable 0.45 micron filter. Both the filtered and unfiltered metals samples were preserved with nitric acid to a pH of less than 2. In the case of an explosives and select metals sample, the explosives bottles were filled first and then the two metals samples were taken. The samples were placed into an ice-filled cooler immediately after sample collection and were maintained at a temperature of 4 degrees from the time of collection until analysis. All samples were recorded in the field parameter form notebook with sampling date and time, preservatives used, requested analysis, and the samplers' name.

- After all of the sample bottles had been filled, the bailer was used again to extract water to obtain the final pH, temperature, and conductivity readings. These readings were noted on both the groundwater sampling form and the field parameter logbook.
- The bailer rope, peristaltic pump tubing and filter, and plastic sheeting were discarded. The bailer, pump, hose, and beaker were taken to the decon pad and cleaned using approved water and scrubbing, rinsing with deionized, organic-free water, rinsing with isopropanol, and then rinsing again with deionized, organic-free water.

Several problems were encountered while purging and sampling the wells. Many of the existing wells were constructed with screens that allowed fine sand particles to enter the well. In many cases, several feet of sand existed at the bottom of the well. This resulted in the sand-locking of several of the pumps used in purging the wells. In addition, many of the existing wells have very low recharge rates, probably because they were not sufficiently developed at the time of installation. The ICF well MI081 in the Agricultural Research Station also had a very low recharge rate of 1.8 gpm, which was observed during well development.

Well constructions did not permit the use of a full-sized submersible pump in several instances. In addition, there is a 2-inch diameter and a 3-inch diameter well among the old wells. For some of the existing wells which were not bailed and these small diameter wells, a 1.8-inch in diameter frequency-controlled stainless steel pump was used to purge the water. This pump was found to be very sand-resistant and could easily be throttled back to match the low recharge rates of the wells.

Eight of the monitoring wells sampled had very high pH and conductivity values at the beginning of pumping. In two of these cases, the pH and conductivity readings would gradually decrease while the well was being purged but would rise again when pumping stopped. In the other six cases, the pH reading did not go up or rose only slightly between the last reading sample while purging and the final pH reading taken after sampling. This behavior is generally attributed to grout contamination in the well or in the filter pack. The wells which exhibited this behavior are MI019 (a USATHAMA well in the ADA), MI057, MI058, MI060, MI065, MI068, MI069, MI070, and MI075. The groundwater in this area has an average pH of about 5.5 to 6 pH units. The above-listed wells had a pH of about 10 pH units or higher at the start of purging. However, with the exception of MI019, these wells appear to have high yield and so the apparent grout contamination has not affected the transmissivity of either the screen or the filter pack.

Many existing wells and a few of the newly-installed wells were very turbid at the start of purging and were not clear even after 5 equivalent volumes were extracted. The presence of solids in the metals samples may result in higher levels of metals in the unfiltered metals sample than in the filtered sample, where all particles larger than 0.45 μm are removed prior to preservation.

While purging well MI055 located in the parking lot of B-Line, the PID reading gradually increased to 18 ppm in the well and 5 ppm in the breathing zone above the well. When pumping stopped, the PID readings decreased but increased again when the pump was turned back on. The personnel who finished purging and sampling this well wore respirators as a safety precaution. Well MI008 on Route 104 also showed PID readings above background but these readings were not persistent. Well MI051 had a reading of 1 ppm upon opening, so it was decided to analyze the water for TAL/TCL and explosives rather than just select metals and explosives, as originally planned.

4.7 PHYSICAL TESTING OF SOILS

Split-spoon samples collected at 5 feet intervals in the soil borings were stored in air-tight containers and labeled according to boring number and depth. Upon boring completion, soil samples were stored in boxes in the ICF on-site supply trailer. An inventory of lithologic samples was kept on the drilling logs. At the conclusion of drilling activities, 15% of all soil samples collected were chosen for geotechnical laboratory physical testing. Samples were chosen by the field geologist to provide a range of values for the geotechnical parameters which is representative of the lithologies encountered during drilling. In borings where monitor wells were installed, a sample from the screened depth was included for analysis.

Geotechnical physical testing was performed at the ICF Pittsburgh geotechnical laboratory. Samples were analyzed for moisture content, grain-size distribution, and Atterberg limits. General descriptions and a USCS classification were also provided for each sample. Results from physical testing are discussed in Section 5.1 of this report.

4.8 AQUIFER TESTING

Aquifer tests were performed on two monitor wells to provide estimates of aquifer hydraulic conductivity. Short duration pumping tests and subsequent recovery tests were performed on wells MI057 and MI063. Nearby wells were monitored to characterize the cone of influence. At the request of USATHAMA, rising and falling head slug tests were performed in well MI057 for comparison purposes. Results from these tests are presented in Section 5.3 of this report.

A Hermit SE 2000 datalogger and pressure transducers were used to measure aquifer response during each of the tests. Data were collected at logarithmic intervals and stored in the datalogger memory. At the conclusion of each test, data were transferred to a computer file for analysis using the AQTESOLV (Geraghty & Miller, 1989) aquifer test analysis package. Field notes were taken throughout the aquifer testing program to provide both verification of electronic data and an alternate record in the event of equipment failure.

4.8.1 Pumping Tests

Pumping tests were performed using a Grundfos (model 60S50-7) stainless steel, 4-inch submersible pump. Pump discharge was monitored and controlled with a Halliburton (model MC-II) flow analyzer system. The flow meter continuously monitored and displayed pump discharge rate and total volume extracted on an LCD display. The discharge rate was controlled by a valve on the discharge line; the desired rate was easily achieved within seconds of the initiation of pumping. Well MI057 was pumped at a rate of 60 gpm for 130 minutes. Well MI063 was pumped at 50 gpm for 120 minutes.

Pressure transducers were set in each of the observation wells at 10 to 20 feet below the water surface. The pressure transducers placed in the pumping wells were set approximately 40 feet below the water surface; the submersible pump was set just above the screened interval. In MI057, there was approximately 70 feet between the transducer and the pump. In well MI063, approximately 15 feet separated the transducer and the pump.

4.8.2 Recovery Tests

After the flow system around the well had reached steady-state conditions, the datalogger was restarted and the pump was shut off. Water-level recovery in the wells was recorded with the pressure transducers at the same sampling interval as during the pumping period. Water levels were monitored until the aquifer had completely recovered to pre-pumping water levels.

4.8.3 Slug Tests

Two slug tests were performed in well MI057 using the following procedure. A transducer was set 20 feet below the water table. After transducer readings had stabilized, the datalogger was turned on, and a slug (72-inch length, 2-inch diameter) was quickly lowered into the water table until it was completely submerged. The water level in the well immediately rose about 2 feet, and measurements were recorded as the water level fell back to its equilibrium state. This was the falling-head slug test. After the equilibrium water level was achieved, the datalogger was restarted and the slug was quickly removed from the well. The water level in the well immediately dropped by about 2 feet and the rate of recovery to equilibrium was recorded as the rising head slug test.

4.9 SURFACE WATER AND SEDIMENT SAMPLING

Sampling of the surface water and sediment in the facility ditches, the Rutherford Fork of the Obion River, Wolf Creek, Halls Branch and Johns Creek took place between August 6 and September 13, 1990. The second round of surface water sampling was accomplished on October 7 and 8, 1990. A summary of surface water sampling is given in Table 4-8, which shows for each surface water body the samples taken, laboratory analysis requested, QA samples, and the date the sample was collected. A summary of the sediment sampling program is provided in Table 4-9, which lists the sediment sample locations, depth interval, laboratory analysis requested, QA samples, and date. A map showing the locations of surface water and sediment samples is given in Figure 4-16. A sediment sample was taken from each marked location on the map. If a surface water sample was also taken, then the sample name is boxed. If two rounds of surface water samples were taken from the location, then the sample name is double-boxed.

4.9.1 Surface Water Sample Location Rationale

Surface water samples were taken, whenever possible, in the same location as a sediment sample. This aids in the evaluation of the data because conclusions can be drawn about the relative amounts of upstream loading of contaminants. This is done by comparing the actual amount of contaminants in a surface water sample to the amount that is in theoretical equilibrium with the amount in sediment at that location.

The first round of sampling took place in August and September, which was a dry period in western Tennessee. The ditches, Wolf Creek, and Halls Branch did not flow during this time period. The only surface water available existed in isolated pockets in low areas. Since these deeper areas of the ditches also would receive sediment deposits scoured from higher areas because of the drop in flow rate, it was deemed appropriate to sample these areas for both surface water and sediment.

It was apparent from the large number of animal tracks around the pools of water that the water in these pockets is used as drinking water by the wildlife. Therefore, the amount of contaminants found in pockets approximates the highest amount that is likely to be transferred along the biological pathway route.

As specified by the RI Work Plan, a surface water sample was taken in the Rutherford Fork of the Obion River downstream of the confluence with Ditches B and C. An upstream sample (collected above the confluence with Johns Creek) was taken to provide background information about this surface water body.

In addition, a sample was taken from Johns Creek downstream of the confluence with Ditch 6. This sample was taken in lieu of a sample in Ditch 7, which was dry at the time of sampling. The Johns Creek sample was taken to determine if the quality of water in Johns Creek is being impacted by contamination

Table 4-8
Surface Water Samples Collected

Site ID	Field Sample Number	Analysis	Duplicate	Date
Rutherford Fork, Obion River				
RVER-1	RVER-1	TAL/TCL+E		12/1/90
RVER-2	RVER-2	TAL/TCL+E		8/22/90
Johns Creek				
CREK-3	CREK-3	TAL/TCL+E		8/21/90
Ditch B, Round 1				
DTCHB-1	SDTB-1	TAL/TCL+E		8/12/90
DTCHB-2	SDTB-2	SM+E		8/12/90
DTCHB-3	SDTB-3	TAL/TCL+E		8/12/90
DTCHB-4	SDTB-4	SM+E		8/13/90
Ditch B, Round 2				
DTCHB-2	SDTB-2A	TAL/TCL+E		10/8/90
DTCHB-4	SDTB-4A	TAL/TCL+E		10/8/90
Ditch C, Round 1				
DTCHC-1	SDTC-1	TAL/TCL+E		8/10/90
DTCHC-2	SDTC-2	SM+E	X	8/11/90
DTCHC-3	SDTC-3	TAL/TCL+E		8/11/90
DTCHC-4	SDTC-4	SM+E		8/13/90
Ditch C, Round 2				
DTCHC-1	SDTC-1A	TAL/TCL+E		10/7/90
DTCHC-3	SDTC-3A	TAL/TCL+E		10/7/90
Ditch 1				
DTCH1-1	SDT1-1	TAL/TCL+E		8/13/90
DTCH1-2	SDT1-2	TAL/TCL+E		8/13/90
Ditch 2				
DTCH2-2	SDT2-2	TAL/TCL+E		8/10/90
DTCH2-3	SDT2-3	TAL/TCL+E (not analyzed for BNAs)		8/14/90

Table 4-8 (continued)
Surface Water Samples Collected

Site ID	Field Sample Number	Analysis	Duplicate	Date
Ditch 3: No samples were collected because this ditch was dry.				
Ditch 4				
DTCH4-2	SDT4-2	TAL/TCL+E		8/22/90
DTCH4-3	SDT4-3	TAL/TCL+E		8/22/90
DTCH4-3	SDT4-3	TAL/TCL+E		9/13/90
DTCH4-4	SDT4-4	TAL/TCL+E		9/13/90
Ditch 5				
DTCH5-2	SDT5-2	TAL/TCL+E (not analyzed for BNAs)		8/14/90
DTCH5-3	SDT5-3	TAL/TCL+E		8/15/90
Ditch 6				
DTCH6-1	SDT6-1	TAL/TCL+E		8/24/90
DTCH6-2	SDT6-2	TALTCL+E		8/24/90
Ditch 7				
DTCH7-6	SDT7-6	TAL/TCL+E	X	9/13/90
Ditch 8				
DTCH8-3	SDT8-3	TAL/TCL+E		8/20/90
Ditch 9: No samples were collected because this ditch was dry.				
Ditch 10				
DTCH10-3A	SDT10-3A	TAL/TCL+E		9/12/90
DTCH10-6	SDT10-6	TAL/TCL+E		9/12/90

SM+E	Select Metals and Explosives
TAL/TCL+E	Target Analyte List/Target Compound List and Explosives

Table 4-9
Sediment Samples Collected

Site ID	Field Sample Number	Interval (ft)	Analysis	Duplicate	Rinse Blank	Date
Rutherford Fork, Obion River						
RVER-1	RVER-1A	0-2	TAL/TCL+E	X	X	8/6/90
RVER-2	RVER-2A	0-1	TAL/TCL+E			8/22/90
RVER-2	RVER-2B	1-2	SM+E			8/22/90
Wolf Creek						
CREK-1	CREK-1A	0-1	TAL/TCL+E			8/26/90
CREK-1	CREK-1B	1-2	SM+E			8/26/90
CREK-2	CREK-2A	0-1	TAL/TCL+E			8/26/90
CREK-2	CREK-2B	1-2	SM+E		X	8/26/90
CREK-6	CREK-6A	0-1	SM+E			9/13/90
CREK-6	CREK-6B	1-2	SM+E			9/13/90
Johns Creek						
CREK-3	CREK-3A	0-1	TAL/TCL+E			8/21/90
CREK-3	CREK-3B	1-2	SM+E			8/21/90
Halls Branch						
CREK-4	CREK-4A	0-1	TAL/TCL+E			8/22/90
CREK-4	CREK-4B	1-2	SM+E			8/22/90
CREK-5	CREK-5A	0-1	TAL/TCL+E			8/22/90
CREK-5	CREK-5B	1-2	SM+E			8/22/90

Table 4-9 (continued)
Sediment Samples Collected

Site ID	Field Sample Number	Interval (ft)	Analysis	Duplicate	Rinse Blank	Date
Ditch B						
DTCHB-1	DTB-1A	0-0.5	TAL/TCL+E	X		8/12/90
DTCHB-1	DTB-1B	0.5-1	SM+E			8/12/90
DTCHB-1	DTB-1C	1-2	SM+E			8/12/90
DTCHB-2	DTB-2A	0-0.5	TAL/TCL+E			8/12/90
DTCHB-2	DTB-2B	0.5-1	SM+E			8/12/90
DTCHB-2	DTB-2C	1-2	SM+E			8/12/90
DTCHB-3	DTB-3A	0-0.5	TAL/TCL+E			8/12/90
DTCHB-3	DTB-3B	0.5-1	SM+E	X		8/12/90
DTCHB-3	DTB-3C	1-2	SM+E			8/12/90
DTCHB-4	DTB-4A	0-0.5	TAL/TCL+E			8/13/90
DTCHB-4	DTB-4B	0.5-1	SM+E			8/13/90
DTCHB-4	DTB-4C	1-2	SM+E			8/13/90
Ditch C						
DTCHC-1	DTC-1A	0-0.5	TAL/TCL+E			8/10/90
DTCHC-1	DTC-1B	0.5-1	SM+E			8/10/90
DTCHC-1	DTC-1C	1-2	SM+E		X	8/10/90
DTCHC-2	DTC-2A	0-0.5	TAL/TCL+E	X		8/11/90
DTCHC-2	DTC-2B	0.5-1	SM+E			8/11/90
DTCHC-2	DTC-2C	1-2	SM+E			8/11/90
DTCHC-3	DTC-3A	0-0.5	TAL/TCL+E			8/11/90
DTCHC-3	DTC-3B	0.5-1	SM+E			8/11/90
DTCHC-3	DTC-3C	1-2	SM+E			8/11/90
DTCHC-4	DTC-4A	0-0.5	TAL/TCL+E			8/13/90
DTCHC-4	DTC-4B	0.5-1	SM+E	X		8/13/90
DTCHC-4	DTC-4C	1-2	SM+E			8/13/90

Table 4-9 (continued)
Sediment Samples Collected

Site ID	Field Sample Number	Interval (ft)	Analysis	Duplicate	Rinse Blank	Date
Ditch 1						
DTCH1-1	DT1-1A	0-1	TAL/TCL+E	X		8/7/90
DTCH1-1	DT1-1B	1-2	SM+E			8/7/90
DTCH1-2	DT1-2A	0-1	TAL/TCL+E			8/7/90
DTCH1-2	DT1-2B	1-2	SM+E			8/7/90
DTCH1-3	DT1-3A	0-1	TAL/TCL+E			8/7/90
DTCH1-3	DT1-3B	1-2	SM+E			8/7/90
DTCH1-4	DT1-4A	0-1	TAL/TCL+E			8/7/90
DTCH1-4	DT1-4B	1-2	SM+E	X		8/7/90
DTCH1-5	DT1-5A	0-1	TAL/TCL+E			8/8/90
DTCH1-6	DT1-6A	0-1	TAL/TCL+E			8/8/90
DTCH1-6	DT1-6B	1-2	SM+E			8/8/90
Ditch 2						
DTCH2-1	DT2-1A	0-1	TAL/TCL+E			8/9/90
DTCH2-1	DT2-1B	1-2	SM+E			8/9/90
DTCH2-2	DT2-2A	0-1	TAL/TCL+E	X		8/8/90
DTCH2-2	DT2-2B	1-2	SM+E			8/8/90
DTCH2-3	DT2-3A	0-1	TAL/TCL+E			8/9/90
DTCH2-3	DT2-3B	1-2	SM+E			8/9/90
DTCH2-4	DT2-4A	0-1	TAL/TCL+E			8/9/90
DTCH2-4	DT2-4B	1-2	SM+E			8/9/90
DTCH2-5	DT2-5A	0-1	TAL/TCL+E			8/9/90
DTCH2-5	DT2-5B	1-2	SM+E			8/9/90
DTCH2-6	DT2-6A	0-1	TAL/TCL+E			8/10/90
DTCH2-6	DT2-6B	1-2	SM+E			8/10/90

Table 4-9 (continued)
Sediment Samples Collected

Site ID	Field Sample Number	Interval (ft)	Analysis	Duplicate	Rinse Blank	Date
Ditch 3						
DTCH3-1	DT3-1A	0-1	TAL/TCL+E			8/23/90
DTCH3-1	DT3-1B	1-2	SM+E			8/23/90
DTCH3-2	DT3-2A	0-1	TAL/TCL+E			8/23/90
DTCH3-2	DT3-2B	1-2	SM+E			8/23/90
DTCH3-3	DT3-3A	0-1	TAL/TCL+E			8/24/90
DTCH3-3	DT3-3B	1-2	SM+E			8/24/90
DTCH3-4	DT3-4A	0-1	TAL/TCL+E			8/24/90
DTCH3-4	DT3-4B	1-2	SM+E			8/24/90
DTCH3-5	DT3-5A	0-1	TAL/TCL+E			8/24/90
DTCH3-5	DT3-5B	1-2	SM+E			8/24/90
DTCH3-6	DT3-6A	0-1	TAL/TCL+E			8/24/90
DTCH3-6	DT3-6B	1-2	SM+E			8/24/90
Ditch 4						
DTCH4-1	DT4-1A	0-1	TAL/TCL+E			8/22/90
DTCH4-1	DT4-1B	1-2	SM+E			8/22/90
DTCH4-2	DT4-2A	0-1	TAL/TCL+E			8/22/90
DTCH4-2	DT4-2B	1-2	SM+E			8/22/90
DTCH4-3	DT4-3A	0-1	TAL/TCL+E			8/22/90
DTCH4-3	DT4-3B	1-2	SM+E			8/22/90
DTCH4-4	DT4-4A	0-1	TAL/TCL+E	X		8/22/90
DTCH4-4	DT4-4B	1-2	SM+E			8/22/90
DTCH4-5	DT4-5A	0-1	TAL/TCL+E			8/23/90
DTCH4-5	DT4-5B	1-2	SM+E			8/23/90
DTCH4-6	DT4-6A	0-1	TAL/TCL+E			8/23/90
DTCH4-6	DT4-6B	1-2	SM+E			8/23/90

Table 4-9 (continued)
Sediment Samples Collected

Site ID	Field Sample Number	Interval (ft)	Analysis	Duplicate	Rinse Blank	Date
Ditch 5						
DTCH5-1	DT5-1A	0-1	TAL/TCL+E			8/14/90
DTCH5-1	DT5-1B	1-2	SM+E			8/14/90
DTCH5-2	DT5-2A	0-1	TAL/TCL+E			8/14/90
DTCH5-2	DT5-2B	1-2	SM+E			8/14/90
DTCH5-3	DT5-3A	0-1	TAL/TCL+E			8/15/90
DTCH5-3	DT5-3B	1-2	SM+E		X	8/15/90
DTCH5-4	DT5-4A	0-1	TAL/TCL+E			8/21/90
DTCH5-4	DT5-4B	1-2	SM+E			8/21/90
DTCH5-5	DT5-5A	0-1	TAL/TCL+E			8/21/90
DTCH5-5	DT5-5B	1-2	SM+E	X		8/21/90
DTCH5-6	DT5-6A	0-1	TAL/TCL+E			8/21/90
DTCH5-6	DT5-6B	1-2	SM+E			8/21/90
Ditch 6						
DTCH6-1	DT6-1A	0-1	TAL/TCL+E			8/24/90
DTCH6-1	DT6-1B	1-2	SM+E			8/24/90
DTCH6-2	DT6-2A	0-1	TAL/TCL+E			8/24/90
DTCH6-2	DT6-2B	1-2	SM+E			8/24/90
DTCH6-3	DT6-3A	0-1	TAL/TCL+E			8/25/90
DTCH6-3	DT6-3B	1-2	SM+E			8/25/90
DTCH6-4	DT6-4A	0-1	TAL/TCL+E			8/25/90
DTCH6-4	DT6-4B	1-2	SM+E			8/25/90
DTCH6-5	DT6-5A	0-1	TAL/TCL+E			8/25/90
DTCH6-5	DT6-5B	1-2	SM+E			8/25/90
DTCH6-6	DT6-6A	0-1	TAL/TCL+E			8/25/90
DTCH6-6	DT6-6B	1-2	SM+E	X		8/25/90

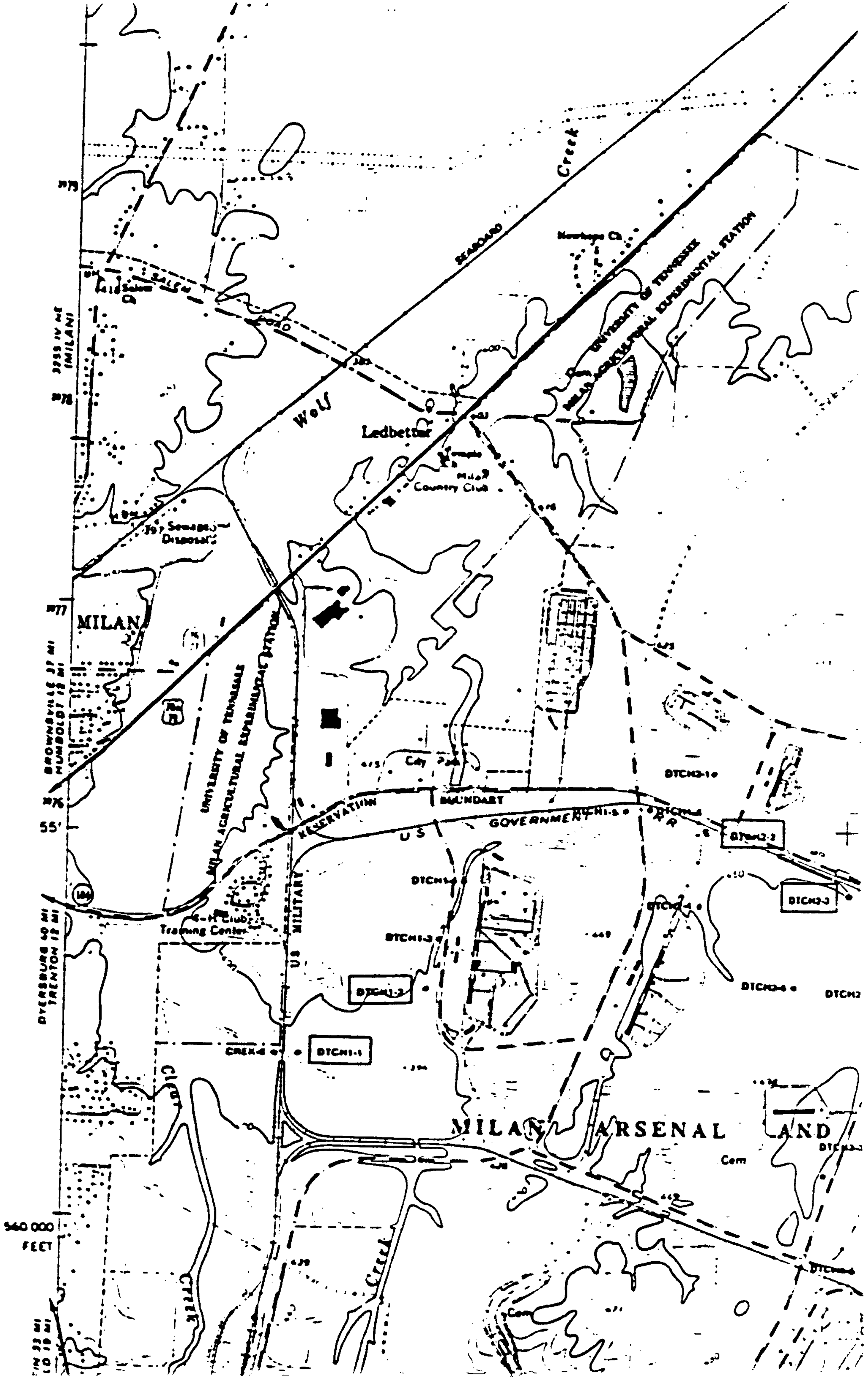
Table 4-9 (continued)
Sediment Samples Collected

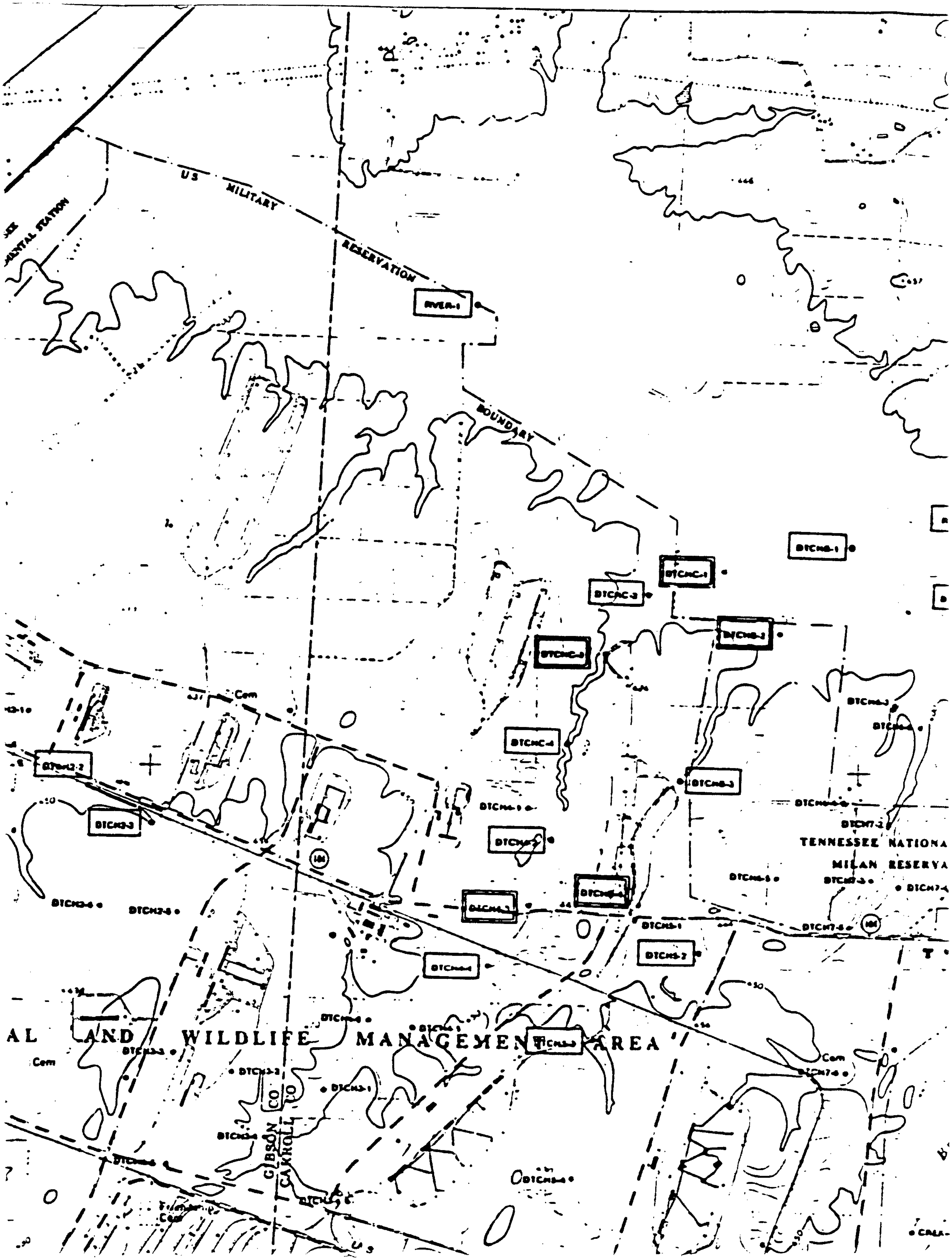
Site ID	Field Sample Number	Interval (ft)	Analysis	Duplicate	Rinse Blank	Date
Ditch 7						
DTCH7-2	DT7-2A	0-1	TAL/TCL+E			8/26/90
DTCH7-2	DT7-2B	1-2	SM+E			8/26/90
DTCH7-3	DT7-3A	0-1	TAL/TCL+E	X		8/26/90
DTCH7-3	DT7-3B	1-2	SM+E			8/26/90
DTCH7-4	DT7-4A	0-1	TAL/TCL+E			8/26/90
DTCH7-4	DT7-4B	1-2	SM+E			8/26/90
DTCH7-5	DT7-5A	0-1	TAL/TCL+E			8/26/90
DTCH7-5	DT7-5B	1-2	SM+E			8/26/90
DTCH7-6	DT7-6A	0-1	TAL/TCL+E			8/26/90
DTCH7-6	DT7-6B	1-2	SM+E		X	8/26/90
Ditch 8						
DTCH8-1	DT8-1A	0-1	TAL/TCL+E			8/20/90
DTCH8-1	DT8-1B	1-2	SM+E	X		8/20/90
DTCH8-2	DT8-2A	0-1	TAL/TCL+E			8/20/90
DTCH8-2	DT8-2B	1-2	SM+E		X	8/20/90
DTCH8-3	DT8-3A	0-1	TAL/TCL+E			8/20/90
DTCH8-3	DT8-3B	1-2	SM+E			8/20/90
DTCH8-4	DT8-4A	0-1	TAL/TCL+E			8/21/90
DTCH8-4	DT8-4B	1-2	SM+E			8/21/90
DTCH8-5	DT8-5A	0-1	TAL/TCL+E			8/21/90
DTCH8-5	DT8-5B	1-2	SM+E			8/21/90

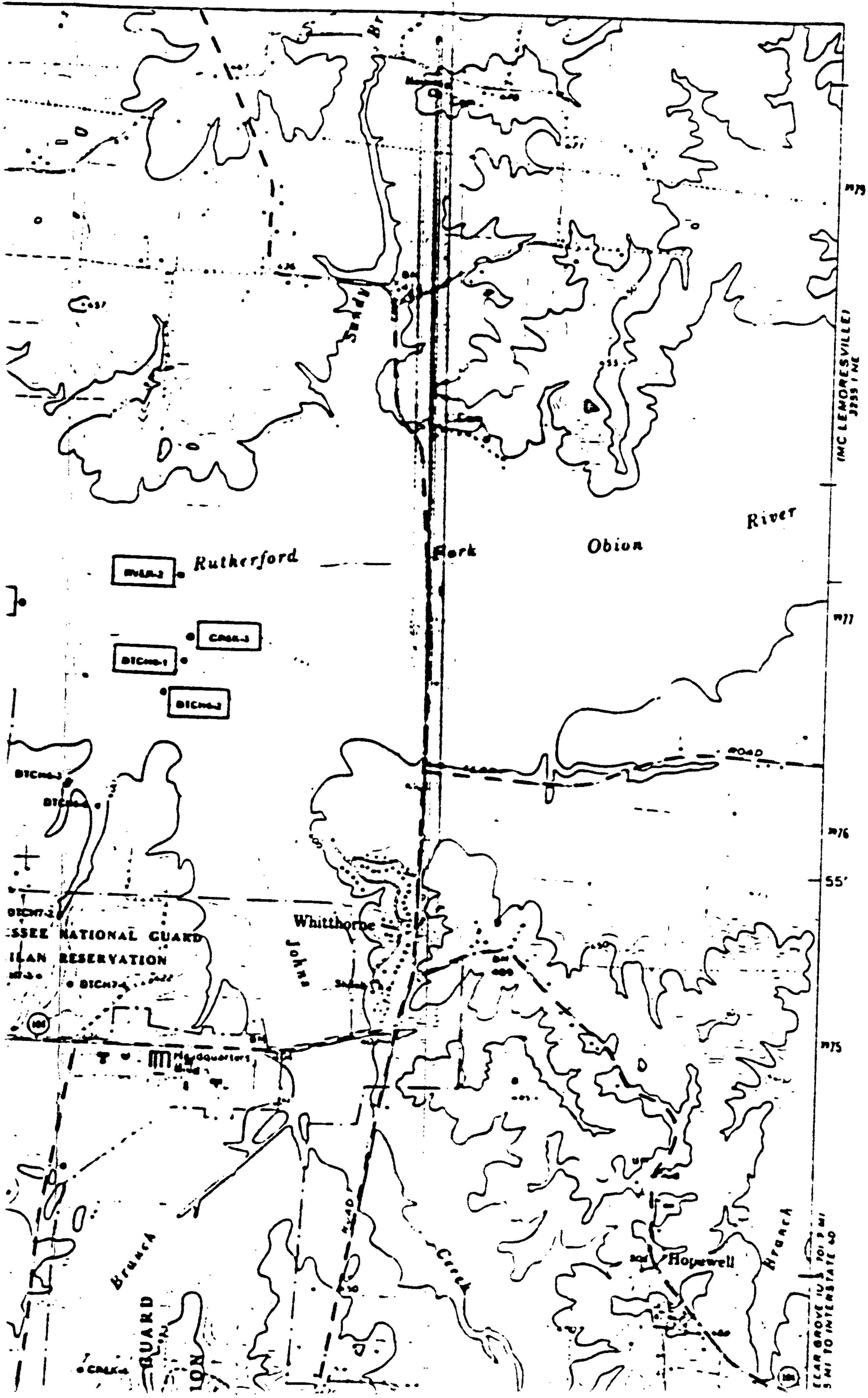
Table 4-9 (continued)
Sediment Samples Collected

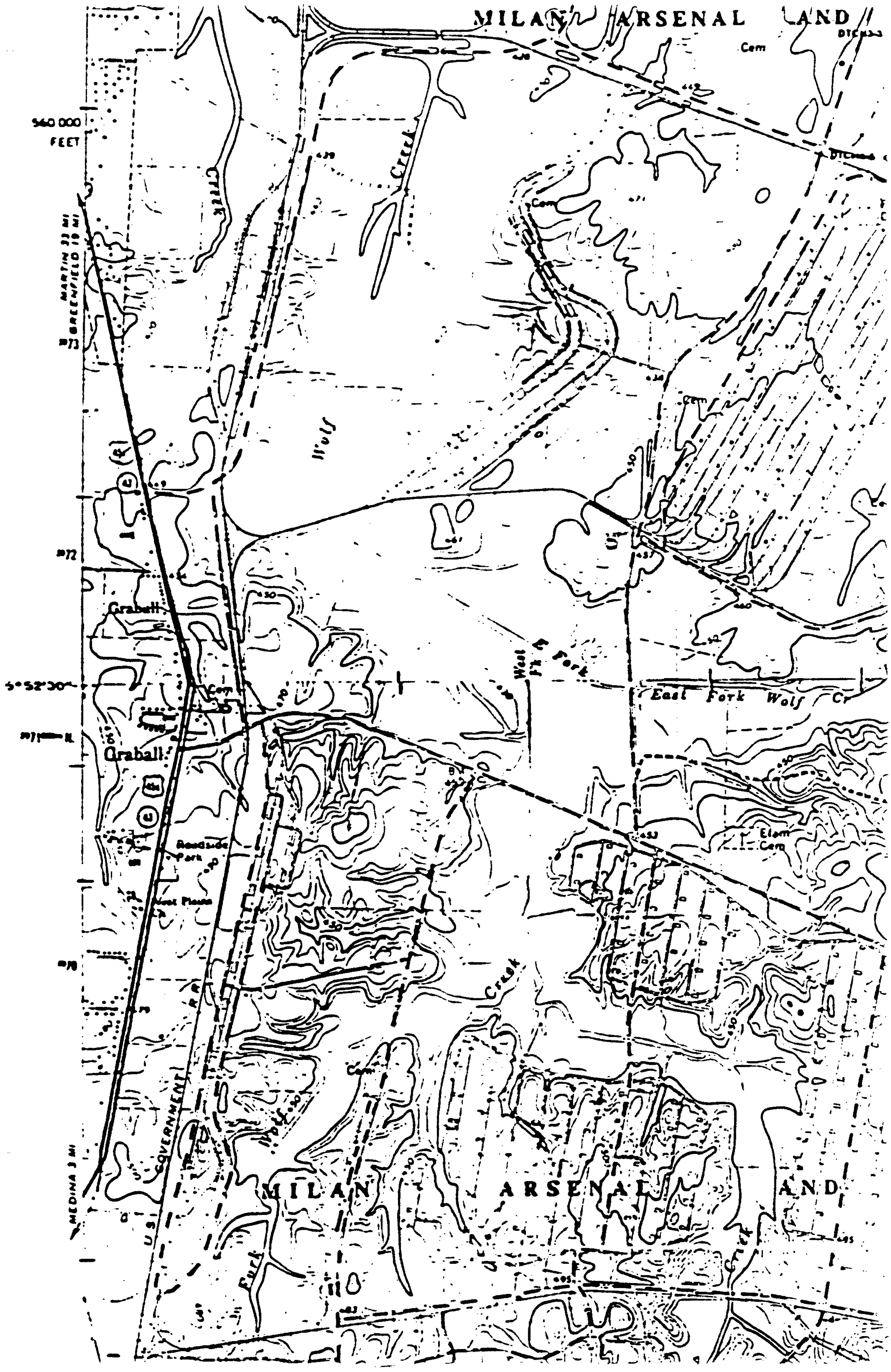
Site ID	Field Sample Number	Interval (ft)	Analysis	Duplicate	Rinse Blank	Date
Ditch 9						
DTCH9-2	DT9-2A	0-1	TAL/TCL+E			8/23/90
DTCH9-2	DT9-2B	1-2	SM+E	X		8/23/90
DTCH9-3	DT9-3A	0-1	TAL/TCL+E	X		8/23/90
DTCH9-3	DT9-3B	1-2	SM+E			8/23/90
DTCH9-4	DT9-4A	0-1	TAL/TCL+E			8/23/90
DTCH9-4	DT9-4B	1-2	SM+E			8/23/90
DTCH9-5	DT9-5A	0-1	TAL/TCL+E			8/23/90
DTCH9-5	DT9-5B	1-2	SM+E		X	8/23/90
DTCH9-6	DT9-6A	0-1	TAL/TCL+E			8/25/90
DTCH9-6	DT9-6B	1-2	SM+E			8/25/90
Ditch 10						
DTCH10-1	DT10-1A	0-1	TAL/TCL+E			8/25/90
DTCH10-1	DT10-1B	1-2	SM+E			8/25/90
DTCH10-2	DT10-2A	0-1	TAL/TCL+E			8/26/90
DTCH10-2	DT10-2B	1-2	SM+E			8/26/90
DTCH10-3	DT10-3A	0-1	TAL/TCL+E			8/25/90
DTCH10-3	DT10-3BR	1-2	SM+E		X	9/12/90
DTCH10-4	DT10-4A	0-1	TAL/TCL+E			8/26/90
DTCH10-4	DT10-4B	1-2	SM+E			8/26/90
DTCH10-5	DT10-5A	0-1	TAL/TCL+E	X		8/26/90
DTCH10-5	DT10-5B	1-2	SM+E			8/26/90
DTCH10-6	DT10-6A	0-1	TAL/TCL+E			8/26/90
DTCH10-6	DT10-6B	1-2	SM+E		X	8/26/90

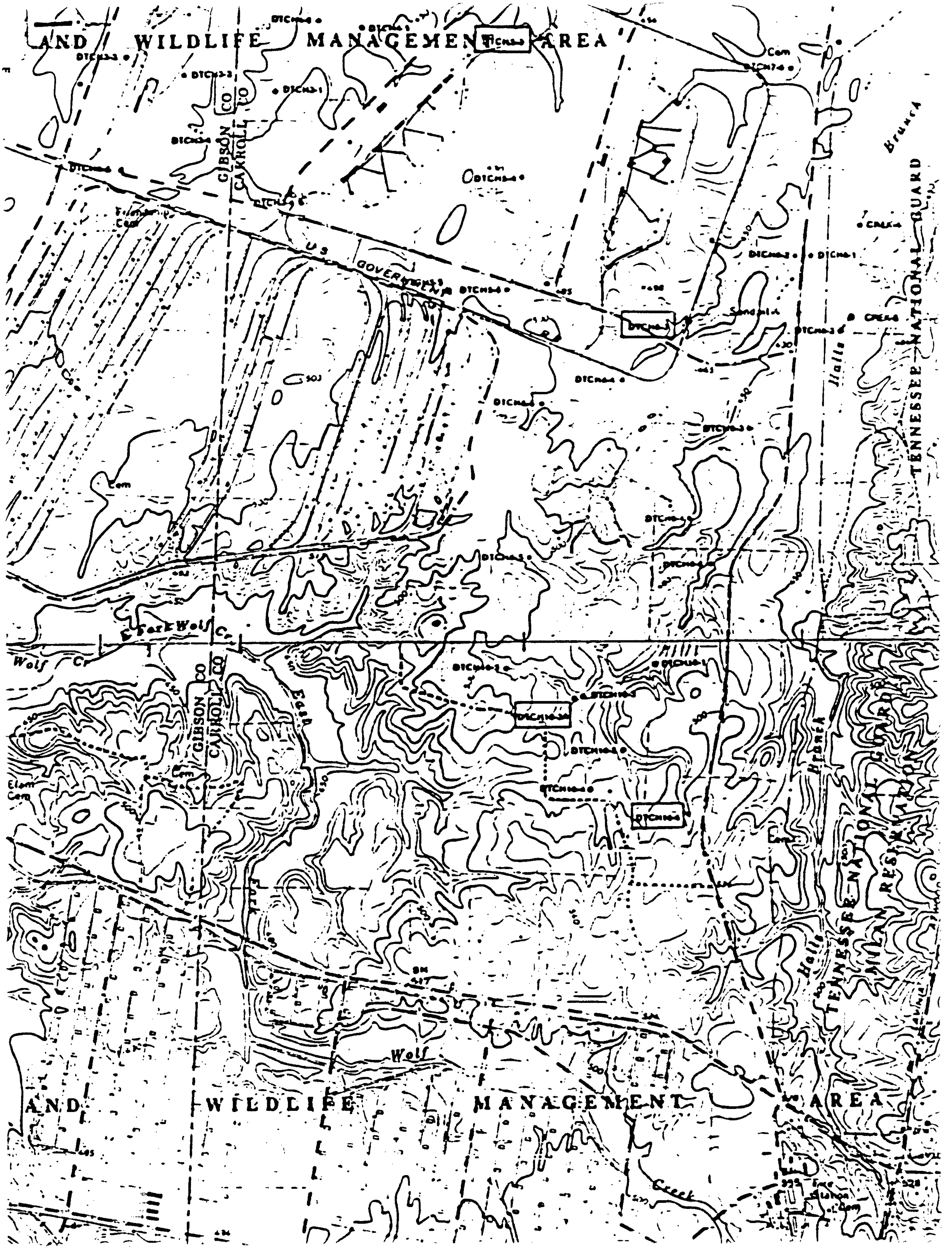
SM+E	Select Metals and Explosives.
TAL/TCL+E	Target Analyte List/Target Compound List and Explosives

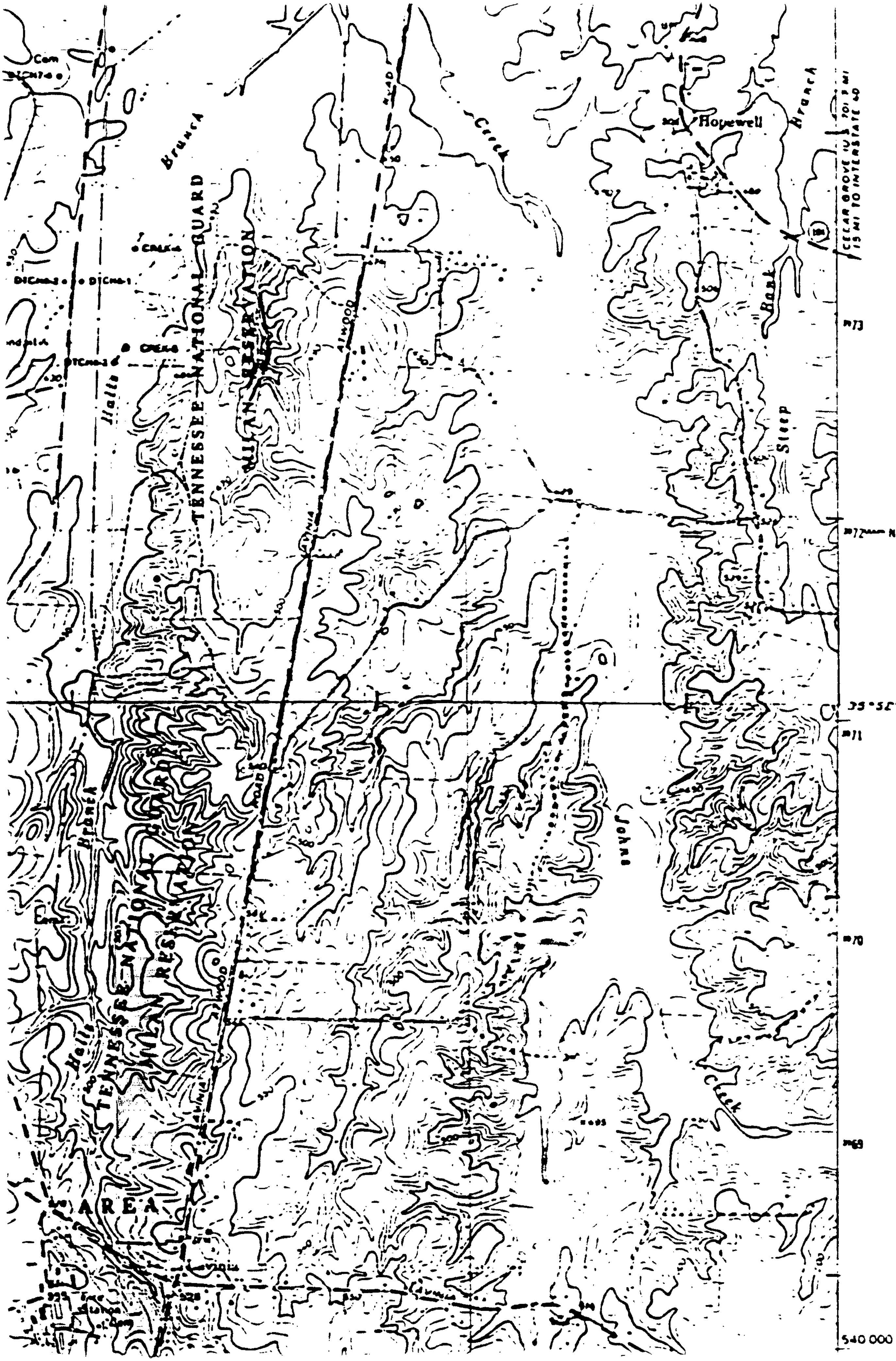
SEABOARD
Creek
Wolf
Newhope Ch
UNIVERSITY OF TENNESSEE
MILAN AGRICULTURAL EXPERIMENTAL STATION
Old Salem Ch
SALEM ROAD
Ledbetter
Temple Ch
Country Club
Sewage Disposal
3255 IV NE (MILAN)
3779
3778
3777
3776
MILAN
BROWNSVILLE 27 MI HUMBOLDT 15 MI
UNIVERSITY OF TENNESSEE MILAN AGRICULTURAL EXPERIMENTAL STATION
City Park
RESERVATION
BOUNDARY
U S
GOVERNMENT
RR
DTCH2-1
DTCH1-5
DTCH1-6
DTCH2-2
DTCH2-3
DTCH1-4
DTCH2-4
DTCH1-3
DTCH1-2
DTCH1-1
DTCH2-6
DTCH2
CREK-6
55'
104
4-H Club Training Center
US MILITARY
DYERSBURG 40 MI TRENTON 15 MI
Clout
Creek
MILAN ARSENAL AND
Cem
560 000 FEET
Cem
Creek


US MILITARY RESERVATION BOUNDARY
RIVER-1
DTCHC-1
DTCHC-2
DTCHC-3
DTCHC-4
DTCH8-1
DTCH8-2
DTCH8-3
DTCH2-2
DTCH2-3
DTCH5-1
DTCH5-2
DTCH7-2
DTCH7-3
DTCH7-6
Com
TENNESSEE NATIONAL
MILAN RESERVA
AL AND WILDLIFE MANAGEMENT AREA
GIBSON CO
CARROLL CO
US

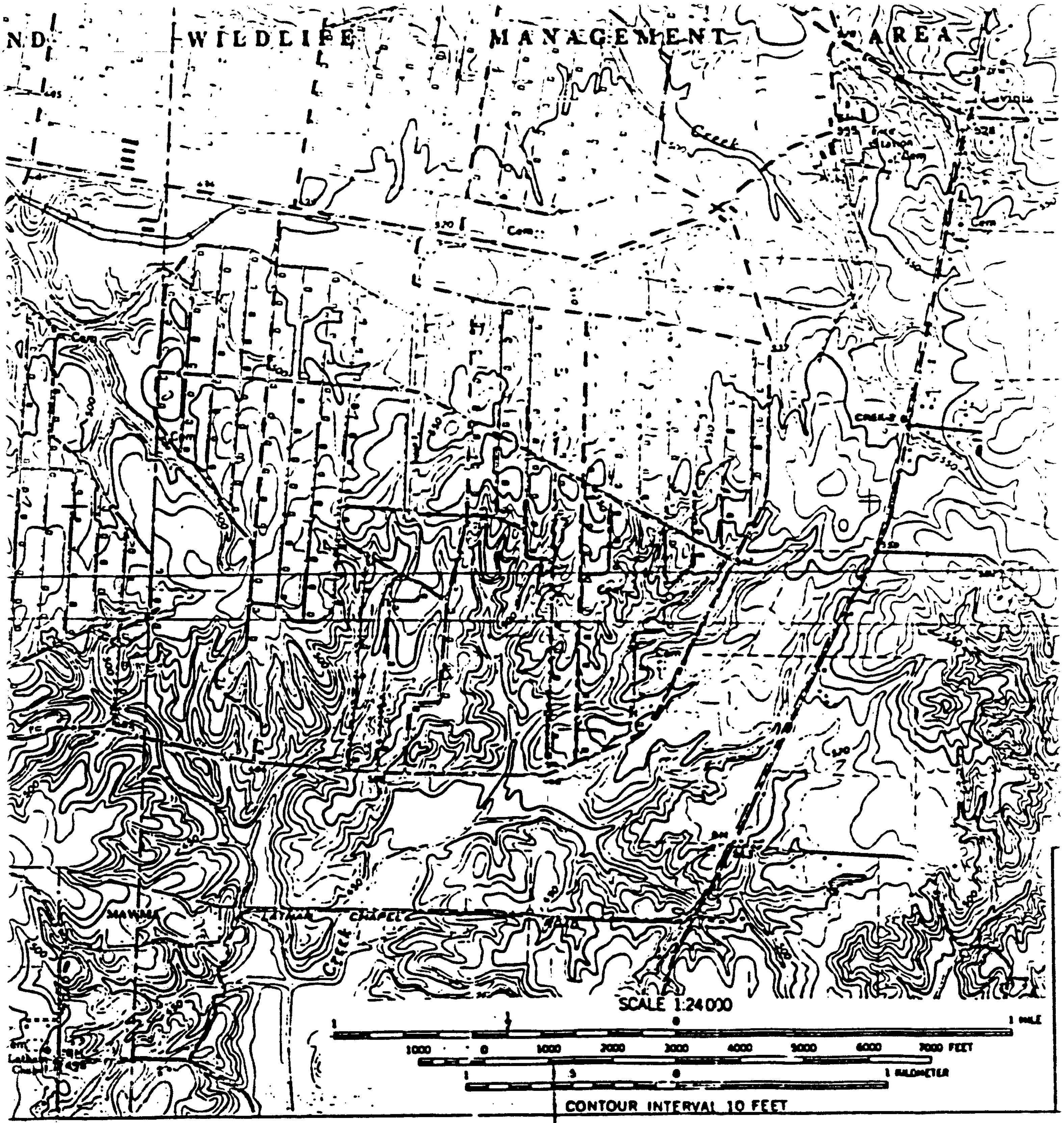
Sandy
Br
Rutherford
Fork
Obion
River
BICH6-1
BICH6-2
ROAD
Whitthorne
Johns
SSEE NATIONAL GUARD
ILAN RESERVATION
BICH7-2
Headquarters
Branch
Creek
Hopewell
Branch
GUARD
ION
55'
IMC LEMORESVILLE)
3953 I NE


MILAN ARSENAL LAND
Cem
560 000
FEET
MARTIN 23 MI
GREENFIELD 19 MI
Creek
Creek
Cem
Wolf
Cem
Graball
5°52'30"
Com
Graball
Roadside Park
Rest Places
West Fk
E Fork
East Fork Wolf Cr
Elam Cem
Creek
Cem
Wolf
Fork
U.S. GOVERNMENT RR
MEDINA 3 MI
MILAN ARSENAL LAND
Creek


AND WILDLIFE MANAGEMENT AREA
GIBSON CO
CARROLL CO
Friendship Cem
US GOVERNMENT
Cem
Sandhill
Halls
Branch
TENNESSEE NATIONAL GUARD
E Fork Wolf Cr
Wolf Cr
Elam Cem
GIBSON CO
CARROLL CO
Halls Branch
TENNESSEE NATIONAL GUARD
MILAN RESERVATION
Wolf
AND WILDLIFE MANAGEMENT AREA
Creek
Station
Cem


Hopewell
Creek
Branch
Branch
TENNESSEE NATIONAL GUARD
MILAN RESERVATION
ALLWOOD
ROAD
Halls
Steep
Bank
Johns
Creek
Branch
Halls
TENNESSEE NATIONAL GUARD
MILAN RESERVATION
ALLWOOD
AREA
Lavinia
Lavinia
Station
CEDAR GROVE (U.S. 70) 3 MI
13 MI TO INTERSTATE 40
73
72
N
35°52'30"
71
70
69
540 000


MILAN ARSENAL AND
MEDINA
50'
3250 IV SE (MEDINA)
1 MI.
500
ROAD
Cem


ND WILDLIFE MANAGEMENT AREA
Lavinia
Fire Station
Cem
Creek
Cem
Cem
Cem
MAWN
Chapel
Creek
Latham Chapel
SCALE 1:24000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 10 FEET

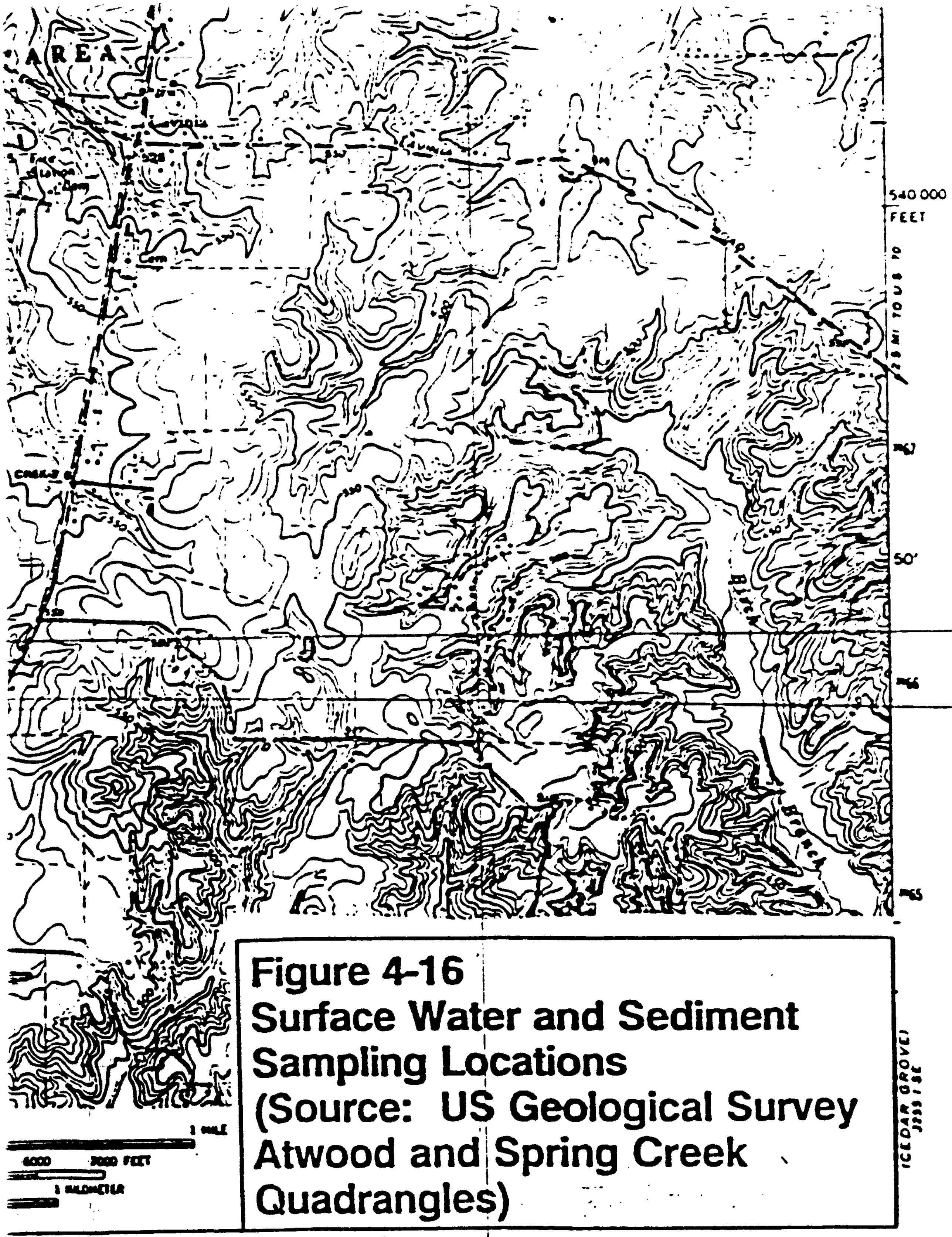


Figure 4-16
Surface Water and Sediment Sampling Locations

(Source: US Geological Survey Atwood and Spring Creek Quadrangles) emanating from the site. The TDC has indicated that Johns Creek is considered to have the same classification as the Rutherford Fork of the Obion River, i.e., Class IV.

Ditches B and C, which are the main drainage pathways from the active lines, were sampled twice. During the first sampling event, locations 1 and 3 from both ditches were sampled for TAL/TCL and explosives analysis, while locations 2 and 4 were sampled for select metals and explosives analysis. During the second sampling round, which took place 2 months later, 2 locations in each ditch were resampled for TAL/TCL and explosives. The first round of sampling consisted of samples from disconnected pockets of water. A rainstorm occurred shortly before and during the second sampling round, and so the samples were taken from the same locations but from flowing water.

The RI Work Plan stated that 2 surface water samples were to be taken from each ditch for Ditches 1 through 10. Due to the dry conditions, some of the ditches had no water. Two samples were taken from Ditches 1, 2, 5, 6, and 10. Due to a communication problem in the field, samples were taken from three locations in Ditch 4, but this may be warranted by the connection with Ditch C. The laboratory mistakenly exceeded the extraction time for BNA/pesticide/PCBs for one of the samples from Ditch 2 and one from Ditch 5. However, a decision was made to analyze those samples anyway because those water pockets had dried up before the samples could be retaken. Ditches 3, 8, and 9 were not sampled because they were dry during the time period that surface water sampling was performed.

4.9.2 Surface Water Sampling Procedures

Once the sampling location had been selected, a description and sketch of the site were put into the field parameter logbook. This included the width and depth of the ditch and the approximate flow rate of water or the size of the puddle. The sediment logbook also contains a detailed description of the sediment down to a depth of 2 feet.

The surface water sample was taken before the sediment sample so that augering activities would not affect the surface water sample. A clean glass beaker was filled with sample water and readings of pH, temperature, and conductivity were taken and recorded in the logbook. The sample bottles were then triple-rinsed with the water to be analyzed. Care was taken to dispose of the rinse water in an area where it could not flow back into the sample location. The bottles were filled in the order of decreasing volatility. In the case of a TAL/TCL and explosives sample, the VOC vials were filled first, followed by the BNA/pesticide/PCB and explosives samples, and finally the metals sample. In the case of a select metals and explosives sample, the bottles to be analyzed for explosives were filled first. For all bottles except the VOC vials, 10% headspace was left. The VOC vials were preserved with 6 drops of hydrochloric acid, and then sample was added by pouring from a cleaned and triple-rinsed glass beaker. The vials were capped in such a way that no air bubbles were present in the sample. This method of pouring the sample from the beaker into the vials was only used for the VOC aliquot and was performed to avoid losing the preservative while the vial is filling. The metals sample bottle was preserved with nitric acid to a pH equal to or less than 2.

The samples were placed in ice-filled coolers and maintained at a temperature of 4 degrees from the time of collection until analysis. Trip blanks were placed in sample coolers which contained aqueous VOC samples to determine if contamination of the samples was occurring during shipping.

4.9.3 Sediment Sample Location Rationale

In all cases, sediment samples were taken from locations which indicated that deposition, rather than scour, was taking place. These included the inside bank of bends and edges of deep pools. When samples were taken from areas where water was flowing, the sample was taken near the bank where the water velocity is lower.

Sediment samples were taken from the Rutherford Fork of the Obion River in two locations. One was taken downstream of the confluence with Ditch C and this was a composite sample from 0 to 2 feet.

Another sample location was situated to give background levels of contamination and this is upstream of the confluence with Johns Creek.

Two background locations were selected on Wolf Creek. One location is on the East Fork where the creek enters the reservation. The other background sample was taken from the West Fork near the Sunny Slope area. These samples will give creek conditions unaffected by plant activities. Another sample was taken from Wolf Creek as it exits the reservation on the west side. This sample was taken because a farmer mentioned to several ICF personnel that he remembers seeing Wolf Creek "run red" north of the plant. The sample was taken to determine if off-site levels of contaminants in sediment may act as a source of surface water contamination, or if the sediment contamination is confined to within the reservation boundary.

A sediment sample was taken in Johns Creek in lieu of a sixth sediment sample in Ditch 7 because it was felt that Ditch 7 had been adequately covered whereas Johns Creek, which flows continuously, should be further investigated. In addition, two sample locations were selected on Halls Branch to investigate the effects of drainage from the OBG and ADA.

Other than these variances, sediment sample locations were laid out as specified in the work plan. There were four sample locations on both Ditch B and Ditch C, and samples from each of these locations were taken from 3 depths: 0 to 6 inches, 6 to 12 inches, and 12 to 24 inches. At all of these locations, a TAL/TCL sample was taken from the 0- to 6-inch interval and a select metals and explosives sample was taken from the two deeper intervals.

From each of Ditches 1 through 10, sediment samples were taken from 2 depths (0-1 feet and 1-2 feet) from 6 locations, except for the samples that were moved to either Johns Creek or Halls Branch. As in Ditches B and C, the top interval was submitted for TAL/TCL and explosives analysis while the deeper interval was submitted for select metals and explosives analysis.

4.9.4 Sediment Sampling Procedures

A clean sheet of plastic was spread on the ground next to the sample location to protect the sampling equipment. If a surface water sample was to be taken at the same location, then the surface water sample was collected first. A 6-inch diameter stainless steel bucket auger was used to take the sediment sample. The bucket auger was emptied into a clean glass bowl. The sample was described, and the following characteristics were noted: primary constituent (silt, clay, sand, or gravel), color, and grain size, and then the secondary constituents were noted along with a rough estimate of relative amount by weight. Then, if a TAL/TCL and explosives sample was taken, the VOC bottles were quickly filled using a stainless steel scoop. Each VOC bottle was filled to the top to eliminate headspace in the jar. After this sample was taken, the sample was composited with a stainless steel trowel. The BNA/pesticides/PCB and/or explosives sample and metals sample were then taken in that order.

For the next depth, the auger and glass bowl were cleaned using any available surface water at the site, wiped with paper towels, and then rinsed with deionized, organic-free water which was stored in teflon bottles. If no surface water was available, then deionized, organic-free water was used for the cleaning. Care was taken to ensure that rinse water did not splash onto the sample location.

All sampling equipment, including the scoop, trowel, auger, and glass bowls were decontaminated between sample locations. Decontamination procedures consisted of the thorough scrubbing of the equipment with an Alconox solution, rinse with approved water, rinse with deionized, organic-free water, rinse with isopropanol, and a final rinse with deionized, organic-free water. All sample equipment was securely wrapped in aluminum foil after decontamination and was not unwrapped until the samplers reached the sample location.

Rinse blanks were taken periodically through the sampling period. This consisted of pouring deionized, organic-free water over the decontaminated sampling equipment and collecting the rinsate in sample containers. The purpose of these rinse blanks is to determine if cross-contamination between sampling locations was occurring.

4.10 STREAM GAGING

Stream gages were installed in five locations around the facility to generate data concerning ditch baseflow, volumetric flow rate as a function of precipitation, and surface water flow versus infiltration into groundwater.

4.10.1 Stream Gage Location Rationale

The gages were installed in the locations shown in Figure 4-17. V1 was located downstream of the outfall of the O-Line PWTF and upgradient from the O-line ponds. Flow measurements taken here give information about the base flow before leachate from the ponds (if any) or surface runoff from the cap enters the ditch.

V2 is on the same ditch as V1, but downstream of the O-line ponds near the junction with Ditch 5. V3 is on Ditch 5, adjacent to V2, and located just upstream of the confluence. The sum of flows measured at V2 and V3 represents the total flow entering Ditch B. The area between the gages is nearly flat and is vegetated. Therefore, estimates of soil infiltration, runoff, and infiltration through the ditch floor were made with information collected from V1, V2, and V3. These calculations are described in Section 5.0.

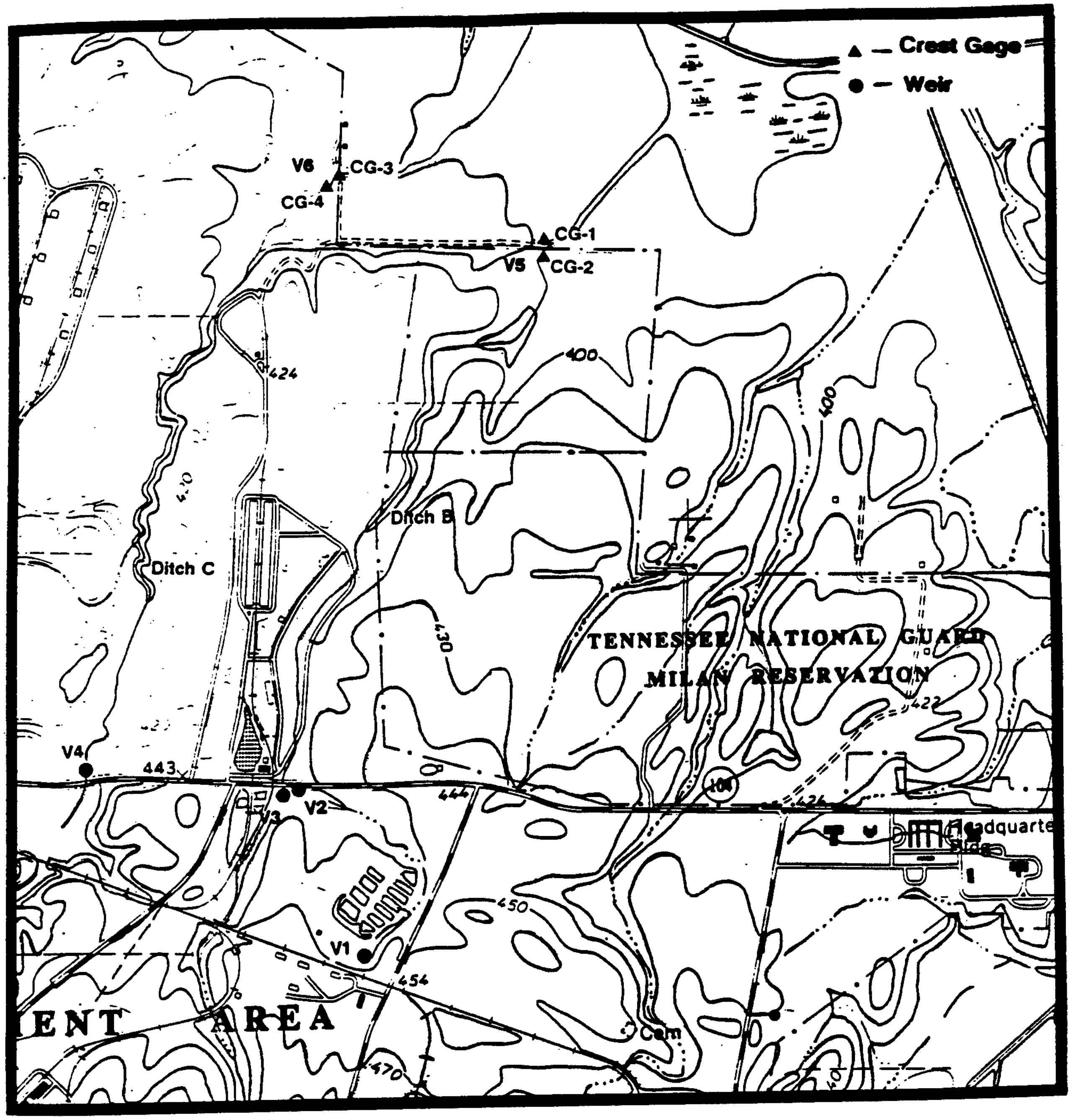
V4 is located just north of Highway 104 on Ditch C. This is downstream of the PWTF outfalls but upstream of the WCOP sewage treatment plant outfall.

V5 is on Ditch B where it leaves the facility reservation. The coal pile runoff outfall contributes water to this ditch between the Ditch 5 gages and V5.

V6 is located on Ditch C where it exits the reservation. At both V5 and V6, the ditches are wide, deeply cut, and the high water marks indicate that large amounts of water sometimes pass through these points.

In choosing the appropriate type of stream gage, consideration was given to several factors. In the first place, the ditches are clearly "losing" ditches; that is, water tends to flow from the ditch bottom and sides and percolates down to the water table. The ditches are all deeply cut, erosional units which appear to have eroded through the low-permeability topsoil into the high-permeability Memphis Sand unit. When the ditches flow, it was observed that the water is very turbid; therefore, a large quantity of sediment is carried into the ditches by surface runoff. Also, the range of flows at each location was considered by examining the high water marks on the ditch sides.

Weirs are most useful for measuring flow in channels where a large variation of flow rate is expected. Flumes are preferred in situations where the flow is fairly steady and are especially useful where the flow is laden with sediment. The stream gages were to be installed in early September, which is characterized by moderate intensity rain events of short to moderate duration. The high water marks on the ditch walls indicated that a wide range of flow rates could be expected. Therefore, since short-term data was desired, it was decided to install V-notch weirs in location V1 through V4. This type of weir is easily calibrated and can provide accurate measurements at low flow rates, where water spills over the V, and at high flow rates where the weir is overtopped. It was expected that the sediment problem could be handled day-to-day by clearing the sediment behind the weirs.



CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Figure 4-17
Locations of Stream Gages

At locations V5 and V6, it was feared that no structure could be built that would withstand the high flows potentially encountered at these points. The ditches here were more than 14 feet wide and approximately 10 feet deep. The high water marks indicated that water sometimes reaches the top of the banks. Also, the amount of silt deposited on vegetation growing on the ditch walls indicated that the water is heavily laden with sediment.

It was therefore decided that crest-stage gages would be installed at V5 and V6. These gages record the highest depth of water flowing in the ditch at that point. The gages were also graduated along the outside so that an observer could determine the height of water at a point in time. The corresponding volumetric flow rate could then be calculated using the slope of the ditch, the cross-sectional area of the ditch, and the Manning friction factor, which takes into account the roughness of the ditch area.

4.10.2 Gage Installation

Gages V1 through V4 were installed on September 7 and 8, 1990. They were constructed of 3/4-inch marine plywood and were braced with 2"x 4" and 4"x 4" lumber. The dimensions of each gage are given in Table 4-10.

As shown in the diagram in Table 4-10, the weirs were installed by first hand-excavating a 1 to 2 foot channel in the ditch bottom and a cavity at least 1 foot horizontally into the ditch walls. The weir was then put into this slot and was braced with wooden posts on the downstream side in four locations. The posts were driven further into the ditch bottom with a sledge hammer until flush with the top of the weir. In addition, the tops of the braces were cut at an angle away from the weir so that the water spilling over the top would be less affected.

Concrete was then poured into the slot on the bottom. Forms made either of plywood or cardboard were placed perpendicular to the weir and parallel to the ditch sides. Concrete was then poured inside the forms so that the slot cut into the bank was also filled. The height of the concrete was brought up nearly to the top of the weir.Care was taken to ensure that for a distance from the weir of at least five times the weir height in both the upstream and downstream directions, the ditch bottom was smooth and flat. Also, when possible, the weirs were not located near a bend in the ditch or a constriction.

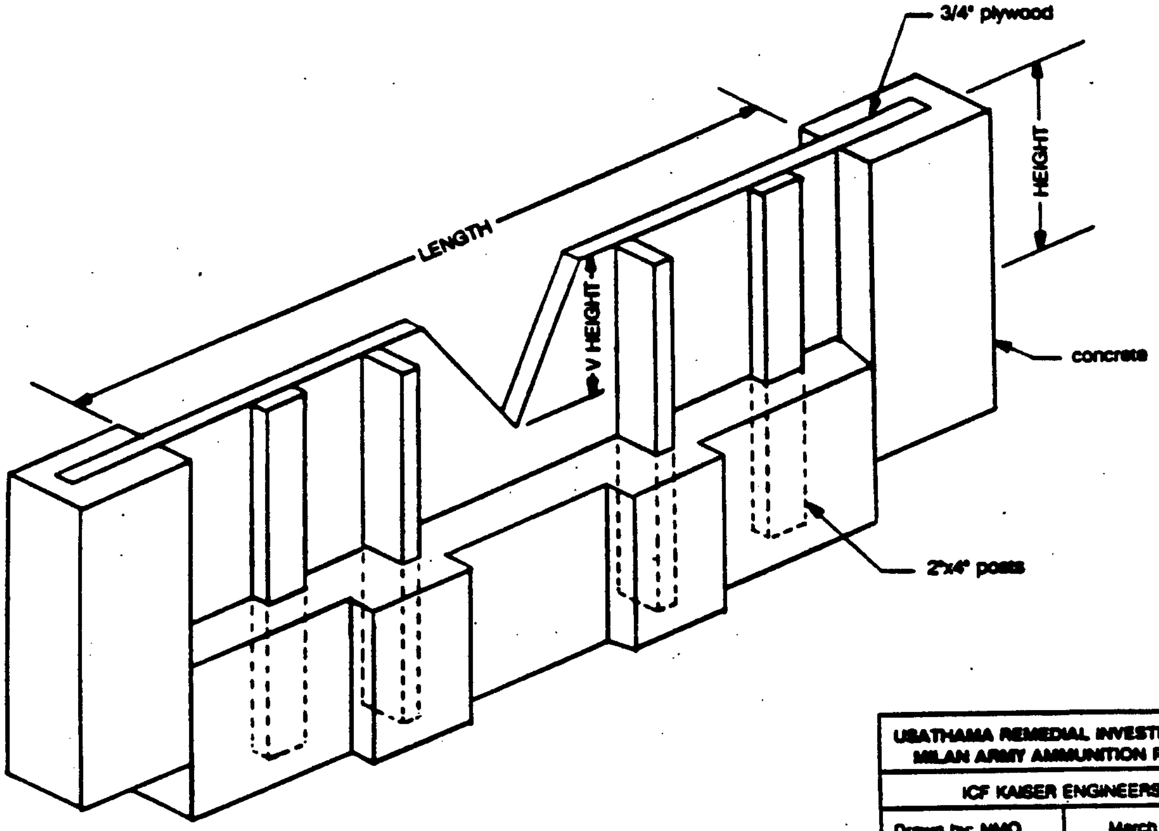
The crest gages were constructed of 1.5-inch PVC pipe, a wooden dowel, and a 2 x 4 mount. A diagram of crest gage construction is shown in Figure 4-18. The PVC pipe was 5 feet long and capped at both ends. A dowel was painted with water-soluble paint and attached to the top cap of the pipe so that it hung straight down the inside of the pipe and reached the bottom cap. Six evenly-spaced holes were drilled through the pipe wall on the bottom to permit water to enter. A hole was drilled just under the top cap to allow air to escape. The holes were small so that the total flow rate into the gage is small. This prevents surging of water into the gage which would distort the actual high water level mark on the dowel. The PVC pipes were attached to 2"x 4" lumber using cold-rolled steel brackets. The outside of the lumber was graduated from ground surface to the top so that an observer standing on the bank could read the water level.

The crest gages were installed in pairs at locations V5 and V6. A post hole digger was used to dig a hole 2 feet into the ditch bottom. The crest gage mount was placed into the hole and concrete was poured into the hole. For location V6, because the water was flowing at the time of installation, and because the ditch bottom is pure sand, forms were used to hold the hole open while it was being dug. The gages were placed into the forms and concrete was poured around it.

The relative height of the ditch bottom was surveyed at several locations both upstream and downstream of each gage. This information was used to calculate the slope of the ditch, as discussed in Section 5.0. In addition, the relative elevations of points along the ditch bottom and up the ditch sides,

Table 4-10
Dimensions of Weirs

WEIR NUMBER	WEIR LENGTH (FT)	WEIR HEIGHT (FT)	V HEIGHT (FT)
V1	2.67	1.0	0.5
V2	6.5	1.25	0.5
V3	8.0	1.75	0.67
V4	9.08	2.0	0.67



USATHAMA REMEDIAL INVESTIGATION
MILAN ARMY AMMUNITION PLANT

ICF KAISER ENGINEERS

Drawn by: NMO | March 1991

Checked by:

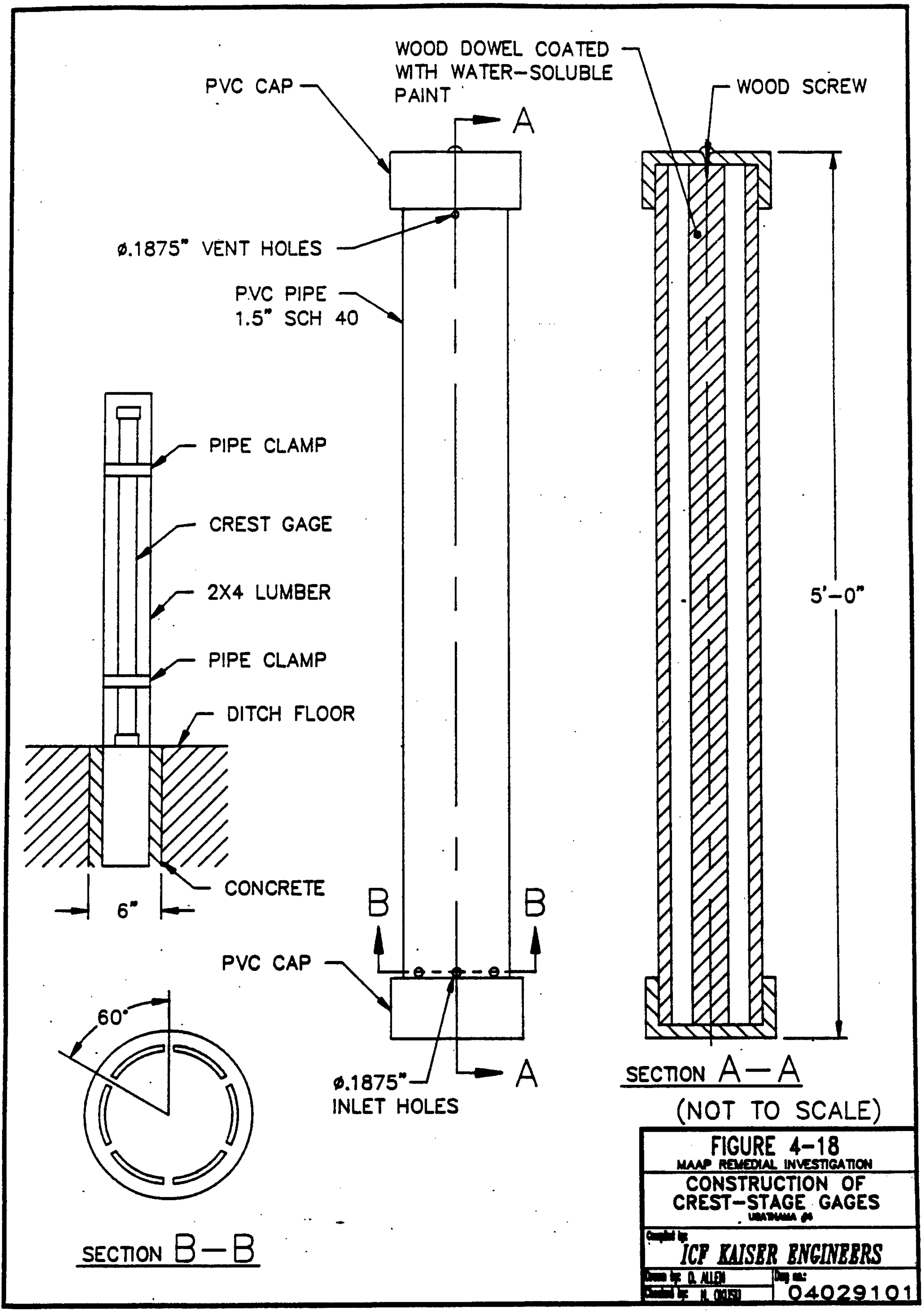


FIGURE 4-18
MAAP REMEDIAL INVESTIGATION
CONSTRUCTION OF
CREST-STAGE GAGES
USATHAMA #4

Compiled by:
ICF KAISER ENGINEERS
Drawn by: D. ALLEN
Checked by: H. OKUSU
Dwg no.: 04029101

on a straight line perpendicular to the ditch flow direction, were measured using a surveyor's level. A reasonably exact diagram of the ditch cross-sectional area was made using this data, and knowing the height of the water, the wetted perimeter was calculated at the location of the crest gage.

4.10.3 Flow Measurement Procedures

Flow measurements were taken during rainfall events. The following two types of weir measurements were made: measurements under unsubmerged conditions and measurements during submerged conditions. A diagram of how these two type of measurements were taken is shown in Figure 4-19. For an unsubmerged weir, an estimate was made of the height of the water measured from the bottom of the V-notch. At a distance three times this height and upstream of the weir, the water level was measured from the ditch bottom.

For a submerged weir, as usually happened at V4, two head measurements were taken. The height of the water both upstream and downstream of the weir was measured. The downstream height was measured beyond the surface oscillations caused by the weir.

The crest-stage gage measurements were made by opening the top of the gage, withdrawing the wooden dowel, and measuring the height of the highest water mark on the painted surface from the bottom of the dowel. This measurement represents the highest volumetric flow rate experienced by the ditch between the present reading and the last reading.

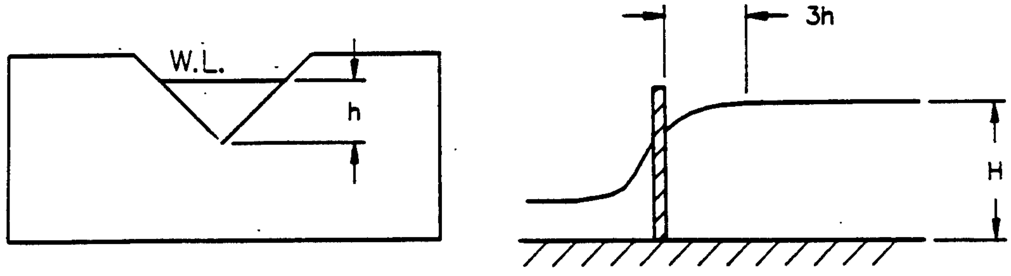
4.11 DOMESTIC DRINKING WATER SAMPLING

On November 27, 1990, two domestic drinking water wells were sampled for select metals and explosives. The wells are the drinking water source for the Bledsoe residence and for the New Hope Church. The procedures used in sampling the wells are as follows:

- The tap nearest to the pump was located.
- The tap was turned on and the well was purged for 15 minutes so that standing water in the well would not be sampled. Because these wells are currently used as drinking water supply, the purge water was not collected or treated.
- pH, temperature, and conductivity readings were taken every 5 minutes during well purging to indicate if the conditions in the well were stabilizing.
- The sample was taken by slowing down the tap flow rate and filling the sample bottles. About 10% headspace was left in each bottle. The filtered metals sample was taken by filling a clean glass beaker with water from the tap and then using a peristaltic pump with a 0.45 micron filter to remove particulates. The peristaltic pump discharged directly into the filtered metals sample container. Both the filtered and unfiltered select metals samples were preserved to a pH less than or equal to 2 with nitric acid.

NOTES: (IF WEIR IS NOT SUBMERGED)

1. MEASURE h.
2. CALCULATE 3h.
3. MEASURE H AT A DISTANCE 3h UPSTREAM OF THE WEIR.



NOTES: (IF WEIR IS SUBMERGED)

1. MEASURE H_1 AT THE LOCATION OF THE HIGHEST HEAD UPSTREAM OF THE WATER.
2. MEASURE H_2 DOWNSTREAM OF THE SURFACE UNDULATIONS.

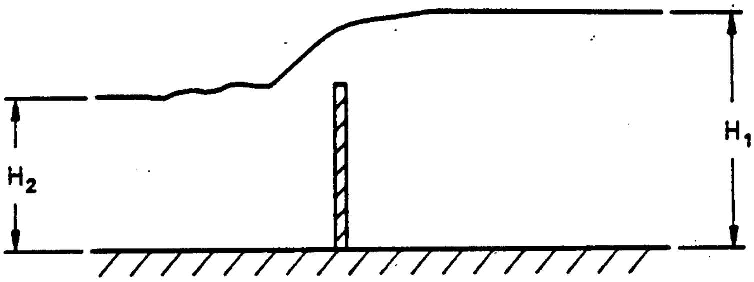


FIGURE 4–19
MAAP REMEDIAL INVESTIGATION
WEIR
MEASUREMENTS
USATHAMA #4
Compiled by:
ICF KAISER ENGINEERS
Drawn by: D. [illegible]
Checked by:
Dwg no:
04039101

Figure 4-19
Weir Measurements

5.0 RESULTS OF PHYSICAL AND CHEMICAL ANALYSES

The physical and chemical data collected during the field investigation performed at MAAP between July and December, 1990, are presented in this section. The field characterization and logging of the subsurface soil samples during drilling was used to develop east-west and north-south geologic cross-sectional diagrams of the site. Estimates of hydraulic conductivity of the aquifer material were calculated from the aquifer tests and soil grain size analyses. These estimates of hydraulic conductivity and the hydraulic gradient obtained from the groundwater level contours yield estimates of the groundwater flow directions and velocity. The stream gage flow measurements were used to estimate the rates of infiltration into the soil, runoff, and infiltration through the ditch floor to the vadose zone. In addition, the results of the chemical analyses of the environmental samples are presented by media.

5.1 GEOLOGY

Background information about the regional and local geology underlying MAAP was presented and discussed in Section 2.0. The additional information about the site-specific geology obtained from the drilling operations and subsurface soil sampling performed as part of this investigation is presented in this section. In addition, the results of the physical testing of soil samples are discussed.

5.1.1 Site Geology

MAAP lies within the Mississippi embayment of the Gulf Coastal Plain. Geologically, the Mississippi embayment is a syncline which plunges to the south with an axis that parallels the Mississippi River. The syncline is filled with sedimentary strata and rocks ranging in age from Jurassic to Quaternary (Cushing et al., 1964). Most of the major geologic units within the embayment include water-bearing strata that form aquifers of regional importance. The lithology and continuity of the geologic units are variable because of modifying structural features and differing depositional environments during the geologic evolution of the embayment region.

The Memphis Sand of the Claiborne Group is the stratigraphic unit which was encountered during drilling at MAAP. Approximately 10 to 20 feet of alluvium was encountered in each borehole. The alluvium is underlain by the sands, silts and clays characteristic of the Memphis Sand. Previous investigators at MAAP have speculated that the Porter Creek Clay is the lower confining unit for this aquifer. However, this clay unit was not encountered during drilling. A detailed review of the available information concerning the regional geology has shown that the thickness of the Memphis Sand is greater than previously thought, and this was confirmed by the results of the drilling.

During drilling of the borehole for monitoring well MI061 (Figure 2-6), a dense clay unit was encountered at a depth of 245 feet. A split spoon sample was collected from 245 to 247 feet which recovered a stiff, light-gray clay of low plasticity. Additional footage could not be drilled because the 6-inch wing bit could not cut and penetrate this dense clay. Drilling of the borehole was terminated and the monitoring well was subsequently completed with the bottom of the well set at a depth of 245 feet. Based upon the calculated thickness of the Memphis Sand at MI061, and the difficulties encountered during drilling into the clay zone, it is interpreted that the clay zone represents the top of the Flour Island Formation.

The geologic cross-section presented in Figure 2-3 shows the stratigraphic units beneath the Milan area. Based on the surface elevations surveyed for each monitoring well and the altitude of the base of the Memphis Sand (shown in Table 5-1), the thickness of the Memphis Sand, including the surface alluvium, was calculated for each monitoring well. The thickness of the Memphis Sand and alluvium varied from a minimum of 216 feet in monitoring well MI080, northwest of MAAP, to a maximum of 374 feet in MI081 located northeast of MAAP. A general thickening from east to west is apparent from the calculated thicknesses of the Memphis Sand.

TABLE 5-1
Elevation of the Memphis Sand and Monitoring Wells at MAAP

WELL ID	GROUND ELEVATION (ft-msl)	ELEVATION OF BASE OF MEMPHIS SAND[1] (ft-msl)	THICKNESS OF ALLUVIUM AND THE MEMPHIS SAND BENEATH MAAP (ft)	DEPTH OF WELL SCREEN INTERVAL (ft)
MI057	439.29	180	259	160-170
MI058	439.29	180	259	64.5-74.5
MI059	391.70	160	232	18-28
MI060	392.00	160	232	139.5-149.5
MI061	392.00	160	232	234.5-244.5
MI062	493.55	200	294	89-99
MI063	493.65	200	294	149.5-159.5
MI064	493.55	200	294	236-246
MI065	475.73	190	286	99-109
MI066	476.53	190	287	160-170
MI067	477.53	190	288	241-251
MI068	472.43	125	347	88-98
MI069	473.13	125	348	161-171
MI070	473.53	125	349	240-250
MI071	436.58	150	287	54-64
MI072	417.18	160	257	34-44
MI073	461.13	150	311	83-93
MI074	436.68	150	287	54-64
MI075	439.19	180	259	160-170
MI076	398.38	25	373	33-43
MI077	396.48	25	371	44.5-54.5
MI078	391.68	25	367	29-39
MI079	419.35	200	219	45-55
MI080	416.35	200	216	44.5-54.5
MI081	399.48	25	374	35-45
MI082	378.00	25	323	34-44

---

[1] Data obtained from the structure contour map of the base of the Memphis Sand (Parks and Carmichael, 1990).

The Memphis Sand consists of a thick body of non-marine sands that include subordinate lenses of clay and silt at various horizons. It was observed during field sampling that the clay and silt lenses varied in thickness; however, most of these lenses were 0.5 to 6 inches thick. The clay and silt are carbonaceous and lignitic. The sands in this unit range from very fine to very coarse, but are commonly fine-to-medium and medium-to-coarse grained. The color of the sands vary, but are predominately white, brown, yellow or gray with minor occurrences of reddish-yellow to red sands occurring as thin bands within the white, yellow, brown and gray sand zones. The sand is thick-bedded, with grain sizes varying vertically as well as laterally. Thin layers of indurated rock fragments were encountered and are probably erosional lag deposits from an iron-cemented sandstone source.

The surface alluvium encountered during drilling ranged in thickness from 10 to 20 feet. The alluvium consisted of a yellowish brown to strong brown, loamy, silty clay. The silty clay was loose to moderately stiff with low plasticity, and contained varying amounts of organic material.

The Flour Island Formation of the Wilcox Group is the lower confining unit for the Memphis Sand and consists predominantly of clay and silt (Parks and Carmichael, 1990). The thickness of this unit beneath the Milan area is estimated to be 50 feet based on the geologic cross section shown in Figure 2-3. The thickness of this clay unit and the dense physical characteristics would explain the difficulties encountered during drilling at MI061.

East-west and north-south geologic cross-sections were developed from the soil boring logs of monitoring wells installed at MAAP (Figures 5-1 and 5-2). Split spoon samples were collected at five-foot intervals from the shallow and deep monitoring well borings at cluster well sites. The lithologic logs from these wells were combined to form a composite stratigraphic column for the site. Other stratigraphic columns were constructed from the boring logs of single wells. The split spoon samples collected are lithologically representative of a two-foot interval within a five-foot drilling interval. The stratigraphic columns illustrate a continuous lithology based on the samples collected and observations recorded during drilling of the borehole. For example, a split spoon sample containing sands from the 20 to 22 foot depth interval was considered continuous if the sands were also recovered in the split spoon sample from the 25 to 27 foot depth interval. If a clay zone was encountered and observed in the drill cuttings during drilling from 20 to 25 feet, the depth and approximate thickness of the clay unit was noted on the boring log.

The geologic cross-sections (Figures 5-1 and 5-2) indicate that the lithology varies both vertically and laterally over short distances. Wells MI057 and MI058 were 800 feet apart, and from the stratigraphic columns shown in Figure 5-1, it is evident that the occurrence and thickness of the clay zones changes considerably over short distances. Therefore, correlation of stratigraphic units has not been attempted because of the lateral variations in lithology and absence of laterally continuous and recognizable stratigraphic units.

Attempts to correlate well log data collected during this investigation to the gamma log data presented by Weston (USATHAMA, 1983b) from adjacent well sites were unsuccessful. The interpretations and conclusions, presented by Weston, indicate that there is lateral continuity of clay-rich sediments not evident in the lithologic logs. The Weston report also indicated that there were concentrations of distinct peaks in three general depth zones: a surface zone from 0-25 feet; an intermediate zone at approximately 40-80 feet; and a deep zone at approximately 200-240 feet. Reevaluation of the Weston gamma log data does not support this generalized conclusion, which tends to oversimplify the stratigraphy of this area. Gamma peaks have been recorded at distinctly different horizons within adjacent wells, except for the surface zone that was recognized in all wells surveyed. Correlations between lithologic logs developed during this investigation and the gamma logs presented by Weston (USATHAMA, 1983b) were unsuccessful, which again supports the interpretation of laterally discontinuous sedimentary units beneath MAAP.

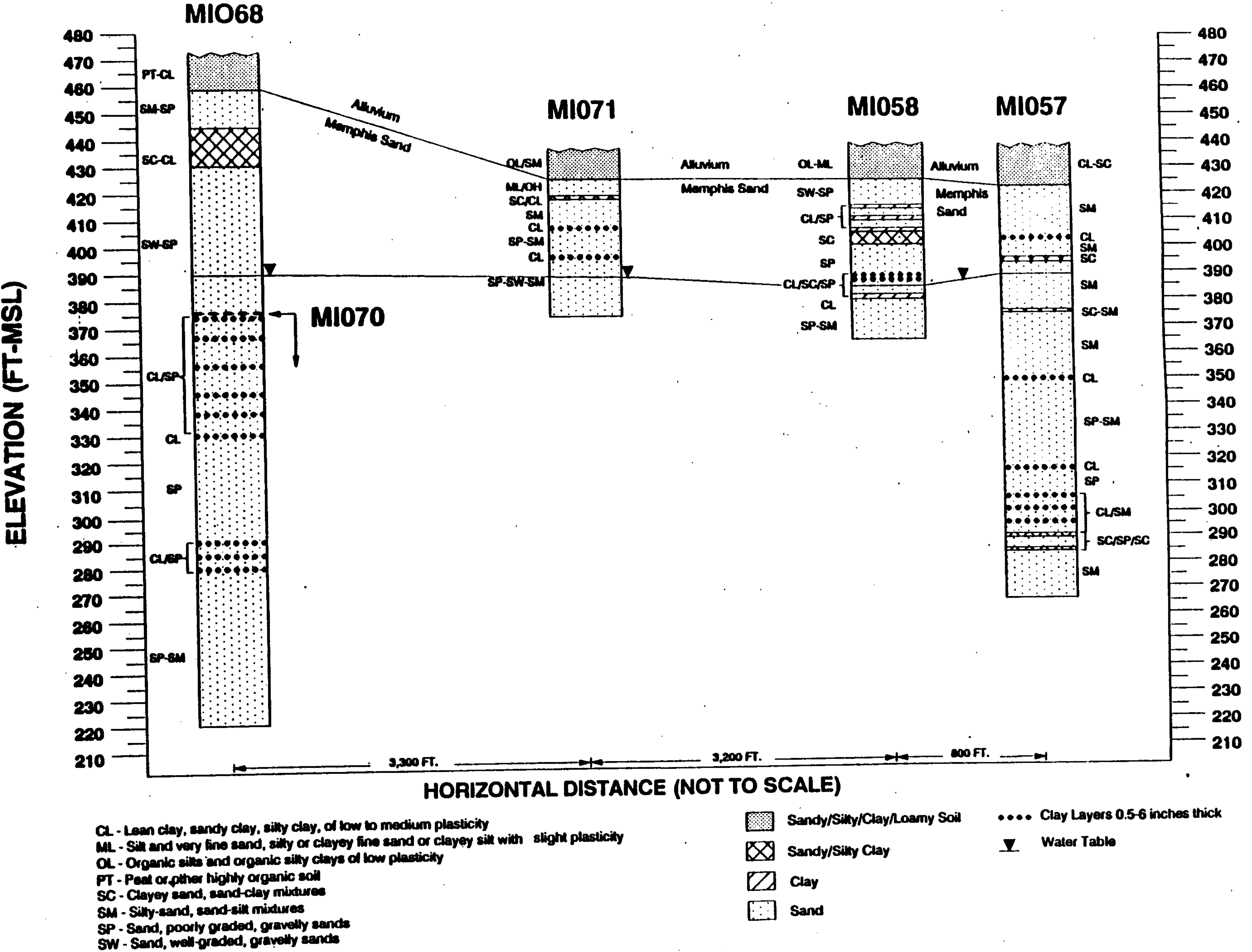


Figure 5-1
East/West Geologic Cross-Section at MAAP

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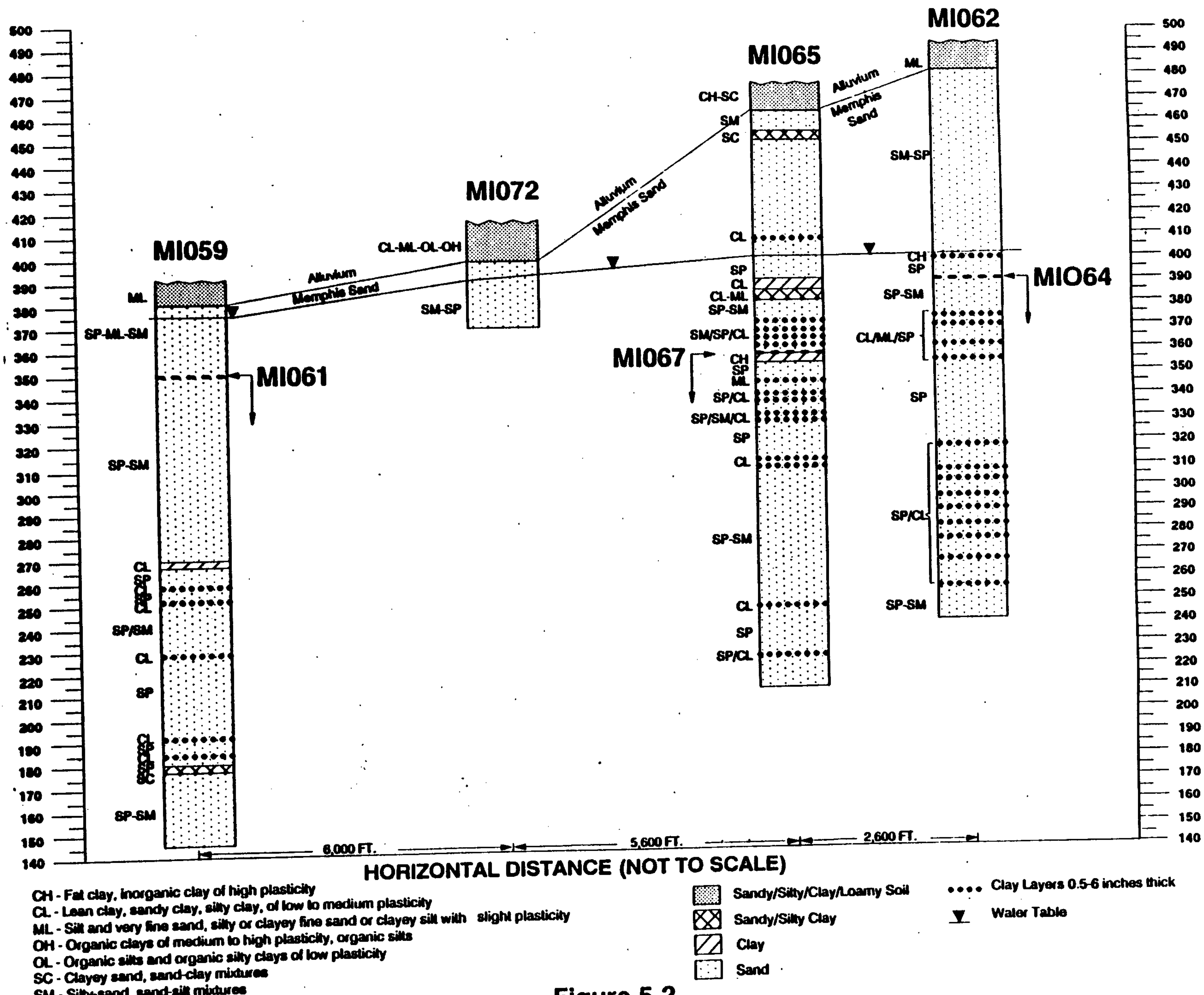

Figure 5-2
North/South Geologic Cross-Section at MAAP

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5.1.2 Soil Physical Test Results

Fifteen percent of the total number of soil samples collected during subsurface drilling at MAAP were analyzed for grain-size distribution, percent moisture content, Atterberg limits, and USCS soil classification criteria. These soil samples represent a wide distribution of drilling locations and depths within the aquifer, and were selected to provide a range of values. Resulting data were used to: (1) qualitatively describe the aquifer material, (2) verify the descriptive logs of the field geologist overseeing drilling, (3) estimate hydraulic conductivity for the aquifer by grain-size analysis methods, and (4) provide qualitative, site-specific information on other hydraulic characteristics of the aquifer, such as infiltration rates, storage capacity, and soil porosity. The calculations of hydraulic conductivity and other hydraulic characteristics are presented in Section 5.2.

Of the 762 lithologic samples collected during subsurface drilling, 112 samples were selected for analysis for geotechnical parameters. Sample depths ranged between 0 and 250 feet. However, the average depth of the samples analyzed was 59 feet due to the greater number of shallow borings than deep borings. Fifty-six percent of the samples analyzed were chosen from monitoring well locations, and 44% were chosen from soil borings. Geotechnical physical test results are provided in Appendix K; general findings from these analyses are summarized here.

Grain size analysis allows for the classification of soils into USCS divisions and groups. The majority of samples analyzed belong to the coarse-grained soils division, within the category of "sandy soils". The other samples are fine-grained soils, containing a significant amount of clay. The sandy soils include 67% of the total samples analyzed and are classified as poorly graded sand and sand/silt mixtures (SP and SM). Fine-grained soils include 20% of the samples analyzed and are classified as clay (CL). However, most of the clay samples were collected from shallow borings above the water table, including some that were collected within the surface alluvium. The remainder of the samples were classified as mixtures of sand, silt, and clay (SC and ML).

In general, the grain-size analyses and descriptive classifications performed on MAAP samples in the laboratory compare well with descriptions recorded in the field during drilling operations. However, grain-size distribution curves indicate that all of the coarse-grained materials contain an important component of fines, including silt. The presence of the silt-sized fraction of sedimentary materials is difficult to discern within fine and medium sands. For this reason, geologic logs for the wells may indicate the presence of better sorted sands than are actually present at the site.

Water content in the samples analyzed ranged between 0.2 and 33.5%, with an average value of 17%. The most porous materials (SP and SM) exhibited the full range in water content, while water content measured in the less porous material (CL and ML) varied only between 10 and 20%. This relationship is expected, as porous material collected above the water table retains little moisture, and below the water table the pores remain saturated with groundwater.

5.2 HYDROGEOLOGY

The unconfined, unconsolidated aquifer beneath the MAAP site was further characterized by the installation of 26 new monitoring wells and numerous soil borings between July and December, 1990. The following information was used to refine the existing conceptual hydrogeologic model for the site developed by previous investigations (USATHAMA, 1982a, 1982b, 1983a):

(1) The aquifer at MAAP is a thick, laterally continuous, and highly transmissive hydrogeologic unit. The shallow portion of this aquifer is hydraulically connected to major streams and rivers in the area. Flow conditions in the deeper portion of the aquifer have not been fully characterized.

(2) The bottom elevation of the aquifer is inferred from the geologic log of MI061. A gray clay was encountered in this well at a depth of 265 feet. This depth corresponds well with published

information regarding the elevation of the top of the Flour Island Formation, which is a thick continuous clay that acts as a regional confining unit for the McNairy Sands.

(3) Thin lenses of clay, silt, and clay-rich material are present throughout the aquifer horizon. The average thickness of these lenses appears to be approximately 0.2 ft. The lenses encountered during drilling ranged from 0.04 to 0.5 ft. Individual clay layers cannot be correlated between wells, and therefore, are considered discontinuous. These lenses are believed to impede the localized downward flow of groundwater without significant effect on horizontal movement or large-scale (regional) vertical migration.

(4) Within sandy intervals the aquifer material is highly stratified. This causes a reduction in vertical hydraulic conductivity, and contributes to anisotropic flow conditions in the aquifer.

These findings represent general hydrogeologic information important to the fate and transport interpretations provided later in this report. Details concerning specific hydraulic properties of the aquifer and flow conditions within the aquifer are discussed below.

5.2.1 Compilation of Hydraulic Conductivity

Hydraulic conductivity (*K*) is a property which describes the rate at which water can move through a permeable medium. Several methods are available for both measuring and estimating *K* for an aquifer, including direct aquifer testing, estimation from physical properties of the aquifer material, and comparison with published *K* values for similar aquifer materials. Four different methods were employed to determine *K* for the aquifer beneath MAAP: grain-size analysis, slug tests, pump tests, and recovery tests. The results from each method are summarized in this section.

5.2.1.1 Grain-Size Analysis. Many researchers have developed methods for estimating hydraulic conductivity using physical characteristics of porous media. The determination of *K* using grain-size information is an inexpensive and relatively simple procedure for estimating reasonable K values for aquifer materials. Other methods, however, provide more reliable estimates of hydraulic conductivity. Therefore, the determination of *K* by grain-size methods is most useful when used in conjunction with aquifer testing methods. In this way, results from grain-size estimation methods can be used for comparison purposes.

Several different grain-size methods for the determination of *K* are presently available. However, each method has been developed for specific porous materials. The selection of an appropriate method is the first, and most critical, step in this type of analysis to ensure reliable results.

The aquifer at the site is a heterogeneous mixture of sand, silt, and clay, exhibiting marked grain-size variations within the sand-sized fraction. The Masch and Denny (1966) method for estimating *K* with grain size distribution data is an appropriate method for this type of aquifer material. This method accounts for a wide range in grain size by incorporating statistical parameters within hydraulic conductivity calculations. These parameters include: (1) mean grain size of the sample, (2) standard deviation of the grain-size distribution, (3) measures of skewness, and (4) measures of modality in the sample. This method is particularly suited for the heterogeneous sandy soils at MAAP, but it is not suitable for the clay and clay-rich samples encountered. The clay and clay-rich samples were not considered for grain-size determinations of *K* because existing methods do not provide reliable results when applied within the clay-sized fraction.

Grain-size distribution results obtained by sieve analysis (Appendix K) were used to estimate K for the sandy soil samples. Table 5-2 provides a list of *K* values determined by the Masch and Denny

Table 5-2
Grain-Size Distribution Analysis

SAMPLE	DEPTH INTERVAL	USCS CLASSIFICATION	K (ft/min)
MI-057	145.0'-147.0'	SM	0.009
MI-057	165.0'-167.0'	SM	0.019
MI-058	65.0'-67.0'	SP-SM	0.017
MI-058	70.0'-72.0'	SP-SM	0.022
MI-059	20.0'-24.0'	SP-SM	0.018
MI-059	25.0'-27.0'	SP	0.019
MI-060	142.0'-144.0'	SP-SM	0.031
MI-061	70.0'-72.0'	SP-SM	0.019
MI-061	160.0'-162.0'	SP-SM	0.019
MI-061	240.0'-242.0'	SP	0.032
MI-062	95.0'-97.0'	SP	0.019
MI-063	155.0'-157.0'	SP-SM	0.016
MI-064	105.0'-107.0'	SP-SM	0.018
MI-064	240.0'-242.0'	SP-SM	0.015
MI-065	100.0'-102.0'	SP-SM	0.019
MI-065	105.0'-107.0'	SP-SM	0.026
MI-066	165.0'-166.5'	SP-SM	0.016
MI-067	145.0'-146.5'	SP-SM	0.021
MI-067	210.0'-211.5'	SP-SM	0.010
MI-067	245.0'-246.5'	SP	0.025
MI-068	85.0'-87.0'	SP	0.032
MI-068	90.0'-92.0'	SP	0.031
MI-069	168.0'-170.0'	SM	0.016
MI-070	220.0'-221.5'	SP-SM	0.025
MI-070	240.0'-241.5'	SP-SM	0.032
MI-071	40.0'-42.0'	SP/SP-SM	0.033
MI-071	60.0'-61.0'	SP-SM	0.019
MI-072	45.0'-47.0'	SP-SM	0.018
MI-073	75.0'-77.0'	SM	0.008
MI-073	80.0'-82.0'	SP-SM	0.031
MI-073	90.0'-92.0'	SP	0.051
MI-074	55.0'-57.0'	SP-SM	0.026
MI-075	165.0'-166.5'	SM	0.016
MI-076	25.0'-27.0'	SM	0.009
MI-076	40.0'-42.0'	SP	0.030
MI-077	25.0'-27.0'	SP-SM	0.018
MI-077	45.0'-47.0'	SM	0.019
MI-078	20.0'-22.0'	SP-SM	0.024
MI-078	30.0'-32.0'	SM	0.013
MI-078	40.0'-42.0'	SP-SM	0.021
MI-079	20.0'-22.0'	SP-SM	0.018
MI-079	40.0'-42.0'	SP-SM	0.014
MI-079	55.0'-57.0'	SM	0.013
MI-080	40.0'-42.0'	SM	0.013
MI-081	40.0'-42.0'	SP-SM	0.023

Table 5-2 (continued)
Grain-Size Distribution Analysis

SAMPLE	DEPTH INTERVAL	USCS CLASSIFICATION	K (ft/min)
MI-082	40.0'-42.0'	SP-SM	0.025
MI-082	45.0'-47.0'	SP-SM	0.027
OBG-A-1	35.0'-37.0'	SP-SM	0.020
OBG-A-2	25.0'-27.0'	SP-SM	0.022
OBG-A-2	45.0'-47.0'	SP-SM	0.026
OBG-A-3	50.0'-52.0'	SP-SM	0.039
OBG-A-3	80.0'-82.0'	SP	0.036
OBG-A-4	45.0'-47.0'	SP	0.033
OBG-A-5	10.0'-12.0'	SM	0.009
OBG-B-2	30.0'-32.0'	SP-SM	0.040
OBG-B-4	80.0'-82.0'	SP-SM	0.026
OBG-B-5	60.0'-62.0'	SP-SM	0.028
OBG-B-6	55.0'-57.0'	SP	0.047
OBG-C-2	60.0'-62.0'	SP	0.022
OBG-C-3	25.0'-27.0'	SP-SM	0.027
OBG-C-3	40.0'-42.0'	SP-SM	0.023
OBG-C-4	30.0'-32.0'	SP-SM	0.027
OBG-C-5	50.0'-52.0'	SM	0.008
OBG-C-5	65.0'-67.0'	SP-SM	0.035
OBG-D-3	20.0'-22.0'	SP-SM	0.026
OBG-D-4	10.0'-12.0'	SP	0.032
ADA-B-1	75.0'-77.0'	SP	0.019
ADA-B-2	45.0'-47.0'	SP-SM	0.016
CDP-1	25.0'-27.0'	SP-SM	0.014
CDP-2	30.0'-32.0'	SM	0.009
SB-18	5.0'-7.0'	SM	0.007
SO-14	10.0'-12.0'	SM	0.008

(1966) method. The estimated *K* values range between 0.007 and 0.040 ft/min for the aquifer material, with an average value of 0.0222 ft/min.

5.2.1.2 Slug Test Results. Two slug tests were performed in monitoring well MI057. Data collected were analyzed using the Bouwer and Rice (1976) method for unconfined aquifers. Figures 5-3 and 5-4 provide the data and graphical solutions for the falling and rising head slug tests, respectively. The two hydraulic conductivity estimates determined by these tests are 0.01736 ft/min (falling head) and 0.01773 ft/min (rising head), with an average of 0.01755 ft/min.

Hydraulic conductivity estimates calculated from slug test data describe K only in the horizontal direction (K_h). Vertical *K* (K_v) cannot be determined from slug test data; however, Morris and Johnson (1967) report a range of K_v values from 2.22×10^{-5} to 1 ft/min for clay/silt and sands. Given the highly stratified nature of the aquifer, it is expected that the K_v values are much smaller than K_h values, by at least an order of magnitude. Therefore, a reasonable estimate for K_v is approximately 1×10^{-3} ft/min.

5.2.1.3 Pump Test Results. Data collected during the pumping tests conducted in monitoring wells MI057 and MI063 were not suitable for conventional pumping test analysis because the highly transmissive aquifer could not be adequately stressed using wells constructed for monitoring purposes. An extraction rate on the order of 200 gpm would be required to fully stress the groundwater flow regime in the vicinity of a 4-inch diameter monitoring well in this aquifer. These rates cannot be achieved with conventional submersible pumps. Therefore, groundwater was extracted during the pumping tests at the highest rate possible with available equipment. Data were recorded with the intent of calculating aquifer properties; however, due to the small drawdown observed during the test, the pumping data were determined to be inappropriate for analysis.

5.2.1.4 Recovery Test Results. Recovery data were collected in pumping wells and observation wells at the conclusion of each pumping test. Analysis of these data by the conventional recovery method (Theis, 1935) was also determined to be inappropriate because the aquifer had not been adequately stressed, and such analyses would provide erroneous estimates of hydraulic conductivity. However, the recovery data do provide information regarding the response of the aquifer to a known change in hydraulic head, similar to the recovery observed in a well casing in response to the removal of a slug.

Slug test solutions are valid under the assumptions that the slug addition/removal is an instantaneous change, and that the head differential occurs within the well casing. In order to apply slug test analysis methods to recovery data collected in MAAP wells, these assumptions must be considered. The following justification is offered for the use of slug solutions for recovery data. The pumping rates in the monitoring wells were insufficient to produce significant drawdown in the pumped well. In both the pumping tests, drawdown in the pumping well accounted for approximately 10% of the aquifer saturated thickness. This fact suggests that pumping these wells had little impact on the highly transmissive aquifer surrounding the pumping well, and no significant affect on the aquifer as a whole.

In addition, very little drawdown was recorded in observation wells near the pumping wells. This indicates that the cone of influence resulting from pumping diminished significantly over a relatively short distance, and that the total drawdown observed in the aquifer was concentrated around the pumping well. Therefore, the hydraulic conditions present around the pumping wells during recovery tests are similar to conditions present during rising head slug tests. Although the application of a slug test solution to recovery data is not a conventional approach, it provides a valid estimation of K surrounding the pumping well, and it is a useful estimate for comparison with other results. It should be noted, however, that only the rate of recovery in the pumping well was analyzed in this fashion, as the drawdown was symmetric around the well casing, which is similar to slug test conditions. Drawdown surrounding an observation well is asymmetric, and flow conditions to the observation well during recovery are different than those surrounding a pumping well.

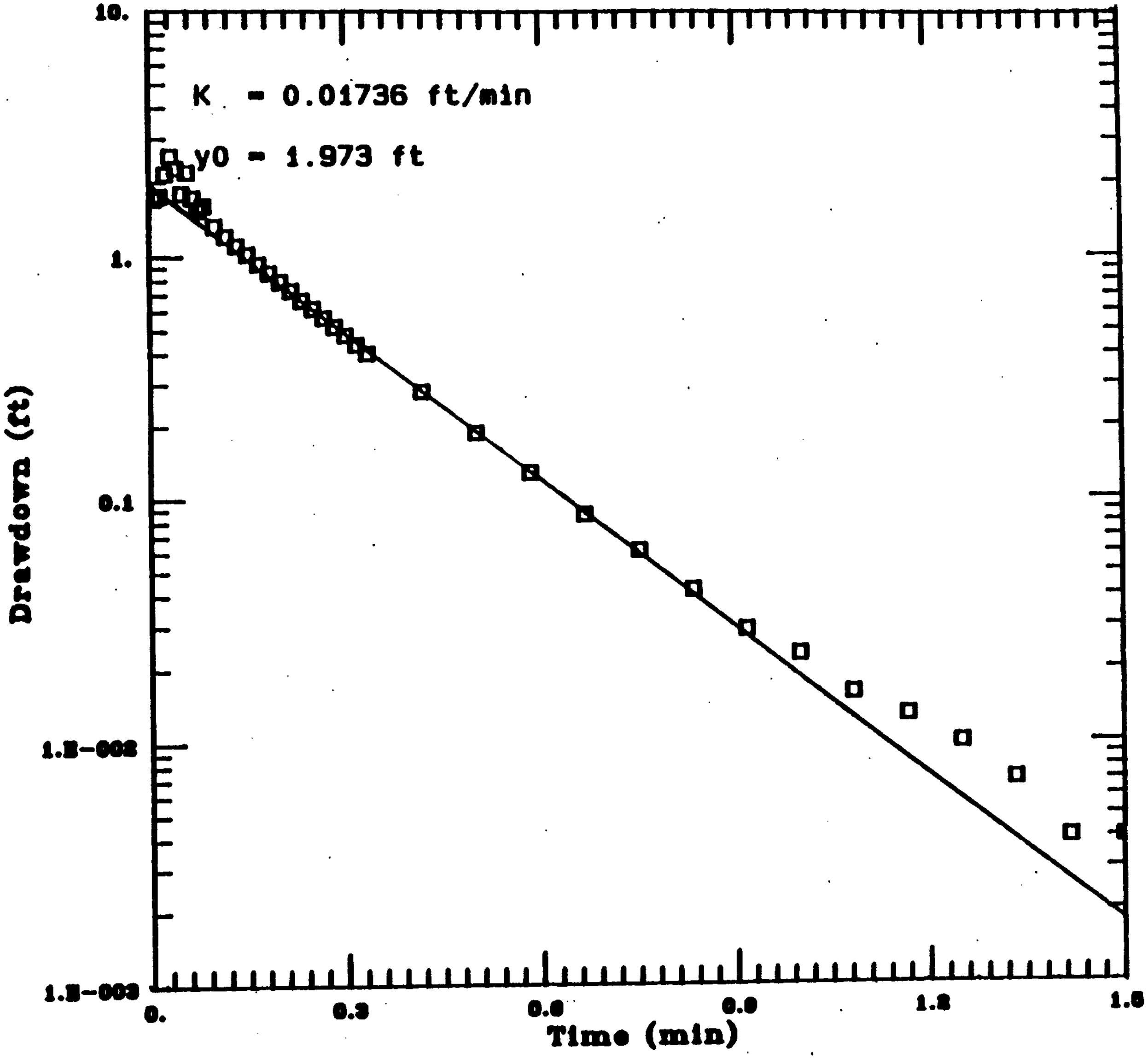


Figure 5-3
Falling Head Slug Test Data from Well MI057

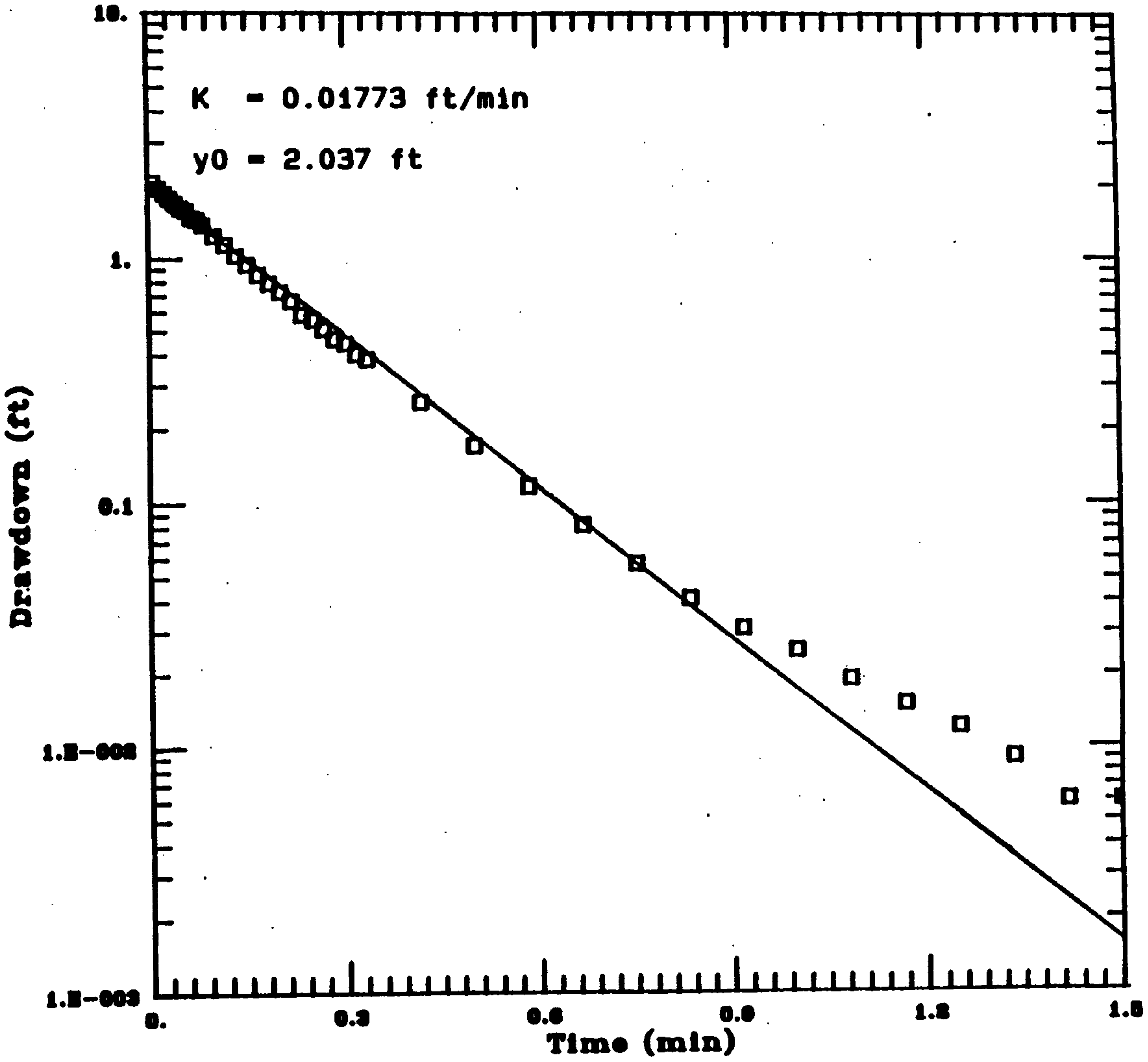


Figure 5-4
Rising Head Slug Test Data from Well MI057

Recovery data collected in the pumping wells, and slug test solutions applied to these data, are provided in Figures 5-5 and 5-6. Hydraulic conductivity estimates determined by this method compare well with slug test and grain-size analysis results provided in Table 5-3.

5.2.1.5 Summary. Horizontal hydraulic conductivity for the aquifer beneath MAAP was estimated by several different methods and compared to previous site investigation results and to published values. Table 5-3 provides a summary of these estimates. Results reported by Weston (USATHAMA, 1983a) offer a greater range in conductivity than those reported here; however, solution methods and rationale employed by Weston may have been inappropriate for the data collected. For example, the solution method employed by Weston is based on the assumption that the tested wells fully penetrate the aquifer. In fact, the wells penetrate only 20 to 55 feet of an aquifer which is approximately 250 feet thick at the locations of the tested wells.

Parks and Carmichael (1990) report a conductivity value of 0.0278 ft/min for the Claiborne Aquifer determined from a pumping test performed in a municipal supply well in the city of Milan. This value compares well with results obtained during this investigation. The Ground Water Manual (U.S. Bureau of Reclamation, 1977) provides a range in K between 10^{-2} to 10^{-4} ft/min for aquifer materials similar to those found at MAAP.

5.2.2 Groundwater Flow

Several steps were taken to characterize the groundwater flow system at MAAP. First, water levels measured in monitoring wells at the site were used to construct a groundwater elevation contour map. The contour map was then revised to include the surface water drainage characteristics of the Rutherford Fork of the Obion River, Johns Creek, and Wolf Creek. The revised map was then used to determine the average hydraulic gradient for representative groundwater flow paths across the site. The average groundwater velocity was then calculated for the site, and potential travel times for contaminants were estimated.

5.2.2.1 Groundwater Contours. Water levels were measured in the monitoring wells on December 3, 1990. Groundwater contours for the aquifer beneath the site are shown in Figure 5-7. Water levels are highest in the southern half of the site, including elevations of 446 ft-msl in MI021 and 412 ft-msl in MI018. The water table elevation decreases in the northern portion of the site, toward the Rutherford Fork of the Obion River, which is consistent with the decrease in ground surface elevations. In monitoring well MI059, approximately 2,000 feet south of the river, the water table elevation is 379 ft-msl. The elevation of the river directly north of MI059 is approximately 370 ft-msl.

The groundwater contours south of Wolf Creek are estimates based on limited data. The contours between monitoring wells MI021 and MI020 may be discounted. The steep gradient in this area appears to be the result of an erroneous elevation survey when the wells were installed, because the surface topography is relatively flat and there is no reason to suspect a major groundwater source or sink in this area. In addition, the surface elevations for previously-installed wells MI051 and MI023 appear to be in error. The dotted contour line north of Line K in Figure 5-7 includes these data while the solid line represents the groundwater elevation if these data are excluded from the calculation.

5.2.2.2 Groundwater Gradients. Groundwater flows in a direction perpendicular to groundwater contours lines, such that groundwater pathlines follow the most direct route from the recharge area to the discharge area. The change in hydraulic head (Δh) over a given distance (ΔL) is the hydraulic gradient ($\Delta h/\Delta L=i$) which drives the flow of water. Representative flow paths for groundwater traveling beneath the site were chosen from starting points south of the OBG to discharge points in surface water bodies or locations beyond the site boundaries. These flow paths are presented in Figure 5-8. Horizontal hydraulic gradients calculated from these pathlines are also provided on this figure. Gradients range between 0.0012 and 0.0019 ft/ft and the average gradient for the site is 0.0015 ft/ft.

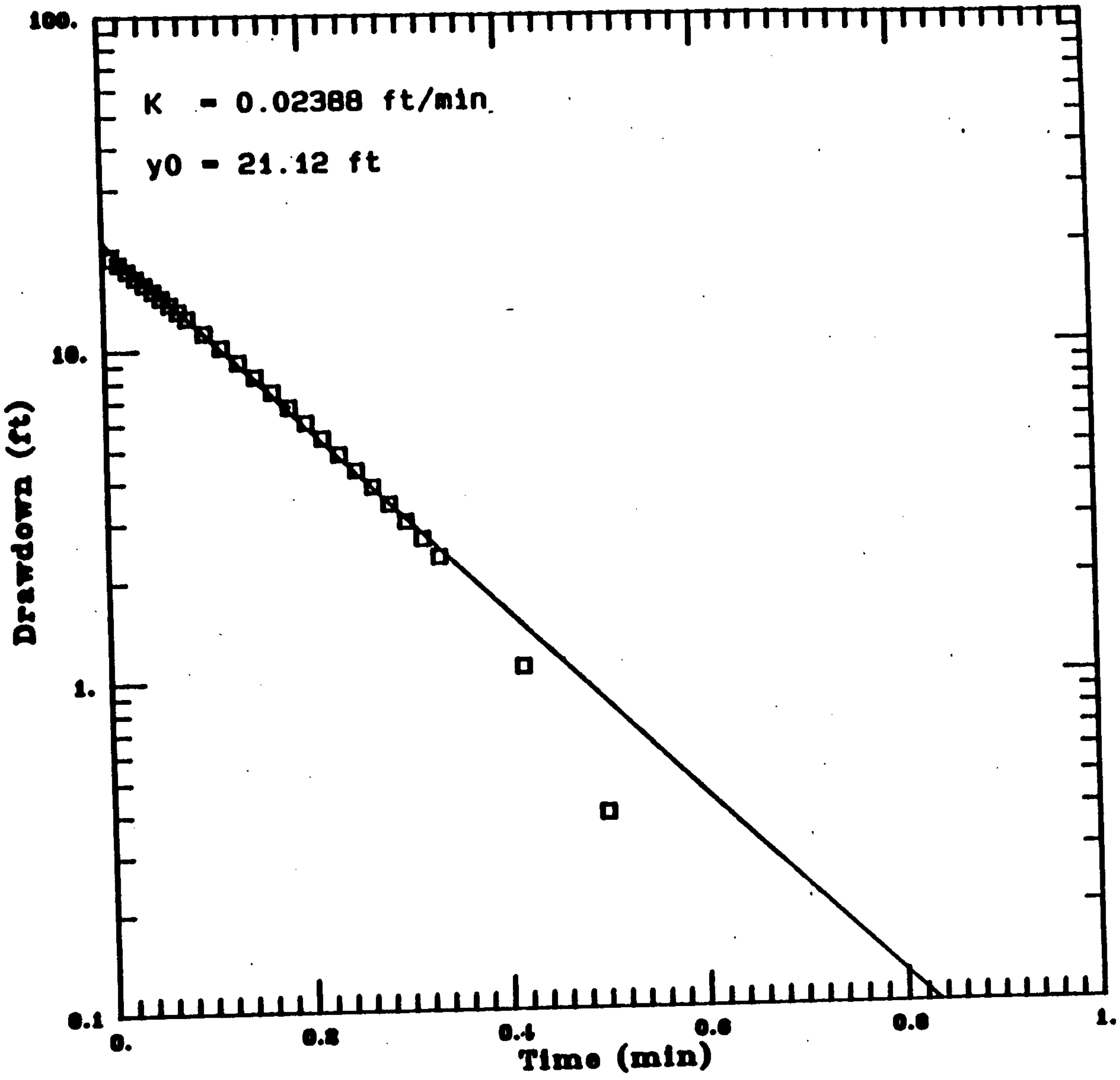


Figure 5-5
Recovery Slug Test Data for Well MI057

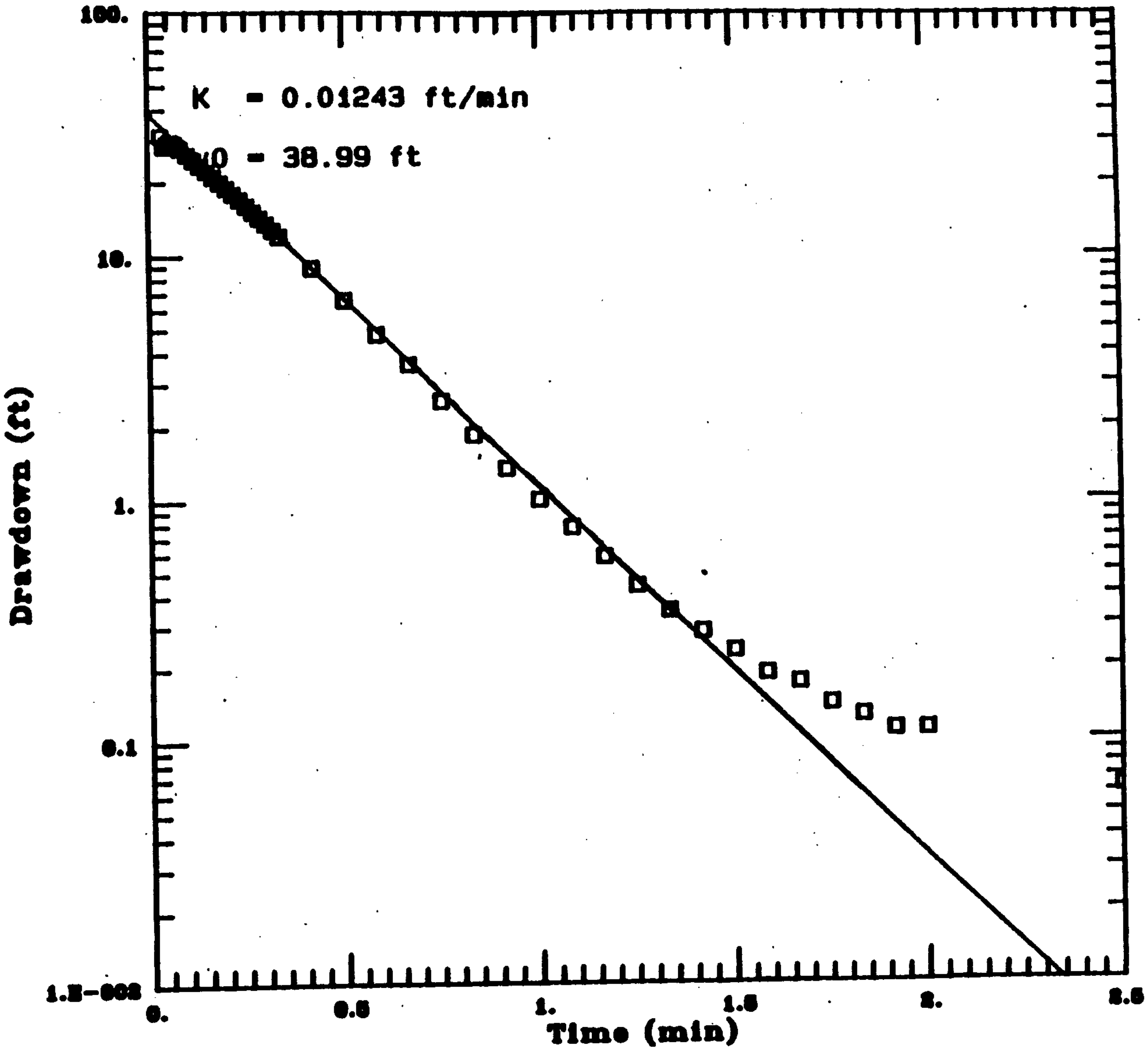


Figure 5-6
Recovery Slug Test Data for Well MI063

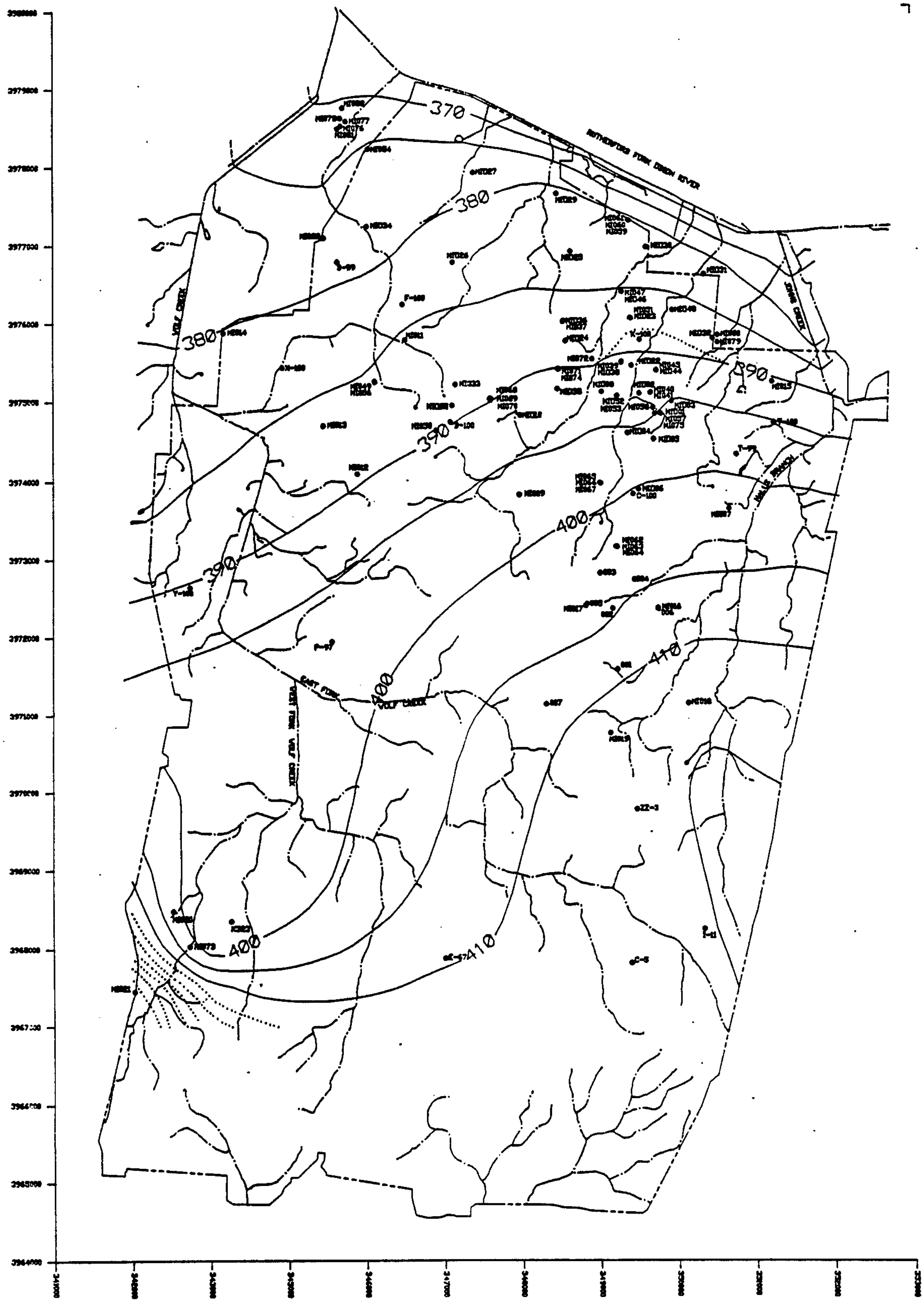
Table 5-3
Hydraulic Conductivity Estimates for the Claiborne Aquifer at MAAP and Surrounding Areas

SOURCE	WELL	TEST METHOD	ANALYSIS METHOD	K (FT/MIN)
ICF[1]	MI057	Recovery	Bouwer-Rice, 1976	0.02388
ICF	MI057	Falling Head Slug	Bouwer-Rice, 1976	0.01736
ICF	MI057	Rising Head Slug	Bouwer-Rice, 1976	0.01773
ICF	MI063	Recovery	Bouwer-Rice,1976	0.01243
ICF	----	Grain Size Analysis Average	Masch & Denny, 1966	0.0222
PREVIOUS STUDIES				
Weston[2]	K-100	Recovery	Theis, 1935	0.1160
Weston	MI030	Recovery	Theis, 1935	0.0110
Weston	MI032	Recovery	Theis, 1935	0.0003
Weston	MI040	Recovery	Theis, 1935	0.0201
Weston	----	Grain Size Analysis Average	Pall & Moshenin, 1980	3.95
WRI 88-4182[3]	Milan Municipal Well	Constant-Rate Pump Test	Unknown	0.0278

[1] Methodology used during ICF analyses is described in Section 5.2.1.

[2] USATHAMA, 1983a.

[3] Parks, W.S. and J.K. Carmichael, 1990. Personal communication, Jan. 1991



LEGEND

STREAM/DRAINAGE

PROPERTY LINE

● MONITORING WELL

GROUNDWATER CONTOUR

APPARENT SURVEY ERROR

0 500 1000 1500 METERS

0 1000 2000 3000 4000 5000 FEET

0 .5 1 MILES

1000 M UTM GRID TICKS, ZONE 16

-N-

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FIGURE 5-7
GROUNDWATER ELEVATION CONTOURS
(WATER LEVELS MEASURED
ON 12/3/90)

SIZE	PROJECT CODE	DWG NO.
B	30874	04019104

SCALE AS NOTED

DRAWN BY: K. BOLER

CHECKED BY: N. OKUSU

The pathlines shown in Figure 5-8 illustrate the general flow directions for groundwater beneath MAAP. Groundwater is recharged primarily by precipitation infiltration in highland areas in the southern portion of the site, and discharges to the Rutherford Fork of the Obion River. Groundwater also discharges to the lower reaches of Wolf and Johns Creeks where they flow into the Obion River. It is evident from the relationships between elevations of the ground surface, the water table, and the stream surface that the aquifer is contributing flow to the surface water bodies. However, given the vertical extent of the aquifer, it is likely that only the shallow portion of the aquifer is discharging to the surface water bodies while deeper portions of the aquifer flow toward regional discharge areas. This partitioning of thick, unconfined aquifers into shallow, intermediate, and deep flow systems is a common occurrence (Toth, 1963). In such settings, local topographic features control flow in the shallowest part of the aquifer while the deeper flow system is influenced by regional controls. The partitioning of flow within the aquifer at MAAP can only be inferred from the available data. However, regional studies have shown that shallow, intermediate, and deep flow systems occur within the Claiborne aquifer (Grubb, 1986).

Well clusters installed at the site allowed for the characterization of vertical groundwater gradients. Water levels measured in December 1990 show the presence of both upward and downward vertical gradients which range between +0.002 ft/ft to -0.004 ft/ft. The observed vertical gradients vary between well cluster locations, and are apparently unrelated to possible discharge effects imposed by the river. The differences in magnitude of vertical gradients may be a result of local stratification within the aquifer material. Nonetheless, the downward vertical gradients observed in some areas, and particularly near the Rutherford Fork, imply that groundwater beneath the site is moving downward within the Claiborne aquifer and much of the groundwater is not discharging to the Rutherford Fork. The downward flow of groundwater at the site is consistent with the findings of a regional aquifer study (Grubb, 1986). This study found that the western Tennessee area is a regional recharge area for the Claiborne and other aquifers. Groundwater recharging in this area travels downward to the deep flow system of Tertiary aquifers and west to the regional groundwater discharge area in the Mississippi alluvial plain. Shallow and intermediate flow systems within the aquifers are in connection with local surface water bodies such as streams, rivers, and lakes.

5.2.2.3 Groundwater Velocities. The average rate at which groundwater travels across the site can be determined using the following relationship:

$$V = \frac{K(i)}{N_e} \qquad (1)$$

where:

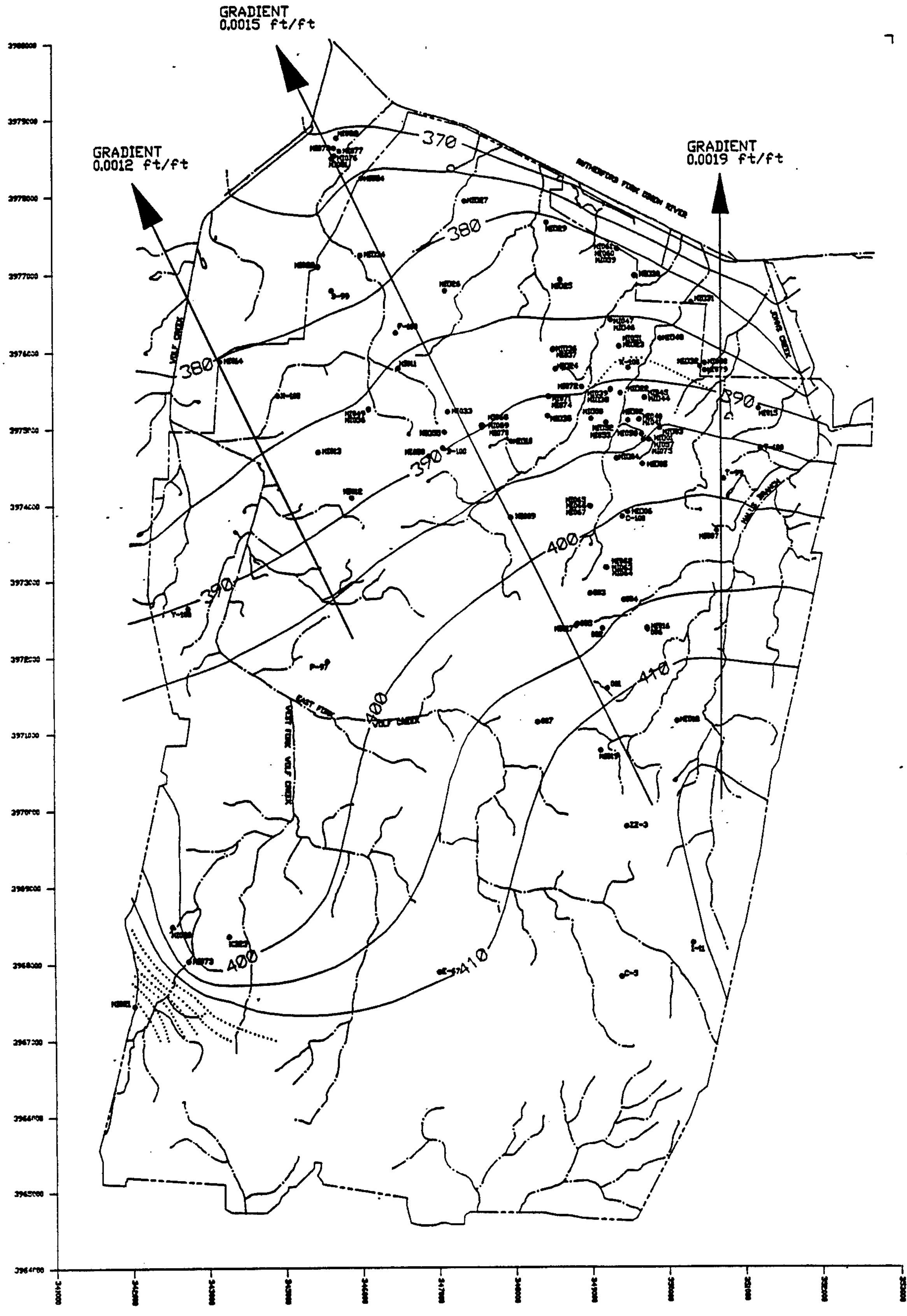
V = average groundwater flow velocity (ft/day)

K = average hydraulic conductivity (ft/day)

i = groundwater hydraulic gradient (dimensionless)

N_e = effective porosity of the soils (dimensionless)

As previously described, the average flow gradient was calculated based on representative groundwater flow paths for the site, and the average K value was estimated from aquifer testing methods. Effective porosity refers to the interconnected porosity in the saturated zone that is available for the flow of groundwater. This excludes any pores that are isolated or too small to contribute to groundwater flow. It is difficult to directly measure effective porosity, so it is common to use specific yield of the aquifer instead of effective porosity. Specific yield refers to the amount of water the formation can provide under gravity drainage conditions. The two parameters describe the same aquifer property, that is, the fractional volume of the aquifer available, or open, to groundwater.



LEGEND
STREAM/DRAINAGE
PROPERTY LINE
● MONITORING WELL
GROUNDWATER CONTOUR
APPARENT SURVEY ERROR

0 500 1000 1500 METERS
0 1000 2000 3000 4000 5000 FEET
0 .5 1 MILES
1000 M UTM GRID TICKS, ZONE 16

N

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FIGURE 5–8
GROUNDWATER FLOW DIRECTIONS
AND HORIZONTAL
HYDRAULIC GRADIENTS

SIZE	PROJECT CODE	DWG NO.
B	30874	04019104

SCALE AS NOTED | DRAWN BY K. BOLER | CHECKED BY N. OKUSU

Specific yield for the aquifer at the site has not been directly measured. Published values for similar formations range between 1.0 and 46% for sandy soils and sand, silt, and clay mixtures (Morris and Johnson, 1967). Unconfined aquifers generally exhibit specific yield values between 1.0 and 30% (Fetter, 1988). An average, or representative, value for specific yield in this aquifer might be 20%.

Based on average values of hydraulic parameters for the aquifer at MAAP, an average groundwater flow velocity for the site has been calculated. Using a specific yield of 20%, an average gradient of 0.0015, and an average K value of 27 ft/day, the average groundwater flow velocity at the site is 0.20 ft/day. It is important to note that this value for velocity represents an average velocity for the site, and that some variation is expected for various areas of the site.

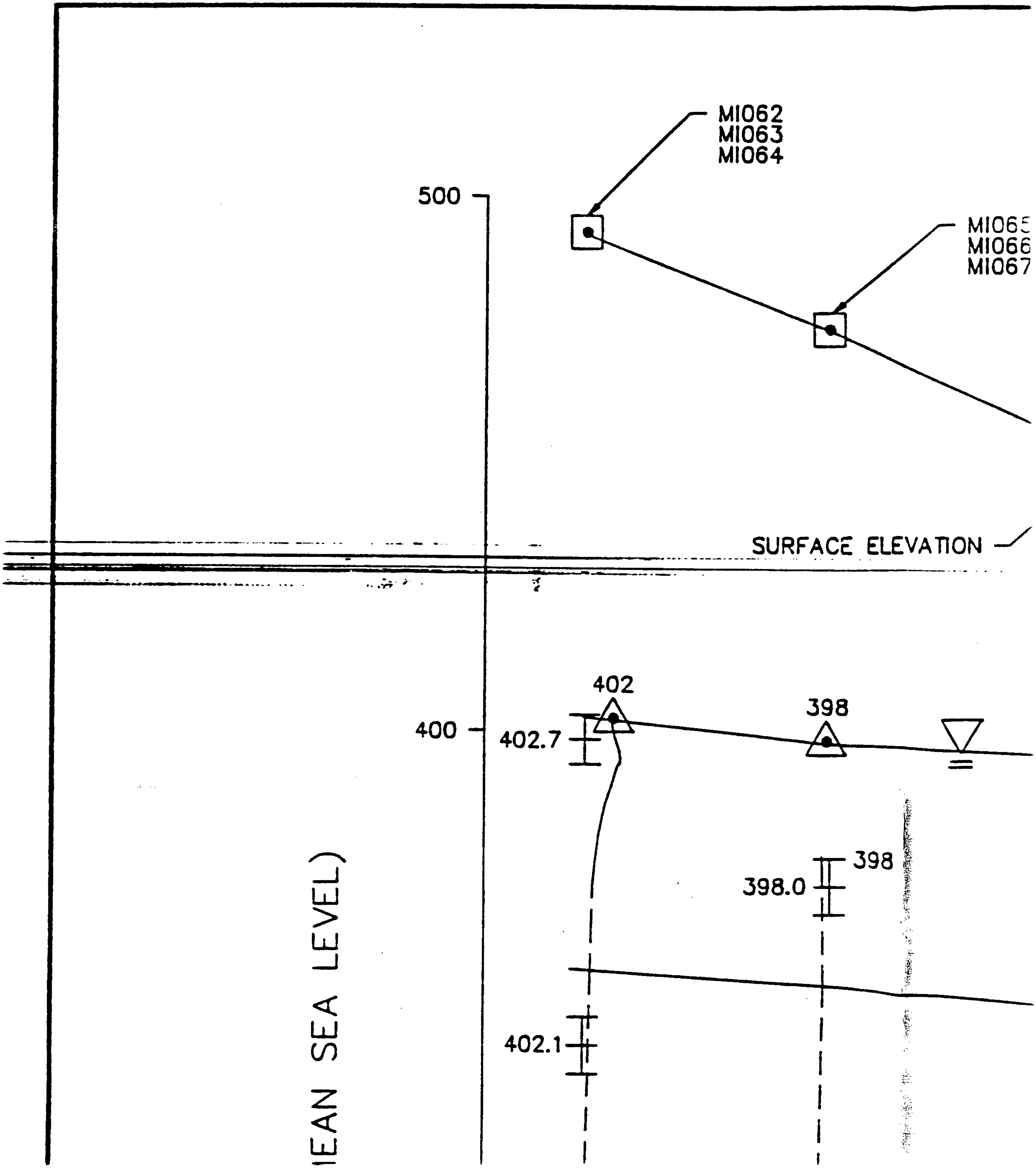
5.2.2.4 Groundwater Potential and Flow Analysis. Decreasing groundwater potential with depth of screened interval is observed at Wells MI059, MI060, and MI061 near the northern boundary at MAAP, and at various other well-cluster locations. Some of the well clusters (e.g., MI052 and MI053) also indicate a slightly increasing potential with depth. The vertical gradients appear to be small (on the order of 0.004 ft/ft) but may be of importance because the horizontal gradients are even smaller (on the order of 0.0015 ft/ft). The vertical gradients depend greatly on the precision of surveying and water level measurements, but if obviously erroneous points (such as the elevations of well cluster MI023/MI051) are excluded, there is a reasonable degree of consistency among water level data at various locations. The possible influence of anisotropy on aquifer discharge zones and migration patterns of contaminants from the source areas prompts further evaluation of groundwater potentials across the site.

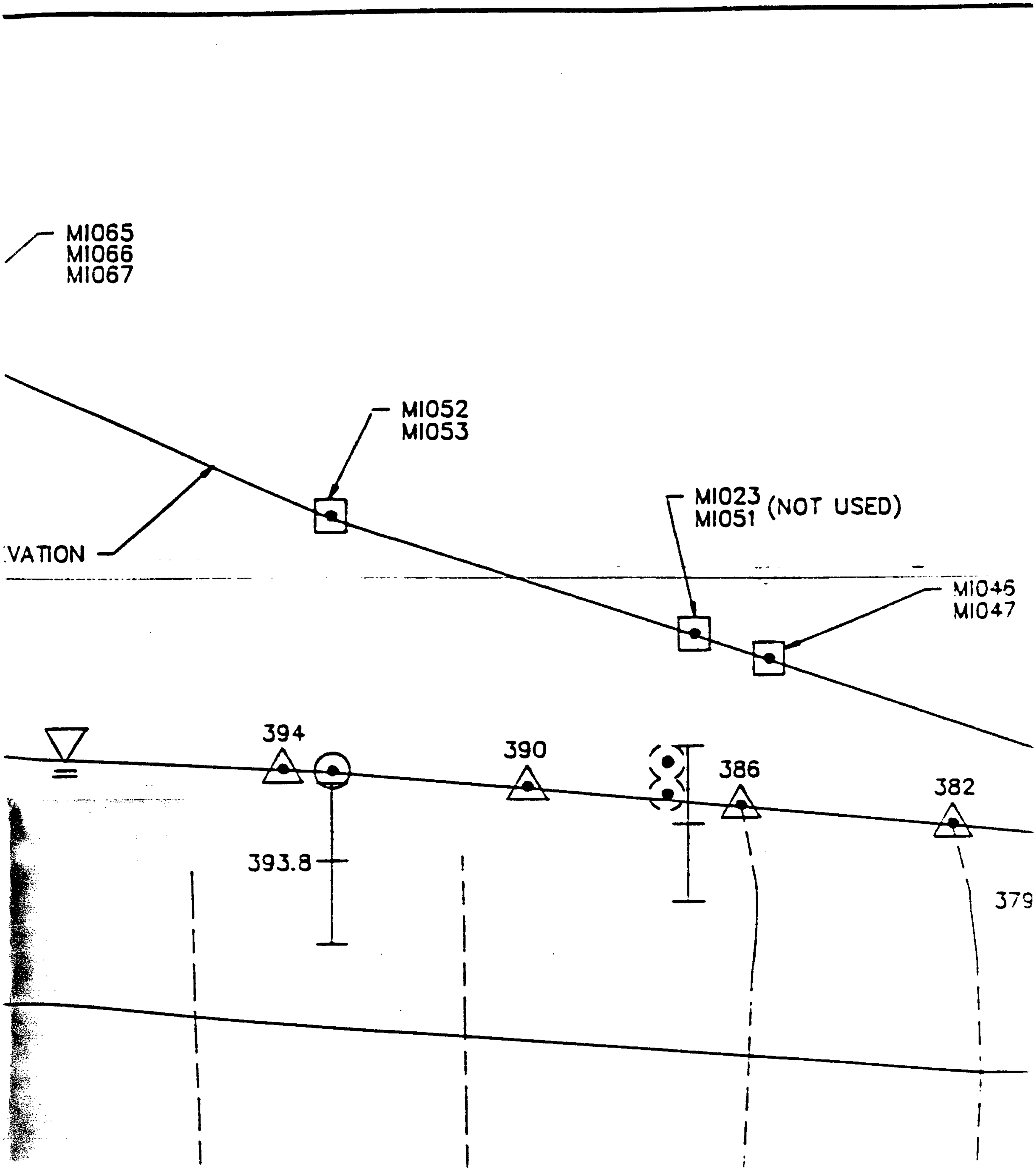
The available three-dimensional hydrologic data at MAAP are not sufficiently detailed to allow a precise flow-net representation to be constructed. For example, potentiometric data from wells along any traverse from the source areas to the boundary are widely spaced when compared to the aquifer thickness. In addition, the screened intervals for well clusters (selected primarily from lithology and the need to determine chemical distribution) generally are not located properly for evaluation of hydrologic aspects. Despite these shortcomings, an analysis was made of available hydrologic data across a broad expanse of the site to evaluate the current concepts of potential and flow relationships between areas containing sources and the presumed discharge zone and impact areas for groundwater.

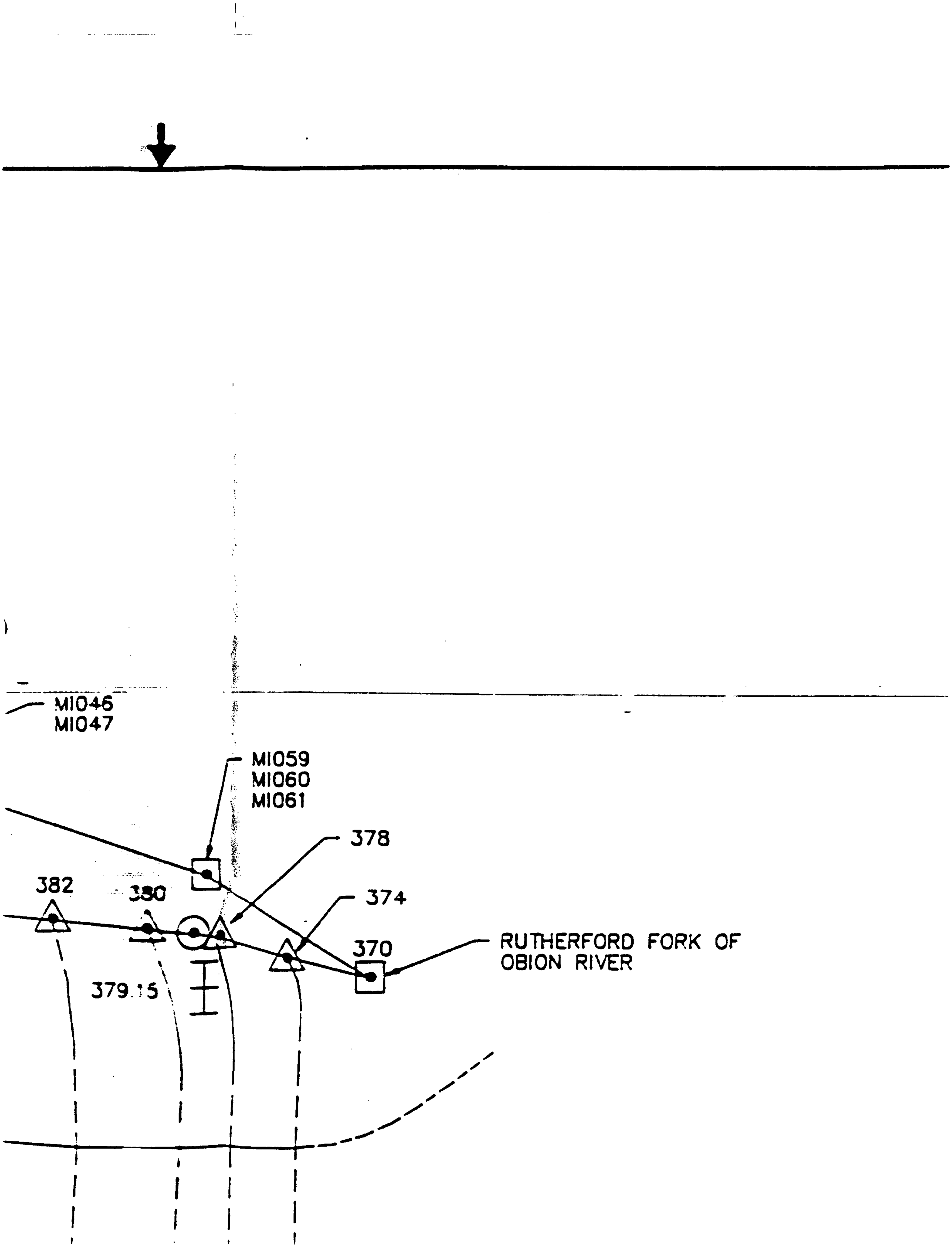
The greatest density of multi-level data exists along a line from the OBG to the Rutherford Fork of the Obion River in a northward direction, which is approximately the direction of flow as determined from the groundwater elevation contours (Figure 5-7). A plot is shown in Figure 5-9 of the topography, the groundwater elevation, screened intervals of wells, the river elevation, and the equipotential lines derived from water levels, for the cross-section extending northward from Well MI062 to the river. Because the horizontal scale is compressed by a factor of 50, this plot is not a true flow-net representation. Also, the equipotential lines have been interpolated linearly across the aquifer thickness because the more complex structure that probably exists cannot be inferred from the limited data.

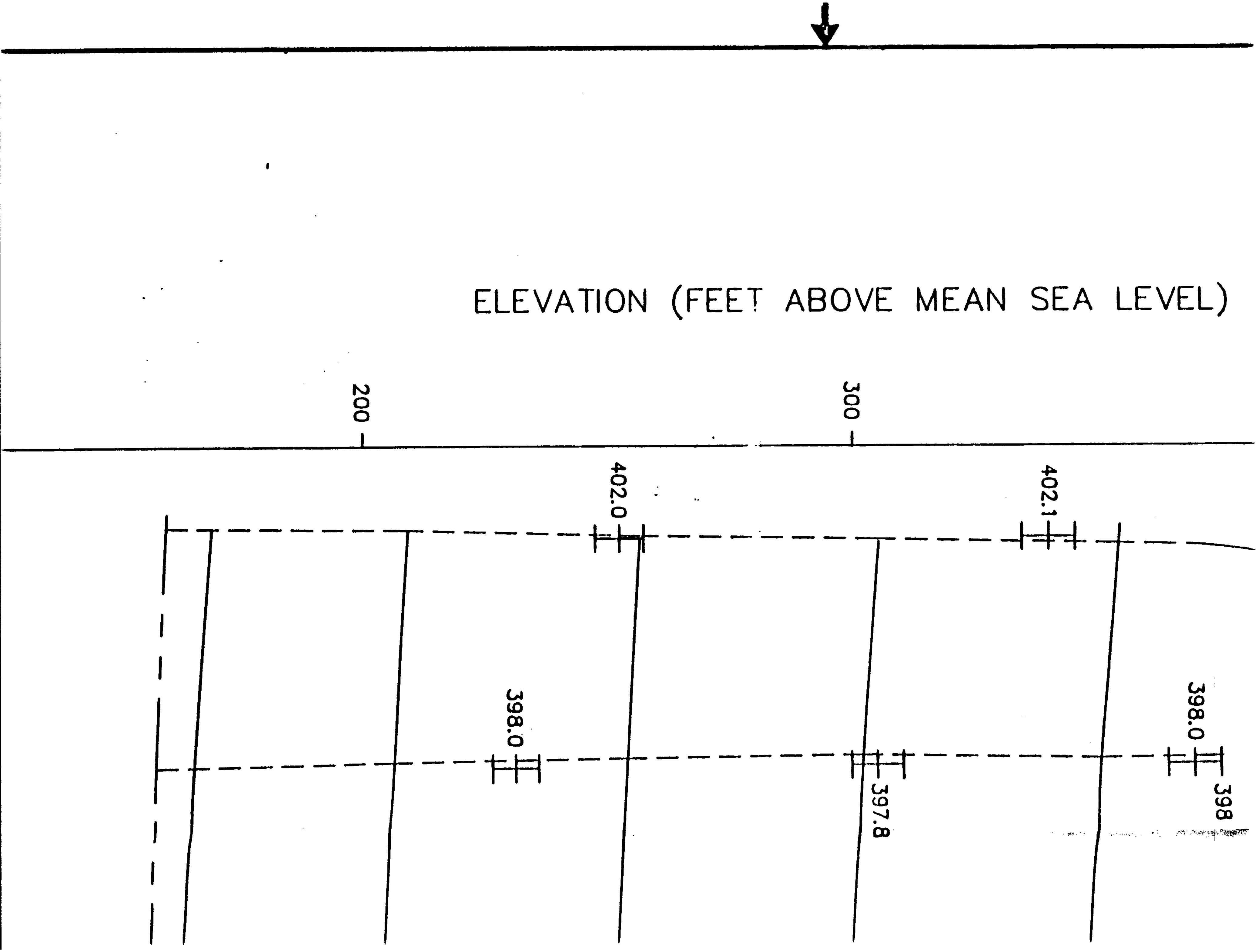
Production of the cross-section required some manipulation of the data set. Because there is no shallow well at the location of intermediate and deep wells MI052 and MI053, the surface elevation and groundwater potential at the "shallow well" were obtained by averaging values from the nearest three shallow wells (MI002, MI004, and MI008). Thus, there is a considerable amount of uncertainty in this datum, particularly because the validity of previously surveyed elevations for these wells was not confirmed. The average surface elevations for these wells (441.5 ft-msl), however, closely matches the elevation of the deeper well pair (441.4 ft-msl). The data from wells MI023 and MI051 were not used in the analysis, because the water levels in these wells as shown in Figure 5-9 indicate that the elevations are in error. It is suspected that the large perturbation to otherwise smooth groundwater elevation contours as shown in Figure 5-7 is an artifact of these errors in elevation.

The negative slope of the equipotential lines in the plot is consistent with the postulate of downward gradients to groundwater flow, as was implied from the decreasing potential with depth at the well-cluster location near the river. The plot also suggests that the gradient varies across the site, from zero slope

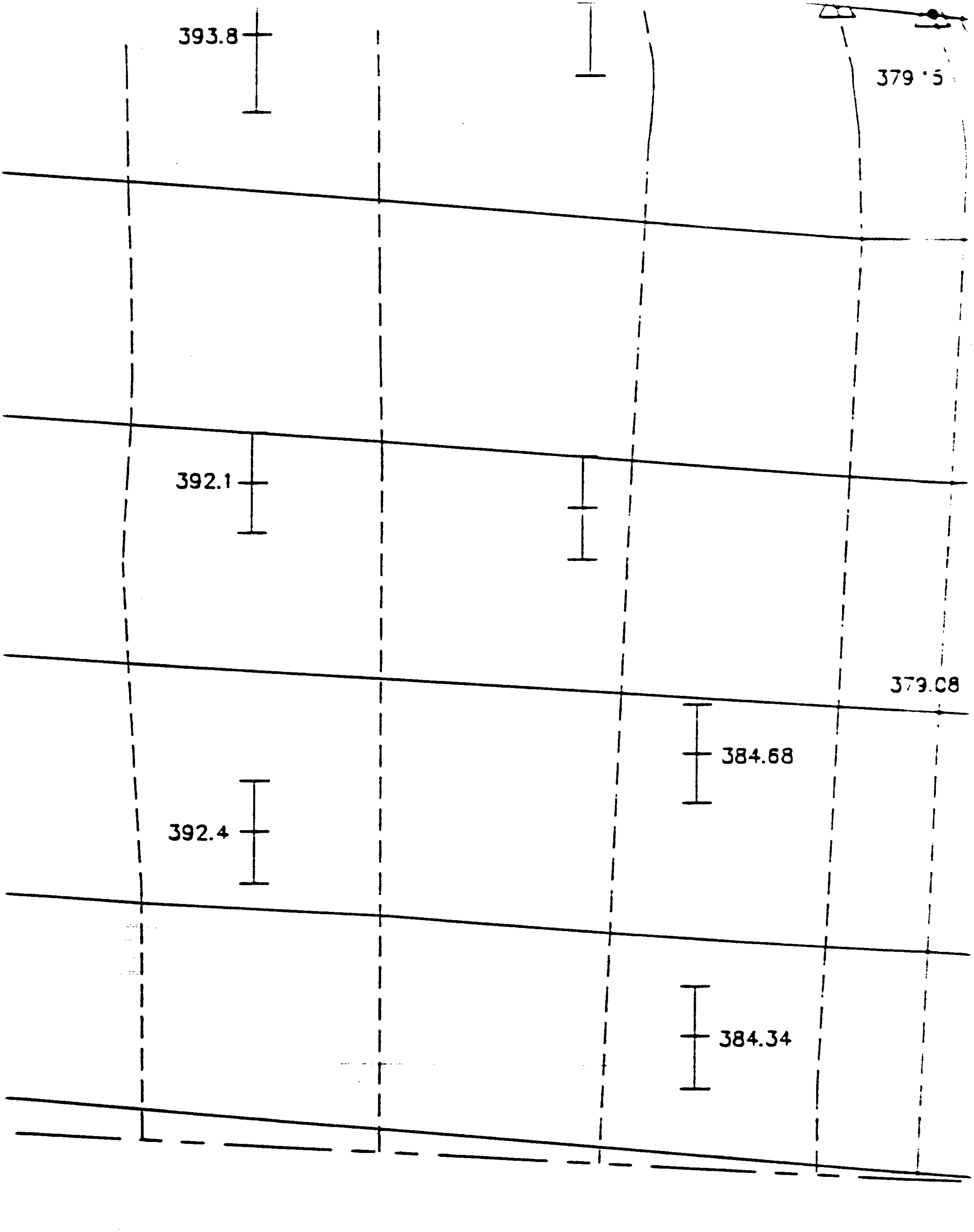

MI062
MI063
MI064
MI065
MI066
MI067
500
SURFACE ELEVATION
402
398
400
402.7
398
398.0
402.1
IEAN SEA LEVEL)

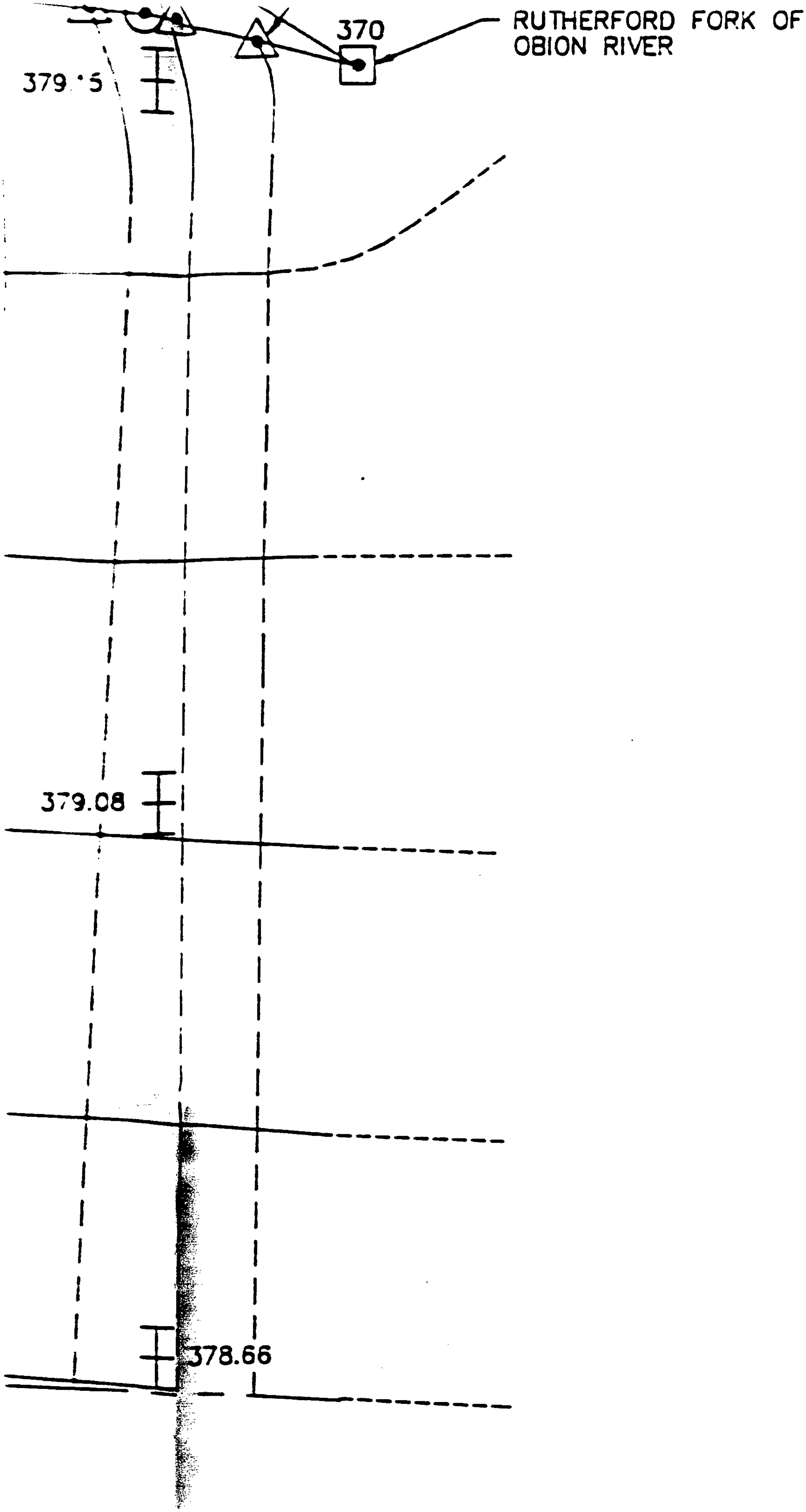

MI065
MI066
MI067
MI052
MI053
MI023
MI051 (NOT USED)
VATION
MI046
MI047
394
390
386
382
393.8
379


MI046
MI047
MI059
MI060
MI061
378
382
380
374
370
379.15
RUTHERFORD FORK OF OBION RIVER



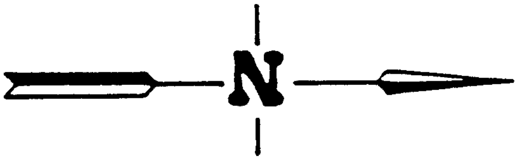
ELEVATION (FEET ABOVE MEAN SEA LEVEL)
200
300
402.0
402.1
398.0
397.8
398.0
398

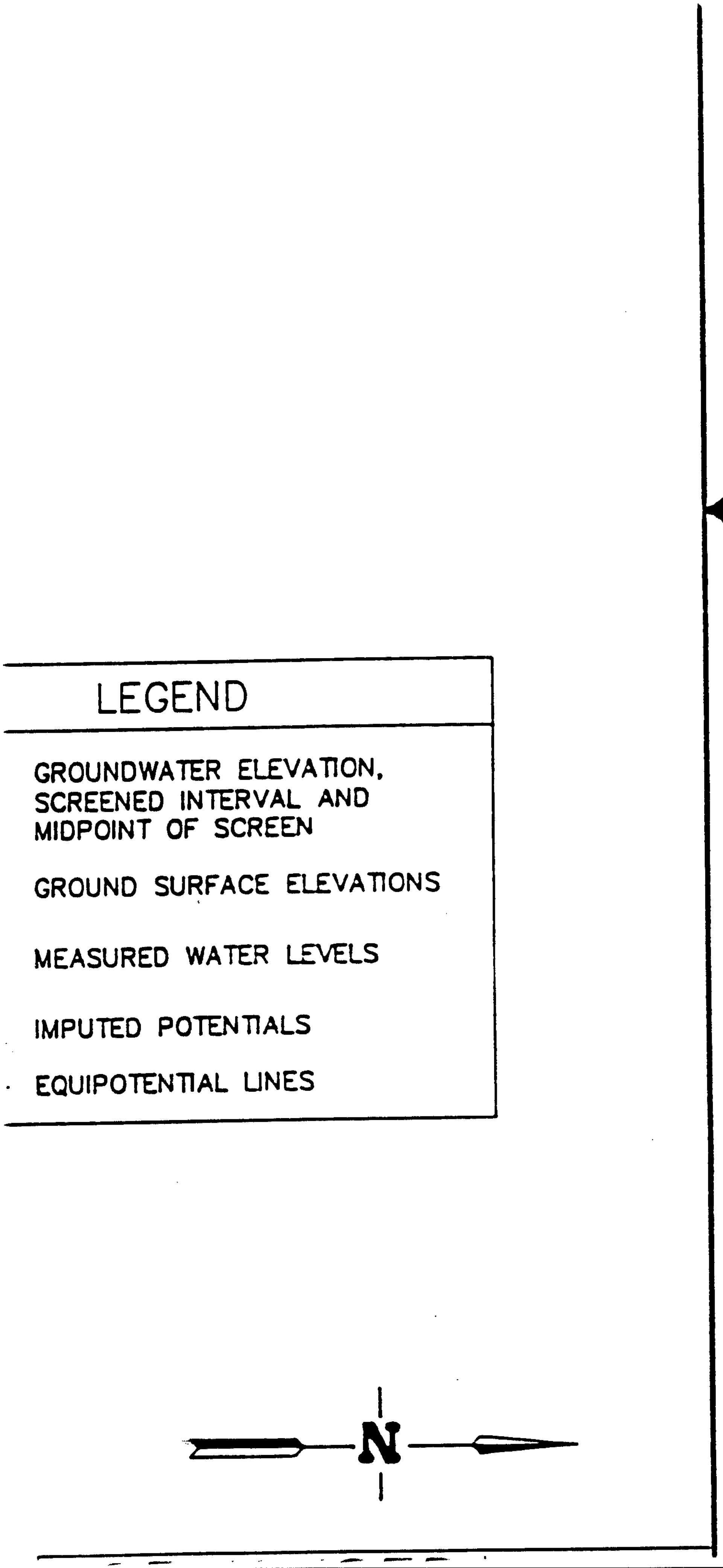

393.8
379.5
392.1
379.08
384.68
392.4
384.34

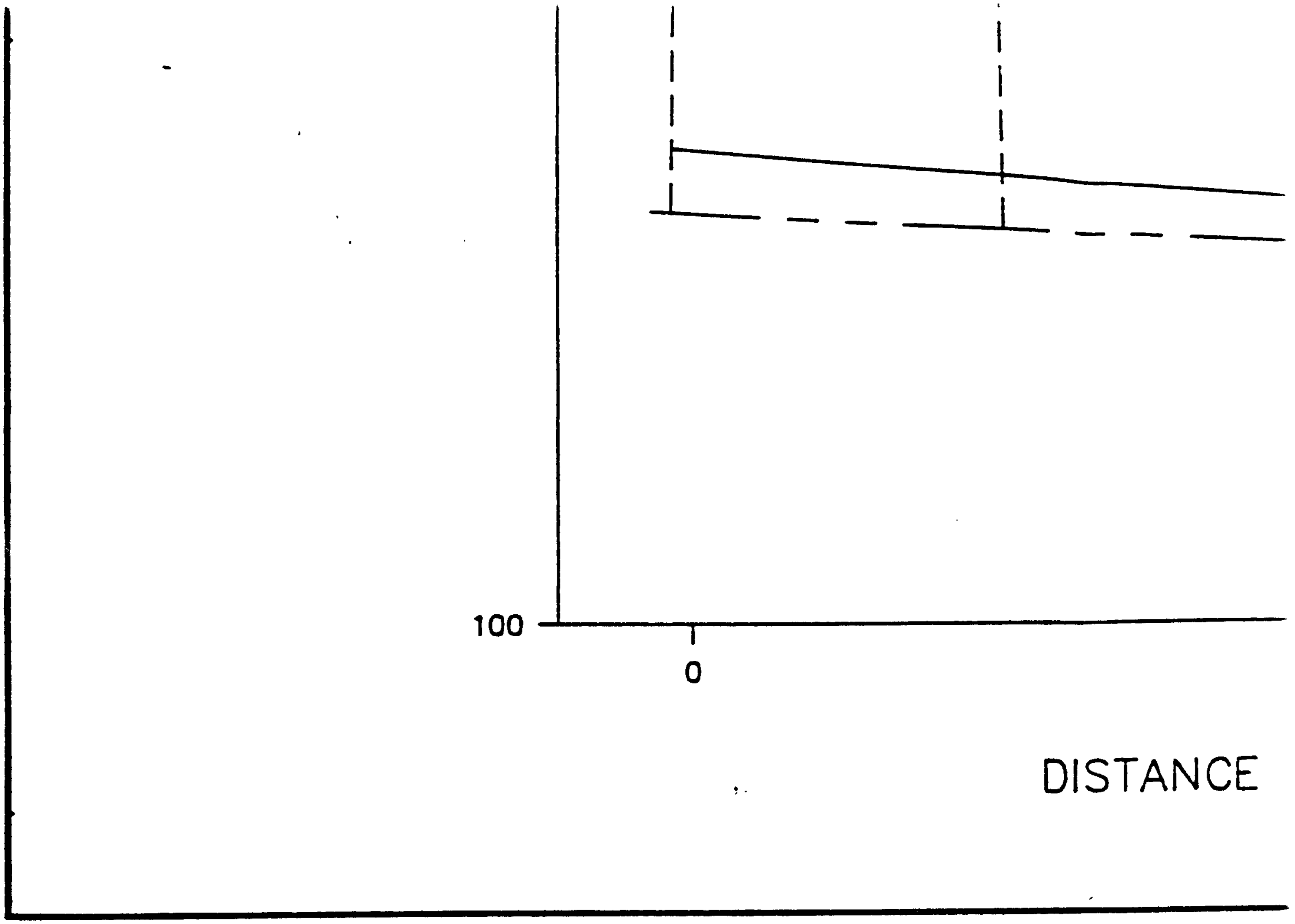

RUTHERFORD FORK OF
OBION RIVER
370
379.5
379.08
378.66

LEGEND

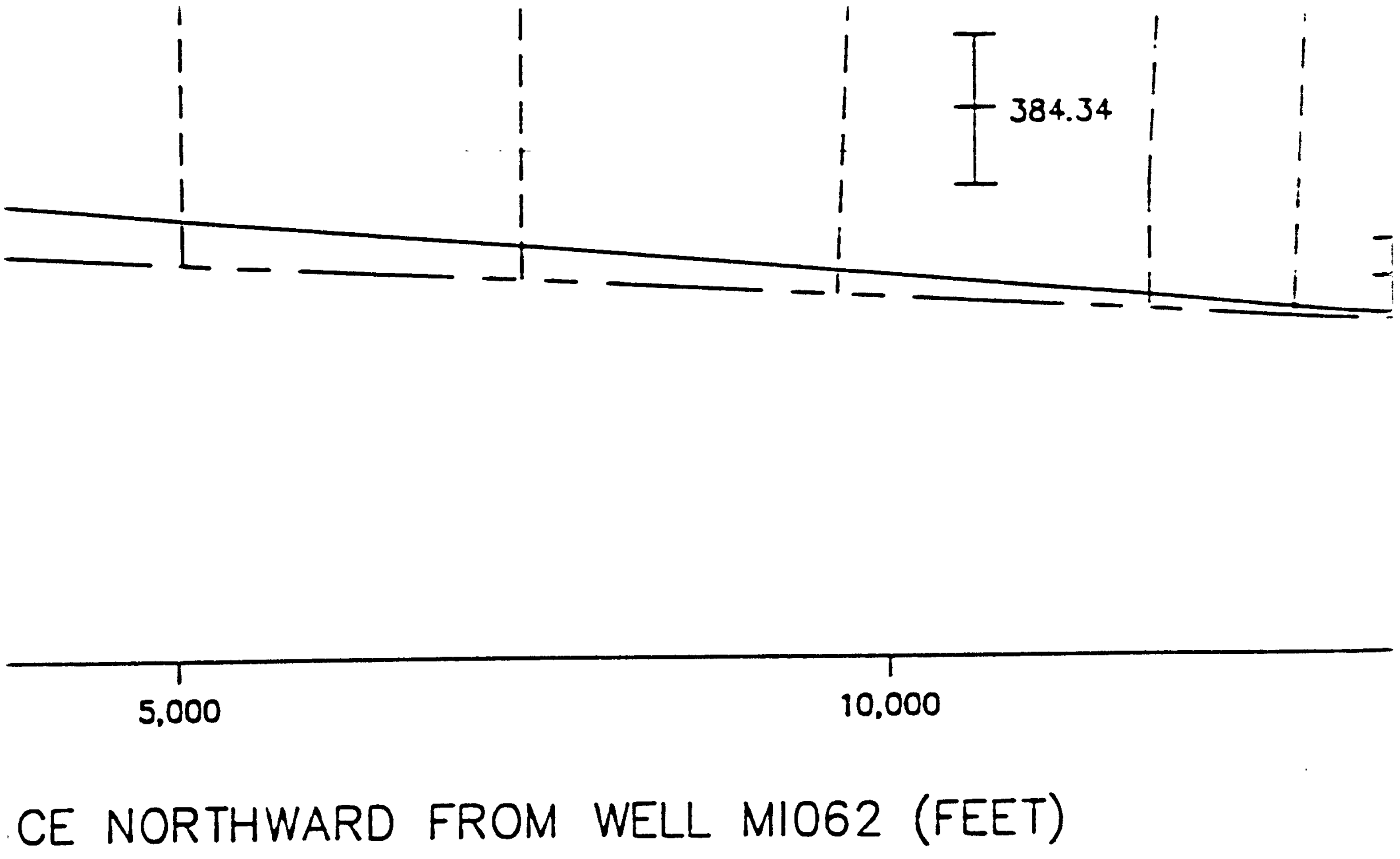
398.0 ⌶	GROUNDWATER ELEVATION, SCREENED INTERVAL AND MIDPOINT OF SCREEN
⊡	GROUND SURFACE ELEVATIONS
⊙	MEASURED WATER LEVELS
◬	IMPUTED POTENTIALS
-------	EQUIPOTENTIAL LINES

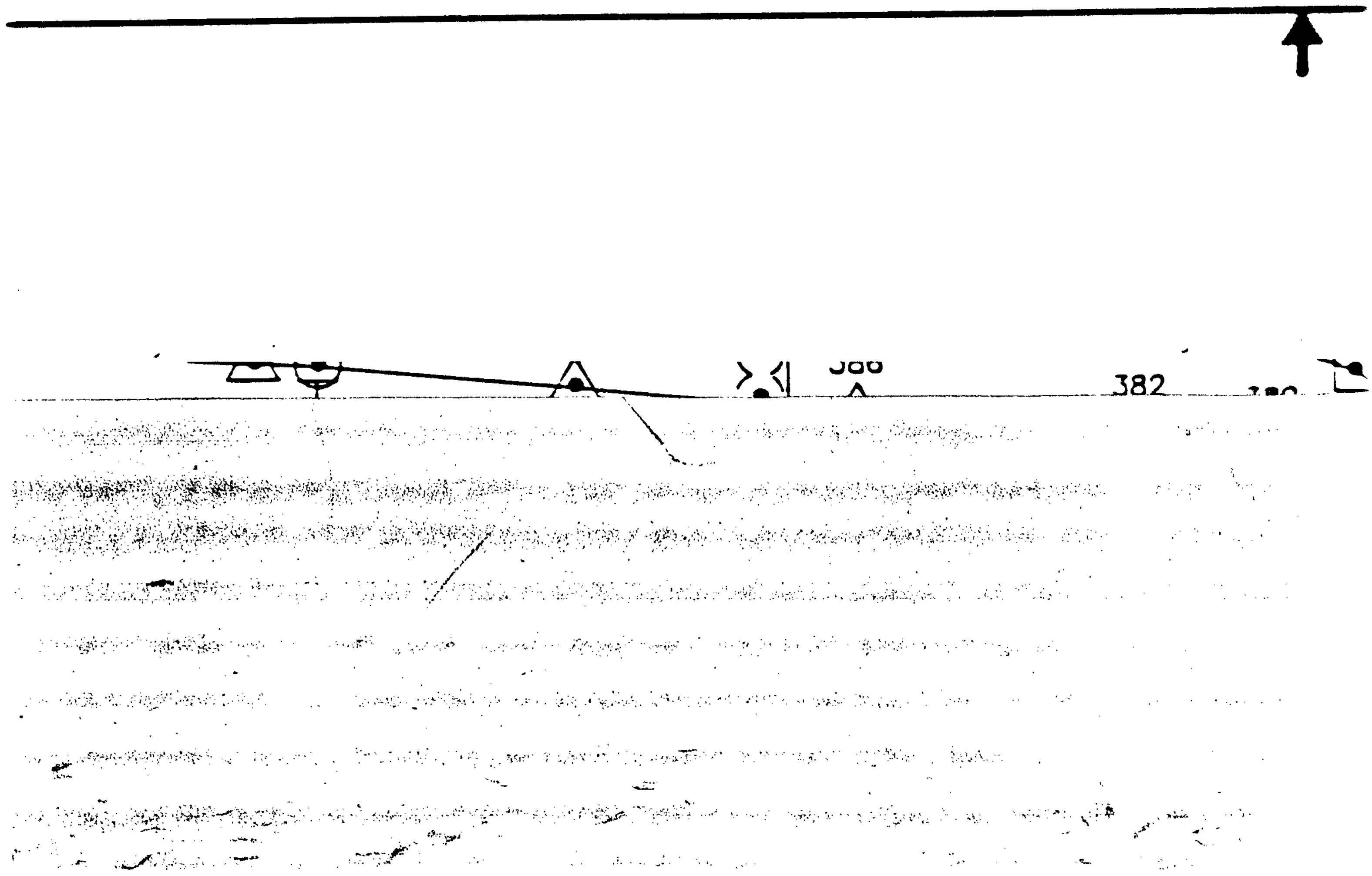


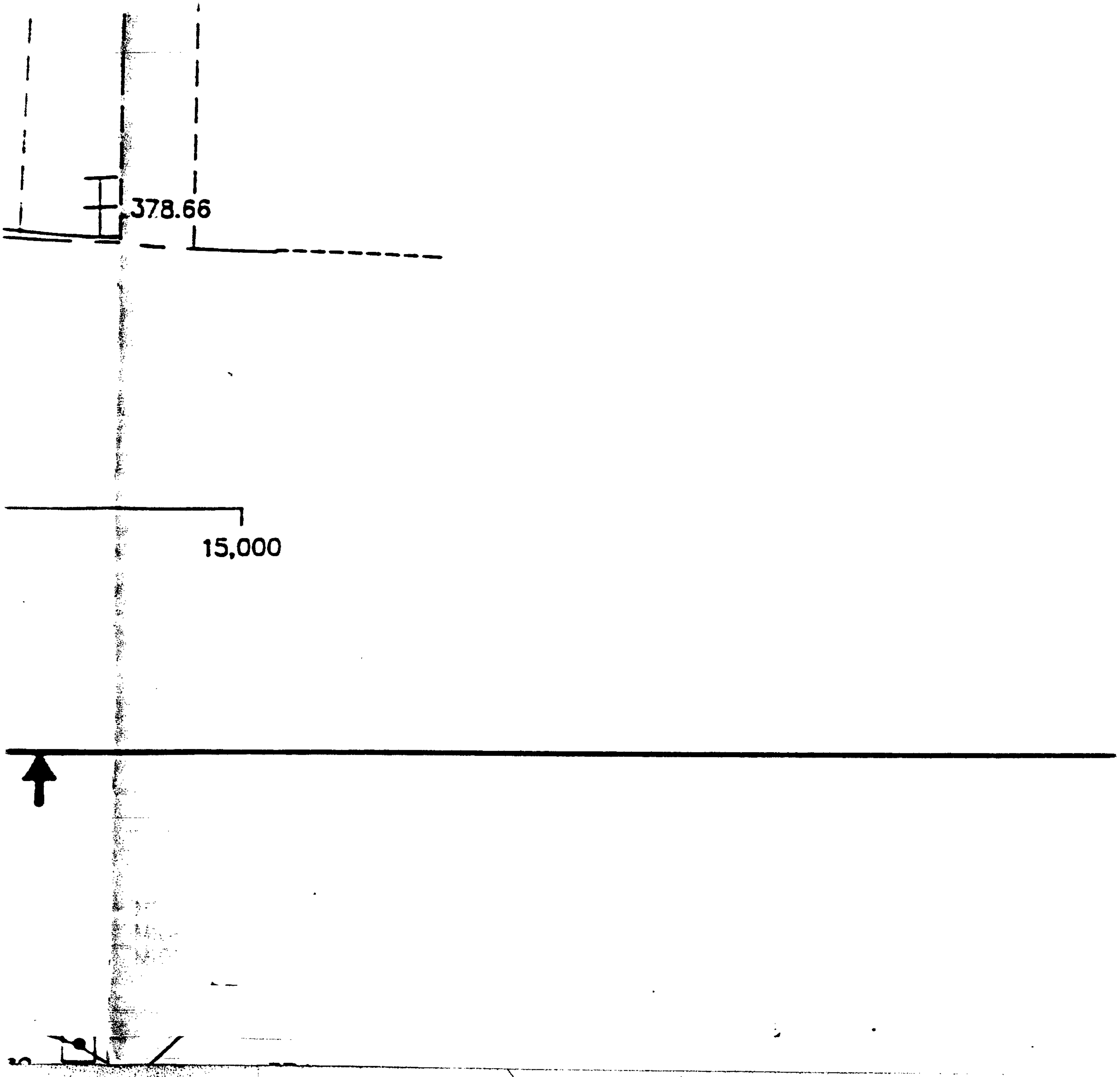

LEGEND
GROUNDWATER ELEVATION, SCREENED INTERVAL AND MIDPOINT OF SCREEN
GROUND SURFACE ELEVATIONS
MEASURED WATER LEVELS
IMPUTED POTENTIALS
EQUIPOTENTIAL LINES
N


100
0
DISTANCE

[illegible]


384.34
5,000
10,000
CE NORTHWARD FROM WELL M1062 (FEET)


382


378.66
15,000

N

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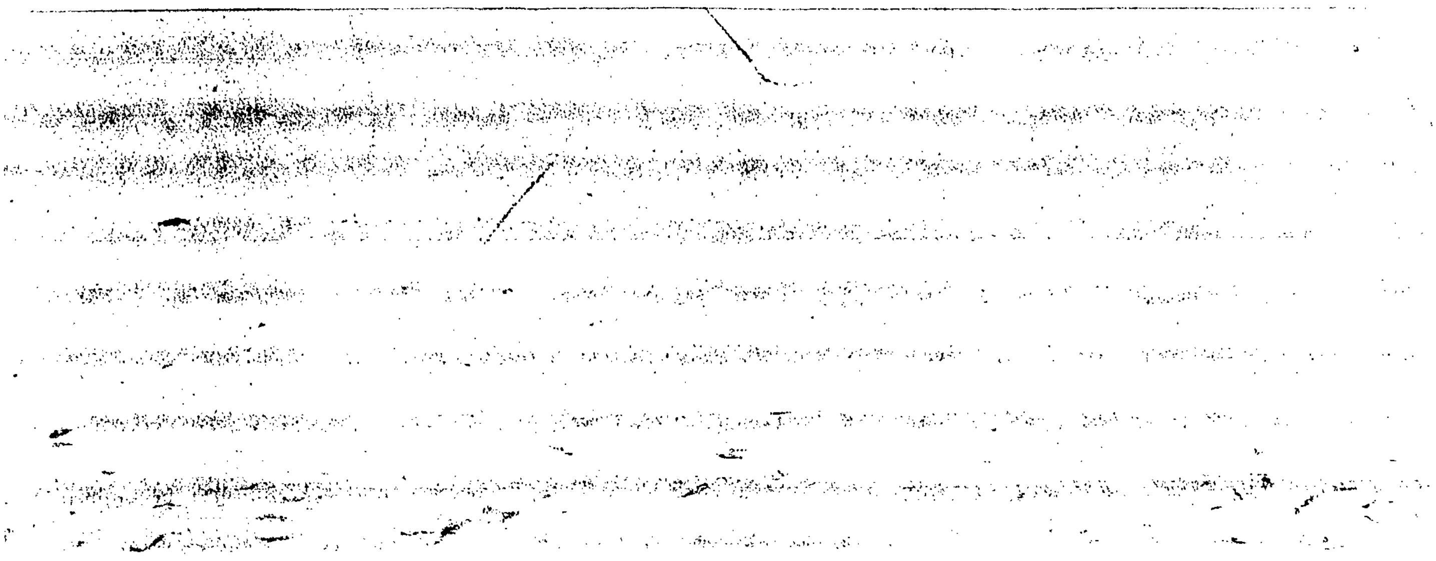
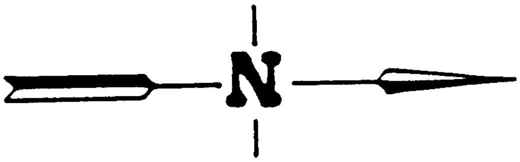
TITLE MAAP REMEDIAL INVESTIGATION

FIGURE 5-9
HYDROLOGIC
CROSS-SECTION OF MAAP
FROM WELL MI062 TO RIVER

SIZE	PROJECT CODE	DWG NO.
D	30874	04019101

SCALE: NONE
DRAWN BY: D. ALLEN
CHECKED BY: G. McKOWN





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GINEERS

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22031-1207

MAAP REMEDIAL INVESTIGATION

FIGURE 5-9
HYDROLOGIC
CROSS-SECTION OF MAAP
ROM WELL MI062 TO RIVER

ROJECT CODE
0874

DWG NO.
04019101

ONE

DRAWN BY: D. ALLEN

CHECKED BY: G. McKOWN

or slightly positive slope (tendency for water to move upward) within the interior of the facility to a negative slope (tendency for water to move downward) nearer the river.

Because of the differences in vertical and horizontal scales, the potential lines shown in Figure 5-9 do not properly depict the gradient. At a 1:1 scale, the slope of the lines would be 50 times that shown in the figure, and the apparently mild gradients actually correspond to relatively steep vertical gradients.Even though the illustration is misleading, the slope of the equipotential lines can be used to determine the apparent flow lines for groundwater. These considerations show that most flow lines near the river would be drawn with a downward angle of about 60 degrees to the horizontal. The data are not sufficient to determine flow lines in the shallow zone, but it appears that only a small fraction (probably less than 10%) of the aquifer discharges into the river.

Some of the observations can be explained by consideration of the topographic and geologic influences at the site. There appears to be a general "regional" downward gradient which is perturbed by the variable degree of partial confinement occurring because of the numerous but discontinuous thin clay strata (see Figure 5-2), the location of screened intervals with respect to zones containing clay layers or sand, and the differing slopes of the geologic structure and the water table. The water table toward the south occurs near the bottom of a 100-ft thick sand layer, but near the top of this geologic feature at locations near the river. Thus, the aquifer at locations toward the south spans the zones where clay lenses are present, and a small degree of confinement may occur because the slope of the lenses exceeds the slope of the groundwater surface. As water flows toward the north, discontinuity in the lenses removes the confining conditions, and potentials trend toward the general regional (i.e., downward gradient) case. For locations near the river, the aquifer spans the entire sand layer and only the lower zones are influenced by the clay lenses. Furthermore, the slope of the groundwater surface may approach the lithologic slope, so the potential for confinement would be reduced and an overall downward gradient prevails. It is expected that only the shallow groundwater discharges into the river because both the downward gradient and the clay lenses occurring in the lower portion of the aquifer effectively inhibit upward movement of water.

The OBG is a major potential source area that is located farther south and at a higher elevation than the limits of the plot in Figure 5-9. There is no direct evidence of a downward gradient in the immediate vicinity of the OBG, but an inference can be made by extrapolating the geologic influence on potentials to this area. An assumption that the clayey strata causing confinement tail out at the higher surface elevations is consistent with the current ideas about how these sedimentary features were formed; in fact, the logs of borings in the OBG show less numerous clayey zones than are evident in areas farther north. If this is the case, then there may be a decided downward gradient and also a higher vertical permeability in and near the OBG, allowing contaminants that enter the water column to move downward quite rapidly. Thus, across the entire section from the OBG to the river the vertical gradients may transition from downward (near the OBG) to upward (through the industrial portion of the site) to downward (near the river). These indications suggest that the vertical component of flow may introduce complexities that are not evident in the relatively simple horizontal flow system as previously conceptualized.

The hydrologic conceptualization matches available chemical evidence to at least a qualitative degree, as discussed subsequently in Section 7.0. The concept of a general downward gradient is consistent with the higher concentrations of explosives in samples obtained from the deeper wells near the river, and the apparent rapid migration downward from sources in the OBG to the deep RCRA wells. The possible presence of areas showing lesser downward potential (including upward gradients) is consistent with the detection of contaminants at shallow to intermediate depths at many locations, rather than occurrences solely in the deeper portion of the aquifer.

5.3 SURFACE WATER HYDROLOGY

This section describes the results of the stream gaging program undertaken at MAAP. Calculations of flow rate were made from the ditch flow measurements, using both the weirs in the small ditches and the crest-stage gages in the larger downstream ditches. The flow measurements were taken between September 9 and October 7, 1990. Using water balance calculations, the rate at which water infiltrates the soil was calculated. Also, estimates were made of the percent of rainfall that flows through the ditches and the percent that infiltrates the ditch bottom. Estimated rates of evapotranspiration were used to calculate the fraction of water which percolates to the groundwater table versus the fraction of water that evapotranspires to the atmosphere.

5.3.1 Weir Measurements

The weir measurements were taken as described in Section 4.10.3. The readings consisted of measuring the head upstream of the weir if it was not overtopped, and measuring both upstream and downstream heads if the weir was submerged.

The calculations of total flow were made using published empirical equations. These equations are based on experimental data obtained from calibration of weirs in ideal conditions: a long, straight approach channel, a sharp-edged weir surface, and fully-ventilated flow over the weir crest. The weirs installed at MAAP do not fully meet these conditions, but attempts were made to minimize deviations from the ideal case. The weirs were located in straight channels as much as practicable given the rationale for each weir location. The ditch floor both upstream and downstream of the weirs was smoothed by hand. The wooden construction materials used in the weirs were coated with an epoxy resin both to minimize water damage and to minimize surface roughness. These actions resulted in flow which was observed to be nearly fully-ventilated over the crest.

The equation for triangular, unsubmerged weirs recommended in the American Society of Mechanical Engineers (ASME) report "Fluid Meters" (1971) was used in calculating the flow rates for cases where the weir was not overtopped. The flow rate is expressed by:

$$Q = \frac{8}{15} C \tan\left(\frac{\theta}{2}\right) 2g^{\frac{1}{2}} (h + \Delta h)^{\frac{5}{2}} \tag{2}$$

where:

Q = flow rate (ft^3/sec)

C = coefficient of discharge as a function of the notch angle

θ = notch angle

g = acceleration of gravity (32.2 ft/sec^2)

h = head above the weir crest (feet)

Δh = correction for the head/crest ratio as a function of the notch angle (feet)

For a notch angle of 90 degrees, $C = 0.579$ and $\Delta h = 0.003$ feet (ASME, 1971).

Substituting these values for C and Δh, the above equation becomes:

$$Q = 2.477(h + 0.003)^{2.50} \tag{3}$$

For a submerged sharp-crested weir, the flow is dependent on both the upstream head (H_1) and the downstream head (H_2), as measured from the crest of the weir. Vennard and Weston (1943) have shown that data collected by various experimenters fall on a single curve when the ratio Q/Q_1 is plotted against H_2/H_1. In this analysis, Q is the discharge over the weir and Q_1 is the discharge at the head H_1, which is computed from the equation for an unsubmerged weir.

The following equation for calculating Q/Q_1 as a function of H_2/H_1 has been developed (Villemonte, 1947):

$$\frac{Q}{Q_1} = \left[1 - \left(\frac{H_2}{H_1}\right)^n\right]^{0.385} \qquad (4)$$

where:

n = exponent in the free discharge equation ($n = 2.50$ for a triangular weir)

This equation was found to be accurate in tests conducted on rectangular, triangular, parabolic, cusped, and crested weirs with a maximum deviation of 5%.

Using the equations for free discharged and submerged conditions, flow rates were calculated from the head measurements taken at MAAP. These values are shown in Table 5-4 for each weir.

Weir V1 was located immediately downstream of the O-Line PWTF and upstream of any runoff from the O-Line Ponds area. Therefore it served as the background flow measurement for the tributary of Ditch 5 upstream of weir V2. The ditch has a silty bottom typically supporting a healthy vegetative cover. Shortly after the September 21, 1990 flow reading was taken, this weir was removed by Martin Marietta personnel because it was felt that the weir was contributing to a water backup problem in the treatment system. Also, Martin-Marietta wanted to clean the ditch of all debris and the weir was installed before this was accomplished.

Because weir V1 was the smallest weir installed, it was used to test the accuracy of using weirs to estimate flow rate. The reading taken at 1825 hours on September 10, 1990, was supplemented with a flow measurement using the bucket and stopwatch method. The rate at which water flowed over the V-notch, measured with the bucket and stopwatch method, was 13 gpm. The calculated flow rate using the weir was 22 gpm. Although this is an apparent error of 40%, the weir method is not expected to be particularly accurate at these low flow rates in a ditch with a rough bottom surface. For example, for a weir with these dimensions, a head measurement error of 0.5 inch results in a 40% difference in flow rate. Therefore, the weir measurements at low flow rates are considered to have an accuracy range on the order of 50 to 150%.

Weir V2 is also located on Ditch 5, downstream of the O-Line Ponds area. This weir was installed in an area of the ditch which has a sandy bed. Even though the weir and the concrete base extended 2 feet into the ditch bed, the weir had been undercut by flow by October 7, 1990. Therefore, the reading made on October 3, 1990, was the last measurement of total flow.

Weir V3 is also located on Ditch 5, but on the tributary coming from the C-Line PWTF south of O-Line rather than the tributary which flows from the O-Line PWTF. This weir was undercut by flow before the October 3 reading was taken.

It was apparent when weir V4 was installed that the flow through the ditch at this location is very large. The channel is deeply cut and is immediately downstream of a large road culvert. Therefore, it was expected that this weir would be submerged most of the time due to high flow rates, and this prediction proved to be true.

Table 5-4a
Weir V1 Readings and Calculated Flow

Date	Time	Unsubmerged Conditions	Submerged Conditions		Calculated Flow (gpm)
		Upstream Head (ft)	Upstream Head (ft)	Downstream Head (ft)	
9/10/90	1745	0.67	-	-	13
9/10/90	1825	0.71	-	-	22
9/12/90	0730	0.0	-	-	0
9/13/90	0950	0.63	-	-	6.8
9/18/90	1100	0.96	-	-	160
9/21/90	1341	-	1.3	1.1	490
Weir was removed by Martin-Marietta					

Table 5-4b
Weir V2 Readings and Calculated Flow

Date	Time	Unsubmerged Conditions	Submerged Conditions		Calculated Flow (gpm)
		Upstream Head (ft)	Upstream Head (ft)	Downstream Head (ft)	
9/10/90	1730	1.33	-	-	280
9/10/90	1815	1.33	-	-	280
9/11/90	0720	0.83	-	-	2.0
9/12/90	0755	0.49	-	-	0.0
9/13/90	0950	0.44	-	-	0.0
9/21/90	1355	-	1.5	1.0	530
10/3/90	0825	-	1.58	1.29	590
Weir undercut by flow, 10/7/90					

Table 5-4c
Weir V3 Readings and Calculated Flow

Date	Time	Unsubmerged Conditions	Submerged Conditions		Calculated Flow (gpm)
		Upstream Head (ft)	Upstream Head (ft)	Downstream Head (ft)	
9/10/90	1730	1.0	-	-	0
9/10/90	1816	1.0	-	-	0
9/11/90	0720	0.58	-	-	0
9/12/90	0755	0.29	-	-	0
9/13/90	1021	0.0	-	-	0
9/21/90	1357	1.33	-	-	35
Weir undercut by flow, 10/3/90					

Table 5-4d
Weir V4 Readings and Calculated Flow

Date	Time	Unsubmerged Conditions	Submerged Conditions		Calculated Flow (gpm)
		Upstream Head (ft)	Upstream Head (ft)	Downstream Head (ft)	
9/10/90	1415	-	2.10	1.85	480
9/10/90	1550	-	2.75	2.17	2400
9/10/90	1700	-	2.75	2.17	2400
9/10/90	1812	-	2.75	2.17	2400
9/11/90	0710	1.33	-	-	0
9/12/90	0755	1.33	-	-	0
9/13/90	1025	1.29	-	-	0
9/21/90	1405	-	2.00	1.83	320
10/3/90	0845	-	2.08	2.00	310
10/7/90	1700	1.25	-	-	0

5.3.2 Crest-Stage Gage Measurements

The crest-stage gages were installed in Ditches B and C near their confluence with the Rutherford Fork and adjacent to the reservation boundary. The ditches in which these gages were installed are approximately 23 feet wide, deeply cut with wall heights between 8 and 10 feet, and rectangular in cross-section. It was apparent from high-water marks that large volumes of water passed through the ditches at these points during storms. Therefore, it was not considered feasible to install weirs or flumes to measure flow. Instead, a pair of crest-stage gages were installed in each ditch to record the water level crest and to allow an observer to read the water levels remotely.

When the gages were installed, a surveyor's level and rod were used to measure the relative elevations of the gage locations and several additional points along the ditch floor both upstream and downstream from the gages. These measurements were used to determine the hydraulic slope of the ditches at the gage locations. The locations of the points and their elevations, relative to a reference point between the gages in each pair, are shown in Figures 5-10 and 5-11. In both of these graphs, the positive direction is downstream of the reference point and the negative distance is upstream of the reference point. The diagonal line in the two graphs is the least-squares fit of the data. The tangent of the angle of the least-squares fit line with the horizontal is taken as the hydraulic slope of the ditch. The calculated hydraulic slope is listed in Table 5-5.

Due to the infrequency of the storms and the difficulty in accessing the gage locations during a storm, only a single reading was taken from gages CG-2 and CG-4. These readings are listed in Table 5-5. These readings correspond to the storm event on September 21, 1990, in which 1.97 inches of rain fell in a 14-hour period.

The cross-sectional profiles of the two ditches at these locations, as obtained by relative elevation measurements, are shown in Figures 5-12 and 5-13. For these two graphs, the profile of the ditch lying to the east of the point where the gage is installed is taken as a negative distance, and the profile of the ditch on the west side of the gage is positive. In both cases, the height of the ditch wall was measured relative to the lowest point in the cross-section at the gage location.

The area of the ditch and the wetted perimeter can be calculated from these graphs and the water level height. The area of the ditch is the area inside the curve from the bottom of the graph to the height of the measured water level. The wetted perimeter is the sum of the lengths of the ditch floor and walls up to the measured water level. The ditch area and wetted perimeter values corresponding to the measured water level are given in Table 5-5. The hydraulic radius of the ditch is expressed as the ratio of the area to the wetted perimeter.

The Manning equation, also known as the slope/area method, was used to calculate the volumetric flow rate for the high-water measurements. A key parameter in this equation is the roughness coefficient of the flow channel. This value is generally taken from published tables. The ditches at MAAP are natural stream channels; clean, winding, with some pools and shoals, and have some weeds and stones. For a stream of this kind, a value of n = 0.035 has been calculated (Horton, 1939).

The Manning equation expresses the flow velocity in terms of the roughness coefficient, the hydraulic radius, and the hydraulic slope as follows:

$$v = \left(\frac{1.49}{n}\right) r^{\frac{2}{3}} s^{\frac{1}{2}} \qquad (5)$$

where:

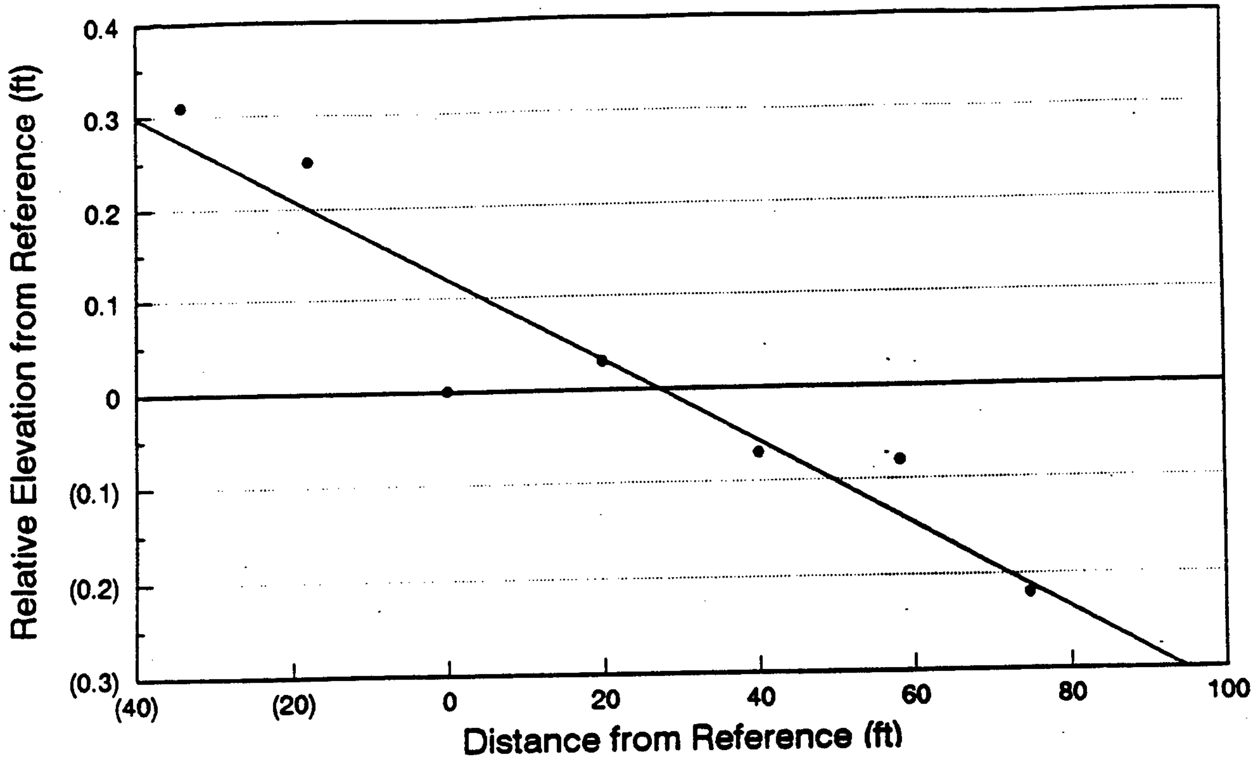


Figure 5-10
Hydraulic Slope of Ditch B at Crest-Stage Gages CG-1 and CG-2

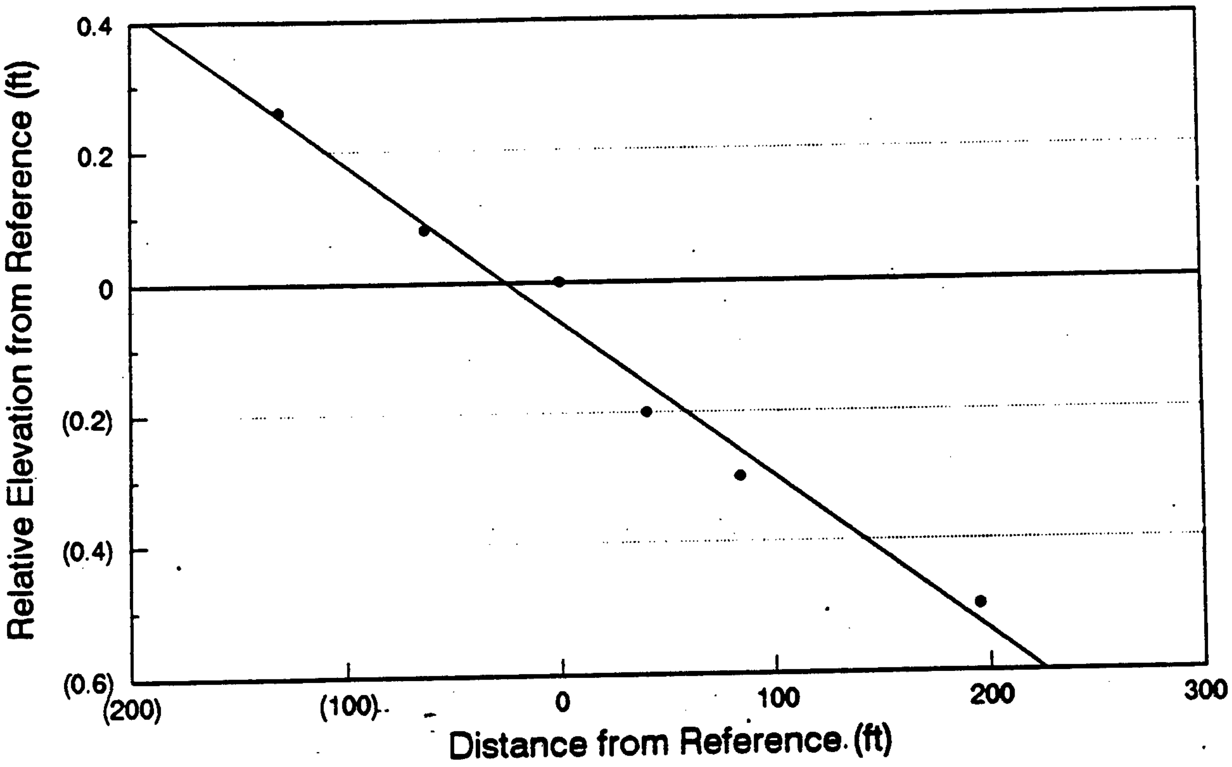


Figure 5-11
Hydraulic Slope of Ditch C at Crest-Stage Gages CG-3 and CG-4

Table 5-5
Crest-Stage Gage Readings and Results of Calculations

	Water Level Reading (ft)	Hydraulic Slope	Wetted Area (ft^2)	Wetted Perimeter (ft)	Flow Velocity (ft/sec)	Volumetric Flow Rate (gpm)
CG-2 (Ditch B)	3.2	2.2×10^{-3}	48.2	22.35	3.35	72,500
CG-4 (Ditch C)	5.5	2.4×10^{-3}	105	28.94	4.94	233,000

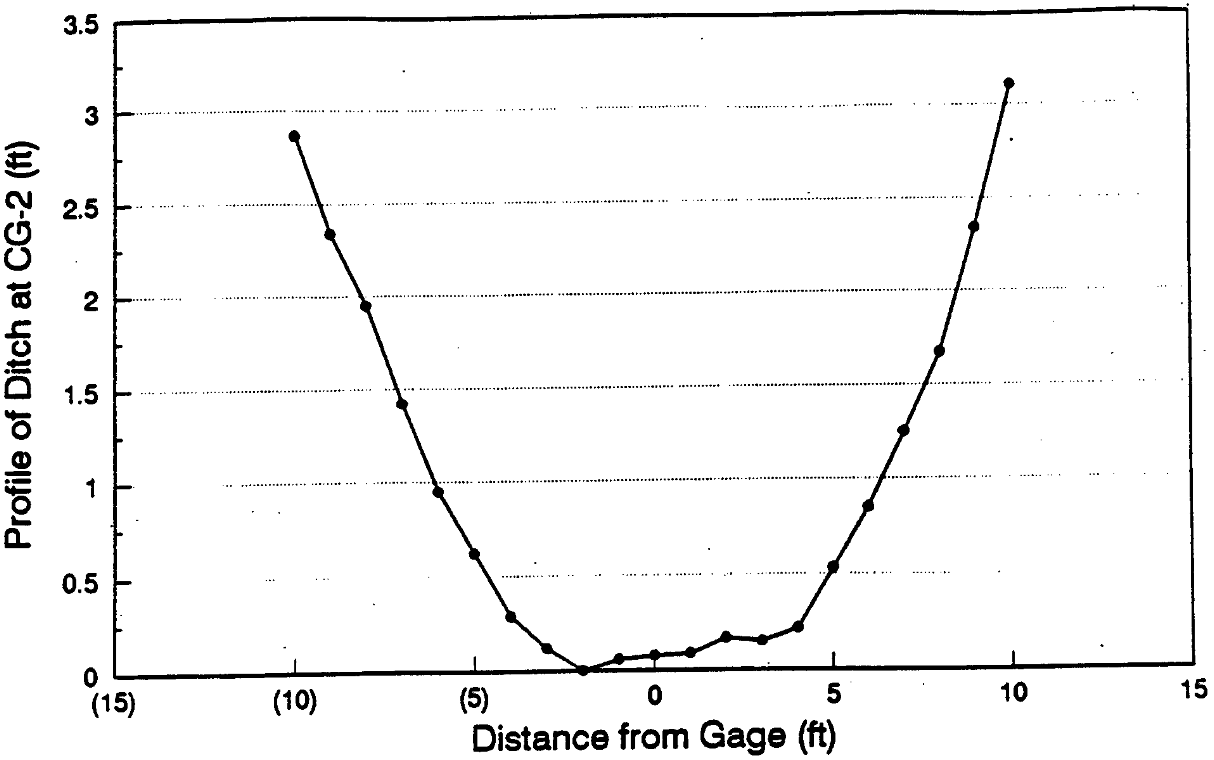


Figure 5-12
Profile of Ditch B at Crest-Stage Gage CG-2

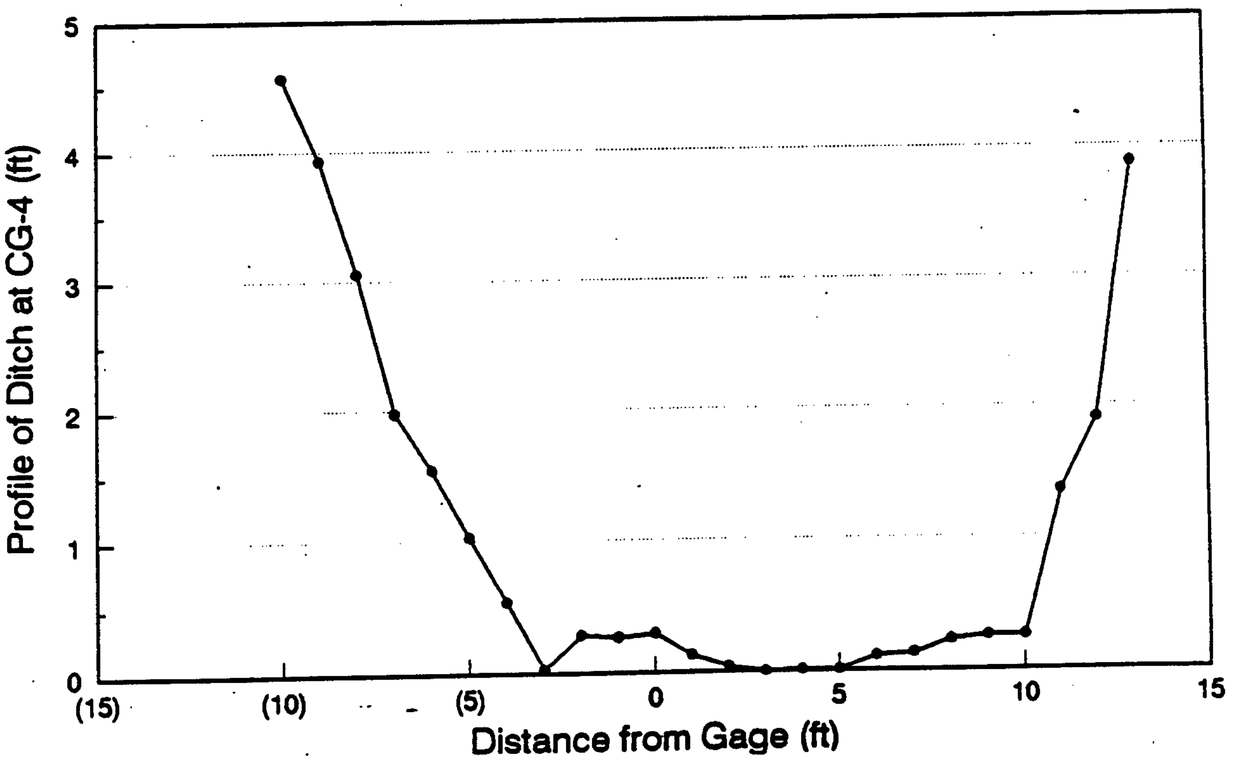


Figure 5-13
Profile of Ditch C at Crest-Stage Gage CG-4

v = flow velocity (ft/sec)

n = roughness coefficient (dimensionless)

r = hydraulic radius (ft)

s = hydraulic slope (dimensionless)

The volumetric flow rate may then be calculated by multiplying the flow velocity by the cross-sectional area of the ditch below the water level reading. The calculated velocity and volumetric flow rates using these relationships are listed in Table 5-5.

The two crest-stage gages located in Ditch C, downstream of the WCOP sewage treatment plant, could not be used directly in this investigation because the concrete used in installing them did not set. One of the gages washed away and could not be found. The other was found floating downstream. However, the water crest at the location of CG-4 was obtained from the height of mud coating the vegetation on the ditch sides.

5.3.3 Calculations of Rainfall Infiltration, Surface Runoff, and Ditch Infiltration

A simple water-balance approach was used in calculating the rate of surface water infiltration into soil, runoff into ditches, and infiltration into the ditch bed and percolation to the groundwater table. Various assumptions were used to simplify the problem:

- The rainfall rate and infiltration rate are assumed to be constant over the rainfall event time period.
- The flow rates measured in the ditches are average values for the rainfall event.
- Interflow is not a significant contributor to flow into the ditches. Interflow, or shallow groundwater flow, is most likely to occur in areas with larger surface gradients than are found at MAAP. Therefore, the major source of water in the ditches is assumed to be surface runoff.
- The rainfall event is assumed to be of short enough duration that evaporation from the land surface during the storm may be neglected.

Two rainfall events were used in making these calculations. The first event occurred on September 10, 1990, shortly after the weirs were installed and before the crest-stage gages were installed in the downstream ditches. As shown on the precipitation graph in Figure 5-14, this rainfall event was the first significant storm after a dry period. The second storm event used in making these calculations occurred on September 21, 1990. This storm occurred after a time period had elapsed in which the weather was more representative of normal conditions in western Tennessee. Between the 10th and the 21st of September, a total of 4.51 inches of rain fell. The saturation of the soil and ditch bottoms was probably at normal levels when the latter storm occurred.

The area covered by Ditch 5 was used in this analysis. The ditch and topography of the surrounding area is shown in Figure 5-15. The land designated as Area A is expected, based on topography, to drain to the tributary of Ditch 5 which begins at the O-Line PWTF and ends at weir V2. The flow rate coming from the treatment plant is measured by weir V1. The land designated as Area B drains to the western tributary of Ditch B from the small ponds in the south to weir V3. The length of the ditch in Area A is 3,200 feet and the corresponding drainage area is 2.38×10^6 square feet. The length of the ditch in Area B is 10,500 feet and the corresponding drainage area is 1.0×10^7 square feet. The average ditch width in this area is estimated to be 6 feet, based on observations made during sediment and surface water sampling.

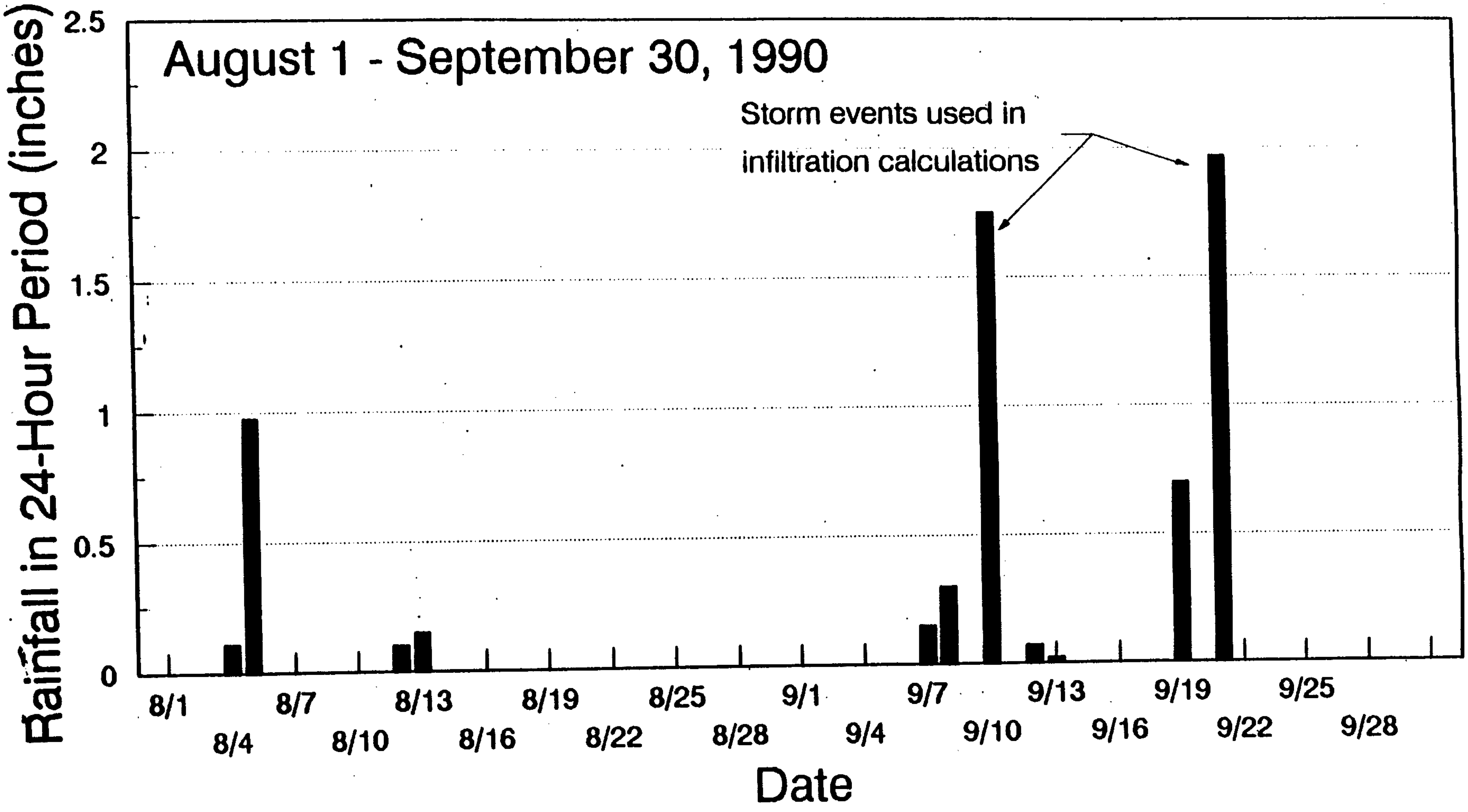


Figure 5-14
Daily Rainfall Between August 1 and September 30, 1990

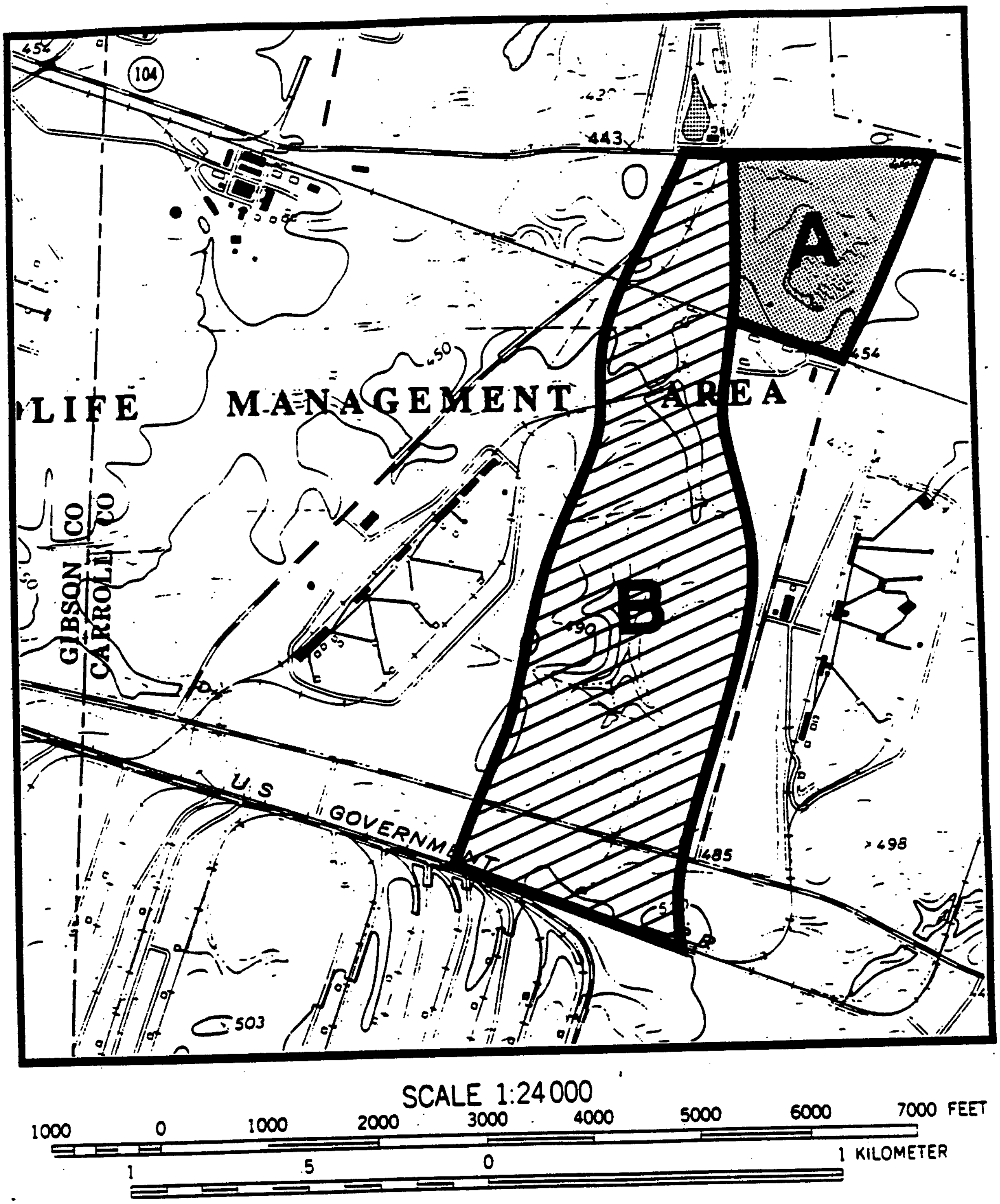


Figure 5-15
Drainage Areas for Ditch 5 Between Weirs V1, V2 and V3

A control system approach was used to balance the flow of water into and out of the ditch of interest. The continuity equation for the system consisting of the soil drainage area and the ditches for an area with known flow rates at two locations can be expressed as:

$$\Delta V = RA - I_S A - I_D A_D \qquad (6)$$

where:

ΔV = difference between the flow rate out of the ditch and the flow rate into the ditch (ft^3/min)

R = rainfall rate (ft/min)

A = surface area of the drainage area around the ditch (ft^2)

I_S = infiltration rate into the soil in the drainage area (ft/min)

I_D = infiltration rate into the ditch bottom (ft/min)

A_D = the area of the ditch within the system (ft^2)

The above equation may be written for both Area A and Area B, as follows:

$$\Delta V_A = RA_A - I_S A_A - I_D W_D L_A \qquad (7)$$

$$\Delta V_B = RA_B = I_S A_B - I_D W_D L_B \qquad (8)$$

where:

A_A and A_B = respective drainage areas within Area A and Area B (ft^2)

W_D = average width of the ditches (ft)

L_A and L_B = respective lengths of the ditches within Areas A and B (ft)

In this analysis, the ditches in Areas A and B are assumed to have the same average width.

Therefore, this system has two equations and two unknown variables: I_D and I_S. These variables may be found by solving the two equations simultaneously. The equation for Area A may be solved for I_D:

$$I_D = \frac{(R - I_S)A_A - \Delta V_A}{W_D L_A} \qquad (9)$$

This expression may be substituted into the equation for Area B, and the result is an expression for I_S in terms of known parameters:

$$I_S = R - \frac{\Delta V_B + \Delta V_A \left(\frac{L_B}{L_A}\right)}{A_B - A_A \left(\frac{L_B}{L_A}\right)} \tag{10}$$

Therefore, I_S can be calculated from the above equation and then I_D can be found from equation (9).

Using the above equations and the values listed in Tables 5-4 and 5-5, the infiltration rates and relative amounts were calculated for the rainfall event on September 10, 1990:

$$I_D = 5.93 \times 10^{-3} \text{ ft/min}$$

$$I_S = 5.6 \times 10^{-4} \text{ ft/min}$$

The percentage of water that infiltrates the soil may be obtained by dividing I_S by the rainfall rate R. The remainder is the percentage of water that runs off into the ditch system. The percentage of water that infiltrates the ditch floor is I_D divided by the rate at which water is running off into the ditch, which is the difference between R and I_S. The remainder of this water, or $R - I_S - I_D$, is the rate at which water is flowing through the ditch.

This analysis indicates that for the first storm event following a dry period, 91% of the rainwater that fell in these drainage areas infiltrated the soil. Only 9% of the rainwater ran off to the ditches. Of the amount of water that reached the ditches, 92% infiltrated the ditch bottom and percolated down. The remaining 8% of the water that reached the ditch flowed through the ditch as surface water. Therefore, the fractional amount of precipitation that infiltrates the soil was 99% during this rainfall event. Only 1% of the precipitation flowed through the ditch system to the Rutherford Fork.

These calculations are consistent with the conceptual model of the flow system. The ditches are deeply eroded through the alluvium, so the ditch bottoms are composed of highly-permeable sand which readily conducts water. Therefore, a high rate of infiltration within the ditch systems is expected. These readings were taken from the first storm event after a dry period, when the soil saturation was observed to be low. At this time, the capillary suction of the soil was particularly high and nearly all of the rainwater was drawn into the soil.

The calculations were performed again for the storm event on September 21, 1990. The results are as follows:

$$I_D = 1.17 \times 10^{-2} \text{ ft/min}$$

$$I_S = 9.35 \times 10^{-5} \text{ ft/min}$$

These infiltration rates imply that 48% of the rainwater infiltrated the soil in the drainage area. The remaining 52% ran off to the ditches. Of the water that reached the ditches, 94% infiltrated the ditch floor and percolated down. The remaining 6% flowed through the ditches. Therefore, the total fractional amount of water that infiltrates the soil is 97%, and only 3% of the precipitation flows to the Rutherford Fork through the ditches. Because the drainage area is well-vegetated, relatively flat, and has a sandy soil, the soil infiltration rate appears to be a reasonable estimate.

Because the flow readings used in these calculations were taken after a relatively wet period, the soil was more saturated than on September 10, 1990, and the capillary suction was lower. Therefore, a larger percentage of the water that fell on the drainage area ran off. However, approximately the same fraction of water that reached the ditches infiltrated the ditch floor.

The weather pattern preceding the readings on September 21 is more representative of normal conditions. For this reason, the calculations of infiltration rates and percentage of infiltration based on the September 21 storm are believed to be more accurate than the results of the calculations made from the September 10 storm.

5.3.4 Calculations of Evapotranspiration

Evaporation is the process by which water is removed from the land or water surface and transported away from the surface. Water is removed from the surface as a vapor by solar radiation, which provides the latent heat of vaporization. The combined effects of the wind velocity over the surface and the specific humidity gradient at the surface act to transport the water vapor away from the evaporative surface. Transpiration is the process by which water is extracted from the soil by plant roots; transported upwards through the plant, and diffused into the atmosphere through the leaves. Although evaporation and transpiration are two separate processes, they are generally considered together because their effect on soil moisture is the same. The combined processes of evaporation and transpiration is known as evapotranspiration.

The amount of evapotranspiration which actually occurs at a given place is governed by the factors mentioned above; namely, the duration and intensity of sunlight, the wind velocity, specific humidity gradient over the surface, and the amount of water needed by the crops or vegetation, as well as other factors. However, actual evapotranspiration is also affected by the amount of water available for the evaporation and transpiration processes, which is strongly dependent on weather conditions. For this reason, a quantity known as potential evapotranspiration has been defined as the water loss which will occur if at no time there is a deficiency of water for use by vegetation. When the potential evapotranspiration is compared to the amount of moisture available in the soil, conclusions may be drawn about the rate of soil moisture recharge or depletion.

A simple water budget model was used to estimate the rate of evapotranspiration at the site. The equations used were developed by Thornthwaite and Mather in 1957 to provide a rational procedure for evaluating soil moisture storage at a particular place using weather data. The model converts monthly air temperature data and geographical factors into values of potential evapotranspiration. The geographical factors used by the model are the latitude of the site (which affects the duration and intensity of sunlight) and the heat index, which is the sum of the twelve monthly heat index values which are dependent upon the respective long-term mean monthly temperatures. The actual equation developed by Thornthwaite for the heat index is:

$$I = \sum_{m=1}^{12} \left[\frac{T_m}{5} \right]^{1.51} \tag{11}$$

where:

I = heat index (degrees Celsius)

m = month

T_m = mean monthly temperature (degrees Celsius)

The value for the heat index (converted into degrees Fahrenheit) is then used in calculating the potential evapotranspiration amount for a particular month. The Thornthwaite equation for estimating potential evapotranspiration is:

where:

$$PET = 1.6\left(\frac{10T_m}{I}\right)^a \qquad (12)$$

PET = potential evapotranspiration (cm per month)

a = $(6.75 \times 10^{-7} I^3) - (7.7 \times 10^{-6} I^2) + 0.0179\, I + 0.49$

In addition, actual monthly precipitation values are used by the model to calculate actual evapotranspiration rates. Soil moisture withdrawal is calculated using an equation which assumes a linear decreasing availability of soil moisture. As the soil moisture decreases, it becomes more difficult for water to be removed from the soil by evapotranspiration.

The computer model which solves the above equations was developed by the Louisiana Office of State Climatology (McCabe et al., 1985). The weather data used in running the model was obtained from the Chemistry Laboratory at MAAP, which takes daily weather readings. The input data are listed in Table 5-6. The model output is shown in Table 5-7.

The results of the calculations indicate that between the months of September to May, soil moisture recharge occurred. Therefore, actual evapotranspiration equalled potential evapotranspiration because sufficient soil moisture was available. From June through August, however, soil moisture was depleted by evapotranspiration faster than it was replenished by precipitation. This resulted in actual evapotranspiration rates which were less than the amount of potential evapotranspiration.

In 1990, the total amount of precipitation was 63.35 inches, which is a wetter-than-normal year. Of this amount, a total of 31.1 inches of water evapotranspired. This indicates that 49% of the rainfall was evapotranspired into the atmosphere.

5.3.5 Summary

When the results of the analysis of evapotranspiration are combined with the results of the weir measurements, the following conclusions may be drawn:

- Approximately 50% of the precipitation at the site infiltrates the soil and 50% runs off into the ditch drainage system. Of the water that runs off, approximately 90% of it infiltrates the soil in the ditch floor and 10% flows through the ditch system to the Rutherford Fork.
- Approximately 95% of the precipitation at the site percolates through the soil zone. However, 50% of this water is evapotranspired to the atmosphere. Therefore, approximately 48% of the precipitation at the site percolates through the vadose zone to recharge groundwater.
- The approximate average annual amount of groundwater recharge through precipitation and percolation is 48% of 50 inches per year, or 24 inches per year of annual recharge.

Table 5-6
Evapotranspiration Model Input Data

Month, 1990	Mean Temperature (degrees F)	Precipitation (inches)
January	45.45	5.05
February	48.66	8.45
March	52.29	5.05
April	57.68	5.70
May	65.02	3.88
June	76.72	4.17
July	78.77	3.43
August	78.44	1.34
September	74.27	4.96
October	50.10	6.51
November	55.68	3.62
December	46.37	11.19
Latitude: 36 degrees		
Heat Index: 69.69 degrees F		

Table 5-7
Evapotranspiration Model Results

Month, 1990	Potential Evapotranspiration (inches)	Actual Evapotranspiration (inches)
January	0.61	0.61
February	0.84	0.84
March	1.40	1.40
April	2.17	2.17
May	3.60	3.60
June	5.86	5.65
July	6.39	5.22
August	5.94	2.85
September	4.52	4.52
October	2.09	2.09
November	1.49	1.49
December	0.66	0.66

5.4 CHEMICAL DATA

The results of chemical analysis of environmental samples collected at the site are presented in this section. Within each environmental medium, the concentrations of inorganic analytes are compared to background concentrations and those analytes which exceed these levels are considered to be contaminants of concern. All organic contaminants which appear in the data above the certified reporting limit (CRL) are considered contaminants of concern in this investigation. In order to put the detected levels of contaminants into perspective, proposed or promulgated regulatory criteria for soil, groundwater, and surface water are presented. However, these regulatory criteria are included for comparison only and the final determination of applicable or relevant and appropriate requirements has not yet been made. The regulatory criteria are discussed in more detail in Section 10.0. Also, the interpretation of the data as to persistence and mobility is not discussed in this section. An evaluation of the nature and extent of contamination appears in Section 7.0.

The laboratory data from the environmental sampling performed at the site are included in this report as Appendix L.

5.4.1 Soil Boring Samples

This section presents the results of chemical analysis of soil samples collected from borings installed at MAAP, with emphasis on the select metals and explosives analytes. Soil samples were collected from the suspected source areas under investigation: the OBG/ADA areas, Former Burnout Area, Former Borrow Pit, Former and Present Landfills, Salvage Yard, and LAP Line sumps. Soil borings were not used to investigate the O-Line Ponds Area.

5.4.1.1 Background Levels. In this investigation, the chemicals of concern are all chemicals which appear in the soil samples above the concentration at which they appear in background samples. For explosives and all other organic compounds, the background concentration is assumed to be zero. Therefore, all organic contaminants detected in soil samples are considered chemicals of concern.

Because many metals and other inorganic constituents occur naturally in soil, they are frequently detected in background samples at levels which vary both regionally and with depth. The background levels used in selecting inorganics of concern should be representative of naturally occurring levels, but should also be reasonably conservative, so that potentially important analytes are included in the risk assessment. The following paragraphs explain how the background levels used for this purpose were obtained.

A possible site-specific range of concentrations for the metals of interest (cadmium, chromium, mercury, and lead) can be determined from the results of the composite samples collected during drilling of the boreholes for monitoring wells MI059, MI062, MI065, and MI068. These wells were not installed in suspected source areas. The range of inorganics detected in these samples is presented in Table 5-8.

The wells used in this comparison are the shallow wells in each cluster. However, the average depth of these wells is 84 feet. The predominant material represented by these samples is not soil; rather, it is aquifer material from the Memphis Sand. Therefore, it is not surprising that the levels of inorganics detected in these samples are non-detectable for cadmium, chromium and mercury, and is very small for lead. Although these values are site-specific background ranges from samples collected during this investigation, they do not represent the mineralogy of the vadose zone. Therefore, these levels were not used in determining chemicals of concern.

TABLE 5-8
Background Values and Proposed Criteria for Select Metals in Soils ($\mu g/g$)

Analyte	Aquifer Material Background Value or Range	County-Specific Background Value[a]	EPA Proposed Concentrations Meeting Criteria for Action Levels[b]	EPA Guideline for Protection of Human Health[c]	Site-Specific (PBSJ Study) Background Value[d]
Alumninum	NA	30,000	NA	NA	NA
Arsenic	NA	3.5	80	NA	NA
Barium	NA	300	4,000	NA	NA
Cadmium	<3.05 (CRL)	NA	40	NA	0.62
Calcium	NA	3,500	NA	NA	NA
Chromium	<12.7 (CRL)	50	400	NA	23.8
Cobalt	NA	10	NA	NA	NA
Copper	NA	20	NA	NA	NA
Iron	NA	15,000	NA	NA	NA
Lead	0.956-4.75	15	NA	500	17.8
Magnesium	NA	2,000	NA	NA	NA
Manganes	NA	200	NA	NA	NA
Mercury	<0.050 (CRL)	0.05	20	NA	NA
Nickel	NA	15	2,000	NA	NA
Potassium	NA	9,000	NA	NA	NA
Selenium	NA	0.3	NA	NA	NA
Silver	NA	<0.5-5[e]	200	NA	NA
Sodium	NA	5,000	NA	NA	NA
Vanadium	NA	50	NA	NA	NA
Zinc	NA	74[f]	NA	NA	NA

CRL	Certified Reporting Limit
NA	Not Available/Not Applicable
a	Boerngen and Shacklette, 1981, unless otherwise specified.
b	55 Federal Register, No. 145, July 27, 1990.
c	USEPA, 1989d
d	PBSJ, 1988
e	Connor and Shacklette, 1975
f	Shacklette and Boerngen, 1984

During the investigation of the OBG and ADA areas by PBSJ in 1988, five background soil samples were taken in areas which were apparently unaffected by disposal/burning activities. The samples were composite soil samples from 0-1 foot or 0-2 feet and were analyzed for cadmium, chromium, and lead. The maximum concentration detected in these background soils is listed in Table 5-8. (One sample had a reported lead concentration of 218 μg/g. This datum was not used by PBSJ, nor is it included in this table.) These values represent site-specific background for near-surface soil; therefore, these values were used as the background level to determine if concentrations of select metals were present at levels of concern. If a metal concentration in a particular sample was above the highest value observed in the PBSJ study, it was considered to be above background.

For the other inorganic analytes, a county-specific level was used as background. The county-specific background value was obtained from analysis of a 0-2 foot sample collected near MAAP (four miles west of Milan on Route 104) and published by the USGS (Boerngen and Shacklette, 1984; Connor and Shacklette, 1975; and Shacklette and Boerngen, 1981). All inorganic analytes which were detected in a sample at two times (or greater) the concentration observed in the county sample, were stated to be present "above background" and were retained as chemicals of concern in that sample. The factor of two is used to give a degree of variability to the background data.

5.4.1.2 Regulatory Criteria. In addition, there exist both proposed regulatory criteria and a guideline for determining at what level concentrations of contaminants in soil may impact human health, These levels are included in this report for comparison purposes only. The EPA Proposed Concentrations Meeting Criteria for Action Levels (55 Federal Register, No. 145, July 27, 1990) are listed and described in Section 10.0. The EPA guideline for a clean-up level of lead in soil (identical to the State of Tennessee proposed soil clean-up level) was established for the protection of human health (USEPA, 1989d) and is 500 μg/g. These levels also appear in Table 5-8.

5.4.1.3 Discussion of Results. To facilitate the presentation, the results are presented by geographic area or use of a particular area. The results for borings installed in the Open Burning Grounds are presented first, followed by results for borings in the Former ADA, Current ADA, Former Burn Out Area-Sunny slope, Former Borrow Pit, Closed Landfill, Present Landfill, and Salvage Yard. Finally, the results for LAP Lines A,B,C,D,E,O,X and Z are presented. Chemical results for Select Metals (cadmium, chromium, lead, mercury) are presented first, followed by EPA TAL analytes, explosive analytes, and EPA TCL constituents. Results are further divided into surface (collected from 0 to 1 foot or 0 to 2 foot depth) and subsurface (greater than 2 foot depth) soils at all areas except the LAP Lines. Risks posed by future exposure to chemicals of concern in surface soils in all areas except the LAP Lines are considered in Section 9.0, Baseline Risk Assessment.

5.4.1.4 Open Burning Ground. Sixteen soil borings were drilled in the area known as the Open Burning Ground (OBG). The analytical results for the soil samples collected suggest insignificant to low metals contamination at these locations. Table 5-9 shows the range of select metals concentrations encountered at each soil boring. Results for borings that were drilled in areas investigated in the PBSJ study are discussed first, followed by results for borings drilled in areas not previously investigated.

Lead concentrations exceeding the PBSJ study and county-specific background values were detected in soil samples collected from the zero to one foot depth interval only. Lead concentrations usually decreased by an order of magnitude at depths of 5 feet and greater at soil borings drilled in the OBG. Cadmium was not detected above its CRL of 3 μg/g in any soil samples collected from this area. There were isolated occurrences where chromium and mercury were detected above their respective (CRLs). There does not appear to be a pattern to the distribution of these elements, except that most detections of mercury occurred in samples collected from the zero to one foot depth interval.

Soils contaminated by explosives compounds were observed at three of the sixteen soil borings drilled in the OBG: OBGA-3, OBGA-4, and OBGB-4. The analytes detected and the ranges of concentrations observed are shown in Table 5-10.

TABLE 5-9
Range of Select Metals Analytical Results ($\mu g/g$) of Soil Samples from Borings in the Open Burning Grounds

Boring/Analyte	Lead	Cadmium	Chromium	Mercury
	Certified Reporting Limit			
	10.0	3.05	12.7	0.05
OBGA-1	0.548-16.1	ND	ND	ND
OBGA-2	0.412-11.8	ND	ND	ND
OBGA-3	0.679-44.6	ND	ND-30.9	ND-0.0991
OBGA-4	0.300-152	ND	ND-49.3	ND
OBGA-5	2.53-16.2	ND	ND-23.7	ND-0.142
OBGA-6	3.15-16.2	ND	ND-45.0	ND-0.128
OBGB-2	0.292-10.5	ND	ND	ND
OBGB-3	0.396-12.7	ND	ND-95.7	ND
OBGB-4	1.05-44.9	ND	ND-26.8	ND
OBGB-5	0.729-32.9	ND	ND-107	ND-2.48
OBGC-2	6.42-11.3	ND	ND	ND-0.0681
OBGC-3	0.505-10.9	ND	ND	ND-0.0629
OBGC-4	1.19-66.2	ND	ND	ND-0.0644
OBGC-5	8.47-20.2	ND	ND-85.0	ND-0.314
OBGD-3	0.666-18.6	ND	ND	ND-0.110
OBGD-4	1.05-20.1	ND	ND-70.3	ND

ND Not detected above the Certified Reporting Limit.

TABLE 5-10
Range of Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings in the Open Burning Grounds

Boring/Analyte	HMX	RDX	2,4,6-TNT	1,3,5-TNB	NB	1,3-DNB	Tetryl	2,4-DNT	2,6-DNT
	Certified Reporting Limit								
	0.666	0.587	0.456	0.488	2.41	0.496	0.731	0.424	0.524
OBGA-3	ND-339	ND-3,320	ND-4,070	ND-2.34	ND-4.30	ND	ND	ND	ND
OBGA-4	ND-66.9	ND-133	ND	ND	ND	ND	ND	ND	ND
OBGB-4	ND-31.0	ND-44.5	ND-1.21	ND	ND	ND	ND	ND	ND
NOTE: Explosive analytes were not detected above the Certified Reporting Limit (CRL) at other borings in the Open Burning Grounds.									

ND Not detected above the Certified Reporting Limit.

Two soil borings in the OBG were placed in locations formerly documented in the PBSJ study as having highly contaminated soils. These two borings were OBGA-3 and OBGC-3.

BORING OBGA-3

Boring OBGA-3 was installed between Areas A and M of the PBSJ study. Significant metals contamination was observed only at the surface.

Select Metals Results

Surface Soil. The lead concentration in the sample collected from the zero to one foot depth interval was 44.6 μg/g, above the site-specific background value (17.8 μg/g) and the county-specific background level (15 μg/g). Cadmium, chromium and mercury were not detected above their respective CRLs.

Subsurface Soil. In subsurface soil, lead concentrations varied from 0.679 to 10.1 μg/g. Chromium was detected above its CRL of 12.7 μg/g once at 30.9 μg/g at a depth of 90 to 92 feet. This value exceeds the site-specific background value (23.8 μg/g), but is below the county-specific background value (50 μg/g). Mercury was detected at 0.099 μg/g in the five to seven foot depth interval. Cadmium was not detected above the CRL. The metals results from this boring are significantly different from what was found in the PBSJ study in this area, as shown in Table 5-11. Higher lead concentrations were observed in that study and cadmium and chromium were detected more frequently and at higher concentrations. However, it should be noted that in the PBSJ study, two trenches were sampled to depths of 8 and 19 feet, while in this investigation only one boring was installed and samples were collected at greater depths.

EPA TAL Results

No EPA TAL analytes other than chromium were detected above background concentrations in the subsurface soil sample (20-22 foot depth interval) collected from this boring.

Explosive Analyte Results

Surface Soil. Explosives contamination of OBGA-3 was observed only at the zero to one foot depth interval, although samples were collected from other depth intervals which profiled the entire borehole. The observed contaminants and their concentrations were: HMX (339 μg/g), RDX (3,320 μg/g), 2,4,6-TNT (4,070 μg/g), nitrobenzene (NB) (4.30 μg/g), and 1,3,5-TNB (2.34 μg/g). Soil boring OBGA-3 did not show contamination by other organic compounds associated with explosives production. These results are similar to those observed in Area A during the PBSJ study, as shown in Table 5-11, except that HMX and NB were not detected, and explosives contamination was observed at depths greater than one foot.

Subsurface Soil. Explosive analytes were not detected in the subsurface soil samples collected.

EPA TCL Results

Trichlorofluoromethane was detected in the subsurface soil at 0.0119 μg/g, but this compound is a common refrigerant, and may be a laboratory artifact.

BORING OBGC-3

Boring OBGC-3 was installed just south of Area H of the PBSJ study. Significant metals or explosives contamination was not observed in this area.

TABLE 5-11
PBSJ Study Results - Contaminant Concentrations ($\mu g/g$) in Soil Samples Collected from Area A

Depth From the Surface (feet)	HMX	RDX	246-TNT	NB	135-TNB	Cd	Cr	Pb
	Certified Reporting Limit							
	*	*	*	*	*	0.14	0.13	0.17
North Trench								
1	ND	ND	ND	ND	ND	139	127	1,340
4	ND	ND	ND	ND	ND	72.1	379	2,960
13	ND	ND	ND	ND	ND	4.05	29.2	218
19	ND	ND	ND	ND	ND	ND	5.72	3.44
South Trench End of Pit Containing Free Water								
4	ND	ND	ND	ND	275	5.01	16.1	15.5
8	ND	ND	ND	ND	1,627	104	53.1	327
Dry Pit								
1	ND	596	259	ND	ND	69	69.9	1,480
8	ND	ND	ND	ND	ND	0.111	11.3	6.95

Source: Modified from PBSJ, 1988.
ND: Not detected above the Certified Reporting Limit.
* Certified Reporting Limit not identified by PBSJ.

Select Metals Results

Surface Soil. Lead was detected at 10.9 μg/g, in the sample collected from the zero to one foot depth interval. Although this value exceeds the upper limit of the aquifer material background range (4.75 μg/g) it is below the site-specific background value (17.8 μg/g) and the county-specific background value of 15 μg/g. Cadmium and chromium were not detected above their respective CRLs. Mercury was detected once above its CRL of 0.05 μg/g at 0.0629 μg/g in the sample collected from the zero to one foot depth interval.

Subsurface Soil. Lead concentrations ranged from 0.505 to 7.57 μg/g. The remaining select metals were not detected. In contrast, the PBSJ study found cadmium, chromium, and lead contamination to a depth of at least fifteen feet.

EPA TAL Results

EPA TAL analytes other than lead were not detected above background concentrations in the surface or subsurface soil samples collected from this boring.

Explosive Analyte Results

Explosives contaminants were not detected in surface or subsurface soil samples collected from boring OBGC-3. In contrast, the PBSJ study found detectable concentrations of several explosive compounds including RDX, TNB and 2,4,6-TNT, which were found in samples taken from a pit in Area H.

EPA TCL Results

The compounds 2-propanol, acetone, and toluene were detected at very low concentrations in a subsurface soil sample (15-17 foot depth interval) from OBGC-3 (0.0229 μg/g, 0.0224 μg/g, and 0.00135 μg/g, respectively). The 2-propanol is probably an artifact of the decontamination procedure for the split spoon, and the latter compounds may be laboratory artifacts, or may be site-related.

BORING OBGA-4

Boring OBGA-4 was drilled along the western perimeter of Area B noted in the PBSJ study. Contamination by metals was limited, but significant explosives and other organic contamination was found.

Select Metals Results

Surface Soil. Lead concentrations ranged from 80.7 μg/g to 152 μg/g in the surface soil samples collected. These values exceed the aquifer material background range, and the site-specific and county-specific background values. Cadmium, chromium, and mercury were not detected above their respective CRLs in the surface soil samples.

Subsurface Soil. Lead concentrations ranged from 0.300 to 48.3 μg/g in subsurface soil samples collected from this boring. The highest lead concentration exceeds the upper limit of the site-specific background range (4.75 μg/g), the county-specific background value of 15 μg/g, and the PBSJ background value of 17.8 μg/g. Chromium was detected once at 49.3 μg/g at a depth interval of 15 to 17 feet. Neither cadmium nor mercury were detected above their respective CRLs. Higher levels of metals were noted in the PBSJ study at Area B. Lead concentrations ranged from 16.4 to 23.9 μg/g, chromium from 12.7 to 19.9 μg/g and cadmium from 0.62 to 227 μg/g in samples collected from depths of up to six feet.

EPA TAL Results

Surface Soil. Arsenic was detected above background (7.0 μg/g) at an average concentration of 9.78 μg/g at the zero to one foot interval.

Subsurface Soil. No EPA TAL analytes were detected above background in subsurface soil samples collected from this boring.

Explosive Analyte Results

Surface Soil. Explosives contamination of OBGA-4 was observed primarily at the zero to one foot interval, although some contamination was detected at the five to nine foot depth interval. Contaminants in three soil samples collected from the zero to one foot interval were HMX at 66.9, 25.8, and 31.0 μg/g and RDX at 61.2, 73.2, and 133 μg/g.

Subsurface Soil. RDX was also observed at 1.12 and 1.06 μg/g in two duplicate samples collected from the five to nine foot depth interval. Two different explosives compounds were detected in the PBSJ study. Tetryl was detected at 250 μg/g, and 2,6-DNT was detected at 238 and 335 μg/g in samples collected from depths of one to six feet.

EPA TCL Results

Surface Soil. In addition, soil boring OBGA-4 showed the most significant (in terms of number of compounds detected and their concentrations) contamination by organic compounds associated with explosives production or handling of all the borings drilled in the OBG. Hexamethylene tetramine, an ingredient used in the manufacture of RDX, was detected in the soil sample collected from the zero to one foot depth interval at an average concentration of 0.932 μg/g. Acetone was detected at a concentration of 0.0816 μg/g.

Subsurface Soil. Three organic compounds potentially associated with explosives production or handling were detected in the soil sample collected from the 5 to 9 foot depth interval in this boring. These were: 1,2-epoxycyclohexene (average concentration, 0.459 μg/g), 2-cyclohexen-1-ol (average concentration, 0.172 μg/g), 2-cyclohexen-1-one (average concentration, 0.172 μg/g). In addition, 2-propanol, acetone and trichlorofluoromethane were detected at concentrations of 0.0367 μg/g (average), 0.0385 μg/g, and 0.00885 μg/g (average) respectively.

The significant differences in contamination observed in the two investigations may be attributed in part to the fact that boring OBGA-4 was on the western perimeter of Area B of the PBSJ study, not directly within Area B. In addition, only one soil sample was collected from this 9.4-acre area in the PBSJ study.

BORING OBGB-4

Soil boring OBGB-4 was located just northwest of the northwest corner of Area D in the PBSJ study. Explosives contamination was detected.

Select Metals Results

Surface Soil. Lead was detected in the soil sample collected from the zero to one foot depth interval at 44.9 μg/g. This exceeds the site-specific background value, and below the county-specific background value. Chromium was detected above its CRL once at 26.8 μg/g in the soil sample collected from the zero to one foot depth interval. This exceeds the site-specific and PBSJ study background values, but is below the county-specific background value.

Subsurface Soil. Lead concentrations at greater depth ranged from 1.05 µg/g to 9.95 µg/g, below the site-specific and county-specific background values. Neither cadmium, chromium nor mercury were detected above their respective CRLs in the subsurface soil samples collected.

EPA TAL Results

No EPA TAL analytes other than lead were detected above background concentrations in the subsurface soil samples collected from this boring.

Explosive Analyte Results

Surface Soil. Explosives contaminants were detected in the soil sample collected from the zero to one foot depth interval. HMX was detected at 31.0 µg/g, RDX at 44.5 µg/g and 2,4,6-TNT at 1.21 µg/g.

Subsurface Soil. Explosive analytes were not detected in subsurface soil samples collected from this boring.

EPA TCL Results

Trichlorofluoromethane was detected in the subsurface soil (5-7 foot depth interval) at 0.00742 µg/g, but is a common refrigerant compound, and is probably a laboratory artifact.

BORING OBGA-1

Soil boring OBGA-1 was located in Area K of the PBSJ study. No significant metals or explosives contamination was detected. This corroborates the finding of the PBSJ study, where chromium and lead were detected, but were below levels of concern.

Select Metals Results

Surface Soil. The lead concentration in the surface soil sample was 16.1 µg/g, below the site-specific, but above the county-specific background value. Cadmium, chromium and mercury were not detected.

Subsurface Soil. Lead concentrations in the subsurface soil samples ranged from 0.548 µg/g to 8.48 µg/g. This range of values falls below the PBSJ study and county-specific background values. Cadmium, chromium, and mercury were not detected.

EPA TAL Results

Manganese was detected above background concentrations at 817 µg/g in the sample collected from the 5 to 7 foot depth interval of this boring.

Explosive Analyte Results

Explosive analytes were not detected in surface or subsurface soil samples collected from this boring.

EPA TCL Results

Subsurface Soil. The compound 2-cyclohexen-1-ol was detected at 0.119 µg/g in the sample collected from the 5 to 7 foot depth interval, with similar concentrations of 2-propanol and acetone at the same depth interval (0.712 and 0.135 µg/g, respectively). 2-propanol is an artifact of decontamination procedures, and the acetone may be a laboratory artifact, or may be site-related. Until approximately ten years ago, RDX came to the facility packed in 2-cyclohexen-1-ol. Therefore, it is a site-related contaminant.

Other soil borings were drilled in the OBG, but not within areas previously defined in the PBSJ study. Chemical analyses of soil samples collected from these borings (OBGA-2, OBGA-5, OBGA-6, OBGB-2, OBGB-3, OBGB-5, OBGC-2, OBGC-4, OBGC-5, OBGD-3, OBGD-4) generally do not indicate explosives or metals contamination. Explosives contaminants were not detected at any of these borings. However, organic compounds associated with explosives were detected at some of the borings.

Lead was detected at each boring, usually at levels above the upper limit of the site-specific background range, and infrequently above the county-specific background value and the PBSJ study background value. These concentrations did not exceed the EPA guideline of 500 µg/g, set for the protection of human health. Cadmium was not detected above its CRL of 3.05 µg/g in any of the soil samples collected from this area.

Chromium and mercury were sometimes detected at concentrations above the site-specific and county-specific background values, but always below EPA Proposed Concentrations Meeting Criteria for Action Levels. Most of the detections of mercury were associated with surface soil samples. There is no trend evident in the spatial or vertical distribution of chromium detections. A brief discussion of the results for these borings follows.

BORING OBGA-2

Select Metals Results

Surface Soil. The lead concentration in the surface soil sample was 11.8 µg/g, which is below site-specific and county-specific background values. Cadmium, chromium, and mercury were not detected.

Subsurface Soil. Lead concentrations ranged from 0.611-5.15 µg/g in the subsurface soil samples, which is below the site-specific and county-specific background values. Cadmium, chromium, and mercury were not detected.

EPA TAL Results

No EPA TAL analytes were detected above background the subsurface soil sample collected from this boring.

EPA TCL Results

Three compounds were detected in the subsurface soil sample collected from the 5 to 9 foot depth interval: 1,2-epoxycyclohexene (0.302 µg/g), 2-cyclohexen-1-ol (0.101 µg/g), 2-cyclohexen-1-one (0.101 µg/g). These three compounds are associated with the production or handling of RDX. Acetone and 2-propanol were also detected at similar levels (0.0995 and 0.0110 µg/g, respectively).

BORING OBGA-5

Select Metals Results

Surface Soil. The lead concentration in the surface sample was 16.2 µg/g; this is below site-specific and county-specific background values. Cadmium was not detected; but chromium was detected at 23.7 µg/g, just below the site-specific background value. Mercury was detected at 0.142 µg/g.

Subsurface Soil. Lead concentrations ranged from 2.53 µg/g to 3.69 µg/g, below the site-specific background value. The remaining select metals were not detected.

EPA TAL Results

No EPA TAL analytes other than lead were detected above background in the subsurface soil sample (5 to 7 foot depth interval) collected from this boring.

EPA TCL Results

Trichlorofluoromethane was detected at 0.00807 μg/g in the subsurface sample collected from 5 to 7 foot depth interval. However, the compound was present at less than 5 times the concentration in the associated method blank, and is thus considered an artifact, and not an actual constituent of the sample.

BORING OBGC-2

Select Metals Results

Surface Soil. Lead was detected at 11.3 μg/g in the surface soil sample, below site-specific and county-specific background values. Cadmium and chromium were not detected. Mercury was detected above its CRL (<0.1 μg/g) at 0.0681 μg/g.

Subsurface Soil. Lead was detected above its CRL in the subsurface soil at 6.42 μg/g, below site-specific and county-specific background values. The remaining select metals were not detected.

EPA TAL Results

No EPA TAL analytes were detected above background in subsurface soil sample (5 to 7 foot depth interval) collected from this boring.

EPA TCL Results

Trichlorofluoromethane was detected at 0.00954 μg/g in the subsurface soil sample collected from the 5 to 7 foot depth interval. However, the compound was present at less than 5 times the concentration in the associated method blank, and is thus considered an artifact, and not an actual constituent of the sample.

BORING OBGA-6

Select Metals Results

Surface Soil. The lead concentration in the surface soil was 9.1 μg/g, below the site-specific and county-specific background values. Cadmium and mercury were not detected. Chromium was detected at 26.2 μg/g, just above the site-specific background value, but below the county-specific value.

Subsurface Soil. Lead concentrations ranged from 3.15 to 16.2 μg/g, below the site-specific and county-specific background values. Cadmium was not detected. Chromium was detected at 45.0 μg/g in the sample from the 40 to 42 foot depth interval, exceeding the PBSJ study and county-specific background values. Mercury was detected in the 5 to 7 foot and 40 to 42 foot depth intervals at 0.0734 and 0.128 μg/g, respectively.

BORING OBGB-2

Select Metals Results

Surface Soil. The lead concentration in the surface soil was 10.5 μg/g, below the site-specific and county-specific background values. The remaining select metals were not detected.

Subsurface Soil. Lead concentrations in the subsurface soil ranged from 0.292 to 7.31 μg/g, below the site-specific and county-specific background values. The remaining select metals were not detected.

EPA TAL Results

No EPA TAL analytes were detected above background values in the subsurface soil sample (5 to 9 foot depth interval) collected from this boring.

EPA TCL Results

Soil boring OBGB-2 showed contamination by organic compounds associated with explosives production or handling in the soil sample collected from the 5 to 9 foot depth interval. The compound 1,2- Epoxycyclohexene was detected at 0.344 μg/g, 2-cyclohexen-1-ol at 0.229 μg/g, and 2-cyclohexen-1-one at 0.115 μg/g. However, the first compound was detected in this sample at a concentration less than 5 times what was found in the associated method blank and is not considered an actual constituent of the sample.

BORING OBGB-3

Select Metals Results

Surface Soil. The lead concentration in the surface soil sample was 12.7 μg/g, below the site-specific and county-specific background values. The remaining select metals were not detected.

Subsurface Soil. Lead concentrations ranged from 0.396 to 9.33 μg/g, below the site-specific and county-specific background values. Cadmium and mercury were not detected. Chromium was detected at 95.7 μg/g in the sample collected from the 22 to 24 foot depth interval, exceeding the county-specific background value.

EPA TAL Results

Manganese was detected above background (400 μg/g) at 1,130 μg/g in the subsurface soil sample collected from the 5 to 7 foot depth interval.

EPA TCL Results

Subsurface Soil. The compounds 1,2-epoxycyclohexene, 2-cyclohexen-1-ol and 2-cyclohexen-1-one were detected at 0.366 μg/g, 0.122 μg/g, and 0.122 μg/g, respectively, in the soil sample collected from the 5 to 9 foot depth interval. However, the first compound was detected at a concentration less than 5 times what was found in the associated method blank, and is thus considered an artifact, and not an actual constituent of the sample. Toluene was also detected at a concentration of 0.0610 μg/g.

BORING OBGB-5

Select Metals Results

Surface Soil. The lead concentration in the surface soil was 32.9 μg/g, exceeding the site-specific and county-specific background values. Cadmium and chromium were not detected. Mercury was detected at 2.48 μg/g. This is the highest mercury concentration detected in any soil sample in this investigation.

Subsurface Soil. Lead concentrations ranged from 0.729 to 15.9 μg/g, just below the site-specific background value. Chromium was detected at 107 μg/g in the sample collected from the 45 to 47 foot depth interval, exceeding the PBSJ study and county-specific background values. Mercury was detected at an average value of 0.116 μg/g in two samples collected from the 5 to 9 foot dept interval.

EPA TAL Results

No EPA TAL analytes other than chromium and mercury were detected above background in the subsurface soils collected from this boring.

EPA TCL Results

Three organic compounds associated with explosives production were detected in the sample collected from the 105 to 107 foot depth interval. 1,2-Epoxycyclohexene was detected at 0.887 μg/g, 2-cyclohexen-1-ol at 0.333 μg/g, and 2-cyclohexen-1-one at 0.222 μg/g. 2-Propanol was also detected in this sample at a concentration of 0.0222 μg/g.

BORING OBGC-4

Select Metals Results

Surface Soil. The lead concentration in the surface soil was 66.2 μg/g, exceeding the site-specific and county-specific background values. The remaining select metals were not detected in the surface soil sample.

Subsurface Soil. Lead concentrations ranged from 1.19 to 13.9 μg/g, below the site-specific and county-specific background values. Cadmium and chromium were not detected. Mercury was detected at 0.0644 μg/g in the sample collected from the 70 to 72 foot depth interval.

EPA TAL Results

No EPA TAL analytes were detected above background in the subsurface soil sample (70 to 72 foot depth interval) collected from this boring.

EPA TCL Results

The compound 2-propanol was detected at 0.231 μg/g in the subsurface soil sample (70 to 72 foot depth interval), but is considered an artifact of equipment decontamination procedures.

BORING OBGC-5

Select Metals Results

Surface Soil. The lead concentration in the surface sample was 20.2 μg/g, exceeding the site-specific and county-specific background values. Cadmium and chromium were not detected. Mercury was detected at 0.0639 μg/g.

Subsurface Soil. Lead concentrations ranged from 8.47 to 13.4 μg/g, below the site-specific and county-specific background values. Chromium was detected at 34.4 μg/g in the sample collected from the 5 to 7 foot depth interval, at 62.3 μg/g in the sample collection from the 45 to 47 foot interval, and at 85.0 μg/g in the sample collected from the 70 to 72 foot depth interval. The two latter concentrations exceed the county-specific background value. Mercury was detected in the 70 to 72 foot depth interval at 0.314 μg/g.

EPA TCL Results

Surface Soil. Trichlorofluoromethane was detected at 0.0249 μg/g.

5.4.1.5 Former ADA. Soil boring OBGB-6 was drilled in the former ADA. The analytical results of soil samples collected from this boring (shown in Table 5-12) suggest possible chromium contamination, but do not indicate explosives contamination.

Select Metals Results

Surface Soil. The lead concentration in the surface sample was 15.5 μg/g, below the site-specific background value, and just above the county-specific background value. The remaining select metals were not detected. Mercury was detected at 0.0737 μg/g, below the background level.

Subsurface Soil. Lead concentrations ranged from 1.97 to 9.93 μg/g, below the site-specific and county-specific background values and the EPA guideline for protection of Human Health (500 μg/g). Chromium concentrations ranged from less than 12.7 μg/g to 27.3 μg/g. These concentrations are close to the site-specific background value (23.8 μg/g) and below the county-specific background value (50 μg/g) and the EPA Proposed Concentrations Meeting Criteria for Action Levels (400 μg/g). Neither cadmium nor mercury were detected above their respective CRLs in the subsurface soil samples collected from this boring.

EPA TAL Results

Manganese was detected at 497 μg/g, which is above the background level (400 μg/g), in the sample subsurface collected from the 5 to 7 foot depth interval from boring OBGB-6.

Explosive Analyte Results

Explosive analytes were not detected in the surface soil or subsurface soil samples collected from the 5 to 7 foot interval.

EPA TCL Results

EPA TCL analytes were not detected in the subsurface soil sample collected from the 5 to 7 foot interval.

Soil samples collected from this area in the PBSJ investigation had similar concentrations of lead and chromium, but cadmium and explosives were also detected. Cadmium concentrations ranged from 0.17 to 7.84 μg/g. Explosive contaminants detected included: RDX (289 to 1273 μg/g), 2,4-DNT (236 to 336 μg/g), 2,6-DNT (376 to 594 μg/g), and tetryl (229 to 367 μg/g).

5.4.1.6 Current ADA. Two soil borings were drilled in the new ADA: ADAB-1 and ADAB-2. Chemical analysis of the associated samples indicate possible chromium contamination, but do not indicate contamination by explosives or other metals. Analytical results for these borings are shown in Table 5-12.

Select Metals Results

Surface Soil. The lead concentrations in the surface samples from borings ADAB-1 and ADAB-2 were 8.29 μg/g and 10.7 μg/g, respectively, below the site-specific and county-specific background values. The remaining select metals were not detected.

EPA TAL Results

No EPA TAL analytes other than chromium and mercury were detected above background in the subsurface soil sample (15 to 17 foot depth interval) collected from this boring.

EPA TCL Results

The compounds 1,2-epoxycyclohexene and 2-cyclohexen-1-one were detected at 0.462 μg/g and 0.0924 μg/g, respectively, in the subsurface soil sample collected from the 15 to 17 foot depth interval. Trichlorofluoromethane was also detected in this sample at a concentration of 0.0197 μg/g.

BORING OBGD-3

Select Metals Results

Surface Soil. The lead concentration in the surface soil sample was 18.6 μg/g, exceeding the site-specific and county-specific background values. Cadmium and chromium were not detected. Mercury was detected at 0.110 μg/g.

Subsurface Soil. Lead concentrations ranged from 0.666 μg/g to 5.95 μg/g, below the site-specific and county-specific background values. The remaining select metals were not detected.

EPA TAL Results

No EPA TAL analytes were detected above background in the subsurface soil sample (5 to 7 foot depth interval) collected from this boring.

EPA TCL Results

Trichlorofluoromethane was detected at 0.041 μg/g in the subsurface soil sample collected from the 5 to 7 foot depth interval.

BORING OBGD-4

Select Metals Results

Surface Soil. The lead concentration in the surface soil sample was 20.1 μg/g, exceeding the site-specific and county-specific background values. Cadmium and mercury were not detected. Chromium was detected at 48.5 μg/g , exceeding the site-specific background value, but below the county-specific background value.

Subsurface Soils. Lead concentrations ranged from 1.05 to 3.53 μg/g, within the site-specific background range. Cadmium and mercury were not detected. Chromium was detected at 7.03 μg/g in the sample collected from the 15 to 17 foot depth interval, below the site-specific and county-specific background values.

EPA TAL Results

Surface Soil. Arsenic was detected below background at 6.37 μg/g, as was silver (0.049 μg/g) and zinc (94.8 μg/g).

TABLE 5-12

Select Metals and Explosives Results ($\mu g/g$) of Soil From Borings in the Former ADA, Current ADA, and Sunny Slope Area

Boring/ Analyte	Lead	Cadmium	Chromium	Mercury	Explosives
	10.0	3.05	12.7	0.0500	*
OBGB-6	1.97-15.5	ND	ND-27.3	ND-0.0737	ND
ADAB-1	1.36-9.1	ND	ND-71.6	ND	ND
ADAB-2	0.581-12.0	ND	ND	ND	ND
CBG-1	6.77-15.4	ND	ND	ND	ND
CBG-2	14.5-30.2	ND	ND	ND	ND
CBG-3	5.97-80.2	ND	ND	ND	ND
CBG-4	7.52-58.0	ND	ND	ND	ND
CBG-5	5.65-13.3	ND	ND-26.6	ND	ND

ND Not detected above the Certified Reporting Limit.

* Refer to Appendix L for the CRLs.

Subsurface Soil. Lead concentrations ranged from 1.36 to 9.10 μg/g in boring ADAB-1 and from 0.581 to 12.0 μg/g in boring ADAB-2. These concentrations are below the site-specific and county-specific background values, as well as the EPA guidelines for the protection of human health. Chromium was detected at boring ADAB-1 at concentrations ranging from below the CRL of 12.7 μg/g to 71.6 μg/g. Although concentrations exceeded site-specific and sometimes county-specific background values, they were below EPA Proposed Concentrations Meeting Criteria for Action Levels (400 μg/g). Chromium was not detected above the CRL in soil boring ADAB-2. Neither cadmium nor mercury was detected above its respective CRL at either soil boring.

EPA TAL Results

Manganese was detected above background concentrations at 1,300 μg/g in the subsurface sample collected from the five to nine foot depth interval at boring ADAB-1.

Explosive Analyte Results

Explosive compounds were not detected above their respective CRLs in the surface or subsurface soil samples collected from either soil boring.

EPA TCL Results

Subsurface Soil. Low levels of three organic compounds associated with explosives production or handling were found in soils samples from both borings. The organic compounds were found in the sample collected from the 5 to 9 foot depth interval at boring ADAB-1: 1,2-Epoxycyclohexene, 2-cyclohexen-1-ol, and 2-cyclohexen-1-one. These compounds were detected at 0.363 μg/g, 0.121 μg/g, and 0.121 μg/g, respectively. These compounds were also detected in the soil sample collected from the 15 to 19 foot depth interval in the sample collected from boring ADAB-2 at 0.328, 0.109, and 0.109 μg/g, respectively. However, it should be noted that the first compound in this group was detected in both samples at a concentration less than 5 times that found in the associated method blank, and is thus considered an artifact. The compounds 2-propanol and chloroform were also detected at low levels (0.00726 μg/g and 0.0656 μg/g for the former, 0.00110 μg/g for the latter compound), but their presence is attributed to decontamination procedures and laboratory cross-contamination, respectively.

5.4.1.7 Former Burn Out Area - Sunny Slope. Five soil borings were drilled in this area. Each boring was drilled to a depth of 12 feet. The analytical results for soil samples collected from these borings (shown in Table 5-12) do not indicate significant contamination by explosives or metals associated with their production.

Select Metals Results

Surface Soil. Lead was detected in the 0 to 1 foot depth interval above the county-specific background value of 15 μg/g four times at 15.4, 30.2, 58.0, and 80.2 μg/g.

Subsurface Soil. All other lead concentrations (5.65 μg/g to 14.7 μg/g) were below the site-specific and county-specific background values, as well as the EPA Guidelines for Protection of Human Health. Chromium was detected only once above its CRL of 12.7 μg/g at 26.6 μg/g, at boring CBG-5 in the ten to twelve foot depth interval. This concentration is below the county-specific background value (40 μg/g), and the EPA Proposed Concentration Meeting Criteria for Action Levels (400 μg/g), although it is slightly above the site-specific background value (23.8 μg/g). Neither cadmium nor mercury were detected above their respective CRLs in any soil samples collected from these borings.

EPA TAL Results

Surface Soil. Calcium and manganese were detected above background concentrations in the soil sample collected from the zero to two foot depth interval in soil boring CBG-1. These elements were detected at 14,900 μg/g and 1,230 μg/g, respectively.

Subsurface Soil. Arsenic and manganese were detected above background concentrations at 9.91 μg/g and 805 μg/g, respectively, in the soil sample collected from the ten to twelve foot depth interval at boring CBG-2. Manganese was detected at an average concentration of 544 μg/g in the soil sample collected from the same depth interval at boring CBG-3. This element was also detected at 461 μg/g in the sample collected from the 5 to 7 foot depth interval at CBG-4, and at 751 μg/g in the sample from the ten to twelve foot depth interval at CBG-5. Arsenic was also detected just above background (7 μg/g) in the 5 to 7 foot depth interval at 7.98 μg/g in boring CBG-4.

Explosive Analyte Results

No explosive analytes were detected above their respective CRLs in any surface or subsurface soil samples collected from these borings.

EPA TCL Results

Organic compounds associated with explosives production or handling were detected in soils samples collected from all five soil borings installed in the Former Burn Out area.

Surface Soil. The following compounds were detected in the soil sample collected from the zero to two foot depth interval at CBG-1: 1,2-epoxycyclohexene (0.335 μg/g), 2-cyclohexen-1-ol (0.223 μg/g), 2-cyclohexen-1-one (0.112 μg/g), palmitic acid (0.223 μg/g), and acetone (0.0253 μg/g). The first and third compounds were detected at concentrations less than 5 times that found in the associated method blanks, and are thus considered to be artifacts. Acetone is also considered an artifact for the same reason.

Subsurface Soil. Boring CBG-2 contained concentrations above the CRL of similar compounds as follows; 1,2-epoxycyclohexene (0.378 μg/g), 2-cyclohexen-1-ol (0.252 μg/g), 2-cyclohexen-1-one (0.126 μg/g), 2-propanol (0.378 μg/g), acetone (0.0520 μg/g), and trichlorofluoromethane (0.0194 μg/g).

Borings CBG-3, CBG-4, and CBG-5 also contained concentrations of 2-propanol (0.536, 0.0690, and 0.02333 μg/g, respectively), acetone (0.0897, 0.0593, and 0.0300 μg/g, respectively), and trichlorofluoromethane (0.0133, 0.0167, and 0.0169 μg/g, respectively.)

5.4.1.8 Former Borrow Pit. Three soil borings (CDP-1, CDP-2, CDP-3) were drilled at this area. The analytical results of soil samples collected from these borings do not suggest contamination by the metal compounds, but do suggest contamination by explosives. A summary of these results is given in Table 5-13.

Select Metals Results

Surface Soil. The lead concentrations in the surface samples from these borings ranged from 13.2 to 17.2 μg/g, with one exceedance of the county specific background value. The remaining select metals were not detected.

Subsurface Soil. Lead concentrations ranged from 0.401 μg/g to 25.4 μg/g, with the highest concentration observed exceeding the site- specific and county-specific background values, but below EPA guidelines for protection of human health. Neither cadmium nor chromium were detected above their

TABLE 5-13
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings in the Former Borrow Pit

Boring/ Analyte	Pb	Cd	Cr	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0	3.05	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
CDP-1	0.401-14.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CDP-2	1.80-25.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CDP-3	2.43-13.2	ND	ND	ND-0.0763	ND	ND	ND	ND	ND-3.43	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit respective CRLs in any subsurface soil sample collected from these borings. Mercury was detected once above its CRL of 0.050 µg/g, at 0.0763 µg/g in the sample collected from the 25 to 27 foot depth interval at boring CDP-3. This concentration is below the EPA Proposed Concentrations Meeting Criteria for Action Levels for this element (20 µg/g).

EPA TAL Results

No EPA TAL analytes were detected above background in the subsurface soil samples collected from the borings in this area.

Explosive Analyte Results

Surface Soil. One explosive analyte, 2,4-DNT, was detected at boring CDP-3. It was detected in a sample collected from the zero to one foot depth interval at 1.43 µg/g

Subsurface Soil. 2,4-DNT compound was also detected in boring CDP-3 at the 10 to 12 foot depth interval at 3.43 µg/g. The detection of explosives contamination was not expected at this area, since it was primarily used to excavate sand for construction activities. However, the dumping of discarded building materials is also known to have occurred here, and this may explain the observed explosives contamination.

EPA TCL Results

Subsurface Soil. Several organic compounds were detected at low levels (less than 1 µg/g) in subsurface soils at the three soil borings installed in the Former Borrow Pit. In the soil sample collected from the 15 to 19 foot depth interval at boring CDP-1, 1,2-epoxycyclohexene was detected at 0.321 µg/g, along with 2-propanol (0.0269 µg/g) and acetone (0.143 µg/g). Low concentrations of phenanthrene (0.305 µg/g) and xylene (0.0562 µg/g) were detected in the soil sample collected from boring CDP-2 from the 22 to 24 foot depth interval, as were 2-propanol (0.709 µg/g) and trichlorofluoromethane (0.0182 µg/g) (which may be artifacts, not actual constituents of the sample). Toluene was detected at 0.217 µg/g in the soil sample collected from the 15 to 17 foot depth interval at boring CDP-3, and may be associated with the assembly of explosive rounds (used as a solvent). Low concentrations of 2-propanol (0.019 and 0.0493 µg/g), trichlorofluoromethane (0.0121 µg/g), and acetone (0.0504 and 0.0542 µg/g) were also detected.

5.4.1.9 Closed Landfill. Five soil borings were installed in the Closed Landfill, four with depths of ten feet, and one with a depth of 15 feet. Chemical analyses of soil samples collected from soil borings CLF-2, CLF-3, and CLF-4 indicate metal and/or explosives contamination. These results are shown in Table 5-14.

Select Metals Results

Surface Soil. Lead concentrations in the surface samples ranged from 7.19 to 12.0 µg/g, below the site-specific and county-specific background values. Mercury was detected above background (0.1 µg/g) at 0.481 µg/g in boring CLF-1. The remaining select metals were not detected.

Subsurface Soil. Lead concentrations ranged from 6.26 to 30.6 µg/g at these borings, generally exceeding the site-specific background range and five instances where the county-specific value of 15 µg/g was exceeded. All concentrations were below the EPA guideline for the protection of human health. Chromium was detected in boring CLF-2 at 36.2 and 144 µg/g at depth intervals of 5 to 7 and 10 to 12 feet. Both of these concentrations exceeded the site-specific value once and the county-specific value once. The EPA Proposed Concentration Meeting Criteria for Action was not exceeded. Cadmium was detected at boring CLF-2 at 14.8 µg/g at the ten to 12 foot depth interval and at boring CLF-3 at 11.0 µg/g at the 5 to 7 foot depth interval. These concentrations exceed the site-specific background value; no

TABLE 5-14
Select Metals and Explosives Anayltical Results ($\mu g/g$) of Soil Samples From Borings in the Closed Landfill

Analyte/ Boring	Pb	Cd	Cr	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0	3.05	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.456	0.488	0.496	2.41
CLF-1	11.1-16.8	ND	ND	ND-0.481	ND	ND	ND	ND	ND	ND	ND	ND	ND
CLF-2	8.95-25.5	ND-14.8	ND-144	ND	ND-455	ND-4,450	ND-2,870	ND	ND-7.88	ND	ND-1.11	ND-0.736	ND
CLF-3	6.26-30.6	ND-11.0	ND	ND	ND	ND-1.60	ND-0.506	ND	ND	ND	ND	ND-1.41	ND
CLF-4	11.2-22.2	ND	ND	ND	ND	ND	ND	ND-0.845	ND	ND-0.678	ND	ND	ND
CLF-5	6.79-12.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.

county-specific value is given. They are below EPA Proposed Concentrations Meeting Criteria for Action Levels.

EPA TAL Results

Surface Soil. Arsenic and manganese were detected above background (7.0 μg/g and 400 μg/g) at 7.77 μg/g and 706 μg/g, respectively).

Subsurface Soil. No EPA TAL analytes were detected above background in the subsurface soil samples collected.

Explosive Analyte Results

Surface Soil. Explosive analytes were not detected in surface soil samples collected from these borings.

Subsurface Soil. Soil borings CLF-2, CLF-3, and CLF-4 showed contamination due to explosives compounds. Table 5-15 shows explosives detected, and the associated sample depth intervals at each boring. HMX, RDX, and 2,4,6-TNT concentrations are actually higher in the 10 to 12 foot depth interval than the 5 to 7 foot interval at boring CLF-2. This suggests contaminants are present at depth within the Closed Landfill. These findings corroborate the results of a contamination survey conducted at this area by USATHAMA in 1982, where TNT, 2,6-DNT and RDX were detected in soils. In addition, several organic compounds (discussed.below) were detected in soil samples collected from the Closed Landfill that were not observed elsewhere at the site. This may reflect the nature of the wastes disposed of in this area. The concentrations of these contaminants were usually higher than the concentrations of organic compounds observed in other areas, also.

EPA TCL Results

Surface Soil. No EPA TCL analytes were detected in the surface soil sample collected from boring CLF-5 at the Closed Landfill.

Subsurface Soil. Eleven organic compounds were detected in the soil sample collected from the 10 to 12 foot depth interval at the boring CLF-1. Decane, dodecane, and benzene were detected at 51.0, 3.82 μg/g, and 0.0127 μg/g, respectively. These compounds are components of gasoline. Tetradecanoic acid and palmitic acid were detected at 11.5 μg/g and 51.0 μg/g, respectively. Both of these compounds are components of natural fats and oils. Naphthalene and tetracosane were detected at 0.594 μg/g and 25.5 μg/g, respectively. These compounds are associated with synthesis of organic chemicals. Bis(2-ethylhexyl)phthalate was detected at 26.2 μg/g, but may be a laboratory artifact. 2-propanol, acetone, and trichlorofluoromethane were also detected at 0.255 μg/g, 0.382 μg/g, and 0.0510 μg/g, respectively.

Four organic compounds were detected in the soil sample collected from the 5 to 7 foot depth interval at soil boring CLF-2. Palmitic acid was detected at 1.27 μg/g, and hexamethylene tetramine was detected at 1.27 μg/g. The former is a component of natural fats and oils, while the latter is an ingredient of the high explosive RDX, although it has other uses. Trichlorofluoromethane and 2-propanol were also detected, but are believed to be artifacts of sample storage and decontamination procedures, respectively.

Thirty volatile and semivolatile organic compounds were detected in the soil sample collected from the 10 to 12 foot depth interval at boring CLF-3. Among those associated with explosives production were: 1,2-epoxycyclohexene (0.355 μg/g), and 9H-carbazole (0.592 μg/g). Several polycyclic aromatic hydrocarbons (PAHs) were also detected at concentrations less than 10 μg/g. Among these were: benzo [A] anthracene, benzo[A]pyrene, benzo[B] fluoranthene, chrysene, pyrene, 1-methylpyrene, 1-phenylnaphthalene, 2-methylnapthalene, acenapthene, acenaphthalene, anthracene, benzo(G,H,I)perylene, benzo[K]fluoranthene, dibenzo[A,H]anthracene, fluoranthene, fluorene, indeno[1,2,3-C,D]pyrene,

TABLE 5-15
Explosive Concentrations of Soil Samples ($\mu g/g$) by Depth Intervals in Soil Borings at the Closed Landfill (CLF)

Analyte	CRL	CLF-2		CLF-3	CLF-4
		Depth of 5-7 feet	Depth of 10-12 feet	Depth of 5-7 feet	Depth of 5-9 feet
HMX	0.666	5.22	455	ND	ND
RDX	0.587	82.0	4,450	1.60	ND
2,4,6-TNT	0.456	35.1	2,870	0.506	ND
1,3-DNB	0.496	ND	0.736	1.41	ND
2,4-DNT	0.424	ND	7.88	ND	ND
1,3,5-TNB	0.488	ND	1.11	ND	ND
Tetryl	0.731	ND	ND	ND	0.845
2,6-DNT	0.524	ND	ND	ND	0.678

CRL	Certified Reporting Limit
ND	Not detected above the CRL.

naphthalene, and phenanthrene. These are compounds which are ubiquitous in the environment and their presence can be attributed to both man-made and natural sources. Dibenzofuran, associated with the burning of hydrocarbons, was detected at 0.710 µg/g. Several compounds associated with organic compound synthesis were also detected. These included: hexacosane (1.07 µg/g), tetracosane (1.07 µg/g), heptanoic acid (0.592 µg/g), and palmitic acid (0.474 µg/g). Three constituents associated with petroleum products were also detected at low levels. These compounds include ethylbenzene (0.00462 µg/g), toluene (0.00237 µg/g) and xylene (0.00604 µg/g). The solvents 2-propanol, acetone, and methyl isobutyl ketone were detected at 0.542, 4.46, and 0.0450 µg/g, respectively.

Several organic compounds were detected in the soil sample collected from the 12 to 14 foot depth interval at boring CLF-4, but are not chemicals associated with explosives production. Among these were: butylbenzylphthalate (0.829 µg/g), myristic acid (1.25 µg/g), pentadecanoic acid (0.499 µg/g), palmitic acid (12.5 µg/g), hexacosane (0.374 µg/g), and stearic acid (1.25 µg/g). The compound 2-propanol was also detected (0.0249 µg/g), but its presence is attributed to split spoon decontamination procedures.

5.4.1.10 Present Landfill. Two soil borings were installed in the present landfill, each completed at a depth of 12 feet. The chemical results from the soil samples (shown in Table 5-16) do not indicate metal or explosives contamination at the soil boring locations.

Select Metals Results

Surface Soil. Lead concentrations in the surface soil samples from these two borings were 14.36 (average concentration) and 17.0 µg/g. The latter value is an exceedance of the county-specific background value, but is below the site-specific background value. The remaining select metals were not detected.

Subsurface Soil. Lead concentrations ranged from 6.94 µg/g to 14.9 µg/g, infrequently exceeding the site-specific and county-specific background values. These concentrations are below those set in EPA guidelines for protection of human health. Cadmium, chromium, and mercury were not detected above their respective CRLs in any of subsurface soil samples collected from these borings.

EPA TAL Results

No EPA TAL analytes other than lead were detected above background in the subsurface soil samples collected and analyzed for these parameters.

Explosive Analyte Results

No explosive analytes were detected above their respective CRLs in the surface or subsurface soil samples collected from these borings. These results tend to indicate that contamination due to explosives or metals is not an issue here. Contamination was not expected here. Because there is no record of hazardous waste disposal.

EPA TCL Results

Subsurface Soil. The compound 2-propanol was detected once at 0.00949 µg/g in the sample collected from the 5 to 7 foot depth interval, but may be an artifact of decontamination procedures.

5.4.1.11 Salvage Yard. Two soil borings were installed in the salvage yard, each completed to a depth of ten feet, with three soil samples collected from each boring. The chemical results (shown in Table 5-17) do not indicate contamination by explosives, the metal elements associated with their production (Cd, Cr, Hg, Pb) or other inorganic elements.

TABLE 5-16
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings in the Present Landfill

Boring/ Analyte	Lead	Cadmium	Chromium	Mercury	Explosives
	Certified Reporting Limit				
	10.0	3.05	12.7	0.050	*
LF-1	6.94-17.0	ND	ND	ND	ND
LF-2	8.58-19.4	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.
* Refer to Appendix L for the CRLs.

TABLE 5-17
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings in the Salvage Yard

Boring/Analyte	Lead	Cadmium	Chromium	Mercury	Explosives
	Certified Reporting Limit				
	10.0	3.05	12.7	0.050	*
SYD-1	14.0-20.6	ND	ND	ND	ND
SYD-2	7.94	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.
* Refer to Appendix L for CRLs.

Select Metals Results

Subsurface Soil. Lead concentrations ranged from 7.94 μg/g to 20.6 μg/g, slightly exceeding the site-specific and county-specific background values on one occasion. These concentrations are below EPA guidelines for protection of human health. Cadmium, chromium, and mercury were not detected above their respective CRLs;

EPA TAL Results

Subsurface Soil. Manganese was detected above background at an average concentration of 984 μg/g in the sample collected from the 5 to 7 foot depth interval from boring SYD-1. It was also detected above background at 761 μg/g in the same depth interval at boring SYD-2.

Explosive Analyte Results

No explosive analytes were detected in the surface or subsurface soil samples collected from these borings.

EPA TCL Results

Subsurface Soil. Acetone, trichlorofluoromethane, and 2-propanol were detected at concentrations less than 0.3 μg/g, but the former compounds may be probably laboratory artifacts and the latter compound may be an artifact of decontamination procedures. Toluene was also detected in the sample collected from boring SYD-1 at 0.240 μg/g.

5.4.1.12 Line A. Four sumps were investigated at A line, with one boring per sump. Select metals and explosive results for all soil borings associated with Line A sumps are shown in Table 5-18.

BORING SA-4

Boring SA-4 is associated with a sump which is different from the other three sumps located at this load line. It is older and is an aboveground concrete structure. The boring itself was located 60 feet west of and downslope from the sump and was completed to a depth of approximately 1 foot below the bottom of the sump.

Select Metals Results

Surface Soil. Lead was detected at 20.2 μg/g in the soil sample collected from the zero to one foot depth interval, just above site-specific and county-specific background values. Cadmium and chromium were not detected. Mercury was detected at 0.0652 μg/g.

Subsurface Soil. Lead concentrations ranged from 7.72 μg/g to 8.54 μg/g in the subsurface soil samples collected from the one to three foot interval. These concentrations are below site-specific and county-specific background values. The remaining select metals were not detected.

EPA TAL Results

Manganese was detected at 470 μg/g in the sample collected from the one to two foot depth interval at this boring, above the background concentration of 400 μg/g.

Explosive Analyte Results

RDX was observed at 0 to 1, 1 to 2, and 2 to 3 foot depth intervals at an average value of 3.28 μg/g. HMX was observed at the 1 to 2 and 2 to 3 foot depth intervals at approximately 2 μg/g.

TABLE 5-18
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings Near Line A Sumps

Boring/ Analyte	Pb	Cd	Cr	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0	3.05	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
SA-4	7.72-20.2	ND	ND	ND-0.0652	ND-2.01	3.10-3.50	ND	ND	ND	ND	ND	ND	ND
SA-7	10.1-15.5	ND	ND-26.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SA-40	8.28-10.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SA-44	4.39-8.83	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SA-A44	10.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

- ND Not detected above the Certified Reporting Limit.

EPA TCL Results

No EPA TCL analytes were detected in the soil samples collected from this boring.

BORING SA-7

Soil boring SA-7 was located 10 feet west southwest of the southwest corner of the sump. The boring was completed to a depth of ten feet, two feet below the depth of the bottom of the sump. Soil samples collected did not show significant contamination by explosive or metal analytes.

Select Metals Results

Surface Soil. Lead was detected at an average concentration of 15.7 μg/g in two surface soil samples. This is essentially equal to the county-specific background value, and is below the site-specific background value. The remaining select metals were not detected.

Subsurface Soil. Lead concentrations ranged from 10.1 to 15.8 μg/g, essentially equal to the county-specific background value and below the site-specific background value. Chromium was detected above the CRL of 12.7 μg/g at 26.7 μg/g at a depth of 10 to 12 feet. This concentration is just above the PBSJ study background value of 23.8 μg/g, but below the county-specific background value. Cadmium and mercury were not detected above their respective CRLs in the subsurface soil samples collected from these borings.

EPA TAL Results

Manganese was detected at an average concentration of 3,150 μg/g in two soil samples collected from the 5 to 7 foot depth interval in this boring, above the background concentration of 400 μg/g.

Explosive Analyte Results

Explosive analytes were not detected above their respective CRLs in surface or subsurface soil samples at this boring.

EPA TCL Results

Organic compounds associated with explosives production were detected at this sump boring where contamination by 1,2-Epoxycyclohexene (1.22 μg/g), and 2-cyclohexen-1-ol (average concentration, 0.305 μg/g) was detected in the soil samples collected from the 5 to 7 foot depth interval. However, these compounds were detected at concentrations less than 5 times what was found in the associated method blank, and are thus considered to be laboratory artifacts. Acetone and chloroform were also detected at 0.0678 and 0.00131 μg/g, respectively.

BORING SA-40

Soil boring SA-40 was collected to evaluate one of the new sumps. It was located 6 feet east of the sump and was completed to a depth of 6.5 feet, approximately one foot below the depth of the bottom of the sump. Chemical analysis of this sample did not indicate contamination by heavy metals or explosives.

Select Metals Results

Surface Soil. Lead was detected at 9.41 μg/g, below the site-specific and county-specific background values. The remaining select metals were not detected.

Subsurface Soil. Lead concentrations ranged from 8.28 µg/g to 10.3 µg/g, below the site-specific and county-specific background values. Cadmium, chromium, and mercury were not detected above their respective CRLs in the subsurface soil samples collected.

EPA TAL Results

Manganese was detected above background (400 µg/g) at a concentration of 927 µg/g.

Explosive Analyte Results

Explosive compounds were not detected above their respective CRLs in any of the soil samples collected from this boring.

EPA TCL Results

2-propanol (0.0498 µg/g), and acetone (0.128 µg/g were detected in soil samples collected from sump boring SA-40.

BORINGS SA-44 & SA-A44

Sump A-44 was investigated with both a vertical (sample SA-44)) and an angular (sample SA-A44) soil boring. The vertical soil boring was located on the effluent side of the tank and the angle boring was located 10.5 feet from the north end of the sump. The boring was completed to a depth of 14 feet, 6.5 feet below the depth of the bottom of the sump. A twenty degree angle on the boring provided access to soil at a depth of 14 feet below ground surface and below the bottom of the sump. There was no significant difference in the chemical results for the samples obtained from the two borings. None of the samples indicated contamination by explosives or the four select metals (Cd, Cr, Hg, and Pb). The results of the angle boring are compared to the vertical boring in Appendix T.

Select Metals Results

Surface Soil. Lead was detected at 8.83 µg/g, below the site-specific and county-specific background values. The remaining select metals were not detected.

Subsurface Soil. Lead was detected at concentrations ranging from 4.39 µg/g to 4.54 µg/g, below the site-specific and county-specific background values. The remaining select metals were not detected.

EPA TAL Results

Manganese was detected at 636 µg/g in the sample collected from the 10.5 to 14 foot depth interval in the angle boring for this sump.

Explosive Analyte Results

Explosive analytes were not detected above their respective CRLs in any of the surface or subsurface soil samples collected from this boring.

EPA TCL Results

Organic compounds that are probably laboratory artifacts only were detected in soil samples collected from sump boring SA-44: 2-propanol (0.0817 µg/g), acetone (0.0938 µg/g), and chloroform (0.00125 µg/g). Trichlorofluoromethane and 1,1,2-Trichloro-1,2,2-trifluoroethane were detected (0.00675 µg/g and 0.00752 µg/g) in the angle boring collected from beneath this sump.

5.4.1.13 Line B. Five sumps were investigated at B Line. Select metals and explosives results for soil borings associated with B Line sumps are shown in Table 5-19.

BORING SB-18

Soil boring SB-18 was drilled to investigate a sump closed in the late 1960s. The soil boring was located 15 feet northeast of Building B-18, and was completed to a depth of 10 feet, 1 foot below the depth of the bottom of the sump. Analysis of these samples revealed possible lead contamination and definite explosives contamination.

Select Metals Results

Lead was detected at 25.8 μg/g in the sample collected from the zero to two foot depth interval, exceeding the site-specific and county-specific background values for this element. However, it is below the EPA guideline for protection of human health. Lead was below the site-specific background value at the other sampling intervals for this boring. The remaining select metals were not detected above their respective detection limits in any soil sample.

EPA TAL Results

No EPA TAL analytes were detected above background in soil samples collected from this boring.

Explosive Analytes Results

Explosive concentrations at various depths for boring SB-18 are shown in Table 5-20. HMX, RDX, 2,4,6-TNT and tetryl were detected in surface and subsurface soil. Explosive concentrations were highest in the sample collected from the zero to two foot depth interval. HMX was detected at 4,520 μg/g, RDX at 6,190 μg/g, 2,4,6 TNT at 610 μg/g, and tetryl at 745 μg/g. Contaminant concentrations decrease significantly beyond depths of two feet, the highest concentration being 7.82 μg/g RDX in this soil sample collected from the 10 to 12 foot depth interval from this boring.

EPA TCL Results

The compound 1,2-epoxycyclohexene was detected at 0.333 μg/g in the soil sample collected from the 5 to 7 foot depth interval.

BORING SB-2

Soil boring SB-2 was located just north of sump B-2 and was drilled to a depth of ten feet, two feet below the bottom of the sump associated with it. Chemical analyses of the soil samples collected indicate possible soil contamination by lead and definite contamination by explosives.

Select Metals Results

The soil sample collected from the zero to two foot depth interval showed 24.6 μg/g lead. The lead concentration exceeds the site-specific and county-specific background values, but is below the EPA guideline for protection of human health. Cadmium and chromium were not detected. Mercury was detected at 0.314 μg/g. Lead concentrations in the subsurface soil ranged from 4.46 to 10.9 μg/g. This range is below the site-specific and county-specific background values. The remaining select metals were not detected.

EPA TAL Results

No EPA TAL analytes other than lead were detected above background in the soil samples collected.

TABLE 5-19
Select Metals and Explosives Analytical Results ($\mu g/g$) for Soil Samples From Borings Near Line B Sumps

Boring/ Analyte	Pb[1]	Cd	Cr	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0	3.05	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
SB-2	4.46-24.6	ND	ND	ND-0.314	ND-126	2.10-204	ND	ND	ND	ND	ND	ND	ND
SB-10	3.85-14.9	ND	ND	ND	ND-3.06	ND-1.62	ND	ND	ND	ND	ND	ND	ND
SB-A10	1.40	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SB-12	5.13-9.67	ND	ND	ND	0.900-13.5	2.94-32.1	ND	ND	ND	ND	ND	ND	ND
SB-18*	4.08-25.8	ND	ND	ND-0.0569	0.847-4,520	3.65-6,190	1.57-610	ND-745	ND	ND	ND	ND	ND
SB-273	4.59-7.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.

* The Certified Reporting Limits for parameters associated with the sample collected from the 0 to 2 foot depth interval differ from those stated above as follows: 2,4-DNT (8.48 $\mu g/g$); 2,6-DNT (10.5 $\mu g/g$); 1,3,5-TNB (9.76 $\mu g/g$); 1,3-DNB (9.92 $\mu g/g$): and NB (48.2 $\mu g/g$).

TABLE 5-20
Explosive Analytical Results ($\mu g/g$) of Soil Samples From Boring SB-18 (LAP Line B)

Depth Interval from Surface (feet)	HMX	RDX	246-TNT	Tetryl
	Certified Reporting Limit			
	0.666	0.587	0.456	0.731
0-2	4,520	6,190	610	745
5-7	1.06	3.65	1.57	ND
10-12	0.877*	7.82*	2.26*	ND

ND Not detected above the Certified Reporting Limit.
* Indicates average concentration of the two duplicate samples.

Explosive Analyte Results

HMX and RDX were detected in the sample collected from the zero to two foot depth intervals at 126 μg/g and 204 μg/g, respectively. HMX was detected at the 5 to 7 foot depth interval at 1.32 μg/g. RDX was detected at the five to seven foot and ten to twelve foot depth intervals at 6.22 μg/g and 2.10 μg/g, respectively.

EPA TCL Results

Possible laboratory artifacts were detected in soil samples collected from sump boring SB-2: 2-propanol (0.0912 μg/g) and acetone (0.0212 μg/g).

BORING SB-12

Soil boring SB-12 was installed via hand auger to investigate a new sump. The boring was located approximately 6 feet west of and downgradient of the sump. The boring was completed to a depth of 10 feet, 2 feet below the depth of the bottom of the sump. Chemical analyses of the three soil samples indicate contamination by explosives.

Select Metals Results

The lead concentration in the surface sample was 9.67 μg/g, below the site-specific and county-specific background values. Lead concentrations in the subsurface soil ranged from 5.13 μg/g to 5.16 μg/g. Cadmium, chromium, and mercury were not detected above their respective CRLs in any of the soil samples collected.

EPA TAL Results

No EPA TAL analytes were detected above background in the soil samples collected from this boring.

Explosive Analyte Results

HMX and RDX were detected in all three samples collected from this boring. HMX was detected at 13.5 μg/g, 1.37 μg/g, and 0.900 μg/g in samples collected from the 0 to 1 foot, 4 to 5 foot, and 9 to 10 foot depth intervals. RDX was detected at these same intervals at 32.1 μg/g, 6.37 μg/g, and 2.94 μg/g. This distribution indicates contamination is most severe at the surface, decreasing by two orders of magnitude within a 10 foot profile.

EPA TCL Results

No EPA TCL analytes were detected in the soil samples collected from this boring.

BORING SB-273

Soil boring SB-273 was located 5 feet northeast of the building containing the sump and was installed by hand augering to a depth of ten feet, two feet below the depth of the bottom of the sump. Chemical analyses of three soil samples collected from this boring did not indicate contamination by metals or explosives.

Select Metals Results

Lead concentrations ranged from 4.59 μg/g to 7.02 μg/g, below the site-specific and county-specific background values. The remaining select metals were not detected.

EPA TAL Results

EPA TAL analytes were not detected above background in the soil samples collected from this boring.

Explosive Analyte Results

Explosive analytes were not detected in the soil samples collected from this boring.

EPA TCL Results

Toluene (0.451 μg/g) and acetone (0.268 μg/g) were detected in soil samples collected from boring SB-273.

BORING SB-10

Both vertical (SB-10) and (sample SB-A10) soil borings were used to investigate sump B10. Chemical analysis of the soil samples show possible lead contamination and slight explosives contamination. There is no significant difference in the level of contamination detected in the vertical boring, as compared to the angular boring. The results of both borings are compared in Appendix T.

Select Metals Results

Lead concentrations in samples from the vertical boring ranged from 3.85 μg/g to 14.9 μg/g, below the site-specific background value and essentially equal to the county-specific background value. Lead, in the sample collected from the angular boring, was detected at 1.40 μg/g, within the site-specific background range. The remaining select metals were not detected in either boring.

EPA TAL Results

EPA TAL analytes were not detected above background in soil samples from the two borings installed at this sump.

Explosive Analyte Results

In the vertical soil boring, HMX was detected at 3.06 μg/g in the zero to two foot depth interval and RDX was detected at 1.62 μg/g at the five to seven foot depth interval. No explosives were detected in the samples from the angular soil boring.

EPA TCL Results

Acetone was detected at 0.0371 μg/g in the vertical boring and 2-propanol was detected in the angular boring at 0.0233 μg/g. These contaminants may be laboratory and decontamination artifacts.

5.4.1.14 Line C. Six sumps were investigated at Line C. Select metals and explosives detected at soil borings associated with these six sumps are shown in Table 5-21.

BORINGS SC-42E & SC-A42E

Both vertical (sample SC-42E) and angular (SC-A42E) soil borings were used to investigate sump C-42E. The vertical boring was located at the end of the concrete drainage spillway, just east of the sump and completed to a depth of 4 feet below the bottom of the sump. The angular soil boring was completed to a depth of 4.5 feet directly below the bottom of the sump. Chemical analyses of soil samples collected

TABLE 5-21
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings Near Line C Sumps

Boring/ Analyte	Pb	Cd	Cr	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0	3.05	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
SC-1	7.46-10.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SC-5	6.10-13.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SC-6	6.82-14.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SC-12	6.35-13.7	ND	ND-40.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SC-42	9.60-11.7	ND	ND-25.5	ND-0.045	ND-1.02	ND-0.908	ND	ND	ND	ND	ND	ND	ND
SC-42E	8.19-10.9	ND	ND	ND	ND	ND-0.669	ND-0.930	ND	ND	ND	ND	ND	ND
SC-A42E	7.50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.

from these borings do not indicate contamination by explosives or metals. These results are compared in Appendix T.

Select Metals Results

There was no significant difference in the results for the two types of borings. Lead concentrations ranged from 7.50 to 10.9 µg/g, below site-specific and county-specific background values for this element. The remaining select metals were not detected above their respective CRLs in any of the soil samples collected from these borings.

EPA TAL Results

Arsenic was detected above background (7.0 µg/g) at an average concentration of 8.24 µg/g in the angular boring. In the vertical boring, manganese was found above background (400 µg/g) at 729 µg/g.

Explosive Analyte Results

2,4,6-TNT and RDX were detected in the vertical boring at depths of 5 to 7 feet and 10 to 12 feet below ground surface at concentrations less than 1 µg/g.

EPA TCL Results

Soil samples collected from boring SC-42E at the 5 to 7 foot depth interval showed contamination by 1,2-epoxycyclohexene at an average concentration (a duplicate sample was also collected) of 0.247 µg/g. 2-propanol was detected in boring SC-42E and SC-A42 at concentrations of 0.0123 and 0.0480 µg/g, respectively.

BORING SC-42

Soil boring SC-42 was installed adjacent to the northeast corner of the new sump C-42, and drilled to a depth of ten feet, 1.5 feet below the depth of the bottom of the sump. Chemical analyses of the soil samples collected from this boring shows minor contamination by explosives and chromium.

Select Metals Results

Lead concentrations ranged from 9.60 to 11.7 µg/g, below the site-specific and county-specific background values. Chromium was detected twice above its CRL: at 23.6 µg/g in the surface sample, and at 25.5 µg/g in the sample collected from the 5 to 7 foot depth interval. The latter value exceeds the PBSJ study background value, but is below the county-specific value. Mercury was detected at 0.0645 µg/g in the sample collected from the ten to twelve foot depth interval.

EPA TAL Results

Manganese was detected above background at 619 µg/g in the sample collected from the 0 to 2 foot depth interval. Arsenic was also detected slightly above background at 7.27 µg/g, in the 0 to 2 foot depth interval.

Explosive Analyte Results

HMX was detected at 1.02 µg/g in the sample collected from the zero to two foot depth interval and RDX was detected at 0.802 µg/g and 0.908 µg/g at zero to two foot and five to seven foot depths, respectively.

EPA TCL Results

The compound 2-propanol was detected at 0.00564 μg/g, but is considered to be an artifact of decontamination procedures.

BORING SC-12

A soil boring was installed 4 feet from the northeast corner of the sump and completed to a depth of 10 feet, two feet below the depth of the bottom of sump C-12, of unknown age. Chemical analyses of the soil samples collected from this boring do not indicate contamination by explosives or associated metals.

Select Metals Results

Lead concentrations ranged from 6.35 to 13.7 μg/g, below site-specific and county-specific background values. Chromium was detected at 40.5 μg/g in the sample collected from the surface, exceeding the site-specific background value, but below the county-specific background value. Cadmium and mercury were not detected above their CRLs in the subsurface soil samples collected from this boring.

EPA TAL Results

Manganese and arsenic were detected above background at 452 μg/g and 11.7 μg/g, respectively, in the sample collected from the 5 to 7 foot depth interval.

Explosive Analyte Results

Explosive analytes were not detected in the soil samples collected from this boring.

EPA TCL Results

Sump boring SC-12 showed contamination by 1,2-epoxycyclohexene (0.372 μg/g), 2-cyclohexen-1-ol (0.124 μg/g), and 2-cyclohexen-1-one (0.124 μg/g) in the sample collected from the 5 to 7 foot depth interval. However, the first compound was detected at a concentration less than 5 times that found in the associated method blank, and thus is considered an artifact.

BORING SC-5

A soil boring was drilled and completed 4 feet from the northeast corner of the sump to a depth of ten feet for sump C-5, approximately one foot below the depth of the bottom of the sump. The soil boring was installed in a drainage ditch approximately 12 feet south of the sump. Buried electrical lines in the vicinity of the sump precluded drilling any closer to the sump. Chemical analyses of the soil samples collected from this boring did not indicate contamination by explosives or associated metals.

Select Metals Results

Lead concentrations ranged from 6.10 μg/g to 13.4 μg/g, with the highest value associated with the surface sample. The range of values are below the site-specific and county-specific background values. Cadmium, chromium and mercury were not detected above their CRLs in any of the soil samples collected from this soil boring,

EPA TAL Results

Manganese was detected above background at 657 μg/g in the soil sample collected from the 5 to 7 foot depth interval.

Explosive Analyte Results

Explosives analytes were not detected in soil samples collected from this boring.

EPA TCL Results

The compound 2- propanol was detected at 0.0719 µg/g, but is an artifact of decontamination procedures.

BORING SC-1

A soil boring was drilled 52 feet northeast and downslope of the sump and completed to a depth of 10 feet, approximately two feet below the bottom of sump C-1, a new sump. Chemical analyses of the samples collected from this soil boring do not indicate contamination by explosives or associated metal compounds.

Select Metals Results

Lead concentrations ranged from 7.46 µg/g to 10.4 µg/g, with the highest value associated with the surface sample. This range of values falls below the site-specific and county-specific background values. Cadmium, chromium and mercury were not detected above their CRLs in any of the soil samples collected from this boring.

EPA TAL Results

Manganese and arsenic were detected above background at 550 and 9.04 µg/g in the sample collected from the 5 to 7 foot depth interval.

Explosive Analyte Results

Explosive analytes were not detected in the soil samples collected from this boring.

EPA TCL Results

Possible laboratory artifacts only were detected in soil samples from this boring: acetone at 0.0513 µg/g and trichlorofluoromethane at 0.0120 µg/g.

BORING SC-6

A soil boring was drilled and completed to a depth of ten feet for sump C-6, approximately 2 feet below the depth of the bottom of the sump. Chemical analyses of the soil samples collected from this boring did not indicate contamination by explosive compounds or associated metals at this location.

Select Metals Results

Lead concentrations ranged from 6.82 to 14.7 µg/g, with the highest value associated with the surface sample. This range of values falls below the site-specific and county-specific background values. Cadmium, chromium and mercury were not detected above their respective CRLs in any of the soil samples.

EPA TAL Results

Manganese was detected above background at 908 µg/g in the sample collected from the 0 to 2 foot depth interval.

Explosive Analyte Results

Explosive analytes were not detected in the soil samples collected from this boring.

EPA TCL Results

Acetone was detected at 0.0246 $\mu g/g$, but is considered a laboratory artifact since it was detected at a concentration less than that found in the associated method blank.

5.4.1.15 Line D. Four sumps were investigated at Line D. Select metals and explosives detected in soil borings associated with these sumps are shown in Table 5-22.

BORING SD-10

One soil boring was drilled 5 feet west of the sump D-10 and completed to a depth of ten feet, which is two feet below the depth of the bottom of sump D-10, a new sump. Chemical analyses of the soil samples collected from this boring do not indicate contamination by explosive compounds or associated metals at this location.

Select Metals Results

Lead concentrations ranged from 8.14 $\mu g/g$ to 12.1 $\mu g/g$, with the highest value associated with the surface sample. This range of values falls below the site-specific and county-specific background values. Cadmium, chromium and mercury were not detected above their respective CRLs in any of the soil samples collected.

EPA TAL Results

No EPA TAL analytes were detected above background in the sample collected from the 5 to 7 foot depth interval.

Explosive Analyte Results

Explosive analytes were not detected in the soil samples collected from this boring.

EPA TCL Results

Acetone was detected at 0.0386 $\mu g/g$, but is probably considered to be a laboratory artifact.

BORING SD-41

One soil boring was hand augered to depth of 6.5 feet to investigate sump D-41, approximately one foot below the bottom of the sump. The boring was located 25 feet south of the outlet pipe for the sump. Chemical analyses of the soil samples collected from this boring do not indicate contamination by explosives or associated metal compounds.

TABLE 5-22
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings Near Line D Sumps

Boring/ Analyte	Lead	Cadmium	Chromium	Mercury	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0	3.05	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
SD-10	8.14-12.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SD-41	4.06-9.92	ND	ND	ND	ND	ND	0.496-830	ND	ND	ND	ND	ND	ND
SD-42	10.0-17.7	ND	ND	ND	ND-8.56	ND	ND-1.75	ND	ND	ND	ND	ND	ND
SD-42B	4.46-12.2	ND	ND	ND	ND-1.08	ND-5.77	ND-0.897	ND	ND	ND	ND-0.551	ND	ND

ND: Not detected above the Certified Reporting Limit.

Select Metals Results

Lead concentrations ranged from 4.06 to 9.92 μg/g with the highest value associated with the surface sample. Considering subsurface soil only, lead concentrations ranged from 4.06 to 5.55 μg/g. All values fell below the site-specific and county-specific background values. Cadmium, chromium and mercury were not detected above their respective CRLs in the soil samples

EPA TAL Results

Calcium was detected above background at 8,760 μg/g in the soil sample collected from the 0 to 2 foot depth interval.

Explosive Analyte Results

Explosive analytes were not detected in the soil samples collected from this boring.

EPA TCL Results

Three polycyclic aromatic hydrocarbons were detected in the 0 to 2 foot depth interval as follows: chrysene (0.197 μg/g), fluoranthene (0.159 μg/g), and pyrene (0.122 μg/g).

BORING SD-42

Soil boring SD-42 was hand augered to a depth of six feet to investigate a sump refurbished in 1981. The depth of the sump was measured to be 4.5 feet. The boring was located 5 feet north of the northwest corner of the sump. Chemical analyses of this sample showed possible lead contamination and definite trace explosive contamination at this location.

Select Metals Results

Lead concentrations ranged from 10.0 μg/g to 17.7 μg/g, just below the site-specific background value, and slightly exceeding the county-specific background value.

EPA TAL Results

Manganese was detected above background at an average concentration of 823 μg/g in the sample collected from the 0 to 2 foot depth interval.

Explosive Analyte Results

HMX and 2,4,6-TNT were detected at the zero to two foot depth interval at average concentrations (two duplicate samples were collected in this interval) of 5.52 μg/g and 0.65 μg/g, respectively. 2,4,6-TNT was also detected at the 3 to 4.5 foot depth interval and the 5 to 6 foot depth interval at 1.75 μg/g and 1.53 μg/g, respectively.

EPA TCL Results

Naphthalene and bis(2-ethylhexyl)phthalate were detected at low concentrations (< 1 μg/g) in the soil sample collected from the 0 to 2 foot depth interval. These may be artifacts or may be site-related contaminants.

BORING SD-42B

Soil boring SD-42B was hand augered to a depth of 6 feet to investigate a sump. The depth to the bottom of this sump was 4.5 feet. The boring was located 6 feet northwest of the sump. Chemical analyses of the soil samples indicate explosives contamination.

Select Metals Results

Lead concentrations ranged from 4.46 μg/g to 12.2 μg/g, below the site-specific and county-specific background values. Cadmium, chromium and mercury were not detected above their respective CRLs in the soil samples collected from this boring.

EPA TAL Results

No EPA TAL analytes were detected in the soil samples collected from this boring.

Explosive Analyte Results

HMX (1.08 μg/g) and RDX (5.77 μg/g) were detected in the sample collected from the zero to two foot depth interval. 1,3,5 TNB and 2,4,6 TNT were detected in the sample from the 3.5 to 4.5 foot depth interval at 0.551 μg/g and 0.897 μg/g, respectively; and in the 5 to 6 foot depth interval at 0.545 μg/g and 0.582 μg/g, respectively.

EPA TCL Results

Two refrigerant compounds, trichlorofluoromethane and 1,1,2-trichloro-1,2,2-trifluoroethane were detected at 0.0144 μg/g and 0.0112 μg/g, respectively.

5.4.1.16 Line E.

BORING SE-4

One soil boring was drilled and completed to a depth of ten feet to investigate a sump at Line E. The depth to the bottom of this sump was 8 feet. The soil boring was located in an area of stressed vegetation on the effluent side of the sump, approximately 40 feet west of the northwest corner of Building E-4. Chemical analyses of the soil samples from this boring (shown in Table 5-23) indicate explosives contamination but do not indicate metals contamination.

Select Metals Results

Lead concentrations ranged from 4.2 to 5.69 μg/g, below site-specific and county-specific background values. Cadmium, chromium and mercury were not detected above their respective CRLs in the soil samples.

EPA TAL Results

No EPA TAL analytes were detected above background concentrations in the soil samples collected from this boring.

Explosive Analyte Results

Tetryl was detected at 81 μg/g, and 2,4,6 TNT at 0.491 μg/g in the sample collected from the zero to two foot depth interval. Tetryl was also detected at 10.6 μg/g and 2,4-DNT at 0.590 μg/g in the sample

TABLE 5-23
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings Near Line E Sumps

Boring/ Analyte	Pb	Cd	Cr	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0	3.05	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
SE-4	4.20-5.69	ND	ND	ND	ND	ND	ND-0.491	ND-81.4	ND-0.590	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.

collected from the 5 to 7 foot depth interval. Past activities at this line include booster assembly and the blending and pelletizing of tetryl.

EPA TCL Results

1,2-epoxycyclohexene was detected in the sample collected from the 5 to 7 foot depth interval at 0.245 μg/g. Acetone and 2-propanol were detected at 0.0228 and 0.0245 μg/g, respectively. These contaminants may be laboratory or decontamination artifacts.

5.4.1.17 Line O. Two soil borings were drilled and completed to depths of 10 feet to investigate sumps at Line O.

BORING SO-3

Soil boring SO-3 was located approximately 60 feet north of Building O-3, in a fenced area north of the railroad tracks. The soil boring was completed to a depth of 9 feet, one foot below the depth of the bottom of the sump. Chemical analyses of the soil samples showed contamination by explosives and associated metals.

Select Metals Results

Lead concentrations ranged from 8.17 to 17.4 μg/g. The latter value represents an exceedance of the county-specific background value for this element, but is below the site-specific background value and EPA guidelines for protection of human health. Cadmium was detected at high concentrations: 64.4 μg/g in the sample collected from the zero to two foot depth interval, and 5.80 μg/g in the sample from the 5 to 7 foot depth interval. These exceed the site-specific background value. Neither chromium nor mercury was detected above their respective CRLs in the soil samples collected.

EPA TAL Results

Manganese was detected slightly above background at 409 μg/g in the sample collected from the 5 to 7 foot depth interval.

Explosive Analyte Results

HMX, RDX, 2,4-DNT, 2,4,6-TNT, and 1,3,5-TNB were detected in all three soil samples collected from this boring. Select metals and explosives detected in both soil borings are shown in Table 5-24. The contaminant concentrations were usually higher in the sample collected from the 5 to 7 foot depth interval than in the sample collected from the ten to twelve foot depth interval.

EPA TCL Results

One organic unknown compound was identified and quantified at 23.1 μg/g.

BORING SO-14

Boring SO-14 was located eight feet south of the sump system and 6 feet east of Building O-14. The boring was completed to a depth of ten feet, one foot below the depth of the bottom of the sump. Soil samples collected from boring SO-14 do not indicate contamination by explosives or associated metals.

TABLE 5-24
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings Near Line O Sumps

Boring/ Analyte	Pb	Cd	Cr	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0	0.305	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
SO-3	8.17-17.4	ND-64.4	ND	ND	1.25-3.88	1.81-10.9	28.8-45.2	ND	0.675-1.63	ND	1.58-63.0	ND	ND
SO-14	5.51-20.3	ND	ND	ND-0.0616	ND	ND	ND-0.763	ND	ND	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.

Select Metals Results

Lead concentrations ranged from 5.51 µg/g to 20.3 µg/g, exceeding site-specific and county-specific background values for this element in the sample collected from the zero to two foot depth interval. However, this concentration is still below EPA guidelines for protection of human health. Mercury was detected just above its CRL of 0.050 µg/g at 0.0616 µg/g in the sample collected from the zero to two foot depth interval. This concentration is below the EPA Proposed Concentration Meeting Criteria for Action Levels. Neither cadmium not chromium were detected above their respective CRLs in the soil samples collected.

EPA TAL Results

Manganese was detected above background at an average concentration of 569 µg/g in the sample collected from the 5 to 7 foot depth interval.

Explosive Analyte Results

2,4,6-TNT was detected in the 5 to 7 foot depth interval at an average concentration of 0.744 µg/g.

EPA TCL Results

The compound 1,2-epoxycyclohexene (associated with explosives production) was detected at 0.236 µg/g in the sample collected from the 5 to 7 foot depth interval at boring SO-14. 2-propanol was also detected at 0.0118 µg/g.

5.4.1.18 Line X. Five soil borings were hand augered to investigate five sumps at LAP Line X. Select metals and explosives detected in these soil borings are shown in Table 5-25.

BORING SX-8

Soil boring SX-8 was completed to a depth of 9 feet, two feet below the bottom of the sump formerly in this area. The soil boring was located 5 feet from the corner of the building that is adjacent to the former sump location. Soil samples collected from boring SX-8 do not indicate contamination by explosives or associated metals, though lead concentrations were slightly elevated.

Select Metals Results

Lead concentrations ranged from 10.3 to 23.9 µg/g, exceeding the site-specific and county-specific background values for this element in the sample collected from the zero to two foot depth interval. However, this concentration is below EPA Guidelines for Protection of Human Health. Cadmium, chromium, and mercury were not detected above their respective CRLs in the soil samples collected.

EPA TAL Results

Manganese was detected above background at 1,290 µg/g in the sample collected from the 5 to 7 foot depth interval.

Explosive Analyte Results

Explosive analytes were not detected in the soil samples collected from this boring.

TABLE 5-25
Select Metals and Explosives Analytical Results ($\mu g/g$) of Soil Samples From Borings Near Line X Sumps

Boring/ Analyte	Pb	Cd	Cr	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	10.0[1]	3.05	12.7	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
SX-8	10.3-23.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SX-26	12.1-19.1	ND	ND	ND	ND	ND	ND-2.41	ND	ND	ND	ND	ND	ND
SX-41	1.93-13.7	ND	ND	ND	1.12-20.0	4.20-39.0	1.02-3.45	ND	ND	ND	ND-0.928	ND	ND
SX-103	12.1-17.0	ND	ND	ND	ND-163	4.08-967	ND	ND	ND	ND	ND	ND	ND
SX-313	10.5-31.5	ND	ND	ND	ND-234	1.80-811	ND	ND	ND	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.

EPA TCL Results

The compound 2-cyclohexen-1-ol was detected at 0.252 μg/g in the soil sample collected from the 5 to 7 foot depth interval from boring SX-8.

BORING SX-26

Boring SX-26 was located 6 feet northwest of Building X-26. The boring was completed to a depth of 5 feet, one foot below the depth of the bottom of the sump. Analyses of soil samples collected indicate trace contamination by 2,4,6-TNT and perhaps VOCs.

Select Metals Results

Lead concentrations ranged from 12.1 to 19.1 μg/g, the highest value exceeding site-specific and county-specific background values for this element. Cadmium, chromium and mercury were not detected above their respective CRLs in the soil samples.

EPA TAL Results

Manganese was detected above background at an average concentration of 678 μg/g in duplicate samples collected from the 2 to 3 foot depth interval.

Explosive Analyte Results

The soil sample collected from the two to three foot depth interval had a 2,4,6-TNT concentration of 0.569 μg/g while the sample collected from the 4 to 5 foot depth interval had a 2,4,6-TNT concentration of 2.41 μg/g.

EPA TCL Results

In addition, 1,1,2,2-tetrachloroethane was detected at 0.134 μg/g in the soil sample collected from the 2.5 to 3.5 foot depth interval at Boring SX-26.

BORING SX-41

Boring SX-41 was located approximately 10 feet southwest of the sump. Soil boring SX-41 was completed to a depth of 5.5 feet, 1.5 feet below the depth of the bottom of the sump. Soil samples from boring SX-41 indicate contamination by explosives.

Select Metals Results

The lead concentration observed in the sample collected from the 0- to 1-foot depth interval was 13.7 μg/g, below site-specific and county-specific background values. Samples collected from the 2.5- to 3- and 4.5- to 5.5-foot depth intervals had lead concentrations within the site-specific background range. Cadmium, chromium, and mercury were not detected above their respective CRLs in the soil samples collected from this boring.

EPA TAL Results

No EPA TAL analytes were detected above background in soil samples from this boring.

Explosive Analyte Results

HMX, RDX, and 2,4,6 TNT were detected in the sample collected from the zero to one foot depth interval at concentrations of 20.0 μg/g, 39.0 μg/g, and 2.03 μg/g, respectively. These three compounds were also detected in samples collected from the 2.5 to 3 foot and 4.5 to 5.5 foot depth intervals at lower concentrations. HMX and RDX concentrations decreased significantly with increasing depth, TNT concentrations remained relatively unchanged. 1,3,5-TNB was detected in the sample collected from the 4.5 to 5.5 foot depth at 0.928 µg/g.

EPA TCL Results

2-propanol was detected at 0.007 µg/g.

BORING SX-103

Soil boring SX-103 was located at the northern end of the sump completed to a depth of 6.5 feet, with the bottom of the associated sump at 5.5 feet. Soil samples from boring SX-103 indicate contamination by HMX and RDX, but not other explosives or associated metals.

Select Metals Results

Lead was detected at concentrations ranging from 12.1 to 17.0 µg/g, below the site-specific background value. The remaining select metals were not detected.

EPA TAL Results

Manganese and arsenic were detected above background at 860 µg/g and 7.94 µg/g in the soil sample collected from this boring.

Explosive Analyte Results

HMX was detected in samples collected from the 0 to 1 foot and 2.5 to 3 foot depth intervals at 163 and 6.97 µg/g, respectively. RDX was detected at the same depth intervals at 967 µg/g and 46.2 µg/g; and at 4.08 µg/g at the 5.5 to 6.5 foot depth interval.

EPA TCL Results

Hexamethylene tetramine, an ingredient of RDX, was detected at 1.25 µg/g in the sample collected from the 5.5 to 6.5 foot depth interval. Acetone was also detected at 0.0257 µg/g.

BORING SX-313

Soil boring SX-313 was located adjacent to the west corner, and on the effluent side, of the existing sump. It was completed to a depth of 7.5 feet. The depth of the associated sump is 6.5 feet. Soil samples from boring SX-313 indicate contamination by HMX and RDX, but not other explosives or associated metals.

Select Metals Results

Lead concentrations ranged from 10.5 to 31.5 µg/g, with the highest value associated with the surface sample. The highest value exceeds the site-specific and county-specific background values. Cadmium, chromium and mercury were not detected above their respective CRLs.

EPA TAL Results

Several EPA TAL analytes were detected above background in the surface soil sample collected from this boring. Cobalt was detected above background at 33.4 µg/g, iron at 48,000 µg/g, manganese at 3,240 µg/g, and vanadium at 100 µg/g in the sample collected from the 0 to 2 foot depth interval.

Explosive Analyte Results

Table 5-26 shows the explosive contaminants detected at this boring and the associated depth intervals. Concentrations of HMX and RDX are highest at the surface and decrease significantly at depths greater than 1 foot. No other explosives compounds were detected.

EPA TCL Results

Several organic compounds related to explosives production were detected in the soil sample collected from the zero to one foot depth interval at boring SX-313. These included: 2-cyclohexen-1-ol (0.125 μg/g), 2-cyclohexen-1-one (0.125 μg/g), and hexamethylene tetramine (6.23 μg/g).

5.4.1.19 Line Z. Four soil borings were drilled to investigate two sumps at Line Z. Select metals and explosives detected in soil borings near Line Z sumps are shown in Table 5-27.

BORINGS SZ-4 & SZ-A4

Both an angular boring (sample SZ-A4) and a vertical boring (sample SZ-4) were drilled to investigate sump Z-4. The angular boring was completed at a depth of 5.5 feet directly below the bottom of the sump. The vertical boring was located at the discharge point of a concrete drainage spillway at the southern end of the sump and was completed to a depth 5 feet below the depth of the bottom of the sump. The chemical results of soil samples collected from these two borings are not significantly different, as shown in Appendix T.

Select Metals Results

Lead concentrations ranged from 5.90 μg/g to 10.3 μg/g, below site-specific and county-specific background values. Cadmium, chromium, and mercury were not detected above their respective CRLs.

EPA TAL Results

Manganese was detected above background at 838 μg/g in the soil sample collected from the 5 to 7 foot depth interval in the vertical boring; and at 678 μg/g in the soil sample collected from the 10.5 to 12.5 foot depth interval in the angular boring. Nickel was also detected above background in the vertical boring collected from the 5 to 7 foot depth interval at 37.2 μg/g.

Explosive Analyte Results

Trace levels of explosives contamination by HMX and RDX were observed in the vertical soil boring, while no explosives contamination was detected in the angular soil boring. However, it should be noted that in the vertical soil boring, three samples were collected at 0- to 2-, 5- to 7-, and 10- to 12-foot depth intervals, while in the angular soil boring, only one sample was collected at a vertical depth of 10.5 feet. HMX and RDX were detected in the soil sample collected from the 0- to 2-foot depth interval at 0.652 μg/g and 0.347 μg/g, respectively. RDX was also detected at 5- to 7-foot and 10- to 12-foot depth intervals at 0.665 μg/g and 0.435 μg/g, respectively. This contaminant distribution indicates only trace levels of contaminants at a depth 5 feet below the bottom of the sump. This suggests that significant soil contamination by explosives does not exist at this area.

TABLE 5-26
Explosive Concentrations ($\mu g/g$) at Specified Depth Intervals in Soil Boring SX-313

Depth Interval from the Surface (feet)	HMX	RDX
	Certified Reporting Limit	
	0.666	0.587
0 - 1	234	811
3.5 - 4	4.39	8.24
4 - 4.5	2.44	9.62
6.5 - 7.5	ND	1.80

ND Not detected above the Certified Reporting Limit.

TABLE 5-27
Select Metals and Explosives Analytical Results (μg/g) of Soil Samples From Borings Near Line Z Sumps

Boring/ Analyte	Cd	Cr	Pb	Hg	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit												
	3.05	12.7	10.0	0.050	0.666	0.587	0.456	0.731	0.424	0.524	0.488	0.496	2.41
SZ-4	ND	ND	5.90-10.3	ND	ND-0.652	0.347-0.665	ND	ND	ND	ND	ND	ND	ND
SZ-A4	ND	ND	8.26	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SZ-4W	ND	ND-32.7	9.08-15.8	ND	ND	ND	ND	ND-1,370	ND	ND	ND	ND-1.05	ND
SZ-2	ND	ND	9.82-33.6	ND	ND-1.61	ND	ND	ND	ND	ND	ND	ND	ND

ND Not detected above the Certified Reporting Limit.

EPA TCL Results

Trichlorofluoromethane, acetone, and 2-propanol were each detected once at concentrations less than 0.05 µg/g.

BORING SZ-4W

Soil boring SZ-4W was completed to a depth of 10 feet with the bottom of the associated sump at 7 feet. Chemical analysis of soil samples from boring SZ-4W showed surficial soil contamination by 1,3-dinitrobenzene (1,3-DNB), tetryl, and by chromium.

Select Metals Results

Lead concentrations ranged from 9.08 to 15.8 µg/g, with all values below the site-specific background value. Chromium was detected above its CRL once at 32.7 µg/g, in the sample collected from the 10 to 12 foot depth interval. This concentration is above the site-specific background value, but below the county-specific background value. Cadmium and mercury were not detected above their respective CRLs.

EPA TAL Results

Arsenic and manganese were detected above background at average concentrations of 8.56 and 468 µg/g, respectively, in the sample collected from the 10 to 12 foot interval.

Explosive Analyte Results

In samples collected from the zero to two foot depth interval 1,3-DNB was detected at 1.05 µg/g and tetryl at 1,370 µg/g. No other explosive analytes were detected.

EPA TCL Results

Acetone and 2-propanol were detected at concentrations less than 0.5 µg/g.

BORING SZ-2

Soil boring SZ-2 was completed to a depth of 10 feet with the bottom of the associated sump at 7 feet. Chemical analyses of soil samples from boring SZ-2 showed minor surface contamination by HMX, but not any other explosives or associated metals.

Select Metals Results

Lead concentrations ranged from 9.82 µg/g to 33.6 µg/g, with the highest value associated with the surface sample. The sample collected from the zero to two foot depth interval only had a lead concentration which exceeded the site-specific and county-specific background values. However, this concentration is still below EPA guidelines for protection of human health. Cadmium, mercury and chromium were not detected above their respective CRLs.

EPA TAL Results

Manganese was detected above background at 1,550 µg/g in the sample collected from the 0 to two foot depth interval.

Explosive Analyte Results

HMX was detected at 1.61 μg/g in the sample collected from the zero to two foot depth interval and 0.747 μg/g from the 10 to 12 foot depth interval. No other explosives were detected.

EPA TCL Results

Acetone was detected at 0.107 μg/g.

5.4.2 Groundwater Samples

The results of the chemical analyses of groundwater samples are presented in this section. One hundred fifteen samples were collected from 104 existing and newly installed wells. The wells were divided into ten groups, on the basis of geographic location or use. Samples drawn from all wells were analyzed for either the full Target Compound List and Target Analyte List (TCL/TAL) and nine explosive compounds or for select metals that are associated with metals production (Cd, Cr, Hg, and Pb) and the nine explosives compounds.

5.4.2.1 Background Samples. Three site-specific background groundwater samples were collected and analyzed for select metals and explosives (samples drawn from wells C-5, I-11, ZZ-3). These samples were collected from wells in the southeast corner of the site which are upgradient of any potential contaminant sources. In addition, these wells are screened in the Memphis Sand aquifer and are therefore representative of background water quality.

Select metals other than lead were not detected. Lead was detected between 4.7 and 23.9 μg/L for unfiltered samples and between 1.63 and 11.1 μg/L for filtered samples. These concentrations are well below the Federal MCL for lead (50 μg/L). None of the explosive analytes were detected in these samples. The background concentration of explosives is assumed to be zero.

To determine background values for the remaining chemicals in groundwater, the following method was used. For select metals, the results for wells C-5, I-11 and ZZ-3 were used to represent the site-specific background range. These wells were sampled as part of this investigation. Chemicals detected at concentrations higher than the highest value observed in this range were determined to be "above background". For many other TAL analytes, concentrations were compared to those detected at well I-11 in June, 1990. This well was sampled by Martin Marietta personnel as part of the regular monitoring of potable water supply wells. If the concentration of a given chemical was twice this value or greater than the concentration of the same chemical detected at I-11, the chemical was determined to be present at a level "above background". Because only one sample is available for comparison, the factor of two is used to add a degree of variability to the background concentration. For the elements arsenic, silver, and vanadium, national average values were used (Walton, 1985). If the concentrations of these elements exceeded these national average values, they were said to be present "above background". This is shown in more detail in Table 5-28.

5.4.2.2 Regulatory Criteria. The State of Tennessee has established groundwater and public water supply standards for the select metals (Cd, Cr, Hg, Pb) which were investigated at this site. Federal Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) also exist for these metals. The MCLs presented for Hg, Cr, and Cd were made final rule January 30, 1991.

Guidance concerning concentrations of explosives in the groundwater is represented by Secondary Maximum Contaminant Levels (SMCLs); the U.S. Army Surgeon General Permissible Drinking Water Criteria (US Army PDWC); 10^{-6} risk levels, proposed by the U.S. Army; and Lifetime Health Advisories (HAs). All but three of the nine explosives investigated (nitrobenzene, tetryl, and 1,3-DNB).possess a guideline criteria under the above-mentioned criteria.

TABLE 5-28
Development of Background Concentrations for Groundwater

Analyte	Well(s) Providing Data	Detected Concentration µg/L	Background Concentration Used for Comparison µg/L
3 Background Samples Available[a]			
Cd (U)	C-5, I-11, ZZ-3	ND (4.01)	4.01
Cd (F)	C-5, I-11, ZZ-3	ND (4.01)	4.01
Cr (U)	C-5, I-11, ZZ-3	ND (6.02)	6.02
Cr (F)	C-5, I-11, ZZ-3	ND (6.02)	6.02
Hg (U)	C-5, I-11, ZZ-3	ND (0.20)	0.20
Hg (F)	C-5, I-11, ZZ-3	ND (0.20)	0.20
Pb (U)	C-5, I-11, Z-33	23.9	23.9
Pb (F)	C-5, I-11, ZZ-3	11.1	11.1
1 Background Sample Available[b]			
Al (U)	I-11*	ND (141)	282
Ba (U)	I-11*	7.28	14.56
Ca (U)	I-11*	1,240	2,480
Co (U)	I-11*	ND (25)	50
Cu (U)	I-11*	ND (8.09)	16.2
Fe (U)	I-11*	ND (38.8)	77.6
K (U)	I-11*	771	1,542
Mn (U)	I-11*	8.75	17.5
Mg (U)	I-11*	ND (500)	1,000
Na (U)	I-11*	2,520	5,040
Ni (U)	I-11*	ND (34.3)	68.6
Zn (U)	I-11*	ND (21.1)	42.2
No Background Sample Available[c]			
Ag (F)	NA	NA	1
As (F)	NA	NA	100
V (F)	NA	NA	100

(U)	Unfiltered sample.
(F)	Filtered sample.
ND	Not detected above the CRL; value in parentheses represents the detection limit.
NA	Not applicable.
*	Well I-11 was sampled for these parameters by Martin-Marietta in June 1990. Samples were analyzed in the MAAP chemical laboratory.
a	Background concentration value is based on maximum detected or on the detection limit.
b	Background concentration value is based on two times maximum detected or on two times the detection limit.
c	Background concentration value represents national average concentration, (Walton, 1985).

Criteria for acetone, bis(2-ethylhexyl) phthalate, and 2-propanol are not currently established by the Federal or State of Tennessee regulations. The other TCL volatiles detected: chloroform, ethylbenzene, toluene and xylenes are regulated by Federal MCLs, MCLGs, Lifetime Health Advisories, and SMCLs.

The State of Tennessee has established Public Water Supply Standards for some of the TAL inorganics detected above this criterion (Ba, Cu, Mn, As, Ag, Fe and Zn). Concentrations of Al, Cu, Fe, Mn, Ag, and Zn are controlled by the Federal SMCLs. Federal MCLs, MCLGs, and HAs regulate concentrations of one or more of the following: As, Ba, Cu, Ni, and Ag. Concentrations of calcium, magnesium, sodium, potassium, cobalt, vanadium are not currently regulated by the State of Tennessee or the Federal Government. The various regulations and guidelines applicable to groundwater at this site are presented in Section 10.0.

5.4.2.3 Discussion of Results. Results are presented for groups of wells, depending on their use or geographic location. Two off-post residential wells, six monitoring wells located near the residential wells, and four currently operating potable water sources were sampled to check for contaminants which may be of immediate concern to public health. The remaining wells were distributed into six geographical sections in order to facilitate the presentation of the data. Wells within each region are listed in Table 5-29. The reader is referred to Figure 4-14 to identify wells with respect to geographic location. Selected metals and TAL constituents (if applicable) results are presented first, followed by explosive analyte results and TCL constituents, if applicable. If a given well was part of a well cluster or well pair, the analytical results obtained for the sample drawn from that well are compared to the other member(s) of the well cluster or pair within the appropriate subsection. The analytical results are then discussed in general for all wells within a particular grouping, and are compared to regulatory criteria.

Well pairs are composed of wells that are identical in construction, except for the well casing material used. Well pairs were installed to determine if casing material had any effect on analytical results for groundwater samples subsequently drawn from the well. Wells within well clusters had screened intervals which intercepted different portions of the aquifer. This was done to determine the vertical distribution of contaminants within the aquifer.

5.4.2.4 Off-Post Residential Wells.

Two off-post residential wells, located northwest of MAAP, were sampled in order to determine if contamination has migrated off-post. Wells DW001 and DW002 are the drinking water sources for the Bledsoe residence and the New Hope Baptist Church.

Select Metals Results

Select metals other than lead were not detected in either sample. Lead was detected in both unfiltered samples and one filtered sample. The concentrations found were below the current MCL for lead (50 μg/L). These results are shown in Table 5-30.

Explosive Analyte Results

None of the explosive analytes were detected in these samples.

5.4.2.5 Monitoring Wells Near Residential Wells. Seven samples were collected from the five monitoring wells (MI076, MI077, MI078, MI081, MI082) which were installed in the vicinity of the Bledsoe and New Hope Church wells. A sixth well was installed at the border of MAAP upgradient of this area (MI054) and one sample was collected.

TABLE 5-29
Listing of Wells Within Each Region

Background Samples (3 Wells)	Off-Post Residential Wells (2 Wells)	Monitoring Wells Near Residential Wells (6 Wells)	Production Wells Currently in Operation (4 Wells)	Southwest Wells (5 Wells)	Southeastern Wells (19 Wells)	Eastern Wells (2 Wells)	Northeastern Wells (41 Wells)	West Central Wells (2 Wells)	North Central Wells (20 Wells)
++C-5 ++I-11 ZZ-3	DW001 DW002	MI054 MI076 MI077 MI078 +MI081 +MI082	C-5 I-11 S-99 T-99	MI020 +MI021 MI073 K-323 E-67	001 002 003 004 005 006 007 MI006 MI007 +MI016 MI017 +MI018 MI019 MI062 MI063 MI064 MI065 MI066 MI067	T-100 MI015	K-100 MI001 MI002 MI003 MI004 MI005 MI008 MI022 MI023 MI024 +MI025 MI029 +MI030 MI031 MI032 MI035 MI036 MI037 MI038 MI039 MI040 MI041 MI044 MI045 MI046 MI047 MI048 MI051 MI052 MI053 MI057 MI058 MI059 +MI060 MI061 +MI071 MI072 MI074 MI075 MI079 MI080	Y-100 P-97	F-100 MI009 MI010 MI011 MI012 MI013 +MI014 MI026 MI027 MI028 MI033 MI034 +MI049 MI050 MI055 +MI056 +MI068 MI069 MI070 X-100

\+ duplicate sample collected at this well
\++ well currently used as a production well

TABLE 5-30
Select Metals Analytical Results (μg/L) for Groundwater Samples; Off-Post Residential Wells, Monitoring Wells Near Residential Wells, Production Wells, SW, SE, and Eastern Wells

Sample/Analyte	Cd		Cr		Hg		Pb	
	F	U	F	U	F	U	F	U
	Certified Reporting Limit*							
	4.01	4.01	6.02	6.02	0.243	0.243	1.30	1.30
Off-Post Residential Wells								
DW001	ND	ND	ND	ND	ND	ND	2.28	1.63
DW002	ND	ND	ND	ND	ND	ND	ND	4.34
Monitoring Wells Near Residential Wells								
MI054	ND	ND	ND	7.90	ND	ND	ND	ND
MI076	26.3	26.1	ND	ND	ND	ND	ND	8.89**
MI077	63.0	63.1	50.5	9.27	ND	ND	1.52**	9.00**
MI078	50.3	46.0	ND	ND	ND	ND	1.63**	13.9
MI081+	ND	ND	ND	ND	ND	ND	ND	2.61
MI082+	ND	ND	ND	11.5	ND	ND	5.10	4.07
Production Wells Currently in Operation								
C-5	ND	ND	ND	ND	ND	ND	1.63	6.18
I-11	ND	ND	ND	ND	ND	ND	11.1	23.9
S-99	ND	ND	ND	ND	ND	ND	ND	5.10
T-99	ND	ND	ND	ND	ND	ND	17.8	11.4
Southwest Wells								
MI020	ND	ND	ND	31.6	ND	ND	ND	17.6
MI021+	ND	ND	ND	41.3	ND	ND	ND	7.43
MI073	15.4	23.2	ND	ND	1.10	ND	2.49	5.42
K-323	ND	ND	ND	ND	ND	ND	60.3	97.8
E-67	ND	ND	ND	ND	ND	ND	ND	17.1
Southeastern Wells								
001	ND	ND	ND	ND	ND	ND	ND	ND
002	ND	ND	ND	ND	ND	ND	ND	ND
003	164	194	ND	ND	ND	ND	3.04**	18.7
004	ND	ND	ND	ND	ND	ND	ND	9.65
005	14.2	15.3	ND	7.90	ND	ND	3.80**	18.8

TABLE 5-30 (Cont'd)
Select Metals Analytical Results (μg/L) for Groundwater Samples; Off-Post Residential Wells, Monitoring Wells Near Residential Wells, Production Wells, SW, SE, and Eastern Wells

Sample/Analyte	Cd		Cr		Hg		Pb	
	F	U	F	U	F	U	F	U
	Certified Reporting Limit*							
	4.01	4.01	6.02	6.02	0.243	0.243	1.30	1.30
Southeastern Wells (continued)								
006	8.21	10.0	ND	ND	ND	ND	2.06	10.4
007	7.76	10.5	ND	ND	ND	ND	1.95	7.16
MI006	5.70	17.1	ND	10.8	0.326	ND	5.86	33.9
MI007	ND	ND	ND	ND	ND	ND	ND	2.60
MI016+	ND	ND	ND	ND	ND	ND	3.25	13.9
MI017	ND	ND	ND	29.8	ND	ND	ND	6.94**
MI018+	ND	ND	ND	ND	ND	ND	4.94	11.9
MI019	ND	ND	ND	ND	0.735	ND	1.84	11.7
MI062	ND	4.08	ND	11.9	ND	ND	ND	9.33
MI063	ND	5.33	ND	9.16	ND	ND	ND	6.50
MI064	55.5	70.9	ND	ND	ND	ND	1.63	7.05
MI065	ND	12.4	ND	20.4	0.238	ND	4.34	11.6
MI066	ND	4.56	ND	ND	ND	ND	2.06	19.5
MI067	9.38	18.6	ND	ND	ND	ND	1.41	6.29
Eastern Wells								
T-100	ND	ND	ND	ND	ND	ND	8.46	23.1
MI015	ND	ND	ND	ND	ND	ND	ND	6.51**

ND Not detected above the CRL.
F Filtered
U Unfiltered
\+ Duplicate sample taken at this well; Where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.
* The laboratory reported two different CRLs for each analyte; the larger of the two CRLs is reported in this table. Refer to Appendix L for other CRLs.
** The analyte was present in the sample above the CRL but less than five times the concentration in the associated method blank and should be considered non-detect.

Select Metals Results

Select metals were detected in all of the unfiltered samples and in all but two filtered samples. Chromium was detected in five samples from three wells (four unfiltered and one filtered). Lead was detected in samples collected from all wells with the exception of the sample collected from the border well (MI054). The concentrations detected were all below the site-specific background concentrations and the current Federal MCL. These results are shown in Table 5-30.

Cadmium was detected in both the filtered and unfiltered samples from three of the wells sampled. Concentrations ranged between 26.1 μg/L and 63.1 μg/L. The concentrations found in these three wells exceeded the Federal MCL (5 μg/L). Cadmium was not found in the wells installed upgradient and downgradient of the group of wells installed near the residential wells (MI081 and MI082). Mercury was not detected in any of the samples collected. The wells in this group are screened at approximately the same elevation and the horizontal spacing between them is very small (see Figure 4-14). Therefore, if a plume of cadmium-contaminated groundwater existed, all of these wells would show contamination. The inconsistent chemical results indicated that the high level of cadmium may be due to well installation, development, and sampling. It is also possible that some of the newly-installed wells had not stabilized by the time they were sampled. Resampling of these wells would allow more definite conclusions to be drawn.

EPA TAL Results

Within this group, analysis for TAL constituents was only on the sample from well MI054. Three TAL constituents were detected above background levels in this sample: sodium, copper, and iron. Sodium was detected at 12,600 μg/L and 13,800 μg/L for filtered and unfiltered samples, respectively, while copper and iron were detected at 22.5 and 148 μg/L, respectively, in unfiltered samples. None of these concentrations represent exceedances of regulatory criteria. TAL constituents detected above background for this group of wells are shown in Table 5-31.

Explosive Analyte Results

Explosives were not detected in any of the samples except for that collected from border well MI054. 1,3,5-TNB was detected in this sample at 0.97 μg/L, well below the U.S. Army PDWC for this explosive (200 μg/L). The source of the contamination is not clear. Explosives results are shown in Table 5-32.

EPA TCL Results

No EPA TCL analytes were detected in the sample drawn from well MI054.

5.4.2.6 Production Wells Currently in Operation for Use as Potable Water Sources. Four of the fifteen existing production wells on site are currently being used as potable water sources. Two other production wells are currently available for this use. Samples were collected from each of these six wells: C-5, I-11, S-99, T-99, F-100 and T-100.

Select Metals Results

Cadmium, chromium, and mercury were not detected in any of the samples drawn from wells in this group. Lead was detected in all of the unfiltered samples and in all but one filtered sample. Lead concentrations in the unfiltered samples ranged from 5.1 to 23.9 μg/L, and in the filtered samples ranged from 2.49 to 60.3 μg/L. The concentration of lead found in all samples was below Federal MCL and State of Tennessee groundwater standards. One sample exhibited concentrations above site-specific background concentrations (F-100 (unfiltered)). These results are shown in Table 5-30.

TABLE 5-31
TAL Inorganics Analytical Results (μg/L) for Unfiltered Groundwater Samples; Off-Post Residential Wells, Monitoring Wells Near Residential Wells, Production Wells, SW, SE, and Eastern Wells

Sample/Analyte	Al	Ba	Ca	Cu	Fe	K	Mn	Mg	Na	Zn
Off-Post Residential Wells										
DW001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DW002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Monitoring Wells Near Residential Wells										
MI054	NA	NA	NA	22.5*	148	NA	NA	NA	13,800	NA
MI076	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI077	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI078	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI081+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI082+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Production Wells Currently in Operation										
C-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
I-11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
S-99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
T-99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Southwest Wells										
MI020	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI021+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI073	1,350	22.3	2,290	NA	974	NA	NA	NA	NA	NA
K-323	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
E-67	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Southeastern Wells										
001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
003	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
004	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
005	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
006	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
007	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 5-31 (Con't)
TAL Inorganics Analytical Results ($\mu g/L$) for Unfiltered Groundwater Samples; Off-Post Residential Wells, Monitoring Wells Near Residential Wells, Production Wells, SW, SE, and Eastern Wells

Sample/Analyte	Al	Ba	Ca	Cu	Fe	K	Mn	Mg	Na	Zn
Southeastern Wells (con't)										
MI006	4,780	121	71,000	NA	3,920	NA	NA	1,920	22,100	60.5
MI007	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI016+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI017	1,840	NA	NA	NA	2,570	NA	72.3	NA	5,940	NA
MI018+	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI062	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI063	1,160	16.9	6,560	NA	1,490	2,430	50.6	NA	NA	NA
MI064	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI065	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI066	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI067	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Eastern Wells										
MI015	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
T-100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA Not applicable; analyte not detected above background.

\+ Duplicate sample taken; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

* The analyte was present in the sample above the CRL but less than five times the concentration in the associated filter blank and should be considered non-detect.

TABLE 5-32
Explosives Analytical Results (μg/L) for Groundwater Samples; Off-Post Residential Wells, Monitoring Wells Near Residential Wells, Production Wells, SW, SE, and Eastern Wells

Sample/Analyte	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit*								
	1.70	2.11	0.600	0.600	0.612	1.20	0.626	0.519	1.10
Off-Post Residential Wells									
DW001	ND	ND	ND	ND	ND	ND	ND	ND	ND
DW002	ND	ND	ND	ND	ND	ND	ND	ND	ND
Monitoring Wells Near Residential Wells									
MI054	ND	ND	ND	ND	ND	ND	0.967	ND	ND
MI076	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI077	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI078	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI081+	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI082+	ND	ND	ND	ND	ND	ND	ND	ND	ND
Production Wells Currently in Operation									
C-5	ND	ND	ND	ND	ND	ND	ND	ND	ND
I-11	ND	ND	ND	ND	ND	ND	ND	ND	ND
S-99	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-99	ND	ND	ND	ND	ND	ND	ND	ND	ND
Southwest Wells									
MI020	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI021+	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI073	ND	ND	ND	ND	ND	ND	ND	ND	ND
K-323	ND	ND	ND	ND	ND	ND	ND	ND	ND
E-67	ND	ND	ND	ND	0.754	ND	ND	ND	ND
Southeastern Wells									
001	ND	ND	ND	ND	ND	ND	ND	ND	ND
002	13.0	118	19.8	ND	ND	ND	1.14	ND	ND
003	16.4	353	18.7	ND	1.12	ND	0.982	ND	ND
004	ND	17.6	21.3	ND	ND	ND	1.36	ND	ND
005	ND	ND	ND	ND	ND	ND	ND	ND	ND
006	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 5-32 (Cont'd)
Explosives Analytical Results (μg/L) for Groundwater Samples; Off-Post Residential Wells, Monitoring Wells Near Residential Wells, Production Wells, SW, SE, and Eastern Wells

Sample/Analyte	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit*								
	1.70	2.11	0.600	0.600	0.612	1.20	0.626	0.519	1.10
Southeastern Wells (continued)									
007	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI006	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI007	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI016+	ND	ND	7.19	ND	ND	ND	ND	0.709	ND
MI017	ND	11.5	ND	ND	ND	ND	ND	ND	ND
MI018+	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI019	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI062	ND	6.04	ND	ND	ND	ND	ND	ND	ND
MI063	ND	12.3	ND	ND	ND	ND	ND	ND	ND
MI064	ND	6.08	3.13	ND	ND	ND	ND	ND	ND
MI065	ND	ND	2.39	ND	ND	ND	ND	ND	ND
MI066	ND	3.44	47.0	ND	ND	ND	1.10	ND	ND
MI067	ND	ND	0.691	ND	ND	ND	ND	ND	ND
Eastern Wells									
T-100	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI015	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND Not detected above the CRL.
+ Duplicate sample taken at this well; Concentrations are represented as the average of the two samples.
* The laboratory reported two different CRLs for each analyte; the larger of the two CRLs is reported in this table. Refer to Appendix L for other CRLs.

Explosive Analyte Results

Explosives were not detected in any of these samples.

5.4.2.7 Southwest Wells. Five monitoring wells were sampled in the Southwest area of MAAP: E-67, K-323, MI020, MI021, and MI073.

Select Metals Results

Lead was detected in all five samples. However, only one sample showed levels above site-specific background levels, State of Tennessee groundwater standards and the Federal MCL. Almost twice the federally regulated concentration (50 μg/L) was found in well K-323. This well is located downgradient of the other five wells within this group.

Cadmium was detected in one well (MI073) at 15.4 and 23.2 μg/L, between three and four times above the Federal MCL (5 μg/L). Mercury was also detected in the sample from this well. The concentration detected (1.1 μg/L) was below the 2 μg/L State groundwater standard and Federal MCL. Chromium was detected below State mandated groundwater levels in the unfiltered samples of two wells (MI020 and MI021). The filtered samples from these two wells showed no detection of chromium. Select metals results for this group of wells are shown in Table 5-30.

EPA TAL Results

One well within this well group (MI073) had a sample analyzed for the full TAL/TCL scan. Several TAL analytes were detected above background. The iron concentration in the unfiltered sample (974 μg/L) exceeded the State of Tennessee Public Water Supply Standard (300 μg/L). All analytes above background are shown in Table 5-31.

Explosive Analyte Results

Explosives were not detected in any of these samples except in well E-67. 2,4-DNT was detected at a concentration of 0.800 μg/L. This concentration is below the U.S. Army PDWC (44 μg/L) and HA (2 μg/L).

EPA TCL Results

The compound bis-2-ethylhexylphthalate was detected at 5.73 μg/L in the sample drawn from well MI073, and may either be a laboratory artifact, or a site-related contaminant.

5.4.2.8 Southeastern Wells. Nineteen wells were sampled in the southeastern part of MAAP, north of the site-specific background well locations. There were two sets of newly installed cluster wells within this well grouping: MI062, MI063, MI064, and MI065, MI066, and MI067. Significant differences were observed in the wells within the first well cluster.

Select Metals Results

Select metals results for this group of wells are shown on Table 5-30. Cadmium concentrations were significantly higher in well MI064, as compared to wells MI062 and MI063. Cadmium was detected at 55.5 μg/L and 70.9 μg/L (filtered and unfiltered samples, respectively) in the sample drawn from MI064 (screened interval, 236 to 246 feet), as compared to < 4.01 μg/L, 4.08 μg/L, and < 4.01 μg/L, 5.33 μg/L for samples drawn from MI062 (screened interval 89 to 99 feet) and MI063 (screened interval 149.5 to 159.5 feet), respectively. This finding suggests that contamination by cadmium is more significant in the lower portion of the aquifer in this area of the installation. No significant differences were observed in the select metals concentrations observed in the three wells MI065, MI066, MI067.

Cadmium, chromium, and lead were detected above their respective CRLs in samples from 17 of the 19 wells in this region. Samples from several wells contained concentrations of select metals which exceeded site-specific background ranges (wells 003-007, MI006, MI017, MI062-MI067). Cadmium was detected in eleven of the unfiltered samples and in seven of the filtered samples (seven of these were corresponding samples). Detected concentrations ranged from 4.08 μg/L to 194 μg/L. Ten of nineteen wells sampled contained cadmium levels above the Federal MCL.

Six samples contained detectable levels of chromium ranging between 7.90 μg/L and 29.8 μg/L. Although this range exceeds site-specific background concentrations, it is below both State of Tennessee groundwater standards and the Federal MCL for chromium.

All lead levels are below site-specific background concentrations except in the sample drawn from well MI006. This unfiltered sample contained 33.9 μg/L lead. This level does not exceed the Federal MCL (50 μg/L). Detectable levels of mercury were found in three filtered samples (MI006, MI019, MI065). Concentrations ranged between 0.238 μg/L and 0.735 μg/L and are below the State groundwater standard and the Federal MCL (2 μg/L).

EPA TAL Results

Three wells within this well group had samples analyzed for the full TAL/TCL scan. Several TAL analytes were detected at concentrations above background in the samples drawn from wells in this group. Notably, iron and manganese concentrations exceeded State of Tennessee Public Water Supply Standards at wells MI006, MI017, and MI063. Analytes detected above background at the various wells and the observed concentrations are listed in Table 5-31.

Explosive Analyte Results

Explosive analyte results for this group of wells are shown in Table 5-32. Two explosive analytes were detected in the sample drawn from MI064, as compared to one in MI062 and MI063. RDX was detected at 6.08 μg/L, and 2,4,6 TNT was detected at 3.13 μg/L at MI064. The former contaminant was also detected at wells MI062 and MI063 at 6.04 and 12.3 μg/L, respectively.

There were differences in the number and concentrations of explosive analytes detected within the well cluster composed of wells MI065, MI066, MI067. 2,4,6 TNT was detected at 2.39 μg/L at MI065 (screened interval, 99 to 109 feet). This compound was also detected at MI066 (screened interval, 160 to 170 feet) at 47.0 μg/L, along with RDX at 3.44 μg/L, and 1,3,5 TNB at 1.1 μg/L. Only 2,4,6 TNT was detected at 0.691 μg/L at well MI067 (screened interval, 241 to 251 feet beneath the surface). These findings may suggest that groundwater contamination by explosives may be most severe at the intermediate depth of the aquifer in this area of the installation.

Explosives were detected in eleven of the nineteen wells in this group. RDX was detected in nine of the samples collected. Detected concentrations ranged from 3.44 to 353 μg/L. This range exceeds the HA (2 μg/L) and the U.S. Army PDWC (35 μg/L). Since the HA is below the analytical detection limit (2.11 μg/L), it cannot be determined if the groundwater at certain locations exceeds this guideline (e.g., 001, 005, 006, 007, MI006, MI007, MI016, MI018, MI019, MI065, MI067).

2,4,6-TNT was detected in seven of these wells. Samples from six wells had concentrations in excess of the 2 μg/L HA for this explosive. The sample from well MI066 exceeded the U.S. Army PDWC (44 μg/L). The concentrations detected ranged between 0.691 μg/L and 47.0 μg/L.

Samples drawn from four wells (wells 002, 003, 004, and MI066) showed contamination by 1,3,5-TNB. The range of concentrations detected was between 0.982 and 1.36 μg/L. This range is well below the 200 μg/L U.S. Army PDWC. HMX was detected in samples from two of the nineteen wells in this area. Monitoring wells 002 and 003 contained 13.0 μg/L and 16.4 μg/L, respectively. These values are below the Federal SMCL (300 μg/L) and the HA (400 μg/L).

The groundwater sample drawn from well 003 also contained 1.12 μg/L of 2,4-DNT. This level exceeds the 10^{-6} risk level proposed by the U.S. Army (0.17 μg/L). It cannot be determined if levels of 2,4-DNT in other samples are also in excess of this level since the analytical detection limit (0.612 μg/L) is above the proposed level. The sample drawn from well MI016 contained 0.709 μg/L of 1,3-DNB. No guideline exists for this constituent. Nitrobenzene, tetryl, and 2,6-DNT were not detected in any of the samples from this area.

EPA TCL Results

Several volatile organic compounds were detected in the groundwater sample drawn from well MI063. The compounds ethylbenzene, toluene, and xylene were detected at concentrations of 7.52 μg/L, 2.65 μg/L, and 5.94 μg/L, respectively. These concentrations are below the respective MCLs for these compounds. These compounds are all components of gasoline and their presence may indicate that another contaminant source exists, or may indicate that the sample was contaminated during collection by a generator or nearby vehicle. Bis(2-ethylhexyl)phthalate was detected at 6.0 μg/L. This compound is a common laboratory contaminant.

5.4.2.9 Eastern Wells. Wells T-100 and MI015 are located in the eastern portion of MAAP.

Select Metals Results

Lead was the only select metal detected and was found within site-specific background range concentrations.

Explosive Analyte Results

Explosives were not detected in either well.

5.4.2.10 Northeastern Wells. Forty-one wells listed in Table 5-29 are located in the northeastern part of MAAP. This group of wells includes two recently installed well pairs and one recently installed well cluster. Wells MI057 and MI075 constitute one well pair, and wells MI071 and MI074 constitute the second well pair. Wells MI059, MI060, MI061 constitute the newly installed well cluster. In addition, there are 7 well clusters, composed of two wells each, which were installed by previous investigators. Wells in each well pair are identical in terms of construction except for the casing used. Stainless steel was used for one well and PVC was used for casing in one well of each well pair. The purpose of the installation of well pairs was to determine if there was any effect on groundwater sample quality by casing material. Wells within clusters have different screened intervals, such that different portions (depths) of the aquifer are intercepted.

Select Metals Results

The analytical results for select metals for the northeastern wells are shown in Table 5-33. Analytical results for the three recently installed cluster wells (MI059, MI060, MI061) were slightly different. Dissolved lead concentrations were slightly higher in groundwater from the shallow aquifer (13.1 μg/L), compared to the intermediate (2.93 μg/L), and lower aquifer (1.95 μg/L). Cadmium was detected at approximately 20 μg/L in filtered and unfiltered samples drawn from MI059, not detected in filtered or unfiltered samples at MI060, and detected in the unfiltered sample only at MI061, at 17.9 μg/L.

Analytical results were significantly different between wells within the old well clusters. The cadmium concentrations observed in the sample drawn from well MI051 (screened interval 135 to 155 feet below the surface) were 135 μg/L, filtered, 138 μg/L, unfiltered as compared to < 4.01 μg/L, filtered, < 4.01 μg/L,

TABLE 5-33
Select Metals Analytical Results ($\mu g/L$) for Groundwater Samples; Northeastern Wells

Sample/Analyte	Cd		Cr		Hg		Pb	
	F	U	F	U	F	U	F	U
	Certified Reporting Limit*							
	4.01	4.01	6.02	6.02	0.243	0.243	1.30	1.30
K-100	ND	ND	ND	ND	ND	ND	28.7	33.1
MI001	ND	ND	ND	13.3	ND	ND	1.80	3.25
MI002	ND	ND	ND	ND	ND	ND	4.88	4.45
MI003	ND	ND	ND	ND	ND	ND	1.84	13.6
MI004	12.0	ND	ND	ND	ND	ND	1.74	4.12
MI005	31.4	40.9	ND	12.4	ND	ND	4.88	20.3
MI008	ND	6.42	ND	ND	ND	ND	2.06	11.9
MI022	ND	ND	ND	ND	ND	ND	ND	1.95**
MI023	ND	ND	ND	ND	ND	ND	2.17	1.41
MI024	ND	ND	ND	ND	ND	ND	ND	9.76
MI025+	ND	ND	ND	ND	ND	ND	ND	11.0
MI029	ND	ND	ND	13.0	ND	ND	ND	4.23
MI030+	ND	ND	ND	ND	ND	ND	3.25**	1.62**
MI031	ND	ND	ND	9.75	ND	ND	ND	5.64
MI032	ND	ND	ND	ND	ND	ND	ND	1.63
MI035	ND	ND	ND	11.2	ND	ND	ND	7.70
MI036	28.8	40.6	12.0	ND	ND	ND	3.80	12.0
MI037	ND	ND	ND	ND	ND	ND	ND	2.17
MI038	112	114	ND	ND	ND	ND	1.84	3.58
MI039	69.1	94.3	ND	ND	ND	ND	5.75	27.1
MI040	46.5	43.7	ND	ND	ND	ND	6.44	ND
MI041	59.8	63.0	ND	ND	ND	ND	1.40	5.64
MI044	31.2	29.3	ND	ND	ND	ND	4.66	13.7
MI045	86.5	107	ND	ND	ND	ND	1.84	7.70
MI046	63.0	64.6	ND	ND	ND	ND	10.1	13.8
MI047	40.0	46.0	ND	ND	ND	ND	2.17	21.9

TABLE 5-33 (Cont'd)
Select Metals Analytical Results (μg/L) for Groundwater Samples; Northeastern Wells

Sample/Analyte	Cd		Cr		Hg		Pb	
	F	U	F	U	F	U	F	U
	Certified Reporting Limit*							
	4.01	4.01	6.02	6.02	0.243	0.243	1.30	1.30
MI048	12.0	12.8	ND	ND	ND	ND	1.84	4.45
MI051	135	138	ND	ND	ND	ND	5.42	16.2
MI052	39.8	50.0	ND	ND	ND	ND	ND	6.07
MI053	28.1	33.9	ND	ND	ND	ND	2.93	30.5
MI057	ND	ND	ND	ND	ND	ND	ND	1.41
MI058	12.2	14.9	ND	ND	0.590	0.417	2.28	3.69
MI059	21.0	22.5	ND	ND	ND	ND	13.1	4.34
MI060+	ND	ND	ND	ND	ND	ND	2.93	5.15
MI061	ND	17.9	6.06	ND	ND	ND	1.95	12.5
MI071+	12.2	14.3	ND	8.58	0.332	ND	1.79	9.38
MI072	27.5	39.9	ND	ND	ND	ND	3.36	3.69
MI074	31.1	44.2	ND	10.9	ND	ND	3.58	4.56
MI075	ND	ND	8.29	10.0	ND	ND	1.52	1.63
MI079	ND	ND	ND	8.38	ND	ND	ND	1.95
MI080	ND	ND	ND	ND	0.250	ND	ND	2.93

ND Not detected above the CRL.
+ Duplicate sample taken at this well; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.
* The laboratory reported two different CRLs for each analyte; the larger of the two CRLs is reported in this table. Refer to Appendix L for other CRLs.
** The analyte was present in the sample above the CRL but less than five times the concentration in the associated method blank.
U Unfiltered sample
F Filtered sample

unfiltered for the sample drawn from well MI023 (screened interval, 30 to 60 feet). Cadmium concentrations also appeared to be somewhat higher at MI036 (screened interval 135 to 155 feet) 28.8 µg/L, filtered, 40.6 µg/L, unfiltered; than at MI037 (screened interval, 240 to 260 feet) < 4.01 µg/L, for both filtered and unfiltered samples.

A significant difference in cadmium concentrations was observed at wells MI044 and MI045. The element was observed at concentrations of 31.2 µg/L filtered, 29.3 µg/L, unfiltered at MI044 (screened interval, 143 to 163 feet, and was detected at 86.5 µg/L filtered, 107 µg/L, unfiltered at MI045 (screened interval, 210 to 230 feet). These three findings suggest that cadmium contamination of groundwater is more severe in the intermediate depth of the aquifer than in the upper and lower depths of the aquifer.

Cadmium concentrations were not significantly different between wells in the remaining older well clusters. However, detected concentrations exceeded the Federal MCL (5 µg/L) at most wells within the old well clusters.

Groundwater samples from 63% of the wells in this region (26 out of 41 wells) were found to have detectable levels of selected metals above site-specific background concentrations, usually due to cadmium. Cadmium concentrations ranged between 6.42 µg/L and 138 µg/L in unfiltered samples and 12.0 µg/L and 135 µg/L in filtered samples. These ranges are above the 5 µg/L Federal MCL for cadmium.

Eleven wells had detectable levels of chromium; detectable concentrations were below 15 µg/L. This level, which is above site-specific background levels, falls below the State of Tennessee groundwater standards (50 µg/L) and the Federal MCL for chromium (100 µg/L).

Mercury was detected in three wells (MI058, MI071, MI080), having concentrations between the range of 0.25 µg/L and 0.59 µg/L. Although above site-specific background levels, this range is below the 2 µg/L Federal MCL.

Lead was detected in samples from all wells in this group. Only three unfiltered samples (from wells K-100, MI039, and MI053) and two filtered samples (wells K-100 and MI058) had concentrations of lead above site-specific background concentrations. These concentrations fell between 13.1 µg/L and 33.1 µg/L. These levels are below the Federal MCL for lead (50 µg/L).

EPA TAL Results

Seven wells within this well group had samples analyzed for the full TAL/TCL scan. All seven wells had iron concentrations exceeding State of Tennessee Public Water Supply Standards. Four of the wells had manganese concentrations exceeding the State of Tennessee Public Water Supply Standards. All analytes exceeding background are listed, by well, in Table 5-34.

Explosive Analytes Results

Explosive analytes detected in this group of wells are listed in Table 5-35. Significant differences were observed in explosive concentrations for wells within the recently installed well cluster. The compound 2,4,6 TNT was detected at 0.951 µg/L at well MI059 (screened interval, 18 to 28 feet). This compound was detected at an average concentration (a duplicate sample was collected here) of 2.47 µg/L at MI060 (screened interval, 139.5 to 149.5 feet), and HMX was also detected at 5.37 µg/L, along with 2,4 DNT at 1.49 µg/L. HMX only was detected at MI061 (screened interval 234.5 to 244.5 feet), at 2.82 µg/L. These findings suggest that explosives contamination may be more severe at intermediate depths of the aquifer in this area of the installation.

Significant differences were also observed in explosives concentrations found within the older well clusters. For instance, RDX, TNT, and 1,3,5 TNB concentrations were an order of magnitude higher at

TABLE 5-34
TAL Inorganics Analytical Results (μg/L) for Unfiltered Groundwater Samples; Northeastern Wells

Sample/Analyte	Al	Ba	Ca	Fe	K	Mn	Mg	Na	Zn
K-100	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI001	8,350	NA	11,200	5,740	NA	1,120	5,770	6,940	NA
MI002	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI003	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI004	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI005	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI008	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI022	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI023	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI024	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI025$^+$	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI029	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI030$^+$	333	42.2	8,090	450	NA	39.0	1,680	7,240	NA
MI031	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI032	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI035	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI036	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI037	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI038	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI039	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI040	NA	NA	NA	NA	NA	NA	NA	NA	NA
MIO41	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI044	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI045	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI046	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI047	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI048	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI051	NA	101	16,400	1,230	NA	56.7	4,110	5,070	239
MI052	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI053	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 5-34 (Con't)
TAL Inorganics Analytical Results (μg/L) for Unfiltered Groundwater Samples; Northeastern Wells

Sample/Analyte	Al	Ba	Ca	Fe	K	Mn	Mg	Na	Zn
MI057	NA	15.0	4,640	291	3,080	27.9	NA	NA	NA
MI058	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI059	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI060$^+$	805	53.5	5,530	306	185,000	30.3	NA	29,300	NA
MI061	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI071$^+$	3,690	66.7	25,500	2,920	7,190	54.2	NA	NA	NA
MI072	343	293	38,000	7,310	2,260	16,000	14,600	6,510	90.2
MI074	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI075	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI079	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI080	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA Not applicable; analyte not detected above background.

\+ Duplicate sample taken at this well; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

TABLE 5-35
Explosives Analytical Results (μg/L) for Groundwater Samples; Northeastern Wells

Sample/Analyte	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
Certified Reporting Limit*	1.70	2.11	0.600	0.600	0.612	1.20	0.626	0.519	1.10
K-100	16.6	881	760	ND	13.5	ND	56.9	21.9	ND
MI001	1,390	9,990	7,020	ND	ND	ND	759	69.7	428
MI002	3.12	44.3	187	ND	4.98	ND	2.31	1.60	4.73
MI003	ND	ND	ND	ND	ND	ND	.0958	ND	ND
MI004	6.95	22.4	21.3	ND	ND	ND	10.4	ND	ND
MI005	1.91	10.3	10.6	ND	ND	ND	1.88	ND	ND
MI008	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI022	3.41	6.57	32.2	ND	ND	ND	0.946	ND	ND
MI023	ND	ND	ND	ND	ND	ND	0.931	ND	ND
MI024	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI025^{+}	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI029	2.20	ND	ND	ND	ND	ND	16.4	ND	ND
MI030^{+}	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI031	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI032	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI035	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI036	ND	4.12	1.01	ND	ND	ND	ND	ND	ND
MI037	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI038	6.61	323	439	ND	14.1	ND	10.0	3.35	ND
MI039	ND	ND	8.25	ND	ND	ND	ND	ND	ND
MI040	2.45	ND	40.9	ND	1.02	ND	3.68	ND	ND
MI041	ND	ND	4.91	ND	ND	ND	ND	ND	ND
MI044	ND	2.59	ND	ND	ND	ND	ND	ND	ND
MI045	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI046	ND	523	702	ND	18.6	ND	52.0	ND	ND
MI047	ND	21.3	26.2	ND	ND	ND	1.44	ND	ND
MI048	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI051	12.1	382	263	12.2	11.7	ND	31.9	36.2	ND

TABLE 5-35 (Cont'd)
Explosives Analytical Results (μg/L) for Groundwater Samples; Northeastern Wells

Sample/Analyte	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit*								
	1.70	2.11	0.600	0.600	0.612	1.20	0.626	0.519	1.10
MI052	ND	ND	2.51	ND	ND	ND	ND	ND	ND
MI053	ND	ND	1.42	ND	ND	ND	ND	ND	ND
MI057	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI058	1,130	17,600	25,700	ND	216	ND	2,450	66.1	692
MI059	ND	ND	0.951	ND	ND	ND	ND	ND	ND
MI060+	5.37	ND	2.47	ND	1.49	ND	ND	ND	ND
MI061	2.82	ND	ND	ND	ND	ND	ND	ND	ND
MI071+	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI072	ND	5.35	9.47	ND	1.47	ND	ND	ND	ND
MI074	ND	ND	7.06	ND	ND	ND	1.14	ND	ND
MI075	2.86	2.50	1.82	ND	ND	ND	ND	ND	ND
MI079	ND	28.8	1.10	ND	ND	ND	ND	ND	ND
MI080	ND	6.00	ND	ND	ND	ND	ND	ND	ND

ND Not detected above the CRL

\+ Duplicate sample taken at this well; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

* The laboratory reported two different CRLs for each analyte; the larger of the two CRLs is reported in this table. Refer to Appendix L for other CRLs.

** The analyte was present in the sample above the CRL but less than five times the concentration in the associated method blank and should be considered non-detect.

MI046 (screened interval, 157 to 177 feet) than they were at MI047 (screened interval 214.5 feet to 234.5 feet) (523 µg/L, 702 µg/L, and 52.0 µg/L, as compared to 21.3 µg/L, 26.2 µg/L, and 1.4 µg/L, respectively). In addition, 2,4 DNT was detected at 18.6 µg/L at the former well, and not detected at the latter. Several explosive analytes were detected at MI051 (screened interval, 135 to 155 feet) that were not detected at MI023 (screened interval, 30 to 60 feet) including HMX (12.1 µg/L), RDX (381.9 µg/L), TNT (263.2 µg/L), 2,4 DNT (11.7 µg/L), and tetryl 12.2 µg/L). The compound 1,3,5 TNB was detected at 31.9 µg/L at MI051, and at 0.931 µg/L at MI023. These findings suggest that explosives contamination is more severe at the intermediate depth of the aquifer than in the upper and lower depths.

Several explosive analytes were detected at MI038 (screened interval, 118 to 138 feet) that were not detected at MI039, (screened interval, 210 to 230 feet) including RDX (323 µg/L), 2,4 DNT (14.1 µg/L), HMX (6.61 µg/L), 1,3,5 TNB (10.0 µg/L), and 1,3 DNB (3.35 µg/L). The compound 2,4,6 TNT was detected at 439 µg/L at MI038 and at 8.25 µg/L at MI039. Finally, low concentrations of a few explosive compounds were detected at MI040 that were not detected at MI041, including 2,4 DNT (1.02 µg/L), HMX (2.45 µg/L) and 1,3,5 TNB (3.68 µg/L). In addition, TNT was detected at 40.9 µg/L at MI040 and 4.91 µg/L at MI041. These findings suggest that explosives contamination is more severe at the intermediate depth of this aquifer than in the upper and lower depths.

Analytical results were also different for wells within well pairs. Stainless steel well MI075 had detectable concentrations of 2,4,6 TNT (1.82 µg/L), RDX (2.5 µg/L), and HMX (2.86 µg/L), while these compounds were not detected above their CRLs (0.588 µg/L, 2.11 µg/L, and 1.65 µg/L, respectively) in well MI057, which was identical in construction except that it had PVC casing. However, it should be noted that both wells had high initial pH readings which is associated with grout contamination of the well. The high pH could cause a negative bias in the chemical data, such that metals and explosives concentrations could be underestimated, and false non-detects could occur. Stainless steel well MI074 had detectable concentrations of 2,4,6 TNT (7.06 µg/L) and 1,3,5 TNB (1.14 µg/L), while these compounds were not detected above their respective CRLs (<0.588 µg/L and <0.626 µg/L) in either of the two samples drawn from well MI071, which had PVC casing. High pH values were not associated with groundwater samples drawn from these two wells.

Groundwater samples from twenty-eight wells contained detectable amounts of explosives. RDX was detected in seventeen of these samples above the 2 µg/L HA. The concentration range was between 2.50 µg/L and 17,600 µg/L. Forty-one percent of these samples contained RDX above the U.S. Army PDWC (35 µg/L).

Samples drawn from wells MI001 and MI058 contained over 9,000 µg/L of RDX (9,990 µg/L and 17,600 µg/L, respectively). The compound 2,4,6-TNT was detected in samples from 22 wells in this area. Detectable concentrations ranged between 0.951 µg/L and 25,700 µg/L with all but two samples (MI001 and MI058) containing less than 1,000 µg/L of 2,4,6-TNT. Nineteen of the samples collected contained concentrations of 2,4,6-TNT above the HA (2 µg/L) and seven contained concentrations above the U.S. Army PDWC (44 µg/L).

Sixteen samples exhibited detectable concentrations of 1,3,5-TNB. Detectable concentrations ranged from 0.931 µg/L to 2,450 µg/L. Only two of the samples (MI001 and MI058) collected are above the U.S. Army PDWC (200 µg/L). HMX was detected above both the SMCL and the HA in the samples collected from these same two wells. Concentrations of 1,390 µg/L and 1,130 µg/L were detected in samples MI001 and MI058, respectively. The remaining nine samples in which HMX was detected had concentrations of this compound between 1.90 µg/L and 16.6 µg/L.

Nine samples contained detectable concentrations of 2,4-DNT. Eight of these samples had detectable concentrations between 1.02 µg/L and 18.6 µg/L. 2,4-DNT was detected at 216 µg/L in sample MI058. The concentrations of 2,4-DNT found in these samples exceed the 10^{-6} risk level (0.17 µg/L) proposed by the U.S. Army. More samples may be in excess of this risk level; this cannot be determined since the analytical detection limit is above the proposed risk level.

Detectable concentrations of 1,3-DNB range between 1.60 μg/L and 69.7 μg/L. This analyte was detected in six of the samples collected. These six samples contained detectable concentrations of five to six other explosives in addition to 1,3-DNB (K-100, MI001, MI002, MI038, MI051, MI058). Three samples contained detectable levels of nitrobenzene. Two samples, MI001 and MI058, contained concentrations of 428 μg/L and 692 μg/L of nitrobenzene, respectively. The sample drawn from well MI002 contained a concentration of less than 5 μg/L.

The sample drawn from well MI051 contained 12.2 μg/L of tetryl. 2,6-DNT was not detected in any of the samples. However, since the 10^{-6} risk level (0.0068μg/L) proposed by the U.S. Army is less than the analytical detection limit (1.15 μg/L), it cannot be determined whether or not groundwater contains levels of 2,6-DNT above the risk level.

EPA TCL Results

High molecular weigh hydrocarbons found in natural fats and oils were detected in the groundwater samples drawn from wells MI030, MI057, MI060, and MI071 at concentrations less than or equal to 200 μg/L. The appearance of these compounds may be associated with the use of petrolatum. Petrolatum is a purified mixture of semisolid hydrocarbons, chiefly of the alkane series of the general formula C_nH_{2n+2}. It is used for lubricating firearms and machinery, among other things. Chloroform was detected at 0.913 μg/L at well MI071; this concentration is well below regulatory guidelines. Acetone, Bis-2-ethylhexylphthalate, 2-propanol were found at concentrations less than 20 μg/L. The first two compounds may be artifacts or may be site-related; the last compound is considered to be artifact of decontamination procedures.

5.4.2.11 West Central Wells. Two wells exist in this area of MAAP.

Select Metals Results

Select metals other than lead were not detected. Lead levels ranged between 8.3 μg/L and 16.3 μg/L; concentrations of lead are within the site-specific background concentration range, with the exception of the filtered sample from well P-97 which slightly exceeds the level. Select metal results for this group of wells are shown in Table 5-36.

Explosive Analyte Results

No explosives were detected in samples drawn from wells Y-100 and P-97.

5.4.2.12 North Central Wells. Groundwater samples drawn from twenty-one wells were collected in the north central area of MAAP. One recently installed well cluster (wells MI068, MI069, MI070) is within this well group.

Select Metals Results

Select metals results for this group of wells are shown in Table 5-36. There was a significant difference in the analytical results for the three wells within the well cluster. Concentrations of cadmium appeared higher in the sample drawn from well MI070 (screened interval, 240-250 feet) than in samples drawn from wells MI068 (screened interval, 88-98 feet) and MI069 (screened interval, 161-171 feet). Cadmium was detected at 23.7 μg/L (filtered) and 36.8 μg/L (unfiltered) at MI070. Cadmium was detected above CRL (4.01 μg/L) only in the unfiltered sample from MI068 at 16.9 μg/L and was below the CRL in both filtered and unfiltered sample from MI069.

Samples from thirteen of the twenty-one wells in this area were found to have detectable levels of selected metals above site-specific background ranges. Cadmium was detected in nine unfiltered and

TABLE 5-36
Select Metals Analytical Results (μg/L) for Groundwater Samples; West Central Wells and North Central Wells

Sample/Analyte	Cd		Cr		Hg		Pb	
	F	U	F	U	F	U	F	U
	Certified Reporting Limit*							
	4.01	4.01	6.02	6.02	0.243	0.243	1.30	1.30
West Central Wells								
Y-100	ND	ND	ND	ND	ND	ND	8.35	12.1
P-97	ND	ND	ND	ND	ND	ND	13.2	16.3
North Central Wells								
F-100	ND	ND	ND	ND	ND	ND	26.2	37.1
MI009	ND	ND	ND	ND	ND	ND	ND	4.23
MI010	ND	ND	ND	ND	ND	ND	ND	1.52**
MI011	ND	ND	ND	ND	ND	ND	4.23	27.8
MI012	ND	ND	ND	9.43	ND	ND	10.3	2.60
MI013	ND	ND	ND	ND	ND	ND	ND	2.82
MI014+	ND	ND	ND	156	ND	0.363	1.74	53.8
MI026	ND	ND	ND	ND	ND	ND	1.52	1.84
MI027	ND	ND	ND	ND	0.416	ND	ND	3.36**
MI028	ND	ND	ND	ND	ND	ND	4.45**	3.25**
MI033	ND	ND	ND	ND	ND	ND	ND	ND
MI034	ND	ND	ND	6.66	ND	ND	1.63	26.0
MI049+	81.8	87.1	ND	ND	ND	ND	1.74	16.3
MI050	11.1	25.2	ND	ND	ND	ND	2.71	21.5
MI055	ND	6.63	ND	9.86	ND	ND	1.52	9.11
MI056+	6.06	13.6	ND	ND	ND	ND	2.93	8.57
MI068+	ND	16.9	ND	11.3	ND	0.200	7.42	13.8**
MI069	ND	ND	ND	6.38	ND	ND	ND	4.66
MI070	23.7	36.8	ND	7.21	ND	ND	ND	8.89
X-100	ND	ND	ND	ND	0.283	ND	4.34	10.5

ND Not detected above the CRL.
F Filtered
U Unfiltered
\+ Duplicate sample taken at this well; Where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.
* The laboratory reported two different CRLs for each analyte; the larger of the two CRLs is reported in this table. Refer to Appendix L for other CRLs.
** The analyte was present in the sample above the CRL but less than five times the concentration in the associated method blank and should be considered non-detect.

six of the respective filtered samples from six wells. Concentrations ranged between 6.63 μg/L and 87.1 μg/L for unfiltered samples and 6.06 μg/L and 81.8 μg/L for filtered samples. All concentrations exceed the Federal MCL (5 μg/L).

Chromium was detected in seven unfiltered samples from eight wells. All but one of the wells had chromium concentrations below 10 μg/L. Sample MI014 was sampled twice and contained 132 μg/L in one sample and 178 μg/L in the second. These samples exceed both the 50 μg/L State groundwater standard and the 100 μg/L Federal MCL. Chromium was not detected in the corresponding filtered samples for these six wells.

Five samples collected from four wells contained between 0.2 μg/L and 0.42 μg/L of mercury. Three were from unfiltered samples (two from MI014 and one from MI068) and two were from filtered samples (MI027 and X-100). The levels represented are below State and Federal guidelines.

Lead was detected in the unfiltered samples from all wells and in the filtered samples from all but seven wells. Ranges are within site-specific background concentrations with the exception of four samples collected from three wells. Samples from MI011, MI014 and MI034 contained lead ranging between 26.0 μg/L and 60.0 μg/L. The unfiltered sample drawn from MI014 had the highest lead concentration (60.0 μg/L), exceeding the federal MCL for lead (50 μg/L).

EPA TAL Metals

Six wells within this well group had samples analyzed for the full EPA TAL/TCL scan. Each of these six wells had manganese concentrations exceeding the State of Tennessee Public Water Supply Standards, and two of the wells had iron concentrations exceeding this standard. Numerous other analytes were detected above background at the various wells. These are listed by well in Table 5-37.

Explosive Analytes Results

Explosive analytical results for this group of wells are shown in Table 5-38. Analytical results for explosive analytes were significantly different for well cluster wells MI068, MI069, MI070. No explosive analytes were detected in the sample drawn from well MI068; while 2,4,6 TNT, RDX, and 2,4 DNT were detected at MI069 (4.53 μg/L, 11.7 μg/L, and 1.01 μg/L, respectively). Four compounds were detected at well MI070. 2,4,6 TNT was detected at 12.4 μg/L, RDX at 34.4 μg/L, HMX at 1.97 μg/L, and 1,3,5 TNB at 0.917 μg/L. These data suggest that there may be more significant groundwater contamination by explosives in the middle and lower portions of the aquifer in this part of the installation. However, it should be noted that high initial pH readings were obtained for all of these wells, due to grout contamination. This may be responsible for an underestimation of explosives concentrations at these wells.

Explosives were detected in samples drawn from ten of the wells within this group. 1,3,5-TNB was detected in five samples with concentrations ranging from 0.917 μg/L to 14.7 μg/L. Five samples (drawn from wells MI010, MI050, MI066, MI069 and MI070) had detectable concentrations of RDX. All samples contained less than 35 μg/L RDX, the US Army PDWC, except for MI010 which had 165 μg/L. None of the other four samples had concentrations below the 2 μg/L HA.

The compound 2,4,6-TNT was detected in six samples (drawn from wells MI010, MI049, MI055, MI056, MI069, MI070). Levels detected in all but one sample (MI066) were below the U.S. Army PDWC (44 μg/L). Half of the samples were above the HA (2 μg/L). HMX concentrations found in three samples (MI010, MI014, MI070) ranged between 1.80 μg/L and 32.2 μg/L. This range is above site-specific background concentrations but well below the SMCL (300 μg/L) and HA (400 μg/L).

The compound 2,4-DNT was detected in sample MI069 at 1.01 μg/L. This level is above the 10^{-6} risk level proposed by the US Army. Samples collected from other wells may also contain concentrations

TABLE 5-37
TAL Inorganics Analytical Results (μg/L) Above Background For Unfiltered Groundwater Samples; West Central and North Central Wells

Sample/Analyte	Al	Ba	Ca	Co	Cu	Fe	K	Mn	Mg	Na	Ni	V*	Zn
West Central Wells													
Y-100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
P-97	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
North Central Wells													
F-100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI009	1,550	NA	NA	NA	NA	2,170	NA	NA	NA	NA	NA	NA	NA
MI010	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI013	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI014^{+}	240,000	557	14,950	62.8	109	181,000	7,250	1,470	10,700	7,520	101	273	271
MI026	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI027	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI028	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI033	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 5-37 (Con't)
TAL Inorganics Analytical Results (μg/L) Above Background For Unfiltered Groundwater Samples; West Central and North Central Wells

Sample/Analyte	Al	Ba	Ca	Co	Cu	Fe	K	Mn	Mg	Na	Ni	V[*]	Zn
North Central Wells (con't)													
MI034	5,120	41.1	2,550	NA	NA	8,050	NA	182	NA	NA	NA	NA	NA
MI049[+]	NA	19.4	4,065	NA	NA	384	NA	51.1	NA	NA	NA	NA	91.4
MI050	NA	100	53,400	NA	22.5**	1,150	NA	57.4	NA	NA	NA	NA	50.9
MI055	6,310	78.2	11,630	NA	NA	7,430	2,290	115	2,630	5,650	NA	NA	NA
MI056[+]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI068[+]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MI069	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MIO70	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
X-100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA Not applicable; analyte not detected above background.

* Concentration is for filtered sample.

** The analyte was present in the sample above the CRL but less than five times the concentration in the associated filter blank and should be considered non-detect.

\+ Duplicate sample taken was taken at this well; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

TABLE 5-38
Explosives Analytical Results (μg/L) for Groundwater Samples; West Central Wells and North Central Wells

Sample/Analyte	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit*								
	1.70	2.11	0.600	0.600	0.612	1.20	0.626	0.519	1.10
West Central Wells									
Y-100	ND	ND	ND	ND	ND	ND	ND	ND	ND
P-97	ND	ND	ND	ND	ND	ND	ND	ND	ND
North Central Wells									
F-100	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI009	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI010	32.2	165	37.1	ND	ND	ND	ND	ND	ND
MI011	ND	ND	ND	ND	ND	ND	3.86	ND	ND
MI012	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI013	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI014+	1.80	ND	ND	ND	ND	ND	14.7	ND	ND
MI026	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI027	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI028	ND	ND	ND	ND	ND	ND	3.43	ND	ND
MI033	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI034	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI049+	ND	ND	1.10	ND	ND	ND	ND	ND	ND
MI050	ND	23.6	ND	ND	ND	ND	2.26	ND	ND
MI055	ND	ND	1.24	ND	ND	ND	ND	ND	ND
MI056+	ND	ND	0.843	ND	ND	ND	ND	ND	ND
MI068+	ND	ND	ND	ND	ND	ND	ND	ND	ND
MI069	ND	11.7	4.53	ND	1.01	ND	ND	ND	ND
MI070	1.97	34.4	12.4	ND	ND	ND	0.917	ND	ND
X-100	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND Not detected above the CRL
\+ Duplicate sample taken at this well; Concentrations are represented as the average of the two samples.
* The laboratory reported two different CRLs for each analyte; the larger of the two CRLs is reported in this table. Refer to Appendix L for other CRLs.

of 2,4-DNT and 2,6-DNT above this proposed level; however, existing detection limits preclude obtaining this information. Nitrobenzene, 1,3-DNB, 2,6-DNT, and tetryl were not detected above their respective CRLs in any of the samples collected in this area.

EPA TCL Results

High molecular weight hydrocarbon compounds (C15-C21), which are components of natural fats and oils, were found in samples drawn from wells MI009, MI034, MI050, and MI055 at concentrations of less than 30 μg/L. Bromacil was also detected at well MI014 at 10 μg/L. The Drinking Water Health Advisory for Lifetime Exposure for this compound is 90 μg/L. The use of this herbicide at MAAP has been documented (USATHAMA, 1978). In the year 1977, 9,392.3 gallons of bromacil was used and applied in open areas. Bis-2-ethylhexylphthalate was also detected at the latter three wells at concentrations less than 30 μg/L, and may be a laboratory artifact, or may be site-related.

5.4.3 Surface Water Samples

The results obtained from the chemical analyses of surface water samples are presented and discussed in this section. The samples were collected from both the ditch drainageways and the major and minor streams on or downgradient from MAAP. Also, this section includes a comparison of concentrations of explosives and select heavy metals detected in the surface water in this study with the concentrations detected in an earlier environmental study (USATHAMA, 1982a); TAL/TCL analyses were not performed in the USATHAMA (1982a) investigation.

5.4.3.1 Regulatory Criteria. The State of Tennessee has proposed surface water criteria for the protection of aquatic life. These levels represent toxicity values for streams and rivers which are designated by the Tennessee Water Quality Control Board as being supportive of aquatic life. The Rutherford Fork of the Obion River and Wolf Creek are listed as Class IV waters, and so these criteria may be applicable requirements. Since they are classified as supporting human recreation, the Federal criteria for protection of human health (ingestion of fish) may also be applicable requirements. These proposed criteria are listed in Table 10-2. The contaminant concentrations in surface water samples taken from the Rutherford Fork and Wolf Creek were compared to these values.

The ditches in the drainage system do not fall under these criteria because they cannot be considered rivers or streams; however, the ditches may qualify as "wet weather conveyances" under the State of Tennessee proposed Rules. The facility's existing NPDES permit limits for nitrobodies (1,000 μg/L total concentration) were used as potentially applicable requirements for explosives in the ditches.

5.4.3.2 Background Sample. Sample RVER-2 was collected upstream of the confluence with Johns Creek, which is outside of the area that could potentially be impacted by facility activities. The results of the chemical analysis of RVER-2 indicate that the background concentrations of explosive compounds and select metals are not detectable using the laboratory methods employed. Therefore, any detectable concentration of these analytes was considered to be above the background concentration in this study. The only analytes that appeared above the CRL are common geochemical parameters: aluminum, barium, calcium, iron, potassium, manganese, magnesium, and sodium. These concentrations are listed in Table 5-39. These levels were considered to be background values; all other surface water samples were compared to twice this background level or to twice the detection limit for those compounds not detected in sample RVER-2.

5.4.3.3 Rutherford Fork of the Obion River. Two samples were taken from the Rutherford Fork of the Obion River near the reservation boundary. Sample RVER-1 was collected downstream of the confluence of Ditch C and the Rutherford Fork. The sample location is in an area which, according to the groundwater contours, is receiving groundwater discharge along flowlines which pass through disposal areas on the facility. The purpose of RVER-1 is to determine if water quality is being degraded by

TABLE 5-39
Inorganics Background Concentrations ($\mu g/L$) for Surface Water

ANALYTE	BACKGROUND CONCENTRATION
Ag	0.500[a]
Al	282[a]
As	5.08[a]
Ba	39.6[b]
Ca	4,200[b]
Cd	8.02[a]
Cr	12.0[a]
Co	50.0[a]
Cu	16.2[a]
Fe	1,114[b]
Hg	0.486[a]
K	3,380[b]
Mg	2,080[b]
Mn	462[b]
Na	6,680[b]
Ni	68.6[a]
Pb	2.52[a]
V	7.64[a]
Zn	42.2[a]

[a] Background concentration based on two times the detection limit; this analyte was not detected in the background sample RVER-2.

[b] Background concentration based on two times the concentration detected in the background sample RVER-2.

surface water and groundwater flow from the facility. RVER-2 was collected to provide background information of water quality.

No explosive compounds were detected above the CRL in sample RVER-1. However, this sample had a lead concentration of 3.04 μg/L. This value exceeds the proposed surface water fish and water life chronic criterion for lead of 1.3 μg/L at 50 mg/L hardness. However, lead was also detected in the sediment samples taken at the same location. Because surface water samples were not filtered, the lead in the surface water sample may be due to sediment particles which entered the sample containers.

Surface water sample RVER-1 also contained concentrations of other TAL inorganics, including Al, Ba, Ca, Fe, K, Mg, Mn, and Na. Only aluminum exceeds twice the background concentration detected in sample RVER-2; sample RVER-1 contained an average of 452 μg/L Al. (Sample RVER-1 was collected twice due to laboratory error in the BNA analysis. The laboratory has provided two sets of TAL data.)

The concentrations of calcium and manganese in sample RVER-1 were used to calculate the hardness of the water. The following equation was used (Sawyer and McCarty, 1978):

$$\text{hardness (mg/L) as } CaCO_3 = M^{2+} \times 50/\text{eq. wt. of } M^{2+}$$

where M^{2+} is the concentration of a divalent cation in mg/L.

This calculation results in a water hardness of 10 mg/L as $CaCO_3$. This is considered normal for a region in the Coastal Plain physiographic province. No volatile or semivolatile constituents were detected above the CRL in samples RVER-1 or RVER-2.

5.4.3.4 Johns Creek. A surface water sample was collected north (downstream) of the confluence of Ditch 6 with Johns Creek. The explosive compounds and heavy metals were not detected at this location. The concentrations of the geochemical parameters (TAL inorganics) do not exceed twice the background level, with the exception of sodium (9,720 μg/L). The presence of 10.0 μg/L of 2-propanol detected in sample CREK-3 is attributed to field contamination; the concentration is qualified as undetected since the concentration is less than five times the value detected in the associated trip blank (refer to Section 6 - Quality Assurance/Quality Control). Toluene was also detected in CREK-3 at low concentrations (0.745 μg/L). The surface water sample from this creek did not contain any semivolatile constituents above the CRL.

These results indicate that this surface water body is not currently being significantly impacted by on-site activities. This implies that conditions have improved since 1981, when a surface water sample taken in Johns Creek north of the confluence with Halls Branch was determined to have an RDX concentration of 0.8 μg/L. However, the fact that this contaminant was not detected may be due to increased dilution which occurred because of a change in the drainage patterns or a larger amount of rain prior to sampling.

5.4.3.5 Ditches B and C. Two rounds of surface water samples were collected in these ditches. The first round of samples was collected in early August 1990 during a dry period. Upstream of the WCOP sewage treatment plant, Ditch C was flowing at a very low flow rate through a narrow channel. Downstream of the treatment plant, Ditch C was flowing at a higher rate due to discharge from the plant. Ditch B was not flowing during this time period, so surface water samples were taken from pools of standing water.

The second round of surface water samples was taken in early September during a light rainstorm. Both ditches were flowing when the samples were collected. Therefore, these samples most likely consisted of recent runoff from the drainage areas.

The results of the chemical analyses of these samples indicate that both ditches are contaminated with low levels of explosive compounds and heavy metals (refer to Tables 5-40 and 5-41). However, the total concentration of nitrobodies does not exceed the NPDES permit limit at any location.

During the first round of sampling, the explosive compounds were detected in Ditch C at concentrations ranging from 1.97 to 18.70 μg/L total nitrobodies. Nitrobodies were detected at every sample location. The second round of sampling consisted of taking samples from two of the four previous locations. These samples had concentrations of total nitrobodies of 32.43 and 44.85 μg/L, which is roughly twice the concentrations detected during the first round of sampling at these locations. A wide variation in contaminant concentrations may be expected in these ditches because of the intermittent discharge from the PWTFs and the precipitation-controlled flow rates in the ditches.

The explosive compounds detected in the first round of Ditch C sampling are HMX, RDX, and 2,4-DNT, at maximum concentrations of 3.58, 15.5, and 1.11 μg/L, respectively. The results from the second round of sampling indicate that only HMX and RDX were present in the ditch at concentrations above the CRL. The maximum concentrations of these contaminants were 7.75 and 37.1 μg/L, respectively.

Of the select metals, only mercury and lead were detected in Ditch C during the first round. Mercury was detected once at 0.283 μg/L and lead was detected at 3 of the 4 locations, with a maximum concentration of 10.5 μg/L. During the second round of sampling, lead was detected in one location at a concentration of 3.15 μg/L. The other select metals were not present in the samples above their respective CRLs.

The maximum concentration of total nitrobodies detected in Ditch B was 1.79 μg/L during the first round of sampling, and 31.2 μg/L during the second round of sampling. These concentrations are well below the NPDES permit limits for discharge from the PWTFs.

The results from the first round of sampling indicate that HMX and tetryl were present in the surface water from Ditch B at maximum concentrations of 1.79 and 0.848 μg/L, respectively. The concentrations of explosive compounds in Ditch B were higher during the second round of sampling. HMX was detected at 3.65 μg/L and RDX was present at 27.5 μg/L.

The only select metal detected in samples collected during the first round of sampling Ditch B is lead, which was present at every sample location at concentrations ranging from 1.74 to 13.4 μg/L. During the second round, lead was detected at a concentration of 1.74 μg/L in one location. The other heavy metals were not present in the sample above their respective CRLs.

Since Ditches B and C are the major drainageways for effluent from the PWTFs to the Rutherford Fork, the contaminant levels detected in these ditches indicate the present loading via surface water to this discharge point. The chemical results indicate that the amount of explosive compounds reaching the Rutherford Fork are very small and well within the permit limits.

In general, the results described above correspond well with the surface water sampling performed in 1981 (USATHAMA, 1982a). During that sampling event, TNT and RDX were detected at low concentrations (between 1.3 and 15 μg/L) in Ditches B and C. Metals were not detected in these two ditches because of the relatively high detection limits.

Four samples (DTCHB-1 and 3, and DTCHC-1 and 3) from Ditches B and C were collected and analyzed for TAL metals during the first round of sampling. During the Round 2 sampling event, samples DTCHB-2 and 4, and DTCHC-1 and 3 were collected from Ditches B and C, respectively, and analyzed for TAL inorganics. TAL inorganics exceeding twice the concentration of background were found in samples from both Round 1 and Round 2. Analytes of concern include Ag (Ditch C only), As (Ditch B only), Al, Ba, Ca, Fe (Ditch B only), K, Mg, Mn (Ditch B only), and Na. Table 5-42 lists these concentrations. Binding agents and lubricants such as magnesium stearate (tetryl) and barium stearate (RDX)

TABLE 5-40
Select Metals Analytical Results (μg/L) for Surface Water

Sample/Analyte	Cd-U	Cr-U	Hg-U	Pb-U
	Certified Reporting Limit			
	4.01	6.02	0.243	1.26
Rutherford Fork, Obion River				
RVER-1⁺	ND	ND	ND	3.04
RVER-2	ND	ND	ND	ND
Johns Creek				
CREK-3	ND	ND	ND	ND
Ditch B				
DTCHB-1	ND	ND	ND	13.4
DTCHB-2(1)	ND	ND	ND	6.40
DTCHB-2(2)	ND	ND	ND	1.74
DTCHB-3	ND	ND	ND	1.74
DTCHB-4(1)	ND	ND	ND	6.62
DTCHB-4(2)	ND	ND	ND	ND
Ditch C				
DTCHC-1(1)	ND	ND	ND	2.17
DTCHC-1(2)	ND	ND	ND	ND
DTCHC-2⁺	ND	ND	ND	ND
DTCHC-3(1)	ND	ND	0.283	1.41
DTCHC-3(2)	ND	ND	ND	3.15
DTCHC-4	ND	ND	ND	10.5
Ditches 1-10				
DTCH1-1	ND	33.3	ND	73.5
DTCH1-2	ND	12.4	0.283	15.8
DTCH2-2	ND	6.04	ND	11.1
DTCH2-3	ND	8.08	ND	5.42
DTCH4-2	ND	9.90	ND	8.03
DTCH4-3(1)	ND	ND	ND	5.64
DTCH4-3(2)	ND	ND	ND	1.52
DTCH4-4	ND	ND	ND	ND
DTCH5-2	6.00	61.5	ND	141
DTCH5-3	ND	ND	ND	5.21
DTCH6-1	ND	ND	ND	2.49
DTCH6-2	ND	ND	ND	4.01
DTCH7-6⁺	ND	ND	ND	4.23
DTCH8-3	ND	ND	ND	3.04
DTCH10-3A	ND	29.7	ND	47.7
DTCH10-6	ND	ND	ND	2.06

ND Not detected above the CRL;
U Unfiltered sample.
(1) Sample collected during Round 1 sampling event.
(2) Sample collected during Round 2 sampling event.
\+ Duplicate sample taken; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

TABLE 5-41
Explosives Analytical Results (μg/L) for Surface Water

Sample/Analyte	HMX	RDX	2,4,6-TNT	Tetryl	2,4-DNT	2,6-DNT	1,3,5-TNB	1,3-DNB	NB
	Certified Reporting Limit								
	1.70	2.10	0.600	0.600	0.600	1.20	0.600	0.500	1.10
Rutherford Fork, Obion River									
RVER-1⁺	ND	ND	ND	ND	ND	ND	ND	ND	ND
RVER-2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Johns Creek									
CREK-3	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ditch B									
DTCHB-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCHB-2(1)	ND	ND	ND	0.848	ND	ND	ND	ND	ND
DTCHB-2(2)	ND	4.68	ND	ND	ND	ND	ND	ND	ND
DTCHB-3	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCHB-4(1)	1.79	ND	ND	ND	ND	ND	ND	ND	ND
DTCHB-4(2)	3.65	27.5	ND	ND	ND	ND	ND	ND	ND
Ditch C									
DTCHC-1(1)	3.58	13.5	ND	ND	ND	ND	ND	ND	ND
DTCHC-1(2)	5.63	26.8	ND	ND	ND	ND	ND	ND	ND
DTCHC-2⁺	3.56	20.15	ND	ND	ND	ND	ND	ND	ND
DTCHC-3(1)	2.09	15.0	ND	ND	1.11	ND	ND	ND	ND
DTCHC-3(2)	7.75	37.1	ND	ND	ND	ND	ND	ND	ND
DTCHC-4	1.97	ND	ND	ND	ND	ND	ND	ND	ND
Ditches 1-10									
DTCH1-1	ND	4.92	ND	ND	ND	ND	ND	ND	1.80
DTCH1-2	3.50	14.7	ND	ND	ND	ND	ND	ND	2.63
DTCH2-2	1.79	14.6	ND	ND	ND	ND	ND	ND	2.83
DTCH2-3	ND	ND	ND	ND	ND	ND	ND	ND	3.79
DTCH4-2	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH4-3(1)	3.88	ND	ND	ND	ND	ND	ND	ND	ND
DTCH4-3(2)	4.79	4.88	ND	ND	ND	ND	ND	ND	ND
DTCH4-4	2.40	4.30	ND	ND	ND	ND	ND	ND	ND
DTCH5-2	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH5-3	ND	ND	ND	ND	ND	ND	ND	ND	1.91
DTCH6-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH6-2	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH7-6⁺	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH8-3	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH10-3A	40.8	306	11.3	ND	0.764	ND	1.84	ND	ND
DTCH10-6	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND	Not detected above the CRL.
F	Filtered sample
U	Unfiltered sample
(1)	Sample collected during Round 1 sampling event.
(2)	Sample collected during Round 2 sampling event.
+	Duplicate sample taken; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

TABLE 5-42
TAL Inorganics Detected In Surface Water Samples Above Background (µg/L) ; Ditches B, C, and 1-10

Sample/Analyte	Ag	Al	As	Ba	Ca	Co	Cu	Fe	K	Mg	Mn	Na	Ni	V	Zn
Ditches B and C															
DTCHB-1	NA	886	5.76	935	19,500	NA	NA	44,100	NA	6,180	19,300	7,000	NA	NA	NA
DTCHB-2	NA	4,190	NA	247	11,100	NA	NA	3,620	6,710	2,560	NA	NA	NA	NA	NA
DTCHB-3	NA	4,970	5.44	193	7,520	NA	NA	3,060	5,890	NA	NA	NA	NA	NA	NA
DTCHB-4(2)	NA	3,200	NA	1,210	22,600	NA	NA	2,210	7,060	6,380	NA	NA	NA	NA	NA
DTCHC-1(1)	3.17	352	NA	40.3	13,100	NA	NA	NA	6,570	NA	NA	44,500	NA	NA	NA
DTCHC-1(2)	8.19	611	NA	56.0	12,600	NA	NA	NA	5,600	2,180	NA	18,900	NA	NA	NA
DTCHC-3(1)	4.63	529	NA	NA	17,400	NA	NA	NA	8,770	NA	NA	50,300	NA	NA	NA
DTCHC-3(2)	13.3	652	NA	NA	14,300	NA	NA	NA	5,490	NA	NA	24,200	NA	NA	NA
Ditches 1-10															
DTCH1-1	NA	59,500	16.8	792	19,700	51.5	53.3	56,500	13,600	9,410	7,170	NA	NA	158	229
DTCH1-2	NA	29,700	25.8	331	10,900	NA	NA	25,300	21,100	4,250	2,780	NA	NA	58	85.7
DTCH2-2	NA	13,700	19.4	175	7,170	NA	NA	12,300	13,700	2,850	1,930	NA	NA	42.5	101
DTCH2-3	NA	15,800	9.06	199	6,440	NA	NA	10,800	11,100	2,380	NA	NA	NA	24.0	45.2
DTCH4-2	NA	17,600	7.36	106	NA	NA	18.8	15,700	4,070	2,090	NA	34,500	NA	27.7	NA
DTCH4-3(1)	NA	485	NA	112	34,900	NA	NA	1,050	NA	3,300	1,870	18,400	NA	NA	NA
DTCH4-3(2)	NA	825	NA	160	13,000	NA	NA	2,940	4,950	3,220	1,380	13,700	NA	NA	NA
DTCH4-4	NA	1,160	NA	57.6	11,800	NA	NA	NA	7,300	2,390	NA	13,900	NA	NA	NA
DTCH5-2	NA	112,000	15.2	4,940	15,200	76.6	76.0	117,000	13,700	10,900	6,100	27,800	87.7	207	329
DTCH5-3	NA	7,490	16.2	105	11,900	NA	27.2	10,100	5,320	2,990	3,210	NA	NA	18.4	NA
DTCH6-2	NA	334	NA	44.6	NA	NA	NA	NA	NA	NA	NA	8,110	NA	NA	NA
DTCH7-6^{+}	NA	2,290	NA	97.2	6,840	NA	NA	1,610	13,100	2,300	NA	NA	NA	NA	NA
DTCH8-3	NA	3,680	52.2	69.4	8,210	NA	23.0	3,420	5,070	2,850	479	NA	NA	10.7	NA
DTCH10-3A	NA	45,900	6.40	236	NA	NA	224	35,500	3,860	3,990	959	NA	NA	59.6	465
DTCH10-6	NA	3,630	NA	95.4	6,240	NA	NA	2,680	10,800	NA	NA	NA	NA	NA	NA

(1)	Round 1 sampling event
(2)	Round 2 sampling event
NA	Not applicable; this analyte was not detected above background level.
+	Duplicate sample taken; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

were often added to the explosives, as well as fuels such as aluminum and iron to increase the heat of reaction (U.S. Department of the Army, 1984), and may account for the high concentration of inorganics detected in the surface water. Arsenic may have been contributed to the system via organic arsenicals which have been applied to vegetation for use as a herbicide at MAAP (USATHAMA, 1978). High concentrations of arsenic may also be attributed to the analysis of unfiltered samples which may have held a large amount of suspended solids. Surface water samples collected from Ditch B during Round 2 tended to contain higher concentrations of TAL inorganics than those collected from Round 1 of sampling; higher concentrations in Round 2 sampling are consistent with the characteristics of the ditch at the time of sampling. The high rate of flow during Round 2 sampling, as opposed to the dry period during Round 1 sampling, resulted in an increased suspension capacity in the ditch.

Volatile organic compounds were detected in the two samples in Ditch C located downgradient of the sewage treatment plant. Sample DTCHC-3 contained concentrations of several bromomethanes; dibromochloromethane (25.5 and 11.2 µg/L) and bromodichloromethane (3.04 and 2.35 µg/L) were detected during the first and second rounds of sampling. Bromoform was also detected in sample DTCHC-3 in the first round of sampling at a concentration of 33.33 µg/L and during the second round of sampling at 73.1 µg/L. These compounds are breakdown products of tetrabromomethane, a compound which is light-sensitive and has been used in photography and photoduplicating systems (Mark et al., 1985). D-Line, which lies just southeast of the sewage treatment plant, formerly operated a photographic laboratory. The RCRA Facility Assessment Report MAAP (USEPA, 1986d) specifies that the former photography lab probably discharged spent solutions to surface drainage. In addition, Lines V, K, C, and the current laboratory in Line T discharge their waste water to the sewage treatment plant. The detection of bromomethane compounds in sample DTCHC-3, located at the mouth of the sewage treatment plant, is attributed to waste produced by the photography labs. Low levels of 2-propanol (10 µg/L) were also found in sample DTCHC-1. Samples from Ditch B contained no concentrations of volatile organic compounds above the respective CRLs.

Two semivolatile compounds were detected in Ditch C, samples DTCHC-1 and DTCHC-3. Di-N-octyl phthalate (DOP) was detected in Round 2 sampling of DTCHC-1 at a concentration of 31.3 µg/L. Diethyl phthalate was detected in Round 1 sampling of location DTCHC-1 (185 µg/L) and Round 2 sampling of DTCHC-3 (19.7 µg/L). Contamination by these plasticizers appears to be directly related to activities at Line B. RDX arrived upon site to Line B as a slurry with acetic acid enclosed in plastic bags. Facility personnel are unaware of the procedure for disposal of the bags, and suggest that the bags may have been discharged to the ditches. Ditch C, which drains Line B, is precisely the area of phthalate contamination. DOP is also a constituent of Type I Plastic Bonded Explosives (PBX) which contain 90% RDX, 8.5% polystyrene and 1.5% DOP; use of DOP in this operation may account for the low levels detected in the surface water. No semivolatile compounds were detected above the CRL in surface water samples collected from Ditch B.

5.4.3.6 Ditches 1 Through 10. Explosive compounds in surface water were detected in Ditches 1, 2, 4, 5, and 10 (refer to Table 5-41). The Line A and Line X PWTFs discharge into Ditch 2, which becomes Ditch 1 before flowing into Wolf Creek. The Line B PWTF discharges into Ditch 4 and the Line D PWTF discharges into Ditch 5. These outfalls account for the presence of explosives in these ditches. The surface water sample collected from Ditch 10, which had detectable amounts of nitrobodies, was taken from a large pool of standing water in the ADA. This sample had a total nitrobodies concentration of 361 µg/L.

The explosive compounds detected in these surface water samples were 2,4-DNT (0.764 µg/L), HMX (maximum concentration of 40.8 µg/L), nitrobenzene (maximum concentration of 3.79 µg/L), RDX (maximum concentration of 306 µg/L), 1,3,5-TNB (1.84 µg/L), and 2,4,6-TNT (11.3 µg/L).

The select metals of concern were detected in Ditches 1, 2, 4, 5, 6, 7, 8, and 10 (refer to Table 5-40). Because these surface water samples were taken from standing pools of water, the samples tended to be somewhat turbid. Sediment particles from the ditch walls may be expected to contribute small amounts of lead and other metals to the samples. Lead was the most commonly detected contaminant, and appeared in samples at concentrations ranging from non-detect to 141 μg/L. Mercury was detected at only one location: 0.283 μg/L in sample DTCH1-2. Cadmium was also detected only once in sample DTCH5-2 at 6.00 μg/L. Chromium was detected in seven samples at concentrations ranging from 6.04 to 61.5 μg/L.

These findings for explosives correspond well to the results of the 1982 USATHAMA study (1982a), in which surface water samples were taken from Ditches 1 through 9. The USATHAMA report indicates that the surface water in the ditches was contaminated with low levels of RDX, TNT, and 2,4-DNT. The highest levels were detected in samples taken from Ditch 9, where the RDX concentration was 110 μg/L and the 2,4-DNT concentration was 0.26 μg/L. Ditch 10 drains into Ditch 9, which was dry during the surface water sampling conducted in 1990. Also in 1981, lead was detected in two locations in Ditch 10 at 349 and 233 μg/L, and chromium was detected in one location at 177 μg/L. Therefore, metals contamination in surface water appears to have greatly decreased from 1981 to 1990.

Ditches 1-10 contained concentrations of TAL metals above background, as listed in Table 5-42. Analytes of concern include As, Al, Ba, Ca, Co, Cu, Fe, K, Mg, Mn, Na, Ni, V, and Zn. The five most contaminated samples were collected in areas adjacent to major features of MAAP: samples DTCH1-1 and DTCH1-2 were collected downgradient of Outfall 006 discharging from X-Line; sample DTCH5-2 was collected from the Outfall 005 discharging from O-Line; sample DTCH8-3 was collected in the major drainage ditch for the Open Landfill; and sample DTCH10-3A was collected from the major drainage ditch for the ADA. Aluminum, barium, and magnesium were the TAL constituents most frequently detected above background concentrations. The occurrence of these elements at elevated levels may be due to disposal of wastes associated with explosives manufacture or production. Binding agents and lubricants such as magnesium stearate (tetryl) and barium stearate (RDX) were often added to the explosives, as well as fuels such as aluminum and iron to increase the heat of reaction (Department of the Army, 1984). High concentrations of inorganics may be attributable to these additives, although no details regarding use of inorganics at these areas is available. Concentrations of As up to 52.2 μg/L may have been contributed to the system via use of organic arsenicals as herbicides (USATHAMA, 1978). High concentrations are also attributable to the analysis of unfiltered samples which may have held a large amount of suspended solids.

Ditch 2 and Ditches 4-8 contained concentrations of volatile organic compounds above their respective CRLs. These compounds were not detected in the corresponding sediment samples. Low concentrations of organic cleaning solvents were detected in samples from Ditches 2, 5, and 8 as follows: 1,1,2-Trichloroethane (7.00 and 6.0 μg/L in samples DTCH2-3 and DTCH5-2), 1,1,2,2-tetrachloroethane (5.00 μg/L in sample DTCH2-3), and trichloroethylene (1.81 μg/L in sample DTCH8-3). Low concentrations of carbon disulfide were detected in samples DTCH4-3 and DTCH8-3 at 1.13 and 1.36 μg/L, respectively. Carbon disulfide is employed as a brightening agent in electroplating baths for deposition of chromium and zinc, and as corrosion protection in treatment of metals for wear resistance (Mark et al., 1980). Electroplating operations at K-line may have contributed carbon disulfide to the system. Sample DTCH4-3 is located just west of K-Line. Carbon disulfide detection in sample DTCH8-3 is most probably a result of sludge from the electroplating process disposed of in the OBG; Ditch 8 drains the OBG. Low levels of 2-propanol were found in DTCH5-3 and DTCH6-1 at concentrations of 19.0 and 30.0 μg/L, respectively and acetone was detected in DTCH5-3 at a concentration of 15.4 μg/L.

One semivolatile compound was detected in samples from Ditches 4 and 7. Samples DTCH4-3 and DTCH7-6 each contained 5.00 μg/L 2-cyclohexen-1-one. The RDX arrived at MAAP as an RDX-acetic acid slurry; 2-cylcohexen-1-one is used to recrystallize the RDX after it is filtered and water washed (Mark et al., 1980). The 2-cyclohexen-1-one detected in samples DTCH4-3 and DTCH7-6 most probably originated from Lines B, C and D.

5.4.4 Sediment Samples

The results of the chemical analyses of sediment samples collected are presented in this section. One hundred fifty-two samples were collected from seventy-three sample locations. Samples were analyzed for either the full Target Compound List and Target Analyte List (TCL/TAL) and explosives or for selected metals that are associated with explosives production (cadmium, chromium, lead, and mercury) and explosives. Select metals and TAL constituent results are presented first, followed by explosive analytes and TCL constituents, if applicable. To facilitate the presentation of data, results are presented for samples collected from groups of streams or ditches. Groups were determined based on geographic location or nearby upstream contaminant source areas.

5.4.4.1 Regulatory Criteria. Regulatory limits for contaminant concentrations in sediment have not been established. Therefore, the results of the sampling were only compared to the range of values observed in the background sediment samples. For select metals and EPA TAL constituents, a chemical concentration in a sediment sample was said to be "above background" if it was detected at a concentration greater than the highest value shown for that chemical among the three background samples. For explosive analytes and EPA TCL constituents, the "background" concentration is assumed to be zero.

5.4.4.2 Discussion of Results. To facilitate the presentation, results are presented for sediment samples collected from streams and/or ditches by geographic region or contaminant source. Results are first presented for the background samples, followed by samples collected from the Rutherford Fork of the Obion River and Wolf Creek, followed by Johns Creek and Halls Branch, Ditches B and C, Ditches 1 through 7, and Ditches 8 through 10. Within each subsection, results for select metals (Cd, Cr, Hg, Pb) are presented first, followed by EPA TAL analytes, explosive analytes, and EPA TCL constituents. Results were also compared to findings of an earlier environmental study (USATHAMA, 1982a), where applicable.

5.4.4.3 Background Samples. The background samples were RVER-2, which is upgradient of the facility on the Rutherford Fork of the Obion River; CREK-1, on the West Fork of Wolf Creek; and CREK-2, located on the East Fork of Wolf Creek. The latter two samples were collected upgradient of the lap lines and OBG/ADA area. All samples were collected at one of two depth intervals: 0 to 1 foot or 1 to 2 feet.

Select Metals Results

Of the four select metals, only lead and chromium were detected, at concentrations less than 50 $\mu g/g$. The range of concentrations detected are shown in Table 5-43.

EPA TAL Results

Several EPA TAL analytes were detected. These are also shown in Table 5-43.

Explosive Analyte Results

Explosive compounds were not detected in any of these background locations.

EPA TCL Results

Several EPA TCL analytes were detected in the background samples. These are listed in Table 5-44. It should be noted that the compound 1,2-epoxycyclohexene was detected at CREK-2 at a concentration (0.208 $\mu g/g$) less than 5 times that found in the associated method blank, and is thus considered an artifact. The compound 2-cyclohexen-1-ol was detected at RVER-2 at a concentration (0.257 $\mu g/g$) less than 5 times that found in the associated method blank, and is therefore considered an artifact.

TABLE 5-43
Inorganics Detected in Background Sediment Samples

Metals Detected	Concentration ($\mu g/g$)
Aluminum	578 - 4,600
Arsenic	1.34 - 15.4
Barium	54 - 1,200
Calcium	196 - 637
Chromium	42.1
Cobalt	54.2
Iron	1,790 - 32,200
Lead	2.12 - 11.3
Magnesium	352 - 519
Manganese	546 - 6,690
Potassium	116 - 224
Sodium	313 - 346
Vanadium	3.85 - 59.9

The background samples are CREK-1, CREK-2 and RVER-2.
The following TAL analytes were not detected: Ag, Se, Hg, Cd, Be, Cu, Ni, Sb, Tl, and Zn.

TABLE 5-44
TCL Constituents Detected in Background Sediment Samples

Organic Analyte	Concentration ($\mu g/g$)
2-Cyclohexen-1-ol	0.208 - 0.257
2-Cyclohexen-one	0.208 - 0.112
Trichlorofluoromethane	0.00966
1,2-Epoxycyclohexene	0.208* - 0.223*

Background samples are CREK-1, CREK-2 and RVER-2.
* The analyte was present in the sample at this concentration above the CRL but less than five times the concentration in the associated method blank and should be considered non-detect.

5.4.4.4 Rutherford Fork of the Obion River and Wolf Creek. Four samples in addition to the background samples were collected from the Rutherford Fork and Wolf Creek. Sample RVER-1 was a composite sample (0-2') collected downstream from the confluence of Ditch C. A duplicate sample was also collected here. Two samples from different depths were collected at CREK-6 located in Wolf Creek where the creek exits the reservation on the west side.

Select Metals Results

Lead was detected in all samples within the site-specific background range. The remaining select metals were not detected.

EPA TAL Results

Aluminum, silver, potassium, magnesium, and sodium were detected above background in sample RVER-1 at average concentrations of 5,470, 0.0662, 371, 670, and 378 µg/g, respectively.

Explosive Analyte Results

Explosive analytes were not detected in these sediment samples. In a 1982 USATHAMA study, a sediment sample was collected just upstream of sampling location CREK-6, and TNT was detected at 3.8 µg/g.

EPA TCL Results

Several EPA TCL constituents were detected in these samples. Diacetone alcohol was detected at an average concentration (duplicate sample collected here) of 5.64 µg/g. This was the only sample location where this compound was detected. Toluene was detected at 0.112 µg/g, and trichlorofluoromethane was detected at an average concentration of 0.0129 µg/g. The former compound may be a laboratory artifact, or may be a site-related contaminant; the latter compound is probably a laboratory artifact. Acetone was also detected at 0.0865 µg/g.

5.4.4.5 Johns Creek and Halls Branch. Samples were collected from two depths from Johns Creek (site CREK-3) downstream from the confluence of Ditch 6. Four samples were collected at two locations in Halls Branch, upstream of Johns Creek (sites CREK-4 and CREK-5).

Select Metals Results

Lead was the only analyte detected and was within the site-specific background range.

EPA TAL Results

Sodium was detected above background in all three samples at the following concentrations: 371 µg/g (CREK-3); 450 µg/g (CREK-4); and 347 µg/g (CREK-5). Zinc was also detected above background in sample CREK-4 at 72.5 µg/g.

Explosive Analyte Results

Explosive analytes were not detected in the sediment samples collected in this area.

EPA TCL Results

At CREK-3, 1,2-epoxycyclohexene was detected at 0.123 µg/g. Trichlorofluoromethane was detected at 0.00594 µg/g at CREK-4, but is probably a laboratory artifact.

The lack of detectable contaminants in these locations indicates that contamination emanating from the OBG/ADA or Ditch 6 is not settling into the sediments of these creeks.

5.4.4.6 Ditches B and C. Twelve samples were collected from each ditch at three depth intervals: 0-0.5 feet, 0.5-1.0 feet and 1.0-2.0 feet. Samples collected from 0-0.5 feet are referred to as A, from 0.5-1.0 feet as B, and from 1.0-2.0 feet as C. Two duplicate samples were also collected from each ditch.

Select Metals Results

Lead and chromium were the only two metals detected in the sediment samples from these ditches. Lead was detected in every sample but was within, or just slightly exceeding, the background range. Chromium was detected in three samples (DTCHB-3, samples B and C, and DTCHC-1, sample C) and one duplicate sample (DTCHB-3, sample B). All levels were below site-specific background levels except for sample B collected at DTCHB-3 (61.3 μg/g). This location is upgradient of Ditch 5 and the storm drainage discharge point.

EPA TAL Results

Six TAL analytes were detected above background in the sediment samples collected from the 0 to 0.5 foot interval in Ditches B and C. Silver was detected in all samples above background, with concentrations ranging from 0.0816 μg/g to 0.678 μg/g (average concentration). The maximum concentration of silver was detected in sample DTCHC-2. Aluminum, potassium, and magnesium concentrations exceeded background in samples DTCHC-3 and DTCHB-4 as follows: Al - 8,660 and 8,210 μg/g, respectively; K - 445 and 495 μg/g, respectively; and Mg - 1,440 and 1,040 μg/g, respectively. Sample DTCHB-3 also contained arsenic at 33.9 μg/g, greater than twice the maximum concentration detected in background.

Explosive Analyte Results

Explosives were detected only in the sediment of Ditch B. Samples collected from DTCHB-4 contained 1,3,5-TNB (1.2 μg/g - 1.69 μg/g), 2,4,6-TNT (21.4 μg/g-33.6 μg/g) and 2,4-DNT (0.71 μg/g - 0.854 μg/g). The highest concentrations of 1,3,5-TNB and 2,4,6-TNT were found in sample C (1-2 foot depth interval). The highest concentration of 2,4-DNT was found in sample A. HMX was detected in sample B at a concentration of 0.719 μg/g and RDX was found in samples B and C at concentrations of 1.02 μg/g and 0.969 μg/g. Site DTCHB-4 is downstream of Ditch 5 into which the Line D PWTF discharges. It should be noted that in a 1982 USATHAMA environmental study (1982a), TNT was detected at sampling station DTCHB-1 at 3.8 μg/g. Although explosives were detected in the surface water of Ditch C, explosives were not detected in the sediment. Therefore, it appears that the wastewater discharge concentration is low enough that contaminants are not accumulating in the sediment.

EPA TCL Results

Several EPA TCL compounds were detected in sediment samples collected from Ditches B and C, some of which were not detected elsewhere. For example, the compounds fluoranthene, phenanthrene, pyrene and 2,6,10,14-tetramethylpentadecane were detected in the sample collected at site DTCHB-3. All EPA TCL compounds detected are listed in Table 5-45. These compounds were not detected in the corresponding surface water samples. In addition, acetone and trichlorofluoromethane were detected in several samples at concentrations less than 0.04 μg/g, but are probably laboratory artifacts.

5.4.4.7 Ditches 1 - 10. A total of 124 samples were collected in these ten ditches. Typically, samples from two depths (0.0-1.0 feet (sample A) and 1.0-2.0 feet (sample B)) at six locations were collected along each ditch. A shallow sample only was collected at DTCH1-5 because samplers encountered concrete one foot below the surface. Only five locations were sampled at Ditches 7, 8 and 9. A total of eleven duplicate samples were collected from these ditches.

TABLE 5-45
TCL Positive Analytical Results for Sediment ($\mu g/g$) From Ditches B and C

Sample/ Analyte	Acetone	2-Cyclohexen-1-one	1,2-Epoxy-cylclohexene	Fluoranthrene	2-Methylnapthalene	Phenanthrene	Pyrene	Tetramethyl-pentadecane	Toluene	Trichloro-fluroro-methane
	Certified Reporting Limit									
	0.020	*	*	0.068	0.049	0.033	0.033	*	0.000780	*
DTCHB-1	0.0215	ND	ND	ND	ND	ND	ND	ND	ND	0.0127
DTCHB-2	ND	0.247	0.865	ND	ND	ND	ND	ND	ND	ND
DTCHB-3	ND	0.119	0.951	0.110	0.0718	0.196	0.0844	0.238	0.0713	0.0122
DTCHB-4	0.0355	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCHC-2	0.0316	0.123	0.859	ND	ND	ND	ND	ND	ND	ND
DTCHC-3	ND	0.237	0.949	ND	ND	ND	ND	ND	ND	ND
DTCHC-4	ND	0.247	0.989	ND	ND	ND	ND	ND	ND	0.0148

ND	Not detected above the Certified Reporting Limit.
*	Certified Reporting Limit unknown; analyte is not on the TCL.

Select Metals Results

Table 5-46 lists select metals results for sediment samples collected from these ditches. Lead was detected in all samples collected from the ten ditches. Fifty-eight percent of the samples expressed lead levels greater than site-specific background levels and generally ranged between 11.6 μg/g and 35.4 μg/g. Three samples contained lead levels which exceeded this range. Both samples collected from DTCH10-2 contained lead well above this range. Samples A and B collected from DTCH10-2 contained lead concentrations of 54.5 μg/g and 59.9 μg/g respectively. Sample B collected from DTCH9-4 contained 138 μg/g of lead.

Chromium was detected in fourteen percent of the samples above the CRL and was found to be above site-specific background levels in five of these samples. Sample A of DTCH2-2 contained 48.2 μg/g chromium. Three samples from Ditch 5 contained concentrations above site-specific background samples. Sample A from DTCH5-4 and sample B from DTCH5-6 contained 42.5 μg/g and 43.5 μg/g, respectively. The highest concentration of chromium detected was in sample A of DTCH5-3 and is over two times the site-specific background level (88.8 μg/g). Sample A of DTCH9-5 contained 66.4 μg/g chromium.

Mercury was detected above background in four samples in Ditch 9 and three samples in Ditch 10. The concentrations ranged between 0.125 μg/g and 3.02 μg/g with the highest concentration being detected in sample A of DTCH9-5. The remaining three samples (DTCH9-3 and duplicate sample and DTCH9-4) contained levels below 0.3 μg/g. Both samples collected at DTCH10-2 contained mercury. Sample A contained 0.527 μg/g and sample B contained 0.656 μg/g. Samples A and B collected from DTCH10-2 were the only samples which contained concentrations cadmium which exceeded background. Sample A contained 6.76 μg/g and sample B contained 11.1 μg/g. The source of the extensive metals contamination found in Ditches 9 and 10 is presumed to be the OBG/ADA.

EPA TAL Results

Sixteen TAL inorganics were detected above background in sediment samples collected from Ditches 1-10 as follows: aluminum, arsenic, beryllium, calcium, iron, potassium, magnesium, sodium, nickel, silver, selenium, vanadium, zinc, thallium, and cobalt. All but four samples (DTCH3-1, DTCH3-4, DTCH4-6, and DTCH8-1) contained concentrations of TAL organics above background.

The element aluminum was the TAL constituent most frequently detected above background in 40 of 57 sampling locations. Aluminum concentrations above background ranged from 4,890 to 18,600 μg/g. Concentrations of other TAL inorganics above background are found in Table 4-47.

Explosive Analyte Results

Explosives were detected in the sediment of Ditches 5 and 10. 2,4,6-TNT was detected at a concentration of 0.924 μg/g in sample B of DTCH5-1. RDX was detected in samples B collected from DTCH10-2 and DTCH10-3 at concentrations of 1.04 μg/g and 2.73 μg/g, respectively. HMX was also detected in sample B collected at DTCH10-3 (1.05 μg/g). The line D PWTF discharges into Ditch 5 and accounts for the explosives detected in sample B of DTCH 5-1. Explosives contamination found in samples from Ditch 10 most likely emanated from the ADA. It should be noted that in a 1982 USATHAMA study (1982a), TNT was detected at a concentration of 3.8 μg/g at a location just downstream of sampling location DTCH1-1. In this investigation, no explosives were detected at sampling points in this area in this investigation.

Table 5-46
Select Metals Positive Analytical Results ($\mu g/g$) Above Background of Sediment Samples From Ditches 1-10

Sample Location	Depth Interval (feet)	Lead	Chromium	Cadmium	Mercury
DTCH1-1	0-1	19.9	NA	NA	NA
DTCH1-4	0-1	28.3	NA	NA	NA
DTCH1-4	1-2	17.2	NA	NA	NA
DTCH1-4 (dup)	1-2	25.8	NA	NA	NA
DTCH1-5	0-1	25.5	NA	NA	NA
DTCH1-6	0-1	12.2	NA	NA	NA
DTCH1-6	1-2	13.9	NA	NA	NA
DTCH2-1	0-1	14.7	NA	NA	NA
DTCH2-1	1-2	20.0	NA	NA	NA
DTCH2-2	0-1	25.0	NA	NA	NA
DTCH2-2 (dup)	0-1	35.4	48.2	NA	NA
DTCH2-2	1-2	33.0	NA	NA	NA
DTCH2-3	0-1	15.5	NA	NA	NA
DTCH2-3	1-2	24.9	NA	NA	NA
DTCH2-4	0-1	15.4	NA	NA	NA
DTCH2-4	1-2	12.4	NA	NA	NA
DTCH2-5	0-1	12.8	NA	NA	NA
DTCH2-5	1-2	11.6	NA	NA	NA
DTCH2-6	0-1	13.6	NA	NA	NA
DTCH2-6	1-2	19.4	NA	NA	NA
DTCH3-3	0-1	15.0	NA	NA	NA
DTCH3-5	0-1	11.6	NA	NA	NA
DTCH3-5	1-2	11.6	NA	NA	NA
DTCH3-6	0-1	28.0	NA	NA	NA
DTCH3-6	1-2	18.0	NA	NA	NA
DTCH4-1	0-1	14.2	NA	NA	NA
DTCH4-1	1-2	12.1	NA	NA	NA
DTCH4-4	0-1	12.7	NA	NA	NA
DTCH4-4 (dup)	0-1	16.7	NA	NA	NA
DTCH4-4	1-2	14.2	NA	NA	NA
DTCH4-6	0-1	12.6	NA	NA	NA
DTCH5-2	1-2	12.5	NA	NA	NA
DTCH5-3	0-1	34.0	88.8	NA	NA
DTCH5-3	1-2	15.9	NA	NA	NA
DTCH5-4	0-1	12.7	42.5	NA	NA
DTCH5-4	1-2	12.0	NA	NA	NA
DTCH5-5	0-1	13.3	NA	NA	NA
DTCH5-6	0-1	21.2	NA	NA	NA
DTCH5-6	1-2	27.4	43.5	NA	NA
DTCH6-1	0-1	19.3	NA	NA	NA
DTCH6-4	0-1	29.3	NA	NA	NA
DTCH6-4	1-2	18.7	NA	NA	NA

Table 5-46 (Con't)
Select Metals Positive Analytical Results (μg/g) Above Background of Sediment Samples From Ditches 1-10

Sample Location	Depth Interval (feet)	Lead	Chromium	Cadmium	Mercury
DTCH6-5	0-1	27.1	NA	NA	NA
DTCH6-5	1-2	11.8	NA	NA	NA
DTCH6-6	1-2	21.9	NA	NA	NA
DTCH7-3	0-1	21.7	NA	NA	NA
DTCH7-3 (dup)	0-1	24.8	NA	NA	NA
DTCH7-3	1-2	17.9	NA	NA	NA
DTCH7-4	0-1	20.4	NA	NA	NA
DTCH7-4	1-2	15.2	NA	NA	NA
DTCH7-6	0-1	13.7	NA	NA	NA
DTCH8-1	1-2	17.8	NA	NA	NA
DTCH8-2	1-2	12.7	NA	NA	NA
DTCH8-3	1-2	14.9	NA	NA	NA
DTCH8-4	0-1	14.9	NA	NA	NA
DTCH8-5	0-1	25.1	NA	NA	NA
DTCH9-3	0-1	23.2	NA	NA	0.294
DTCH9-3 (dup)	0-1	NA	NA	NA	0.190
DTCH9-4	0-1	11.7	NA	NA	0.125
DTCH9-4	1-2	138	NA	NA	NA
DTCH9-5	0-1	34.1	66.4	NA	3.02
DTCH9-6	0-1	17.1	NA	NA	NA
DTCH9-6	1-2	18.4	NA	NA	NA
DTCH10-1	0-1	18.5	NA	NA	NA
DTCH10-1	1-2	18.5	NA	NA	NA
DTCH10-2	0-1	54.5	NA	6.76	0.527
DTCH10-2	1-2	59.9	NA	11.1	0.656
DTCH10-3	0-1	18.7	NA	NA	NA
DTCH10-3	1-2	18.9	NA	NA	NA
DTCH10-4	0-1	15.3	NA	NA	NA
DTCH10-4	1-2	14.1	NA	NA	NA
DTCH10-5	0-1	14.4	NA	NA	NA
DTCH10-5	1-2	12.2	NA	NA	NA

NA	Not applicable; this analyte was not detected above background level.
dup	Duplicate sample.

TABLE 5-47
TAL Inorganics Detected Above Background (µg/g) in Sediment Samples From Ditches 1-10

Sample Number	Ag	Al	As	Be	Ca	Co	Fe	K	Mg	Mn	Na	Ni	Se	Tl	V	Zn
	Background Concentrations															
	0.0500^{a}	4,600^{b}	15.4^{b}	3.72^{a}	637^{b}	30.0^{a}	32,000^{b}	224^{b}	519^{b}	6,690^{b}	346^{b}	25.2^{a}	0.500^{a}	62.6^{a}	59.9^{b}	6.04^{a}
DTCH1-1^{+}	NA	8,980	NA	NA	956	NA	NA	593	1,190	NA	432	NA	NA	NA	NA	NA
DTCH1-2	NA	12,000	NA	NA	925	NA	NA	967	1,580	NA	363	NA	NA	NA	NA	NA
DTCH1-3	NA	13,400	NA	NA	1,880	NA	NA	677	946	NA	NA	NA	NA	NA	NA	NA
DTCH1-4	NA	8,310	28.7	NA	1,290	NA	NA	569	987	NA	448	NA	0.613	NA	96.6	NA
DTCH1-5	NA	13,100	NA	6.50	3,340	101	59,700	901	1,760	18,600	NA	58.6	NA	NA	NA	13.3
DTCH1-6	NA	12,000	NA	NA	1,280	NA	NA	755	1,330	NA	NA	NA	NA	NA	NA	NA
DTCH2-1	0.0527	9,320	NA	NA	1,790	NA	NA	880	1,410	NA	416	NA	0.514	NA	NA	73.0
DTCH2-2^{+}	NA	11,950	39.2	5.68	1,125	37.5	55,700	771	1,335	NA	390	NA	0.881	149	84.1	84.8
DTCH2-3	NA	11,900	NA	NA	1,750	NA	NA	1,040	1,930	NA	NA	NA	NA	NA	NA	NA
DTCH2-4	NA	13,400	NA	NA	2,400	NA	NA	785	2,370	NA	386	NA	NA	NA	NA	108
DTCH2-5	NA	18,600	NA	NA	2,010	NA	NA	969	3,190	NA	353	NA	NA	NA	NA	72.4
DTCH2-6	0.0506	12,800	NA	NA	1,310	NA	NA	1,140	2,080	NA	393	NA	NA	NA	NA	NA
DTCH3-2	NA	7,500	NA	NA	863	NA	NA	250	1,170	NA	407	NA	NA	NA	NA	NA
DTCH3-3	NA	12,000	NA	NA	1,310	NA	NA	1,200	1,750	NA	NA	NA	NA	NA	NA	NA
DTCH3-5	NA	7,120	NA	NA	1,110	NA	NA	605	958	NA	NA	NA	NA	NA	NA	NA
DTCH3-6	0.0513	NA	25.5	NA	2,120	NA	NA	241	593	NA	NA	NA	0.662	NA	NA	67.0
DTCH4-1	NA	14,800	NA	NA	NA	NA	NA	1,070	2,100	NA	394	NA	NA	NA	NA	66.6
DTCH4-2	0.0762	NA	NA	NA	NA	NA	NA	NA	NA	NA	349	NA	NA	NA	NA	NA
DTCH4-3	0.0977	NA	NA	NA	NA	NA	NA	NA	NA	NA	394	NA	NA	NA	NA	NA
DTCH4-4^{+}	0.249	NA	16.7	NA	NA	NA	NA	238	NA	NA	353	NA	NA	NA	NA	NA
DTCH4-5	0.124	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DTCH5-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	370	NA	NA	NA	NA	NA
DTCH5-2	NA	7,800	NA	NA	907	NA	NA	534	1,190	NA	392	NA	NA	NA	NA	NA

TABLE 5-47 (Con't)
TAL Inorganics Detected Above Background (μg/g)
in Sediment Samples From Ditches 1-10

Sample Number	Ag	Al	As	Be	Ca	Co	Fe	K	Mg	Mn	Na	Ni	Se	Tl	V	Zn
	Background Concentrations															
	0.0500^{a}	4,600^{b}	15.4^{b}	3.72^{a}	637^{b}	30.0^{a}	32,000^{b}	224^{b}	519^{b}	6,690^{b}	346^{b}	25.2^{a}	0.500^{a}	62.6^{a}	59.9^{b}	6.04^{a}
DTCH5-3	NA	6,790	23.0	NA	922	38.7	NA	319	608	NA	NA	NA	NA	NA	NA	NA
DTCH5-4	NA	16,200	21.5	NA	1,360	NA	NA	966	2,860	NA	NA	NA	NA	NA	71.5	64.3
DTCH5-5	NA	GT 5,000	NA	NA	1,330	NA	NA	458	1,660	NA	347	NA	NA	NA	NA	NA
DTCH5-6	NA	8,100	NA	NA	1,450	NA	NA	602	1,370	NA	NA	NA	NA	NA	NA	NA
DTCH6-1	1.08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DTCH6-2	0.788	4,890	NA	NA	NA	NA	NA	NA	631	NA	393	NA	NA	NA	NA	NA
DTCH6-3	NA	6,290	NA	NA	NA	NA	NA	405	848	NA	370	NA	NA	NA	NA	NA
DTCH6-4	0.0531	9,720	NA	NA	1,450	NA	NA	841	1,240	NA	357	NA	NA	NA	NA	16.0
DTCH6-5	NA	11,200	19.8	NA	1,610	NA	NA	554	1,130	NA	NA	NA	NA	NA	NA	NA
DTCH6-6	0.339	5,580	NA	NA	NA	61.2	NA	297	NA	10,900	NA	NA	NA	NA	NA	NA
DTCH7-2	0.562	NA	NA	NA	766	NA	NA	N	NA	NA	NA	NA	NA	NA	NA	NA
DTCH7-3^{+}	0.0800	6,830	NA	NA	1,05	NA	NA	469	939	NA	367	NA	0.504	NA	NA	NA
DTCH7-4	0.0616	5,160	NA	NA	75	NA	NA	319	928	NA	NA	NA	NA	NA	NA	NA
DTCH7-5	0.229	NA	NA	NA	682	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DTCH7-6	0.0585	13,300	NA	NA	2,460	NA	NA	1,130	1,960	NA	399	NA	NA	NA	NA	72.0
DTCH8-2	0.0920	NA	NA	NA	NA	NA	NA	238	614	NA	NA	NA	NA	NA	NA	NA
DTCH8-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	413	NA	NA	NA	NA	NA
DTCH8-4	NA	5,960	NA	NA	673	NA	NA	315	1,010	NA	371	NA	NA	NA	NA	NA
DTCH8-5	0.0673	6,370	NA	NA	NA	NA	NA	397	1,020	NA	NA	NA	NA	NA	NA	NA
DTCH9-2	NA	7,670	NA	NA	1,040	NA	NA	550	1,550	NA	426	NA	NA	NA	NA	NA
DTCH9-3^{+}	NA	NA	NA	NA	NA	NA	NA	280	NA	NA	359	NA	NA	NA	NA	59.8
DTCH9-4	NA	NA	NA	NA	NA	NA	NA	288	612	NA	357	NA	NA	NA	NA	NA
DTCH9-5	NA	6,810	NA	NA	NA	NA	61,200	355	870	NA	NA	37.4	NA	NA	65.5	48.3
DTCH9-6	NA	6,700	NA	NA	NA	NA	NA	397	814	NA	NA	NA	NA	NA	NA	138

TABLE 5-47 (Con't)
TAL Inorganics Detected Above Background ($\mu g/g$) in Sediment Samples From Ditches 1-10

Sample Number	Ag	Al	As	Be	Ca	Co	Fe	K	Mg	Mn	Na	Ni	Se	Tl	V	Zn
	Background Concentrations															
	0.0500^{a}	4,600^{b}	15.4^{b}	3.72^{a}	637^{b}	30.0^{a}	32,000^{b}	224^{b}	519^{b}	6,690^{b}	346^{b}	25.2^{a}	0.500^{a}	62.6^{a}	59.9^{b}	6.04^{a}
DTCH10-1	0.0746	6,910	NA	NA	NA	NA	NA	309	924	NA	NA	NA	NA	NA	NA	89.7
DTCH10-2	0.387	8,680	NA	NA	704	NA	NA	554	1,490	NA	359	NA	NA	NA	NA	569
DTCH10-3	NA	7,520	NA	NA	NA	NA	NA	410	966	NA	NA	NA	NA	NA	NA	127
DTCH10-4	NA	9,750	NA	NA	1,330	NA	NA	643	1,820	NA	NA	NA	NA	NA	NA	NA
DTCH10-5^{+}	NA	10,300	NA	NA	944	NA	NA	580	1,660	NA	387	NA	NA	NA	NA	NA
DTCH10-6	NA	11,100	NA	NA	NA	NA	NA	379	730	NA	360	NA	NA	NA	NA	NA

$^{+}$ Duplicate sample taken; concentrations represented are average concentrations of the two samples, when detected in both samples.
NA Not applicable; not detected above the background concentration.
^{a} Background concentration based on two times the detection limit; this analyte was not detected in background samples.
^{b} Background concentration based on maximum concentration detected in the background samples (CREK-1, CREK-2, and RVER-2).
GT Greater than the concentration indicated.

EPA TCL Results

Several EPA TCL constituents were detected in these samples. These are listed in Tables 5-48 and 5-49. Among the compounds detected were: 1,2-epoxycyclohexene, 2-cyclohexen-1-ol, 2-cyclohexen-1-one (associated with explosives packaging), acetone, diacetone alcohol, toluene, and trichlorofluoromethane. These compounds were not detected in the corresponding surface water samples.

TABLE 5-48
TCL Volatile Organic Compounds Positive Analytical Results ($\mu g/g$) for Sediment Samples From Ditches 1-10

Sample/ Analyte	Acetone	Chloro- benzene	Chloroform	Diacetone alcohol	2-Propanol	1,1,2,2-Tetra- chloroethane	Tetra- chloroethene	Toluene	Trichloro- fluoromethane	1,1,2-Trichloro- 1,2,2-trifluorethane
	Certified Reporting Limit									
	0.0200	0.000860	0.000870	**	**	0.00240	0.000810	0.000780	**	**
DTCH1-1$^+$	0.0850	ND	ND	2.53	ND	ND	ND	ND	0.0110	ND
DTCH1-2	0.0334	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH1-3	ND	ND	ND	ND	ND	ND	ND	ND	0.00771	ND
DTHC1-4	ND	ND	ND	13.4	ND	ND	ND	0.0938	0.0321	ND
DTCH1-6	ND	ND	ND	ND	ND	ND	ND	ND	0.0169	ND
DTCH2-1	ND	ND	ND	ND	ND	ND	0.00159	ND	ND	ND
DTCH2-2$^+$	ND	ND	ND	ND	ND	ND	ND	ND	0.0199	ND
DTCH3-1	ND	ND	ND	ND	ND	ND	ND	ND	0.0136	ND
DTCH3-2	0.103	ND	ND	ND	0.0115	ND	ND	ND	0.0118	ND
DTCH3-4	ND	ND	ND	ND	ND	ND	ND	ND	0.00706	ND
DTCH3-5	ND	ND	ND	ND	ND	ND	ND	ND	0.00664	ND
DTCH3-6	ND	ND	ND	ND	ND	ND	ND	ND	0.0101	ND
DTCH4-3	ND	ND	ND	ND	ND	ND	ND	ND	0.0851	ND
DTCH5-1	ND	ND	ND	ND	ND	ND	ND	ND	0.0189	0.0105
DTCH5-2	ND	ND	ND	ND	ND	ND	ND	ND	0.0233	0.0130
DTCH5-3	ND	ND	ND	ND	ND	ND	ND	ND	0.0135	ND
DTCH5-4	ND	ND	ND	ND	ND	ND	ND	ND	0.00614	ND
DTCH5-6	0.0267	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH6-1	GT 0.100	ND	ND	ND	ND	ND	ND	ND	ND	ND
DTCH6-3	ND	ND	0.00104	ND	ND	ND	ND	ND	0.0130	ND
DTCH6-5	ND	ND	ND	ND	ND	ND	ND	ND	0.00701	ND

TABLE 5-48 (Con't)
TCL Volatile Organic Compounds Positive Analytical Results (μg/g) for Sediment Samples From Ditches 1-10

Sample/ Analyte	Acetone	Chloro-benzene	Chloroform	Diacetone alcohol	2-Propanol	1,1,2,2-Tetra-chloroethane	Tetra-chloroethene	Toluene	Trichloro-fluoromethane	1,1,2-Trichloro-1,2,2-trifluorethane
	Certified Reporting Limit									
	0.0200	0.000860	0.000870	**	**	0.00240	0.000810	0.000780	**	**
DTCH6-6	ND	ND	ND	ND	ND	ND	ND	ND	0.0196	ND
DTCH7-3⁺	ND	ND	ND	ND	ND	ND	ND	ND	0.00998	ND
DTCH7-4	ND	ND	ND	ND	ND	ND	ND	ND	0.0119	ND
DTCH7-6	ND	ND	ND	0.967	ND	ND	ND	ND	ND	ND
DTCH8-1	GT 0.100	ND	ND	ND	0.0339	ND	ND	ND	ND	ND
DTCH8-4	0.0533	ND	ND	ND	0.0112	ND	ND	ND	ND	ND
DTCH9-2	0.0470	ND	ND	ND	0.0240	0.00276	ND	ND	0.0236	ND
DTCH9-3⁺	ND	ND	ND	ND	ND	ND	ND	ND	0.0123	ND
DTCH9-5	0.0430	ND	ND	ND	ND	0.00350	ND	ND	0.0141	ND
DTCH10-1	ND	ND	ND	ND	ND	ND	ND	ND	0.0191	ND
DTCH10-3	ND	ND	ND	ND	ND	ND	ND	ND	0.00940	ND
DTCH10-6	ND	0.00130	ND	ND	ND	ND	ND	0.00137	ND	ND

ND Not detected above the Certified Reporting Limit.
GT Signifies a number greater than the concentration reported.
* Certified Reporting Limit unknown; this analyte is not on the TCL.
\+ Duplicate sample taken; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

TABLE 5-49
TCL Semivolatile Compounds Positive Analytical Results (μg/g) for Sediment Samples From Ditches 1-10

Sample/ Analyte	Bis (2-ethylhexyl) phthalate	2-cyclohexen-1-ol	2-cyclo-hexen-1-one	1,2-epoxy-cyclohexene	Palmitic Acid	Stearic Acid	Trichloro-napthalenes
	Certified Reporting Limit						
	**	**	**	**	**	**	**
DTCH2-1	ND	ND	ND	ND	0.252	ND	ND
DTCH3-1	ND	ND	ND	0.106	ND	ND	ND
DTCH3-3	ND	ND	ND	0.109	ND	ND	ND
DTCH3-4	ND	ND	ND	0.109	ND	ND	ND
DTCH3-5	ND	0.108	0.108	ND	0.108	ND	ND
DTCH4-1	ND	0.227	0.227	ND	ND	ND	ND
DTCH4-2	ND	0.387*	0.258*	ND	ND	ND	ND
DTCH4-4$^+$	ND	0.252*	ND	ND	ND	ND	ND
DTCH5-1	ND	ND	0.117	0.699	ND	ND	ND
DTCH5-2	ND	ND	0.130	0.910	ND	ND	ND
DTCH5-3	ND	ND	0.242	0.848	ND	ND	ND
DTCH6-1	ND	ND	ND	0.255	ND	ND	ND
DTCH6-2	ND	ND	ND	ND	0.125	ND	ND
DTCH6-5	1.25	ND	ND	ND	ND	ND	ND
DTCH7-3$^+$	ND	0.124*	ND	ND	0.112	ND	ND
DTCH7-4	ND	0.233	0.233	0.233*	0.116	ND	ND
DTCH7-5	ND	0.108	0.108	0.215*	ND	ND	ND
DTCH7-6	ND	0.363	0.242	0.363*	0.605	0.363	ND
DTCH9-3$^+$	ND	ND	ND	0.110	ND	ND	ND
DTCH9-5	ND	ND	ND	0.220	ND	ND	ND

TABLE 5-49 (Con't)
TCL Semivolatile Compounds Positive Analytical Results (μg/g) for Sediment Samples From Ditches 1-10

Sample/ Analyte	Bis (2-ethylhexyl) phthalate	2-cyclohexen-1-ol	2-cyclo-hexen-1-one	1,2-epoxy-cyclohexene	Palmitic Acid	Stearic Acid	Trichloro-napthalenes
	Certified Reporting Limit						
	**	**	**	**	**	**	**
DTCH10-2	ND	ND	0.225	0.338*	ND	ND	0.113
DTCH10-4	ND	0.247	0.247	0.247*	ND	ND	ND
DTCH10-5+	ND	0.174	0.116	0.232*	ND	ND	ND
DTCH10-6	ND	0.232	0.232	0.465*	ND	ND	ND

ND Not detected above the Certified Reporting Limit.
* The analyte was present in the sample above the CRL but less than five times the concentration in the associated method blank, and should be considered undetected.
** Certified Reporting Limit unknown; this analyte is not on the TCL.
\+ Duplicate sample taken; where the analyte was detected in both samples, the concentration is expressed as the average of the two samples.

6.0 QUALITY ASSURANCE/QUALITY CONTROL

An independent quality assurance program was developed for the project, which included planning, specification of data quality objectives, application of quality control measures to prevent out-of-control situations, and the establishment of monitoring systems to ensure the expeditious identification, evaluation, and correction of system deficiencies. The quality assurance program was developed using specifications contained in the following USATHAMA and EPA guidance documents: *Installation Restoration Quality Assurance Program*, December 1985, 2nd Edition, March 1987, and the *Geotechnical Requirements for Drilling, Monitor Well, Data Acquisition, and Reports*, March 1987, and the EPA Region IV *Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual*, April 1986.

Operational verification of the MAAP quality assurance program was achieved through periodic monitoring of sampling and analysis systems, and frequent evaluation of management activities. The following sections identify the quality assurance program established and maintained during the performance of the MAAP work assignment. Specific areas that are discussed in this section include: sampling activity assessment; analytical services; data quality assessment; blank contamination assessment; and data management.

6.1 OVERVIEW OF QUALITY CONTROL MEASURES

The quality control criteria used to ensure the integrity of data generated in support of project activities include:

- **Project Planning and Site Characterization:** A site visit was conducted in April 1989 to obtain additional information about the site. This site visit occurred prior to development of the project work plan.
- **Project Work Plan:** A Remedial Investigation Work Plan was finalized in July 1990 and consisted of the following documents: RI Work Plan, Health and Safety Plan; Sampling Analysis Plan, which included the Field Sampling Plan and the Quality Assurance Project Plan; and the Data Management Plan.
- **Data Quality Objectives:** Data quality objectives were developed concurrently with the work plan to ensure: (1) the reliability of field sampling, chemical analyses, and physical analysis; (2) the collection of sufficient data; (3) the quality of data generated was acceptable for its intended uses; and (4) valid assumptions could be inferred from the data.
- **Standard Operating Procedures:** Sampling activities were performed in compliance with standard operating procedures defined in the USATHAMA and EPA guidance documents.
- **Sampling Personnel:** Field team members possessed the qualifications and training necessary to collect representative environmental samples. Each individual performing sampling was aware of the requisite protocols for collection of environmental samples. Each geologist was experienced in drilling techniques, monitoring well installation, characterization of soil samples, and soil sampling techniques. All team members were provided a copy of the RI Work Plan, Quality Assurance Plan, and Health and Safety Plan.
- **Documentation:** Field documentation was provided to the laboratory on parameter forms developed by ICF specifically for USATHAMA investigations. The completed forms contained all required information for encoding chemical data into the Installation Restoration Data Management System (IRDMS). All entries into field logbooks were evaluated for completeness and accuracy.

- **Chain-of-Custody:** All samples were collected and relinquished under stringent chain-of-custody protocols as specified in the project quality control plan.
- **Document Control:** All documents generated in support of project activities were input into the ICF USATHAMA Document Control System. A unique control number was assigned to each document prior to its being archived into the system. Access into and out of the document control system was restricted to designated personnel.
- **Monitoring:** Audits were conducted to verify the integrity of work performed in support of this project, and to provide formal documentation attesting to the conformance of the system with the QA Plan.
- **Analytical Services:** Chemical analyses were performed by Environmental Science and Engineering (ESE) in Gainesville, FL, using USATHAMA-certified methodologies. The data generated for this project was comparable to EPA Level IV data. This level is characterized by rigorous QA/QC protocols and legally defensible documentation. Level IV analyses are currently used for the majority of RI/FS activities and are of sufficient quality to support risk assessments.

6.2 FIELD MEASUREMENT AND SAMPLING ACTIVITY ASSESSMENT

The integrity of field sampling and measurement systems have been assessed through the data quality indicators consisting of accuracy, precision, completeness, and representativeness. In addition, the results of field audits conducted at the site were used to infer the level of accuracy, precision, completeness, and representativeness associated with sampling activities.

6.2.1 Accuracy

Accuracy is defined as the bias in a measurement system. Sampling accuracy has been assessed through the evaluation of trip and rinse blank data. This information indicates whether or not contamination has been introduced during the sampling event. The rinse blank data provides an assessment of decontamination efficiency and the potential for cross-contamination to occur during the field investigation. A more detailed discussion of the use of blanks appears in the blank contamination assessment section.

The accuracy of field measurements of the pH and conductivity of water samples can be inferred from the calibration logs generated before, during, and after analyses. The sampling crew generally adhered to the requisite protocols for the calibration of field equipment. Documentation of this fact is contained on the field parameter form generated for each sample.

6.2.2 Precision

Precision is a quantitative measure of the variability of a group of measurements in comparison to the average value. The precision associated with field measurement readings was inferred from the duplicate measurements taken at the completion of sampling.

Field calibration was performed on the photoionization detectors (PIDs) and pH and conductivity meters. The PIDs were used to screen samples for the purpose of: (1) determining the appropriate level of protection for personnel health and safety; and (2) selecting soil samples for volatile organic analysis. A review of the field logbooks indicated that the appropriate calibration procedures had been used for the daily calibration of the PIDs.

The conductivity and pH of water samples collected during surface water sampling, well development, and pre-sample purging of wells were measured. Several types of meters were used, including Hydac combination meters, Fisher Scientific meters, and pH and conductivity single-point calibration meters. All pH and conductivity calibrations were generally performed in accordance with standard operating procedures. When calibrated readings were compared to initial readings obtained the next day, results generally did not vary by more than 10%. A few minor deviations were noted for the calibration: (1) samples collected for monitoring wells MI019, MI012, MI026 were measured using a pH meter for which calibrations had not been properly recorded on the day of collection; and (2) conductivity measurements for monitoring well samples MI040, MI041, MI036, MI035 were obtained using a conductivity meter that had not been calibrated due to the lack of adequate standard. The deficiencies were corrected immediately. Occurrences of instrument malfunctions were carefully recorded in the field logbook. When the pH meter was inoperative, pH paper was used as a backup. Surface water samples collected for locations RVER-1, DTCH2-3, DTCH 5-2, and DTCH 5-3 were measured using pH paper. The impact to the data quality of inoperative conductivity and pH meters is negligible since the measurements were only used for stabilization purposes. In the case of surface water samples, pH and conductivity measurements were taken for information only.

Sampling precision was assessed for this project through the evaluation of duplicate samples. Duplicate samples are defined as samples collected simultaneously from the same source under identical conditions. It is noted that information from a single pair of replicates presents an inaccurate estimate of precision. The following subsections will assess the precision associated with duplicate samples when the requested analyte relative percent difference (RPD) is greater than 25% for aqueous samples and 40% for sediment/soil samples. A higher variance has been included for sediment/soil because the variability between samples may be greater than for aqueous samples. Tables containing the RPD values for detected analytes in all matrices have been provided in Appendix M.

6.2.2.1 Surface Water Investigation. Duplicate samples were collected at sites DTCHC-2 and DTCH7-6 for this investigation. All of the RPDs are within 25% with the exception of lead (133%) detected in the DTCH7-6 samples. A review of the quality control spike information for lead in Lot TUC indicated that the data quality for spiked samples was accurate. This indicates that there were no problems associated with the analytical method. The deviation between the lead duplicates may be attributed to the fact that a small amount of sediment could have been included with the DTCH7-6 standing water sample.

6.2.2.2 Sediment Investigation. A total of 15 duplicate samples were collected for this investigation, and these duplicates include 9 samples for EPA TAL/TCL and explosives and 7 samples for select metals and explosives. Sample results are listed below.

EPA TAL/TCL and Explosives.

RVER-1: All analytes had RPDs less than 40% for the duplicate sample.

DTCHB-1: Analytes with RPDs greater than or equal to 40% for the duplicate sample included: iron (60%); manganese (54%); and silver (40%).

DTCHC-2: Analytes with RPDs greater than 40% for the duplicate sample included lead (47%) and manganese (44%).

DTCH1-1: Analytes with RPDs greater than 40% for the duplicate sample included arsenic (48%) and manganese (44%).

DTCH2-2: Analytes with RPDs greater than or equal to 40% for the duplicate sample included: barium (40%); beryllium (62%); chromium (48%); and manganese (48%).

DTCH4-4: Analytes with RPDs greater than or equal to 40% for the duplicate sample included: aluminum (67%); arsenic (51%); iron (50%); magnesium (67%); manganese (125%); and silver (40%).

DTCH7-3: Analytes with RPDs greater than 40% for the duplicate sample included calcium (48%) and silver (67%).

DTCH9-3: Analytes with RPDs greater than or equal to 40% for the duplicate sample included: chromium (59%); mercury (40%); and lead (71.4%). It should be noted that lead was analyzed for one sample using graphite furnace analysis and was analyzed using inductively coupled argon plasma for the duplicate sample.

DTCH10-5: All analytes had RPDs less than 40% for the duplicate sample.

Select Metals and Explosives.

DTCHB-3: All analytes had RPDs less than 40% for the duplicate sample.

DTCHC-4: All analytes had RPDs less than 40% for the duplicate sample.

DTCH1-4: Lead had an RPD equal to 40%.

DTCH5-5: All analytes had RPDs less than 40% for the duplicate sample.

DTCH6-6: Lead had an RPD equal to 83%.

DTCH8-1: Lead had an RPD equal to 56%.

DTCH9-2: All analytes had RPDs less than 40% for the duplicate sample.

6.2.2.3 Surface and Subsurface Soil Investigation. A total of 30 duplicate samples were collected for this investigation. All of the duplicates samples were analyzed for the 9 explosive constituents of concern for this project. Thirteen were analyzed for EPA TAL/TCL constituents, and 17 samples were analyzed for cadmium, chromium, mercury, and lead. Samples results are listed below.

EPA TAL/TCL and Explosives.

CBG-3: All analytes had RPDs less than 40% for the duplicate sample.

CDP-1: All analytes had RPDs less than 40% for the duplicate sample.

CLF-3: Analytes with RPDs greater than or equal to 40% for the duplicate sample included: aluminum (106%); barium (87%); calcium (46%); iron (67%); potassium (79%); magnesium (133%); manganese (125%); and sodium (49%).

LF-1: All analytes had RPDs less than 40% for the duplicate sample.

OBGA-2: All analytes had RPDs less than 40% for the duplicate sample.

OBGA-4 (0-1'): All analytes had RPDs less than 40% for the duplicate sample.

OBGA-4 (5-9'): Lead had an RPD of 40%.

SA-7: Analytes with RPDs greater than or equal to 40% for the duplicate sample included magnesium (75%) and manganese (40%).

SC-42E: Magnesium had an RPD of 46%.

SD-42: Barium had an RPD of 86%.

SO-14: Calcium had an RPD of 43%.

SX-26: Lead had an RPD of 45%.

SYD-1: Magnesium had an RPD of 44%.

Select Metals and Explosives.

ADAB-1: All analytes had RPDs less than 40% for the duplicate sample.

ADAB-2: All analytes had RPDs less than 40% for the duplicate sample.

CBG-4: All analytes had RPDs less than 40% for the duplicate sample.

CDP-1: All analytes had RPDs less than 40% for the duplicate sample.

CLF-4: All analytes had RPDs less than 40% for the duplicate sample.

LF-2: Lead had an RPD of 70%.

OBGA-2: Lead had an RPD of 91%.

OBGA-4: Lead had an RPD of 169%.

OBGB-3: All analytes had RPDs less than 40% for the duplicate sample.

OBGB-4: Lead had an RPD of 136%.

OBGB-5: All analytes had RPDs less than 40% for the duplicate sample.

OBGC-3: All analytes had RPDs less than 40% for the duplicate sample.

SB-18: All analytes had RPDs less than 40% for the duplicate sample.

SC-5: All analytes had RPDs less than 40% for the duplicate sample.

SE-4: All analytes had RPDs less than 40% for the duplicate sample.

SZ-2: All analytes had RPDs less than 40% for the duplicate sample.

SZ-4W: All analytes had RPDs less than 40% for the duplicate sample.

6.2.2.4 Groundwater Investigation. A total of 13 duplicate samples were collected for this investigation including 5 TAL/TCL and explosive samples and 8 select metals and explosives. Sample results are listed below.

EPA TAL/TCL and Explosives.

MI014: Analytes with RPDs greater than 25% for the duplicate unfiltered sample included: mercury (44%); arsenic (31%); silver (29%); cobalt (26%); chromium (50%); and iron (33%). Although the variances for mercury, iron, and silver are greater than 25%, a control limit of ± the method certified reporting limit can also be used to assess method variations. The control limits for the noted analytes were not in control, which indicates that the variance was not significant for these three analytes. The RPDs for filtered samples were not assessed because many of the filtered analytes were reported less than the certified reported limit.

MI030: Analytes with concentration variances greater than 25% for the duplicate unfiltered sample included: lead (26%); iron (36%); and potassium (43%). Although the RPDs were greater than 25%, the variances for all three analytes were in control. All filtered sample variances were less than 25%.

MI049: Iron was the only analyte with concentration variances greater than 25% for the duplicate unfiltered sample. The variance of 26% was in control. Analytes with concentrations variances greater than 25% for the duplicate filtered sample included manganese (46.2%) and potassium (58%). The variances for potassium was within ± the method certified reporting limit.

MI060: Lead had an RPD of 44.7% for the duplicate unfiltered sample and potassium had an RPD of 26% in the unfiltered sample. In addition, the RPD for 2,4,6-trinitrotoluene was 91%. The method accuracy is reported as 85.5% for this analyte.

MI071: Lead had an RPD 49.6% for the unfiltered sample. The RPDs for all of the filtered samples were less than 25%.

Select Metals and Explosives.

MI016: All requested analytes had RPDs less than 25%.

MI018: This sample contained lead in both filtered and unfiltered samples with RPD values greater than 25%. The variance for the filtered sample was 51% and the variance for the unfiltered sample was 26%.

MI021: All requested analytes had duplicate sample results less than 25%.

MI025: All requested analytes had RPDs less than 25%.

MI056: All requested analytes had duplicate sample results with RPDs less than 25%.

MI068: The RPD for lead in the filtered sample was 154%. The samples were processed in two separate lots and the method accuracy for lead was 92% for both lots.

MI081: All requested analytes had duplicate sample results with RPDs less than 25%.

MI082: The RPD for lead in the filtered sample was 145% and 78% for lead in the unfiltered sample. The RPD for chromium in the unfiltered sample was 26%. Although the chromium result was differed by greater than 25%, the results were in control.

6.2.2.5 Summary. Although variances between field duplicates were identified, information acquired from a single pair of replicates presents an inaccurate estimate of precision because the certainty associated with precision increases with sample size. However, despite the variation in RPDs, most of the analytes were in control.

6.2.3 Completeness

Sampling completeness was assessed through the evaluation of the total number of samples proposed in the work plan versus the actual number of samples collected and analyzed for the project. (This criterion expresses the degree of accuracy and precision to which sample data represents the population.) The criterion for completeness specified in the USATHAMA QA Program is 80% or greater.

All investigation areas were in compliance with the USATHAMA criterion for completeness. This section discusses the completeness objectives attained for this project according to investigative areas.

6.2.3.1 Surface Water Investigation. A total of 29 environmental and 4 field quality control samples were initially proposed for collection and analysis in support of this investigation. The actual totals collected were 31 environmental and 2 field quality control samples. Four surface water locations could not be sampled because of the locations were dry, and four additional sampling locations were substituted in one of the investigative areas. The overall completeness for this area was 100%. An explanation of the variations from the project work plan are explained below.

Ditches B and C: A total of 8 environmental and 2 field quality control samples were collected in this area. A total of 12 environmental samples and 1 field quality control sample were collected in this area. The additional samples included as part of this investigation did not introduce any data gaps for other investigative areas. The completeness quotient for this investigative was approximately 100%.

Ditches 1-10: The samples planned for collection in these areas included 20 environmental samples and 1 quality control sample. A total of 16 environmental samples and 1 field quality control sample was collected. One of the surface water samples scheduled for this area was collected in Johns Creek. Three of the remaining surface water samples were not collected because there was no water in the ditches. Accounting for these factors, the completeness quotient for this area was 95%.

Rutherford Fork: The planned number of environmental and field quality control samples were collected and analyzed. The completeness quotient for this investigative area was 100%.

6.2.3.2 Sediment Investigation. A total of 158 environmental and 26 field quality control samples were initially proposed in the project work plan. Additional sediment samples were approved by USATHAMA and EPA in the Wolf Creek area. The necessity for field quality control samples for the drilling mud was reevaluated in the field and deemed unnecessary. The impact of these two conditions effectively increased the total number of samples to 186 samples. The total numbers of environmental and field quality control samples collected during this investigation were 152 and 22, respectively. The overall completeness quotient for this investigation was 94%.

Drilling Fluid: Nine drilling fluid samples and 3 quality control samples were proposed for this area. The quality control samples should not have been scheduled for this sampling event since the purpose of these samples was to discern potential cross-contamination from mud rotary drilling activities. The actual number of samples collected was 6, which resulted in a completeness of 67%. Although this value is low, a drilling mud sample was collected at least once per 10 day sampling event. The number of samples collected should provide an indication of potential contamination associated with this activity.

Well Construction Material: The planned number of environmental and field quality control samples were collected and analyzed. The completeness quotient for this investigative area was 100%.

Ditches B and C: The planned number of environmental samples were collected and analyzed. Three rinse blanks initially scheduled for this area were shifted to Ditches 1-10 to allow a more even distribution of quality control samples. In view of this fact, the completeness quotient for this investigative area was 100%.

Ditches 1-10: A total of 120 environmental and 15 field quality control samples were scheduled for collection in this area. In addition, three rinse blanks were shifted from Ditches B and C, bringing the total number of samples proposed for collection in this area to 138. The actual number of samples collected for this investigation included 113 environmental and 16 field quality control samples. Six samples scheduled for this location were collected in Johns Creek and Halls Branch.

The effective number of samples for this investigation including the Johns Creek and Halls Branch samples was 135. The completeness quotient for this investigative area was 98%.

Wolf Creek: Two samples were initially planned for collection and subsequent analysis in this investigative area. Four additional sediment samples were approved by USATHAMA and EPA prior to the commencement of sampling activities. The completeness quotient for this investigative area was 100%.

6.2.3.3 Surface and Subsurface Soil Investigation. A tentative total of 277 environmental samples and 53 field quality control samples were specified for collection and analysis in the project work plan. A reduction in the scope of work for the sump investigative area resulted in a modified number of 250 environmental samples and 49 field quality control samples. The actual number of environmental samples and field samples collected for this project was 234 and 49, respectively. The overall completeness quotient for this investigation was 95%. An explanation of the variations from the project work plan are explained below for each investigative area.

Open Burning Ground and Ammunition Demolition Area: The number of samples planned for collection and analysis in this area included 100 environmental samples and 17 field quality control samples. The actual number of samples collected and analyzed was 90 environmental samples and 17 field quality control samples. The number of environmental samples collected and analyzed was reduced because the water table was encountered at a shallower depth than anticipated in several locations. In addition, one soil boring was not completed in this area because the location was inaccessible to the drill rig.

Former Burnout Area: The planned number of environmental and field quality control samples was collected and analyzed. The completeness quotient for this investigative area was 100%.

Former Borrow Pit: An additional sample was collected for the analysis of EPA TAL/TCL constituents and explosives because an elevated photoionization reading was measured for the sample in question. The collection of this sample did not introduce any data gaps in the soil investigation program because it did not replace any sample that was initially proposed for collection. The completeness quotient for this investigative area was 100%.

Former Landfill Area: The planned number of environmental and field quality control samples was collected and analyzed. The completeness quotient for this investigative area was 100%.

Present Landfill: One of the environmental samples planned for collection and analysis in this area was not collected because the maximum sampling depth was limited to 10 feet in this area. The completeness quotient for this area was 88%.

Salvage Yard: The planned number of environmental and field quality control samples were collected and analyzed. The completeness quotient for this investigative area was 100%.

Explosive Wastewater Sumps: Vertical and angular soil borings were proposed for this investigation to obtain soil samples from beneath the sumps. A total of 93 soil borings was proposed for collection and analysis. The actual number of vertical boring soil samples collected and analyzed was 91. The reduction in samples occurred because drilling activities could not be conducted at one of the sumps in LAP area. Thirty-one angular soil boring were proposed for completion in support of this investigative area. Because of low clearance and space limitations, angular boring could not be conducted at many of the sumps. Only 4 sumps were investigated using this drilling technique. The reduction in angular borings was approved by USATHAMA prior to commencement of sampling. The completeness quotient for this area was 98% based upon the reduction in scope of this investigative area.

6.2.3.4 Groundwater Investigation. A total of 104 environmental and 35 field quality control samples were proposed for collection during this investigation. The actual numbers of environmental and field quality control samples collected and analyzed were 102 and 28, respectively. The overall completeness for the groundwater investigation was 96%. An explanation of the variations from the project work plan are explained below for each investigative area.

On-Site Monitoring Wells: The planned number of environmental samples were collected and analyzed. The number of field quality control samples varied from the project work plan because the total number of samples collected during each sampling shift deviated from the initial assumption. This deviation produced a reduction in the number of rinse blanks required during this investigation. The completeness quotient for this investigative area was 98%.

On-Site Production Wells: The proposed numbers of environmental and field quality control samples for this area were 15 and 4, respectively. A total of 13 environmental samples were collected and analyzed in support of the project. Two of the production wells could not be sampled because the pumps were inoperative during the groundwater sampling event. Rinse blanks were not collected in this area because the samples were collected directly into their respective sample containers. In addition, the need to collect the duplicate sample was evaluated in the field and it was decided that because three of the production wells had been sampled in June, it was not necessary to collect duplicate samples. The completeness quotient for this investigative area, based upon the reduction in quality control samples, was 87%.

On-Site RCRA Wells: The planned number of environmental and field quality control samples were collected and analyzed. The completeness quotient for this investigative area was 100%.

Off-Site Wells: The planned number of environmental samples were collected and analyzed. The number of rinse blanks was reduced due to the sampling efficiency associated with the event. The completeness quotient for this investigative area was 93%.

6.2.4 Field Audits

A field audit was conducted at MAAP during the week of August 6, 1990, by the Task QA Manager. The following investigation areas were evaluated: sediment sampling, surface and subsurface soil sampling , and monitoring well installation. The field audit was conducted early in the project to assist in identifying potential out-of-control situations.

6.2.4.1 Sediment Sampling. An audit of the sediment sampling activity was conducted on August 7, 1990. (An EPA auditor from EPA Region IV was also present to oversee contractor sampling activities.) The areas observed during the audit included: (1) sample documentation and management; (2) field measurements and calibration; and (3) sampling protocols.

Sample Documentation and Management. A copy of the project work plan was available on site during this sampling activity and was located in the site trailer. Information collected during the sediment sampling investigation was recorded in the field logbook to provide supplementary information concerning sample location, sample depth, a description of the sample, etc. A review of the sample documentation indicated that the correct information had been written on the field parameter form.

Field Calibration. A photoionizaton detector (HNu) was used to monitor organic vapors and gases to measure the relative concentrations of organic vapors in the work area. The information was primarily used to establish levels of protection for the field sampling crew. The HNu was calibrated prior to use with isobutylene and the equivalent benzene concentrations was calculated. The HNu calibration measurement was recorded in the field logbook that accompanied the unit from the equipment warehouse to the field. A review of the logbooks indicated that the correct calibration procedures had been used.

Sampling. Sediment samples were collected in accordance with procedures defined in Section 4.9. All sample management activities were in compliance with applicable SOPs. During the audit, it was noted that one set of rinse blanks collected for volatile organic analytes (VOAs) did not have custody seals on the individual sample bottles. These samples were subsequently placed into a secondary tin container prior to shipment to the laboratory. Custody tape was sealed across the opening seam of the tin can, and it was determined that the custody seal on the secondary container served the same purpose as the custody seal on the individual bottles.

6.2.4.2 Subsurface Soil Sampling. An audit of the subsurface soil investigation was conducted at the Former Burnout Area on August 9, 1990 by the Task Quality Assurance Manager. The areas observed during the audit included: (1) sample documentation and management; (2) field measurements and calibration; and (3) sampling protocols.

Sample Documentation and Management. A copy of the project work plan was available on site during this sampling activity and was located in the site trailer. Information acquired during the sediment sampling investigation was recorded in the field logbook to provide evidentiary information that representative samples had been collected. A review of the sample documentation indicated that the correct information had been written on the field parameter form.

Field Calibration. A photoionizaton detector (HNu) was used to monitor potential organic contamination from the split spoon samples obtained from the borehole. The information was used to screen samples and determine which sample would be analyzed for the EPA TAL/TCL parameters. The HNu was calibrated prior to use with isobutylene and the resultant value was corrected to read equivalent benzene concentrations. The HNu calibration measurement was recorded in the field logbook that accompanied the unit from the equipment warehouse to the field. A review of the logbooks indicated that the correct calibration protocols had been used.

Sampling. Sampling protocols were consistent with information contained in Section 4.3. When the split-spoon was opened by the Site Geologist, the contents were scanned with the HNu, and the measurement was recorded in the field logbook. The Site Geologist classified the soil samples and documented this information in a boring log to characterize the vertical soil profile. All samples were composited prior to transferral to the sample container with the exception of samples requiring VOA. All requisite paperwork was completed in accordance with project SOPs.

6.2.4.3 Monitoring Well Installation. Hollow stem auger drilling methods were used for the installation of monitoring wells at the time of the audit. All procedures were in compliance with activities specified in Section 4.4.

6.3 ANALYTICAL SERVICES AND DATA QUALITY

The laboratory selected to perform analytical services for this project was ESE, which is located in Gainesville, Florida. ESE is a participant in the USATHAMA Contract Laboratory Analytical Support Services (CLASS) program and was required to submit quality control data to USATHAMA on a frequent basis during the period it processed MAAP samples. ESE implemented its internal quality control program for monitoring internal laboratory procedures and analytical method performance. In addition, ESE is audited by USATHAMA on a semi-annual basis.

6.3.1 Analytical Parameters

The constituents required for analysis by the approved Work Plan included: EPA target analyte list (TAL) inorganic constituents; EPA target compound list (TCL) volatile and semivolatile constituents; explosives, and select metals (cadmium, chromium, mercury, and lead). Lists of the noted parameters have been provided in Appendix M.

EPA TAL inorganic constituents were analyzed for 23 metals in accordance with USATHAMA Class 1 protocols, which specify the processing of a method blank and spikes of all control analytes. The method blank was processed to verify that the laboratory was not a source of sample contamination. The control analytes were spiked into quality control samples to assess method performance.

Total and dissolved metal samples were collected for this project. The metal constituents were analyzed using one of the following methodologies: inductively coupled argon emission plasma spectroscopy (ICAP), graphite furnace atomic absorption spectroscopy (GFAA), or cold vapor atomic absorption (CVAA). The methodologies require acid digestion of a sample aliquot to ensure dissolution of metallic constituents.

The ICAP method involves the simultaneous or sequential multi-element determination of trace elements in solution. The basis of the method is the measurement of atomic emission by optical spectrometry. The ICAP source consists of a flowing stream of argon gas ionized by an applied radio frequency field. This field is inductively coupled to the ionized gas by a water-cooled coil surrounding a quartz torch that supports and confines the plasma. Samples are nebulized and the resulting aerosol is transported to the plasma torch where excitation occurs. Characteristic atomic line emission spectra are produced by the radio-frequency inductively coupled plasma. The USATHAMA methods used for the analysis of ICAP metals in soil and water were JS11 and SS10, respectively.

The GFAA technique involves the digestion of a representative sample using nitric acid and hydrogen peroxide. The digestate was subsequently analyzed by GFAA using the optimum instrumental conditions for the analytes of interest. The corresponding USATHAMA method numbers for soil samples were JD15 (selenium), JD16 (vanadium), JD17 (lead), JD18 (silver), and JD19 (arsenic). Water samples were analyzed using methods SD09 (thallium), SD19 (vanadium), SD20 (lead), SD21 (selenium), SD22 (arsenic), and SD23 (silver).

CVAA analysis for mercury is based on the absorption of radiation at 253.7 nm. A sample aliquot was initially digested with nitric acid to free any combined mercury. The mercury was then reduced to its elemental state and aerated from the solution into a closed system. The mercury vapor was passed through a cell positioned in the path of a mercury light source. The measured absorbance is proportional to the concentration of mercury in the sample. USATHAMA method numbers JB01 and SB01 were used for the analysis of soil and water samples.

EPA TCL volatile and semivolatile constituents were analyzed in accordance with USATHAMA Class 1A protocols for gas chromatography/mass spectroscopy analysis. Method blanks and surrogate samples were required to monitor the analytical method performance. The non-surrogate portion of the method blank was used to verify that the laboratory was not a source of sample contamination, while the surrogate portion was used to verify the accuracy of the method. The control surrogates were processed in every environmental sample and functioned to assess sample matrix effects.

USATHAMA method number LM19 was used for the analysis of volatile organic compounds in soil samples and UM20 was used for the analysis of water samples. The water method involved purging five milliliters of volatile organic free water containing surrogates and internal standards with helium gas. The soil method included the addition of five grams of soil in the purging vessel. The purging chamber was heated to a predefined temperature and the vapor was transferred to a sorbent tube which effectively trapped the volatile organic compounds. The constituents were then backflushed onto a gas chromatographic column that was temperature programmed to separate the organic constituents. The volatile compounds were then detected using a mass spectrometer.

The analytical method for the analysis of semivolatile constituents involved spiking the sample with a known amount of surrogate compounds and extracting a designated amount of sample with methylene chloride. The extract was concentrated to a predefined volume, and internal standards were added to the extract prior to injection onto the chromatographic column. Separation of constituents was performed on the chromatographic column and detection was effected by a mass spectrometer. USATHAMA methods LM18 and UM18 were used for the analysis of soil and water samples, respectively.

6.3.2 USATHAMA Certified and Upper Reporting Limits

The lowest concentration that is reported for any analyte has been established in the USATHAMA program from a statistical analysis of spikes and blanks. The concentration, termed the certified reporting limit, is the lowest value that can be reported within a 90% confidence limit. The upper reporting limit for the certified range was developed during the method certification. Detection limits (certified reporting limits) for non-certified GC/MS constituents have been reported as the EPA Contract Laboratory Program's contract required quantitation limits (CRQL). A list of the certified and upper reporting limits for inorganic and organic constituents are presented in Appendix M.

6.3.3 Laboratory Lot Designations

All samples submitted to ESE have been identified according to laboratory designated lot numbers, method numbers, parameters, sampling dates, analytical preparation date (if applicable), and analysis date. A list of this information is contained in Appendix M.

6.4 DATA QUALITY ASSESSMENT

The quality of the data generated by the analytical laboratory was assessed by evaluating the quality control charts. The information contained in the analysis of trip, rinse, and method blanks was used to further qualify the chemical data. A brief description of this process is given in this section.

The USATHAMA project chemist is responsible for checking the holding time information, spike recovery data, and surrogate recovery data. In addition to standard USATHAMA quality assessment, spot-checking of these items was performed as part of this data quality assessment.

6.4.1 Data Quality Objectives

Data quality objectives for analytical services were developed during the development of the project work plan and evaluated throughout the course of chemical analyses. Quality control samples were analyzed to provide verification that the analytical method performance was comparable or better than levels achieved during initial method certification. Data acquired from the quality control samples were plotted on control charts to assist in the evaluation of the method performance.

In accordance with USATHAMA protocols, ESE submitted quality control charts for the analytes of interest showing spike recovery upper and lower control and warning limits. The quality control charts were submitted to USATHAMA on a frequent basis during sample analysis and used by USATHAMA to monitor the daily variations in the USATHAMA-certified analyses and provide inferences on method performance. The USATHAMA project chemist was responsible for evaluating the quality control chart submittals and determining the data acceptability based upon trend analysis. A lot confirmation letter was submitted to the USATHAMA project officer and the ICF Quality Assurance Manager. A review of the lot confirmation letters indicated that the control data for lots submitted by ESE were acceptable.

6.4.2 Data Validation

Data validation is defined as the systematic process for reviewing a data package against a set of criteria to provide assurance that the data are adequate for their intended uses. Although the primary responsibility for data quality is the responsibility of the analytical laboratory, USATHAMA is responsible for reviewing the integrity of environmental data prior to its submission to the Data Management System. USATHAMA has developed a dynamic system that consists of a review of the data package contents, contract compliance screening, analytical method performance, laboratory auditing, and verification of data results. A series of checklists have been developed to assist USATHAMA in the review of data received from the laboratory.

6.4.3 Data Qualification

In addition to data validation, data was qualified based upon method performance and potential contamination acquired in the field, during transit to the laboratory, and in the laboratory environment. A detailed discussion of the qualifiers associated with this data is contained in the next section.

6.5 BLANK CONTAMINATION ASSESSMENT

The blank contamination assessment was performed to determine the impact of contaminant contributions originating from non-point sources. These potential sources include the field sampling procedures, sample shipment, and the laboratory environment. An evaluation of the non-point sources is presented below. The potential field sampling contamination was assessed through the evaluation of field blanks. Field blanks are defined as a standard matrix sample that does not contain any of the analytes of interest to the project, and are transported with the environmental samples to the laboratory to determine if contamination was introduced during shipment. Field blanks consist of rinse blanks that are generated in the field by the sampling crew, and trip blanks that are supplied to the sampling team by the laboratory. In addition, method blanks are used to determine the potential contamination from the laboratory environment and analytical method used to process the samples.

Rinse blank samples were collected for all sample matrices to evaluate the effectiveness of sampling decontamination and to assess potential field cross-contamination. Rinse blank samples collected for the project and the associated contaminants and samples are contained in Appendix M.

Potential sample contamination contributed by the laboratory environment were discerned through the evaluation of the laboratory method blanks. Method blanks were processed at the beginning of the analytical run by the laboratory to determine whether the internal laboratory environment, reagents used during analyses, analytical techniques, or the instrumentation system were sources of contamination that could affect the integrity of the sample.

The criterion for the evaluation of blank contamination applies to any blank associated with the samples and states that no contamination should be in the blank. If contamination is detected, all data associated with blank must be carefully evaluated to determine whether there is an inherent variability in the data for the lot, or the problem is an isolated occurrence not affecting all samples in the lot. In cases where more than one blank was associated with a given sample, qualification was based upon a comparison with the associated blank having the highest concentration of the contaminant. Data results were not corrected by subtracting the associated blank value from the sample.

Sample results greater than the CRDL but less than five times the amount in any blank are qualified as undetected for inorganic constituents. The criteria for organic contamination is dependent upon whether or not the contamination is a common laboratory contaminant. Sample results are qualified accordingly for organic constituents: (1) the sample result is reported as non-detected when the compound concentration is greater than the CRDL but less than ten times the amount in any blank for common laboratory contaminants, (i.e., methylene chloride, acetone, toluene, 2-butanone, carbon disulfide, and common phthalate esters); and (2) the sample result for other contaminants are reported as non-detected when the sample concentration is greater than the CRDL but less than five times the amount detected in the associated blank.

6.5.1 USATHAMA-Approved Water Source

Samples from Production Well F-100, T-99, and I-111 were collected on June 29, 1990 and analyzed for the EPA TAL/TCL list and explosives. Semivolatile, volatile, and explosive constituents were not detected above the CRL in the noted samples, however several inorganic constituents were detected above the CRL. Table 6-1 contains the results for analytes detected above the CRL.

The information was submitted to USATHAMA on July 20, 1990, and the agency approved T-99 as the approved water source. When evaluating rinse blanks, the concentrations of inorganic species detected in the approved water source will not be used to evaluate decontamination efficiencies and cross contamination unless the result detected in the rinse blank is five times the concentration initially detected in the approved-water source.

6.5.2 Sample Qualification

This section will discuss the qualification of environmental data for each media based upon the result of quality control data associated with the samples. An in-depth analysis of each area is presented in Appendix M.

6.5.2.1 Surface Water Investigation. The blank contamination assessment for this investigation area was based upon data acquired from trip and method blanks. Since the samples were collected directly into the sample container, rinse blanks were not required. A deviation to the normal protocol was noted for trip blanks used during this investigation. The trip blanks supplied by the laboratory were examined by the sampling team, and air bubbles and void spaces were noted. Since the purpose of the trip blank is to assess potential volatile organic contamination acquired during sample transport, the use of trip blanks with visible bubbles and voids would result in a substantial loss of information. Therefore, from July to September, 1990, the sampling teams used trip blanks that were made on the site. These blanks consisted of laboratory-cleaned, triple-rinsed 40-ml vials, preserved with HCl, and filled with organic-free, deionized water. Table 6-2 presents the noted qualifiers.

Zinc was detected in the Lot TGL method blank at a concentration of 22.6 μg/L for site IDs DTCH4-2 (32.8 ug/L), and DTCH6-1(28.1 ug/L); Manganese was detected in the method blank for lot TGN at a concentration of 7.19 ug/L for samples DTCH10-3A, DTCH10-6, DTCH4-3, and DTCH4-4. A review of the associated samples in these lots indicated that zinc was the only element requiring qualification. Sample results were qualified as undetected for zinc in DTCH4-2 and DTCH6-1 since the concentration in the sample was less than five times the value detected in the associated method blank. Organic contamination noted in the trip blank was qualified for Unknown 25 in sample SDTC-1. The isopropanol detected in sample CREK-1 was also qualified.

6.5.2.2 Sediment Investigation. The qualification for sediment data was based on contaminants detected in the rinse blank and method blanks associated with the samples. Table 6-3 presents the qualifiers used for sediment data.

6.5.2.3 Surface and Subsurface Soil Investigation. The evaluation of soil samples at MAAP resulted in the qualification of several soil samples. Table 6-4 presents the findings.

6.5.2.4 Groundwater Investigation. Table 6-5 presents the qualification of groundwater data for this investigation. The qualification of data for this investigation was based upon method, rinse, and trip blanks.

TABLE 6-1
Inorganic Data for Potential Decontamination Water Sources

ANALYTE	F-100	T-99	I-111
Barium	6.9	9.1	7.3
Calcium	1860	1540	1240
Copper	8.4	ND[1]	ND
Lead	20.2	3.1	14.2
Magnesium	540	569	ND
Manganese	ND	3.4	8.7
Potassium	659	728	771
Sodium	2960	2530	2510
Zinc	ND	34.5	ND

[1] Not detected above CRL

TABLE 6-2
Surface Water Data Qualified By Contaminant Assessment

SITE ID	FIELD SAMPLE NUMBER	CONTAMINANT	QUALIFICATION
DTCHC-1	SDTC-1	Unknown#25: 7.0 ug/L	**UNDETECTED:** The sample result should be qualified as undetected since the concentration in the sample is less than five times the value detected in the associated trip blank.
CREK-3	CREK-3	Isopropanol: 10.0 ug/L	**UNDETECTED:** The sample result should be qualified as undetected since the concentration in the sample is less than five times the value detected in the associated trip blank.
DTCH4-2	SDT4-2	Zinc: 32.8 ug/L	**UNDETECTED:** The sample result should be qualified as undetected since the concentration in the sample is less than five times the value detected in the associated method blank.
DTCH6-1	SDT6-1	Zinc: 28.1 ug/L	**UNDETECTED:** The sample result should be qualified as undetected since the concentration in the sample is less than five times the value detected in the associated method blank.

TABLE 6-3
Sediment Data Qualified By Contaminant Assessment

Organic Compounds

ANALYTE	FIELD SAMPLE NO.	QUALIFIER
2-Cyclohexen-1-ol	I-SED*89 I-SED*95 I-SED*99 -SED*155	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.
2-Cyclohexen-1-one	I-SED*95	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.
1,2-Epoxycyclohexene	-SED*156 -SED*170 -SED*171 -SED*173 -SED*175 -SED*177 -SED*179 -SED*181 -SED*182 -SED*184 -SED*186 -SED*188	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.
UNK641	-SED*122	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.
UNK650	I-SED*65	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.
UNK653	-SED*153 -SED*155 -SED*156 -SED*186	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.
UNK70	I-SED*56	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.

TABLE 6-4
Soil Data Qualified By Contaminant Assessment

SITE ID	DEPTH	ANALYTE	Q
ADAB-1	5	12EPCH*	U
ADAB-2	15	12EPCH*	U
OBGB-2	5	12EPCH*	U
OBGB-3	5	12EPCH*	U
OBGA-5	5	CCLF3*	U
OBGC-2	5	CCLF3*	U
OBGA-3	20	UNK70*	U
CBG-1	0	12EPCH*	U
		2CHE10*	U
CBG-2	0	12EPCH*	U
		2CHE10*	U
OBGA-2	5	12EPCH*	U
		2CHE10*	U
CBG-3	10	UNK573*	U
		UNK573*	U
CLF-3	10	12EPCH*	U
SC-12	5	12EPCH*	U
SA-7	5	2CHE1L*	U
SA-7 (duplicate)	5	12EPCH*	U
		2CHE1L*	U
SX-8	5	2CHE1L*	U
SC-6	0	ACET	U
SB-273	4.5	MEC6H5	U
CBG-1	0	ACET	U
CBG-2	10	ACET	U
CBG-3	10	ACET	U
CBG-3 (duplicate)	10	ACET	U
CBG-4	5	ACET	U
CBG-5	10	ACET	U
CBG-3	0	Hg	R
	5	Hg	R
CBG-4	10	Hg	R
CBG-4 (duplicate)	10	Hg	R
CBG-5	0	Hg	R
	5	Hg	R
CDP-2	0	Hg	R
	12	Hg	R
	26	Hg	R
30	Hg	R	
SA-A44	5	Ba	U
SA-44	5	Ba	U
SD-42	9	Ca	U
SA-40	0	135TNB	UJ
	2.5	13DNB	UJ
	5.5	246TNT	UJ
		24DNT	UJ
		26DNT	UJ
		HMX	UJ
		RDX	UJ
		NB	UJ
		Tetryl	UJ
SB-12	0	135TNB	UJ
	4.0	13DNB	UJ
	9.0	246TNT	UJ
		24DNT	UJ
		26DNT	UJ
		HMX	UJ
		RDX	UJ
		NB	UJ
		Tetryl	UJ
SX-41	0	135TNB	UJ
	2.5	13DNB	UJ
	4.5	246DNT	UJ
		24DNT	UJ
		26DNT	UJ
		HMX	UJ
		RDX	UJ
		NB	UJ
		Tetryl	UJ

LEGEND:

12EPCH = 1,2-Epoxycyclohexene; 2CHE10 = 2-Cyclohexen-1-one; U = Undetected; CCLF3 = Trichlorofluoromethane; ACET = Acetone; R = Rejected; 2CHE1L = 2-Cyclohexen-1-ol; MEC6H5 = Toluene; E = Estimated; * = Tentatively identified compound; UJ = Estimated detection limit

TABLE 6-5
Groundwater Data Qualified By Contaminant Assessment

Inorganic Analytes

ANALYTE	FIELD SAMPLE NO.	QUALIFIER
Calcium	MI054U	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.
Copper	MI-GW*6 MI-GW*1 MI-GW*27 MI-GW*44 MI-GW*24 MI-GW*35 MI-GW*25 MI-GW*31	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated filter blank.
Mercury	MI047U MI040U	R — Reject result due to extended holding time.
Lead	MI-GW*80 MI-GW*81 MI010U MI015U MI017U MI022U MI027U MI028U MI-GW*79 MI030U MI030U MI-GW*98 MI068 MI076U MI-GW*85 MI077U MI-GW*94	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated method blank.

TABLE 6-5 (Cont'd)
Groundwater Data Qualified by Contaminant Assessment

Organic Compounds

ANALYTE	FIELD SAMPLE NO.	QUALIFIER
Acetone	I-GW*117 I-GW*100 MI-GW*70	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated rinse blank.
Isopropanol	I-GW*100 I-GW*116 MI-GW*70 MI-GW*71 MI-GW*98	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated rinse blank.
Chloroform	I-GW*100	U - The analyte was present in the sample above the CRL but less than 5 times the concentration in the associated rinse blank.

6.6 DATA MANAGEMENT

Chemical and geotechnical data were entered into the USATHAMA Installation Restoration Data Management System (IRDMS) and were group- and record-checked prior to submittal to Potomac Research Incorporated, the subcontractor responsible for maintaining the USATHAMA database. In addition to routine data management protocols, several supplementary activities were performed to produce accurate and complete data reports. The tasks required to finalize the existing Level 3 data included editing site identification numbers, locating missing information, placing the correct data into the appropriate data files, verification of Method 99 designations, and evaluating holding times.

Editing Site Identification Numbers: The Level 3 information that was initially contained in the IRDMS was assumed to be error-free; however, a number of inconsistencies were noted while performing sample request verification. Several of the media site identification numbers were incorrectly recorded. One of the site identification numbers listed for a surface water sample was actually applicable to a sediment sample. Since the map file for the sediment sample had been loaded into the system, the IRDMS checking routine did not indicate an error. The groundwater database also contained erroneous site identification numbers and sampling dates.

Missing Information: When the surface water database was reviewed for completeness, it was noted that data were missing for samples DTCH7-6, DTCH7-6 (duplicate), and DTCHC-3. The DTCH7-6 samples were missing 22 metal results, VOC analysis results, and all explosives data. In addition, the DTCH7-6 duplicate was missing BNA information. DTCHC-3 was missing selenium data. The laboratory was contacted in an effort to retrieve the missing information. The laboratory stated that the information had been submitted to IRDMS, and provided the date the information had been transferred. The missing surface water data for DTCH7-6 and its duplicate were eventually located in the sediment database. The DTCHC-3 data for selenium was contained in the surface water database, but the site identification number had been incorrectly reported as DTCH3-3.

Verification of Method 99 Designations: One of the tasks associated with data qualification was to determine the reason for Method 99 designations on lots TMW (mercury in soil), TQK (VOAs in soil), TXV (explosives in soil), TXL (explosives in soil) , UIK (mercury in water), and UIN (mercury in water). The samples associated with each lot were reviewed for holding times prior to contacting the USATHAMA Chemist. A review of Lot TMW sample data indicated that 10 samples associated with the lot had holding times in excess of the 28 day criterion for mercury, but the remaining 25 samples were in compliance with the holding time criterion. A review of the data for Lot TQK did not indicate holding time problems because all VOCs had been preserved in the field with hydrochloric acid which extended the maximum holding time to 14 days. The holding times for Lots TXL and TXV were also in compliance with holding time criteria. Samples associated with Lots UIK and UIN for the analysis of mercury in water had holding times in excess of 28 days. The USATHAMA Chemist was then contacted on the clarification of designations associated with Method 99 data when the holding times were in conformance to the USATHAMA program. It was determined that Lot TMW could be split into two lots--one lot would contain the 10 soil samples that exceeded holding times and the remaining lot would be used to contain the compliant samples. The status of Lots TQK, TXL, and TXV has not been determined. The USATHAMA Chemist is currently working on the resolution of quality control problems associated with these lots.

Extended Holding Times: Samples DTCH2-3 and DTCH5-2 were held by the lab longer than the maximum allowed holding time. The samples were collected on August 14, 1990, extracted on September 4, 1990, and analyzed on September 10, 1990. The holding time criteria for this analysis specifies that samples must be extracted within 7 days and analyzed within 40 days of extraction. Although the samples were analyzed within 40 days of extraction, the extraction occurred 24 days after sample collection. The data quality for these samples is questionable since the extended extraction time introduces the potential for Type II errors or false negative results. However, the data for these samples were not included as Method 99 in the IRDMS report.

7.0 NATURE AND EXTENT OF CONTAMINATION

An interpretation of the chemical data presented in Section 5.0 is discussed in this section. The extent of contamination in the suspected source areas is qualitatively addressed. In cases where both source and contaminant loading data are available, the strength of the source area is estimated. This chapter focuses primarily on the major contaminants of concern: the explosive compounds, cadmium, chromium, mercury, and lead.

The groundwater data show that two contaminant plumes exist in the subsurface. The most severe plume extends from the O-Line Ponds area to the northern facility boundary. It appears that the drainage ditches and Line K are secondary sources for this plume. The second plume begins at the OBG/ADA area and also apparently includes drainage ditches and sumps at the LAP lines. This plume is traveling toward the northwestern boundary of the facility.

The extent of contamination in surface water is also discussed. The concentration of nitrobodies in surface water did not exceed the facility's NPDES permit limit at any sample location. As far as can be determined by the analytical data, the explosives detected in surface water can be attributed to regulated sources.

7.1 SOURCE AREAS

The data collected during this investigation were used to determine whether each suspected source area is contributing contamination to either groundwater, surface water or air contamination. In cases where sufficient data are available, the strength of each source was also estimated.

7.1.1 O-Line Ponds Area

The O-Line Ponds were identified by previous investigators (USATHAMA, 1982a, 1983) as the major source of groundwater contamination at the site. The data available for this analysis are historical pond sediment data, groundwater data collected during this investigation, and historical groundwater monitoring data.

7.1.1.1 Extent of Contamination. The monitoring wells closest to the O-Line Ponds are MI001, MI058, MI057, and MI075. MI001 and MI058 are shallow wells, while MI057 and MI075 are screened at an intermediate depth in the aquifer. The contaminants detected in these wells are TNT, RDX, 2,4-DNT, HMX, nitrobenzene, 1,3-DNB, 1,3,5-TNB, tetryl, and low levels of lead, mercury, and chromium.

The historical groundwater monitoring data for MI001 in the IRDMS database indicate that between 1986 and 1989, the levels of TNT, RDX, and TNB did not decrease significantly over time (Figure 7-1). There are four possible scenarios which could explain this behavior. These are as follows:

1. The cap is not leaking and contaminants are no longer being contributed to groundwater by the existing soil contamination. However, the magnitude of the groundwater velocity is so small that contaminated groundwater which was on the south (upgradient) side of the ponds at the time of capping (1983) has not yet moved past the monitoring wells on the north (downgradient) side of the cap. After this "slug" of contaminated water passes the wells, the detected levels should decrease rapidly in time.

2. The cap is not leaking but past use of the ponds resulted in a column of nearly-saturated soil under the cap which extends from the bottom of the former ponds to the water table. The water in this column is slowly draining over time and loading contaminants into groundwater.

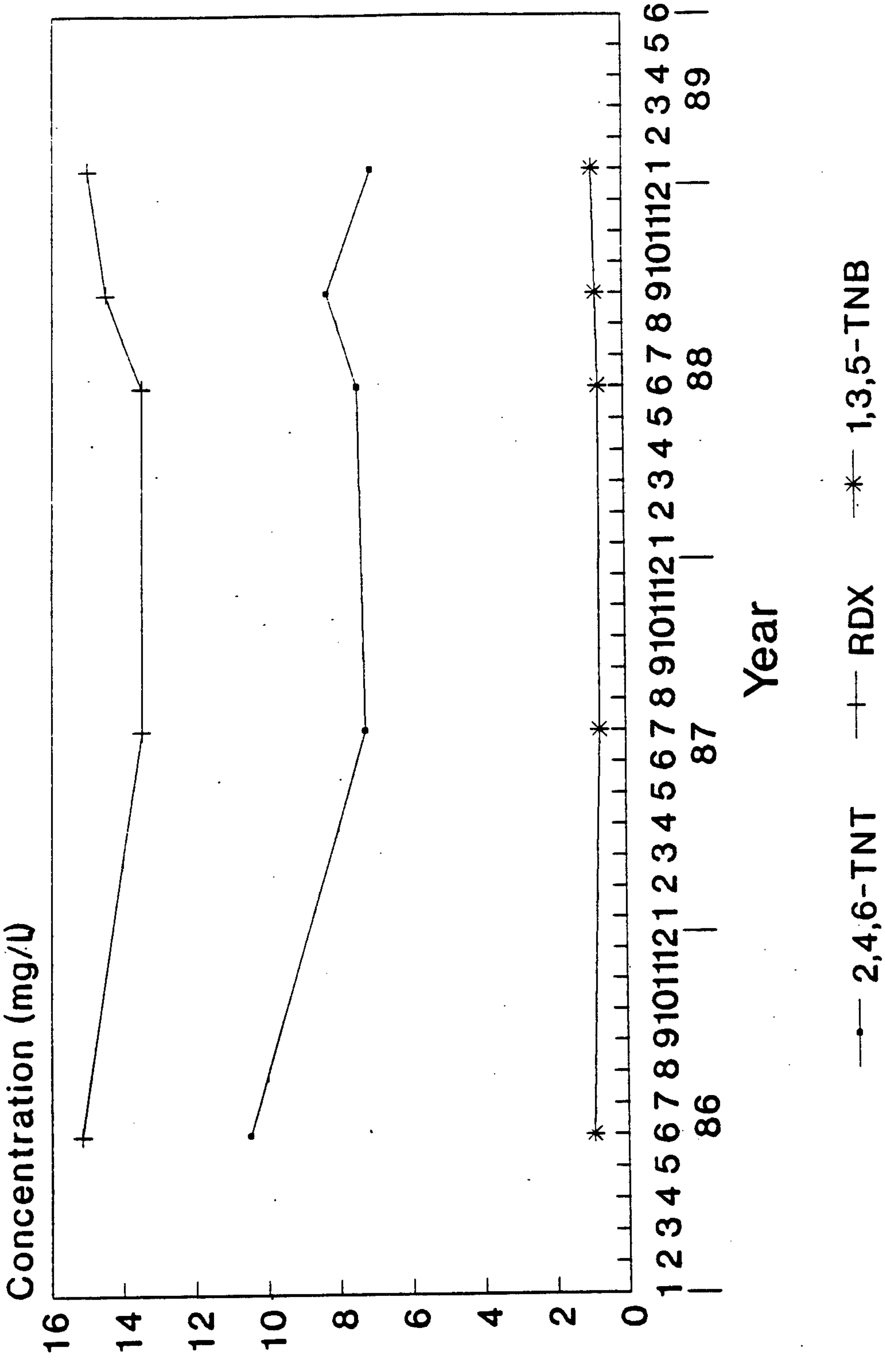


FIGURE 7-1
Concentrations of TNT, RDX, and TNB Detected in MI001 Between 1986-89

3. The cap is not leaking and the soil under the cap is less saturated than the surrounding soil because of the absence of recharge. A horizontal saturation gradient thus exists at the boundary of the capped region, which creates a horizontal capillary suction gradient. As water infiltrates the soil near the cap boundary, it is drawn radially inwards and comes into contact with the contaminated soil under the cap. The contaminants partition into the aqueous phase and are transported to the water table.

4. The cap is leaking. As water percolates through the contaminated soil under the cap, the contaminants partition into the aqueous phase and are transported to the water table.

Using available data, it cannot be determined which of the above scenarios is correct. However, given the multi-layered nature of the cap, Scenario 4 is the least plausible. Scenarios 2 and 3 are more plausible, and it is recommended that soil moisture and contaminant concentration profile data be collected to determine if loading is currently occurring. Scenario 1 is also plausible because the estimated groundwater velocity of 0.20 feet/day (Section 5.0) results in a flow distance of 580 feet in 8 years. This distance is roughly equivalent to the length of the capped area in the direction of groundwater flow. Because the most conservative scenario is to assume that the O-Line Ponds are continuing to act as a source of groundwater contamination, the assumption will be made through the remainder of this report that one of Scenarios 2 through 4 describes the physical processes occurring at O-Line.

The chemical data collected during this investigation indicate that the shallow groundwater under the ponds is being impacted predominantly by contamination emanating from the ponds. The intermediate wells, MI057 and MI075, had very low concentrations of explosives. MI001 is screened from elevation 386 to 356 ft-msl and MI058 is screened from 375 to 365 ft-msl. In general, the level of contaminants detected in MI001 is lower than that detected in MI058. This dilution of the concentrations indicates that the concentration distribution in groundwater decreased rapidly with depth. Based on the differences between the concentration levels detected in wells MI001, MI058, and MI057, it is estimated that the high levels detected in the shallow zone may extend to only about 40 feet below the water table before attenuating rapidly.

7.1.1.2 Source Strength and Potential for Release. Soil samples were not collected from the O-Line Ponds area during this investigation for the purpose of determining the level of contamination in this area. Therefore, in estimating the extent to which this area is contributing to the observed groundwater contamination, data collected by Environmental Science and Engineering (USATHAMA, 1981) were used. These data were collected prior to the capping of the ponds. Therefore, they represent the magnitude of pond sediment contamination under the cap. Since infiltration through the cap theoretically does not occur, and assuming that degradation has not caused significant concentration reduction, the level of contamination currently should be approximately the same.

In the 1982 study of the ponds, both surficial and core samples of the pond sediment were collected. The maximum depth of the core samples was three feet. RDX and TNT were detected at high concentrations in these samples. The range of concentrations at which RDX was detected is 22.8 to 572 mg/kg in the core samples, and as high as 1,340 mg/kg in the surface sediment. The range of concentration for TNT was 6.24 to 41,300 mg/kg in the core and surface samples. The only other two explosive compounds which were analytes in this study, 2,4-DNT and 2,6-DNT, were not detected. Lead was detected at moderate levels (the concentrations ranged from 18 to 29 mg/kg in the core samples and as high as 39 mg/kg in surface sediment), as was chromium (8 to 15 mg/kg in the core samples, and a maximum of 19 mg/kg in surface sediment), and cadmium (not detected to 6 mg/kg in the core samples, and detected up to 11.3 mg/kg in surface sediment). Mercury was not detected.

These results indicate that the O-Line Ponds sediment are not a significant source of heavy metal contamination. However, the surface and near-surface were heavily contaminated with explosive compounds at the time of capping. Because the ponds were in use for approximately 40 years, it is likely that the constant hydraulic pressure exerted by the pond water resulted in downward infiltration of contaminated water to the aquifer.

Normally, transport through the vadose zone progresses relatively slowly. The downward movement of water in the unsaturated subsurface is driven by both gravity and capillary forces. At the same time, it is impeded by the effective permeability of the soil, which depends on the interfacial tension between the fluid and the soil, and the necessity for the water to find a connected pathway through the porous medium. Effective permeability is a function of the soil type and is also a strong function of the percent of water saturation. As the percent saturation increases, the effective permeability increases and transport through the unsaturated zone approaches the rate at which water travels through the aquifer. It is theoretically possible that the zone beneath the ponds contains more water in the pore spaces than is present in the vadose zone in the surrounding area due to the saturated conditions at the surface. This would allow relatively rapid transport of contaminants to the water table.

Historical groundwater quality data obtained from the IRDMS database indicate that the concentrations of explosives detected in MI001, the nearest downgradient well from the O-Line Ponds, has remained roughly the same since 1985. These data strongly suggest either that the O-Line Ponds are continuing to contribute explosive compounds to the groundwater or that a massive concentration in the groundwater at the time of capping has not yet migrated from the area. If the first hypothesis is correct, then the soil in contact with groundwater must be contaminated. It can be assumed, therefore, that the zone of contaminated soil extends from the cap down to the water table.

If the above assumption is true, then the mass of explosives under the cap can be estimated. The total area of the ponds is approximately 279,500 square feet. According to the surveyed elevation of well MI058, the elevation of ground surface near the ponds is 440 feet. The elevation of the water table is 395 feet. Therefore, the vadose zone under the cap extends for 45 feet. The volume of soil under the cap from the surface to the water table is 279,500 square feet multiplied by the depth of 45 feet, or 1.26×10^7 cubic feet. Assuming that the density of the soil is 2.65 g/cm^3, or 165 lbs/ft^3, and the porosity of the soil is 20%, the mass of soil between the cap and the water table is 7.56×10^8 kg, or 1.66×10^9 lbs.

The concentration of RDX and TNT in surficial sediment was presented in Table 2-4 (source: USATHAMA, 1981). The average concentration in surface sediment shortly before pond closure was estimated from these data by averaging the values for each sample. Using this method, the average concentration of TNT in surface sediment is 5,976 mg/kg. The average concentration of RDX in surface sediment is 413 mg/kg. Because the ponds are capped, the primary mechanisms for diluting this concentration have been removed. Therefore, in this analysis of source strength, it has been assumed that these concentrations of explosives in the soil immediately under the cap currently exists.

In order for the ponds to continue acting as a source, the contamination in the soil beneath the ponds must extend to the water table. As a first approximation of the concentration distribution, it was assumed that the concentration of each explosive decreases by a factor of 0.1 within each 10-foot depth interval from the surface to the water table (the concentration is a logarithmic function of depth). This approximation was made because in the sump boring samples, it was observed that the concentrations of explosives decreased at a rate greater than or equal to one order of magnitude per 10 feet of depth. Using this approximation, the estimated mass of TNT under the cap is 960,000 lbs. The estimated mass of RDX under the cap is 66,000 lbs.

According to the Installation Assessment performed by USATHAMA (1978b), it was reported that 300 to 500 lbs. of material (explosives) were washed out in an 8-hour shift. Assuming that one shift per day operated at O-Line, 260 days per year, then in the 40 years that the O-Line Ponds were used, 4,000,000 lbs. of explosives were disposed of in the ponds. Therefore, it is not unlikely that a large mass of explosives is currently entrained in the soil under the cap.

7.1.1.3 Contaminant Loading into Groundwater. Even without making assumptions about the rate of transport through the vadose zone under the pond cap, it is possible to estimate the rate at which contaminants are entering the groundwater under the ponds. The level of contamination detected in groundwater can be used to estimate the contaminant mass that is continuously added to the water to maintain that concentration level.

Because the observed concentration in monitoring well MI001 has not decreased from 1985, it appears that the O-Line Ponds may be contributing contamination into the groundwater at a constant rate. If this scenario is correct, then the assumption can be made that the mass transfer process is occurring under steady-state conditions. The mass conservation equation for the contaminant is:

$$\frac{dm}{dt} = V\,(C_{out} - C_{in}) \tag{1}$$

where:

dm/dt = rate of contaminant loading into groundwater from the source area (lbs/day)

V = volumetric rate of groundwater flow through the affected zone (ft^3/day)

C_{out} = concentration of the solute leaving the affected zone (lbs/ft^3)

C_{in} = concentration of the solute entering the affected zone (lbs/ft^3)

For these calculations, it was assumed that the width of the affected zone is 500 feet, the height is 40 feet (the shallow region of the aquifer), and C_{in} is conservatively approximated to be zero. The results of these calculations, as given in Table 7-1, show that more than 1 lb of explosives appear to be released into the groundwater per day.

7.1.1.4 Contaminant Loading into Surface Water. The chemical data for surface water and sediment in Ditch 5, which runs downgradient from the O-Line Ponds, do not indicate that leachate from the ponds are entering surface water. The levels of explosives detected in surface water are well within the facility's NPDES permit limits and therefore are attributed to discharge from the O-Line PWTF.

7.1.2 Open Burning Ground, Former ADA, Current ADA

The results of a trenching survey conducted in the OBG (PBSJ, 1988) indicated that two areas of highly contaminated soils exist in the northern area and a widespread area of lower contaminant levels exists in the southern portion of the OBG. Because the horizontal extent of contamination was not determined by the previous study, a fixed grid boring system was used in this study. The distance between each grid node was 800 feet. The grid was oriented so that nine of the nineteen boring locations were situated in the central portion of the OBG. One boring was located in each of the two areas identified in the PBSJ study as being highly contaminated. These two borings were OBGA-3 (between Areas A and M) and OBGC-3 (just south of Area H). The remaining borings are located around the perimeter of the OBG.

7.1.2.1 Extent of Contamination. A review of the chemical analytical results for soil samples collected from these borings shows that contamination by explosives was observed at only three soil borings: OBGA-3, OBGA-4 and OBGB-4. In addition, explosives contamination was not observed at these borings at depths greater than 15 feet. Significant contamination by select metals (cadmium, chromium, mercury, and lead) was not detected.

Table 7-1
Calculated Rates of Contaminant Loading into Groundwater in the O-Line Ponds Area

Contaminant	Estimated Rate of Loading into Groundwater (lbs/day)
RDX	0.69
2,4,6-TNT	0.82
HMX	0.064
1,3,5-TNB	0.078
1,3-DNB	0.0034
Nitrobenzene	0.028
2,4-DNT	0.0055

Boring OBGA-3 is located between Areas A and M of the PBSJ study. Area M was reportedly used for disposal of O-Line Pond sludge. Area A contains two trenches used primarily for the disposal of explosive-contaminated shells and ash from the surface burning of explosives and propellants. The explosives contamination detected at this location was observed only at the zero to one foot depth interval, although samples were collected from other depth intervals which profiled the entire borehole.

Boring OBGA-4 is located west of the western perimeter of Area B of the PBSJ study. Again, explosives contamination was observed primarily at the zero to one foot depth interval. The explosives HMX and RDX were detected, as well as hexamethylene tetramine, a compound used in the manufacture of RDX, and three organic compounds associated with explosives production and/or handling.

Boring OBGB-4 is located just northwest of the northwest corner of Area D of the PBSJ study. HMX, RDX, and TNT were found in the soil sample collected from the zero to one foot depth interval only. These compounds were also detected at depths down to four feet in Area D in the PBSJ study.

The chemical analytical results for the soil samples collected from the soil borings indicate that most of the soil boring locations are not highly contaminated. The vertical extent of soil contamination by explosives at these locations is limited to a depth of fifteen feet, with the concentrations of contaminants decreasing significantly at depths beyond 5 feet. It appears that the areas which are causing the observed groundwater contamination were not investigated during this study. Most of the boring locations do not correspond to the source areas identified by PBSJ. Therefore, it is likely that widespread subsurface contamination does not exist in the OBG, and that the groundwater contamination is caused by localized regions.

Historical methods of waste disposal in the OBG would provide a means for explosive contaminants to reach the aquifer in several disposal areas. The waste disposal trenches at Areas A and F were filled to a depth of 15 feet with debris, ordnance components and ash from bulk explosive burn operation. After the trench was filled, the excavation was covered with soil. It is possible that precipitation infiltrates the surface soil cover of these trenches more readily than undisturbed soil, that the trenches collect water, and that the contaminated water gradually percolates to the water table.

Another past method of waste disposal in this area could also provide a mechanism for explosive contaminants to reach the aquifer. Area M is a natural depression which is located at the west end of trench "A". Mud and sludge from the O Line Ponds was disposed of here. During the PBSJ study, it was noted that the spoils at the west end of "A" appeared to be holding water in the area where the sludge was disposed of. The disposal area appeared to be about 40 feet wide at the lowest point of the depression. A depression of this size holding water would be expected to exert a constant or near constant downward gradient below itself, enabling explosives contaminants to vertically migrate to the water table over time.

7.1.2.2 Source Strength. The soil boring chemical data was not used to calculate contaminant loading to water because explosives contamination in the borings was not observed at depths beyond 15 feet, and in general, the depth to groundwater is approximately 90 feet. The location of the source(s) of groundwater contamination were not defined in this investigation. However, water quality data collected from the RCRA wells were used to calculate source strength as described below.

7.1.2.3 Contaminant Loading into Groundwater. The mass balance approach used in the previous subsection was applied to the groundwater data collected from the wells downgradient of the OBG (RCRA monitoring wells 002, 003, 004, and 005). As before, several assumptions were made. First, it was assumed that there is no upgradient contribution to groundwater contamination. The groundwater sample from RCRA monitoring well 001, located upgradient of the OBG, did not contain either explosives or metals. Second, contaminant concentrations observed at the relevant wells are assumed to be constant. Third, the entire aquifer underlying the OBG (aquifer thickness and width) is assumed to be contaminated at a level which is the average contaminant level at the relevant wells. This assumption was made because the relevant wells are screened at different depths, ranging from 212 to 134 feet below the surface. The well in which the highest explosive levels were detected, 003, is screened at a depth of 192 feet below the surface (310 ft-msl).

The source strength required was calculated for each of the contaminants observed at the specified wells. Non-detections of contaminants were not included in the averaging scheme so that a reasonably conservative estimate can be made. Source strengths were calculated for all contaminants detected. These source strengths are listed in Table 7-2. The source strength calculated for RDX (the contaminant observed at the highest concentration in the specified wells) is 0.2 lb/day.

7.1.2.4 Contaminant Loading into Surface Water. Ditches 8, 9, and 10 are in the OBG/ADA area or downgradient from this area. The highest concentration of explosives in surface water was detected in a sample taken from Ditch 10, in the current ADA. However, the surface water samples taken from Johns Creek, which is the receiving stream for these ditches, did not reveal explosives or heavy metal contamination.

7.1.2.5 Contaminant Loading into Air. Because much of the OBG and ADA is unvegetated, the potential exists for wind-blown transport of contaminated soil to receptor populations both on-site and off-site. This mode of transport is discussed further in Section 8.0 and evaluated in Section 9.0.

7.1.3 Former Burn Out Area

The Former Burn Out Area was investigated with five soil borings, the installation and sampling of a new monitoring well (MI073), and sampling of this well, downgradient wells MI020 and K-323, and upgradient well MI021.

7.1.3.1 Extent of Contamination. As discussed in Section 5.0, the results of this investigation do not indicate that this area represents a significant source of contamination. Lead was detected in surface soil at a maximum concentration of 80.2 mg/kg. Organic compounds associated with the production or packaging of explosives were detected in soil at very low concentrations. Explosives were not detected in soil samples.

7.1.3.2 Source Strength. Because no significant contamination was detected in this area, the estimated source strength is zero.

7.1.3.3 Contaminant Loading into Groundwater. Lead was detected in the unfiltered sample at a concentration of 5.43 μg/L, which is below the site-specific background level in groundwater. No explosives were detected. The facility's production well K-323 is located approximately 2,000 feet northeast of MI073. Lead was detected in this sample at a concentration of 97.8 μg/L. This is an elevated level, but given the low mobility of lead in the environment, it is highly unlikely that the source of this contamination is the Former Burn Out Area. Therefore, there is no evidence that this area is contributing to groundwater contamination.

7.1.4 Line A

Soil samples were collected from the borings installed near the four wastewater sumps at Line A. The chemical analysis of these soil samples did not indicate that significant soil contamination exists near the sumps.

7.1.4.1 Extent of Contamination. The surface and near-surface soil near the sumps are not contaminated by explosives and heavy metals. However, the two existing monitoring wells installed inside Line A indicate that the groundwater underlying this load line is contaminated with cadmium (the maximum concentration is 88.7 μg/L), TNT (1.1 μg/L), and nitrobenzene (88.7 μg/L). The wells upgradient of Line A are not contaminated with cadmium or TNT. In the case of nitrobenzene, the upgradient wells show contamination but the concentrations detected at Line A are higher. These factors indicate that Line A, or an area near Line A, is contributing to groundwater contamination.

7.1.4.2 Source Strength. The strength of the source at or near Line A cannot be quantified without additional data. The soil data do not indicate that a source exists near the wastewater sumps, yet groundwater data indicate that contaminant loading is occurring.

7.1.4.3 Contaminant Loading into Groundwater. The monitoring wells at Line A were previously sampled in 1983, according to the IRDMS database, and explosives were not detected. Cadmium was detected at a concentration of 6.58 μg/L. It appears from these two rounds of samples that the concentration of contaminants has increased over time.

7.1.5 <u>Line B</u>

Line B was investigated by installing borings near each of the five wastewater sumps. Monitoring wells MI050, MI055, and MI033 were sampled to assess the extent of groundwater contamination under this load line.

7.1.5.1 Extent of Contamination. Explosives were detected at relatively high concentrations in soil. However, the concentrations decreased rapidly with depth. The most contaminated boring, SB-18, had a concentration of 6,200 mg/kg at the surface and 7.82 mg/kg at the 10 to 12 foot interval. This boring was not extended to the water table, therefore it is not known if the source of groundwater contamination is the soil near this sump.

Production well B-100 is not used because of RDX contamination (personal communication, Bill Blaylock, Martin Marietta, April 10, 1991). This well could not be sampled during this investigation because the pump has been removed. The three monitoring wells installed downgradient of Line B are contaminated with low to moderate levels of RDX, cadmium, TNT, 1,3,5-TNB, and nitrobenzene. Also, the wells located 600 feet northeast of Line B (MI010, MI068, MI069, and MI070) are contaminated with RDX, cadmium, TNT, 2,4-DNT, HMX, 1,3,5-TNB, and nitrobenzene. Because of this apparent widespread groundwater contamination, it appears possible that the source of groundwater contamination in this area is Ditch 4, which begins near Line B. Historically, wastewater from Line B was discharged into this ditch from the sumps. It is possible that the soil beneath the ditch has retained a large amount of explosive compounds, and that it is now contributing contamination to groundwater. Additional evidence that this is happening is the relative concentrations between the wells. Monitoring MI010 is the well situated closest to Ditch 4. In the cases of RDX, TNT, HMX, and nitrobenzene contamination, the highest concentration detected in these wells was found in well MI010. The concentrations appear to decrease as the distance to the ditch increases.

7.1.5.2 Source Strength. The results of the soil borings indicate that the soil near the sumps contains high levels of explosives at the surface which decrease with depth. Because the borings did not extend to the water table, it cannot be determined whether the areas which are causing groundwater contamination have been located. Another possible source of the observed groundwater contamination is the soil underlying Ditch 4.

7.1.5.3 Contaminant Loading Into Groundwater. The rate at which contaminants are entering groundwater from these possible sources cannot be determined quantitatively without additional sampling data.

7.1.6 <u>Line C</u>

Soil borings were installed near the six wastewater sumps to investigate the surface and near-surface contamination in this area. In addition, monitoring wells MI006, MI065, MI066, and MI067, located downgradient of Line C, were sampled.

Table 7-2
Calculated Rates of Contaminant Loading into Groundwater in the OBG/ADA Area

Contaminant	Estimated Rate of Loading into Groundwater (lbs/day)
RDX	0.2
2,4,6-TNT	0.0021
HMX	0.02
1,3,5-TNB	0.0013
1,3-DNB	0.0089
Nitrobenzene	0.1
2,4-DNT	0
Tetryl	0
Cadmium	0.1

7.1.6.1 Extent of Contamination. The select metals were not detected at elevated levels in the soil borings. Low levels of HMX and RDX (less than 1 mg/kg) were detected in near-surface soil samples near one of the sumps. Explosives were not detected in soil samples taken near the other sumps.

Lead was detected in well MI006 at 33.9 mg/kg, but explosives were not detected in this well. Farther downgradient, and on the downgradient side of Ditch 5 (which received wastewater from Line C), RDX, cadmium, TNT, and nitrobenzene were detected in the cluster wells MI065, MI066, and MI067. The maximum detected concentration of RDX was 12.3 μg/L in the intermediate well, cadmium was detected at a maximum concentration of 70.9 μg/L in the deep well, and TNT was detected at a maximum concentration of 3.13 μg/L in the deep well. The source of the contamination detected in these wells is either Line C or the OBG/ADA area.

7.1.6.2 Source Strength. Because of the low concentrations of explosives and select metals in the sump boring samples, it does not appear likely that the soil near the sumps is contributing to groundwater contamination.

7.1.6.3 Contaminant Loading into Groundwater. Ditch 5 and the OBG/ADA area are possible sources of groundwater contamination observed in wells MI065, MI066, and MI067. However, because the movement of cadmium is relatively slow compared to the rate at which the explosives move through the subsurface, it is more likely that the source of the contamination is Ditch 5. The rate of contaminant migration is discussed in more detail in Section 8.0.

7.1.7 Line D

This line was investigated with soil borings installed near each of the four wastewater sumps. There are no monitoring wells directly downgradient of Line D within one-half mile.

7.1.7.1 Extent of Contamination. HMX, TNT, RDX, and 1,3,5-TNB were detected at very low levels in surface and near-surface soil. The explosive detected at the highest concentration is tetryl, which was found in a surface soil sample near one of the sumps at 81 mg/kg. Tetryl is one of the more soluble and mobile of the explosives, but it is not known if tetryl contamination extends through the soil column to the water table.

7.1.7.2 Source Strength. The source strength cannot be evaluated without further data.

7.1.8 Line O

Line O was investigated with three borings located near the wastewater sumps. In addition, monitoring well MI004, located inside of Line O, was sampled.

7.1.8.1 Extent of Contamination. HMX, RDX, 2,4-DNT, TNT, and 1,3,5-TNB were detected in the soil samples. These explosives were detected at maximum concentrations of 3.9 mg/kg, 10.9 mg/kg, 1.6 mg/kg, 45.2 mg/kg, and 5.2 mg/kg, respectively. In addition, cadmium was detected at a maximum concentration of 64.4 mg/kg and lead was detected at 17.0 mg/kg.

7.1.8.2 Source Strength. Monitoring well MI004 shows evidence of contamination by chromium, 1,3,5-TNB, TNT, HMX, and RDX. The source of this observed groundwater contamination may be the sumps in Line O. Alternatively, it is possible that the contamination detected in this well is related to the groundwater plume underlying the O-Line Ponds. Theoretically, dispersion causes contaminant transport against the groundwater flow direction. It is also possible that historical use of the production well at Line C has lowered the potentiometric surface between Line C and Line O, and caused contaminated groundwater to flow back. However, it is more likely that the contamination observed in this well is due to infiltration either from the soil near the sumps or from Ditch 4, which received wastewater from Line C as well as Line O. Given that the source of the observed groundwater contamination cannot be determined from available data, the strength of this source cannot be estimated.

7.1.8.3 Contaminant Loading into Groundwater. It is unknown if the soil near the sumps is contributing contaminants to groundwater. The concentrations of explosives and heavy metals attenuate rapidly in the soil. Contaminants were not detected in the deepest soil samples taken. Therefore, groundwater loading cannot be determined.

7.1.9 Line X

The five sumps at Line X were investigated with shallow borings. The production well at Line X, X-100, was sampled as part of this investigation. This well is no longer used because of explosives contamination. However, historical monitoring data for this well does not exist in the IRDMS database. Monitoring well MI014 is located further downgradient from Line X.

7.1.9.1 Extent of Contamination. Explosives were detected in two borings. Samples obtained from the boring installed near Building X-26 had low levels of TNT contamination. The concentration detected in the 2 to 3 foot sample was 0.56 mg/kg while the sample in the 4 to 5 foot interval had a concentration of 2.41 mg/kg. Soil samples taken from the boring SX-103 had much higher levels of explosives. HMX was detected at 163 mg/kg in the surface soil sample and 7.0 mg/kg between 2.5 and 3 feet. RDX was detected at 966.6 mg/kg in the surface soil, 46.2 mg/kg in the 2.5 to 3 foot interval, and 4.1 mg/kg in the 5.5 to 6.5 foot interval. Although the surface soil concentrations are high, the concentration attenuates rapidly with depth. Therefore, although it is possible that the soil near the sumps are contributing to groundwater contamination, it appears unlikely because of the rapid decrease in concentration. The groundwater sample collected from production well X-100 was not contaminated with explosives. However, MI014 is contaminated with HMX (1.8 μg/L) and 1,3,5-TNB (14.7 μg/L). The source of this contamination may either be the sumps or, more likely, the drainage ditch (Ditch 1) that receives wastewater from both Line X and Line A.

7.1.9.2 Source Strength. Because it cannot be determined whether the sumps at this load line are a source of groundwater contamination, the source strength cannot be evaluated without additional data.

7.1.9.3 Contaminant Loading into Groundwater. It is not known if the source of downgradient groundwater contamination is the soil near the sumps or the drainage ditch.

7.1.10 Line Z

This load line was investigated with four borings installed near two wastewater sumps. In addition, wells MI028, MI034, and S-99 are located downgradient of this line.

7.1.10.1 Extent of Contamination. Low levels of HMX and RDX were detected in soil from the surface to a depth of 5 feet below the sump. The level of contamination is very low at the maximum depth of the borings (12 feet). In the surface soil sample taken near the sump, 1,3-DNB was detected at a low level and tetryl was detected at 1,400 mg/kg. For boring SZ-2, HMX was detected at a low level in the surface soil sample and also at the 10 to 12 foot interval. Explosives were not detected in samples collected from the downgradient monitoring and production wells.

7.1.10.2 Source Strength. The groundwater samples collected from wells downgradient of this load line do not indicate that groundwater contamination is occurring. The levels of contaminants detected in surface soil samples are not insignificant, but are attenuated with depth.

7.1.10.3 Contaminant Loading into Groundwater. The available data for the downgradient wells suggest that this load line is not currently contributing to groundwater contamination.

7.1.10.4 Contaminant Loading into Surface Water. Historical data indicate that this load line has caused surface water contamination, which later caused off-site groundwater contamination. The monitoring of the off-site domestic wells by the State of Tennessee shows that these wells were contaminated with RDX and HMX in the 1980s. The most likely source of this contamination is the ditch which received wastewater from Line Z. According to facility personnel (personal communication, Bill Blaylock, April 10, 1991), this line used tetryl and Composition A5 (RDX and barium stearate) while it was operating. Given the large distances between the off-site wells and the other known sources of groundwater contamination, it appears most likely that shallow groundwater flow from the ditch resulted in a slug of contaminated water which moved off-site. Work at the line stopped in the 1970s, which could account for the gradual increase in groundwater quality in the off-site wells.

7.1.11 Present Landfill

The Present Landfill was investigated with two soil borings. In addition, RCRA monitoring wells 003 and 004 are located downgradient from this area. Newly installed monitoring wells MI062, MI063, and MI064 are located farther downgradient.

7.1.11.1 Extent of Contamination. The soil samples collected from the borings do not show that this area is contaminated with either explosives or select metals. Wells 003 and 004 are contaminated with explosives, but given the depth of these wells, the small distance between the landfill and the wells, and the fact that soil contamination was not observed, it is unlikely that this area is causing the observed groundwater contamination at MAAP.

7.1.11.2 Source Strength. Based on the above reasoning, the source strength of this area is zero.

7.1.12 Closed Landfill

This area was investigated with five soil borings, and the installation of monitoring wells MI071, MI072, and MI074.

7.1.12.1 Extent of Contamination. The results of the soil investigation indicate that this area is contaminated with explosives and select metals at depth. In soil boring CLF-2, TNT was detected at 2,866 mg/kg at a depth of 10 feet. HMX was detected at a concentration of 455 mg/kg and RDX was detected at 4,452 mg/kg in this same sample. Two other soil samples had low levels of explosives. Surface soil samples had elevated levels of lead and chromium.

Samples collected from monitoring well MI072 and MI074 were contaminated with low levels of explosives: 1,3,5-TNB, 1,3-DNB, TNT, 2,4-DNT, and RDX. The concentrations of these contaminants did not exceed 10 μg/L for any analyte. Cadmium was detected in well MI074 at an elevated level (44.2 μg/L) and in MI072 (39.9 μg/L). These wells are upgradient of the Former Borrow Pit, and drainage Ditch C. As will be discussed below, the extent of contamination by explosives in the Former Borrow Pit appears to be much less than that in the Former Landfill. Therefore, it is likely that the source of the explosives contamination observed in these wells is either the Closed Landfill or Ditch C. Because the soil borings in the Closed Landfill did not extend to the water table, it cannot be determined if the contamination detected in the near-surface soil extends through the vadose zone to the water table. Therefore, it is not known if the Closed Landfill is a source of the explosives detected in groundwater.

Manganese was detected in well MI072 at 16,000 μg/L and magnesium was detected in this well at 14,900 μg/L. Magnesium stearate is used as a binding agent and lubricant with tetryl. Although magnesium was not detected at elevated levels in the soil borings, it is possible that the Closed Landfill is the source of magnesium in groundwater. A possible source of the manganese in groundwater cannot be determined with available data.

7.1.12.2 Source Strength. The near-surface soil in the Closed Landfill is contaminated with explosives and select metals. However, it cannot be determined using available data whether the Closed Landfill is the source of the observed groundwater contamination. Another possible source of the contaminants in groundwater is Ditch C, which has received wastewater discharge from Line B and Line D.

7.1.12.3 Contaminant Loading into Groundwater. The extent to which this area is contributing to groundwater contamination cannot be quantified using available data.

7.1.13 Former Borrow Pit

This area was investigated with three soil borings. In addition, the newly-installed monitoring wells MI071 and MI074 are located downgradient from the Former Borrow Pit and the Former Landfill.

7.1.13.1 Extent of Contamination. Lead was detected in surface soil at a maximum concentration of 25.4 mg/kg. A variety of organic compounds were detected at low concentrations in subsurface soil. The only explosive detected in soil was 2,4-DNT, which appeared at a concentration of 1.4 mg/kg in a surface soil sample.

7.1.13.2 Source Strength. Based on available data, this area does not appear to be a source of either explosives or select metals. Volatile and semivolatile organic contaminants were detected at depths down to 24 feet from the surface. It should be noted that the organics detected in the groundwater sample from MI071 do not correspond to the organics detected in the soil samples. Therefore, it appears that the Former Borrow Pit is not a source of groundwater contamination by organic compounds.

7.1.13.3 Contaminant Loading into Groundwater. Available data indicate that this area is not a source of groundwater contamination.

7.1.14 Salvage Yard

This area was investigated with two soil borings downgradient from the lead bin and the metals scrap pile. Monitoring well MI035 is located downgradient from this site.

7.1.14.1 Extent of Contamination. The soil samples do not indicate that significant contamination by explosives, heavy metals, or other inorganic analytes has occurred. Lead was detected at a maximum concentration of 20.6 mg/kg at a depth of 5 feet. This does not exceed the background concentration by a significant amount. Manganese was detected at 981.65 mg/kg at a depth of 5 feet in the boring near the lead bin and at 761.4 mg/kg at a depth of 5 feet in the boring near the metal scrap pile.

7.1.14.2 Source Strength. The concentrations of lead and manganese detected in soil samples collected in this area are above the background concentration. However, only one sample was taken from each borehole. It therefore cannot be determined if these inorganic compounds are leaching through the vadose zone. However, the concentration of lead detected in the groundwater sample from MI035 was not above the detection limit and manganese was detected at a concentration of 5.91 μg/L. Given the relative immobility of inorganic compounds in soil, it does not appear likely that this area is contributing to groundwater contamination, and this is corroborated by the low levels of inorganic compounds in the downgradient monitoring well.

7.1.14.3 Contaminant Loading into Groundwater. Contaminant loading into groundwater is not occurring, based on presently available data.

7.2 GROUNDWATER

In this section, the groundwater quality data discussed in Section 5.4 is interpreted with respect to source areas. This interpretation is also based on the groundwater level contours presented in Figure 5-7.

The data indicate that two distinct plumes are migrating from source areas to the facility boundaries on the north and northwest sides. In addition, the downward gradient that exists in the north central region of the facility is causing the plume which is emanating from the O-Line Ponds to move downward through the aquifer.

7.2.1 O-Line Ponds Plume

The explosive-contaminated plume emanating from the O-Line Ponds area appears to be moving toward the northern boundary. Figures 7-2 through 7-13 present the concentrations of explosives and select metals detected in the wells cross-gradient and downgradient from the O-Line Ponds area. The concentration contour lines were drawn by interpolating between the data points. In the case of well clusters, the highest concentration detected was used.

Figures 7-2 through 7-9 indicate that the explosives plume, as it currently exists, encompasses a relatively narrow region between the ponds and the facility boundary. The southern limit is the area around the O-Line Ponds, which is the location of the highest concentrations. The plumes for TNT and HMX (Figures 7-3 and 7-4) extend to the northern boundary as these compounds were detected in cluster wells MI059, MI060, and MI061. The true northern extent of the plume for these two compounds cannot be determined using empirical evidence. However, the contaminant mass contained within the plume has been estimated and compared to the estimated loading rate of explosives into groundwater (Section 7.2.2.) The close agreement between these numbers indicates that the plume is probably not significantly larger than shown in these figures.

These figures also indicate that Ditches B and C probably are concurrent sources of explosives contamination. For example, the RDX plume (Figure 7-2) contour lines around the O-Line Ponds show that the level of contamination is greatly attenuated as the distance from the ponds increases. The concentration of RDX then increases rapidly downgradient of Ditch B. The same trend is apparent in the plumes for the other detected explosive compounds.

It is possible that the years of wastewater discharge into the drainage ditches created a soil column which is contaminated with explosives. At present, the wastewater discharge into the ditches is contaminated with lower levels of explosives. However, the water is infiltrating the ditch floor and percolating through contaminated soil. Transport of explosives from the soil column underlying the ditches to the water table may be occurring.

Other evidence that the ditches are sources of explosive contamination is the slow groundwater flow rate at the site. The groundwater flow velocity estimated in Chapter 5.0 is 0.20 ft/day. The O-Line Ponds were constructed in the early 1940s. If it is assumed that groundwater contamination began immediately after pond construction, then the maximum extent of the plume, assuming that the explosives are conservative and non-reactive (i.e. they move at the same rate as the groundwater) is 3,650 feet. This is the distance from the ponds to the northern edge of Line K. Therefore, in order for the plume to have reached the northern facility boundary, an intermediate source or sources of contamination must exist.

It does not seem likely that Line K is the source of explosives in groundwater. According to facility personnel, explosives were not handled to a large extent at this line (personal communication, Tom Allen, Martin Marietta, February 27, 1991). There are no wastewater sumps at Line K.

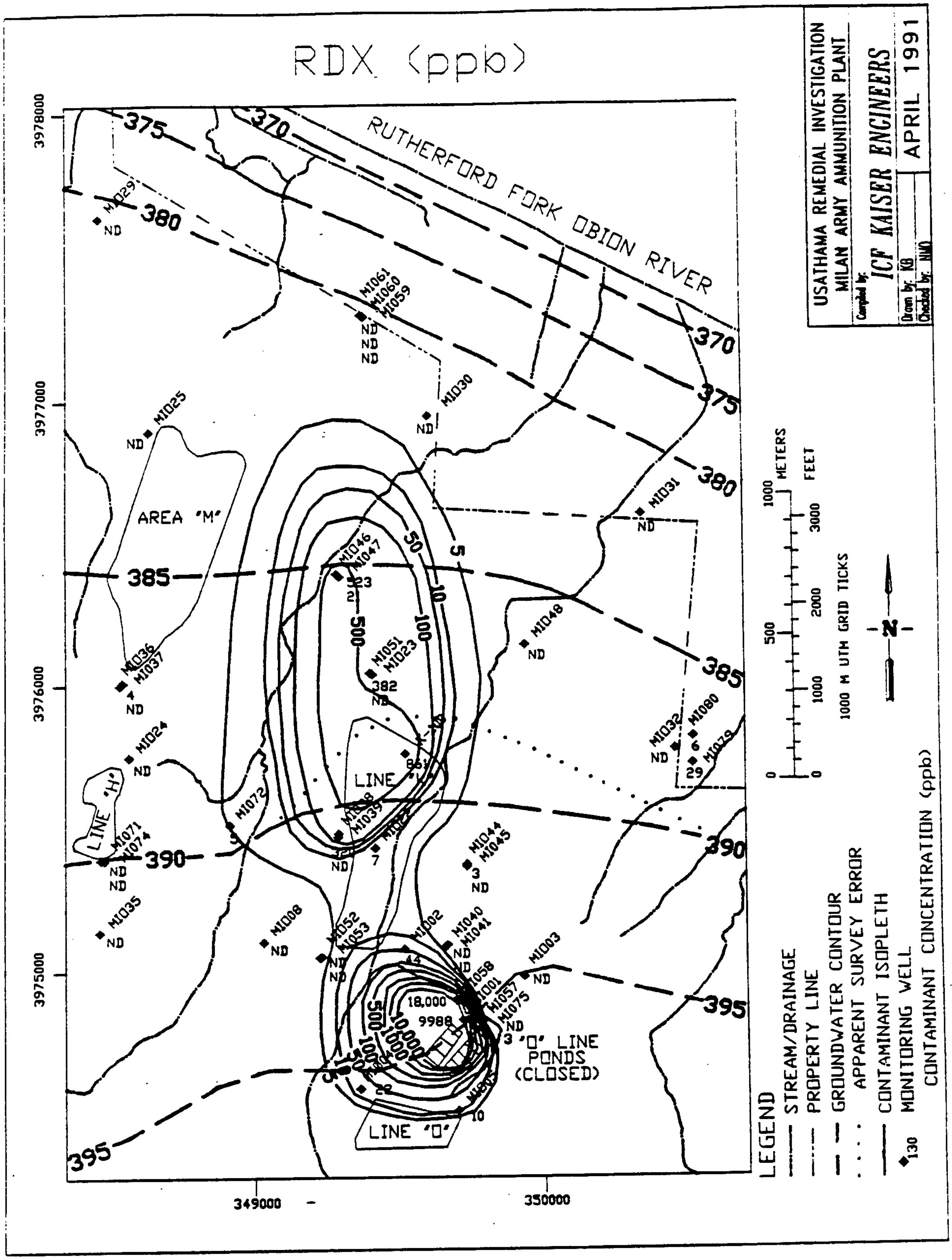


Figure 7-2
RDX Concentrations Associated With O-Line Ponds Area

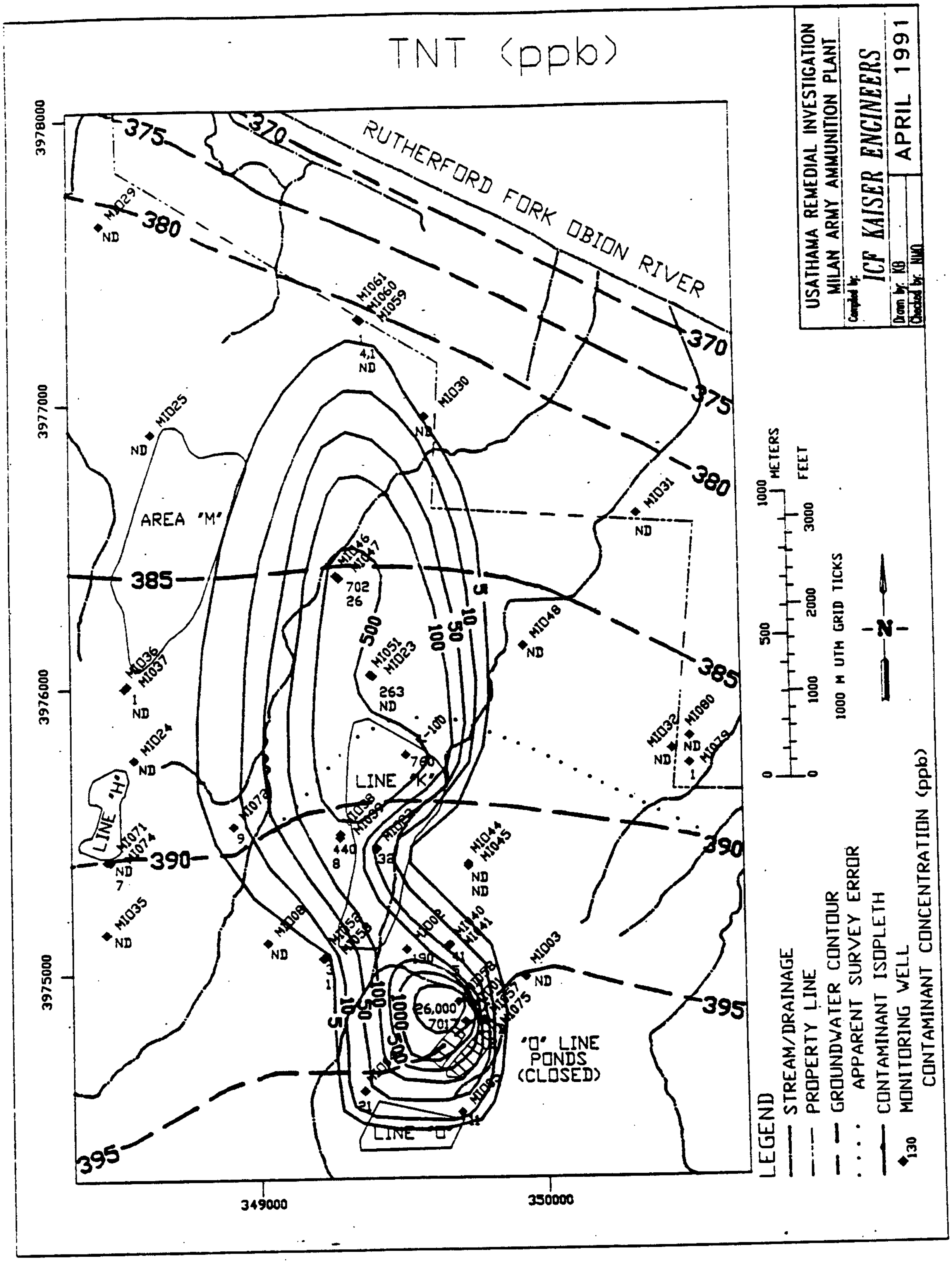


Figure 7-3
TNT Concentrations Associated With O-Line Ponds Area

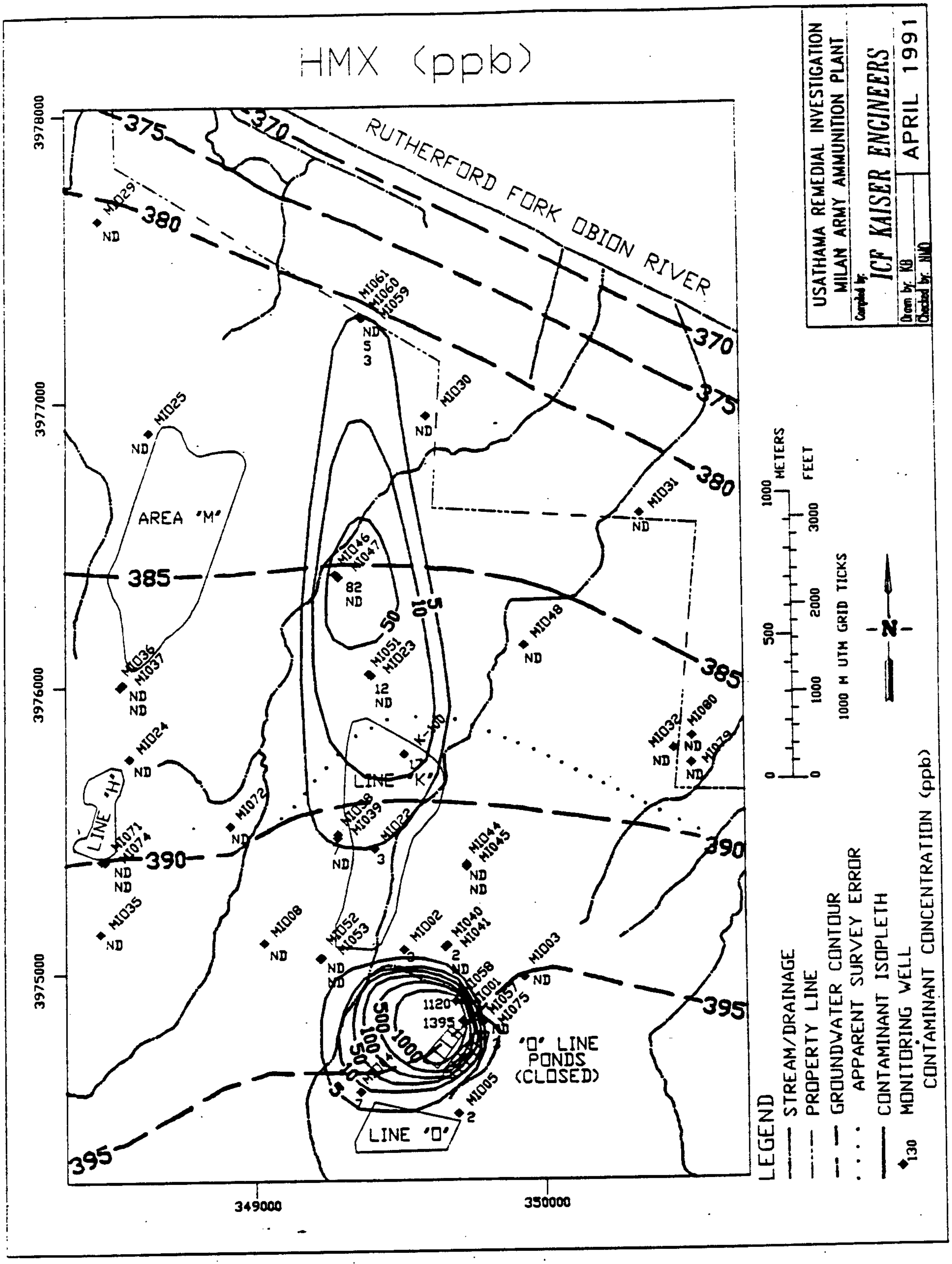


Figure 7-4
HMX Concentrations Associated With O-Line Ponds Area

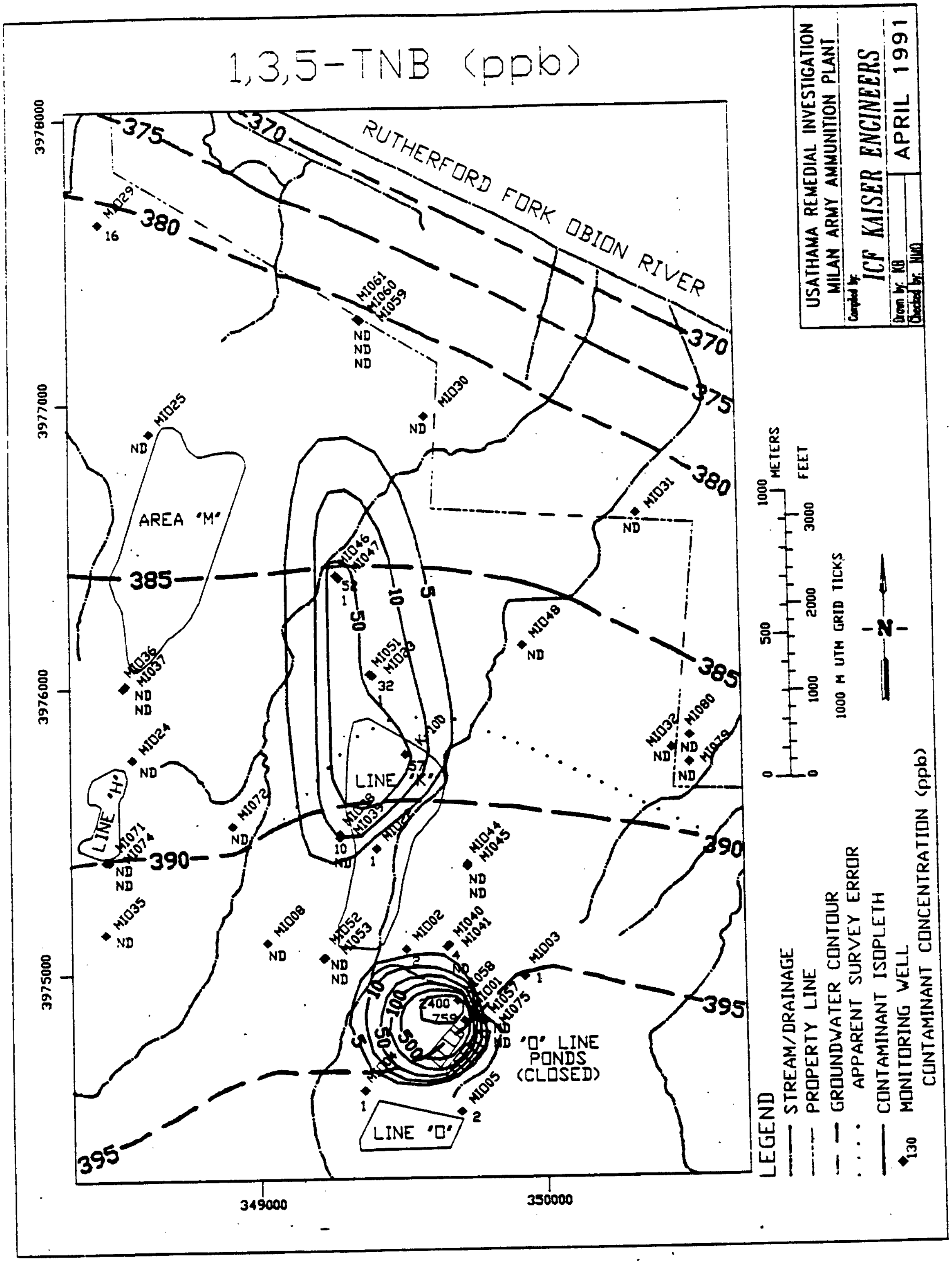


Figure 7-5
1,3,5-TNB Concentrations Associated With O-Line Ponds Area

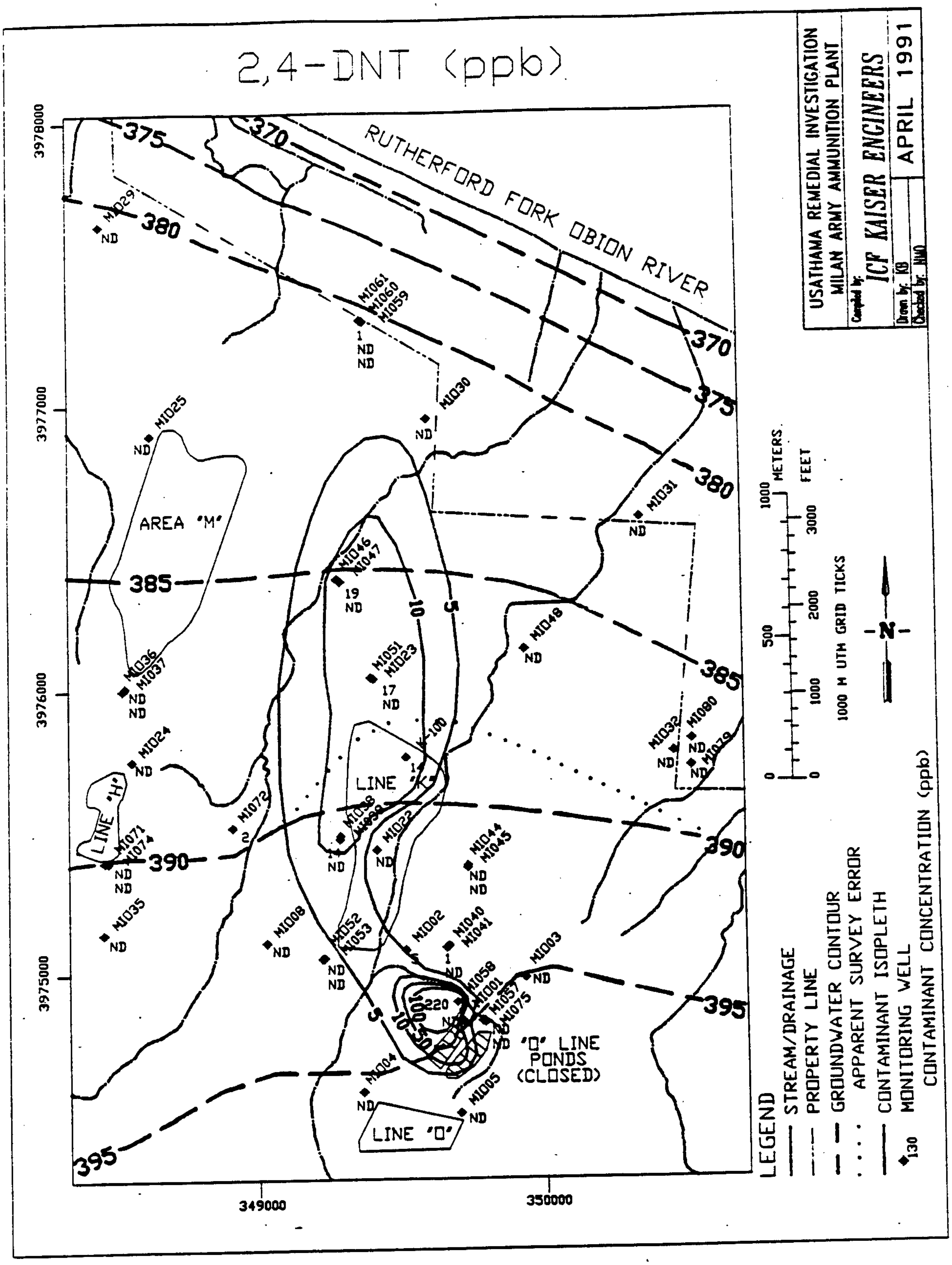


Figure 7-6
2,4-DNT Concentrations Associated With O-Line Ponds Area

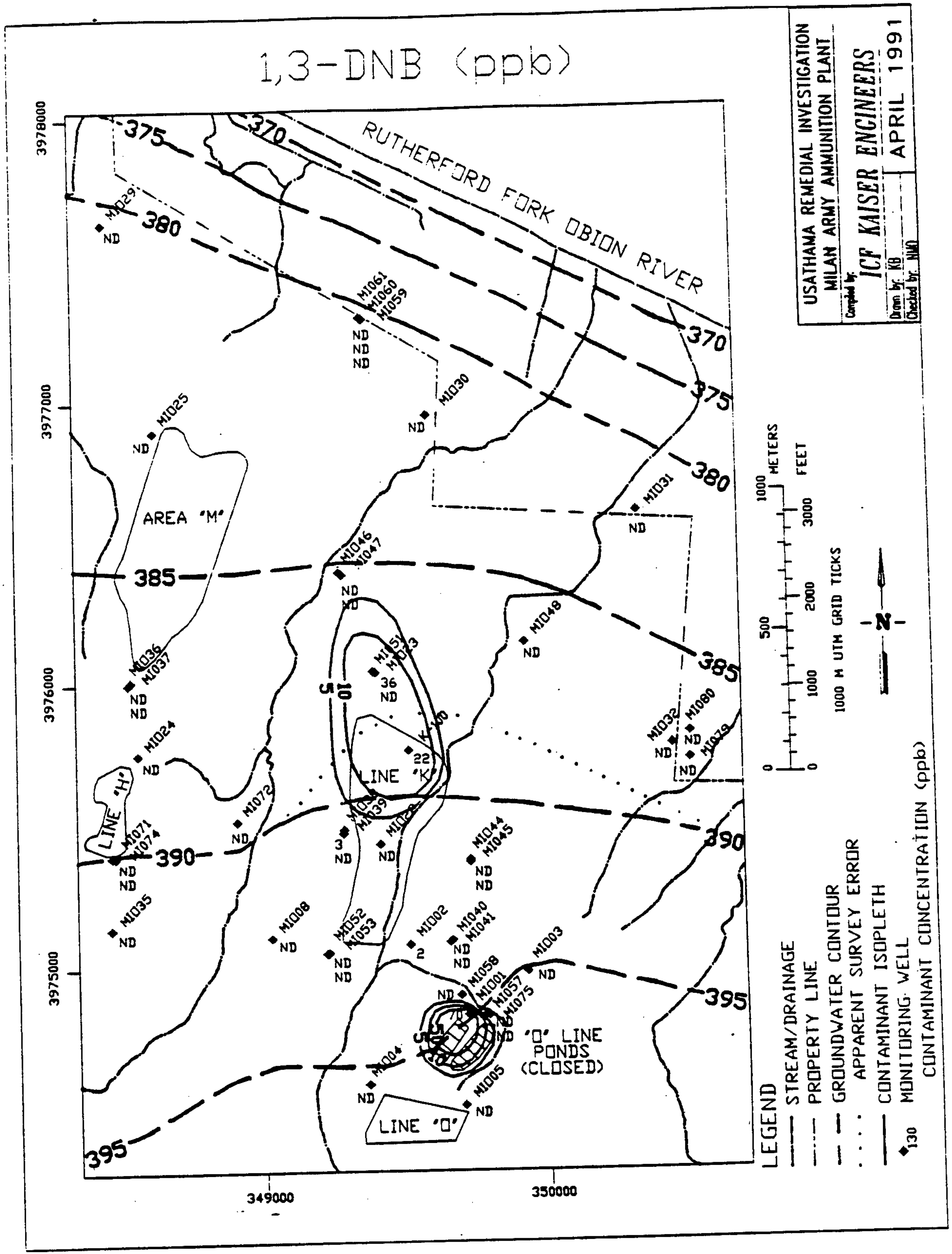


Figure 7-7
1,3-DNB Concentrations Associated With O-Line Ponds Area

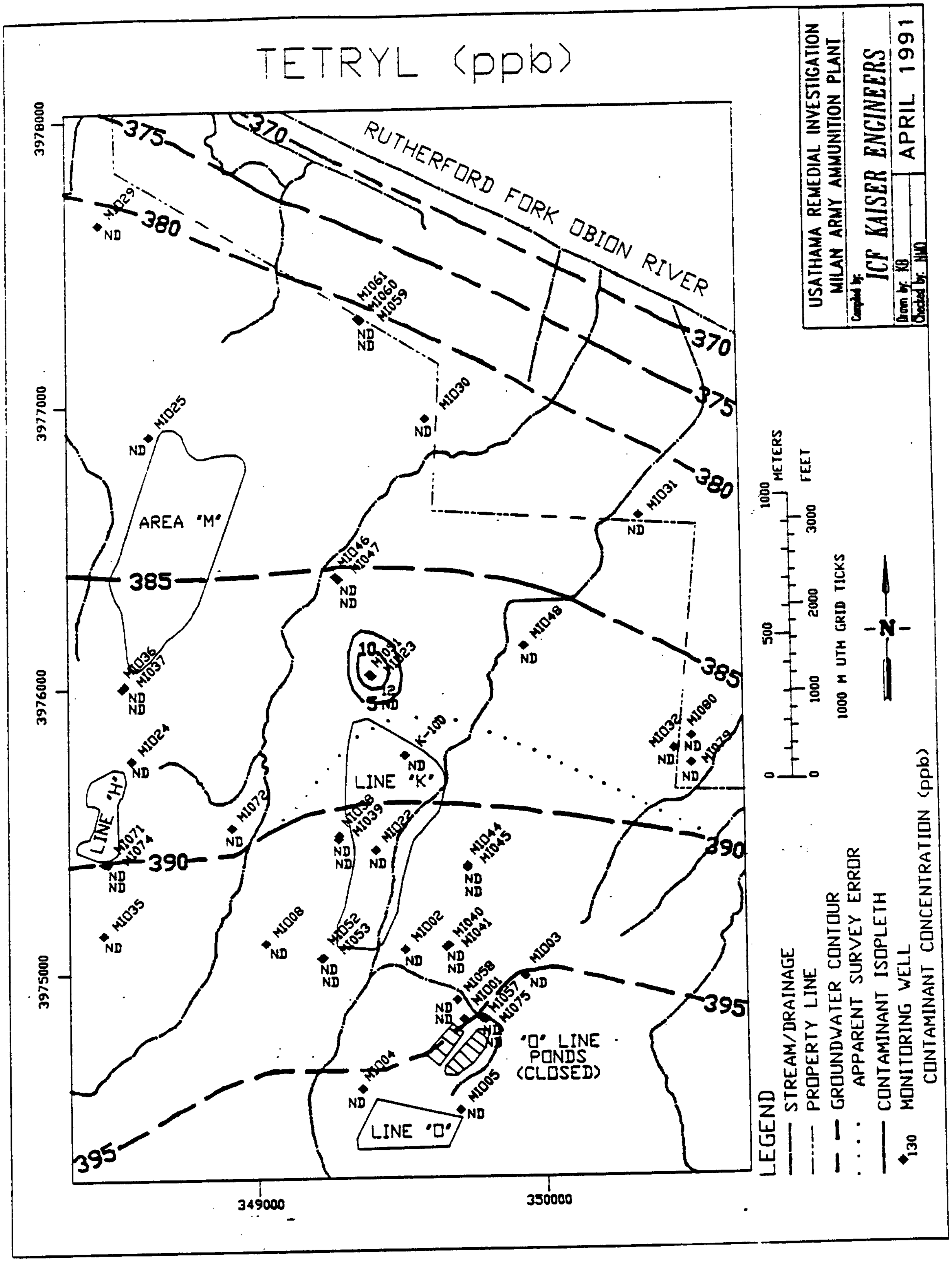


Figure 7-8
Tetryl Concentrations Associated With O-Line Ponds Area

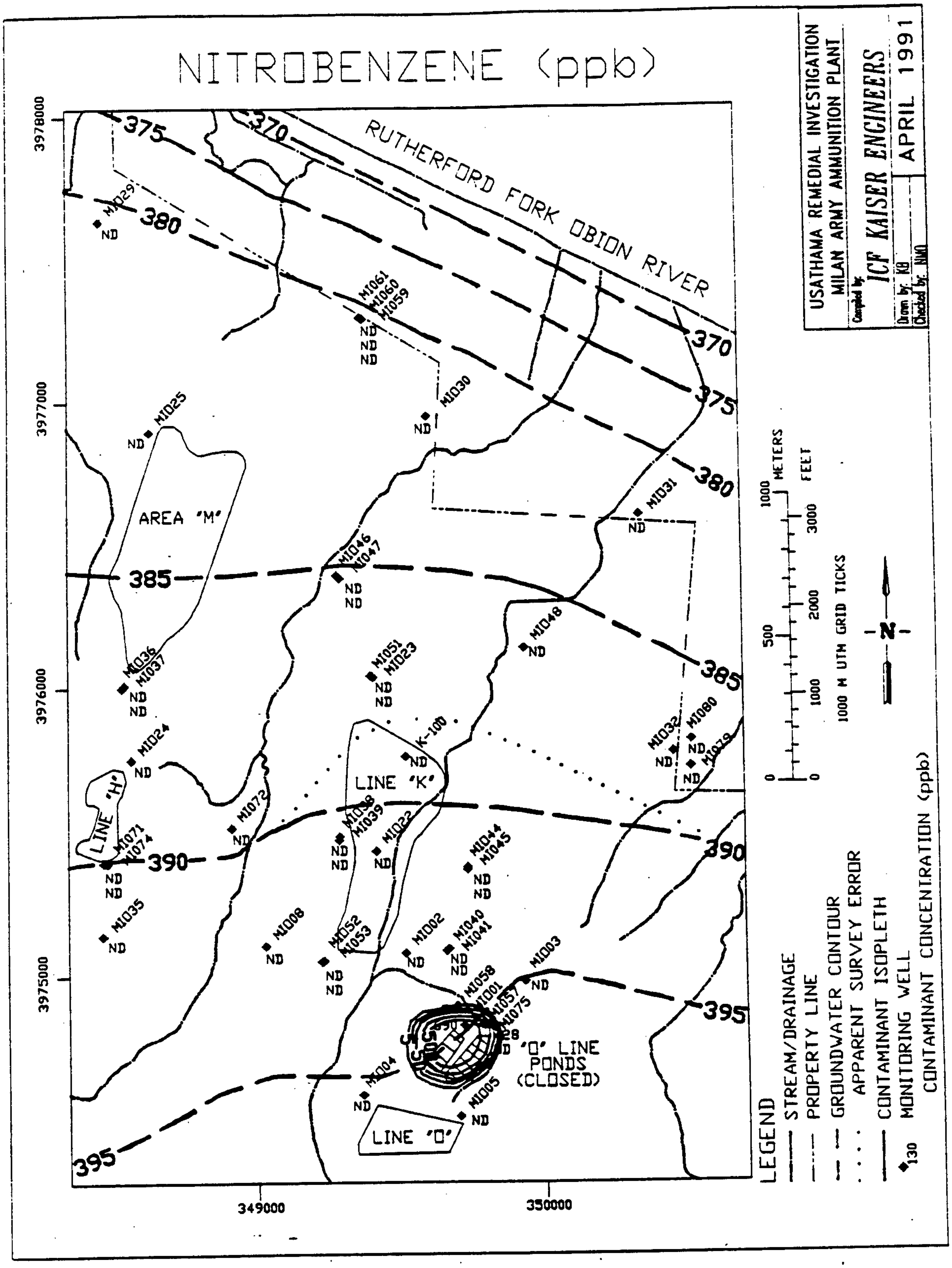


Figure 7-9
Nitrobenzene Concentrations Associated With O-Line Ponds Area

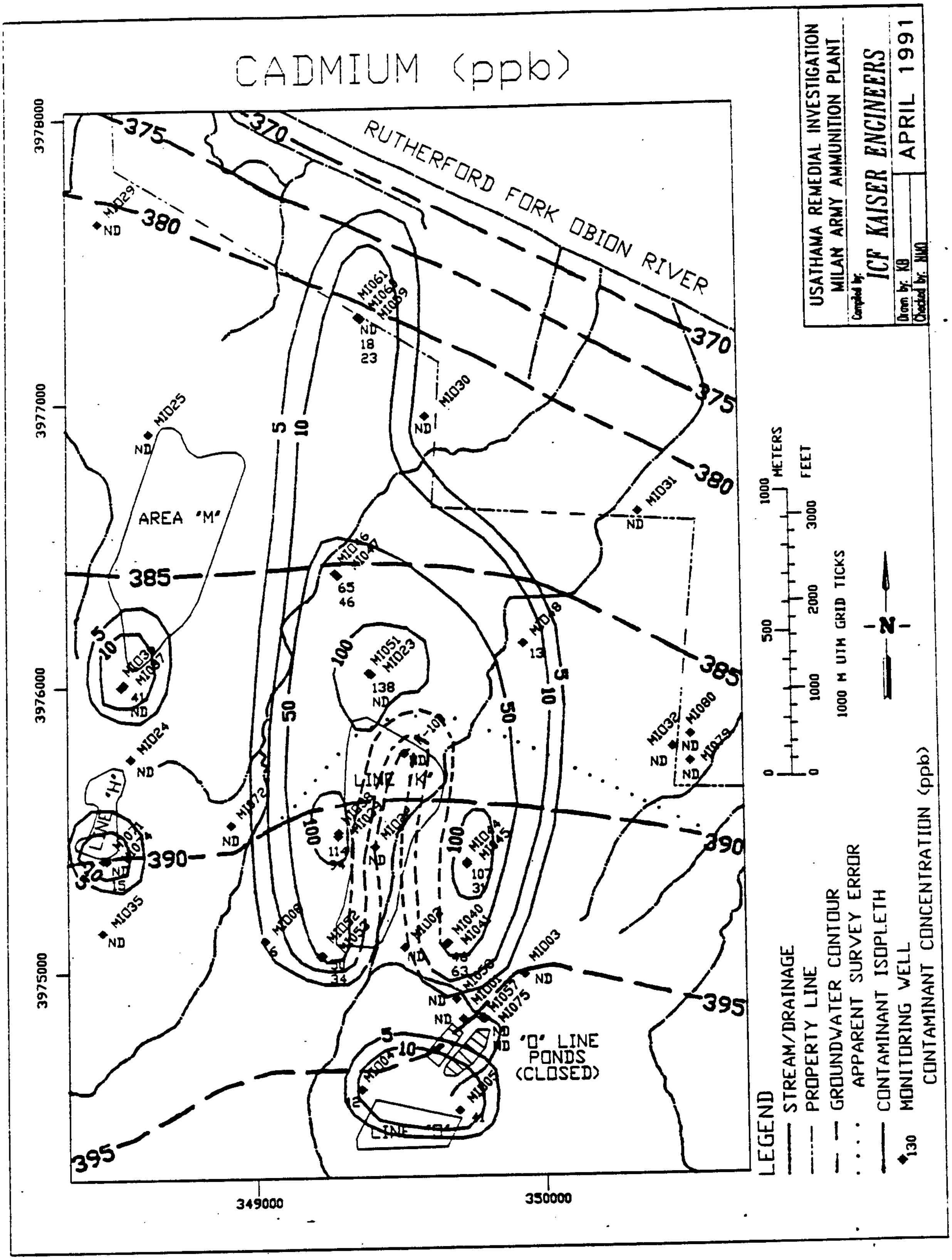


Figure 7-10
Cadmium Concentrations Associated With O-Line Ponds Area

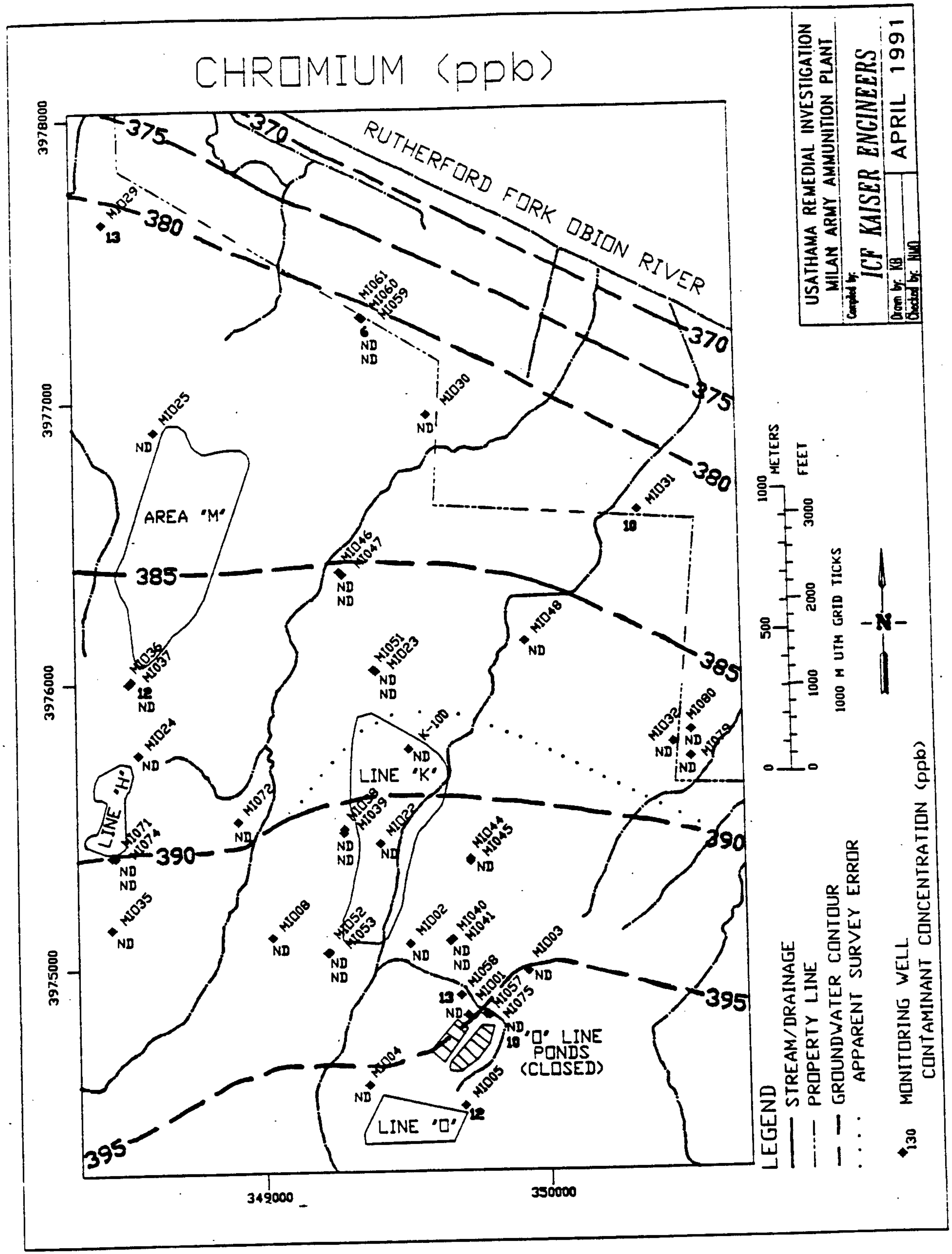


Figure 7-11
Chromium Concentrations Associated With O-Line Ponds Area

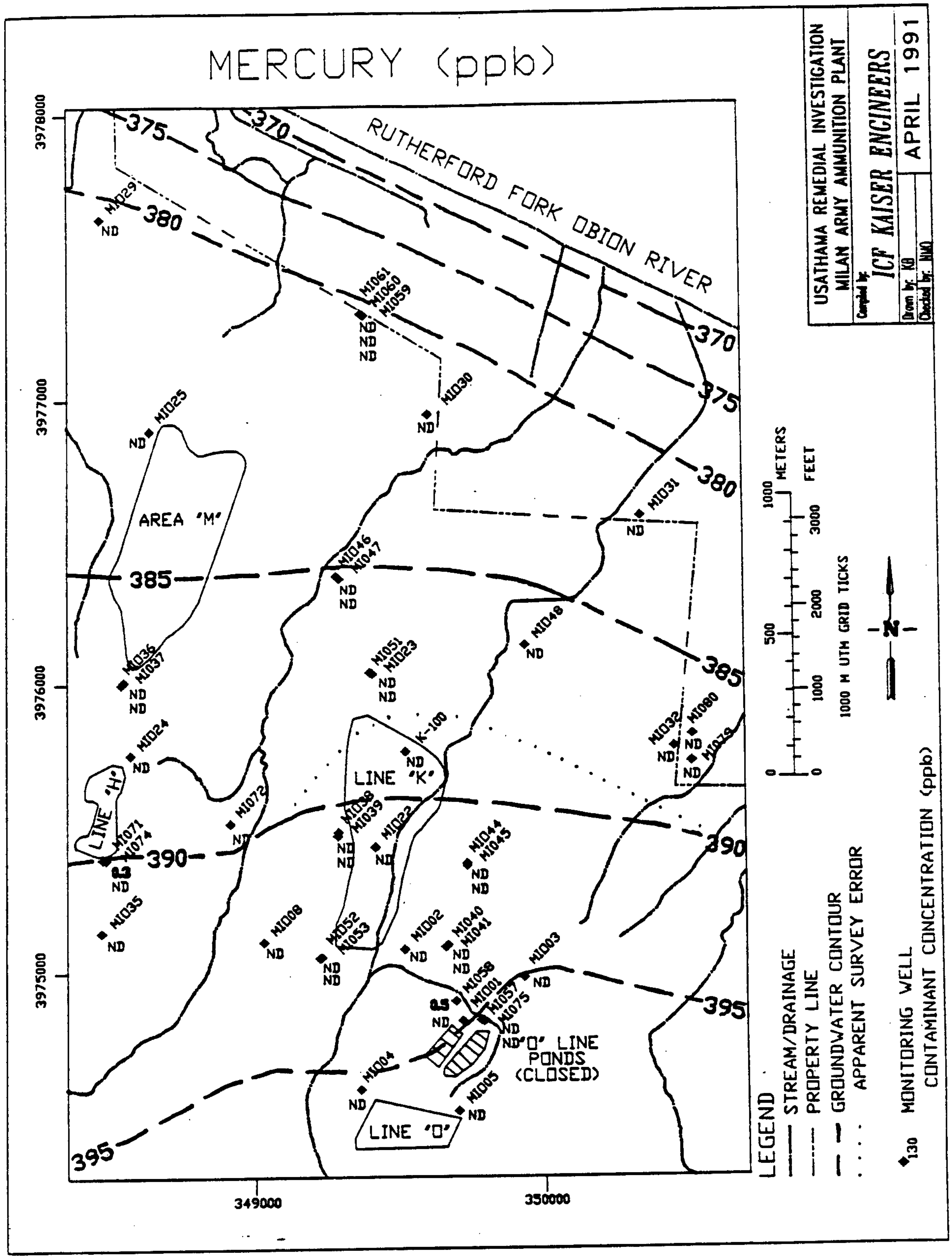


Figure 7-12
Mercury Concentrations Associated With O-Line Ponds Area

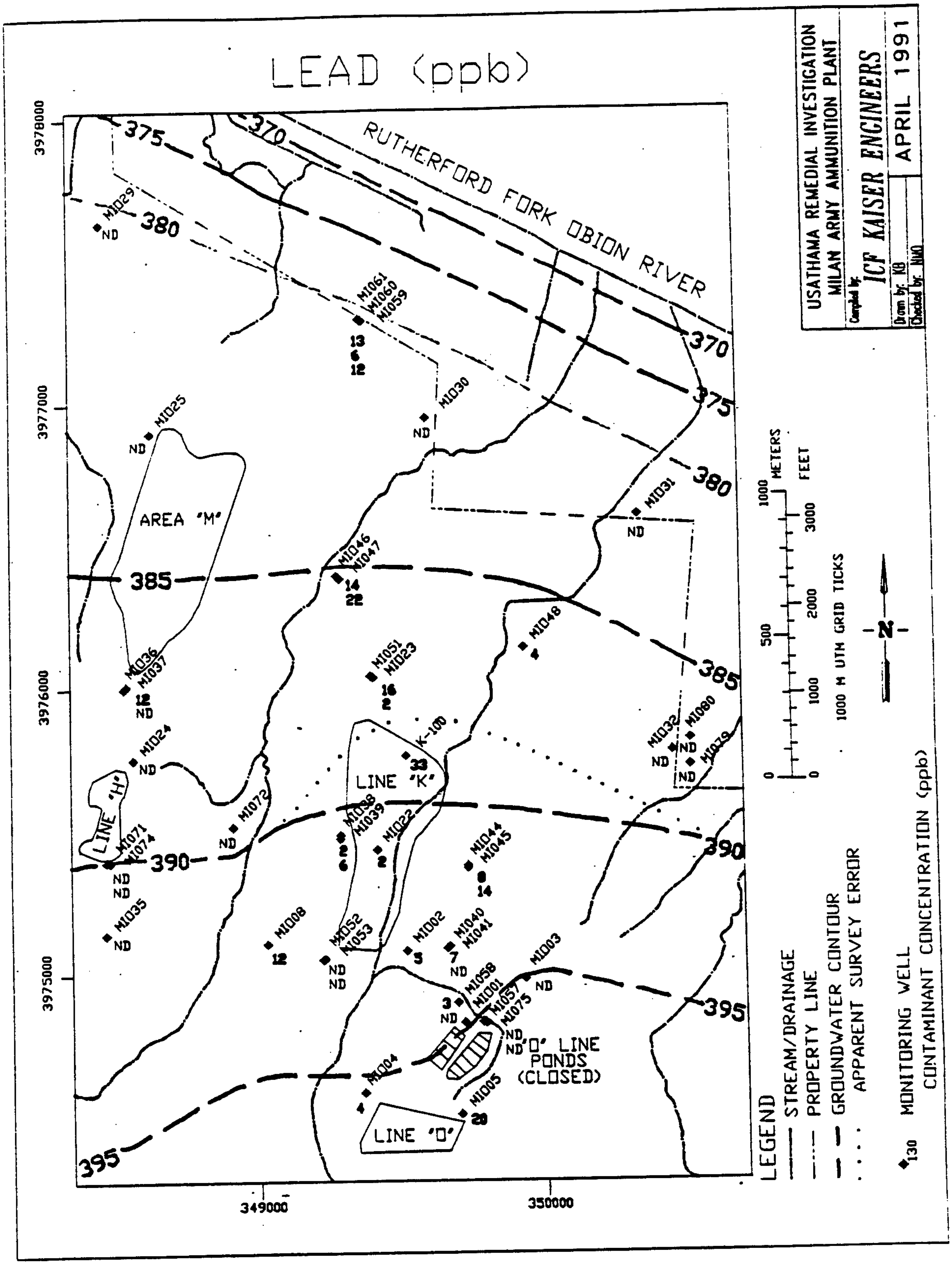


Figure 7-13
Lead Concentrations Associated With O-Line Ponds Area

Tetryl was detected once in the well cluster between Ditch B and Ditch C. Because this compound was not detected in the wells immediately downgradient of the O-Line Ponds, the ponds are apparently not the source. It is possible that the source of the detected tetryl is either Ditch B or Line K.

The nitrobenzene plume is highly localized near the O-Line Ponds. Nitrobenzene is a contaminant of tetryl, is sometimes used as a solvent for TNT, and is a degradation product of TNT. As a breakdown product, it might be expected to appear in areas which are highly contaminated with TNT for a long period of time. It probably was not discharged to the ditches in significant quantities.

The low levels of explosives detected in wells MI079 and MI080 cannot be attributed to a known or suspected source. Resampling of these wells is indicated.

Although the plume emanating from the O-Line Ponds and the plume emanating from Ditch B appear to be distinct for several of the explosives (1,3-DNB, 1,3,5-TNB, and HMX), the source of all of the contaminants may be the O-Line operation. Wastewater from the ponds was discharged to Ditch B, and this ditch also received all pond overflow. It appears likely that surface water transport of explosives and percolation to the water table from the ditch floor is a more rapid mode of transport than groundwater transport. The historical use of the ditch for O-Line discharge and overflow has accelerated the rate at which groundwater contamination has occurred.

The groundwater results for select metals are presented in Figures 7-10 to 7-13. The only metal which appears to be emanating from a source area is cadmium. Three monitoring wells near Line K were contaminated with high levels of cadmium. One of these wells, MI051, is located immediately downgradient from the former wastewater pond for the plating operation. The other two areas of high cadmium levels are on the east and west sides of Line K. The source of the contamination at these locations is not known. However, it appears from Figure 7-10 that the O-Line Ponds are not a significant source of cadmium.

The results for the other select metals (chromium, mercury, and lead), presented in Figures 7-11 to 7-13, do not indicate that a significant source of these metals exists. The levels detected are not highly elevated and there is no apparent pattern.

7.2.2 O-Line Ponds Vertical Plume

Figure 7-14 is a schematic of the total explosives concentration profile in the vertical cross-section. The cross-section begins at the O-Line Ponds and ends near the cluster wells MI059, MI060, and MI061. The chemical results agree with the hydrologic evaluation of the aquifer, which indicated that downward flow is occurring in this area. The shallow groundwater near the O-Line Ponds is heavily contaminated with explosives. As the distance from O-Line increases, the center of the contaminant plume decreases in elevation.

As in the horizontal plumes, it is apparent in the vertical plume that more than one source is contributing to groundwater contamination. The concentrations in the intermediate zone of the aquifer are larger downgradient of well MI022 (which is located immediately upgradient of Ditch B) than on the upgradient side of this well. The scarcity of shallow wells in the northern area (on the right side of the graph) make it difficult to interpret the actual distribution of explosives contamination.

The total mass of explosive contained in the O-Line Ponds plume downgradient of the immediate pond area was estimated. This estimate was made by calculating the volume of water within each contour line and multiplying by the concentration. Using this method, the accuracy of the calculation is probably within the order-of-magnitude range. The estimated mass of total explosives in the downgradient plume is 20,000 pounds. This value was divided by the estimated mass loading rate from the O-Line Ponds (Section 7.0) of 1.5 pounds/day. The resulting time is 36 years, which is approximately the same as the

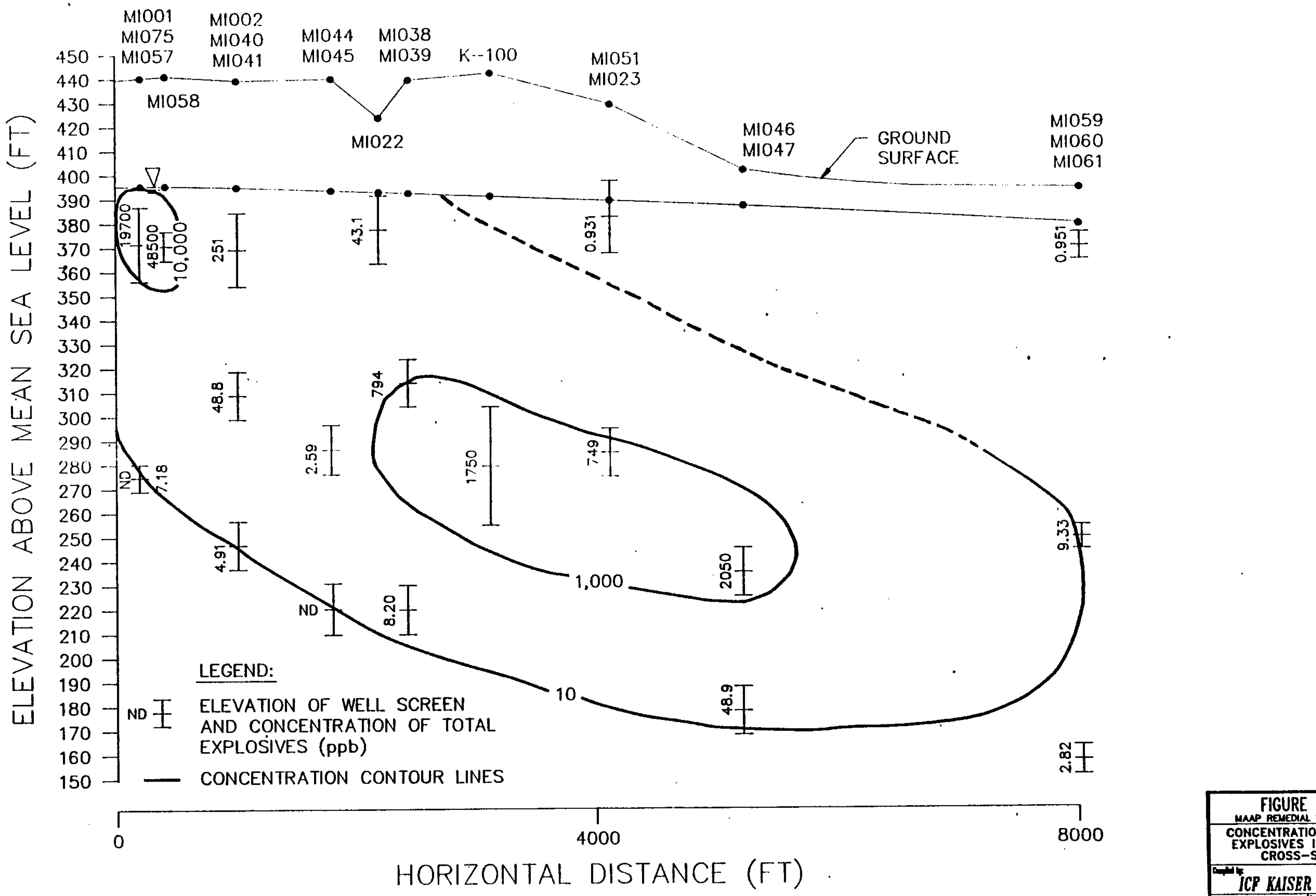


FIGURE 7-14:
MAAP REMEDIAL INVESTIGATION

CONCENTRATION OF TOTAL EXPLOSIVES IN VERTICAL CROSS-SECTION

Compiled by:
ICF KAISER ENGINEERS

Drawn by: B. ALLEN
Checked by:
Dwg no.: 04059101

length of time that the ponds were operating. The close correlation indicates that the actual plume is probably not significantly larger than the sizes indicated in Figure 7-2 through 7-9.

7.2.3 OBG/ADA Area Plume

The groundwater underlying the area of the site which begins at the OBG/ADA areas and extends to the northwestern boundary is contaminated with explosives and select metals. The potential sources of this contamination are the OBG/ADA areas, the drainage ditches, and the wastewater sumps in the load lines.

The groundwater in the area immediately downgradient of the OBG/ADA areas is contaminated with high levels of explosives, especially RDX and nitrobenzene. As there are no shallow wells in this area, the vertical distribution of contamination is not known. However, the groundwater is contaminated at depth.

The horizontal extent of contamination cannot be determined because of the scarcity of wells in the direction of groundwater flow. However, as stated above, the maximum theoretical extent of contamination is 3,650 feet. This assumes that groundwater contamination began occurring immediately upon disposal and that the contaminants behave as a non-reactive, conservative tracer. Therefore, the explosives detected in other wells along the flowpath must be emanating from other sources.

Figures 7-15 through 7-24 show the analytical results of the groundwater quality investigation overlain on the facility map. These figures show the areal distribution of the explosive compounds and select metals. The area of interest begins at the OBG/ADA and extends to the facility's western and northwestern boundary. Contaminant isopleths were not constructed in these drawings because of the numerous sources and the lack of data in many areas. Maps showing the distribution of tetryl, nitrobenzene, and 2,6-DNT are not included because these explosives were not detected in groundwater samples collected from the area of interest.

In the case of RDX, the groundwater downgradient from the OBG/ADA area has a maximum concentration of 350 μg/L. The apparent source of this is the OBG/ADA. It also appears that Ditch 4 and/or the wastewater sumps at B-Line are contributing to the contamination detected in monitoring wells MI010, MI068, MI069, MI070, MI050, and MI055. This contaminant was not detected in the wells which are located on the northwestern boundary.

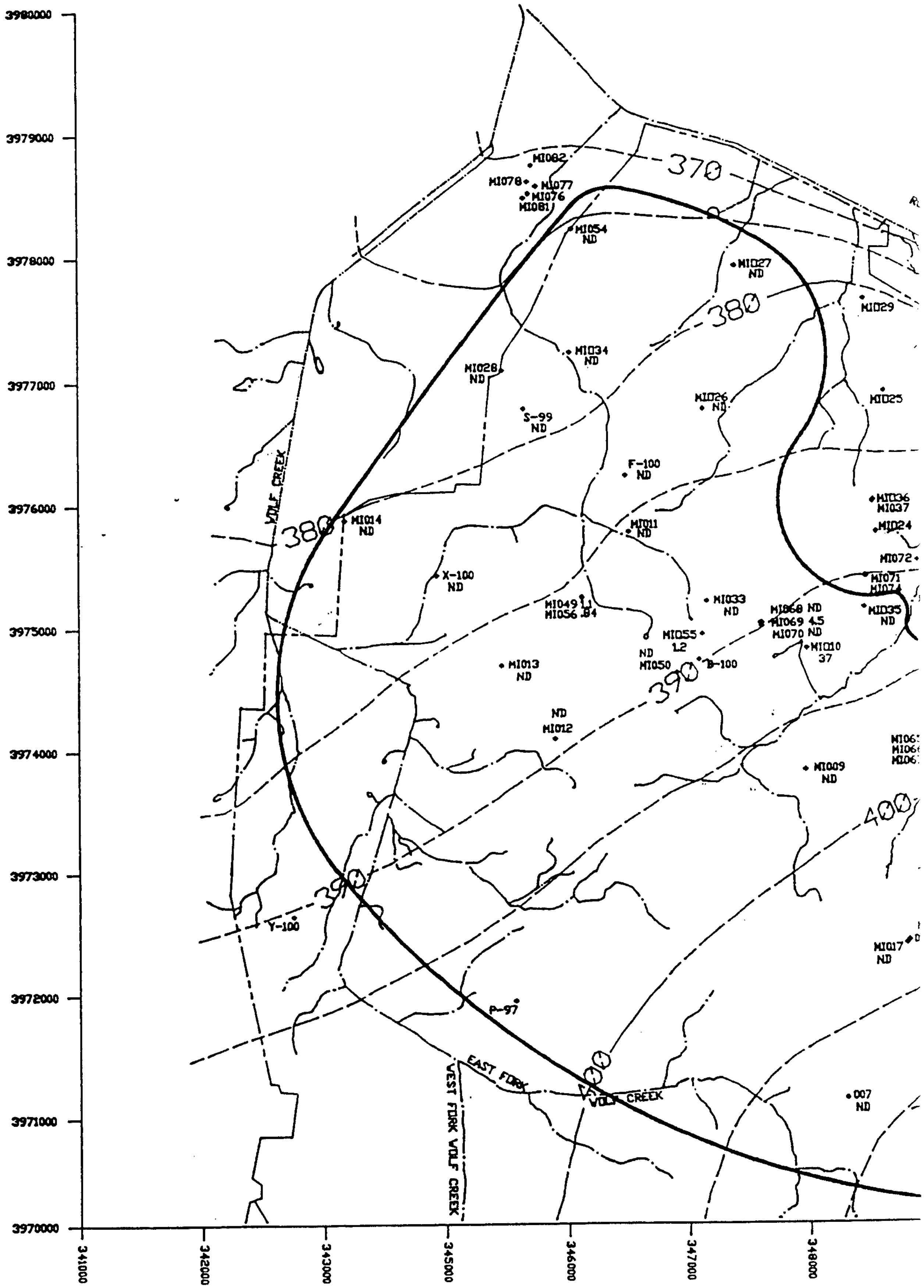
There appear to be many scattered sources of TNT contamination. The groundwater underlying the area downgradient of the OBG/ADA is contaminated, as are the areas downgradient of Ditch 5, Ditch 4, Line B, Line C, and Line A. The wells on the northwestern boundary are not contaminated with TNT.

The OBG/ADA, Ditch 4, and Ditch 1 appear to be the sources of HMX contamination. HMX was detected at the facility boundary in well MI014 at 1.8 μg/L.

1,3,5-TNB was detected at low levels downgradient of the OBG/ADA, Line C, Line D and Ditch 4, and Line B. However, 1,3,5-TNB was detected in the northwestern perimeter wells MI014 (14.7 μg/L), MI028 (3.43 μg/L), and MI054 (0.967 μg/L). The sources of this contaminant appear to be Ditch 1 and Line Z. The highest concentrations appear to be at the site boundary rather than downgradient of the suspected source areas.

2,4-DNT was detected at 1.01 μg/L in well MI069, which is an intermediate well downgradient of Line D and Ditch 4. This contaminant was not detected downgradient of the other suspected source areas, nor was it detected in the perimeter wells.

1,3-DNB was detected in well MI016, which is upgradient of the OBG. It was not detected in the wells downgradient of the OBG.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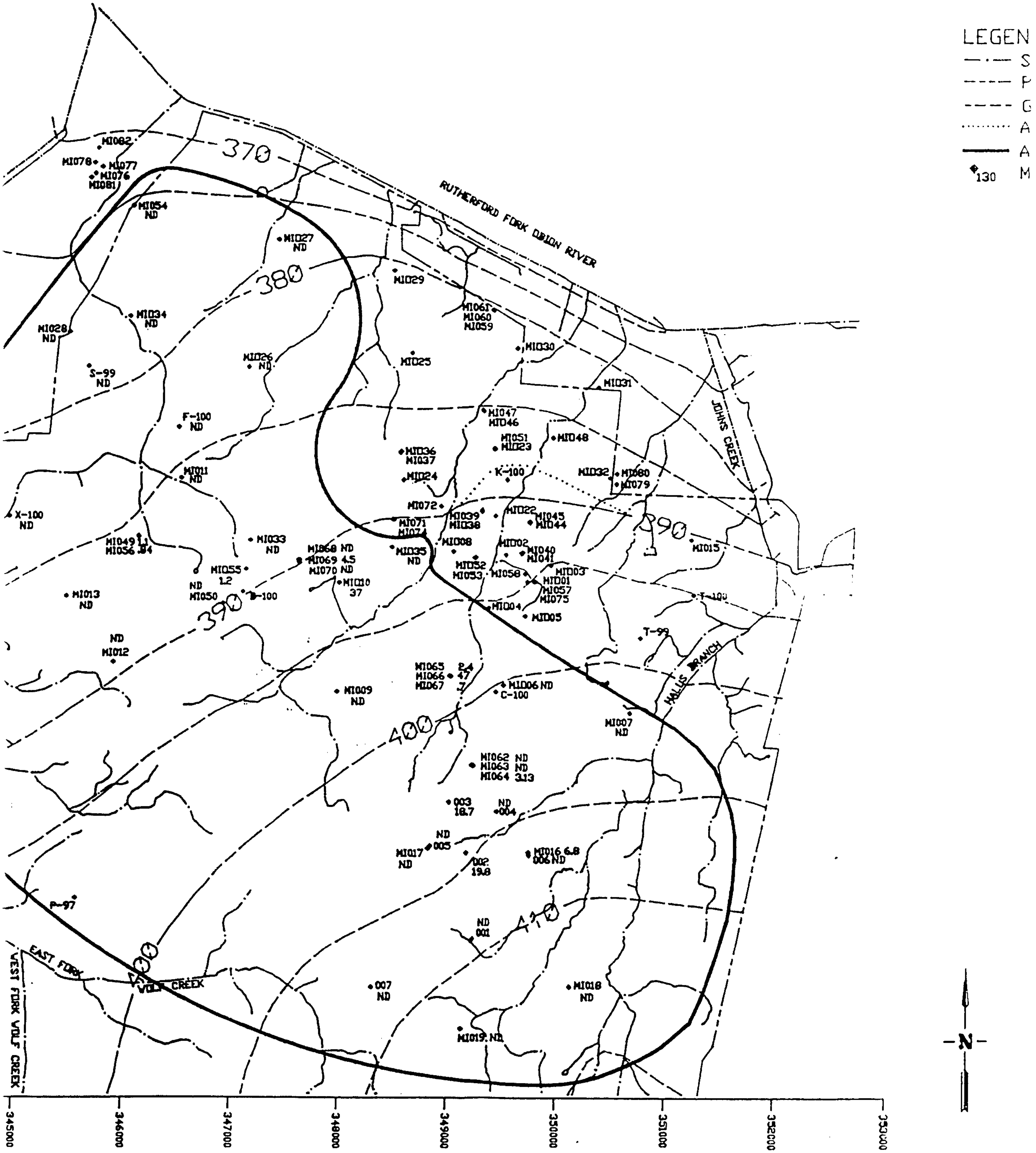
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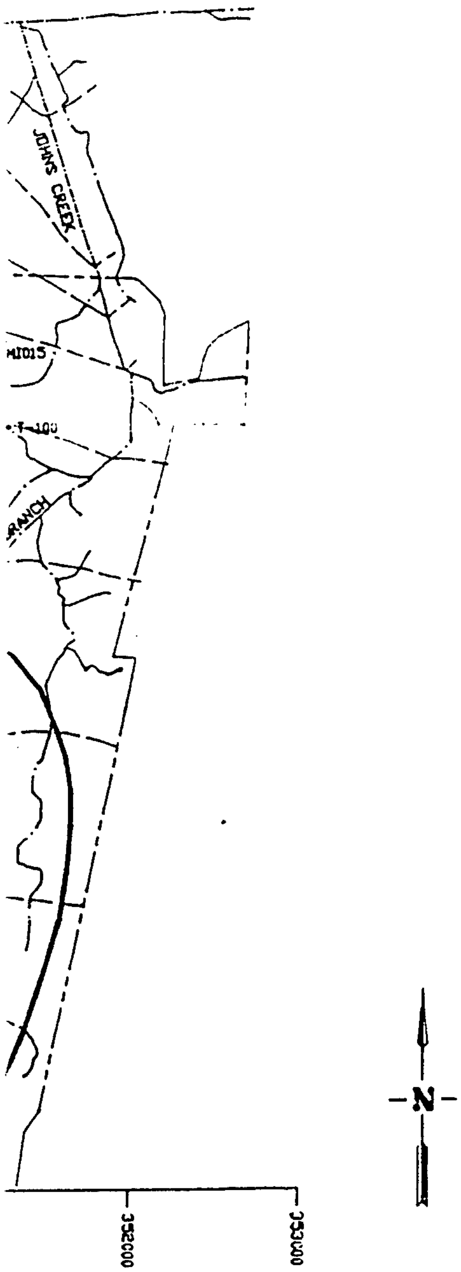

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FIGURE 7-16
TNT CONCENTRATIONS
ASSOCIATED WITH THE OBG/ADA
AND OTHER SOURCES

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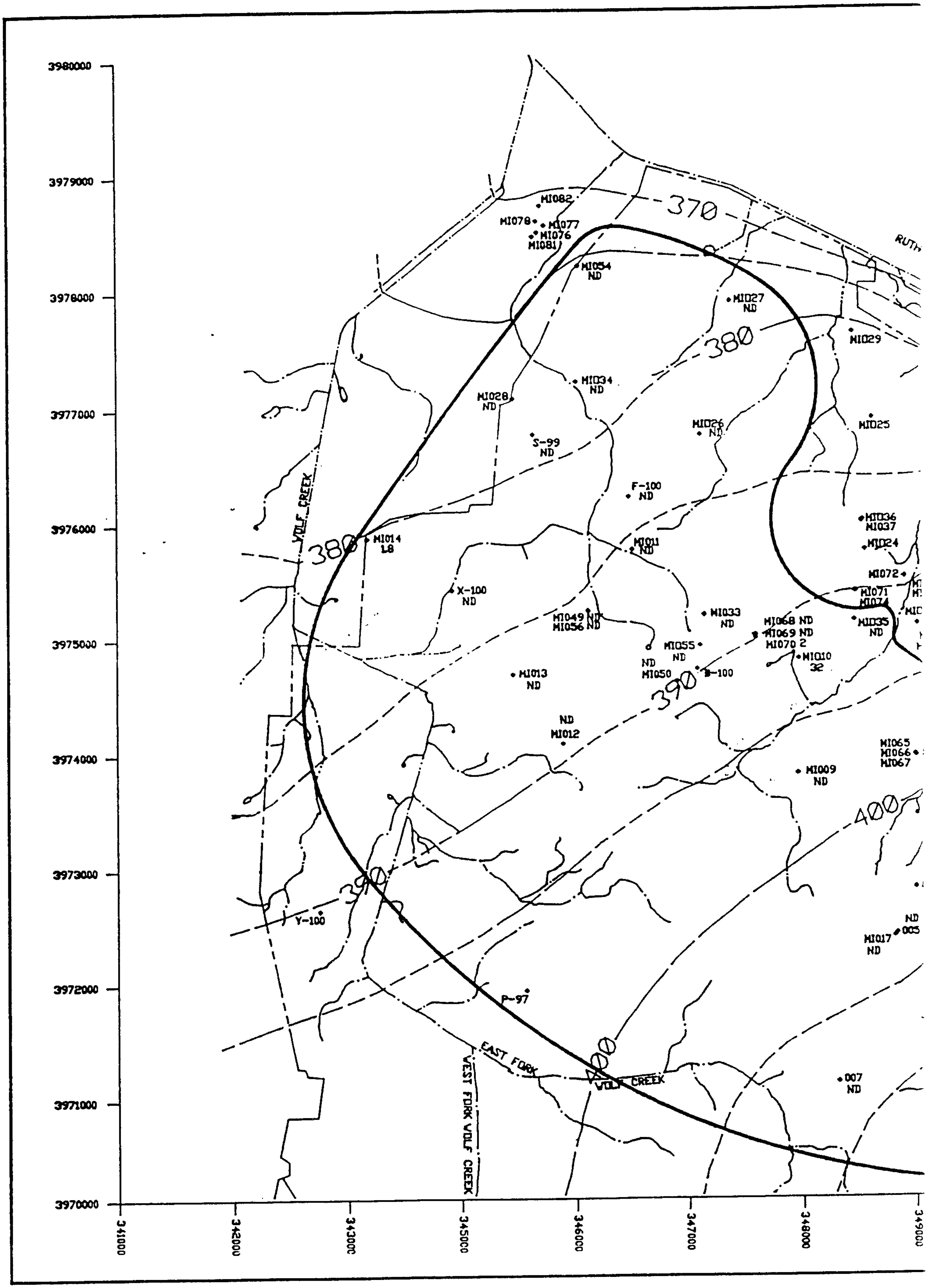

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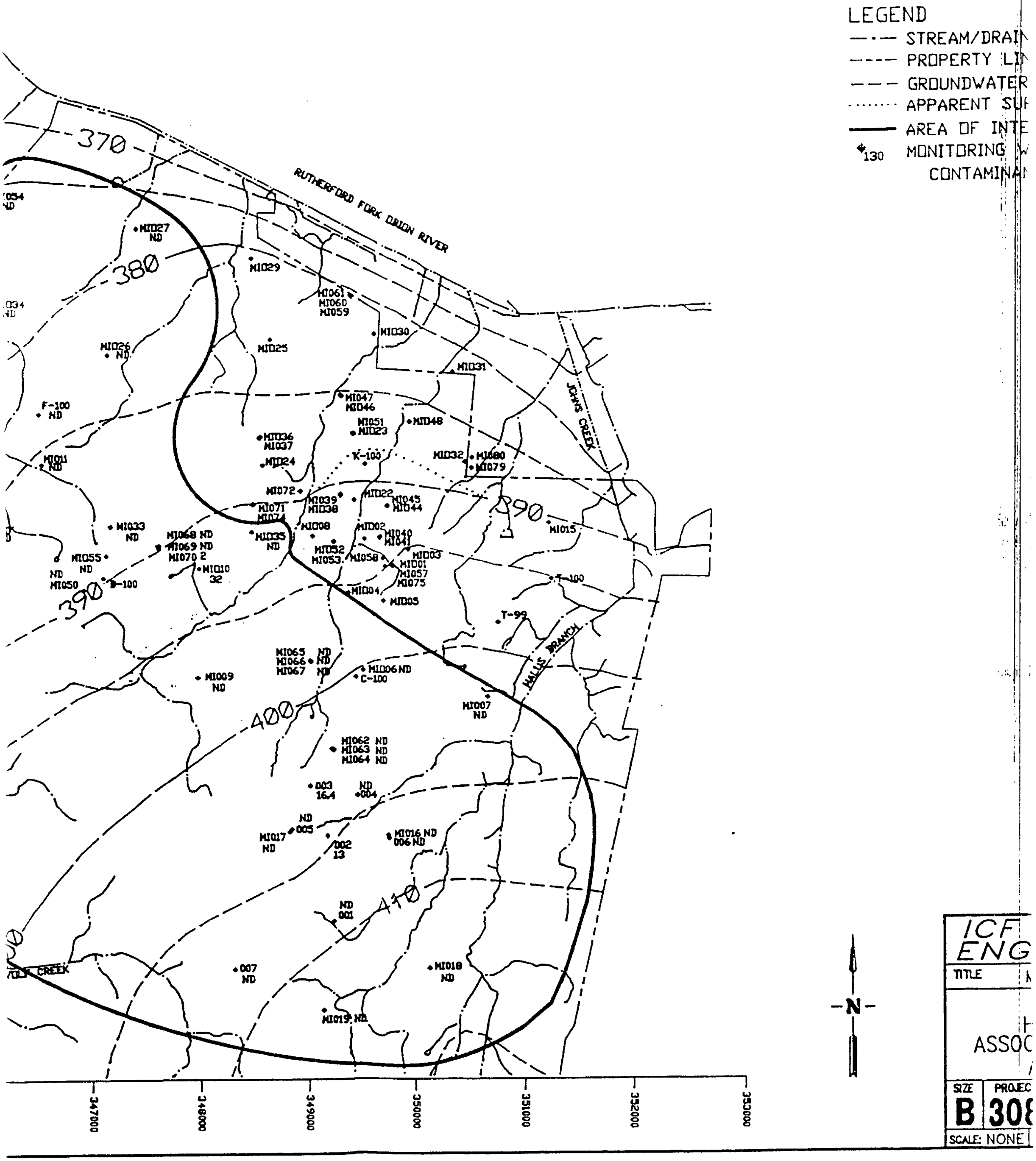
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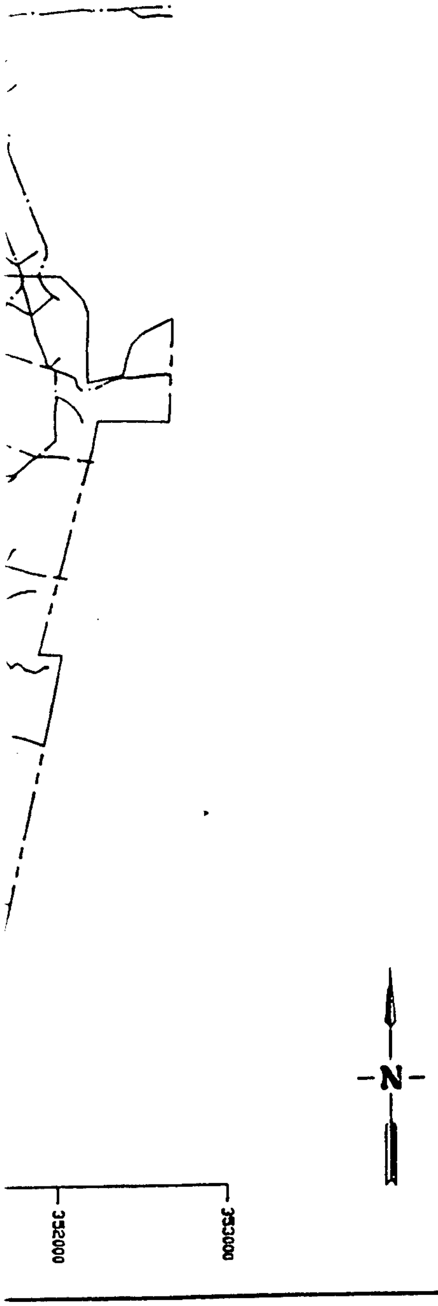

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FIGURE 7-17
HMX CONCENTRATIONS
ASSOCIATED WITH THE OBG/ADA
AND OTHER SOURCES

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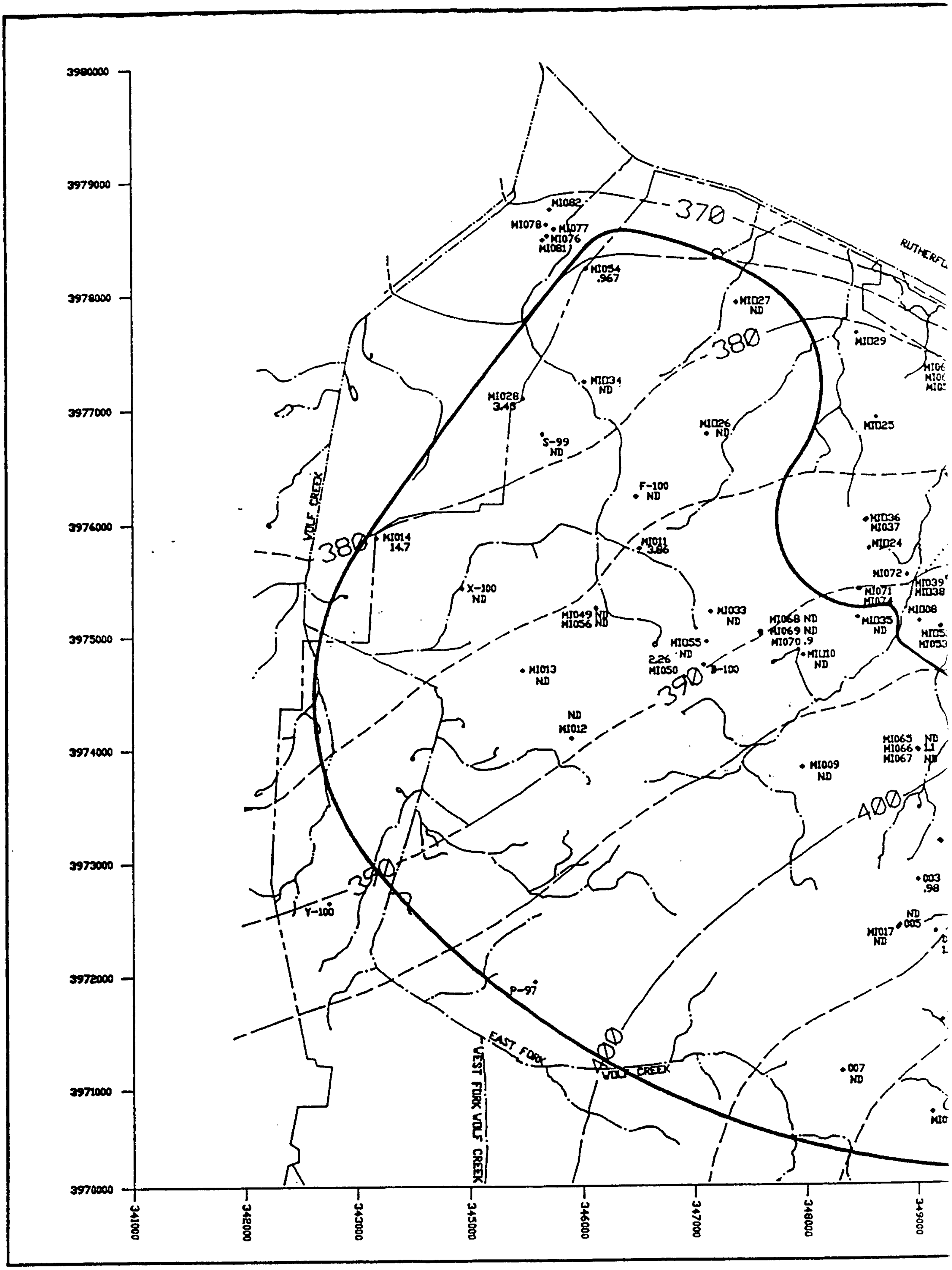

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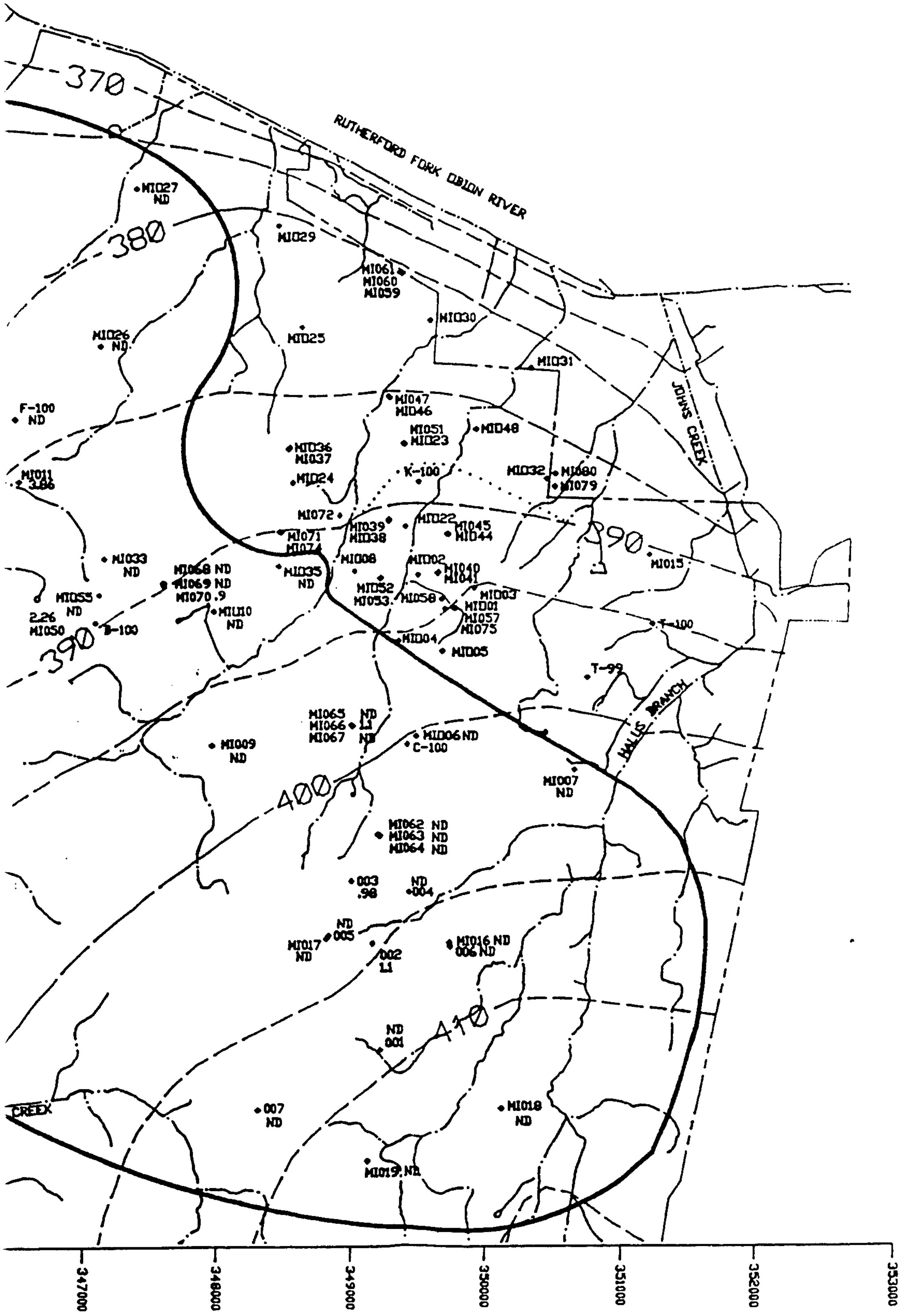

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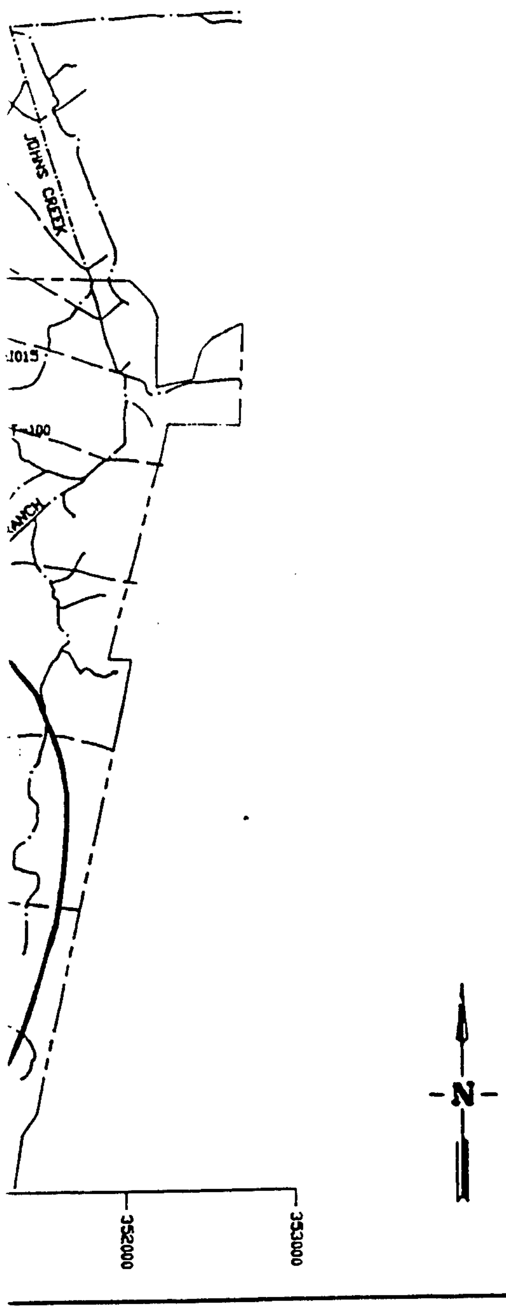

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TITLE NAAP REMEDIAL INVESTIGATION

FIGURE 7-18
1,3,5-TNB CONCENTRATIONS ASSOCIATED WITH THE OBG/ADA AND OTHER SOURCES

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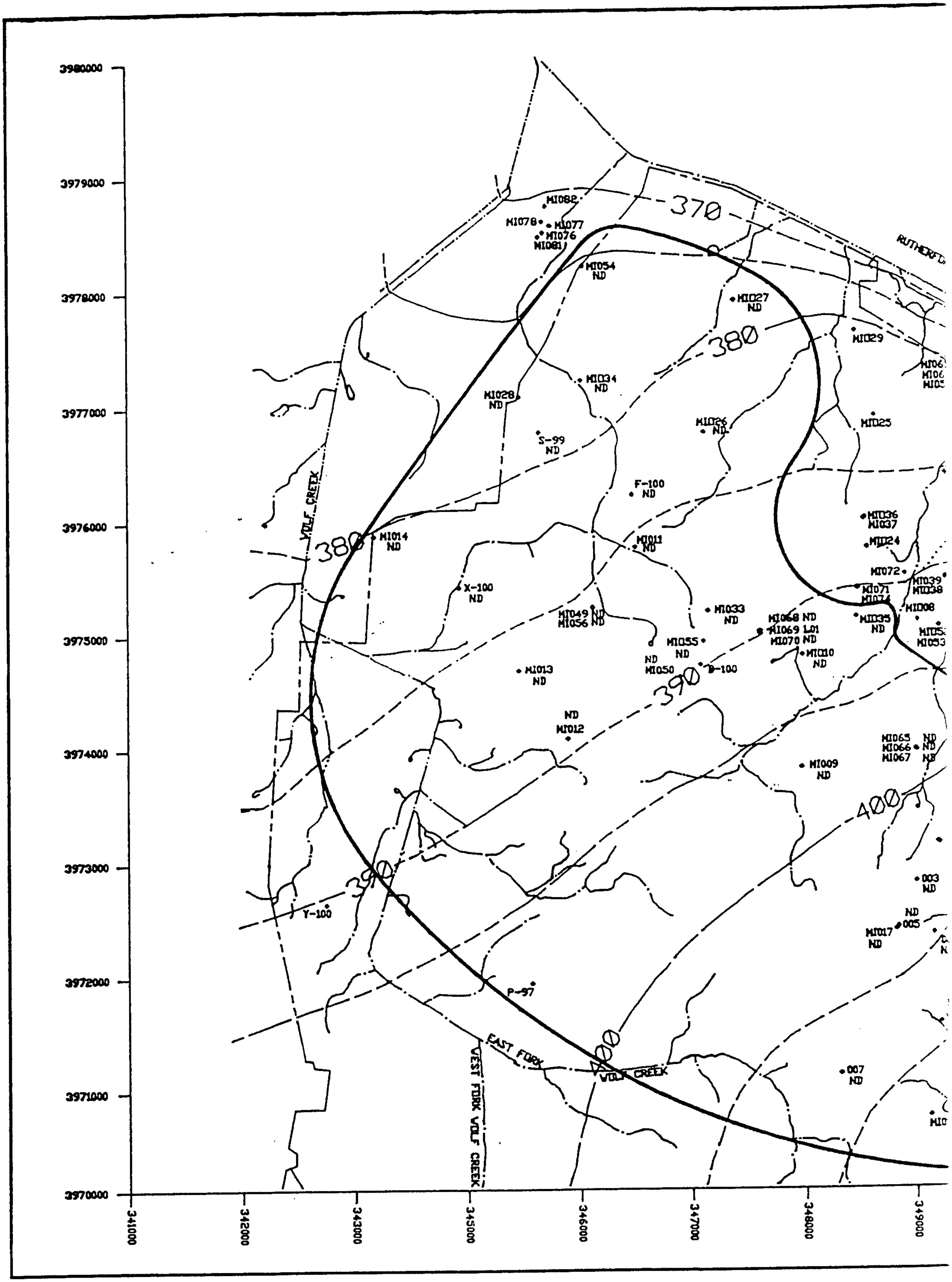
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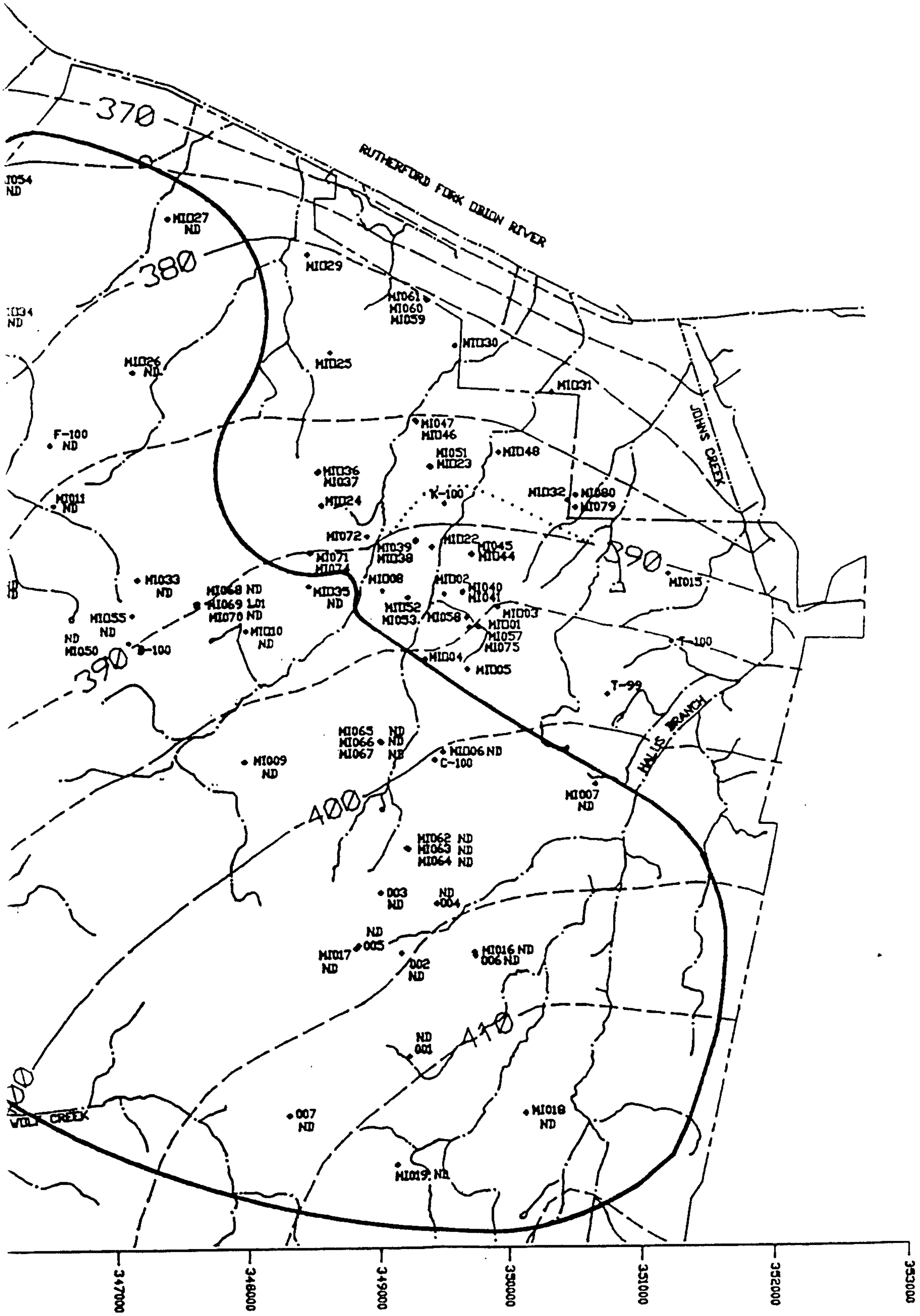

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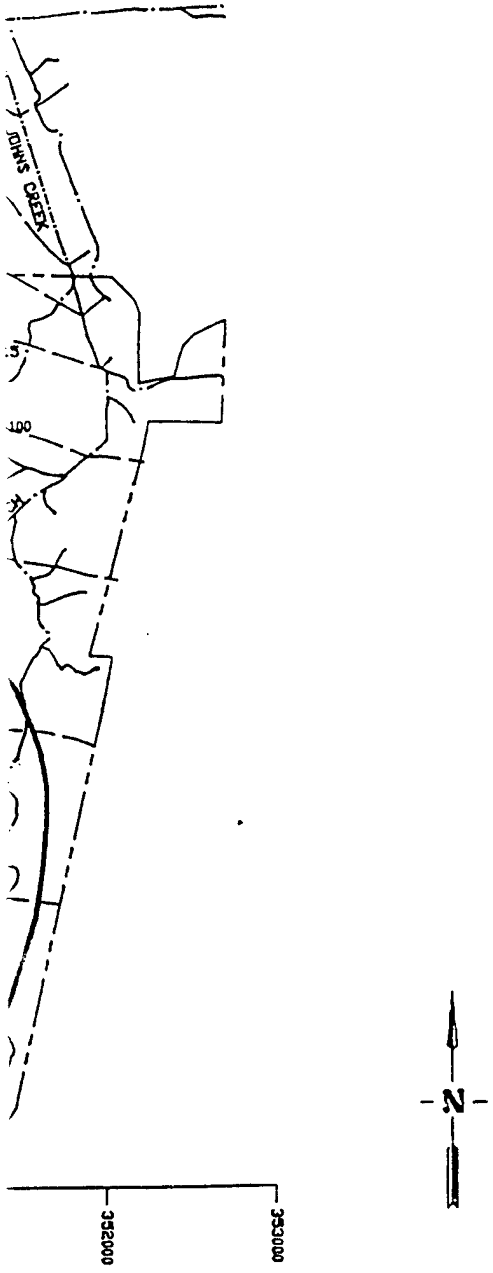

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TITLE MAAP REMEDIAL INVESTIGATION

FIGURE 7-19
2,4-DNT CONCENTRATIONS
ASSOCIATED WITH THE OBG/ADA
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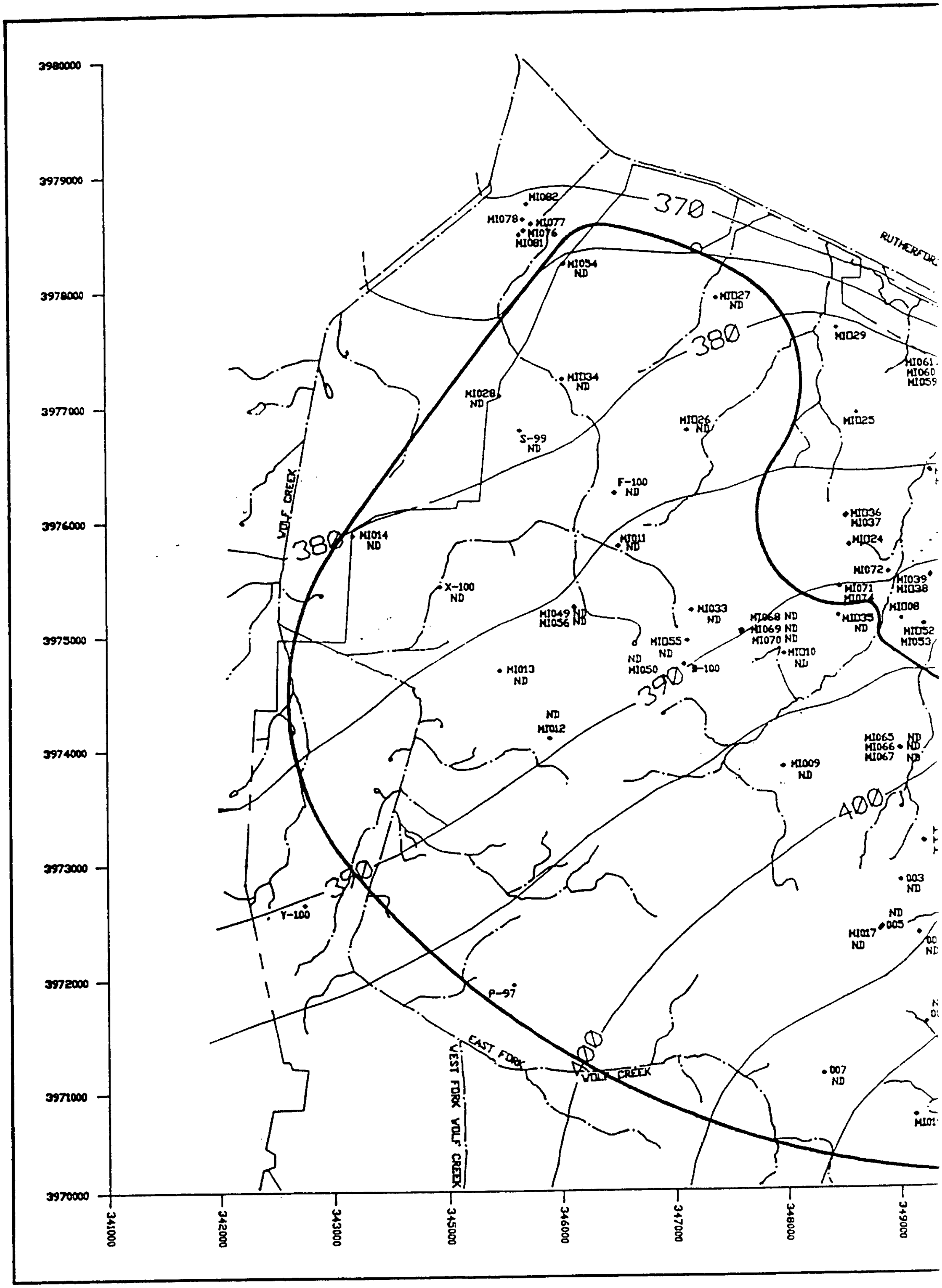
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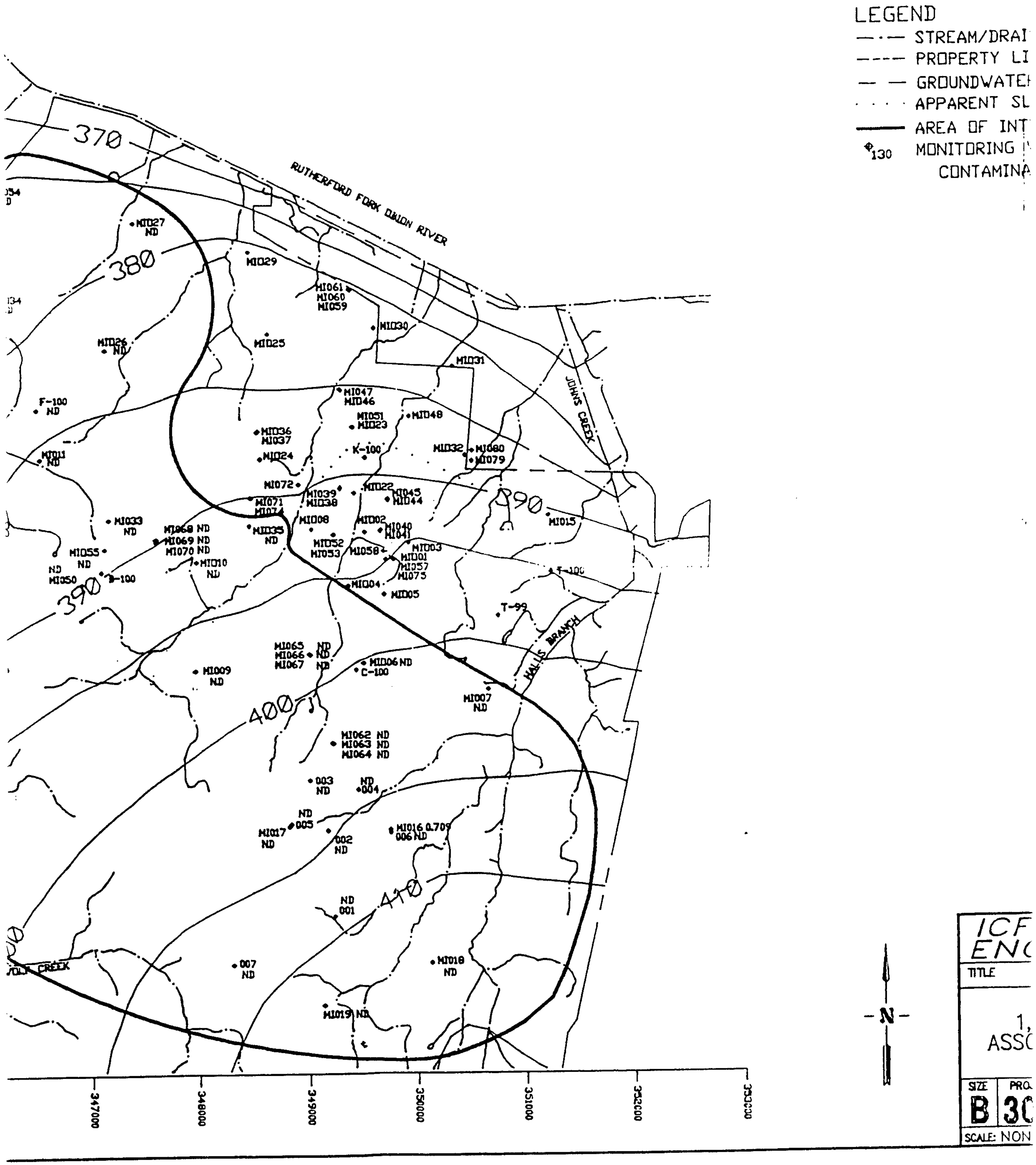

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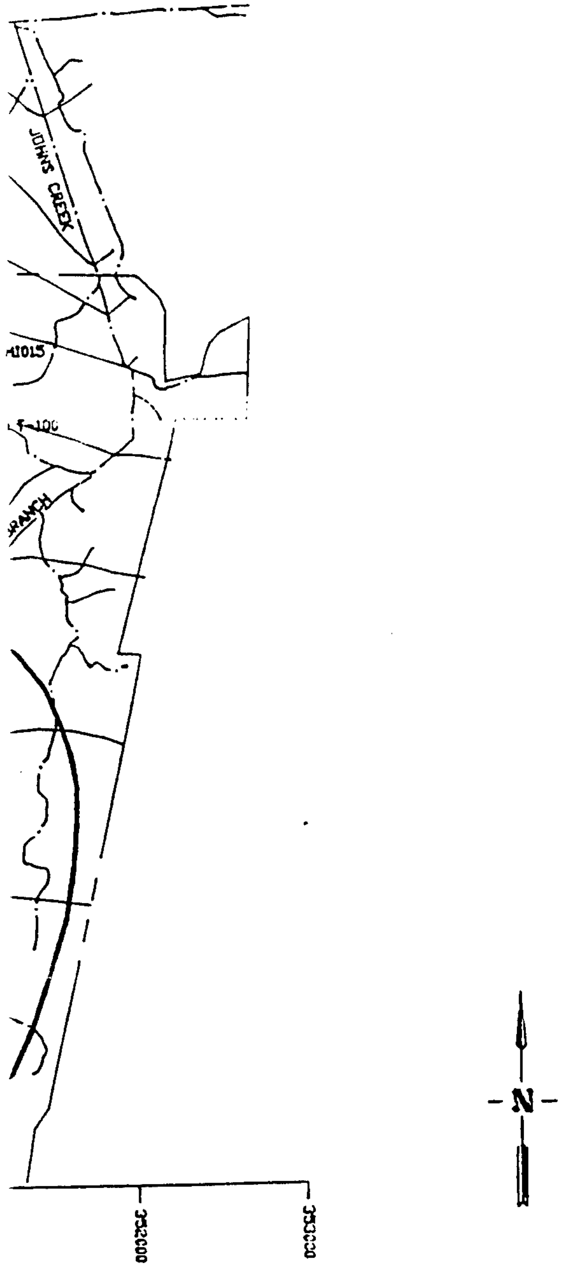

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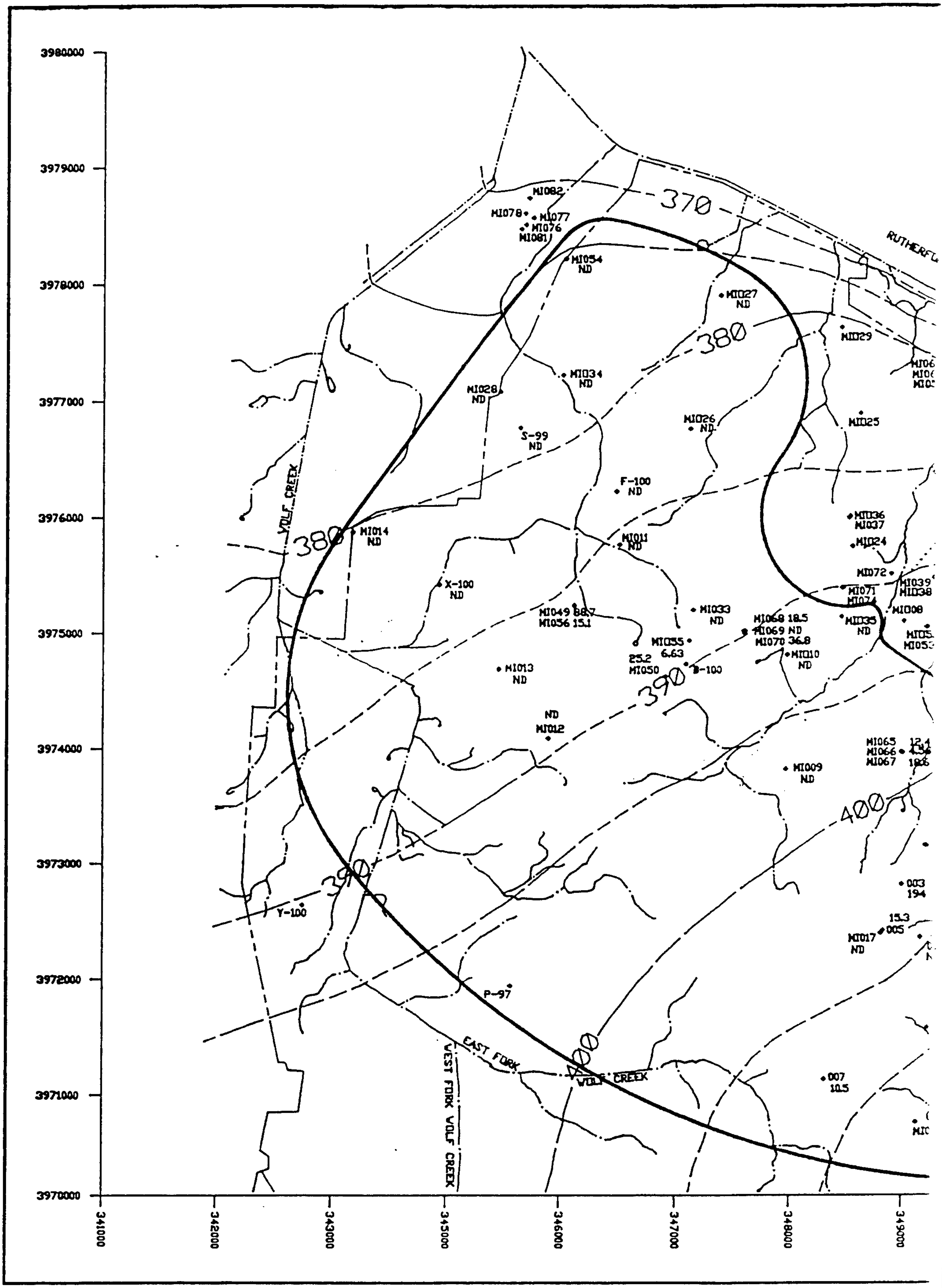
TITLE MAAP REMEDIAL INVESTIGATION

FIGURE 7-20
1,3-DNB CONCENTRATIONS
ASSOCIATED WITH THE OBG/ADA
AND OTHER SOURCES

SIZE B
PROJECT CODE 30874
DWG NO. 05109106
SCALE: NONE
DRAWN BY: D. ALLEN
CHECKED BY: N. OKUSU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MI036
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MI024
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MI049 88.7
MI056 15.1
MI033
ND
MI068 18.5
MI069 ND
MI070 36.8
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MI065 12.4
MI066 4.56
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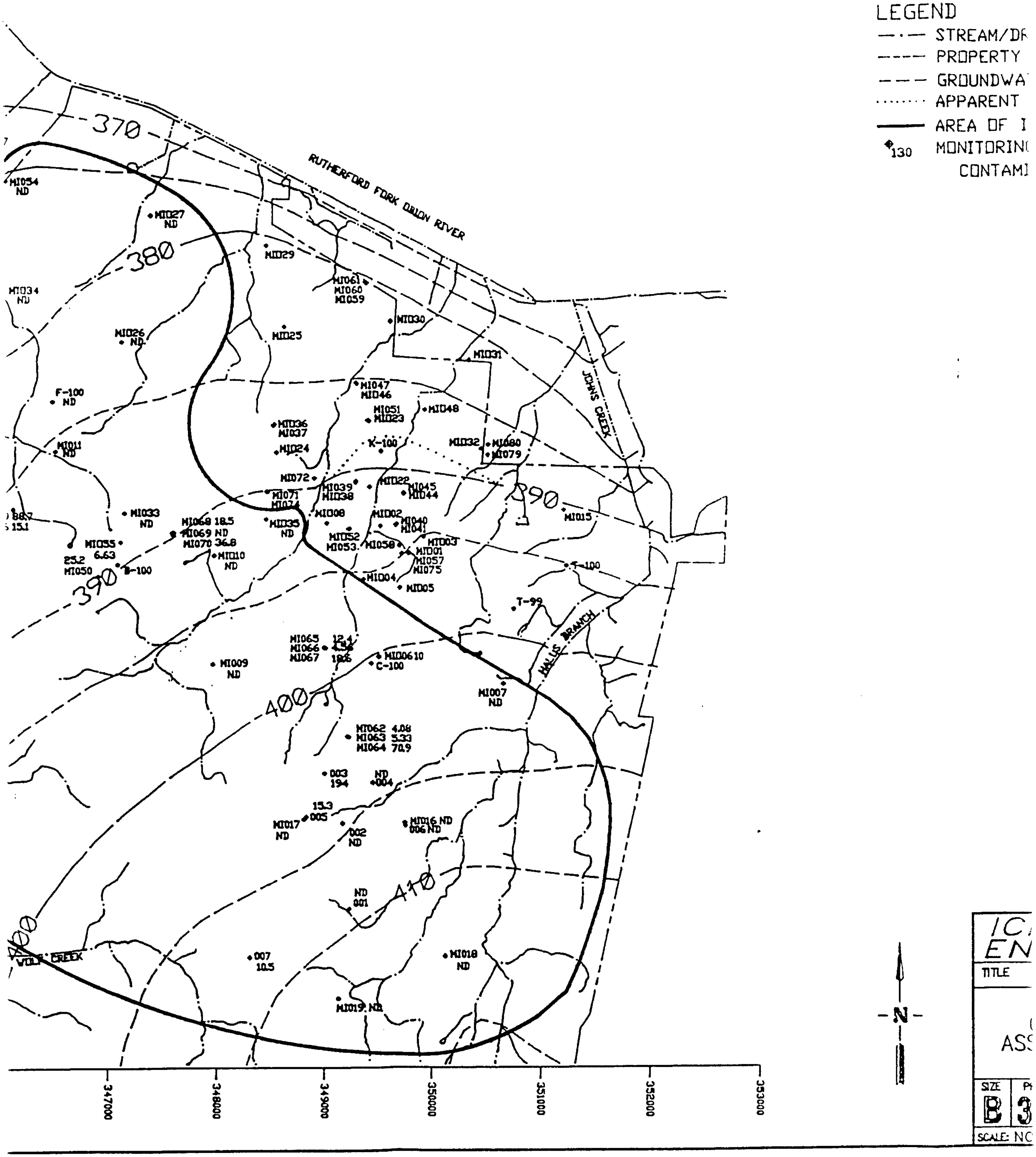
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— — — GROUNDWATER CONTOUR

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CONTAMINANT CONCENTRATION (ppb)

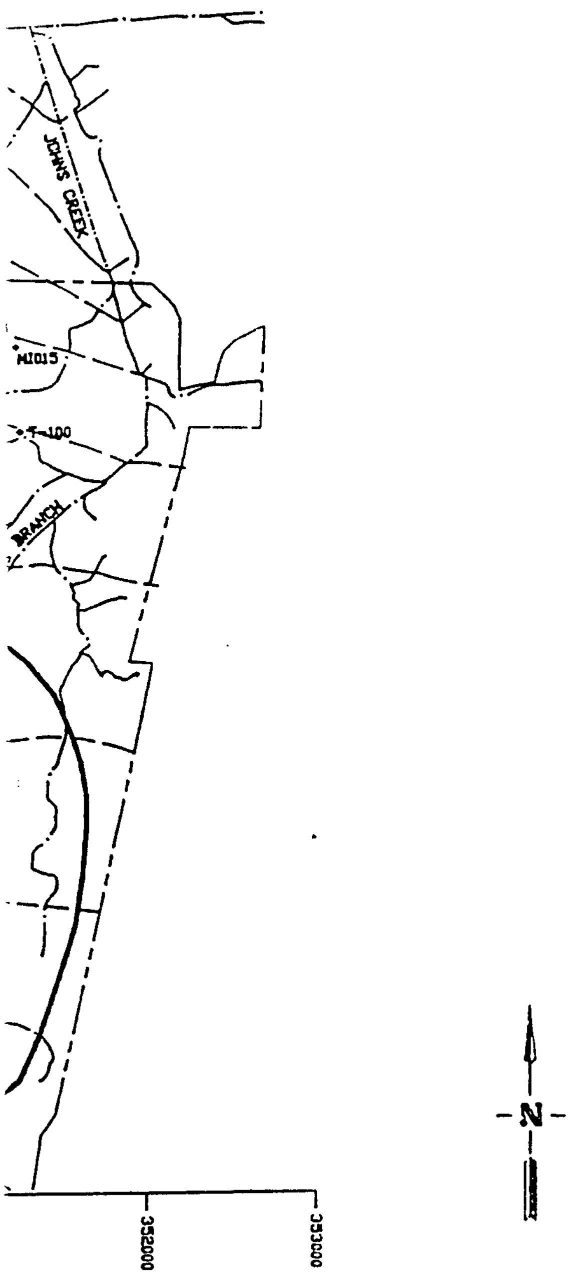

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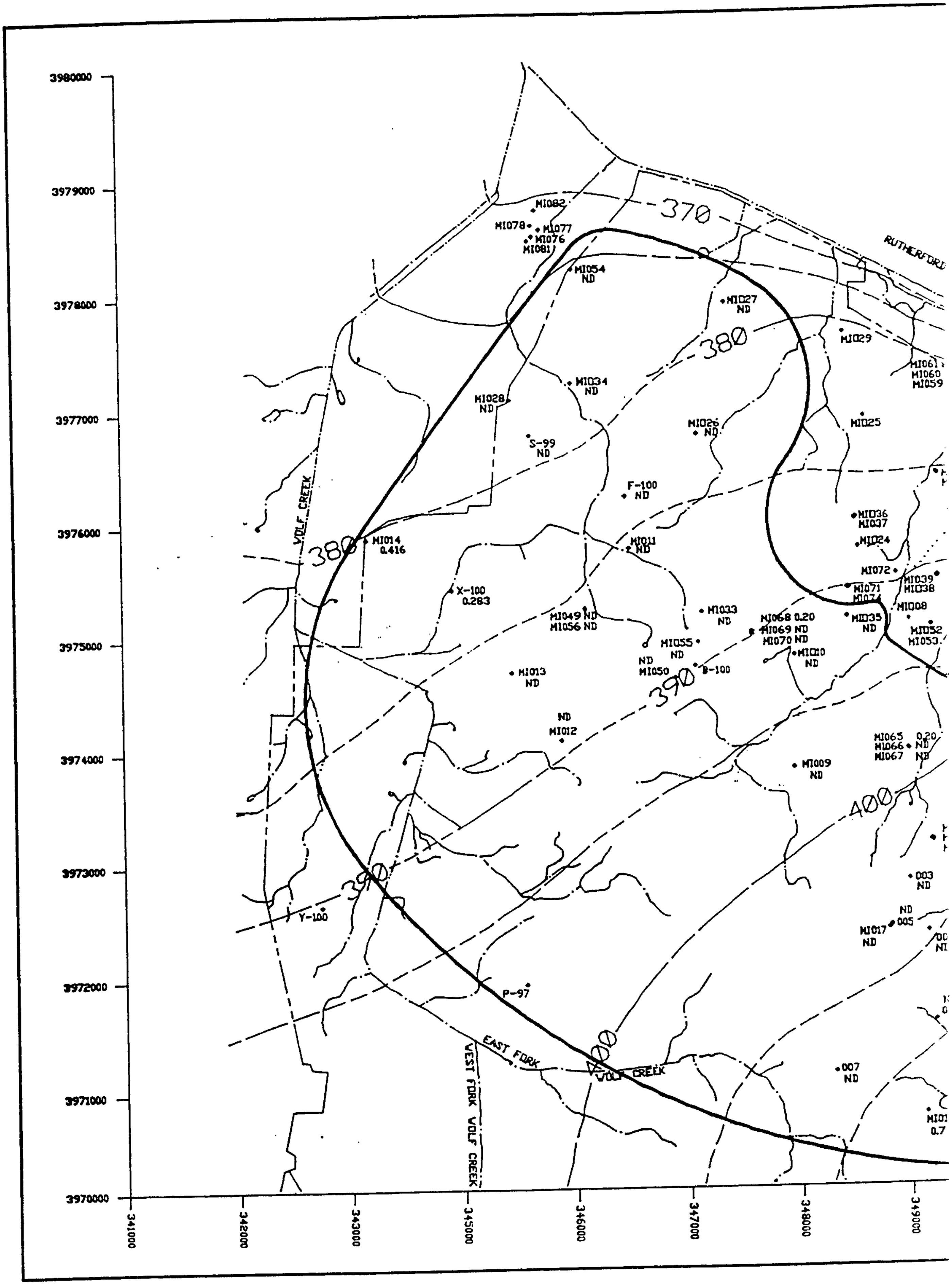
FIGURE 7-21
CADMIUM CONCENTRATIONS
ASSOCIATED WITH THE OBG/ADA
AND OTHER SOURCES

SIZE B | PROJECT CODE 30874 | DWG NO. 05109107

SCALE: NONE | DRAWN BY: D. ALLEN | CHECKED BY: N. OKUSU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F-100
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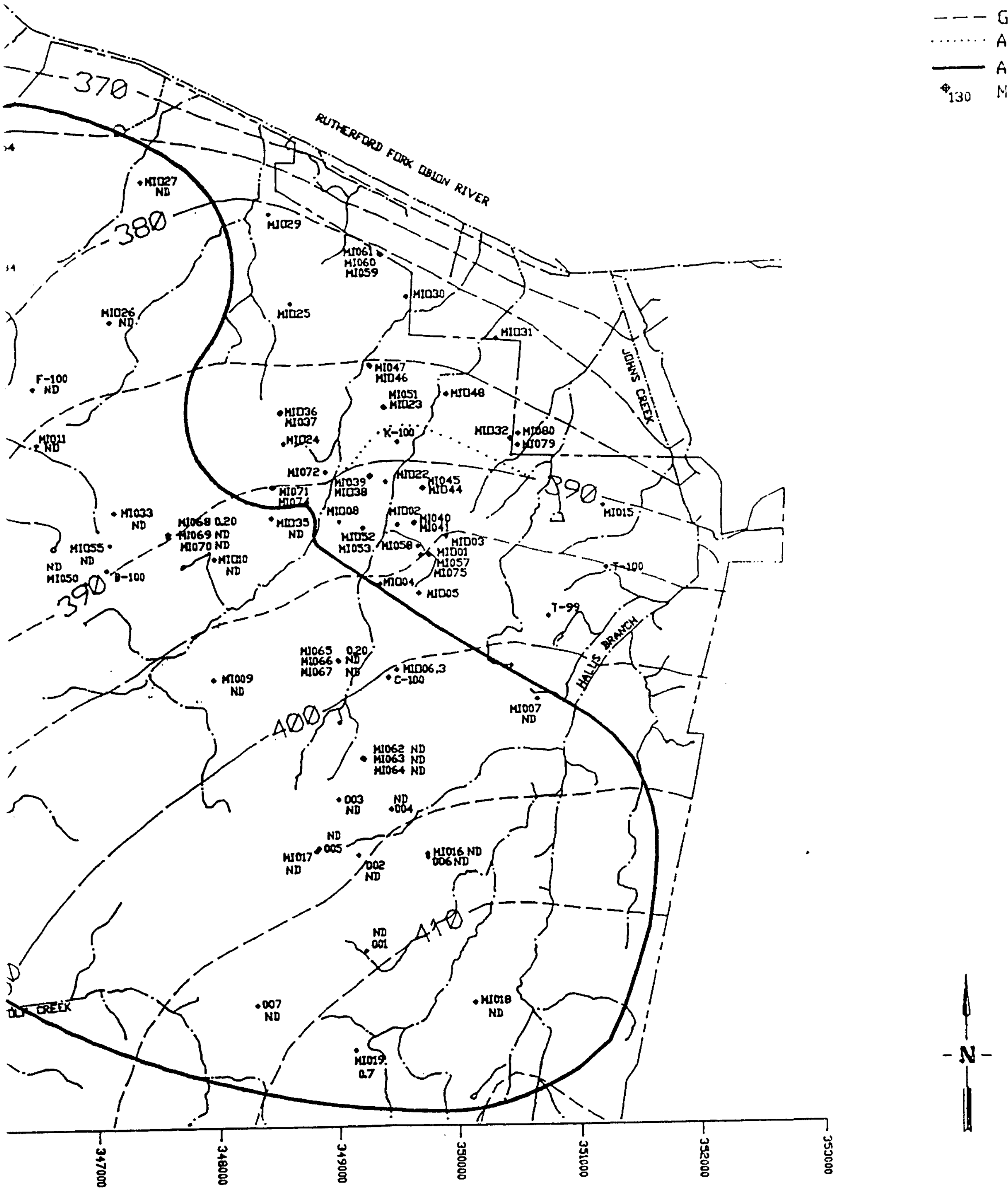

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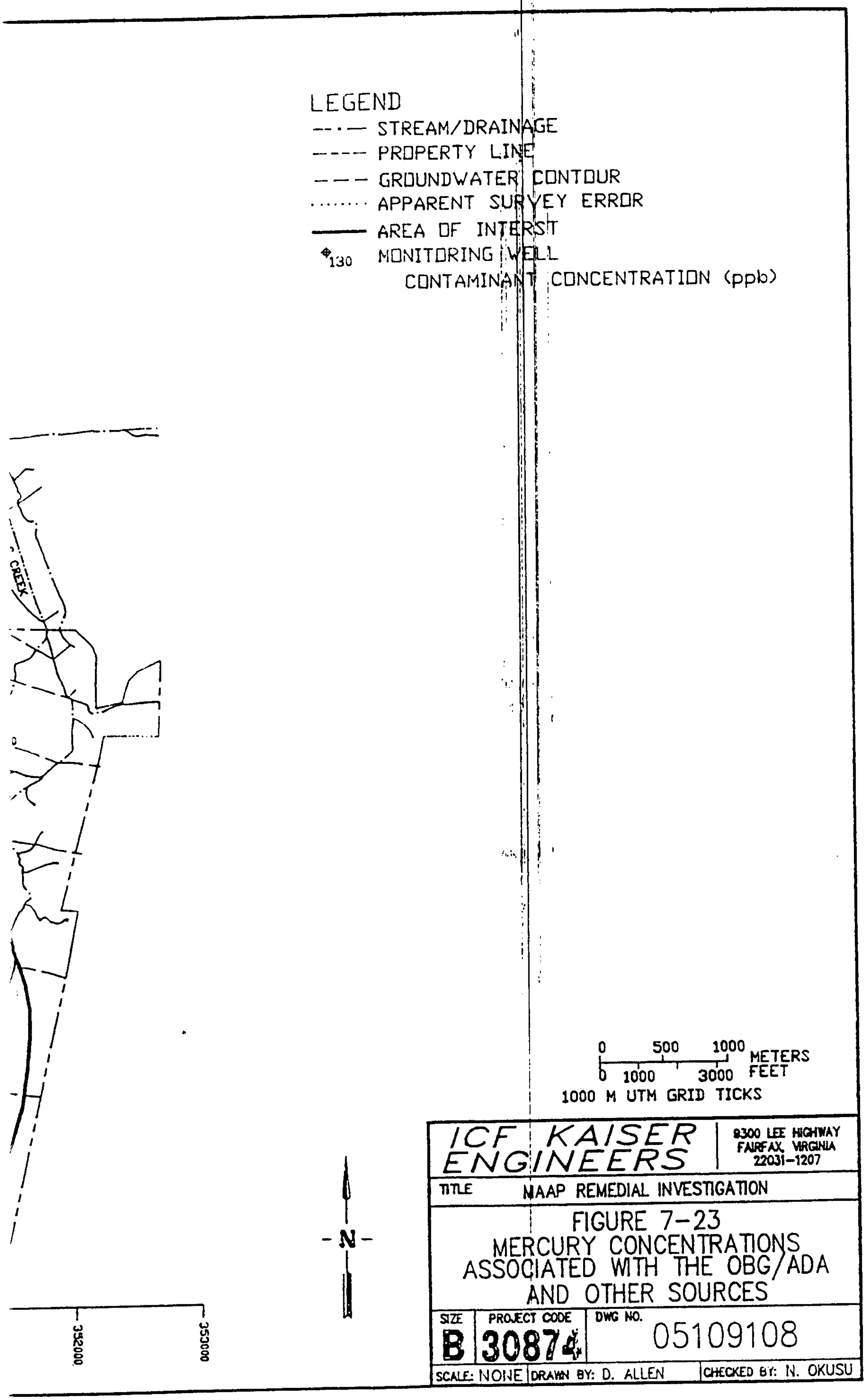

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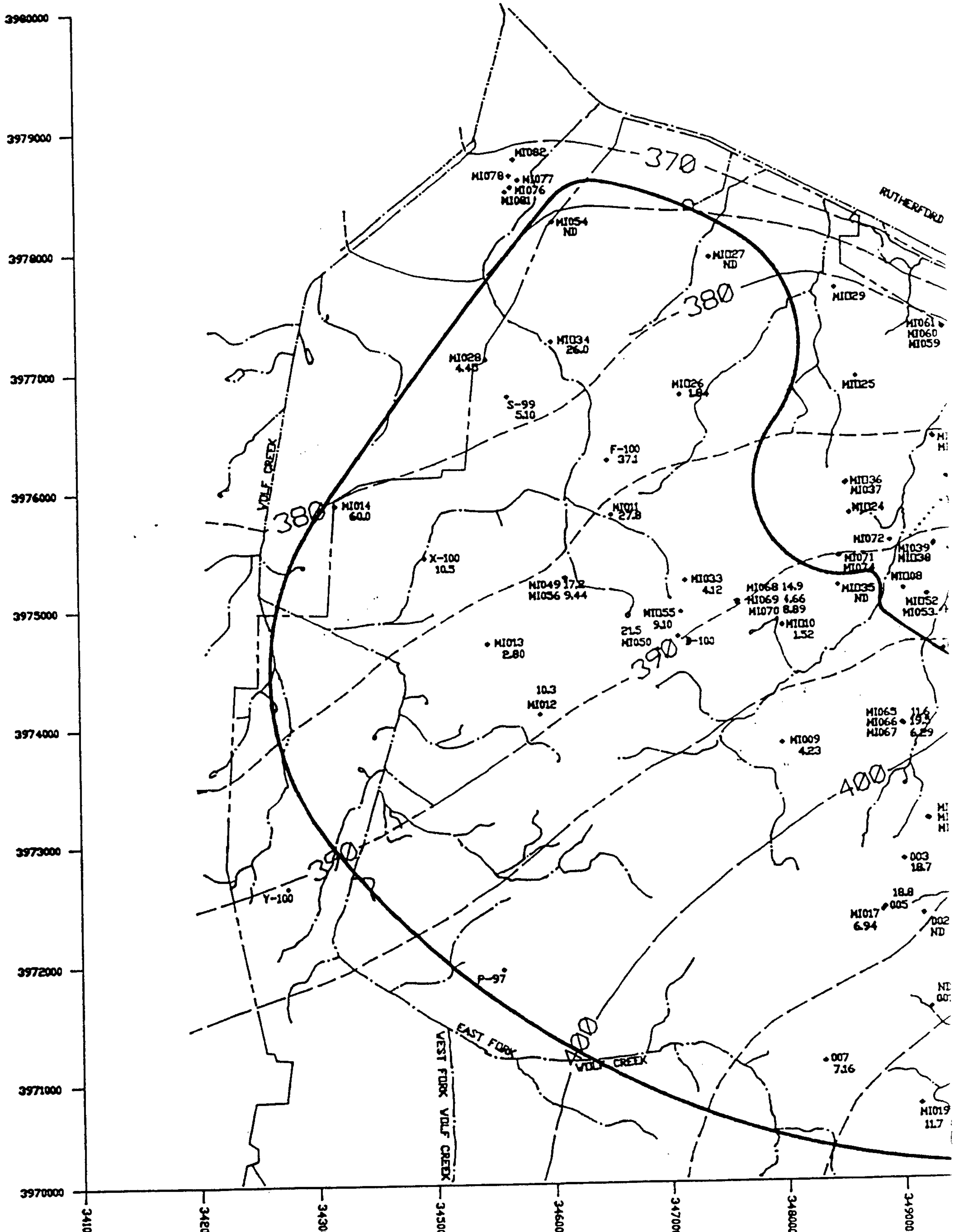
TITLE NAAP REMEDIAL INVESTIGATION

FIGURE 7-23
MERCURY CONCENTRATIONS ASSOCIATED WITH THE OBG/ADA AND OTHER SOURCES

SIZE	PROJECT CODE	DWG NO.
B	30874	05109108

SCALE: NONE | DRAWN BY: D. ALLEN | CHECKED BY: N. OKUSU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MI056 9.44
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MI069 4.66
MI070 8.89
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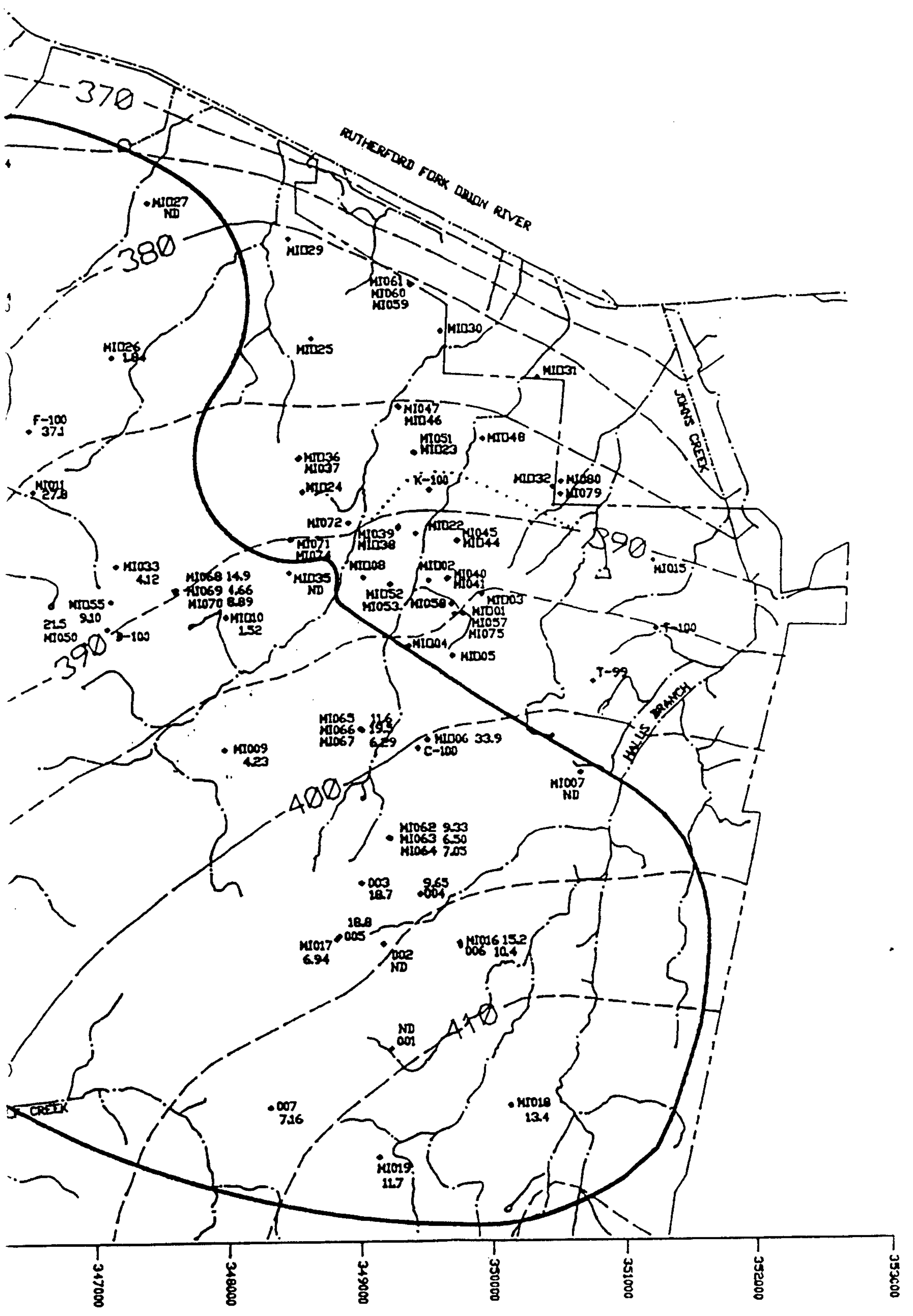

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LEGEND

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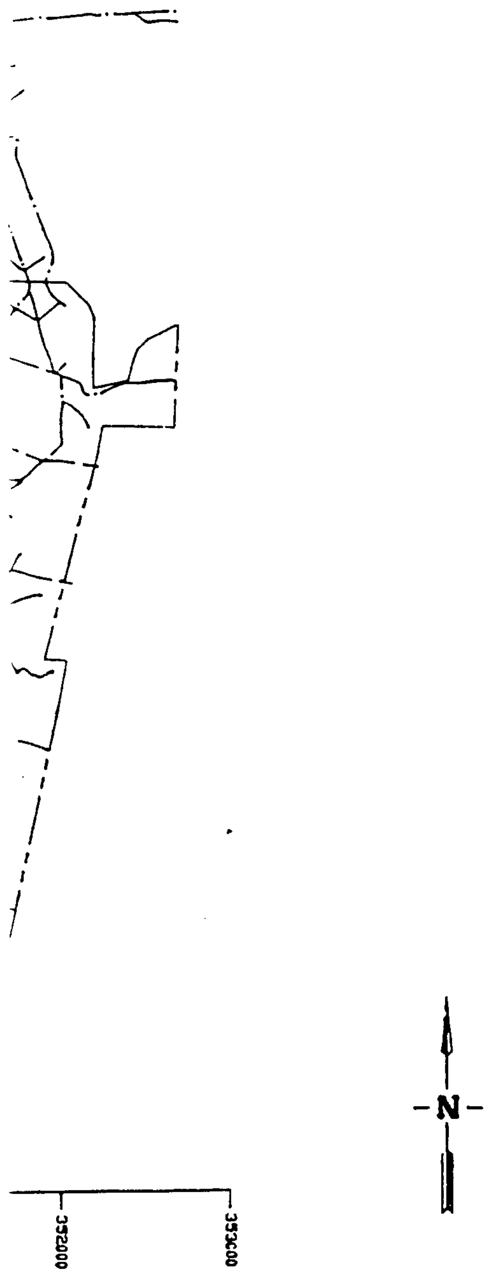
◆130 MONITORING WELL
CONTAMINANT CONCENTRATION (ppb)



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1000 M UTM GRID TICKS

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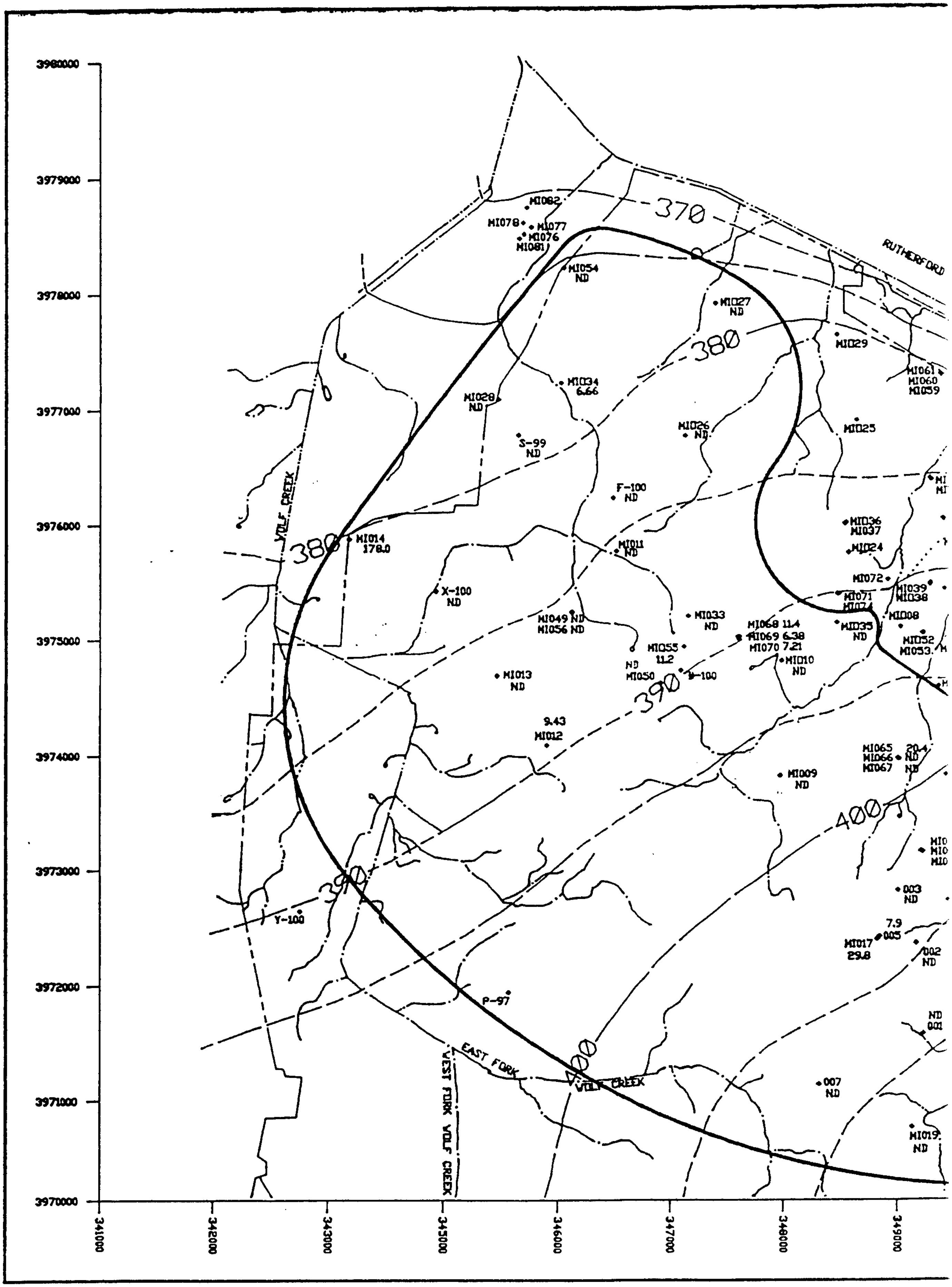
22031-1207

TITLE MAAP REMEDIAL INVESTIGATION

FIGURE 7-24
LEAD CONCENTRATIONS
ASSOCIATED WITH THE OBG/ADA
AND OTHER SOURCES

SIZE	PROJECT CODE	DWG NO.
B	30874	05109109

SCALE: NONE	DRAWN BY: D. ALLEN	CHECKED BY: N. OKUSU



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MI069 6.38
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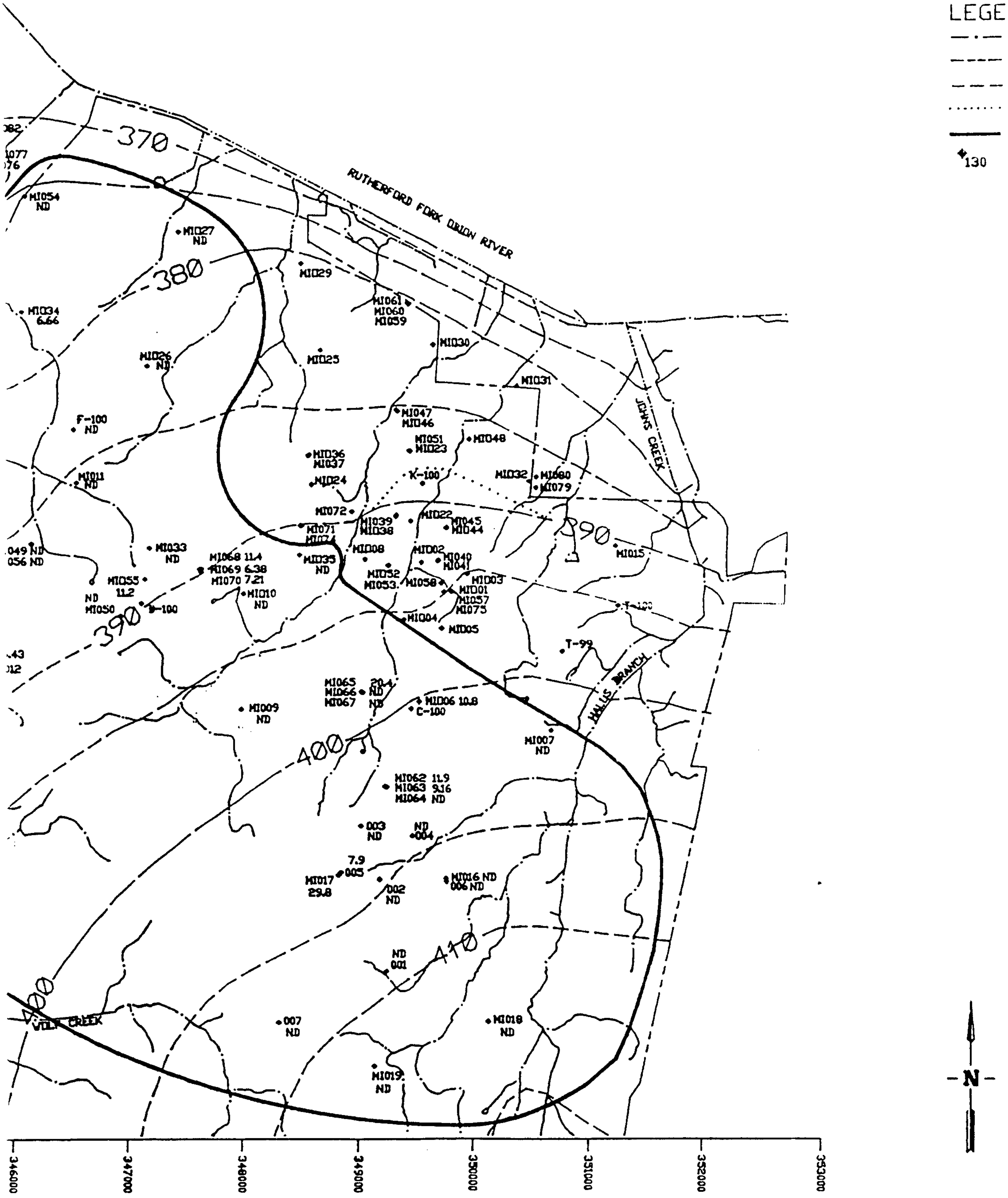

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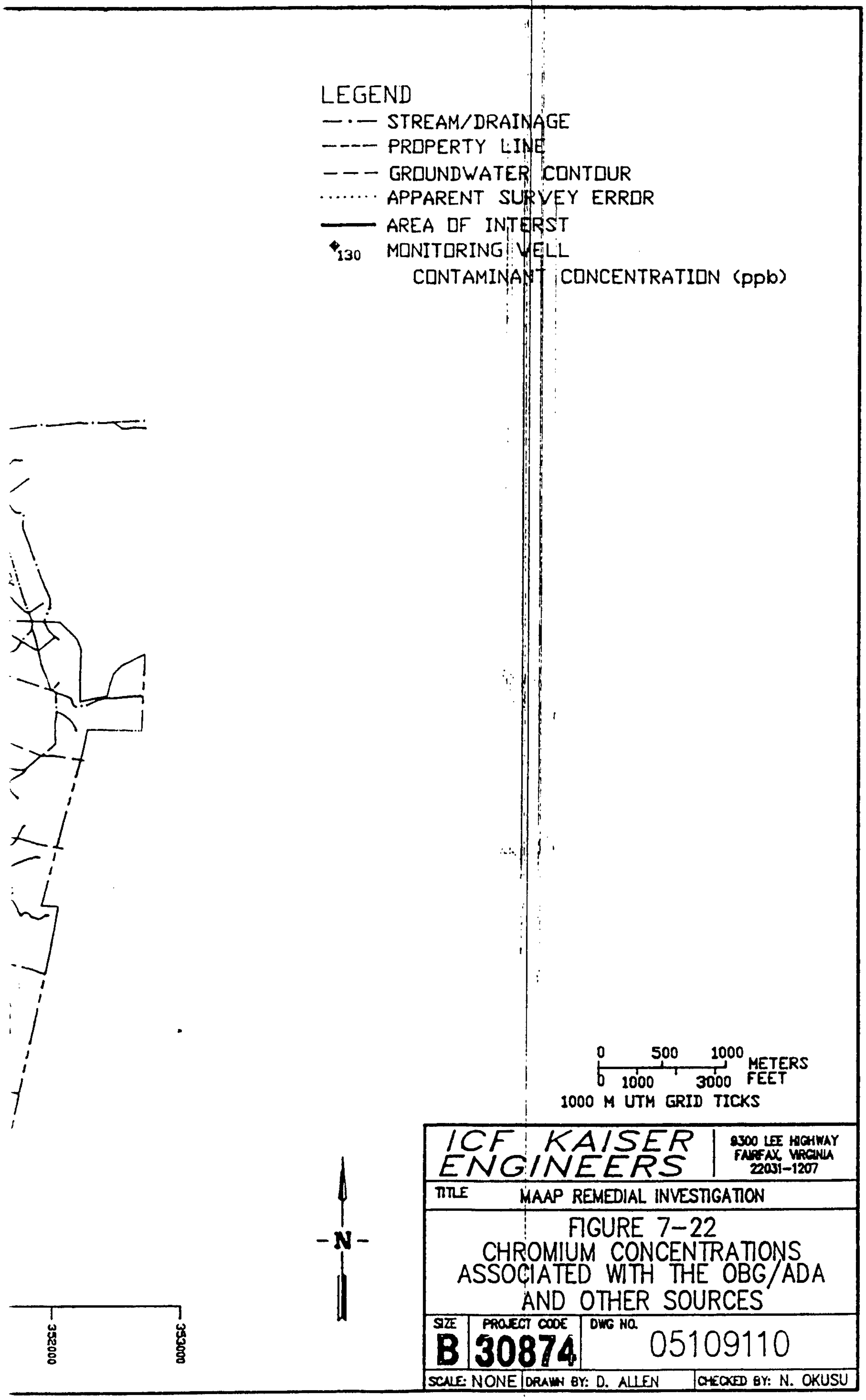

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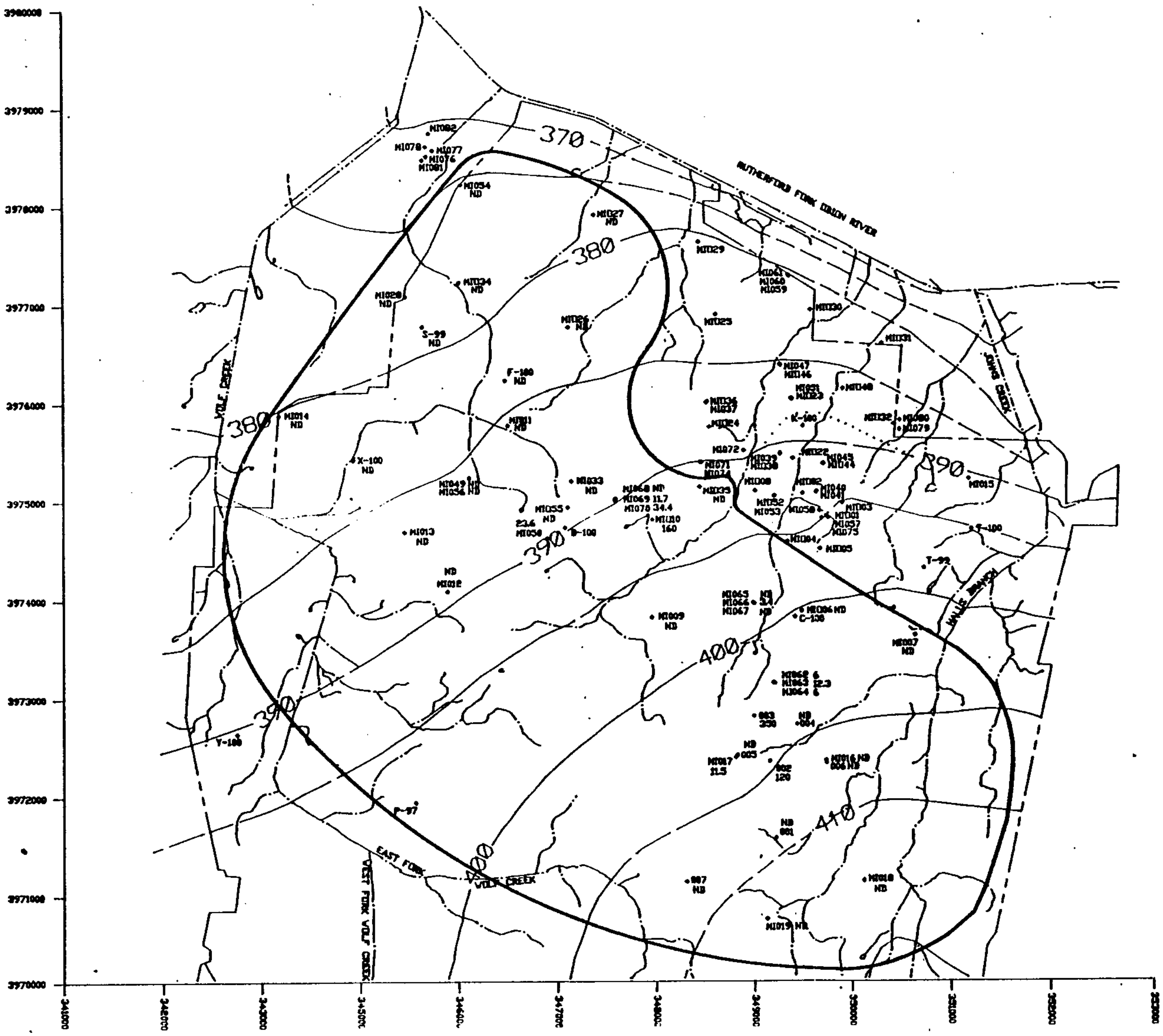
TITLE MAAP REMEDIAL INVESTIGATION

FIGURE 7-22
CHROMIUM CONCENTRATIONS
ASSOCIATED WITH THE OBG/ADA
AND OTHER SOURCES

SIZE	PROJECT CODE	DWG NO.
B	30874	05109110

SCALE: NONE | DRAWN BY: D. ALLEN | CHECKED BY: N. OKUSU



LEGEND
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- — - — PROPERTY LINE
- — — GROUNDWATER CONTOUR
- ······ APPARENT SURVEY ERROR
- ——— AREA OF INTERST
- ◆130 MONITORING WELL
  CONTAMINANT CONCENTRATION (ppb)

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TITLE	MAAP REMEDIAL INVESTIGATION
	FIGURE 7-15 RDX CONCENTRATIONS ASSOCIATED WITH THE OBG/ADA AND OTHER SOURCES
SIZE B	PROJECT CODE 30874
DWG NO.	05109101
SCALE: NONE	DRAWN BY: D. ALLEN
CHECKED BY: N. OKUSU	

Tetryl and nitrobenzene were not detected in this area of the site.

Cadmium was detected at high levels downgradient of the OBG/ADA area. It was also detected downgradient of Line C, Line D and Ditch 4, Line B, and Line A.

There does not appear to be a pattern to the appearance of the other select metals in groundwater samples in this area of the site.

7.2.4 Off-Site Contamination

The RDX and HMX contamination which was observed in the off-site domestic wells between 1982 and 1988 does not appear to be caused by either the O-Line plume or the OBG/ADA plume. It appears likely that the source of these contaminants is the drainage ditch which flows between Line Z and Line F. Both of these fuze lines used tetryl and RDX at some time. HMX is a common contaminant of tetryl.

If this ditch is the source of the historical contamination, then the fact that contamination has not been observed since 1988 indicates that the concentration of contaminants in the soil under the ditch has decreased sufficiently over time.

7.3 SURFACE WATER

The concentrations of explosives detected in surface water did not exceed the facility's NPDES permit limit at any location. It cannot be determined if all of the explosives detected are due to current discharge or if runoff from the suspected source areas is carrying additional contamination. Explosives were not detected in the receptor streams, which indicates that sufficient surface water infiltration through the ditch floor and dilution in the receptor streams is currently occurring.

In general, the select metals were detected in ditch surface water samples collected downstream of load line outfall locations. The select metals detected in Ditches 1 and 2 flow into Wolf Creek. However, a sample was not collected from Wolf Creek and so it cannot be determined if the ditch water quality is affecting this receptor stream. The metals detected in Ditches 4 and 5 were not detected in Ditches B and C, with the exception of lead and a single detection of mercury just over the CRL. The sample collected from the Rutherford Fork had a low concentration of lead. It cannot be determined if this contaminant is site-related.

7.4 SUMMARY OF CONTAMINANTS DETECTED AT MAAP AND POSSIBLE CONNECTION TO SITE ACTIVITIES

The focus of this investigation centered on the examination of select metals and explosives contamination at MAAP; however, other organic and inorganic compounds were detected at low to elevated levels. The occurrence of many of these compounds may be related to site activities. A summary of the contaminants detected is provided in Table 7-3. Background research into site activities has revealed that contaminants such as cyanide, nitrates, phosphates, nitrates, and other explosive compounds (NG and PETN) have been used at the site. The environmental samples collected during this investigation were not analyzed for these constituents; therefore, the nature and extent of contamination has not been fully defined. It is recommended that further environmental investigation at the site involve analyses for an expanded list of analytes.

TABLE 7-3
Summary of Contaminants Detected at MAAP

Contaminant	Media Where Detected	Potential Use at MAAP
Select Heavy Metals		
Cadmium	Soil Groundwater Surface Water Sediment	• Ordnance frequently plated with cadmium to inhibit corrosion. Electroplating of cadmium was performed at Line K. • Cadmium dust from buffing fuzes at Line X. • Spill: An unknown quantity of cadmium plating solution was released from Building K-50 into the sumps at the north end of Line K in 1968 (USATHAMA, 1978).
Chromium	Soil Groundwater Surface Water Sediment	• Zinc chromate used in the electroplating process. Electroplating was performed at Line K. • Chromic acid used in Area J. • Waterproofing of metallic fuels in pyrotechnics may have been performed by a coating of a solution of potassium dichromate.
Lead	Soil Groundwater Surface Water Sediment	• Lead flooring in Buildings for grounding purposes. • X-ray facilities used lead sheeting at D, C, and K-Lines. • Lead azide, a primary explosive, is used as an initiating agent in devices like primers, fuzes, and detonators, especially for use with tetryl, RDX, and PETN. Handling of lead azide occurred at Line F. • Lead from paint grinding and firing and removing primers at Line B. • Lead from spray painting at Lines C and O. • Melting and smoldering of lead in the battery shop at Area I. • Lead from firing detonators in fuze heads and from lead paint at Line X. • Lead in thin film preservative mix used in Area J. • Peroxides of lead may have been used as a source of oxygen for pyrotechnics.
Mercury	Soil Groundwater Surface Water Sediment	• Mercury fulminate, a primary explosive, is used as an initiating agent in devices like primers, fuzes, and detonators, especially for use with 2,4,6-TNT, tetryl, RDX, and PETN. The explosive mercury fulminate contains a minimum of 98% mercury fulminate and a maximum of 1% free mercury. Handling of mercury fulminate occurred at Line F. • Mercury from firing fuze detonators at Line X.
Explosives		
RDX	Soil Groundwater Surface Water Sediment	• RDX, a booster and secondary explosive used in ammunition, is a major component of cyclotols. Handling of RDX occurred at every load and fuze line.
HMX	Soil Groundwater Surface Water Sediment	• Bursting charge and secondary explosive used in ammunition. • Major contaminant of RDX.

TABLE 7-3 (Continued)
Summary of Contaminants Detected at MAAP

Contaminant	Media Where Detected	Potential Use at MAAP
2,4,6-TNT	Soil Groundwater Surface Water Sediment	• 2,4,6-TNT is a bursting charge explosive used in Composition B high level explosives, propellants, amatols, and pentolites. Handling of 2,4,6-TNT occurred at the following Lines: C, D, K (manufacture of amatol), O (washout of amatol and TNT from loaded rejects), X, and Area J (chemical laboratory).
2,4-DNT	Soil Groundwater Surface Water Sediment	• Contaminant of 2,4,6-TNT; finished 2,4,6-TNT contains up to 0.50% 2,4-DNT. • Degradation product of 2,4,6-TNT.
2,6-DNT	Soil	• Contaminant of 2,4,6-TNT; finished 2,4,6-TNT contains up to 0.25% 2,6-DNT. • Degradation product of 2,4,6-TNT.
1,3,5-TNB	Soil Groundwater Surface Water Sediment	• Contaminant of 2,4,6-TNT; finished 2,4,6-TNT contains up to 0.10% 1,3,5-TNB. • Major degradation product of 2,4,6-TNT.
1,3-DNB	Soil Groundwater	• Contaminant of 2,4,6-TNT; finished 2,4,6-TNT contains up to 0.02% 1,3-DNB. • Degradation product of 2,4,6-TNT.
Tetryl	Soil Groundwater Surface Water	• Primary explosive used in boosters. Assembly of booster, blending and pelletizing of tetryl occurred at Line E. Other areas of handling occurred at the following lines: Line A, B, H, and Z.
NB	Soil Groundwater Surface Water	• Contaminant of tetryl • Use as a solvent. • Degradation product of 2,4,6-TNT.
	TAL Inorganics (Above Background)	
Aluminum	Groundwater Surface Water Sediment	• Powdered aluminum used as a sensitizer in amatols and pyrotechnics to increase the heat of reaction. • Aluminum nitrate may have been used as a source of oxygen in pyrotechnics.
Arsenic	Soil Surface Water Sediment	• Arsenicals were used as herbicides.
Barium	Groundwater Surface Water	• Barium stearate used as a binding agent and lubricant, especially for use with RDX. • Up to 14% barium nitrate used in M2 and M5 propellants. • Barium nitrate provides source of oxygen in pyrotechnics.
Beryllium	Sediment	Unknown
Calcium	Soil Groundwater Surface Water Sediment	• Calcium stearate used as a binding agent for Composition CH6 RDX explosives (contained 1.5% calcium stearate). • Calcium silicate used in Type 2B cyclotols. • Calcium carbonate used as a retardant in pyrotechnics.

TABLE 7-3 (Continued)
Summary of Contaminants Detected at MAAP

Contaminant	Media Where Detected	Potential Use at MAAP
Cobalt	Soil Groundwater Surface Water Sediment	Unknown
Copper	Groundwater Surface Water	Unknown
Iron	Soil Groundwater Surface Water Sediment	Unknown
Magnesium	Groundwater Surface Water Sediment	• Used as a binding agent and lubricant, especially for use with tetryl; tetryl explosives contain up to 2% magnesium stearate. • Magnesium pellets used in explosive charges. • Powdered magnesium used as a fuel in pyrotechnics.
Manganese	Soil Groundwater Surface Water Sediment	Unknown
Nickel	Soil Groundwater Surface Water Sediment	Unknown
Potassium	Soil Groundwater Surface Water Sediment	• Up to 1.28% potassium nitrate and up to 1% potassium sulfate used in M2, M5, M8, M10, and IMR propellants. • Potassium nitrate is an ingredient of black powder used extensively for artillery and rocket propelling charge ignition. Black powder was pelletized, dried, screened and stored at Line L. • Potassium nitrate provides source of oxygen in pyrotechnics. • Metallic fuels in pyrotechnics may have been waterproofed with a solution of acidified potassium dichromate.
Selenium	Sediment	Unknown
Silver	Soil Groundwater Surface Water Sediment	• Silver brazing occurred in Area J.
Sodium	Soil Groundwater Surface Water Sediment	• Red water contains 11% sodium sulfate, and 4% sodium nitrate. • Sodium nitrate provides source of oxygen for pyrotechnics, and is a contaminant of black powder. • Sodium oxalate acts as a color intensifier for pyrotechnics.
Thallium	Sediment	Unknown

TABLE 7-3 (Continued)
Summary of Contaminants Detected at MAAP

Contaminant	Media Where Detected	Potential Use at MAAP
Vanadium	Soil Groundwater Surface Water Sediment	Unknown
Zinc	Soil Groundwater Surface Water Sediment	• Zinc used as a fuel in explosives to increase the heat of reaction. • Zinc chromate used in the electroplating process which was performed at Line K.
TCL Volatiles		
Acetone Diacetone alcohol	Soil Groundwater Sediment	• Acetone used at Line H as a cleaning solvent. • Nitroglycerin (NG), a booster and secondary explosive handled at Lines A, B, C, and X, is commonly transported as a 70:30 part NG:acetone mixture. The mixture is separated by precipitating out the NG.
Bromodichloromethane Dibromochloromethane Bromoform	Surface Water	• Used in photography and photoduplicating systems. Photography labs: Lines V, K, C and D.
Chlorobenzene	Sediment	• Constituent of paint thinners as a mold inhibitor. Paint thinner handling at Lines A, B, C, D, K, O, X and Area I.
Chloroform	Soil Groundwater Sediment	• Chloroform is used as a solvent, potentially in combination with pentolites.
Ethylbenzene Toluene Xylene	Soil Groundwater Sediment	• Toluene used at Line D as a solvent. • Primary constituents of gasoline and other petroleum products.
2-Propanol	Soil Groundwater Surface Water Sediment	• Used as a solvent. • Decontaminating agent used during the RI.
1,1,2-Trichloroethane 1,1,2,2-Tetrachloroethane Trichloroethylene	Soil Surface Water Sediment	• Petroleum solvents used at Area I.
Trichlorofluoromethane 1,1,2-Trichloro- 1,2,2-trichloroethane	Soil Sediment	• Used as solvents and refridgerants.
Semivolatile Compounds		
Butyl benzyl phthalate	Soil	• Used as a plasticizer with explosives
Bis-(2-ethylhexyl) phthalate Diethyl phthalate	Soil Groundwater Surface Water Sediment	• Used as plasticizers, as a component of plastic bags which carried the RDX-acetic acid slurry as it arrived on site to Line B. Used in Dupont Sheeting, cutting of sheeting for use in explosives occurred at Line D. • Up to 3% diethyl phthalate in M8 propellants.

TABLE 7-3 (Continued)
Summary of Contaminants Detected at MAAP

Contaminant	Media Where Detected	Potential Use at MAAP
Bromacil	Groundwater	• Used as an herbicide to treat weeds, brush, and grass on approximately 100 acres of railroad right-of-way.
Carbon disulfide	Surface Water	• Employed as a brightening agent in electroplating baths for deposition of chromium and zinc, and as corrosion protection in the treatment of metals for wear resistance.
2-cyclohexen-1-one 2-cyclohexen-1-ol 1,2-epoxycyclohexene	Soil Groundwater Surface Water Sediment	• RDX packed in these compounds upon arrival at MAAP. • Used also in the precipitation of RDX from the RDX-acetic acid slurry following filtering and washing.
Dibenzofuran	Soil	• Compounds produced from the burning of petroleum products.
Di-N-octyl phthalate (DOP)	Surface Water	• Constituent of Type I Plastic Bonded Explosives (PBX) which contain 90% RDX, 8.5% polystrene, and 1.5% DOP.
9H-Carbazole	Soil	Unknown
Hexamethylene tetramine	Soil	• Compound used in the production of RDX-HMX, in extracting RDX-HMX from the acetic acid slurry at Line B. • Used in infrared flare formulas.
Polycyclic Aromatic Hydrocarbons: Acenapthenes, antracenes, benzenes, chrysenes, fluorenes, napthalenes, phenantrenes, and pyrenes	Soil Sediment	•Coal tar and petroleum contaminants, originating potentially from coal pile in north-central portion of MAAP.
Stearic Acid	Soil Sediment	• Shaped charges and grenades. • Used as a desensitizer with RDX in Composition A combination explosives; a minimum of 1.6% used in A5 Type and 1.5 +/- 0.5% used in A% Type 2. • Used as a binding agent with tetryl; may contain up to 2% stearic acid.
		Other
High molecular weight hydrocarbons (cosanes) and associated acids (heptanoic, palmitic and tetradecanoic)	Soil Groundwater Sediment	Potential source is petrolatum (cosmolene), used in lubricating firearms and machinery.

8.0 CONTAMINANT FATE AND TRANSPORT

This section discusses the fate and transport of chemicals detected in different media at MAAP. Section 8.1 qualitatively addresses the primary pathways and mechanisms of contaminant migration at the site. Section 8.2 discusses the quantitative modeling of groundwater flow and contaminant transport that was performed to evaluate the future extent of groundwater contamination.

8.1 PATHWAYS AND MECHANISMS FOR MIGRATION

Contaminant migration through soil, groundwater, surface water/sediment and air is examined below as are the principal factors that influence the extent of migration through these media.

8.1.1 Soil

Three primary routes of migration exist for contaminants detected in soil at MAAP; these are leaching to groundwater, volatilization to air, and transport through air via sorption on wind-eroded soil particles. In addition to chemical-specific properties, the principal factors that influence the migration of contaminants in soil include soil composition, presence of microorganisms, and infiltration rate. In the context of the routes of migration, these factors are discussed below in general terms with specific references to the primary chemicals detected in soil at MAAP.

The degree to which a chemical in soil leaches to groundwater is largely controlled by the clay and organic carbon content of the soil as well as the sorption tendencies of the chemical. For organic compounds, the latter of these is characterized by the soil organic carbon/water partition coefficient (K_{oc}) of the chemical. The product of this adsorption coefficient and the fraction of organic carbon in soil (f_{oc}) is referred to as the partition or distribution coefficient (K_d) and is a measurement of the potential of a chemical to adsorb onto a specific soil matrix from water. As defined by this relationship, larger K_{oc} and f_{oc} values result in a greater degree of sorption to soil. In general, higher amounts of clay in soil result in greater chemical sorption.

As described in Section 5, the aquifer material at MAAP consists largely of well-sorted sand with only thin, discontinuous layers of clay. Additionally, the organic matter content of the aquifer material was below the method detection limit so a value of 0.1% (0.001) was assumed. Both of these factors suggest that the aquifer material in the vicinity of MAAP would, at most, only moderately inhibit the migration of chemicals to groundwater.

However, the surface alluvium at MAAP consists of a loamy, silty clay with varying amounts of organic material. Although the fractional organic content of the alluvium was not determined, it is believed that significantly more organic matter exists in the alluvium than in the aquifer material. In general, the alluvium has a thickness of approximately 10 feet across the site.

K_{oc} values for the explosive compounds were obtained from literature (Burrows et al., 1989 and Mabey et al., 1982). Estimated values for K_d were then calculated for the aquifer material. The organic matter content (0.1%) was converted to the organic carbon content by multiplying by 0.58 (Burrows et al., 1989). These K_{oc} and K_d values are presented in Table 8-1. All of the explosives detected in soil have low K_d values (i.e., less than one) which indicates that these compounds readily leach from the aquifer material. The K_d values for the surface alluvium are expected to be much larger; perhaps by as much as two orders of magnitude. Therefore, the mobility of explosives greatly depends on the nature of the source. If explosives exist at the surface (e.g. surface burning or overflowing from a sump), they are relatively immobile. If, however, explosives are disposed of in the aquifer material (e.g. flowing through a ditch which has incised through the surface alluvium or disposal in a trench), then their mobility is expected to be high and transport will not be significantly retarded by sorption onto soil.

Table 8-1
Development of MAAP Site-Specific K_d Values for Munitions Compounds

Munition Compound	log K_{oc} Value[a]	K_{oc} Value (mL/g)	K_d Value (mL/g)
2,4,6-TNT	2.72	525	0.304
2,4-DNT	2.40	251	0.146
2,6-DNT	1.89	77.6	0.0450
1,3,5-TNB	1.30	9.95	0.0116
1,3-DNB	1.56	36.3	0.0211
RDX	2.00	100	0.058
HMX	0.54	3.47	0.00201
Tetryl	1.69	48.98	0.0284
Nitrobenzene	1.56	36.0[b]	0.0209

a Adopted from Burrows et al. (1989), except where noted
b Source: Mabey et al. (1982)

The partitioning of metals species between soil and water is characterized by a similar distribution coefficient, K_d. In general, this coefficient is determined by laboratory experiments. In some cases, a column method is used to determine breakthrough of the material through uniformly packed soil. Another type of experiment simulates leaching by shaking a mixture of soil and the material until equilibrium is achieved. Because of the different methods for generating partitioning data, the reported range of values is large. Another source of variability in the reported values is the soil type used in the experiments. The organic matter content, pH, redox potential, and clay content influence the K_d values obtained.

In determining appropriate distribution coefficients for the select metals present at MAAP, professional judgement was exercised. First, reasonably conservative values were chosen so that transport will not be underestimated. Secondly, based on the lithology of the aquifer material, which is predominantly sand, distribution coefficients were chosen on the lower end of the range.

Lead is the metal most frequently detected at MAAP. In general, it was detected at low to high levels in surface soil and groundwater, and at low to moderate levels in subsurface soil, surface water, and sediment. It is a ubiquitous contaminant, but its appearance at MAAP is probably enhanced by site activities. K_d values as high as 7,640 mL/g have been reported in the literature (Baes et al., 1984). A conservative estimate of the site-specific partitioning is 900 mL/g.

Two of the three other select metals of concern, cadmium and mercury, although less mobile than the explosive compounds, are relatively mobile and do not appear to adsorb to soil material. Conservative assumptions for the purpose of the toxicological and transport assessments dictate that all chromium at MAAP be considered to exist in the hexavalent oxidation state, the second most common oxidation state. Although the trivalent state of chromium is the most common state, chromium(VI) is the most toxic and mobile of all of the oxidation states, and thus will dominate the discussion. Based on estimates by Baes and Sharp (1983) and Gerritse et al. (1982), the K_d value for chromium (VI) is estimated at 20 mL/g, suggesting that sorption will not be a significant process for removing chromium from the aqueous environment. The contrast of chromium(III) characteristics is noted: chromium(III) is reported by Baes et al. (1984) to have a K_d value of 850 mL/g, ranking it second in immobility after lead. The K_d values of cadmium (6.5 ml/g) and mercury (10 ml/g), estimated by Baes et al. (1984), suggest that these contaminants will not be persistent in the soil. Table 8-2 lists the site specific K_d values adopted for select heavy metals at MAAP.

It appears that the low organic carbon content of the soil and the method of wastewater disposal have been the controlling factors for leaching of contaminants through soil. Specifically, much of the contamination present at MAAP was discharged for many years in aqueous form to the ponds and ditches, thereby creating a constant or near-constant downward gradient below these features. Because of this downward gradient, greater quantities of contaminants could migrate to groundwater than would have occurred under the conditions of relatively infrequent infiltrating precipitation. This is supported by the subsurface soil sampling results which indicate that where contaminants were discharged primarily onto surface soils in nonaqueous forms (e.g., portions of the Open Burning Ground), the downward migration of those contaminants has been limited; in most such areas, contaminants were not detected in soil below 15 feet. Therefore, it is unlikely that a significant amount of the contaminants found in groundwater are from these areas, but instead it is much more likely that the ponds and ditches are the sources for a vast majority of these contaminants. Thus, the soil characteristics, and other contributing factors discussed above, appear to influence chemical leaching more than the K_d values of the individual chemicals present in soil at MAAP.

An alternative theory for the rapid attenuation with depth of the contaminants in near-surface soil is that the contaminants readily leach from the aquifer material underlying the alluvium. It is possible that the contaminants have migrated to the water table and that the concentration of contaminants sorbed to the soil is below the method detection limits.

Table 8-2
MAAP Site-Specific K_d Values Adopted for Select Heavy Metals

Select Metal	K_d Value (mL/g)
Lead	900
Cadmium	6.5
Chromium	20
Mercury	10

As no information is available on microorganisms at MAAP, site-specific discussion of the effects of microorganisms on contaminant concentrations is not possible. However, it should be noted that the metabolism of explosives by microorganisms under both aerobic and anaerobic conditions can, over time, significantly alter the soil concentrations of the explosives. As described by Burrows et al. (1989), 2,4-DNT, 2,6-DNT, and 1,3-DNB have been shown to undergo biodegradation. While 2,4,6-TNT, 2,4-DNT, 2,6-DNT, and 1,3,5-TNB can undergo biotransformation, these explosives have been found to be highly persistent (i.e., remain for many years) in soil and lagoon sediment. Additionally, the biotransformation of RDX and HMX under aerobic conditions has been shown to be insignificant. However, under certain anaerobic conditions, it is speculated that these compounds and their congeners undergo biotransformation, and the biotransformation rate of RDX is larger than that of HMX. (Burrows et al., 1989)

An assessment was performed to determine the potential for the lower molecular weight explosive compounds in soil to volatilize rather than remain on the soil matrix; inorganic chemicals are generally considered nonvolatile. For this purpose, a conservative screening approach was applied. The screening approach involved using a soil:air partition coefficient (K_{as}) which combines the chemical's affinity for the organic carbon in soil with its affinity for air as follows:

$$K_{as} = \frac{K_d}{H} \tag{1}$$

where:

K_{as} = soil:air partition coefficient (mL-mole/g-atm-m^3)

K_d = soil:water partition coefficient (mL/g)

H = Henry's law constant (atm-m^3/mole)

K_d values, based on K_{oc} values and a fraction of organic carbon of 0.1% (0.001) as discussed above, and Henry's law constant values for the munitions compounds detected at MAAP were obtained from Burrows et al. (1989). Those chemicals with K_{as} values less than 10 are considered unlikely to persist in soil or on surfaces in general due to a strong tendency to partition to air. Based on this screening, none of the explosive compounds of concern, with the exception of nitrobenzene, were found to be volatile. In fact, 1,3-DNB was calculated to have the smallest K_{as} value of any of the explosives (7×10^5 mL-mole/g-atm-m^3). Because of this, the migration of contaminants from soil to air via volatilization is expected to be insignificant.

Another means of contaminant transport to air involves the wind erosion of soil particles which have contaminants sorbed to them. The extent to which this occurs is dependent upon such factors as wind velocity, soil particle size, and the percent of vegetative cover. A more detailed discussion and quantitative modeling of these processes are presented in Section 9.0 and in Appendices O.

8.1.2 Groundwater

Contamination discharging at MAAP primarily to the ponds and ditches has affected the quality of groundwater. The constant or near-constant downward gradient below these features and the low sorption to the soil, dictated by the nature of the contaminants and geology, has transported the contamination into the aquifer system. The rate of contaminant transport through the groundwater is dictated predominantly by advection/dispersion.

Advection is the transport of a non-reactive, conservative solute at an average groundwater velocity. The average linear velocity, V, at which groundwater flows through a porous aquifer is (Freeze and Cherry, 1979):

$$V = \frac{K(i)}{N_e} \qquad (2)$$

where:

V = average groundwater flow velocity (ft/day)

K = average hydraulic conductivity (ft/day)

i = groundwater hydraulic gradient (dimensionless)

N_e = effective porosity of the soils (dimensionless)

The velocity of the contaminant front can be substantially different for solutes that exhibit precipitation/dissolution, adsorption, and/or partitioning within the geologic media. The ratio of the solute front velocity to the groundwater flow velocity is the retardation factor R, where R is defined as:

$$R = 1 + \frac{\rho_b K_d}{N_e} \qquad (3)$$

where:

R = retardation factor (dimensionless)

ρ_b = bulk density of the soil (g/cm^3)

K_d = partition coefficient (mL/g)

N_e = effective porosity of the soil (dimensionless)

The retardation factors for the explosives and select metals of concern are presented in Table 8-3.

The advective transport of explosive compounds and cadmium, chromium(VI), and mercury is due to relatively low values for R. Lead and chromium(III) will tend to sorb to the soil and remain relatively immobile and shallow in the aquifer system.

Hydrodynamic dispersion is the combination of mechanical and chemical processes which causes the contaminant plume to spread out in the lateral, vertical, and transverse directions. Mechanical dispersion is the mixing that occurs as a solute is convected through the porous medium. Molecular diffusion is the other component of hydrodynamic dispersion, and it is driven by the concentration gradient. In situations where the scale of the problem is small (i.e. a laboratory column experiment) or the velocity of convective flow is very small, hydrodynamic dispersion is dominated by molecular diffusion. However, in most field situations, hydrodynamic dispersion is dominated by mechanical dispersion and molecular diffusion may be neglected.

The coefficient of hydrodynamic dispersion is a function of the aquifer material, and is also scale-dependent. Gelhar et al. (1979) determined that the coefficient of hydrodynamic dispersion is also time-dependent, and that it approaches a maximum asymptotic value for a large time span. In general, the coefficient of hydrodynamic dispersion is determined through calibration of a contaminant transport model. The plumes presented in Section 7.0 (Figures 7-1 through 7-13) are relatively narrow, which indicates that the coefficient of hydrodynamic dispersion is small.

Table 8-3
MAAP Site-Specific Retardation Coefficients

Contaminant	Retardation Coefficient
2,4,6-TNT	5.0
2,4-DNT	2.9
2,6-DNT	1.6
1,3,5-TNB	1.15
1,3-DNB	1.28
RDX	1.77
HMX	1.03
Tetryl	1.4
Nitrobenzene	1.28
Cadmium	87
Chromium(III)	11,300
Chromium(VI)	266
Mercury	134
Lead	12,000

A process which may affect the fate of the contaminants of concern in groundwater is biodegradation. As no information is available on microorganisms at MAAP, a site-specific discussion of the effects of microorganisms on contaminant concentrations is not possible.

8.1.3 Surface Water/Sediment

For many years, wastewater from the different manufacturing operations at MAAP was discharged to ponds and sumps as well as to a system of ditches. These ditches, in turn, discharged to Hall's Branch and John's Creek to the east, Wolf Creek to the west, and Rutherford Fork to the north. As previously discussed, the primary contaminants at MAAP (explosives and select heavy metals) are nonvolatile. Therefore, once in a surface water body, these contaminants would either tend to stay in solution or sorb to particulate matter such as sediment; those contaminants with smaller K_d values would tend to remain in solution and be transported with the water. The contaminants that sorb to sediment particles could be, in turn, transported with the particles depending upon the size of the sediment particle and the velocity of the surface water. In either case, the transport of contaminants in surface water bodies (i.e., ditches, streams, and rivers) results in large degrees of mixing and dilution. Physical transport of explosive compounds and select heavy metals, with the exception of lead and chromium (III), from aqueous systems is believed to be unimportant based on both low adsorption and volatility coefficients. The two major processes affecting the fate and distribution of explosives in surface water are photochemical transformations and microbiological transformations (Burrows et al., 1989). There is as yet no evidence for other important chemical transformation processes, such as hydrolysis or oxidation, under environmental conditions, with the possible exception of a very slow hydrolysis of tetryl (Burrows et al., 1989).

Photochemical transformation due to the effect of sunlight on munitions compounds in surface water is an important process in the transformation and degradation of explosive compounds. 2,4,6-TNT appears to be most susceptible to photochemical transformations, with other nitrobodies such as RDX, HMX, DNT, and 1,3,5-TNB degrading to a lesser degree or at a lower rate (Burrows et al., 1989). In fact, photolysis has been shown experimentally to be the primary process for 2,4,6-TNT loss in the natural environment (Spanggord et al., 1980). The rate at which explosive compounds are lost in the natural environment is affected by the concentration of organic substances in the environment; high concentration of humic acids, for example, has been shown to significantly increase the rate of photolysis (Spanggord et al., 1980). A 0.1% estimation of organic carbon content for MAAP sediments suggests that photolysis will not be influenced significantly by this rate enhancement. In addition, photodegradation products have been shown to sensitize the photolysis of 2,4,6-TNT and 2,4-DNT (Spanggord et al., 1980), and may significantly affect concentrations of explosive compounds in surface water at MAAP. For instance, the major photoproduct of 2,4,6-TNT, 1,3,5-TNB, as observed in a study of the effect of sunlight on 2,4,6-TNT in natural river water (Burlinson, 1980), may enhance the rate of transformation of remaining explosive compounds. The effects of photolysis on munitions compounds at MAAP has not yet been studied in detail, but remains a potential process for transformations and degradations of these compounds in surface waters. The select heavy metals are not expected to be significantly influenced by photolysis.

The potential for microbiological transformation is addressed in Section 8.1.1. Microorganisms have the potential to metabolize many of the nitrobodies in surface water, and this process is an important factor in discussing the fate and transport of contamination via surface water. Microbial transformation of 2,4,6-TNT is slow in most natural waters, but may become rapid if significant populations of microorganisms are available. The biotransformation of 2,4,6-TNT in natural waters is 1,000-fold slower than phototransformation (Spanggord et al., 1980). RDX is not readily biotransformed in water under aerobic conditions like those found in the surface water at MAAP. As no information is available on microorganisms at MAAP, site-specific discussion of the effects of microorganisms on contaminant concentrations is not possible. Select heavy metals are not expected to be influenced by microbial transformation in surface waters.

8.1.4 Air

The mechanisms of contaminant transport into and through air via volatilization and sorption on wind-eroded soil particles are presented in Section 8.1.1 and, when appropriate, quantitatively modeled in Appendices O.

8.2 QUANTITATIVE MODELING OF CONTAMINATION TRANSPORT

A groundwater flow model was constructed and calibrated for the site. This model was used to determine flow lines and velocities in areas near the suspected groundwater contamination sources. Calibration of the model also yielded refined values of conductivity and effective porosity for the aquifer.

A contaminant transport model was then used to simulate the future movement of explosives and cadmium to the site boundary using the retardation factors calculated in Section 8.1. The average concentration of contaminants along the site boundary was calculated from the near-steady state shape of the eventual contaminant plume. These values of average concentration were used in the baseline risk assessment (Section 9.0).

8.2.1 Flow Model Analysis

Steady-state groundwater flow conditions at MAAP were simulated with the construction and partial calibration of a groundwater flow model. The purpose of the groundwater flow model is to simulate the distribution of hydraulic heads in the aquifer, and the rates and directions of groundwater flow. The flow model is implemented by a computer program that numerically solves mathematical equations describing the physics of fluid flow in a porous medium. The flow model is calibrated to actual site conditions by matching the equipotential lines simulated by the model to equipotential lines determined from the water level survey performed as part of this investigation.

The observed/calculated equipotential matching process is achieved by adjusting the hydraulic parameters that influence the groundwater flow system. During the calibration process, input parameters are allowed to vary within a reasonable range. The range in parameter variation is dictated by the geologic framework and the current understanding of the local flow system.

8.2.1.1 Code Selection. FLOWPATH, a two-dimensional horizontal aquifer simulation model developed by Waterloo Hydrogeologic (Franz and Guiguer, 1990), was used to characterize groundwater flow conditions at MAAP. FLOWPATH is a versatile code that can be used to calculate hydraulic head distributions, groundwater velocities, pathlines, travel times, capture zones and wellhead protection areas. Hydrogeologic layers can be simulated as confined, unconfined, or leaky. External stresses such as extraction or injection wells, surface water bodies, and areal recharge, including infiltration and evaporation, can also be incorporated in the model structure. Groundwater flow is simulated in FLOWPATH by the use of block-centered, finite difference equations. The equations are solved using the modified iterative alternating direction implicit method (IADI), originally developed by Peaceman and Rachford (1958) and described in detail by Prickett and Lonnquist (1971). This model was selected because of the versatility, ease of use, and accepted use in the modeling industry make it well suited for modeling groundwater flow at MAAP.

8.2.1.2 Model Configuration and Assumptions. The two dimensional groundwater flow model developed for MAAP covers approximately 15,000 acres. The model domain extends from the Rutherford Fork of the Obion River on the north to just south of the Open Burning Grounds on the south, and from Wolf Creek on the west to the property boundary on the east. The finite difference grid consists of 53 columns and 56 rows; grid cell dimensions vary from 75,000 square feet (ft^2) for the large grid cells, to 37,500 ft^2 for the medium grid cells, and 25,000 ft^2 for the small grid cells. To enhance the accuracy of the numerical results, small grid cells were used directly over the two areas of greatest concern, O-Line and the Burning Grounds.

The Claiborne aquifer underlying the MAAP site is simulated as a single, unconfined aquifer, with the bottom elevation of the aquifer varying from 100 feet above mean sea level (ft-msl; as determined from National Geodetic Vertical Datum of 1929) in the northwest to 300 feet ft-msl in the southeast (Cushing et al., 1964). On-site production wells were simulated in the model as pumping well cells with extraction rates equal to the rates at which the wells were pumping during the water level survey. Well T-99 was set in the model with a pumping rate of 86,000 gallons per day (gpd) and well S-99 was set at a pump rate of 331,000 gpd. The wells are screened in the Claiborne Aquifer.

The two-dimensional groundwater flow model boundaries simulated by FLOWPATH correspond to natural hydrologic boundaries in the flow system. The model employs constant head boundaries on the northern and southern margins (129 constant head nodes identified), and no-flow boundaries on the western and eastern margins. The surveyed elevations of locations along the Rutherford Fork of the Obion River (retrieved from IRDMS), combined with elevations gathered from the USGS, 7.5' Atwood topographic quadrangle were used as constant head values along the northern boundary of the model. These values range from 360 to 390 ft-msl.

Along the southern boundary of the site, where no water level records were available, constant head values were extrapolated from equipotential lines generated from the water level survey. These constant head values ranged from 400 to 417 ft-msl. The no-flow boundaries on the western and eastern sides of the model are parallel to the direction of groundwater flow (i.e., perpendicular to equipotential lines) and represent stream line directions.

8.2.1.3 Model Calibration and Results. Calibration of the model was performed by visual comparison of the model equipotential lines to the equipotential lines established by the water level survey. Hydraulic conductivity and precipitation recharge are known within a range of values based on limited data and were allowed to vary during different stages of the calibration process. The initial stages of calibration involved varying the boundary conditions, hydraulic conductivity, and recharge. It was determined during this process that the curved equipotential lines in the center of the site are probably due to the stratified nature of the aquifer, with the deeper regions less influenced by topographic features than the shallow region. The somewhat radial flow lines in the central region of the site could not be reproduced with a two-dimensional model without making unsubstantiated assumptions of the conductivity distribution. Therefore, the result of the calibration yielded equipotential lines which matched the observed contour lines in the source areas of concern, but were not totally satisfactory in other areas.

Hydraulic conductivity was assumed heterogeneous and anisotropic throughout the model. Vertical and horizontal hydraulic conductivities were allowed to vary until optimum conditions were achieved. Horizontal hydraulic conductivity, calculated from pump tests at 27 ft/day, was varied up to 75 ft/day. Based on the geologic framework of the aquifer, the vertical hydraulic conductivity was varied between 0.27 ft/day and 5 ft/day. The resultant optimum conditions for hydraulic conductivity were achieved with the following values: 27 ft/day horizontal hydraulic conductivity, and 0.27 ft/day vertical hydraulic conductivity.

Two distinct zones of areal recharge were defined in the model representing differential infiltration in intermittent streams versus all other areas. Recharge in the intermittent stream areas simulated differently to reflect increased precipitation infiltration along the porous stream beds. Recharge values for the intermittent streams were based on the yearly average of nine inches per year (0.0021 ft/day) documented by Zurawski (1978); this value is consistent with recharge calculated from weir measurements in this investigation. Thus, during model calibration, the recharge occurring in the zones which represent the intermittent streams was varied between 0 ft/day and 0.0021 ft/day. Recharge in the areas outside the streams was varied during calibration from 0 ft/day to 0.0011 ft/day, assuming that evapotranspiration and runoff account for three quarters of total precipitation for the area. Results from these estimations suggest that the relative effect of recharge in the system is less than the effect of varying the boundary conditions or hydraulic conductivity. The optimum conditions were reached when recharge was set at 0.0021 ft/day in the streams and at 0.00005 ft/day in all other areas.

The model results, together with a flow analysis as described in Section 5.2., suggest that the hydrologic/aquifer system at MAAP is a complicated, unconfined system with a stratified flow system. A close calibration was accomplished only at the two source areas of concern, O-Line and the OBG, whereas simulation results in areas close to the model boundaries remained unsatisfactory. These results indicate that model calibration is limited by the lack of additional information and data necessary to describe the nature of the aquifer system, and by the limited capabilities of FLOWPATH to simulate complex and inter-related flow systems. The fate of contaminants originating from O-Line and the OBG predicted in the model match the pathways discussed in Section 8.2.2 below. The input and output data for the model are provided in Appendix N.

8.2.2 Contaminant Transport Model

A two-dimensional transport model was used to calculate the future extent of the existing groundwater contaminant plumes. The model used was PLUME2D, which was developed by the International Ground Water Modeling Center at Butler University (1989). An assumption made in using this model is that the flow field is uniform. Therefore, the model was run by aligning the grid and flow field with the flowlines indicated by the equipotential contour lines. Using this method, the plume from the O-Line Ponds area, Line K, and the northern drainage ditches was moved in a north-northwesterly direction towards the northern boundary of the site. The plume which begins at the OBG/ADA area and includes the sumps and associated drainage ditches was moved toward the northwestern site boundary.

The purpose of the contaminant transport modeling was to estimate the maximum average concentration of contaminants along the facility boundary. These values were used in the baseline risk assessment (Section 9.0) to estimate the potential risk to human health from groundwater contaminated by site activities.

8.2.2.1 O-Line Ponds Plume. Because the extent of the plume was reasonably well defined by the groundwater sampling, the first step in contaminant transport was to define the current state of the plume within the model. The current state of the plume is approximated by the contaminant contour lines shown in Figures 7-2 through 7-10 for the explosives and cadmium. The transport of the other select metals (lead, chromium, and mercury) was not modeled because their appearance cannot be attributed to a known or suspected source using available data.

Although the source strength of the O-Line Ponds area has been estimated, the loading of explosives into groundwater from the drainage ditches was not determined during this investigation. However, the shape of the contaminant plumes (shown in Figures 7-2 through 7-9) is not dissimilar from a large plume emanating from O-Line. Therefore, a source area was modeled in the location of the O-Line Ponds with a source strength as calculated in Section 7.0. The transport of contaminants from this source was then calculated by the model until the modeled plume approximated the observed plume. The criteria used in matching the modeled plume to the observed plume was that the concentration contour lines were located at the observed concentration lines or downgradient from them. The dispersion coefficient for both lateral and transverse directions were adjusted until the shape of the actual plume was matched by the modeled plume. At a minimum, the concentration of the contaminant at the most downgradient location, and at an intermediate location were matched. A conservative approach was taken for the other contour lines so that at least as much mass of the solute was in the modeled plume as was estimated from the observed plume.

This approach for the O-Line Ponds plume was taken to reduce the uncertainties in the modeled results which could arise from modeling the ditches as sources using the limited available information. Clearly, the plume emanating from the O-Line Ponds will dominate the long-term groundwater contamination problem.

The current state of the cadmium plume was approximated by placing a large source area at the location of Line K. The strength of this source was calibrated by comparing the modeled plume results to the concentrations of cadmium detected in the downgradient wells.

The model was then run into the future from the current state. The run continued until the concentrations at the site boundary, 8,000 feet from the source area, were observed to change very little in time. The process of contaminant transport does not reach steady-state, but as the time increases, the change at a fixed distance from the source will change more and more slowly in time. The criterion for stopping the run is when the concentrations at the site boundary did not change for an additional 100 years. This concentration distribution was assumed to be the long-term distribution if the source strength continues (i.e. no remedial action).

The average concentration across the site boundary was then calculated by determining the average concentration across the plume width at the location of the site boundary, and multiplying by the ratio of the width of the plume at the boundary to the total width of the boundary (20,800 feet). The results of these calculations are presented in Table 8-4.

These calculations are believed to be conservative estimates of the average concentration across the northern boundary. The effects of biodegradation are neglected, and it is assumed that the source strength will not diminish in time. In addition, the model simulated transport for a long period of time, so the effects of an error in the retardation coefficient are somewhat diminished.

8.2.2.2 OBG/ADA and Sumps Plume. A similar approach was used in modeling the plume which appears to begin in the OBG/ADA area and is moving toward the northwestern site boundary. The source strength of the OBG/ADA area was estimated in Section 7.0. The effects of the other sources tentatively identified in Section 7.0 were added by creating an element within the model grid which was assigned a source strength necessary to maintain the observed concentrations in the downgradient monitoring wells. The current state of the plume was therefore modeled as a series of small plumes emanating from point sources.

The model was then run for a long time period, as before. In general, the model was run for a minimum of 100 years before the modeled plume size at the northwestern boundary was observed to change very slowly in time. The average concentration across the site boundary in this area (23,200 feet) was then calculated as described above. These values are presented in Table 8-5.

Table 8-4
Maximum Average Concentrations of Contaminants at the Northern Border of the Facility (O-Line Ponds Plume)

Contaminant	Concentration (μg/L)
2,4,6-TNT	28.9
2,4-DNT	0.14
Nitrobenzene	0.72
1,3,5-TNB	4.6
1,3-DNB	0.2
RDX	28.2
HMX	3.4
Tetryl	6×10^{-4}
Cadmium	1.4

Table 8-5
Maximum Average Concentrations of Contaminants at the Northwestern Border of the Facility (OBG/ADA Area and Sumps Plume)

Contaminant	Concentration (µg/L)
2,4,6-TNT	0.36
2,4-DNT	0.04
1,3,5-TNB	6.37
1,3-DNB	0.006
RDX	6.8
HMX	0.33
Cadmium	4.5

PREFACE

This risk assessment does not necessarily meet the requirements of a baseline risk assessment, as defined under Section 300.430(d) of the National Contingency Plan (40 CFR Part 300). If it is determined in subsequent negotiations between USATHAMA and the EPA that this assessment does not meet the requirements of a baseline risk assessment, a baseline risk assessment will be conducted for the facility or for specific waste areas within the facility.

9.0 RISK ASSESSMENT

This section contains an evaluation of potential human health and environmental impacts associated with past waste disposal activities at the Milan Army Ammunition Plant (MAAP) near Milan, Tennessee. The overall goal of this risk assessment is to determine if the chemicals of concern at the site pose a current risk to human health or the environment. The results of the risk assessment are used to determine whether remediation or additional investigation is necessary, to provide justification for performing remedial action, and to assist in determining the level of remediation for each exposure medium.

This risk assessment was conducted using generally conservative assumptions, including the concept of "reasonable maximum exposure," as outlined by the U.S. Environmental Protection Agency (USEPA 1989e, 1990a). The general purpose of using conservative assumptions is to ensure that the decisions made will be protective of human health, even in the absence of comprehensive and definitive health studies. Thus, the risks calculated in this section do not necessarily represent the true risks which are or may be experienced by the exposed population; rather, they are upper-bound risks, which are designed to provide a high level of protectiveness against adverse health effects. This is compatible with EPA's policy of protecting all members of the population, including sensitive subgroups, from adverse effects associated with exposures to hazardous chemicals.

This risk assessment follows EPA guidance for risk assessment in general (USEPA 1986a,b,c), and for Superfund sites in particular (USEPA 1989c,e). The risk assessment relies on exposure factors and toxicity values provided in EPA guidance documents (USEPA 1989c,e) and other EPA data sources to estimate potential risks. EPA-recommended values are used without independent verification. In the absence of EPA-recommended values, data from the scientific literature are used in conjunction with professional judgement.

The hydrogeologic, surface water, soil, and sediment investigations conducted from July to December 1990, as detailed in the previous sections, are the primary sources of sampling data considered in this risk assessment. Data from previous studies at MAAP are briefly discussed where applicable to support evaluations of potential exposures or risks.

The exposure pathways that were selected for quantitative evaluation in this assessment were discussed extensively and were agreed upon during a scoping meeting on March 19, 1991 with the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) and the Army Environmental Hygiene Agency (AEHA).

The remainder of this risk assessment is organized into seven principal sections, as follows:

- Section 9.1 Data Summary and Identification of Chemicals of Potential Concern
- Section 9.2 Human Health Exposure Assessment
- Section 9.3 Human Health Toxicity Assessment
- Section 9.4 Human Health Risk Assessment
- Section 9.5 Environmental Assessment
- Section 9.6 Uncertainty Analysis
- Section 9.7 Summary and Conclusions

9.1 DATA SUMMARY AND IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

This section briefly summarizes available environmental monitoring data and identifies chemicals of potential concern for further evaluation in the risk assessment. Chemicals of potential concern are defined as those chemicals believed to be associated with past activities at the site and, therefore, those chemicals present at or below natural (i.e., background) concentrations, as well as those associated with laboratory or sampling artifacts, are excluded. The data evaluation presented in Section 5.0 and the quality assurance/quality control (QA/QC) procedures described in Section 6.0 were used to identify chemicals of potential concern for this risk assessment. All chemicals identified as potentially site-related in those sections are identified below and are selected as chemicals of potential concern for this assessment. Those sections should be consulted for a description of the methods used to identify potentially site-related chemicals (e.g., comparison to background levels and QA blank concentrations), as well as for a complete presentation of the available sampling data.

As described fully in previous sections, soil, groundwater, surface water, and sediment samples were collected during this investigation. All samples were analyzed for cadmium, chromium, lead, mercury and nine explosive compounds (1,3-DNB, 2,4-DNT, 2,6-DNT, HMX, nitrobenzene, RDX, tetryl, 1,3,5-TNB, and 2,4,6-TNT). In addition, selected samples were analyzed for Target Compound List (TCL) organic chemicals and Target Analyte List (TAL) inorganic chemicals. Library searches of chromatographic peaks also were conducted on selected samples to identify additional organic chemicals not included in the TCL. Many of these tentatively identified compounds (TICs) are long-chain aliphatic compounds, some of which are associated with explosives production. However, due to the uncertainties surrounding the identity and concentrations of these chemicals, none was selected as a chemical of potential concern.

Environmental monitoring data are summarized below by environmental medium. This summary is primarily qualitative. A quantitative data summary (i.e., mean and maximum concentrations) will be presented in Section 9.2 for those media and source areas for which exposures are being evaluated.

9.1.1 Soil

Surface and subsurface soil samples were collected from eight suspected source areas at MAAP: (1) the Open Burning Ground (OBG); (2) the Ammunition Destruction Area (ADA); (3) the 30 settling sumps at the loading, assembly and production (LAP) lines; (4) the Former Burn Out Area (i.e., Sunny Slope); (5) the Former Borrow Pit; (6) the Closed Sanitary Landfill; (7) the Current Sanitary Landfill; and (8) the Salvage Yard.

Explosives were detected at the OBG, the LAP line area sumps, the Closed Landfill, and the Former Borrow Pit. Explosives were detected most frequently and at higher concentrations in the OBG. The highest concentrations (over 100 mg/kg) for individual explosives were reported for the OBG, the Closed Landfill, and the sumps at LAP Lines B, X, and Z. The maximum reported concentrations of explosive constituents are: RDX -- 4,450 mg/kg in the Closed Landfill; HMX -- 4,500 mg/kg at the Line B sump; 2,4,6-TNT -- 4,100 mg/kg at the OBG; and tetryl -- 750 mg/kg at the Line B sump.

A variety of other organic chemicals, including several volatile organic chemicals (VOCs), phthalates, and PAHs also were detected, but at relatively low levels compared to the explosive compounds. It is not known if all these chemicals are site-related. For example, the PAHs were detected at concentrations ranging from less than 1 mg/kg to 10 mg/kg, which may represent local background concentrations for these ubiquitous chemicals. The phthalates and some of the VOCs are possible laboratory or sampling artifacts. Other sources of PAH contamination may be exhaust from the drill rig, the generator used in burning the submersible pumps, or exhaust from cars on the nearby roads. In addition, the former and current uses of several VOCs have been documented at MAAP. For example, several phthalate and VOC compounds are used in the manufacture, packaging and loading of explosives, and will thus be detected in all explosive-contaminated areas.

Nine inorganic chemicals, including the target metals cadmium, chromium, lead, and mercury were detected in soil samples at concentrations above background concentrations. Lead was the inorganic chemical detected most frequently at a concentration above background concentrations. However, this may be the result of uncertainties in the background levels, rather than the presence of lead as a contaminant. Most lead concentrations were in the range of 6 mg/kg to 20 mg/kg, and only two sampling locations (in the OBG) had reported lead concentrations greater than 50 mg/kg. Of the remaining inorganic chemicals, chromium and manganese were detected most frequently at concentrations above background concentrations.

9.1.2 Groundwater

Groundwater samples were collected from monitoring wells, with well screens installed at various depths in the aquifer, active and inactive water supply wells, and two off-site residential wells, to define the presence and extent of contamination in the Memphis Sand of the Claiborne Group, the major aquifer that underlies MAAP. This unconfined aquifer consists of fine- to coarse-grained sand with thin, discontinuous clay lenses. Local groundwater flow is to the north and north-northwest. Regional flow is to the northwest, towards major groundwater discharge areas near the Mississippi River.

As detailed in Section 7.0, groundwater data have indicated that there are two distinct plumes of contaminated groundwater at MAAP. One plume originates from the O-Line Pond area and various drainage ditches, and is traveling toward the northern boundary of MAAP. The other plume originates from the OBG/ADA area, and incorporates contamination from some of the sumps and drainage ditches associated with the LAP lines. This plume is believed to be traveling in a more northwesterly direction at MAAP.

All explosive analytes except 2,6-DNT, were detected in the contaminant plume associated with the O-Line Ponds. Concentrations ranged from below detection to 26,000 μg/L. 2,4,6-TNT and RDX were the explosives detected most frequently and at the highest concentrations. The only other organic chemicals that were detected in this plume were chloroform and bis(2-ethylhexyl)phthalate, both of which were detected in a single well and at low concentrations (0.6 μg/L and 6 μg/L, respectively). In addition, 15 inorganic chemicals, including the target metals cadmium, chromium and mercury were detected at concentrations above background levels. Of the inorganic chemicals, only cadmium displays a concentration distribution which suggests that there is a concentrated source of this metal. The other inorganic chemicals appear to be present at relatively equal concentrations across the study area, possibly indicating that they are ubiquitous at the site, either because of high background concentrations or low-level widespread contamination due to site-related activities.

Six explosives (HMX, RDX, 1,3-DNB, 1,3,5-TNB, 2,4,6-TNT and 2,4-DNT) and five other organic chemicals were detected in the contaminant plume associated with the OBG/ADA area and sumps from the manufacturing lines. 2,4,6-TNT and RDX again were the explosive compounds detected most frequently and at the highest concentrations. However, the maximum detected concentrations are substantially lower than those reported for the O-Line plume. The highest explosive compound concentration reported was 350 μg/L (for RDX).

Acetone, ethyl benzene, toluene, xylene, and bis(2-ethylhexyl)phthalate were other organic chemicals detected in the OBG/ADA plume area. Each of these chemicals was detected at low concentrations (i.e., $\leq$ 30 μg/L), and all except bis(2-ethylhexyl)phthalate were detected only in single samples. Each of these chemicals is a possible laboratory contaminant. However, none of these chemicals was detected in QA/QC blanks associated with these samples, although it is possible that they were present in the blanks at concentrations below the CRL. In addition, it should be noted that these chemicals are also used in the manufacture and packaging of explosives. In the absence of more definitive information, these chemicals are retained as chemicals of potential concern for this risk assessment.

Eighteen inorganic chemicals, including the target metals chromium, cadmium, and mercury were detected in the OBG/ADA plume area at concentrations above background concentrations. Again, only cadmium displays a concentration distribution suggesting that there could be a concentrated source of this metal.

In addition to groundwater sampling on-site (i.e., within the MAAP boundary), monitoring and residential wells in off-site areas also were sampled and analyzed for select metals and explosives. No explosives were detected in these off-site wells. However, data from these wells may indicate that there is an additional source of inorganic contaminants near the northwest boundary of MAAP that has impacted current water quality in the adjacent off-site area. Cadmium and chromium were detected in these wells at levels above background concentrations. The maximum concentration of cadmium was 63 μg/L and that of chromium was 50 μg/L (neither chemical was detected in the background samples at a detection limit of 6 μg/L). These data appear to somewhat anomalous, however, as neither of the chemicals was detected at elevated levels during past groundwater monitoring conducted in this area by the State of Tennessee. Cadmium and chromium in this area are nevertheless retained in the risk assessment, in order to derive a conservative risk value.

9.1.3 Surface Water

Surface water samples were collected from drainage ditches associated with the LAP lines, from Johns Creek, and from the Rutherford Fork of the Obion River.

All explosive chemicals except 1,3-DNB and 2,6-DNT were detected in surface water samples. RDX and HMX were the explosive compounds detected most frequently (11 out of 25 and 10 out of 25 samples, respectively) and at the highest concentrations (310 μg/L and 41 μg/L, respectively). The other explosive chemicals were detected less frequently and at relatively lower concentrations, ranging from less than 1 μg/L to 11 μg/L. Ditch 10, which flows through the ADA, had the highest concentrations of explosive chemicals. However, no explosives were detected in the downstream surface water samples collected in Johns Creek, which is the perennial surface water body that eventually receives Ditch 10 drainage. It appears that either explosive compounds are not entering the perennial streams, or are being attenuated, degraded, or diluted during transport.

Eleven other organic chemicals, primarily volatile organic solvents, were detected infrequently (1 or 2 out of 23 samples) and at low concentrations. These chemicals were detected in the ditches draining the areas near the LAP lines and could be associated with manufacturing operations, although some of these chemicals are possible laboratory contaminants (e.g., acetone, toluene).

In addition, 19 inorganic chemicals were present at concentrations above background concentrations. All four target metals (i.e., cadmium, chromium, lead, and mercury,) were detected in surface water, but only lead (22 out of 25 samples) was detected frequently. Cadmium was detected in 1 out of 25 samples, mercury in 2 out of 25 samples, and chromium in 7 out of 25. The highest concentrations of lead (74 μg/L and 140 μg/L) were detected in ditches draining the areas surrounding the LAP lines. Many of the remaining inorganic chemicals appear to be elevated substantially (e.g., 10 times or more) above background concentrations, with the highest concentrations in the ditches draining the LAP line areas.

9.1.4 Sediment

Sediment samples were collected from drainage ditches, Johns Creek, Wolf Creek, Halls Branch, and from the Rutherford Fork of the Obion River.

Explosive chemicals were detected infrequently in sediments across the site. 1,3,5-TNB, 2,4,6-TNT, and 2,4-DNT were detected in only one out of 69 surface sediment samples. RDX and HMX were not detected in any surface sediment samples and were detected in 4 and 2 subsurface (0.5 - 1 ft) sediment samples, respectively, out of a total of 71. With the exception of 2,4,6-TNT, which was detected at a concentration of 29 mg/kg, the explosive chemicals were detected at concentrations less than 3 mg/kg.

A variety of other organic chemicals (VOCs, PAHs, and bis[2-ethylhexyl]phthalate) also were detected infrequently and generally at low concentrations (0.001 mg/kg to 1.3 mg/kg). Some of these chemicals may in fact be due to laboratory contamination (e.g., some of the VOCs, bis[2-ethylhexyl]phthalate) or may be present at background levels (i.e., PAHs). Alternatively, they may represent low-level contamination, which is associated with waste disposal in the ditches.

A large number (17) of inorganic chemicals was detected in sediments at concentrations above available background concentrations. It is not known if all of these inorganic chemicals are site-related because too few background samples are available with which to make a more reliable comparison.

9.1.5 Summary of Chemicals of Potential Concern

Table 9-1 summarizes the chemicals of potential concern by media. As the table and the previous discussions indicate, a variety of organic and inorganic chemicals have been detected at MAAP in addition to the explosive compounds and the four metals that were the focus of the field investigation. Acetone, trichlorofluoromethane, and bis(2-ethylhexyl)phthalate were the non-explosive organic chemicals detected most frequently in samples across all media. As discussed previously, these chemicals could be present as a result of past activities at MAAP, or alternatively, they may represent QA/QC blank contamination. A large number of inorganic chemicals was detected at concentrations apparently elevated above background concentrations, but this may be due to the lack of sufficient background data to evaluate them. These organic and inorganic chemicals were conservatively retained in this risk assessment. However, should any of these chemicals drive the estimates of risk, additional sampling should be conducted before actions are taken to remediate the site for these chemicals.

9.2 HUMAN HEALTH EXPOSURE ASSESSMENT

This section identifies the potential pathways by which human populations may be exposed to the chemicals of potential concern, and quantifies exposures for selected pathways. This exposure assessment is divided into three principal sections. Section 9.3.1 discusses land use and population activities at and near MAAP. Section 9.3.2 identifies the pathways by which human populations at or near MAAP may be exposed to chemicals of potential concern, and selects pathways for further evaluation. Finally, Section 9.3.3 presents quantitative exposure estimates for those pathways selected for quantitative evaluation.

This section only addresses potential exposures associated with past waste disposal in the particular study areas that were the focus of this investigation. Potential exposures associated with current waste disposal (e.g., NPDES permitted discharges) or past waste disposal in areas of MAAP which were not investigated are not specifically evaluated in this assessment.

9.2.1 Land Use and Population Activity Analysis

As described earlier, the primary mission of MAAP is ammunition manufacturing, receiving, storing and shipping. The manufacturing facilities are located principally in the northcentral portion of MAAP, as shown earlier in Figure 2-5. This area of MAAP also supports administrative and maintenance facilities. Some housing facilities are located in the northeastern portion of MAAP, east of the manufacturing areas. A small playground is located adjacent to the housing area and is frequented by children of these families.

The central portion of MAAP is used as storage for day-to-day supplies. The OBG and ADA are located in the eastern central portion of MAAP. These areas are used to destroy or dispose of off-specification ordnance items and explosive-contaminated wastes. Current operations at the OBG consist primarily of open burning in above-ground containment pans. The ADA is used primarily for below-ground detonation of ordnance items. The OBG and ADA are relatively sandy, unvegetated areas. Both areas are fenced.

TABLE 9-1

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN AT MAAP

SOIL

Explosives:
1,3-DNB (SMP)
2,4-DNT (BP, SMP)
HMX (OBG, CLF, SMP)
Nitrobenzene (OBG)
RDX (OBG, CLF, SMP)
Tetryl (SMP)
1,3,5-TNB (OBG, SMP)
2,4,6-TNT (OBG, CLF, SMP)

Other Organic Chemicals:
Acetone (OBG, FBA, SY, SMP)
Butylbenzylphthalate (CLF)
bis(2-Ethylhexyl)phthalate (CLF, SMP)
PAHs (CLF, SMP)
1,1,2,2-Tetrachloroethane (SMP)
Toluene (SMP)
Trichlorofluoromethane (OBG, FBA, CLF, SY)
Xylene (BP)

Inorganic Chemicals:
Arsenic (OBG)
Calcium (FBA, SMP)
Chromium (OBG, ADA, FBA, CLF, SMP)
Cadmium (CLF, SMP)
Lead (OBG, FBA, BP, CLF, PLF, SY, SMP)
Manganese (ADA, FBA, SY, SMP)
Mercury (OBG)
Silver (OBG)
Zinc (OBG, FBA, SMP)

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Codes:
OBG = Open Burning Ground
ADA = Ammunition Destruction Area
FBA = Former Burn-Out Area (Sunny Slope)
BP = Borrow Pit
CLF = Closed Landfill
PLF = Present Landfill
SY = Salvage Yard
SMP = Sumps at LAP lines

GROUNDWATER

Explosives:
1,3-DNB (1,2)
2,4-DNT (1,2)
HMX (1,2)
Nitrobenzene (1)
RDX (1,2)
Tetryl (1)
1,3,5-TNB (1,2)
2,4,6-TNT (1,2)

Other Organic Chemicals:
Acetone (2)
Chloroform (1)
Ethylbenzene (2)
bis(2-Ethylhexyl)phthalate (1,2)
Toluene (2)
Xylene (2)

Inorganic Chemicals:
Arsenic (1,2)
Aluminum (1,2)
Barium (1,2)
Cadmium (1,2,3)
Calcium (2)
Chromium (1,2,3)
Cobalt (2)
Copper (2)
Iron (1,2)
Magnesium (1,2)
Manganese (1,2)
Mercury (1,2)
Nickel (2)
Potassium (1,2)
Silver (1,2)
Sodium (1,2)
Vanadium (1,2)
Zinc (1,2)

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Codes:
1 = Present in O-line plume area
2 = Present in OBG/ADA plume area
3 = Present in off-post wells

TABLE 9-1 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN AT MAAP

SURFACE WATER

Explosives:
- 2,4-DNT
- HMX
- Nitrobenzene
- RDX
- Tetryl
- 1,3,5-TNB
- 2,4,6-TNT

Other Organic Chemicals:
- Acetone
- Bromodichloromethane
- Bromoform
- Carbon disulfide
- Dibromochloromethane
- Diethylphthalate
- Di-n-octylphthalate
- 1,1,2,2-Tetrachloroethane
- Toluene
- 1,1,2-Trichloroethane
- Trichloroethene

Organic Chemicals:
- Aluminum
- Arsenic
- Barium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Silver
- Sodium
- Vanadium
- Zinc

SEDIMENT

Explosives:
- 2,4-DNT
- HMX
- RDX
- 1,3,5-TNB
- 2,4,6-TNT

Other Organic Chemicals:
- Acetone
- Chloroform
- Chlorobenzene
- bis(2-Ethylhexyl)phthalate
- PAHs
- 1,1,2,2-Tetrachloroethane
- Tetrachloroethene
- Toluene
- Trichlorofluoromethane

Inorganic Chemicals:
- Aluminum
- Arsenic
- Beryllium
- Cadmium
- Calcium
- Chromium
- Copper
- Lead
- Magnesium
- Manganese
- Nickel
- Potassium
- Selenium
- Silver
- Thallium
- Vanadium
- Zinc

The southern portion of MAAP is largely undeveloped and is used primarily as a storage area for finished ordnance and general supplies, as well as for short-term storage of hazardous wastes associated with the ammunition manufacturing processes. The storage areas are fenced and are remote from the source areas being investigated in this RI. The Former Burn Out area, located in the southwestern portion of the site (i.e., Sunny Slope area), is where washout of naval shells occurred, and above-ground burning took place in cement containment areas. The Former Burn Out Area, which is now vegetated, is used on an infrequent basis as a pistol range.

Portions of MAAP are leased as beef and dairy cattle rangeland or as cropland. The crops grown at MAAP are used almost exclusively for livestock feed and include soybeans, corn, milo, and wheat, as well as cotton. It is possible (although currently unknown) that a small portion of these crops is used for human consumption. The crop and pasturelands are scattered throughout MAAP but are not located in any source areas that are being investigated in this assessment. The closest cropland to a source area is located over a quarter of a mile south of the O-Line area and the closest pastureland is approximately two miles west of the OBG.

Hunting is popular at MAAP and is permitted in all non-secured areas. Game species include deer, quail, squirrel, rabbit, raccoon and dove. Fishing occurs in several stocked ponds located at MAAP. Stocked species include largemouth bass, channel catfish, and bluegill. The Rutherford Fork of the Obion River which forms part of the northern boundary of MAAP also is fished, although not as frequently as the stocked ponds (personal communication, Jim Covington, March 13, 1991).

The land surrounding MAAP is largely rural and consists mainly of woodlots and farm fields. Scattered residents live throughout the area. The land immediately north of MAAP is primarily floodplain and is relatively undeveloped. The town of Milan is located northwest of MAAP. A 4-H Club training center and the University of Tennessee Agricultural Research Station are immediately adjacent to the northwest border of MAAP.

9.2.2 Potential Exposure Pathways

An exposure pathway describes the course a chemical takes from the source to the exposed individual. An exposure pathway generally consists of four elements:

- a source and mechanism of chemical release;
- a receiving or transport medium;
- a point of potential contact with the contaminated medium (i.e., the "exposure point"); and
- an exposure route (e.g., inhalation) at the contact point.

An exposure pathway is considered complete only if all these elements are present. Only complete pathways are evaluated in risk assessments. The first two elements of a complete exposure pathway have been discussed extensively in earlier sections of this RI report. In this section, information presented previously on the sources, fate, and transport of chemicals at MAAP is combined with information on population locations, activity patterns, and land use to define exposure pathways. The exposure assessment focuses on potential exposure pathways under current land-use conditions, as it is considered most likely that MAAP will continue to be used as a military installation with some land continuing to be used for cropland and for cattle grazing. Development of MAAP as a residential area or other public use area is considered unlikely, given the low population density, and the high availability of land in adjacent areas, as well as the probable low density of growth in the future. However, potential residential use of MAAP may be subsequently evaluated as part of a baseline risk assessment conducted for the facility or for individual waste areas.

Workers and residents at MAAP as well as residents in nearby areas are the principal human populations potentially exposed under current land-use conditions. Table 9-2 summarizes the pathways by which these populations could be exposed to chemicals at or originating from MAAP. The potential human exposure pathways are discussed below by exposure medium.

TABLE 9-2

POTENTIAL HUMAN EXPOSURE PATHWAYS AT MAAP

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposure (a)	Method of Evaluation
Surface soil OBG/ADA	Dermal absorption and/or incidental ingestion of chemicals in surface soil by workers in the OBG/ADA area.	Negligible. Workers come into contact with surface soils infrequently during activities at the OBG and ADA areas. No chemicals of potential concern were detected in surface soil at the ADA.	None, given the low potential for exposure.
Surface soil Other areas	Dermal absorption and/or incidental ingestion of chemicals by workers.	Negligible. Soils in these areas are either vegetated or paved, or are not contacted by workers. Therefore, direct contact exposures are unlikely.	None, given the low potential for exposure.
Subsurface soil	Dermal absorption and/or incidental ingestion of chemicals by workers.	Negligible. Persons do not come into contact with subsurface soil at MAAP.	None. No complete exposure pathway exists.
Groundwater	Ingestion, dermal and inhalation exposures to chemicals in the six active supply wells, by users at MAAP.	Low. Active supply wells for potable water are tested regularly and have not shown evidence of contamination. Supply wells are monitored weekly for explosives and the three target metals (Cd, Cr and Pb).	None. Institutional controls at MAAP will prohibit use of contaminated water for potable purposes.
Groundwater	Dermal and inhalation exposures by users at MAAP, to chemicals in water from supply wells that are used for non-potable purposes.	Low. These wells are primarily used for restrooms, fire protection, and some industrial purposes. Signs are posted to indicate when water is not potable. No, or insignificant contamination currently exists in these wells, for ingestion exposures.	None, given the low potential for exposure.
Groundwater	Ingestion, dermal and inhalation exposures of current residents northwest of MAAP, to inorganic contaminants potentially present in residential wells.	Low-medium for ingestion exposures. Negligible for inhalation and dermal exposures to inorganic chemicals.	Quantitative.
Groundwater	Future ingestion, dermal and inhalation exposures of residents north and northwest of MAAP, to chemicals present in contaminant plumes originating from the O-Line Ponds and the OBG/ADA.	Low-high, depending on where the off-site wells are located in relation to the contamination.	Quantitative evaluation for ingestion exposures, and qualitative evaluation for dermal and inhalation exposures.
Surface water/ sediment	Dermal absorption and/or incidental ingestion of chemicals in surface water/ sediment in ditches and creeks by persons working the MAAP area, by hunters, or by children.	Negligible. Persons are unlikely to engage in activites that would result in extensive contact with chemicals in sediment or surface water in the ditches. The ditches are surrounded by dense vegetation, making access difficult. The ditches in which children could play in the northeastern portion of the site are unlikely to be contaminated.	None, given the low potential for exposure.

(a) Based on considerations of the types and concentrations of chemicals present, and on consideration of current land use.

TABLE 9-2 (Continued)

POTENTIAL HUMAN EXPOSURE PATHWAYS AT MAAP (Continued)

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposure (a)	Method of Evaluation
Air Dusts	Inhalation of wind-blown dusts by workers.	Low-moderate for workers at the OBG. Negligible in other areas due to no contamination, or the presence of vegetation or pavement on surface soils.	Quantitative, for emissions from the OBG.
Air Dusts	Inhalation of wind-blown dusts by residents along the eastern boundary of MAAP.	Low for residents closest to the OBG. The nearest residents are over one mile from the OBG/ADA, and any dusts that would be transported are likely to be present in very diluted concentrations. Negligible for other areas.	Quantitative, for emissions from the OBG.
Air Volatilized organics	Inhalation of organic chemicals that have volatilized from soil, surface water or sediment.	Negligible. Organic chemicals were detected at low frequencies and concentrations.	None, given the low potential for exposure.
Fish Rutherford Fork of the Obion River	Ingestion of fish that have accumulated chemicals from surface water/sediment by those who fish along the Rutherford Fork of the Obion River.	Low. Fishing is not popular in this river. Further, chemical concentrations in the river are low, and chemicals present or potentially present do not bioaccumulate significantly in aquatic life.	None, given the low potential for exposure.
Fish Stocked ponds on-site	Ingestion of fish that have accumulated chemicals from surface water/sediment in the stocked ponds at MAAP.	None. These ponds are not located near contaminated areas.	None. No complete exposure pathway exists.
Game	Ingestion by hunters of game that has accumulated chemicals from the MAAP study area.	Unknown. No deer tissue samples have been collected. However, deer are prevalent at MAAP, including in potentially contaminated areas. Hunting is popular at MAAP.	Quantitative for deer exposures to surface water at MAAP (the only exposure medium for which there are sampling data).
Agricultural produce	Ingestion of crops that are grown at MAAP in areas receiving wind-blown dust from the OBG.	Negligible. Most crops are used for livestock feed. Deposition on crops potentially consumed by humans will be low.	Screening-level evaluation presented in Appendix S.
Beef/dairy produce	Ingestion of dairy milk or beef from livestock that has grazed on land near the source areas, that has consumed crops grown near the source areas, or that has ingested water from ditches at MAAP.	Negligible. Surface waters in pasture areas are not contaminated and deposition on crops or pasture grass will be low. Further, beef and dairy products from MAAP are distributed over a large area.	Screening-level evaluation presented in Appendix S.

(a) Based on considerations of the types and concentrations of chemicals present, and on consideration of current land use.

9.2.2.1 Surface Soil. Exposures to chemicals in surface soil could occur via direct contact with surface soil and subsequent dermal absorption and/or incidental ingestion of soil (as a result of hand-to-mouth contact). Of all study areas investigated in this RI, the potential for direct contact is greatest in the OBG and ADA, as both of these areas are unvegetated and are used daily (OBG) or occasionally (ADA) by MAAP personnel. However, no organic chemicals or explosives were detected in surface soils of the ADA and no inorganic chemicals were detected in concentrations greater than background. Thus no chemicals of concern were selected for evaluation at the ADA. Further, worker activities in the area are limited primarily to bulldozer operations (trench digging and ammunition burial prior to detonation) and do not involve long term direct contact with soils.

Chemicals of concern, including explosives, were detected in the surface soils of the OBG. However, worker activities at the OBG also do not involve direct contact with soils. The primary activity at the OBG is burning of ordnance in above-ground flash pans. Workers do not come into contact with the surface soils during this activity. The only instance during which workers in the OBG could contact surface soils is if they walked to other areas of the OBG to pick up miscellaneous materials or metals from the ground (personal communication, Mike Harris, April 1, 1991). This occurs only occasionally. As a result, worker exposures to surface soil in the OBG are expected to be minimal and infrequent, and therefore are not evaluated in this assessment.

Direct contact with surface soils is not likely to occur in the other MAAP source areas, as these areas are either vegetated or paved (thus limiting exposure potential) or are not contacted by workers (i.e., sumps). Therefore, no direct contact exposures to surface soils are evaluated in this assessment.

Because of the large quantities of chemicals and ordnance that are disposed of in the MAAP study area, the potential exists for acute exposures and physical hazards when setting off unexploded ordnance. The likelihood of this occurring is greatest in the OBG and ADA. However, the risk associated with accidental detonation of live ordnance was not evaluated in this assessment.

9.2.2.2 Subsurface Soil. The ADA is the only area where workers could contact subsurface soils. As mentioned above, activities at the ADA involve digging trenches to bury ammunition prior to detonation. Trenches are bulldozed to a depth of five to seven feet. However, workers in the ADA are not expected to come into contact with subsurface soil because the site personnel in the bulldozer remains in the vehicle. Since this exposure pathway is not complete, it will not be evaluated.

9.2.2.3 Groundwater. Persons could be exposed to chemicals in groundwater via ingestion of drinking water, dermal absorption during use, or inhalation of chemicals that have volatilized during use. Currently, groundwater at MAAP is used as a source of potable water. However, because of institutional controls, none of the exposure pathways described above is considered complete. MAAP has a weekly monitoring program in which all active potable wells are sampled for select explosives (HMX, RDX, TNT, TNB, 2,4-DNT, 2,6-DNT) and metals (cadmium, chromium and lead) that are most likely to be associated with past waste disposal at the site. If explosives are detected or if metals are detected at concentrations above Federal MCLs, the production well is closed and water is obtained from another well or from bottled water. (Four production wells at MAAP have been closed as a result of explosives contamination.) As a result, groundwater use is stopped before any significant exposures could occur.[1] Given the potential for groundwater contamination at MAAP, it is reasonable to assume that these institutional controls will continue in the future. Therefore, no exposures of on-site users to chemicals in groundwater are evaluated in this assessment.

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[1] Exposures of 1-week in duration could possibly occur. These exposures are unlikely to result in significant health risks given their brevity. However, too few toxicological data are available to allow definitive statements regarding potential health risks associated with such short-term exposures to explosive compounds. For example, the 10-day drinking water health advisories (HAs) proposed by EPA for HMX, RDX, and 2,4,6-TNT are equal to the lifetime HAs, in the absence of toxicological data on shorter-term exposures.

Groundwater at MAAP also is used as a source of water for fire hydrants and sprinkler systems, and for other non-potable uses (e.g., industrial uses, water in restrooms). Groundwater from non-potable supply wells is pumped for these uses. Water from these wells is not monitored by MAAP, and therefore theoretically could be contaminated. Persons using water from these wells could be exposed via inhalation to organic chemicals that have volatilized during use and via dermal absorption if water is contacted during use (e.g., while washing). Only exposure to organic chemicals is likely by these pathways; exposures to inorganic chemicals are not a concern as they are not volatile and are not dermally absorbed to any appreciable extent. With the exception of 2,4-DNT which was reported at the detection limit of 1 μg/L in well E-67, no organic chemicals were detected in the non-potable production wells at the site. Well E-67 is located in the southern portion of MAAP and is not used currently. This well could be used in the future, but use of water containing 1 μg/L of 2,4-DNT for non-potable uses will result in insignificant exposures. Therefore, no exposures associated with the use of non-potable water at MAAP will be evaluated in this assessment. (It should be noted that worker safety issues are investigated by the Army Environmental Hygiene Agency.)

No institutional controls exist to prevent exposures of off-site users to chemicals that have migrated in groundwater from MAAP to off-post areas. Therefore, potential exposures of off-site users will be evaluated in this risk assessment. Drinking water exposures to off-post residents will be evaluated quantitatively. Dermal and inhalation exposures will be evaluated qualitatively.

As discussed previously, it is believed that two major contaminant plumes exist at MAAP: one plume originates from the O-Line Pond area and various drainage ditches, and is migrating toward the northern MAAP boundary, and one plume originates from OBG/ADA area and some sumps and drainage ditches associated with the LAP lines, and is migrating toward the northwestern boundary of MAAP. This assessment will evaluate potential exposures and risks associated with groundwater use at the MAAP boundary using estimated future concentrations. The MAAP boundary is selected as the exposure point to evaluate the quality of groundwater as it leaves MAAP. Currently, off-post supply wells exist adjacent to the northwest MAAP boundary but not adjacent to the northern boundary. Additional off-post wells may or may not be constructed at the boundary in the future.

Some of the available monitoring data suggest that there may be an additional source of inorganic chemicals near the northwest boundary that has affected current water quality in the adjacent off-post area. Therefore, potential exposures of current users to off-post water will be evaluated separately from potential future exposures as a result of chemical migration. Residential drinking water exposures will be evaluated quantitatively. No inhalation or dermal exposures will be evaluated because the only chemicals detected currently in these off-post wells are inorganic chemicals which do not volatilize and which are not dermally absorbed to any appreciable extent.

9.2.2.4 Surface Water/Sediment. Persons could be exposed via dermal absorption and/or incidental ingestion to chemicals in surface water and sediment at MAAP. Children are the most likely receptors for these pathways, as they could contact surface water and sediments while playing in ditches and creeks. Workers, hunters, and adult residents are not likely to frequent these areas or to contact surface water or sediment if near ditches or creeks. Children are present in the residential areas in the northeast portion of MAAP. However, ditches in this area are unlikely to be contaminated (although they have not been sampled as part of this RI) as they are upgradient of known contaminant sources. Children are not likely to roam in the other portions of MAAP (e.g., near the production lines) where surface water and sediment contamination does exist, given the distance of these areas from the residential area (e.g., >2 miles) as well as the security measures in place at the installation (e.g., security guards, fences), particularly near production line areas. Therefore, it is considered unlikely that there will be human exposures to surface water or sediment, and this pathway is not selected for evaluation in this assessment.

9.2.2.5 Air. Airborne emissions of chemicals of potential concern at MAAP could occur as a result of volatilization of chemicals from contaminated media and as a result of transport of chemicals present on wind-entrained particulate matter.

TABLE 9-10

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER BY FUTURE RESIDENTS AT THE NORTHERN BOUNDARY OF MAAP (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Exposure Point Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Organic Chemicals:		
Chloroform (CHCL3)	0.4	6.5E-06
2,4-DNT (24DNT)	0.14	2.3E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	5.6	9.1E-05
RDX (RDX)	28.2	4.6E-04
2,4,6-TNT (246TNT)	29	4.7E-04
Inorganic Chemicals:		
Arsenic (AS)	1.9	3.1E-05

Chemicals Exhibiting Noncarcinogenic Effects (b)	Exposure Point Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Organic Chemicals:		
Chloroform (CHCL3)	0.4	1.5E-05
1,3-DNB (13DNB)	0.2	7.6E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	5.6	2.1E-04
HMX (HMX)	3.4	1.3E-04
Nitrobenzene (NB)	0.72	2.7E-05
RDX (RDX)	28.2	1.1E-03
1,3,5-TNB (135TNB)	4.6	1.7E-04
2,4,6-TNT (246TNT)	29	1.1E-03
Inorganic Chemicals:		
Arsenic (AS)	1.9	7.2E-05
Barium (BA)	371	1.4E-02
Cadmium (CD)	1.4	5.3E-05
Chromium (CR)	5.4	2.0E-04
Manganese (MN)	16,000	6.1E-01
Mercury (HG)	0.1	3.8E-06
Silver (AG)	13	4.9E-04
Vanadium (V)	24.9	9.5E-04
Zinc (ZN)	239	9.1E-03

(a) CDIs are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals are not presented due to lack of oral toxicity criteria: aluminum, calcium, iron, magnesium, potassium, sodium and tetryl.

(b) USATHAMA chemical codes are listed in parentheses.

TABLE 9-11

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER BY FUTURE RESIDENTS AT THE NORTHWESTERN BOUNDARY OF MAAP

Chemicals Exhibiting Carcinogenic Effects (a)	Exposure Point Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)
Organic Chemicals:		
2,4-DNT (24DNT)	0.04	6.5E-07
bis(2-Ethylhexyl)phthalate (B2EHP)	30.5	5.0E-04
RDX (RDX)	6.8	1.1E-04
2,4,6-TNT (246TNT)	0.36	5.9E-06
Inorganic Chemicals:		
Arsenic (AS)	5.1	8.3E-05

Chemicals Exhibiting Noncarcinogenic Effects (a)	Exposure Point Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)
Organic Chemicals:		
Acetone (ACET)	12.1	4.6E-04
1,3-DNB (13DNB)	0.006	2.3E-07
Ethylbenzene (ETC6H5)	4.8	1.8E-04
bis(2-Ethylhexyl)phthalate (B2EHP)	30.5	1.2E-03
HMX (HMX)	0.33	1.3E-05
RDX (RDX)	6.8	2.6E-04
1,3,5-TNB (135TNB)	6.4	2.4E-04
2,4,6-TNT (246TNT)	0.36	1.4E-05
Toluene (MEC6H5)	1.2	4.6E-05
Xylenes [total] (XYLEN)	2.8	1.1E-04
Inorganic Chemicals:		
Arsenic (AS)	5.1	1.9E-04
Barium (BA)	557	2.1E-02
Cadmium (CD)	4.5	1.7E-04
Chromium (CR)	15.9	6.0E-04
Copper (CU)	72.8	2.8E-03
Manganese (MN)	737	2.8E-02
Mercury (HG)	0.2	7.6E-06
Nickel (NI)	41.3	1.6E-03
Silver (AG)	0.2	7.6E-06
Vanadium (V)	270	1.0E-02
Zinc (ZN)	262	9.9E-03

(a) USATHAMA chemical codes are listed in parentheses.

(b) CDIs are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals are not presented due to lack of oral toxicity criteria: aluminum, calcium, cobalt, iron, magnesium, potassium, and sodium.

Volatilization. A variety of volatile organic chemicals was detected in soil, surface water, and sediment at MAAP. These chemicals were detected infrequently and at relatively low concentrations. For example, acetone (the most frequently detected VOC) was detected in 1 out of 23 samples in surface water and 11 out of 77 samples in sediment at a maximum concentration of 15 μg/L in surface water and 0.1 mg/kg in sediment. Acetone and other VOCs detected at MAAP may represent low-level VOC contamination, and therefore could be a source of volatile emissions. However, their sporadic distribution across such a large area at MAAP (e.g., roughly 17 square miles) and low concentrations would result in negligible emissions of these compounds. Therefore, inhalation exposures to volatile chemicals present in soil, surface water or sediment would be negligible and will not be evaluated in this assessment.

Dust Transport. Migration of particulate matter in surface soil by wind entrainment, however, could be an important transport process at MAAP. In particular, the OBG and ADA are of greatest concern with respect to wind erosion as these areas are large, unprotected and primarily unvegetated areas, and are thus susceptible to wind erosion. The other source areas investigated in this RI are vegetated or paved and therefore are not a source of dust emissions. No chemicals of potential concern were detected in the surface soils of the ADA. Therefore, the evaluation of dust transport in this assessment will be limited to wind-erosion of surface soils in the OBG.

Persons could be exposed via inhalation to chemicals present on wind-blown dust. Workers who are present daily at the OBG are the principal receptors of concern for this pathway. In addition, residents who live near the eastern border of MAAP, approximately one mile from the OBG also are of concern. Inhalation exposures in each of these receptor populations will be quantitatively evaluated in this assessment. No air samples have been collected at MAAP to support the evaluation of this pathway. Therefore, air concentrations of the chemicals of potential concern were modeled from the available surface soil data to estimate air concentrations of particulate matter to which the workers could be exposed.

Workers at the ADA could be exposed to chemicals present on dust generated during excavation of subsurface soils, as part of ammunition destruction activities. However, these exposures are not expected to be significant, given their relatively short duration and the fact that workers are present at the ADA only for a total of three months per year.

9.2.2.6 Fish. Fishing occurs in the Rutherford Fork of the Obion River, as well as in many of the stocked fish ponds at MAAP. Persons could be exposed to chemicals in surface water and sediment via the ingestion of fish that have accumulated chemicals from these media.

Only one surface water sample was collected from the Rutherford Fork of the Obion River downstream of where the ditches and streams enter the River. Therefore, few data are available by which to estimate bioaccumulation of potentially site-related chemicals in fish that live in this river. However, based on results at the single sampling point, the potential for bioaccumulation appears to be low. Toluene, aluminum, copper, lead and sodium were the chemicals of concern detected in the river and, based on data from the scientific literature, none of these chemicals accumulates to any appreciable degree in fish or other aquatic life. The river receives drainage from most of the northern portions of MAAP and thus, other chemicals associated with MAAP could be reaching the river. However, data from John's Creek, which is a perennial tributary draining the northeastern portion of MAAP, suggest that extensive surface transport of site-related chemicals is not occurring. Further, with the exception of mercury, none of the principal contaminants associated with MAAP accumulates in fish to any significant extent. Mercury can accumulate extensively in fish but was an infrequent and low-level constituent of surface waters at the site. Therefore, the potential for significant exposures via ingestion of fish is considered negligible.

Fishing is also popular in the numerous stocked ponds at MAAP. Although no surface water concentrations were collected for the stocked fish ponds, these ponds are not located in areas that would be expected to be affected by site-related contamination. Because human exposures to chemicals of potential concern via ingestion of these fish are unlikely, this pathway was not evaluated.

9.2.2.7 Game. Persons hunting at MAAP could be exposed via ingestion to site-related contaminants that have accumulated in game species. Game could be exposed to chemicals via ingestion of surface water, ingestion of food that has accumulated chemicals, or ingestion of sediment or soil while foraging or grooming. The degree of accumulation in the game would depend on the types and concentrations of chemicals present in these media, the areal extent of contamination relative to the size of the home range of the game species, and the foraging habits of the game species.

Since deer hunting is popular at MAAP, exposures to those who consume deer killed at MAAP will be evaluated. The only media to which the deer could be exposed and for which sampling data are available is surface water. (Surface soil data were collected from areas that generally do not provide good deer habitat.) Thus, an analysis of deer uptake of chemicals of potential concern in surface water was first modeled, and then the human exposures as a result of venison ingestion were estimated.

9.2.2.8 Agricultural Produce. As mentioned earlier, there are scattered plots of land at MAAP that are leased as cropland. Virtually all of the feed crops grown at MAAP are dedicated to livestock consumption (personal communication, Jim Covington, March 13, 1991). However, some small (and unknown) portion of these crops may be consumed by humans. None of these crops is grown in known contaminated land and none was grown in areas sampled as part of this study. Further, these crops are not irrigated and would therefore not be exposed to chemicals in groundwater or surface water. Some contamination could reach these crops as a result of deposition of wind-blown chemicals that are carried from surface soils in the OBG. However, because most (if not all) of the crops grown at MAAP are consumed by livestock and not humans, little or no human exposures via ingestion of crops will occur. If some portion of the crops is consumed by humans, some exposure via ingestion could occur. Such exposures are unlikely to be significant, however, given that the MAAP croplands are relatively distant from the OBG and would therefore receive small amounts of dust from the OBG. Further, no one person is likely to obtain a significant portion of their diet from crops grown at MAAP. Appendix S presents a conservative screening-level evaluation of the dust-transport, crop-uptake, human ingestion pathway which demonstrates that exposures associated with this pathway result in negligible risks. It is considered unlikely that potential source areas, such as the OBG or O-Line, would be leased as cropland in the future.

9.2.2.9 Beef and Dairy Produce. Both beef cattle, and dairy cattle to a lesser degree, consume feed crops grown at MAAP, and also are known to graze in leased pasture areas. None of the crop or pasture areas are located in known contaminated land. However, as noted above, chemicals of potential concern adsorbed to wind-blown dusts could be deposited on crops near the OBG or on pasture grass that the cattle could consume. Chemicals that are deposited on crops or pasture grass could be ingested by and accumulate in beef and dairy cattle, resulting in human exposures via ingestion of local beef or milk. However, such exposures are unlikely to be significant because dust deposition in crop or pasture areas is likely to be low. Further, because the livestock feed crops grown at MAAP are distributed to livestock over a large area, and because no single individual is likely to receive a significant portion of their total beef or milk intake from cattle grazing at MAAP or feeding on crops grown at MAAP, accumulation in livestock and subsequent human exposure would be negligible. Appendix S presents a conservative, screening-level evaluation which demonstrates that exposures associated with this pathway result in negligible risks.

9.2.3 Quantification of Exposure

The human exposure pathways selected for quantitative evaluation are:

- Groundwater. Residential drinking water exposures using (1) estimates of future groundwater concentrations at the northern and northwestern boundaries of MAAP, and (2) using current measured concentrations in off-site wells.

- Air. Inhalation exposures of workers and nearby residents to chemicals adsorbed onto wind-generated dust from surface soils at the OBG.
- Game. Ingestion of deer killed at MAAP.

To quantitatively assess the potential exposures associated with these pathways, estimates of chemical concentrations at the exposure point are combined with values describing the extent, frequency, and duration of exposure to estimated chronic daily intakes (CDIs). Based on USEPA (1989e) guidance, CDIs should be quantified by estimating the reasonable maximum exposure (RME) associated with the pathway of concern. The RME is intended to represent a possible upper-bound exposure to a typical individual and is combined with upper-bound toxicity criteria to estimate risks.

In the following sections, exposure point concentrations are first presented and then are combined with other exposure parameters to estimate intake for each of the selected exposure pathways.

9.2.3.1 Estimation of Exposure Point Concentrations. Exposure point concentrations can be estimated using monitoring data alone or by using monitoring data in combination with environmental fate and transport models. In this assessment, exposure point concentrations have been derived using a combination of monitoring data and fate and transport models.

For exposure point concentrations based on monitoring results, the 95% upper confidence limit of the population mean concentration is recommended by USEPA (1989e). A statistical test developed by Land (1971, 1975) is used to estimate the 95% upper confidence limit of the population mean assuming a log-normal distribution. This approach is used because studies have shown that environmental contaminants tend to be log-normally distributed in nature (Dean, 1981; Ott, 1988). The equation for calculating the 95% upper confidence limit of the population mean is presented below (Land 1971, 1975):

$$UL_{95th} = EXP\ [AM + (0.5 \times STD) + (VAR \times H_{(95th)} / (N - 1)^{1/2})] \qquad \text{(Eq. 1)}$$

where:

UL = 95% upper confidence limit of the population mean

EXP = the inverse natural log of the sum of the parameters within the brackets,

AM = the population mean of the natural log transformed data

STD = the standard deviation of the natural log transformed data

VAR = the variance of the natural log transformed data

H = tabular value that is based on the degrees of freedom and variance of the data for the 95% percentile of the H distribution (Land 1971, 1975)

N = sample size

In certain instances, the calculated 95% upper confidence limit of the population mean may exceed the maximum detected concentration for a particular chemical in a specific medium. This often happens when the variance of the data is large and/or the sample size is small. In these cases, the maximum detected concentration of the chemical is used instead of the estimated 95% upper confidence limit of the population mean, to present a more reasonable estimate of exposure (USEPA 1989e).

The methods used to estimate exposure point concentrations in each exposure medium (i.e., groundwater, air, and deer) are described below.

Exposure Point Concentrations in Groundwater. Three different exposure scenarios are being evaluated for residential groundwater exposures: (1) future exposures at the northwest boundary as a result of contaminant transport from the OBG/ADA area; (2) future exposures at the northern boundary as a result of contaminant transport from the O-Line area; and (3) current exposures of off-post residents to chemicals currently present in off-post areas. Exposure point concentrations for these three scenarios are derived based on a combination of modeling and monitoring results. The exposure point concentrations for this pathway are presented in Table 9-3 and are described below. The exposure point concentrations for inorganic chemicals in groundwater are reported as unfiltered concentrations.

The groundwater flow and contaminant fate and transport modeling described in Section 8.0 yielded estimates of future concentrations of explosive compounds at the northwestern and northern MAAP boundaries. Monitoring data indicate that plumes of these compounds are emanating from the OBG/ADA and from the O-Line areas, and therefore chemical transport modeling from these sources was possible. Since monitoring data also suggested concentrated sources of cadmium existing in the OBG/ADA area, and the A-Line, B-Line, and K-Line areas, future cadmium concentrations at the northwestern and northern boundaries also were modeled. The modeled concentrations presented in Section 8.0 for explosive chemicals and cadmium are used as the groundwater exposure point concentrations for future residential exposures at the northern and northwestern boundaries. As discussed in Section 8.0, the modeled concentrations are estimates based on currently available data. It was assumed that the concentrations of contaminants in groundwater near the suspected source areas will not decrease in time.

It was not possible to model future concentrations at the boundary for the other chemicals of potential concern detected during on-site groundwater sampling, either because too few monitoring data were available to support model estimates (TCL and TAL compounds) or because there was no apparent source of the chemical from which to model transport (this was the case for target metals chromium and mercury). Therefore, on-site monitoring data were used as an estimate of possible future concentrations of these chemicals at the northwestern and northern MAAP boundaries. Monitoring data from all wells associated with the OBG/ADA plume of contamination were averaged to derive the estimate of future exposure point concentrations at the northwestern boundary. Data from all wells associated with the O-Line plume of contamination were averaged to derive estimated future exposure point concentrations at the northern boundary. The RME concentration is the lower value of the 95% upper confidence limit on the population mean concentration and the maximum detected value. Use of monitoring data as estimates of future concentrations at the border as a result of contaminant transport will result in over-estimates of exposure concentrations, as this approach does not account for dispersion, dilution, degradation, or retardation of chemicals during transport.

Exposure point concentrations for the evaluation of current exposures of off-post residents were estimated using monitoring data from the off-post wells. It should be noted that for one of the samples, the more elevated concentration of chromium was in the filtered (rather than unfiltered) sample. In order to be conservative, this more elevated concentration was used. For all other cases when determining the exposure point concentrations, unfiltered data were used. Again, the RME concentration is the lower value of the 95% upper confidence limit on the population mean concentration and the maximum detected value.

Exposure Point Concentrations in Air. No monitoring of wind-blown dust levels was conducted as part of the RI. Therefore, chemical concentrations on wind-blown dust from the OBG were estimated using data on chemical concentrations in surface soils at the OBG and appropriate transport models. Estimates of dust emissions due to wind erosion were derived based on Cowherd et al. (1984). These emission estimates were input (1) into a box model to estimate air concentrations for persons working at the OBG and (2) into a Gaussian-dispersion fugitive dust model (Winges, 1990) to estimate air concentration for nearby residents. Appendix O provides a detailed description of the models and assumptions used to estimate ambient concentrations of dust-borne chemicals.

TABLE 9-3

EXPOSURE POINT CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT MAAP (a)

(Concentrations reported in ug/L)

Exposure Point/ Chemical	Arithmetic Mean	95 % Upper Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Value	RME Concentration (c)
NORTHERN BOUNDARY				
Organic Chemicals				
Chloroform (CHCL3)	0.3	0.4	0.6	0.4
1,3-DNB (13DNB)	NC	NC	NC	0.2 *
2,4-DNT (24DNT)	NC	NC	NC	0.14 *
bis(2-Ethylhexyl)phthalate (B2EHP)	3.2	5.6	6.2	5.6
HMX (HMX)	NC	NC	NC	3.4 *
Nitrobenzene (NB)	NC	NC	NC	0.72 *
RDX (RDX)	NC	NC	NC	28.2 *
Tetryl (TETRYL)	NC	NC	NC	0.0006 *
1,3,5-TNB (135TNB)	NC	NC	NC	4.6 *
2,4,6-TNT (246TNT)	NC	NC	NC	29 *
Inorganic Chemicals (d)				
Aluminum (AL)	2,750	527,000	8,440	8440
Arsenic (AS)	1.5	1.9	3.2	1.9
Barium (BA)	130	527	371	371
Cadmium (CD)	NC	NC	NC	1.4 *
Calcium (CA)	14,600	32,300	38,000	32,300
Chromium (CR)	4.7	5.4	3.3	5.4
Iron (FE)	3,680	74,000	11,200	11,200
Magnesium (MG)	4,050	20,900	14,600	14,600
Manganese (MN)	2,180	525,000	16,000	16,000
Mercury (HG)	0.1	0.1	0.6	0.1
Potassium (K)	25,300	836,000	185,000	185,000
Silver (AG)	1.7	19.8	13.0	13.0
Sodium (NA)	8,450	16,000	29,300	16,000
Vanadium (V)	7.6	31	24.9	24.9
Zinc (ZN)	56.7	357	239	239
NORTHWESTERN BOUNDARY				
Organic Chemicals				
Acetone (ACET)	8.7	12.1	21.0	12.1
1,3-DNB (13DNB)	NC	NC	NC	0.006 *
2,4-DNT (24DNT)	NC	NC	NC	0.04 *
Ethylbenzene (ETC6H5)	1.2	4.8	7.5	4.8
bis(2-Ethylhexyl)phthalate (B2EHP)	10.3	36.4	30.5	30.5
HMX (HMX)	NC	NC	NC	0.33 *
RDX (RDX)	NC	NC	NC	6.8 *
1,3,5-TNB (135TNB)	NC	NC	NC	6.4 *
2,4,6-TNT (246TNT)	NC	NC	NC	0.36 *
Toluene (MEC6H5)	0.6	1.2	2.7	1.2
Xylenes (total) (XYLEN)	1.1	2.8	5.9	2.8

TABLE 9-3 (Continued)

EXPOSURE POINT CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT MAAP (a)

(Concentrations reported in ug/L)

Exposure Point/ Chemical	Arithmetic Mean	95 % Upper Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Value	RME Concentration (c)
Inorganic Chemicals (d)				
Aluminum (AL)	28,800	2,830,000	240,000	240,000
Arsenic (AS)	2.6	5.1	11.8	5.1
Barium (BA)	107	715	557	557
Cadmium (CD)	NC	NC	NC	4.5 *
Calcium (CA)	19,100	175,000	71,000	71,000
Chromium (CR)	9.4	15.9 (e)	156	15.9
Cobalt (CO)	17.3	24.9	55.6	24.9
Copper (CU)	18.6	72.8	109	72.8
Iron (FE)	22,600	305,000	180,000	180,000
Magnesium (MG)	1,930	5,590	10,700	5,590
Manganese (MN)	239	737	1,470	737
Mercury (HG)	0.1	0.2	0.7	0.2
Nickel (NI)	26.4	41.3	101	41.3
Potassium (K)	1,550	9,680	7,250	7,250
Silver (AG)	0.1	0.2	0.3	0.2
Sodium (NA)	6,520	11,900	22,500	11,900
Vanadium (V)	38.0	474	270	270
Zinc (ZN)	63.4	262	271	262
EXISTING RESIDENTIAL WELLS (d)				
Cadmium (CD)	21.0	11,000	63.0	63.0
Chromium (CR)	9.9	160	50.5	50.5

(a) Concentrations given for explosive compounds and cadmium are from modeled estimates. Values for remaining chemicals are derived from on-site sampling data.
(b) Value reflects a positively skewed distribution, except as noted.
(c) Except as noted, value listed is the lower of the 95 % upper confidence limit on the arithmetic mean and the maximum detected value.
(d) Reported as unfiltered concentrations.
(e) Value reflects a normal distribution.

NC = Not calculated. Exposure concentrations were modeled.
* = Designates a modeled chemical concentration.

Surface soil monitoring data from the OBG were used to define the source areas for dust emissions. Two source areas were defined to account for an apparent difference in the distribution of explosive and inorganic chemicals at the OBG. The source area for the explosive chemicals encompassed the area in the OBG where the explosives were detected. The source area for the inorganic chemicals encompassed the area in the OBG where inorganic chemicals were detected above background concentrations. Explosives were detected in only three surface soil sampling locations at the OBG. These three locations were clustered in the central western portion of the OBG. The inorganic chemicals also appeared to be clustered, but over a larger area. (See Appendix O for more information on the location of the detected concentrations.)

Table 9-4 presents the concentrations of explosive and inorganic chemicals within their respective source areas. The 95% upper confidence limit on the population mean or the maximum detected concentration (if lower) was used as input to the emissions model. Table 9-5 presents the estimated exposure point concentrations for workers at OBG and for off-site residents.

The dust transport model does not include two volatile chemicals (acetone and trichlorofluoromethane) which were detected in the surface soils of the OBG. These chemicals were detected in a single sample at concentrations of 0.05 mg/kg and 0.02 mg/kg, respectively, and were excluded from the dust transport model because they would preferentially partition to air and would be less likely to remain adhered to particulate matter. Volatile emissions were not modeled for these chemicals because their low concentrations in soil would result in negligible air concentrations.

Volatile emissions of the explosive compounds also are expected to be negligible based on their chemical nature. The Henry's law constant can be used to predict the volatility of a compound. All of the explosive compounds detected at the OBG, with the exception of nitrobenzene, have Henry's law constants that are less than 10^{-8} atm-m^3/mole, and can therefore be considered essentially nonvolatile. Nitrobenzene has a Henry's law constant of 1.3×10^{-5} atm-m^3/mole, and is therefore considered a semi-volatile compound with a limited potential for volatile emissions. To determine the relative distribution of nitrobenzene in the soil matrix (e.g., soil gas, or sorbed to soil), a comparison was made between its Henry's law constant and K_d. The K_d for nitrobenzene was estimated as the product of its K_{oc} (38 mL/g), which predicts a chemical's propensity to sorb onto organic matter found in the soil, and the fraction of organic carbon in the local soil (0.006 or 0.6%). This comparison indicates that nitrobenzene has a much greater tendency to sorb onto organic matter than to partition into the gas phase. Therefore, it is more appropriate to treat nitrobenzene as a compound sorbed onto wind-blown particles than as a volatile emission.

Exposure Point Concentrations in Deer. Chemical concentrations in deer meat were estimated assuming deer would be exposed to chemical contaminants while ingesting surface waters at MAAP. Surface water concentrations to which deer could be exposed were estimated by averaging the concentrations detected in all surface water samples collected at MAAP, assuming that a deer could roam across the site and be exposed to chemicals in all surface waters. The 95% upper confidence limit on the population mean concentration or the maximum detected concentration (if lower) was used as input to model contaminant accumulation in deer. These concentrations are presented in Table 9-6. The exposure point concentrations for inorganic chemicals in surface water are reported as unfiltered concentrations.

To determine the total amount of chemical ingested by a deer each day, the deer's daily intake of surface water (assumed to be 2 liters per day; personal communication, H. Jacobson, University of Mississippi) was multiplied by the chemical concentrations in the water. The following equation, adapted from Moghissi et al. (1980), was used to estimate chemical concentrations in deer tissue:

TABLE 9-4

SURFACE SOIL CONCENTRATIONS AT THE OBG USED AS INPUT TO THE DUST EMISSION/TRANSPORT MODEL

(Concentrations reported in mg/kg)

Chemical (a)	Arithmetic Mean	95 % Upper Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Explosives (d):				
HMX (HMX)	140	1.2E+09	340	340
Nitrobenzene (NB)	2.1	4,600	4.3	4.3
RDX (RDX)	1,100	NC	3,300	3,300
1,3,5-TNB (135TNB)	0.9	7.8E+06	2.3	2.3
2,4,6-TNT (246TNT)	1,400	2.8E+116	4,100	4,100
Inorganic Chemicals (e):				
Arsenic (AS)	8.1	NC	9.8	9.8
Chromium (CR)	16.0	35.0	48.5	35.0
Lead (PB)	42.0	93.0	118	93.0
Mercury (HG)	0.3	1.4	2.5	1.4
Silver (AG)	0.05	NC	0.1	0.1
Zinc (ZN)	83.0	NC	94.8	94.8

(a) USATHAMA chemical codes are listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower of the 95 % upper confidence limit on the arithmetic mean and the maximum detected value.
(d) Data used in estimating RME concentrations incorporate sampling locations OBGA-3, OBGA-4 and OBGB-4.
(e) Data used in estimating RME concentrations incorporate sampling locations OBGA-3, OBGA-4, OBGA-6, OBGB-4, OBGB-5, OBGC-4, OBGC-5, OBGD-3, and OBGD-4.

NC = Not calculated. Sample size was too small to calculate an upper 95 % confidence limit.

TABLE 9-5

ESTIMATED AIR CONCENTRATIONS DUE TO WIND EROSION OF CHEMICALS OF POTENTIAL CONCERN FROM SURFACE SOILS OF THE OBG

Chemical (a)	RME Concentration in Surface Soil (g/g) (b)	On-Site Air Concentration (ug/m3) (c)	Off-Site Air Concentration (ug/m3) (c)
Explosives (d)			
HMX (HMX)	3.4E-04	3.5E-02	3.8E-04
Nitrobenzene (NB)	4.3E-06	4.5E-04	4.8E-06
RDX (RDX)	3.3E-03	3.4E-01	3.7E-03
1,3,5-TNB (135TNB)	2.3E-06	2.4E-04	2.6E-06
2,4,6-TNT (246TNT)	4.1E-03	4.3E-01	4.6E-03
Inorganic Chemicals (e)			
Arsenic (AS)	9.8E-06	1.4E-03	7.6E-05
Chromium (CR)	3.5E-05	4.9E-03	2.7E-04
Lead (PB)	9.3E-05	1.3E-02	7.3E-04
Mercury (HG)	1.4E-06	1.9E-04	1.1E-05
Silver (AG)	1.0E-07	1.4E-05	7.8E-07
Zinc (ZN)	9.5E-05	1.3E-02	7.4E-04

(a) USATHAMA chemical codes are listed in parentheses.
(b) Surface soil samples are from the 0-1 ft. depth.
(c) See Appendix O for details on air modeling.
(d) Data used in estimating RME concentrations incorporate sampling locations OBGA-3, OBGA-4, and OBGB-4.
(e) Data used in estimating RME concentrations incorporate sampling locations OBGA-3, OBGA-4, OBGA-6, OBGB-4, OBGB-5, OBGC-4, OBGC-5, OBGD-3, and OBGD-4.

TABLE 9-6

SURFACE WATER CONCENTRATIONS USED TO ESTIMATE DEER UPTAKE OF CHEMICALS OF POTENTIAL CONCERN

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	95 % Upper Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Organic Chemicals:				
Acetone (ACET)	7.8	8.7	15.4	8.7
Bromodichloromethane (BRDCLM)	0.5	0.6	2.7	0.6
Bromoform (CHBR3)	4.0	7.8 (d)	53.3	7.8
Carbon Disulfide (CS2)	0.4	0.5	1.4	0.5
Dibromochloromethane (DBRCLM)	0.9	0.9	11.4	0.9
Diethylphthalate (DEP)	5.8	13.4 (d)	93.2	13.4
Di-n-octylphthalate (DNOP)	8.1	8.7	19.4	8.7
2,4-DNT (24DNT)	0.3	0.4	0.8	0.4
HMX (HMX)	3.3	4.0	41.0	4.0
Nitrobenzene (NB)	0.6	0.7	2.0	0.7
RDX (RDX)	17.8	27.4	310	27.4
1,1,2,2-Tetrachloroethane (TCLEA)	0.4	0.5	2.6	0.5
Tetryl (TETRYL)	0.3	0.3	0.6	0.3
1,3,5-TNB (135TNB)	0.4	0.4	1.8	0.4
2,4,6-TNT (246TNT)	0.7	1.5 (d)	11.3	1.5
Toluene (MEC6H5)	0.3	0.3	0.8	0.3
1,1,2-Trichloroethane (112TCE)	1.0	1.3	3.8	1.3
Trichloroethene (TRCLE)	0.4	0.5	1.8	0.5
Inorganic Chemicals (e):				
Aluminum (AL)	14,200	113,700	110,000	110,000
Arsenic (AS)	8.6	18.4	52.2	18.4
Barium (BA)	440	972	4,940	972
Cadmium (CD)	2.2	2.3	6.0	2.3
Calcium (CA)	10,130	15,900	24,000.0	15,900
Chromium (CR)	8.6	11.2	61.5	11.2
Cobalt (CO)	17.8	20.9	76.6	20.9
Copper (CU)	22.9	34.6	224	34.6
Iron (FE)	15,400	65,700	120,000	65,700
Lead (PB)	14.7	30.0	140	30.0
Magnesium (MG)	3,300	4,501	10,900	4,501
Manganese (MN)	2,015	6,450	19,300	6,450
Mercury (HG)	0.1	0.1	0.3	0.1
Nickel (NI)	22.0	25.0	87.7	25.0
Potassium (K)	7,260	13,200	21,100.0	13,200
Silver (AG)	0.7	0.7	8.8	0.7
Sodium (NA)	9,502	28,800	37,300.0	28,800
Vanadium (V)	28.2	87.8	207	87.8
Zinc (ZN)	64.8	111	465	111

(a) USATHAMA chemical codes are listed in parentheses.
(b) Values reflect a positively skewed distribution, except as noted.
(c) Value listed is the lower of the 95 % upper confidence limit on the arithmetic mean and the maximum detected value.
(d) Value reflects a normal distribution.
(e) Reported as unfiltered concentrations.

$$C_v = (C_s)\,(IR_s)\,(TC)\,(Bio)\,(X) \qquad \text{(Eq. 2)}$$

where:

C_v = concentration of chemical in venison (mg/kg)

C_s = concentration of chemical in surface water (μg/L)

IR_s = surface water ingestion rate (2 liters/day)

TC = transfer coefficient (day/kg)

Bio = fraction of the chemical that is bioavailable (unitless)

X = conversion (mg/10^3 μg)

Not all of the chemical that the deer is exposed to will be transferred to the tissue. An important parameter in the above equation that reflects this fact is the transfer coefficient, which is used in estimating the chemical concentrations in deer tissue at a steady state. Transfer coefficients ideally should be obtained from controlled animal studies that measure the concentration of contaminant in muscle as a result of a long-term exposure or under steady-state conditions.

Because no transfer coefficients exist specifically for deer, transfer coefficients for inorganic chemicals were obtained from Baes et al. (1984) for feed-to-beef studies. In the case of mercury, however, a feed-to-chicken transfer coefficient was used (Ng et al., 1982). This parameter was utilized because there are no adequate cattle feeding studies from which a feed-to-beef transfer coefficient could be derived.

For organic chemicals, transfer coefficients were estimated from regression equations based on log K_{ow} values. An equation for beef transfer coefficients has been developed that compares favorably with feeding study results (Travis and Arms, 1988). This equation is shown below in a modified form to adjust for the fact that the authors have assumed 25% fat content in beef, and 1% fat in cooked venison:

$$TF_{org} = (10^{-7.6 + \log K_{ow}})\,(0.01/0.25) \qquad \text{(Eq. 3)}$$

where:

TC_{org} = transfer coefficient for organic chemicals

All but one of the organic chemicals detected in surface water at MAAP have a low log K_{ow} (less than 3), indicating that bioaccumulation of these chemicals in deer is likely to be insignificant. The only exception is di-N-octylphthalate, which has a log K_{ow} of 5.22. Nevertheless, potential accumulation of all chemicals was evaluated quantitatively given the prevalence of deer hunting at MAAP. Table 9-7 presents the log K_{ow} values used in these calculations, in addition to the transfer coefficients for all the chemicals of potential concern.

A bioavailability factor of 1.0 (100%) was assumed for chemicals in surface water ingested by deer. The use of a bioavailability factor of 1.0 assumes that chemicals in surface water are as available for absorption as they were in the solvent matrix used in administered experimental studies.

TABLE 9-7

LOG KOWs AND TRANSFER COEFFICIENTS USED TO ESTIMATE CHEMICAL CONCENTRATIONS IN DEER

Chemical	Log Kow (a)	Transfer Coefficient (days/kg) (b)
Organic Chemicals		
Acetone	-2.40	4.00E-12
Bromodichloromethane	2.24	1.75E-07
Bromoform	2.40	2.52E-07
Carbon Disulfide	2.00	1.00E-07
Dibromochloromethane	2.24	1.75E-07
Diethylphthalate	2.46	2.90E-07
Di-n-octylphthalate	5.22	1.67E-04
2,4-DNT	1.98	9.60E-08
HMX	0.26	1.83E-09
Nitrobenzene	1.85	7.11E-08
RDX	0.87	7.45E-09
1,1,2,2-Tetrachloroethane	2.39	2.47E-07
Tetryl	2.38	2.41E-07
1,3,5-TNB	1.18	1.52E-08
2,4,6-TNT	1.84	6.95E-08
Toluene	2.69	4.92E-07
1,1,2-Trichloroethane	2.07	1.18E-07
Trichloroethene	2.42	2.64E-07
Inorganic Chemicals		
Aluminum	NA	1.5E-03
Arsenic	NA	2E-03
Barium	NA	1.5E-04
Cadmium	NA	5.5E-04
Calcium	NA	7.0E-04
Chromium	NA	5.5E-03
Cobalt	NA	2E-02
Copper	NA	1E-02
Iron	NA	2E-02
Lead	NA	3E-04
Magnesium	NA	5E-03
Manganese	NA	4E-04
Mercury	NA	2.7E-02
Nickel	NA	6E-03
Potassium	NA	2E-02
Silver	NA	3E-03
Sodium	NA	5.5E-02
Vanadium	NA	2.5E-03
Zinc	NA	1E-01

(a) Log Kow values for explosives from (USAEHA, 1991). Remaining log Kows from Chemical/Physical Parameters table.

(b) See text for derivation of transfer coefficients for organic chemicals. Inorganic transfer coefficients from Baes et al. (1984).

NA = Not applicable. Log Kows are not used for derivation of transfer coefficients for inorganic chemicals.

Table 9-8 presents the surface water exposure concentrations and the estimated chemical concentrations in deer meat.

9.2.3.2 Estimation of Chemical Intakes. This section presents estimates of CDIs for each exposure pathway. CDIs are expressed as the amount of a substance taken into the body per unit body weight per day, or mg/kg-day. A CDI is averaged over a lifetime for carcinogens and over the exposure period for noncarcinogens (USEPA, 1989e).

Ingestion of Groundwater by Residents. CDIs are calculated for residential drinking water exposures using the estimated exposure point concentrations presented in Table 9-3 and the exposure parameters presented in Table 9-9 and discussed below.

Drinking water exposures were evaluated for persons between the ages of 0 and 30. (This age period was conservatively chosen for evaluation because exposures for this age period are greater than those estimated for persons 18 and older.) A time-weighted average body weight of 48 kg (based on data in USEPA [1989c]) and a drinking water ingestion rate of 1.9 liters/day were used as parameters for the reasonable maximum exposure case. The drinking water consumption rate was calculated assuming a consumption rate of 1 liter/day for individuals up to 10 kg (approximately 3 years of age), and a rate of 2 liters/day for persons over three years of age. Residents are assumed to be at home 50 weeks (350 days/year) and ingest groundwater daily during this time. Residents are assumed to be exposed for 30 years, which is an upper-bound estimate of the time a person is likely to spend in any one residence (USEPA, 1989e). Individuals are assumed to live for 70 years (USEPA, 1989c).

Bioavailability factors represent the ratio of the chemical's bioavailability from an environmental medium, to its bioavailability from the vehicle used in the relevant toxicity study. The bioavailability of 1.0 used when calculating groundwater ingestion CDIs indicates that the chemical is equally bioavailable from both water and the vehicle used in the toxicity study. Absorption factors represent the extent to which a chemical is transported into the bloodstream under the exposure being evaluated relative to that observed in the toxicity study upon which the toxicity criteria was based. For evaluation of drinking water exposures in this assessment, absorption of the chemical from water is assumed to be equal to that observed in the toxicity study.

Drinking water exposures were calculated using these assumptions and the following equation:

$$CDI = \frac{(C_w)(IR)(EF)(ED)(Z)(Bio)(Abs)}{(BW)(DY)(YL)} \qquad \text{(Eq.4)}$$

where:

CDI = chronic daily intake (mg/kg-day)

C_w = exposure point concentration in groundwater (μg/L)

IR = ingestion rate (L/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

Z = conversion factor (mg/10^3 μg)

Bio = relative oral bioavailability factor (unitless)

TABLE 9-8

ESTIMATED SURFACE WATER CONCENTRATIONS AND CONCENTRATIONS IN DEER AS A RESULT OF SURFACE WATER INGESTION

Chemical	RME Surface Water Concentration (ug/L) (a)	Concentration in Deer (mg/kg)
Organic Chemicals		
Acetone	8.7	7.0E-14
Bromodichloromethane	0.6	2.1E-10
Bromoform	7.8	3.9E-09
Carbon Disulfide	0.5	1.0E-10
Dibromochloromethane	0.9	3.1E-10
Diethylphthalate	13.4	7.8E-09
Di-n-octylphthalate	8.7	2.9E-06
2,4-DNT	0.4	7.7E-11
HMX	4.0	1.5E-11
Nitrobenzene	0.7	1.0E-10
RDX	27.4	4.1E-10
1,1,2,2-Tetrachloroethane	0.5	2.5E-10
Tetryl	0.3	1.4E-10
1,3,5-TNB	0.4	1.2E-11
2,4,6-TNT	1.5	2.1E-10
Toluene	0.3	3.0E-10
1,1,2-Trichloroethane	1.3	3.1E-10
Trichloroethene	0.5	2.6E-10
Inorganic Chemicals		
Aluminum	110,000	3.3E-01
Arsenic	18.4	7.4E-05
Barium	972	2.9E-04
Cadmium	2.3	2.5E-06
Calcium	15,900	2.2E-02
Chromium	11.2	1.2E-04
Cobalt	20.9	8.4E-04
Copper	34.6	6.9E-04
Iron	65,700	2.6E+00
Lead	30	1.8E-05
Magnesium	4,501	4.5E-02
Manganese	6,450	5.2E-03
Mercury	0.1	5.4E-06
Nickel	25	3.0E-04
Potassium	13,200	5.3E-01
Silver	0.7	4.2E-06
Sodium	28,800	3.2E+00
Vanadium	87.8	4.4E-04
Zinc	111	2.2E-02

(a) Concentrations are averaged across all surface water bodies at MAAP.

TABLE 9-9

PARAMETERS USED TO ESTIMATE RESIDENTIAL DRINKING WATER EXPOSURES

Parameter	Value
Exposure Frequency (a)	350 days/year
Exposure Duration (b)	30 years
Ingestion Rate (c)	1.9 liters
Body Weight (c)	48 kg
Relative Oral Bioavailability Factor (d)	1.0
Absolute Absorption (Arsenic only) (e)	0.8

(a) Based on residents drinking water every day of the year.
(b) Based on the upperbound time period that a person is likely to remain at the same residence (USEPA, 1989e).
(c) Average value for persons between the ages of 0-30 (USEPA, 1989c).
(d) Assumed value for all chemicals.
(e) EPA (1984).

Abs = absorption factor (unitless)

BW = body weight over the period of exposure (kg)

DY = days in a year (365 days/year)

YL = period over which risk is being estimated (a lifetime [70 years] for potential carcinogens and the period of exposure for noncarcinogens) (years)

Exposure estimates were calculated separately for potential future receptors at the northern and northwestern boundaries of MAAP and for current groundwater users in off-post areas. Tables 9-10 through 9-12 present the estimated CDIs for these receptors.

__Inhalation of Dust by Workers at the OBG and by Nearby Residents__. Chronic daily intakes for workers and residents were calculated by combining exposure point concentrations presented in Table 9-5 with the exposure parameters listed in Table 9-13, and discussed below. For both of these exposure groups, indoor and outdoor chemical concentrations are assumed to be equal.

Workers are assumed to weigh 70 kg (USEPA, 1989c) and breathe at a rate of 20 m^3 per 8-hour work day. The latter value is estimated based on an inhalation rate of 2.5 m^3/hr reported for male workers engaged in moderate activity (USEPA, 1989c). Workers are assumed to be present at the OBG 8 hours/day for a total of 241 days/year, based on a 5-day work week and assuming two weeks vacation and 9 federal holidays each year. However, wind erosion of surface soils is not considered a likely phenomenon for the entire year because rain, snow cover and frost will reduce the potential for dust generation. Based on data from NOAA (1978) for nearby Memphis, Tennessee, precipitation occurs a total of 112 days/year, or approximately 30% of the year. For this assessment, workers are assumed to be exposed the remaining portion of the year when no precipitation occurs, for a total exposure frequency of 170 days/year, which reflects the fact that this is the joint probability of erosion potential and being at work. Workers are assumed to work at the OBG for a period of 30 years and to live for 70 years (USEPA 1989e).

Residential inhalation exposures are evaluated for adult residents living adjacent to the eastern border of MAAP. (Exposures are evaluated for persons 18 and older, instead of other age group combinations [e.g., 0-30 year olds] because this results in the most conservative exposures estimates.) Residents are assumed to weigh 70 kg and breathe at a rate of 30 m^3/day (USEPA, 1989e). Further, residents are assumed to be at home 50 weeks (350 days/year) and to be exposed 70% of this time to dust generated from the OBG, for a total of 245 days/year. Residents are again assumed to be exposed for a total of 30 years, as was the case for drinking water exposures (USEPA, 1989e). Once again, standard assumptions for a lifetime of 70 years (USEPA, 1989e) were used.

For this pathway, it was assumed that all chemicals of potential concern were 100% bioavailable to the lung. Since arsenic's inhalation slope factor is based on an absorbed dose, the percent absorption of inhaled arsenic was used in estimating arsenic CDIs. Based on USEPA (1984), the retention and absorption of arsenic in the lung was assumed to be 30%.

Chronic exposures from inhalation of dusts for workers and nearby residents were calculated using these assumptions and the following equation:

$$CDI = \frac{(C_a)\,(IR)\,(EF)\,(ED)\,(X)\,(Bio)\,(Abs)}{(BW)\,(DY)\,(YL)} \qquad \text{(Eq. 5)}$$

TABLE 9-12

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER BY CURRENT OFF-SITE RESIDENTS

Chemicals Exhibiting Noncarcinogenic Effects (a)	Exposure Point Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Inorganic Chemicals:		
Cadmium (CD)	63.0	2.4E-03
Chromium (CR)	50.5	1.9E-03

(a) USATHAMA chemical codes are listed in parentheses.

TABLE 9-13

PARAMETERS USED TO ESTIMATE DUST INHALATION EXPOSURES

Parameter	Workers	Residents
Exposure Frequency	170 days/year (a)	245 days/year (b)
Exposure Duration	30 years (c)	30 years (d)
Inhalation Rate	20 m3 (e)	30 m3 (f)
Body Weight (g)	70 kg	70 kg
Relative Inhalation Bioavailability Factor (h)	1.0	1.0
Absolute Absorption (Arsenic only) (i)	0.3	0.3

(a) Assumes a 241-day work year, and that wind erosion occurs 70% of the time.
(b) Assumes residents are at home 50 weeks each year, and that wind erosion occurs 70% of the time.
(c) Based on the length of time one could work at the OBG.
(d) Based on upper-bound time period that a person is likely to remain at the same residence (USEPA, 1989e).
(e) Based on moderate activity for a male during an 8-hour day (USEPA, 1989c).
(f) Upper-bound estimate of daily inhalation rate (USEPA, 1989e).
(g) Adult body weight (USEPA, 1989c).
(h) Assumed value for all chemicals.
(i) USEPA (1984).

where:

CDI = chronic daily intake (mg/kg-day)

C_a = exposure point concentration in air (μg/m^3)

IR = inhalation rate (m^3/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

X = conversion factor (mg/10^3 μg)

Bio = relative inhalation bioavailability factor (unitless)

Abs = absorption factor (unitless, for arsenic only)

BW = body weight over the period of exposure (kg)

DY = days in a year (365 days/year)

YL = period over which risk is being estimated (a lifetime [70 years] for potential carcinogens and the period of exposure for noncarcinogens) (years)

Exposure estimates were calculated separately for workers at the OBG and for residents along the eastern border of MAAP. Tables 9-14 and 9-15 present the estimated CDIs for these receptors.

Ingestion of Venison. CDIs are calculated for the ingestion of venison by persons who hunt at MAAP, using the estimated exposure point concentrations presented in Table 9-8 and the exposure parameters presented in Table 9-16 and discussed below.

Venison exposures were evaluated for adults based on the assumption that adults would eat a greater amount of venison than children. Adults were again assumed to weigh 70 kg (USEPA, 1989e), and were assumed to eat the meat from 1 deer each year (e.g., each family would eat 2 deer per year). To estimate the amount of venison that could be consumed, deer were assumed to weigh 100 pounds field-dressed and provide 75 pounds of edible meat (personal communication, Peggy Beasley, April 2, 1991). Thus, for this exposure scenario, it was assumed that the average person could consume 75 pounds (34 kg) of venison over the period of one year. Individuals are assumed to consume venison from MAAP for 30 years and to live a total of 70 years.

No reduction in concentrations due to preparation of the venison by cooking or other preparation was assumed to occur. All chemicals present in the venison were assumed to be 100% bioavailable. In addition, since arsenic's oral slope factor is based on an absorbed dose, the percent absorption of arsenic in the gut was used in estimating arsenic CDIs. Based on EPA (1984) the absorption of arsenic was assumed to be 80%.

Ingestion exposures were calculated using these exposure assumptions and the following equation:

$$CDI = \frac{(C_v)\,(IR)\,(YR)\,(Bio)\,(Abs)}{(BW)\,(DY)\,(YL)} \qquad \text{(Eq. 6)}$$

TABLE 9-14

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INHALATION INTAKES FOR WORKERS AT THE OBG (a)

Chemicals Exhbiting Carcinogenic Effects (b)	OBG Soil Concentration (g/g)	Air Concentration at OBG (ug/m3) (c)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Inorganic Chemicals:			
Arsenic (AS)	9.8E-06	1.4E-03	2.3E-08
Chromium (CR)	3.5E-05	4.9E-03	2.8E-07

Chemicals Exhibiting Noncarcinogenic Effects (b)	OBG Soil Concentration (g/g)	Air Concentration at OBG (ug/m3) (c)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Organic Chemicals:			
Nitrobenzene (NB)	4.3E-06	4.5E-04	6.0E-08
Inorganic Chemicals:			
Chromium (CR)	3.5E-05	4.9E-03	6.5E-07
Mercury (HG)	1.4E-06	1.9E-04	2.6E-08

(a) CDIs are calculated only for chemicals of potential concern with inhalation toxicity criteria. The following chemicals are not presented due to lack of inhalation toxicity criteria: HMX, lead, RDX, silver, 1,3,5-TNB, 2,4,6-TNT, and zinc.

(b) USATHAMA chemical codes are listed in parentheses.

(c) See Appendix O for a discussion of air modeling.

TABLE 9-15

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INHALATION INTAKES FOR RESIDENTS ALONG THE EASTERN BOUNDARY OF MAAP (a)

Chemicals Exhbiting Carcinogenic Effects	OBG Soil Concentration (g/g)	Air Concentration at Boundary (ug/m3) (c)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Inorganic Chemicals:			
Arsenic (AS)	9.8E-06	7.64E-05	2.8E-09
Chromium (CR)	3.5E-05	2.73E-04	3.4E-08

Chemicals Exhibiting Noncarcinogenic Effects	OBG Soil Concentration (g/g)	Air Concentration at Boundary (ug/m3) (c)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Organic Chemicals:			
Nitrobenzene (NB)	4.3E-06	4.8E-06	1.4E-09
Inorganic Chemicals:			
Chromium (CR)	3.5E-05	2.7E-04	7.9E-08
Mercury (HG)	1.4E-06	1.1E-05	3.1E-09

(a) CDIs are calculated only for chemicals of potential concern with inhalation toxicity criteria. The following chemicals are not presented due to lack of inhalation toxicity criteria: HMX, lead, RDX, silver, 1,3,5-TNB, 2,4,6-TNT, and zinc.
(b) USATHAMA chemical codes are listed in parentheses.
(c) See Appendix O for a discussion of air modeling.

TABLE 9-16

PARAMETERS USED TO ESTIMATE EXPOSURES FROM INGESTION OF CHEMICALS IN DEER

Parameter	Value
Exposure Duration (a)	30 years
Ingestion Rate (b)	34.1 kilograms
Body Weight (c)	70 kg
Relative Oral Bioavailability Factor (d)	1.0
Absolute Absorption (Arsenic only) (e)	0.8

(a) Based on the upper-bound time period that a person is likely to remain at the same residence (USEPA, 1989e).

(b) Based on a person consuming venison from one deer over the period of one year.

(c) Adult body weight (USEPA, 1989c)

(d) Assumed value for all chemicals.

(e) EPA (1984).

where:

CDI = chronic daily intake (mg/kg-day)

C_v = chemical concentration in venison (mg/kg)

IR = ingestion rate (kg/year)

YR = years of exposure (years)

Bio = relative oral bioavailability factor (unitless)

Abs = absorption factor (unitless, for arsenic only)

BW = body weight (kg)

DY = days in a year (365 days/year)

YL = period over which risk is being estimated (a lifetime [70 years] for potential carcinogens and the period of exposure for noncarcinogens) (years)

Table 9-17 presents the exposure point concentrations of chemicals of potential concern in venison and the estimated CDIs calculated using the exposure assumptions for this pathway.

9.3 HUMAN HEALTH TOXICITY ASSESSMENT

This Section presents the general methodology for classifying the health effects of toxic chemicals and for developing health effects criteria. Then, the health effects criteria to be used in this assessment are presented.

9.3.1 Health Effects Classification and Criteria Development

For risk assessment purposes, individual chemicals are separated into two categories of chemical toxicity depending on whether they exhibit noncarcinogenic or carcinogenic effects. This distinction relates to the currently held scientific opinion that the mechanism of action for each category is different. When assessing risks associated with potential carcinogens, EPA has adopted the scientific position that a small number of molecular events can cause changes in a single cell or a small number of cells that can lead to tumor formation. This is described as a no-threshold mechanism, because there is essentially no level of exposure (i.e., a threshold) to a carcinogen that will not result in some finite possibility of causing the disease. In the case of chemicals exhibiting noncarcinogenic effects, it is believed that organisms have protective mechanisms that must be overcome before the toxic endpoint is manifested. For example, if a large number of cells performs the same or similar functions, it would be necessary for significant damage or depletion of these cells to occur before an effect could be seen. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without appreciable risk of causing the disease (USEPA, 1989e). Some chemicals can also exhibit both carcinogenic and noncarcinogenic effects.

9.3.1.1 Health Effects Criteria for Potential Carcinogens. Slope factors are developed by EPA's Health Assessment Group (HAG) for potentially carcinogenic chemicals and are expressed in units of $(mg/kg\text{-}day)^{-1}$. Slope factors are derived from the results of human epidemiological studies or chronic animal bioassays. The animal studies usually must be conducted using relatively high doses to detect possible adverse effects. Because humans are expected to be exposed to doses lower than those used in the animal studies, the data are adjusted by using mathematical models. The data from animal studies

TABLE 9-17

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF VENISON AT MAAP

Chemicals Exhibiting Carcinogenic Effects (a)	Concentration in Deer (mg/kg)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)
Organic Chemicals:		
Bromodichloromethane (BRDCLM)	2.1E-10	1.2E-13
Bromoform (CHBR3)	3.9E-09	2.3E-12
Dibromochloromethane (DBRCLM)	3.1E-10	1.8E-13
2,4-DNT (24DNT)	7.7E-11	4.4E-14
RDX (RDX)	4.1E-10	2.3E-13
1,1,2,2-Tetrachloroethane (TCLEA)	2.5E-10	1.4E-13
2,4,6-TNT (246TNT)	2.1E-10	1.2E-13
1,1,2-Trichloroethane (112TCE)	3.1E-10	1.8E-13
Trichloroethene (TRCLE)	2.6E-10	1.5E-13
Inorganic Chemicals:		
Arsenic (AS)	7.4E-05	3.4E-08

Chemicals Exhibiting Noncarcinogenic Effects (a)	Concentration in Deer (mg/kg)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)
Organic Chemicals:		
Acetone (ACET)	7.0E-14	9.3E-17
Bromodichloromethane (BRDCLM)	2.1E-10	2.8E-13
Bromoform (CHBR3)	3.9E-09	5.3E-12
Carbon Disulfide (CS2)	1.0E-10	1.3E-13
Dibromochloromethane (DBRCLM)	3.1E-10	4.2E-13
Diethylphthalate (DEP)	7.8E-09	1.0E-11
Di-n-octylphthalate (DNOP)	2.9E-06	3.9E-09
HMX (HMX)	1.5E-11	2.0E-14
Nitrobenzene (NB)	1.0E-10	1.3E-13
RDX (RDX)	4.1E-10	5.4E-13
1,1,2,2-Tetrachloroethane (TCLEA)	2.5E-10	3.3E-13
1,3,5-TNB (135TNB)	1.2E-11	1.6E-14
2,4,6-TNT (246TNT)	2.1E-10	2.8E-13
Toluene (MEC6H5)	3.0E-10	3.9E-13
1,1,2-Trichloroethane (112TCE)	3.1E-10	4.1E-13
Trichloroethene (TRCLE)	2.6E-10	3.5E-13
Inorganic Chemicals:		
Arsenic (AS)	7.4E-05	7.9E-08
Barium (BA)	2.9E-04	3.9E-07
Cadmium (CD)	2.5E-06	3.4E-09
Chromium (CR)	1.2E-04	1.6E-07
Copper (CU)	6.9E-04	9.2E-07
Manganese (MN)	5.2E-03	6.9E-06
Mercury (HG)	5.4E-06	7.2E-09
Nickel (NI)	3.0E-04	4.0E-07
Silver (AG)	4.2E-06	5.6E-09
Vanadium (V)	4.4E-04	5.9E-07
Zinc (ZN)	2.2E-02	3.0E-05

(a) USATHAMA chemical codes are listed in parentheses.

(b) CDIs are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals are not presented due to a lack of oral toxicity criteria: aluminum, calcium, cobalt, iron, lead, magnesium, potassium, sodium and tetryl.

are typically fitted to the linearized multistage model to obtain a dose-response curve. The 95th percentile upper confidence limit slope of the dose-response curve is subjected to various adjustments and an interspecies scaling factor is applied to derive the slope factor for humans. Thus, the actual risks associated with exposure to a potential carcinogen quantitatively evaluated based on animal data are not likely to exceed the risks estimated using these slope factors, but they may be much lower. Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves on a case-by-case basis. These models provide rough, but plausible, estimates of the upper limits on lifetime risk. Slope factors based on human epidemiological data are also derived using very conservative assumptions and, as such, they too are unlikely to under-estimate risks. Therefore, while the actual risks associated with exposures to potential carcinogens are unlikely to be higher than the risks calculated using a slope factor, they could be considerably lower.

EPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as either Class A, Class B1, Class B2, Class C, Class D, or Class E. Class A chemical (human carcinogens) are agents for which there is sufficient evidence to support the causal association between exposure to the agents in humans and the development of cancer. Class B1 chemicals (probable human carcinogens) are agents for which there is limited evidence of carcinogenicity from human studies, and animal evidence can range from no data or evidence to sufficient evidence of carcinogenicity. Class B2 chemicals (probable human carcinogens) are agents for which there is inadequate evidence from human studies, but for which there is sufficient evidence of carcinogenicity from animal studies. Class C chemicals (possible human carcinogens) are agents for which there is limited evidence of carcinogenicity in animals, and Class D chemicals (not classified as to human carcinogenicity) are agents with inadequate human and animal evidence of carcinogenicity or for which no data are available. Class E chemicals (evidence of non-carcinogenicity in humans) are agents for which there is no evidence of carcinogenicity in adequate human or animal studies.

9.3.1.2 Health Effects Criteria for Noncarcinogens. Health effects criteria for noncarcinogenic chemicals are termed reference doses (RfDs). These criteria are generally developed by the EPA RfD Work Group, or are obtained from Health Effects Assessments (HEAs). The RfD, expressed in units of mg/kg-day, is an estimate of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. These RfDs are usually derived either from human studies involving workplace exposures or from animal studies, and are adjusted using uncertainty factors. The RfD provides a benchmark to which chemical intakes may be evaluated.

9.3.2 Health Effects Criteria for the Chemicals of Potential Concern

Tables 9-18 and 9-19 present chronic health effects criteria for oral and inhalation exposures, respectively. RfDs and slope factors are presented for those chemicals for which exposures are being evaluated.

No EPA-approved oral toxicity criteria are available for aluminum, calcium, cobalt, iron, lead, magnesium, potassium, sodium and tetryl. Therefore potential risks associated with exposure to these chemicals are not quantitatively evaluated. The potential contribution of these chemicals to the overall estimates of risk for each exposure pathway is discussed qualitatively in the risk characterization sections. It should be noted, that calcium, cobalt, iron, potassium, and sodium are essential human nutrients and are toxic only at very high doses. Because of their low toxicity, it is unlikely that contact with these chemicals at the site would result in adverse health effects.

No inhalation toxicity criteria are available for 1,3-DNB, 2,4- and 2,6-DNT, HMX, lead, RDX, silver, 1,3,5-TNB, 2,4,6-TNT, and zinc. Therefore, potential risks associated with exposure to these chemicals via inhalation are not quantitatively evaluated. A qualitative discussion of potential risks associated with these chemicals will be included in the risk characterization section. Toxicity summaries for all chemicals of potential concern are included in Appendix P.

TABLE 9-18

ORAL CRITICAL TOXICITY VALUES FOR CHEMICALS OF POTENTIAL CONCERN AT MAAP

Chemical	Chronic Reference Dose (mg/kg-day)	Uncertainty Factor (a)	Target Organ (b)	Reference Dose Source	Cancer Slope Factor (mg/kg-day)-1	EPA Weight of Evidence Classification (c)	Slope Factor Source
Organic Chemicals:							
Acetone	1.0E-01	1,000	Kidney/Liver	IRIS	--	D	IRIS
Bromodichloromethane	2.0E-02	1,000	Kidney	IRIS	1.3E-01	B2	IRIS
Bromoform	2.0E-02	1,000	Liver	IRIS	7.9E-03	B2	IRIS
Carbon disulfide	1.0E-01	100	Fetus	IRIS	--	--	--
Chloroform	1.0E-02	1,000	Liver	IRIS	6.1E-03	B2	IRIS
Dibromochloromethane	2.0E-02	1,000	Liver	IRIS	8.4E-02	C	IRIS
Diethylphthalate	8.0E-01	1,000	Body weight	IRIS	--	D	IRIS
1,3-DNB	1.0E-04	3,000	Spleen/Weight	IRIS	--	--	--
DNT (2,4-,2,6-)	--	--	--	HEAST	6.8E-01	B2	HEAST
Di-n-octylphthalate	2.0E-02	1,000	Liver/Kidney	HEAST	--	--	--
Ethyl Benzene	1.0E-01	1,000	Liver/Kidney	IRIS	--	D	IRIS
bis(2-Ethylhexyl)phthalate	2.0E-02	1,000	Liver	IRIS	1.4E-02	B2	IRIS
HMX	5.0E-02	1000	Liver	IRIS	--	D	IRIS
Nitrobenzene	5.0E-04	10,000	Kidney/Liver	IRIS	--	D	IRIS
RDX	3.0E-03	100	Prostate	IRIS	1.1E-01	C	IRIS
1,1,2,2-Tetrachloroethane	4.6E-04	1,000	Liver/White Blood Cells	(d)	2.0E-01	C	IRIS
Tetryl	--	--	--	--	--	--	--
Toluene	2.0E-01	1,000	Liver/Kidney	IRIS	--	D	IRIS
1,1,2-Trichloroethane	4.0E-03	1,000	Liver	IRIS	5.7E-02	C	IRIS
Trichloroethene	7.3E-03	1,000	Liver	HA	1.1E-02	B2	HEAST
Trichlorofluoromethane	3.0E-01	1,000	Mortality	IRIS	--	--	--
1,3,5-TNB	5.0E-05	10,000	Spleen	IRIS	--	--	--
2,4,6-TNT	5.0E-04	1,000	Liver	IRIS	3.0E-02	C	IRIS
Xylenes (total)	2.0E+00	100	CNS/Mortality	IRIS	--	D	IRIS
Inorganic Chemicals:							
Aluminum	--	--	--	HEAST	--	--	--
Arsenic	1.0E-03	1	Skin	HEAST	2.0E+00 (e)	A	IRIS
Barium	7.0E-02	3	Cardiovascular System	IRIS	--	--	--
Cadmium (water)	5.0E-04	10	Kidney	IRIS	--	--	IRIS
(food)	1.0E-03	10	Kidney	IRIS	--	--	IRIS
Calcium	--	--	--	--	--	--	--
Chromium VI and compounds	5.0E-03	500	CNS	IRIS	--	--	IRIS
Cobalt	--	--	--	--	--	--	--
Copper	3.7E-02 (f)	1	Gastrointestinal Tract	HEAST	--	--	--
Iron	--	--	--	HEAST	--	--	--
Lead	--	--	--	IRIS	--	B2	IRIS
Magnesium	--	--	--	--	--	--	--
Manganese	1.0E-01	1	CNS	IRIS	--	D	IRIS
Mercury, inorganic	3.0E-04	1,000	Kidney	HEAST	--	D	IRIS
Nickel	2.0E-02	300	Body weight	IRIS	--	--	IRIS
Potassium	--	--	--	--	--	--	--
Silver	3.0E-03	2	Skin (Argyria)	IRIS	--	--	--
Sodium	--	--	--	--	--	--	--
Vanadium	7.0E-03	100	None observed	HEAST	--	--	--
Zinc	2.0E-01	10	Blood (Anemia)	HEAST	--	--	--

See footnotes on the following page.

ORAL CRITICAL TOXICITY VALUES FOR CHEMICALS OF POTENTIAL CONCERN AT MAAP

(a) Safety factors are the products of uncertainty factors and modifying factors. Uncertainty factors used to develop reference doses generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors include the following:
- a 10-fold factor to account for the variation in sensitivity among the members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs; and
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

Modifying factors are applied at the discretion of the reviewer to cover other uncertainties in the data.

(b) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies;
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies; and
[D] = Not classified as to human carcinogenicity.

(d) Interim RfD approved by ECAO, Cincinnati.

(e) USEPA, 1988c. Special report on ingested inorganic arsenic skin cancer; nutritional essentiality. Risk assessment forum. EPA, Washington, D.C. EPA/625/3-87/013F. July 1988.

(f) Drinking water standard reported in mg/L was converted to mg/kg-day by assuming a 70 kg adult drinks 2 liters of water per day.

NOTE: IRIS = Integrated Risk Information System - March 1, 1991.
HA = Health Advisory.
HEAST = Health Effects Assessment Summary Tables - First Quarter 1991.
-- = No information available.

TABLE 9-19

INHALATION CRITICAL TOXICITY VALUES FOR CHEMICALS OF POTENTIAL CONCERN AT MAAP

Chemical	Chronic Reference Dose (mg/kg-day)	Uncertainty Factor (a)	Target Organ (b)	Reference Dose Source	Cancer Slope Factor (mg/kg-day)-1	EPA Weight of Evidence Classification (c)	Slope Factor Source
Organic Chemicals:							
1,3-DNB	--	--	--	IRIS	--	--	--
DNT (2,4-,2,6-)	--	--	--	IRIS	--	B2	HEAST
HMX	--	--	--	IRIS	--	D	IRIS
Nitrobenzene	5.7E-04 (d)	3,000	Liver/Kidney	HEAST	--	D	IRIS
RDX	--	--	--	IRIS	--	C	IRIS
1,3,5-TNB	--	--	--	IRIS	--	--	--
2,4,6-TNT	--	--	--	IRIS	--	C	IRIS
Inorganic Chemicals:							
Arsenic	--	--	Cancer	IRIS	5.0E+01	A	IRIS
Chromium VI and compounds	5.7E-07 (d)	300	Nasal mucosa	HEAST	4.2E+01 (e)	A	IRIS
Lead	--	--	CNS	IRIS	--	B2	IRIS
Mercury, inorganic	9.0E-05 (d)	30	Neurotoxicity	HEAST	--	D	IRIS
Silver	--	--	--	IRIS	--	--	--
Zinc	--	--	--	HEAST	--	--	--

(a) Safety factors are the products of uncertainty factors and modifying factors. Uncertainty factors used to develop reference doses generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors include the following:
- a 10-fold factor to account for the variation in sensitivity among the members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs; and
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

Modifying factors are applied at the discretion of the reviewer to cover other uncertainties in the data.

(b) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies;
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies; and
[D] = Not classified as to human carcinogenicity.

(d) Inhalation RfD reported in mg/m3 was converted to mg/kg-day by assuming a 70 kg adult inhales 20 m3/day.

(e) Inhalation Cancer Slope Factor reported in (ug/m3)-1 was converted to (mg/kg-day)-1 by assuming a 70 kg adult inhales 20 m3/day.

NOTE: IRIS = Integrated Risk Information System - April 1, 1991.
HEAST = Health Effects Assessment Summary Tables - Fourth Quarter, 1990.
-- = No information available.

9.4 HUMAN HEALTH RISK ASSESSMENT

This section presents quantitative risk estimates for the exposure pathways and chemicals examined in this assessment. To calculate risks, the chronic daily intakes estimated for each chemical of potential concern were combined with health effects criteria (slope factors or RfDs).

For potential carcinogens, excess lifetime cancer risks are obtained by multiplying the CDI for each chemical by its cancer slope factor. A risk level of 10^{-6} represents a probability of one in 1,000,000 that an individual could contract cancer due to exposure to the potential carcinogen. The upper-bound lifetime excess cancer risks derived in this report can be compared to EPA's risk range for health protectiveness at Superfund sites. EPA recommends that the total cancer risk to individuals resulting from exposure at a Superfund site be reduced to zero where possible. EPA has implemented actions under Superfund associated with total cancer risks ranging from 10^{-4} to 10^{-6}.

Potential risks for noncarcinogens are presented as the ratio of the CDI to the reference dose (CDI:RfD) or as the ratio of the exposure concentration to the reference concentration. Ratios that are greater than one indicate the potential for adverse effects to occur, while ratios less than one indicate that adverse effects are unlikely to occur.

The sum of the CDI:RfD ratios is referred to as the hazard index. The hazard index is useful as a reference point for gauging the potential effects of environmental exposures to complex mixtures. In general, hazard indices that are less than one are not likely to be associated with adverse health effects, and are therefore less likely to be regulatory concern than hazard indices greater than one. A conclusion should not be categorically drawn, however, that all hazard indices less than one are "acceptable" or that hazard indices of greater than one are "unacceptable." This is a consequence of the possible one order of magnitude or greater uncertainty inherent in estimates of the RfD and CDI, in addition to the fact that the uncertainties associated with the individual terms in the hazard index calculation are additive.

In the absence of specific information on the toxicity of the mixture of chemicals to be assessed or on similar mixtures, EPA guidelines recommend assuming that the effects of different components on the mixtures are additive when affecting a particular organ or system. Synergistic or antagonistic interactions may be taken into account if there is specific information on particular combinations of chemicals. Information on the toxic effects of the specific chemical mixtures in the various environmental media at MAAP are not available. Accordingly, it is assumed in this assessment that the toxic effects of the chemical of potential concern are additive. Thus, lifetime excess cancer risks and the CDI:RfD ratios for individual chemicals are summed to indicate the potential risks associated with mixtures of potential carcinogens and noncarcinogens, respectively. In this assessment, CDI:RfD ratios are summed across all chemicals exhibiting noncarcinogenic effects. If the hazard index resulting from this summation exceeds one, the contribution of chemicals affecting the same target organ is analyzed.

The exposure pathways selected for quantitative or qualitative evaluation are:

- Inhalation exposures of workers and nearby residents to chemicals adsorbed onto wind-generated dust from surface soils at the OBG;
- Residential drinking water exposures to future groundwater users at the northern and northwestern boundaries of MAAP and to current users of off-site wells;

- Residential inhalation and dermal exposures during in-home use of groundwater; and
- Ingestion of deer killed at MAAP.

The potential risks associated with each of these pathways are discussed below.

9.4.1 Ingestion of Groundwater

Risks associated with future residential use of groundwater at the northern and northwestern MAAP boundary and associated with current use of groundwater in off-post wells were evaluated in this assessment. Tables 9-20 through 9-22 present the estimated CDIs, toxicity criteria and risks for groundwater users in these areas. These risks are discussed below.

The risk evaluation below does not include risks associated with exposure to aluminum, calcium, iron, magnesium, potassium, sodium and tetryl, as oral toxicity criteria have not been developed for these chemicals. This will result in under-estimates of the risks and hazards associated with the groundwater pathway, although this is unlikely to change the conclusions regarding this pathway.

9.4.1.1 Future Groundwater Ingestion Exposures at the Northern Boundary. As shown in Table 9-20, excess lifetime cancer risk estimates associated with groundwater ingestion exposures for future residents at the northern MAAP boundary are $1x10^{-4}$, due primarily to RDX, 2,4,6-TNT and arsenic. This value is above the risk level of $1x10^{-6}$ often used by regulatory agencies in determining the need for corrective action at hazardous waste sites. It is important to note, however, that half of this risk is caused by RDX and 2,4,6-TNT which are Class C carcinogens (i.e., possible human carcinogens based on only limited evidence from animal studies). The other half of this risk is caused by arsenic at an exposure concentration of 1.9 μg/L. This concentration is very low and may in fact represent background concentrations of arsenic in the area. As a result, potential excess lifetime cancer risks at the northern boundary may be over-estimated.

As noted in Table 9-20, the Hazard Index for ingestion of groundwater from the northern boundary of MAAP is greater than one. When the hazard index for a particular pathway is greater than one, the chemicals of potential concern are grouped with respect to target organ toxicity. The CDI:RfD ratio exceeds 1 for several organs or systems: the spleen, due to 1,3,5-TNB; the liver, primarily due to 2,4,6-TNT, and the central nervous system, due to manganese.

Although there is a risk and hazard associated with this pathway, it should be noted that the northern boundary of MAAP is in a floodplain, and it is unlikely that people would build there in the future. Therefore, any exposures via ingestion of groundwater would be unlikely to occur here.

9.4.1.2 Future Groundwater Exposures at the Northwestern Boundary. As shown in Table 9-21, excess lifetime cancer risk estimates associated with groundwater ingestion exposures for future residents at the northwestern boundary are $2x10^{-4}$ (again above the risk level of 10^{-6}), due primarily to RDX and arsenic.

Once again, it should be noted that the RME concentration of arsenic in the groundwater was low (5.1 μg/L) and may be present at background concentrations. In addition, since RDX is a Class C carcinogen, potential carcinogenic risks associated with drinking groundwater at the northwestern boundary may be over-estimated.

As noted in Table 9-21, the Hazard Index for ingestion of groundwater in the future from the northern boundary of MAAP is greater than one. The CDI:RfD ratio exceeds 1 for the spleen, due to 1,3,5-TNB and for vanadium (which has no specific target organ associated with its effects).

TABLE 9-20

POTENTIAL RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER BY FUTURE RESIDENTS AT THE NORTHERN BOUNDARY OF MAAP (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Organic Chemicals:				
Chloroform (CHCL3)	6.5E-06	6.1E-03	B2	4E-08
2,4-DNT (24DNT)	2.3E-06	6.8E-01	B2	2E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	9.1E-05	1.4E-02	B2	1E-06
RDX (RDX)	4.6E-04	1.1E-01	C	5E-05
2,4,6-TNT (246TNT)	4.7E-04	3.0E-02	C	1E-05
Inorganic Chemicals:				
Arsenic (AS)	3.1E-05	2.0E+00	A	6E-05

Total	--	--	--	1E-04

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Organic Chemicals:					
Chloroform (CHCL3)	1.5E-05	1.0E-02	1,000	Liver	2E-03
1,3-DNB (13DNB)	7.6E-06	1.0E-04	3,000	Spleen/Weight	8E-02
bis(2-Ethylhexyl)phthalate (B2EHP)	2.1E-04	2.0E-02	1,000	Liver	1E-02
HMX (HMX)	1.3E-04	5.0E-02	1,000	Liver	3E-03
Nitrobenzene (NB)	2.7E-05	5.0E-04	10,000	Liver/Kidney	5E-02
RDX (RDX)	1.1E-03	3.0E-03	100	Prostate	4E-01
1,3,5-TNB (135TNB)	1.7E-04	5.0E-05	10,000	Spleen	3E+00
2,4,6-TNT (246TNT)	1.1E-03	5.0E-04	1,000	Liver	2E+00
Inorganic Chemicals:					
Arsenic (AS)	7.2E-05	1.0E-03	1	Skin	7E-02
Barium (BA)	1.4E-02	7.0E-02	3	Cardiovasc. system	2E-01
Cadmium (CD)	5.3E-05	5.0E-04 (f)	10	Kidney	1E-01
Chromium (CR)	2.0E-04	5.0E-03 (g)	500	CNS	4E-02
Manganese (MN)	6.1E-01	1.0E-01	1	CNS	6E+00
Mercury (HG)	3.8E-06	3.0E-04	1,000	Kidney	1E-02
Silver (AG)	4.9E-04	3.0E-03	2	Skin (Argyria)	2E-01
Vanadium (V)	9.5E-04	7.0E-03	100	None observed	1E-01
Zinc (ZN)	9.1E-03	2.0E-01	10	Anemia	5E-02

Hazard Index (h)	--	--	--	--	>1 (1E+01)

(a) Risks are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals are not presented due to lack of oral toxicity criteria: aluminum, calcium, iron, magnesium, potassium, sodium and tetryl.

(b) USATHAMA chemical codes are listed in parentheses.

(c) EPA Weight of Evidence for Carcinogenic Effects:

[A] = Human carcinogen based on adequate evidence from human studies.

[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;

[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.

(d) Factor that reflects the uncertainty in the estimated RfD. Larger factors are associated with greater uncertainty.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.

(f) Value reported is cadmium ingested with water.

(g) RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.

(h) The hazard index is the sum of the CDI:RfD ratios for the chemicals listed.

TABLE 9-21

POTENTIAL RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER
BY FUTURE RESIDENTS AT THE NORTHWESTERN BOUNDARY OF MAAP (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Organic Chemicals:				
2,4-DNT (24DNT)	6.5E-07	6.8E-01	B2	4E-07
bis(2-Ethylhexyl)phthalate (B2EHP)	5.0E-04	1.4E-02	B2	7E-06
RDX (RDX)	1.1E-04	1.1E-01	C	1E-05
2,4,6-TNT (246TNT)	5.9E-06	3.0E-02	C	2E-07
Inorganic Chemicals:				
Arsenic (AS)	8.3E-05	2.0E+00	A	2E-04
Total	--	--	--	2E-04

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Organic Chemicals:					
Acetone (ACET)	4.6E-04	1.0E-01	1,000	Kidney/Liver	5E-03
1,3-DNB (13DNB)	2.3E-07	1.0E-04	3,000	Spleen/Weight	2E-03
Ethylbenzene (ETC6H5)	1.8E-04	1.0E-01	1,000	Liver/Kidney	2E-03
bis(2-Ethylhexyl)phthalate (B2EHP)	1.2E-03	2.0E-02	1,000	Liver	6E-02
HMX (HMX)	1.3E-05	5.0E-02			3E-04
RDX (RDX)	2.6E-04	3.0E-03	100	Prostate	9E-02
1,3,5-TNB (135TNB)	2.4E-04	5.0E-05	10,000	Spleen	5E+00
2,4,6-TNT (246TNT)	1.4E-05	5.0E-04	1,000	Liver	3E-02
Toluene (MEC6H5)	4.6E-05	2.0E-01	1,000	Liver/Kidney	2E-04
Xylenes [total] (XYLEN)	1.1E-04	2.0E+00	100	CNS, Mortality	5E-05
Inorganic Chemicals:					
Arsenic (AS)	1.9E-04	1.0E-03	1	Skin	2E-01
Barium (BA)	2.1E-02	7.0E-02	3	Cardiovasc. syst	3E-01
Cadmium (CD)	1.7E-04	5.0E-04 (f)	10	Kidney	3E-01
Chromium (CR)	6.0E-04	5.0E-03 (g)	500	CNS	1E-01
Copper (CU)	2.8E-03	3.7E-02 (h)	1	GI Tract	7E-02
Manganese (MN)	2.8E-02	1.0E-01	1	CNS	3E-01
Mercury (HG)	7.6E-06	3.0E-04	1,000	Kidney	3E-02
Nickel (NI)	1.6E-03	2.0E-02 (i)	300	Body Weight	8E-02
Silver (AG)	7.6E-06	3.0E-03	2	Skin (Argyria)	3E-03
Vanadium (V)	1.0E-02	7.0E-03	100	None observed	1E+00
Zinc (ZN)	9.9E-03	2.0E-01	10	Anemia	5E-02
Hazard Index (j)	--	--	--	--	>1 (8E+00)

(a) Risks are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals are not presented due to lack of oral toxicity criteria: aluminum, calcium, cobalt, iron, magnesium, potassium, and sodium.
(b) USATHAMA chemical codes are listed in parentheses.
(c) EPA Weight of Evidence for Carcinogenic Effects:
  [A] = Human carcinogen based on adequate evidence from human studies.
  [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
  [C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.
(d) Factor which reflects the uncertainty in the estimated of the RfD. Larger factors are associated with greater uncertainty.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.
(f) Value shown is cadmium ingested with water.
(g) RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.
(h) Drinking water standard reported in mg/L converted to mg/kg-day assuming a 70 kg adult drinks 2 liters of water per day.
(i) Value shown was derived for nickel soluble salts.
(j) The hazard index is the sum of the CDI:RfD ratios for the chemicals listed.

TABLE 9-22

POTENTIAL RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER CURRENT BY OFF-SITE RESIDENTS

Chemicals Exhibiting Noncarcinogenic Effects (a)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (b)	Target Organ (c)	CDI:RfD Ratio
Inorganic Chemicals:					
Cadmium (CD)	2.4E-03	5.0E-04 (d)	10	Kidney	5E+00
Chromium (CR)	1.9E-03	5.0E-03 (e)	500	CNS	4E-01
Hazard Index (f)	--	--	--	--	>1 (5E+00)

(a) USATHAMA chemical codes are listed in parentheses.
(b) Factor that reflects the uncertainty in the estimated RfD. Larger factors are associated with greater uncertainty.
(c) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.
(d) Value reported is cadmium ingested with water.
(e) RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.
(f) The hazard index is the sum of the CDI:RfD ratios for the chemicals listed.

9.4.1.3 Groundwater Exposures by Off-Site Residents. As shown in Table 9-22, hazards associated with groundwater ingestion exposures for residents who live at the northwest corner of MAAP and obtain their water from their own wells is greater than one. Only two inorganic chemicals were detected during sampling at these off-site wells. The CDI:RfD ratio exceeds 1 for the kidney, due to cadmium.

There is some uncertainty associated with the sampling results upon which these risks were based. The two existing residential off-site wells were sampled in 1990 by the State of Tennessee and Martin Marietta personnel. Sampling results from June 1990 showed that only barium (50 µg/L to 79 µg/L) exceeded assumed background concentrations (2 times the detection limit of 7.28 µg/L) in the two residential wells. Although sampling results from this RI showed that concentrations of cadmium and chromium exceeded background levels in the off-site wells, these two chemicals were not detected in the two existing residential wells. Elevated levels of cadmium and chromium were detected in only three of the five newly-installed wells. The cause of this is unknown. If a cadmium and chromium plume were emanating from the site, it seems more likely that all of the wells would show evidence of contamination. One possible reason for the high cadmium and chromium levels is that some of the wells did not fully stabilize. It should be noted, therefore, that there is uncertainty associated with the hazards calculated for this pathway.

9.4.1.4 Inhalation and Dermal Exposures During In-home Use of Groundwater. Persons using groundwater from the northern and northwestern boundary of MAAP in the future also could be exposed to organic chemicals of concern via inhalation of chemicals that have volatilized during use, and via dermal absorption. Inhalation exposures to volatile chemicals are not expected to be significant, as few volatile chemicals were detected in groundwater, and those that were, were detected at low concentrations. Dermal exposures could occur but are likely to be small relative to those associated with ingestion exposures.

9.4.2 Inhalation Exposures

As discussed in Section 9.2.2.5, workers at the OBG and residents who live approximately one mile to the east of the OBG could be exposed to chemicals adsorbed onto dust generated by wind erosion of surface soils at the OBG. Estimated CDIs, toxicity criteria, TLVs, and risks for this pathway are presented in Tables 9-23 through 9-25.

It is important to note that inhalation toxicity criteria have not been developed for the majority of the chemicals of potential concern in the OBG surface soil. Specifically, inhalation toxicity criteria have not been developed for HMX, lead, RDX, silver, 1,3,5-TNB, 2,4,6-TNT, and zinc. This will result in an underestimation of the risks and hazard indices for this pathway.

Exposures to lead are not evaluated in the same manner as the other chemicals of potential concern. Instead, exposures to lead are evaluated for 1-6 year olds using the Integrated Uptake/Biokinetic (IU/BK) lead uptake model (USEPA, 1990b), since this age group is most susceptible to adverse effects as a result of lead exposure. It is therefore not relevant to evaluate adult exposures (i.e., workers) with this model. Since modeled concentrations of lead in the air at the boundary of MAAP are too low to provide accurate modeling for the IU/BK model, it could not be used for residential exposures to lead. Instead, a comparison was made between the modeled on- and off-site air concentrations of lead and the National Ambient Air Quality Standards (NAAQS) (i.e., health-based ambient air concentrations for criteria pollutants, set by the EPA).

As shown on Table 9-5, the modeled air concentration of lead at the OBG is 0.013 µg/m^3, while the predicted off-site concentration of lead is 0.00073 µg/m^3. The NAAQS quarterly standard for lead is 1.5 µg/m^3. Since the modeled concentrations represent annual average concentrations, and the NAAQS represents a quarterly standard, it is inappropriate to make direct comparisons. However, because the modeled concentrations are several orders of magnitude lower than the NAAQS, it was assumed that the

TABLE 9-23

POTENTIAL RISKS ASSOCIATED WITH INHALATION OF WIND-BLOWN DUSTS BY WORKERS AT THE OBG (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Inorganic Chemicals:				
Arsenic (AS)	2.3E-08	5.0E+01	A	1E-06
Chromium (CR)	2.8E-07	4.2E+01 (d,e)	A	1E-05
Total	--	--	--	1E-05

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (f)	Target Organ (g)	CDI:RfD Ratio
Organic Chemicals:					
Nitrobenzene (NB)	6.0E-08	5.7E-04 (h)	3,000	Liver/Kidney	1E-04
Inorganic Chemicals:					
Chromium (CR)	6.5E-07	5.7E-07 (d,h)	300	Nasal mucosa	1E+00
Mercury (HG)	2.6E-08	9.0E-05 (h)	30	Neurotoxicity	3E-04
Hazard Index (h)	--	--	--	--	>1 (1E+00)

(a) Risks are calculated only for chemicals of potential concern with inhalation toxicity criteria. The following chemicals are not presented due to lack of inhalation toxicity criteria: HMX, lead, RDX, silver, 1,3,5-TNB, 2,4,6-TNT and zinc.
(b) USATHAMA chemical codes are listed in parentheses.
(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies.
(d) The Cancer Slope Factor and RfD reported are for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.
(e) Inhalation Cancer Slope Factor reported in (ug/m3)-1 was converted to (mg/kg-day)-1 by assuming a 70 kg adult inhales 20 m3/day.
(f) Factor that reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.
(g) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.
(h) Inhalation RfD reported in mg/m3 was converted to mg/kg-day by assuming a 70 kg adult inhales 20 m3/day.
(i) The hazard index is the sum of the CDI:RfD ratios for the chemicals listed.

TABLE 9-24

THRESHOLD LIMIT VALUES FOR CHEMICALS OF POTENTIAL CONCERN IN SURFACE SOIL

Chemical (a)	Air Concentration at the OBG (mg/m3)	8-Hour TLV (mg/m3) (b)
Explosives		
HMX (HMX)	3.5E-05	NA
Nitrobenzene (NB)	4.5E-07	5.0E+00 (c)
RDX (RDX)	3.4E-04	1.5E+00 (c)
1,3,5-TNB (135TNB)	2.4E-07	NA
2,4,6-TNT (246TNT)	4.3E-04	5.0E-01 (c)
Inorganic Chemicals		
Arsenic (AS)	1.4E-06	2.0E-01
Chromium (CR)	4.9E-06	5.0E-02 (d)
Lead (PB)	1.3E-05	1.5E-01
Mercury (HG)	2.0E-07	1.0E-01 (e)
Silver (AG)	1.4E-08	1.0E-02 (f)
Zinc (ZN)	1.3E-05	1.0E+01 (g)

(a) USATHAMA chemical codes are listed in parentheses.
(b) ACGIH (1990).
(c) The TLV is based on absorption of the chemical through the skin.
(d) The TLV listed is for chromium VI, as all chromium is conservatively assumed to be in this more toxic form.
(e) The TLV is for aryl and inorganic compounds.
(f) The TLV is for soluble compounds, as Ag.
(g) The TLV is for zinc oxide dusts.

NA = Not Available. No TLV was available for this chemical.

TABLE 9-25

POTENTIAL RISKS ASSOCIATED WITH INHALATION OF WIND-BLOWN DUSTS BY RESIDENTS ALONG THE EASTERN BOUNDARY OF MAAP (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Inorganic Chemicals:				
Arsenic (AS)	2.8E-09	5.0E+01	A	1E-07
Chromium (CR)	3.4E-08	4.2E+01 (d,e)	A	1E-06
Total	--	--	--	2E-06

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (f)	Target Organ (g)	CDI:RfD Ratio
Organic Chemicals:					
Nitrobenzene (NB)	1.4E-09	5.7E-04 (h)	3,000	Liver/Kidney	2E-06
Inorganic Chemicals:					
Chromium (CR)	7.9E-08	5.7E-07 (d,h)	300	Nasal mucosa	1E-01
Mercury (HG)	3.1E-09	9.0E-05 (h)	30	Neurotoxicity	3E-05
Hazard Index (i)	--	--	--	--	<1 (1E-01)

(a) Risks are calculated only for chemicals of potential concern with inhalation toxicity criteria. The following chemicals are not presented due to lack of inhalation toxicity criteria: HMX, lead, RDX, silver, 1,3,5-TNB, 2,4,6-TNT and zinc.

(b) USATHAMA chemical codes are listed in parentheses.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies.

(d) The Cancer Slope Factor and RfD reported are for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.

(e) Inhalation Cancer Slope Factor reported in (ug/m3)-1 was converted to (mg/kg-day)-1 by assuming a 70 kg adult inhales 20 m3/day.

(f) Factor that reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(g) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

(h) Inhalation RfD reported in mg/m3 was converted to mg/kg-day by assuming a 70 kg adult inhales 20 m3/day.

(i) The hazard index is the sum of the CDI:RfD ratios for the chemicals listed.

concentrations to which workers and residents are exposed are within acceptable levels, and these receptor populations would not have adverse health effects as a result of exposure to lead in ambient air.

9.4.2.1 Worker Exposures. Inhalation exposures to workers were evaluated in two ways. First, cancer slope factors and reference doses were combined with worker CDIs to obtain an upper-bound excess lifetime cancer risk and hazard index. Second, a comparison was made between ambient air concentrations of the chemicals of potential concern at the OBG and Threshold Limit Values (TLVs) developed by the American Conference of Governmental Industrial Hygienists (ACGIH). TLVs have been developed for a large number of chemicals and are the chemical concentration in air to which a worker could be exposed for 8 hours a day, 5 days a week without adverse health effects. This comparison was made to determine whether estimated worker exposures exceeded those standards set for the workplace.

The CDIs are presented in Table 9-23, along with risk estimates associated with inhalation exposures. The excess lifetime cancer risk for the RME case is 1×10^{-5} (below the risk level of 10^{-3} for workers [Rodricks et al. 1987]), due to chromium. The estimated chromium risk was generated based on the assumption that all chromium in the surface soils at the OBG is in the hexavalent (VI) form. The form of chromium in the surface soils of the OBG is not known, but it is possible that chromium is in the trivalent (III) state, which is readily adsorbed or precipitated onto particulate matter. Chromium (VI) is a known human carcinogen whereas chromium (III) is noncarcinogenic. Therefore, the assumption that all chromium is in the hexavalent state has important ramifications on the risk estimate. If all chromium is in the trivalent state, the cancer risk estimate would be due to arsenic alone, which was present in the soils of the OBG at a maximum concentration of 9.8 mg/kg. This arsenic concentration may be within the range of background concentrations for this area.

The Hazard Index for worker inhalation exposures at the OBG is greater than one. The CDI:RfD ratio exceeds 1 for the nasal mucosa, due to inhalation of chromium.

The second method for evaluating worker exposures is a comparison of the unit air chemical concentrations to which the workers could be exposed, and the TLVs. The TLVs used in this assessment were time-weighted average (TWA) air concentrations for an 8-hour work day and 40-hour work week. It should be noted that TWAs for nitrobenzene, RDX and 2,4,6-TNT were based on the dermal absorption of chemicals in a vapor phase. Although use of the TLVs for these chemicals is not directly applicable to TLVs for inhalation exposures to dust, they are nevertheless used here to provide a conservative estimate of possible worker hazards.

When evaluating worker exposures, TLVs are most appropriately compared to 8-hour average air concentrations. However, the air concentrations estimated for the OBG area are annual average air concentrations, instead of 8-hour average concentrations. Eight-hour average concentrations could not be estimated for the OBG but could be approximately an order-of-magnitude larger than annual average concentrations.

The TWA-TLVs for the chemicals of concern that could be present in wind-blown particulate matter are presented in Table 9-24. As the comparisons in the table show, the estimated ambient air concentrations for the chemicals of concern are between three and seven orders-of-magnitude below the TWA-TLVs. Even given the perhaps order-of-magnitude difference between 8-hour and annual average air concentrations, this suggests that workers are not at risk from exposures to wind-blown dusts at the OBG.

9.4.2.2 Residential Exposures. Table 9-25 presents the estimated chronic daily intakes and inhalation risks for residents living approximately one mile east of the OBG.

The excess lifetime cancer risk for the RME case is 2×10^{-6}. This value is above the risk level of 1×10^{-6}, due to inhalation exposures to chromium (VI). If chromium is present in the trivalent state rather than the hexavalent state as assumed in this risk assessment, the estimated cancer risks would be less than 10^{-6}.

As shown in Table 9-25, all of the individual hazard indices as well as the total hazard index are below a value of one. The total hazard index for inhalation exposures for residents one mile from the OBG area is ten times below a value of one. This indicates that adverse noncarcinogenic effects are unlikely to occur for residents for this exposure pathway.

9.4.3 Ingestion of Venison

As discussed in Section 9.3.3.2, deer hunters at MAAP and others who consume deer killed at MAAP could be exposed to chemicals that have accumulated in deer. Estimated CDIs, toxicity criteria and risks for this pathway are presented in Table 9-26.

As shown in Table 9-26, the excess lifetime cancer risk estimate associated with consumption of venison is 7×10^{-8}. This is well below EPA's target risk range of 10^{-6} to 10^{-4} for Superfund sites.

All of the individual hazard indices as well as the total hazard index were below a value of one, as shown in Table 9-26. The total hazard index for ingestion of venison was three orders-of-magnitude below the value of one. This indicates that adverse noncarcinogenic effects are unlikely to occur for those who consume venison from MAAP.

Oral toxicity criteria have not been developed for aluminum, calcium, cobalt, iron, lead, magnesium, potassium, sodium and tetryl. Excluding these chemicals from quantitative evaluation could result in an under-estimation of the risk and hazard indices for this pathway, although this is unlikely to change the conclusions regarding the lack of risks or hazard associated with this pathway.

9.5 ENVIRONMENTAL ASSESSMENT

This section assesses potential impacts to nonhuman receptors associated with the chemicals of potential concern at the MAAP site. The approaches used in this environmental assessment roughly parallel those used in human health risk assessment. Below, potentially exposed populations (receptors) are identified, and then information on exposure and toxicity is combined to derive qualitative or quantitative estimates of impact.

9.5.1 Receptor Characterization

The MAAP site is located in a rural agricultural area which occupies parts of both Gibson and Carroll Counties, Tennessee. The terrain of MAAP consists mainly of gently rolling hills and numerous small drainage courses. A brief description of terrestrial and aquatic habitats and potential receptors is presented below.[2]

9.5.1.1 Terrestrial Habitats and Receptors. The natural vegetation of the installation has been largely altered due to human activities. Approximately 13,600 of the 22,540 total acres is leased for agricultural purposes. 3,984 acres are used as cropland, cultivated primarily for cotton, corn, and soybean, and also grain sorghum and wheat. These crops are largely used for livestock feed. 8,700 acres of land is used as pastureland, and over 6,000 acres is managed timberland..

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[2] Common species names are used in this section. Appendix Q provides a complete list of common and scientific names for the species mentioned in this report.

TABLE 9-26

ESTIMATED RISKS ASSOCIATED WITH INGESTION OF VENISON FROM MAAP (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Organic Chemicals:				
Bromodichloromethane (BRDCLM)	1.2E-13	1.3E-01	B2	2E-14
Bromoform (CHBR3)	2.3E-12	7.9E-03	B2	2E-14
Dibromochloromethane (DBRCLM)	1.8E-13	8.4E-02	C	2E-14
2,4-DNT (24DNT)	4.4E-14	6.8E-01	B2	3E-14
RDX (RDX)	2.3E-13	1.1E-01	C	3E-14
1,1,2,2-Tetrachloroethane (TCLEA)	1.4E-13	2.0E-01	C	3E-14
2,4,6-TNT (246TNT)	1.2E-13	3.0E-02	C	4E-15
1,1,2-Trichloroethane (112TCE)	1.8E-13	5.7E-02	C	1E-14
Trichloroethene (TRCLE)	1.5E-13	1.1E-02	B2	2E-15
Inorganic Chemicals:				
Arsenic (AS)	3.4E-08	2.0E+00	A	7E-08
Total	--	--	--	7E-08

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Organic Chemicals:					
Acetone (ACET)	9.3E-17	1.0E-01	1,000	Kidney/Liver	9E-16
Bromodichloromethane (BRDCLM)	2.8E-13	2.0E-02	1,000	Kidney	1E-11
Bromoform (CHBR3)	5.3E-12	2.0E-02	1,000	Liver	3E-10
Carbon Disulfide (CS2)	1.3E-13	1.0E-01	100	Fetus	1E-12
Dibromochloromethane (DBRCLM)	4.2E-13	2.0E-02	1,000	Liver	2E-11
Diethylphthalate (DEP)	1.0E-11	8.0E-01	1,000	Body weight	1E-11
Di-n-octylphthalate (DNOP)	3.9E-09	2.0E-02	1,000	Liver/Kidney	2E-07
HMX (HMX)	2.0E-14	5.0E-02	1,000	Liver	4E-13
Nitrobenzene (NB)	1.3E-13	5.0E-04	10,000	Kidney/Liver	3E-10
RDX (RDX)	5.4E-13	3.0E-03	100	Prostate	2E-10
1,1,2,2-Tetrachloroethane (TCLEA)	3.3E-13	4.6E-04	1,000	Liver/Blood	7E-10
1,3,5-TNB (135TNB)	1.6E-14	5.0E-05	10,000	Spleen	3E-10
2,4,6-TNT (246TNT)	2.8E-13	5.0E-04	1,000	Liver	6E-10
Toluene (MEC6H5)	3.9E-13	2.0E-01	1,000	Liver/Kidney	2E-12
1,1,2-Trichloroethane (112TCE)	4.1E-13	4.0E-03	1,000	Liver	1E-10
Trichloroethene (TRCLE)	3.5E-13	7.3E-03	1,000	Liver	5E-11
Inorganic Chemicals:					
Arsenic (AS)	7.9E-08	1.0E-03	1	Skin	8E-05
Barium (BA)	3.9E-07	7.0E-02	3	Cardiovasc. sys.	6E-06
Cadmium (CD)	3.4E-09	1.0E-03 (f)	10	Kidney	3E-06
Chromium (CR)	1.6E-07	5.0E-03 (g)	500	CNS	3E-05
Copper (CU)	9.2E-07	3.7E-02 (h)	1	GI tract	2E-05
Manganese (MN)	6.9E-06	1.0E-01	1	CNS	7E-05
Mercury (HG)	7.2E-09	3.0E-04	1,000	Kidney	2E-05
Nickel (NI)	4.0E-07	2.0E-02 (i)	300	Body weight	2E-05
Silver (AG)	5.6E-09	3.0E-03	2	Skin (Argyria)	2E-06
Vanadium (V)	5.9E-07	7.0E-03	100	None observed	8E-05
Zinc (ZN)	3.0E-05	2.0E-01	10	Blood (Anemia)	1E-04
Hazard Index (i)	--	--	--	--	<1 (5E-04)

See footnotes on the following page.

TABLE 9-26 (Continued)

ESTIMATED RISKS ASSOCIATED WITH INGESTION OF VENISON FROM MAAP

(a) Risks are calculated only for chemicals of potential concern with oral toxicity criteria. The following chemicals are not presented due to a lack of oral toxicity criteria: aluminum, calcium, cobalt, iron, lead, magnesium, potassium, sodium and tetryl.
(b) USATHAMA chemical codes are listed in parentheses.
(c) USEPA Weight of Evidence for Carcinogenic Effects:
 [A] = Human carcinogen based on adequate evidence from human studies.
 [B2] = Probable Human Carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies.
 [C] = Possible Human Carcinogen based on limited evidence from animal studies in the absence of human studies.
(d) Factor reflecting the uncertainty in the estimated RfD. Larger factors are associated with greater uncertainty.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.
(f) Value shown is for cadmium ingested with food.
(g) RfD reported is for Chromium VI, as all chromium is conservatively assumed to be in the more toxic form of Chromium VI.
(h) Drinking water standard, reported in mg/L, was converted to mg/kg-day by assuming a 70-kg adult drinks 2 liters of water per day.
(i) Value shown was derived for nickle soluble salts.
(j) Hazard index is the sum of the intake:RfD ratios for each chemical.

Common grasses at the site include orchard grass, buttonweed, plume grass, cudweed, jewelweed, and rye grass. Queen Anne's lace, daisy fleabane, and daylily are other common field species. Tree species at MAAP include box elder, river birch, hickory, white ash, honey locust, holly, flowering dogwood, yellow poplar, red cedar, black walnut, osage orange, black gum, and numerous oak, maple, and pine species. In an earlier site assessment (Martin Marietta, 1978) one State rare plant was observed at the site: compass plant (Silphium laciniatum). This species was observed in the southeastern corner of the site (distant from the study areas for this investigation). It is not known if this species currently exists at the site.

Terrestrial wildlife of the area most likely consists of species typical of field and forest edge habitats. Mammal species of the area include white-tailed deer, bobcat, beaver, gray and red fox, cottontail rabbit, gray and fox squirrel, raccoon, groundhog, opossum, coyote, and muskrat (Martin Marietta, 1991). The deer population of MAAP is considered overabundant, and under the existing deer management plan, attempts are being made to reduce the population via hunting to a level which is not detrimental to the vegetation in the area. Bird species of the area consist of game species such as quail, mourning dove, wild turkey, and Canada geese, and nongame species including raptors (e.g., hawks and owls), songbirds (e.g., sparrows and warblers), and species common to agricultural areas (e.g., meadowlarks, starlings, and crows).

9.5.1.2 Aquatic Habitats and Receptors. Surface water in the study area is comprised of 2 major water courses: Wolf Creek and the Rutherford Fork of the Obion River. Wolf Creek originates near the southeastern boundary and drains the southern and central portions of the installation. It enters the Rutherford Fork of the Obion River at the northwest boundary of the site. Halls Branch and Johns Creek, which drain the northeastern portion of the site, also drain into the Rutherford Fork of the Obion River. Northern portions of the site are drained by several ephemeral ditches referred to as Ditches A through D and Ditches 1 through 10, which also empty into the Rutherford Fork of the Obion River. The southernmost portion of the site drains into the Forked Deer River. Both the Forked Deer and Obion Rivers drain into the Mississippi River about 60 miles west of the site.

Aquatic life in the ditches likely includes seasonal populations of a variety of invertebrate species, such as crustaceans, copepods, crayfish, snails, and aquatic insects. Wolf Creek and Halls Branch are intermittent streams that also are likely to provide invertebrate habitat. Fish are unlikely to live in these surface waters due to their intermittent, seasonal nature. Salamanders, turtles, frogs, and toads also may occur in or near the seasonal surface waters and use such waters as breeding habitat.

A large number of small, stocked ponds also occur at MAAP. Some of these ponds historically have been stocked with bluegill, bass, and channel catfish, and they also provide habitat for aquatic invertebrates and amphibians.

Bluegill, bass, and channel catfish are three of the fish species known to occur in the Rutherford Fork of the Obion River and the Obion River. Johns Creek also is believed to be capable of supporting fish populations. These larger surface waters also provide potential habitat for numerous aquatic invertebrates.

9.5.1.3 Endangered Species. No endangered amphibians, reptiles, birds, or plants were identified during the previous investigation. The river otter (Lutra canadensis), listed as a State threatened mammal (Martin Marietta, 1978), was considered to be a likely inhabitant of the Rutherford Fork of the Obion River. It is unlikely that otter would regularly utilize this stretch of the river given the seasonal fluctuations in flow rate. Any occasional use of the river would be unlikely to result in significant exposures.

9.5.2 Potential Exposures and Estimation of Impact

Surface soil, groundwater, surface water, and sediment samples have been collected and analyzed. No pathways exists by which plants or wildlife can be exposed to chemicals of potential concern in groundwater, as it is not accessible to potential receptors. Therefore, this environmental assessment is limited to an evaluation potential exposures and impacts associated with chemicals in surface soils, surface water, and sediment. Below, potential exposures and impacts to terrestrial and aquatic wildlife and plants are discussed.

9.5.2.1 Terrestrial Plants. Terrestrial plants may be exposed to chemicals of potential concern in soil. Exposure, which results from plant uptake through the roots, is generally limited to those chemicals that occur within the root zone. The depth of the root zone varies with species, but for grasses, forbs, and small shrubs and trees, the root zone can be expected to occur in the top one to two feet of soil.

Few data are available on the phytotoxicity of the chemicals of potential concern in surface soils at the MAAP site. However, surface soil contamination is limited to localized areas at the burning grounds and ADA areas. No areas potentially impacted by military operations at the installation have been leased as cropland. However, some of the leased cropland is located in areas near the burning ground and ADA areas, and wind erosion of contaminants in soil from these areas and subsequent deposition onto agricultural crops could periodically occur. Given the levels of contamination in soils at the burning ground and ADA areas, deposition of environmentally significant levels onto vegetation is unlikely. If effects to other vegetative communities are occurring, they are likely to be limited to localized source areas (e.g., production lines, where vegetation has already been disturbed by human activity) and would be expected to have minor impacts on the plant communities and habitat quality of the area at the MAAP site.

The one rare plant species reported to occur at the site in 1978 was observed in the southeastern corner of the installation, near storage igloos and pastureland where no soil contamination is believed to exist. Therefore, if this species is still present at this location, it is unlikely that it is being impacted in this location.

9.5.2.2 Terrestrial Wildlife (and Livestock). Terrestrial wildlife may be exposed to chemicals of potential concern in surface soil, surface water, and sediment by several pathways: 1) ingestion of soil or sediment while foraging or grooming; 2) ingestion of food that has accumulated chemicals from soil, surface water, or sediment; 3) ingestion of surface water; and 4) dermal absorption. However, evaluation of receptor-specific exposures via some of these pathways is limited by the lack of appropriate exposure assessment information. For example, the amount of chemical that is dermally absorbed following direct contact with contaminated soil or sediment by wildlife cannot be estimated given the available data. Further, wildlife toxicity data for many of the chemicals present at the site are not available. For these reasons, the evaluation of potential wildlife exposures and impacts at the MAAP site is limited to a largely qualitative evaluation of potential impacts associated with exposure to surface soil, surface water, and food. These potential exposure pathways are discussed below.

Surface Soil. As stated earlier, surface soil contamination is localized to areas with limited habitat value due to human disturbances. Although these areas may be traversed by wildlife, significant exposures to chemicals in surface soil are unlikely. Some of the acreage at MAAP is leased as pastureland for grazing of livestock. Livestock are unlikely to be impacted by chemicals present in surface soil due to the limited extent of surface soil contamination and the isolation of the land leased as pastureland relative to these areas.

Surface Water. The on-site surface waters are potential drinking water sources for terrestrial species. Many birds and small mammals generally obtain much of their daily water from dietary sources, and the possible occasional use of these surface waters is not expected to result in significant exposures in these species. However, larger animals such as deer probably obtain much of their water from surface water. In this assessment, drinking water exposures will be evaluated for deer because they are known to obtain a large proportion of their daily water from surface water.

To evaluate potential impacts in deer, it is assumed that a deer obtains all of its drinking water from on-site surface water. Toxicity data for deer are currently unavailable. However, NAS (1974) presented maximum tolerable drinking water limits for livestock and poultry for a number of inorganic chemicals.

These levels were derived using data from studies on cattle, sheep, chickens, and turkeys. Deer and cattle have similar digestive systems: both are ruminants (i.e., they have multi-chambered stomachs and chew a cud). Given the similarity in digestive systems, levels derived to be protective of cattle also may be protective of deer and therefore the values derived by NAS (1974) are used here as estimates of levels which might be considered safe for deer. These levels are available only for the inorganic chemicals of concern. Table 9-27 presents a comparison of surface water exposure point concentrations (presented previously in the human health risk assessment in Table 9-6) for surface water over the entire installation and recommended maximum tolerable limits for livestock presented in NAS (1974).

Based on this comparison, which is limited to inorganic chemicals, it is unlikely that wildlife ingesting surface water would be adversely affected by the chemicals present there. Although toxicity data were not available for the organic chemicals detected in surface water, based on reported dietary toxicity data in laboratory species these chemicals are not likely to be very toxic to deer, and they are present in surface water at such low concentrations (i.e., generally $<50\ \mu g/L$) that significant exposures are unlikely even in animals which obtain most of their daily water requirement from surface water on-site.

Food. Some of the inorganic chemicals present in surface soil and sediment (e.g., mercury, cadmium) have been shown to accumulate in aquatic or terrestrial systems, and conceivably, wildlife species at MAAP could be exposed to such chemicals that have accumulated in their food. However, potential exposures and impacts associated with such exposures are not expected to be significant because of the generally low concentrations and limited distribution of these chemicals at MAAP. None of the organic chemicals of potential concern are expected to accumulate in aquatic or terrestrial foodchains. Even if chemicals are accumulating in terrestrial systems, exposures and effects would likely be limited to carnivorous species with small foraging ranges (e.g., shrews) that could be completely encompassed by potentially contaminated areas. Carnivorous species with larger foraging ranges (e.g., raptorial bird species including hawks and owls), would be less likely to have significant exposures and effects because a larger portion of their food would be from uncontaminated areas. Because the contaminated areas are relatively small (when compared to the acreage of the entire installation) and occur in disturbed areas with limited habitat or foraging value (e.g., at the OBG/ADA, production lines), any potential negative impacts would likely be limited to a small number of organisms, and would not be expected to have significant impacts on wildlife populations over the entire installation.

Cattle that are grazing at MAAP or feeding on crops grown at MAAP could be exposed to chemicals that have reached pasture grass or crops as a result of dust transport from the OBG area. However, significant exposures to livestock ingesting pasture grass or crops are highly unlikely, given that pasture and crop areas are relatively distant from the OBG and therefore would receive only small amounts of dust from the OBG. Therefore impacts to agricultural species are not expected.

9.5.2.3 Aquatic Life. Aquatic life may be exposed to chemicals of potential concern by direct contact with water and sediment and by ingestion of sediments and food containing chemicals of potential concern. However, most available aquatic toxicity studies express toxicity as a function of concentration in the exposure medium (i.e., surface water or sediment). To be consistent with available toxicity data, exposures of aquatic life were evaluated in this assessment by using measured surface water and sediment concentrations. Impacts are evaluated by comparing measured concentrations with promulgated aquatic life criteria or with values derived from toxicity studies on aquatic life. These evaluations are discussed below by medium.

Surface Water. Surface water sampling data are available for the Rutherford Fork of the Obion River, Wolf Creek, Halls Branch and Johns Creek, and several ephemeral ditches from areas downgradient to the production lines and the OBG/ADA area. No sampling data were available for the numerous stocked ponds at MAAP. Because the aquatic communities in ephemeral ditches will differ from those

TABLE 9-27

COMPARISON OF SURFACE WATER CONCENTRATIONS AND SAFE DRINKING WATER LEVELS FOR DEER (BY ANALOGY TO LIVESTOCK)

Chemical (a)	Exposure Point Concentration (b) (ug/L)	Recommended Safe Limit (c) (ug/L)
Arsenic	18.4	200
Cadmium	2.3	50
Chromium	11.2	1,000
Cobalt	20.9	1,000
Copper	34.6	500
Lead	30	100
Mercury	0.1	10
Nickel	25	1,000
Vanadium	87.8	100
Zinc	111	25,000

(a) Only chemicals with recommended safe levels are presented here. For a complete list of chemicals detected in surface water across the site see Table 9-6.
(b) Exposure point concentration for this pathway calculated by grouping all surface water data together.
(c) Source: NAS (1974).

in the perennial stream and river, sampling data for the different surface water bodies were kept separate for the ecological assessment. Also, surface waters were grouped with respect to general location and potential source area. The surface water data were grouped as follows:

- Ditches 1 & 2
- Ditches 4,5,B & C
- Ditches 6 & 7
- Ditches 8 & 10
- Johns Creek and Rutherford Fork of the Obion River

These data are summarized in Table 9-28.

The EPA Region IV Water Quality Standards Unit (1991) has developed maximum and continuous screening values for toxic substances under Section 304(a) of the Clean Water Act. For most of the inorganic chemicals of concern, these values are identical to acute and chronic Ambient Water Quality Criteria promulgated by the federal EPA for protection of aquatic life. Maximum Screening Values (and Acute AWQC) are intended to be protective against short-term effects whereas Continuous Screening Values (and Chronic AWQC) are intended to be protective against long-term effects. The State of Tennessee also has developed water quality standards similar or identical to AWQC for surface waters of the State.

The aquatic toxicity of organic chemicals has not been studied to the same extent as that of inorganic chemicals, and consequently the EPA has not yet promulgated criteria for many of the organic chemicals. EPA Region IV Screening Values are available for several of the organic chemicals of concern. For those chemicals for which no screening values are available, toxicity values obtained from the literature are used. For example, Oak Ridge National Laboratories (ORNL) has developed water quality criteria for three explosive compounds (RDX, TNT, and 2,4-DNT), using a methodology similar to that used by EPA. Given the different degrees of confidence in the toxicity values for inorganic and organic chemicals, comparisons of concentrations and criteria are presented in separate tables for these two groups.

Table 9-29 presents a comparison of the surface water exposure point concentrations for inorganic chemicals with the screening values. Exposure point concentrations are presented for several different source areas. Table 9-30 presents a comparison of the surface water exposure point concentrations for organic chemicals with screening values or other available toxicity values. The exposure point concentration listed for each chemical is the lower value of the 95% upper confidence limit on the mean and the maximum detected value.

Surface water exposure point concentrations for inorganic chemicals exceeded maximum and continuous screening values in several instances. Results for each surface water group are discussed below.

- Ditches 1 and 2: Concentrations of aluminum, chromium, copper, lead, and zinc exceeded both maximum and continuous screening values. Concentrations of iron and mercury exceeded the continuous screening value only.

- Ditches 4, 5, B, and C: Concentrations of aluminum, cadmium, copper, lead, silver, and zinc exceeded both maximum and continuous screening values. Concentrations of chromium, iron, and mercury exceeded the continuous criteria only.

- Ditches 6 and 7: Concentrations of aluminum and copper exceeded both maximum and continuous screening values. Both iron and lead exceeded the continuous screening value, but were well below the maximum screening value.

TABLE 9-28

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT MAAP
(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Arithmetic Mean	Range of Detected On-Site Concentrations	Background Concentrations
DITCHES 1 & 2				

Organic Chemicals:				
* HMX (HMX)	2 / 4	1.8	1.8 - 3.5	ND
* Nitrobenzene (NB)	4 / 4	1.5	1 - 2	ND
* RDX (RDX)	3 / 4	8.8	4.9 - 14.7	ND
* 1,1,2,2-Tetrachloroethane (TCLEA)	1 / 4	0.9	2.6	ND
* 1,1,2-Trichloroethane (112TCE)	1 / 4	1.6	3.8	ND
Inorganic Chemicals:				
* Aluminum (AL)	4 / 4	29,700	13,700 - 59,500	ND
* Arsenic (AS)	4 / 4	17.8	9.1 - 25.8	ND
* Barium (BA)	4 / 4	374	175 - 792	19.8
* Calcium (CA)	4 / 4	11,100	6,440 - 19,700	2,100
* Chromium (CR)	4 / 4	15	6 - 33.3	ND
* Cobalt (CO)	1 / 4	22.3	51.5	ND
* Copper (CU)	3 / 4	20.2	8.9 - 53.3	ND
* Iron (FE)	4 / 4	26,200	10,800 - 56,500	557
* Lead (PB)	4 / 4	26.5	5.4 - 73.5	ND
* Magnesium (MG)	4 / 4	4,730	2,380 - 9,410	1,040
* Manganese (MN)	4 / 4	3,050	319 - 7,170	231
* Mercury (HG)	1 / 4	0.2	0.3	ND
* Nickel (NI)	1 / 4	27.2	57.4	ND
* Potassium (K)	4 / 4	14,900	11,100 - 21,100	1,690
Sodium (NA)	4 / 4	1,490	584 - 2,910	3,340
* Vanadium (V)	4 / 4	70.6	24 - 158	ND
* Zinc (ZN)	4 / 4	115	45.2 - 229	ND
DITCHES 4, 5, B & C				

Organic Chemicals:				
* Acetone (ACET)	1 /11	8.7	15.4	ND
* Bromodichloromethane (BRDCLM)	1 /11	0.7	2.7	ND
* Bromoform (CHBR3)	1 /11	6.7	53.3	ND
* Carbon Disulfide (CS2)	1 /11	0.3	0.7	ND
* Dibromochloromethane (DBRCLM)	1 /11	1.5	11.4	ND
* Diethylphthalate (DEP)	2 /10	11.2	10.4 - 93.2	ND
* 2,4-Dinitrotoluene (24DNT)	1 /13	0.3	0.7	ND
* Di-n-octylphthalate (DNOP)	1 /10	8.7	19.4	ND
* HMX (HMX)	7 /13	2.3	2 - 4.9	ND
* Nitramine (TETRYL)	1 /12	0.3	0.6	ND
* Nitrobenzene (NB)	1 /13	0.5	1.1	ND
* RDX (RDX)	7 /13	7.1	2.9 - 26.3	ND
* 1,1,2-Trichloroethane (112TCE)	1 /11	1.2	3.3	ND
Inorganic Chemicals:				
* Aluminum (AL)	11 /11	13,800	482 - 110,000	ND
* Arsenic (AS)	7 /11	5.5	2 - 16.2	ND
* Barium (BA)	11 /11	728	23.4 - 4,940	19.8
* Cadmium (CD)	1 /13	2.3	6	ND
* Calcium (CA)	11 /11	14,200	3,560 - 24,000	2,100
* Chromium (CR)	2 /13	8	9.9 - 61.5	ND
* Cobalt (CO)	2 /11	20.1	31.6 - 76.6	ND
* Copper (CU)	5 /11	14.5	6.3 - 76	ND
* Iron (FE)	11 /11	18,500	524 - 120,000	557
* Lead (PB)	11 /13	15	1.4 - 140	ND
* Magnesium (MG)	11 /11	3,830	1,640 - 10,900	1,040
* Manganese (MN)	11 /11	2,860	60.4 - 19,300	231
* Mercury (HG)	1 /13	0.1	0.2	ND
* Nickel (NI)	1 /11	23.6	87.7	ND
* Potassium (K)	11 /11	6,350	2,720 - 13,700	1,690
* Silver (AG)	2 /11	1.4	5.7 - 8.8	ND
* Sodium (NA)	10 /11	16,300	2,750 - 37,300	3,340
* Vanadium (V)	5 /11	25.2	5.7 - 207	ND
* Zinc (ZN)	3 /11	42.8	25.3 - 329	ND

See footnotes on the following page.

TABLE 9-28 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER AT MAAP
(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Arithmetic Mean	Range of Detected On-Site Concentrations	Background Concentrations
DITCHES 6 & 7				
Inorganic Chemicals:				
* Aluminum (AL)	3 / 3	950	229 - 2,290	ND
* Barium (BA)	3 / 3	55.8	25.7 - 97.2	19.8
* Calcium (CA)	3 / 3	3,990	2,430 - 6,840	2,100
* Copper (CU)	1 / 3	5.9	9.7	ND
* Iron (FE)	3 / 3	995	481 - 1,610	557
* Lead (PB)	3 / 3	3.6	2.5 - 4.2	ND
* Magnesium (MG)	3 / 3	1,600	1,120 - 2,300	1,040
Manganese (MN)	3 / 3	166	65 - 326	231
* Potassium (K)	3 / 3	4,850	568 - 13,100	1,690
* Sodium (NA)	3 / 3	4,750	750 - 8,110	3,340
* Vanadium (V)	1 / 3	2.4	3.3	ND
* Zinc (ZN)	1 / 3	17.5	27.8	ND
DITCHES 8 & 10				
Organic Chemicals:				
* Carbon Disulfide (CS2)	1 / 3	0.6	1.4	ND
* 2,4-Dinitrotoluene (24DNT)	1 / 3	0.5	0.8	ND
* HMX (HMX)	1 / 3	14.2	41	ND
* RDX (RDX)	1 / 3	104	310	ND
* Trichloroethene (TRCLE)	1 / 3	0.8	1.8	ND
* 1,3,5-Trinitrobenzene (135TNB)	1 / 3	0.8	1.8	ND
* 2,4,6-Trinitrotoluene (246TNT)	1 / 3	4	11.3	ND
Inorganic Chemicals:				
* Aluminum (AL)	3 / 3	17,700	3,630 - 45,900	ND
* Arsenic (AS)	2 / 3	20	6.4 - 52.2	ND
* Barium (BA)	3 / 3	134	69.4 - 236	19.8
* Calcium (CA)	3 / 3	5,440	1,860 - 8,210	2,100
* Chromium (CR)	1 / 3	11.9	29.7	ND
* Copper (CU)	2 / 3	83.7	23 - 224	ND
* Iron (FE)	3 / 3	13,900	2,680 - 35,500	557
* Lead (PB)	3 / 3	17.6	2.1 - 47.7	ND
* Magnesium (MG)	3 / 3	2,880	1,800 - 3,990	1,040
* Manganese (MN)	3 / 3	624	435 - 959	231
* Potassium (K)	3 / 3	6,580	3,860 - 10,800	1,690
Sodium (NA)	3 / 3	1,940	1,160 - 2,740	3,340
* Vanadium (V)	3 / 3	25.7	6.7 - 59.6	ND
* Zinc (ZN)	1 / 3	162	465	ND
JOHNS CREEK AND RUTHERFORD FORK OF THE OBION RIVER				
Organics:				
* Toluene (MEC6H5)	1 / 2	0.5	0.8	ND
Inorganics:				
* Aluminum (AL)	1 / 2	261	452	ND
Barium (BA)	2 / 2	20.6	11.9 - 29.3	19.8
Calcium (CA)	2 / 2	2,380	1,880 - 2,890	2,100
* Copper (CU)	1 / 2	8.4	12.8	ND
Iron (FE)	2 / 2	499	419 - 580	557
* Lead (PB)	1 / 2	1.2	1.8	ND
Magnesium (MG)	2 / 2	1,000	695 - 1,310	1,040
Manganese (MN)	2 / 2	143	68.3 - 218	231
Potassium (K)	2 / 2	1,620	896 - 2,340	1,690
* Sodium (NA)	2 / 2	6,760	3,810 - 9,720	3,340

* = Chemical of Potential Concern
ND = Not Detected

(a) USATHAMA chemical codes are listed in parentheses.
(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.

TABLE 9-29

A COMPARISON OF SURFACE WATER EXPOSURE POINT CONCENTRATIONS AND TOXICITY VALUES FOR THE INORGANIC CHEMICALS OF CONCERN AT MAAP

		Critical Toxicity Value (ug/L)			
		EPA Region IV Screening Values (c)		Tennessee General Water Quality Criteria	
Chemical (a)	Exposure Point Concentration (ug/L) (b)	Maximum	Continuous	Acute	Chronic
DITCHES 1 & 2					
Aluminum (AL)	59,500	750	87	--	--
Arsenic (AS)	25.8	360 (d)	190 (d)	360 (d)	190 (d)
Barium (BA)	792	--	--	--	--
Calcium (CA)	19,700	--	--	--	--
Chromium (CR)	33.3	16 (e)	11 (e)	16 (e)	11 (e)
Cobalt (CO)	51.5	--	--	--	--
Copper (CU)	53.3	9.2 (f)	6.5 (f)	9 (f)	7 (f)
Iron (FE)	56,500	--	1,000	--	--
Lead (PB)	73.5	34 (f)	1.3 (f)	34 (f)	1 (f)
Magnesium (MG)	9,410	--	--	--	--
Manganese (MN)	7,170	--	--	--	--
Mercury (HG)	0.3	2.4	0.012	2.4	0.012
Nickel (NI)	57.4	789 (f)	88 (e)	790 (f)	88 (f)
Potassium (K)	21,100	--	--	--	--
Vanadium (V)	158	--	--	--	--
Zinc (ZN)	229	65 (f)	59 (f)	65 (f)	59 (f)
DITCHES 4, 5, B & C					
Aluminum (AL)	110,000	750	87	--	--
Arsenic (AS)	14.8 *	360 (d)	190 (d)	360 (d)	190 (d)
Barium (BA)	4,940	--		--	--
Cadmium (CD)	2.7 *	1.8	0.66 (f)	2 (f)	0.7 (f)
Calcium (CA)	21,300 *	--		--	--
Chromium (CR)	12.0 *	16 (e)	11 (e)	16 (e)	11 (e)
Cobalt (CO)	29.3 *	--	--	--	--
Copper (CU)	34.2 *	9.2 (f)	6.5 (f)	9 (f)	7 (f)
Iron (FE)	120,000	--	1,000	--	--
Lead (PB)	51.2 *	34 (f)	1.3 (f)	34 (f)	1 (f)
Magnesium (MG)	5,970 *	--	--	--	--
Manganese (MN)	19,300	--	--	--	--
Mercury (HG)	0.1 *	2.4	0.012	2.4	0.012
Nickel (NI)	31.5 *	789 (f)	88 (f)	790 (f)	88 (f)
Potassium (K)	8,400 *	--	--	--	--
Silver (AG)	8.8	1.23	0.012	1 (f)	--
Sodium (NA)	37,300	--	--	--	--
Vanadium (V)	139 *	--	--	--	--
Zinc (ZN)	80.6	65 (f)	59 (f)	65 (f)	59 (f)
DITCHES 6 & 7					
Aluminum (AL)	2,290	750	87	--	--
Barium (BA)	97.2	--	--	--	--
Calcium (CA)	6,840	--	--	--	--
Copper (CU)	9.7	9.2 (f)	6.5 (f)	9 (f)	7 (f)
Iron (FE)	1,610	--	1,000	--	--
Lead (PB)	4.2	34 (f)	1.3 (f)	34 (f)	1 (f)
Magnesium (MG)	2,300	--	--	--	--
Potassium (K)	13,100	--	--	--	--
Sodium (NA)	8,110	--	--	--	--
Vanadium (V)	3.3	--	--	--	--
Zinc (ZN)	27.8	65 (f)	59 (f)	65 (f)	59 (f)
DITCHES 8 & 10					
Aluminum (AL)	45,900	750	87	--	--
Arsenic (AS)	52.2	360 (d)	190 (d)	360 (d)	190 (d)
Barium (BA)	236	--	--	--	--
Calcium (CA)	8,210	--	--	--	--
Chromium (CR)	29.7	16 (e)	11 (e)	16 (e)	11 (e)
Copper (CU)	224	9.2 (f)	6.5 (f)	9 (f)	7 (f)
Iron (FE)	35,500	--	1,000	--	--
Lead (PB)	47.7	34 (f)	1.3 (f)	34 (f)	1 (f)
Magnesium (MG)	3,990	--	--	--	--
Manganese (MN)	959	--	--	--	--
Potassium (K)	10,800	--	--	--	--
Vanadium (V)	59.6	--	--	--	--
Zinc (ZN)	465	65 (f)	59 (f)	65 (f)	59 (f)

See footnotes on the following page.

TABLE 9-29 (Continued)

A COMPARISON OF SURFACE WATER EXPOSURE POINT CONCENTRATIONS AND TOXICITY VALUES FOR THE INORGANIC CHEMICALS OF CONCERN AT MAAP

Chemical (a)	Exposure Point Concentration (ug/L) (b)	Critical Toxicity Value (ug/L)			
		EPA Region IV Screening Values (c)		Tennessee General Water Quality Criteria	
		Maximum	Continuous	Acute	Chronic
JOHNS CREEK AND RUTHERFORD FORK OF THE OBION RIVER					
Aluminum (AL)	452	750	87	--	--
Copper (CU)	12.8	9.2 (f)	6.5 (f)	9 (f)	7 (f)
Lead (PB)	1.8	34 (f)	1.3 (f)	34 (f)	1 (f)
Sodium (NA)	9,720	--	--	--	--

(a) USATHAMA chemical codes are listed in parentheses.
(b) Except as noted, value listed is the maximum detected concentration.
(c) Provided by USEPA Region IV (1991). With the exception of values for silver, maximum and continuous values for inorganic chemicals of concern are identical to federal acute and chronic Ambient Water Quality Criteria.
(d) Value given is for arsenic III.
(e) Value given is for chromium VI.
(f) Criteria for these chemicals are dependent upon water hardness. A water hardness of 10 mg/L CaCO3 was measured at MAAP; in cases such as this, where the water hardness is less than 50 mg/L, EPA recommends using the criteria corresponding with 50 mg/L.

-- = Not available.
* = Value is the upper 95% confidence limit on the mean.

TABLE 9-30

A COMPARISON OF SURFACE WATER EXPOSURE POINT CONCENTRATIONS AND AQUATIC LIFE TOXICITY VALUES FOR THE ORGANIC CHEMICALS OF CONCERN AT MAAP

Chemical (a)	Exposure Point Concentration (ug/L) (b)	EPA Region IV Screening Value	
		Maximum	Continuous
DITCHES 1 & 2			
HMX (HMX)	3.5	>32,000 (c)	---
Nitrobenzene (NB)	2	2,700	270
RDX (RDX)	14.7	6,600 (d)	---
1,1,2,2-Tetrachloroethane (TCLEA)	2.6	932	240
1,1,2-Trichloroethane (112TCE)	3.8	3,600	940
DITCHES 4, 5, B & C			
Acetone (ACET)	11.2 *	---	---
Bromodichloromethane (BRDCLM)	1.2 *	---	---
Bromoform (CHBR3)	16.2 *	2,930	293
Carbon Disulfide (CS2)	0.5 *	---	---
Dibromochloromethane (DBRCLM)	3.4 *	---	---
Diethylphthalate (DEP)	57.4 *	---	---
2,4-Dinitrotoluene (24DNT)	0.4 *	5,500 (e)	200 (e)
Di-n-octylphthalate (DNOP)	10.5 *	---	320 (f)
HMX (HMX)	4.1 *	>32,000 (c)	---
Nitramine (TETRYL)	0.4 *	---	---
Nitrobenzene (NB)	0.6 *	2,700	270
RDX (RDX)	26.3	6,600 (d)	---
1,1,2-Trichloroethane (112TCE)	1.9 *	3,600	940
DITCHES 6 & 7			
None			
DITCHES 8 & 10			
Carbon Disulfide (CS2)	1.4		
2,4-Dinitrotoluene (24DNT)	0.8	5,500 (e)	200 (e)
HMX (HMX)	41	>32,000 (c)	---
RDX (RDX)	310	6,600 (d)	---
Trichloroethene (TRCLE)	1.8	2,200 (g)	---
1,3,5-Trinitrobenzene (135TNB)	1.8	---	---
2,4,6-Trinitrotoluene (246TNT)	11.3	2,000 (h)	40 (h)
JOHNS CREEK AND RUTHERFORD FORK OF THE OBION RIVER			
Toluene (MEC6H5)	0.8	1,750	175

(a) USATHAMA chemical codes are listed in parentheses.
(b) Except as noted, value listed is the maximum detected concentration.
(c) Bentley et al. 1984.
(d) Etnier 1986. 96-hour flow-through LC50.
(e) Etnier 1987.
(f) McCarthy and Whitman 1985. No-observed-effect-concentration (NOEC).
(g) Leblanc 1980. No-observed-effect-concentration (NOEC).
(h) Ryon 1987.

* = Value is the 95 % upper confidence limit on the mean.

- Ditches 8 and 10: Concentrations of aluminum, chromium, copper, lead, and zinc exceeded both maximum and continuous screening values. The concentration of iron exceeded the continuous screening value.

- For Johns Creek and Rutherford Fork of the Obion River, copper and lead exceeded both maximum and continuous screening values. Aluminum exceeded the continuous value only.

The exposure point concentrations for organic chemicals were well below screening or toxicity values for these chemicals. It should be noted, however, that the screening values and many of the acute toxicity values are based on median lethal concentrations (LC_{50}). An LC_{50} is the concentration which is lethal to 50 percent of the test population. For chemicals with no screening values, lowest observed effect concentrations (LOEC) or no observed effect concentrations (NOEC) were used if available. These levels are more indicative of the threshold for toxic effects.

Based on the results presented above, it is likely that seasonal invertebrate populations in the drainage ditches could experience adverse effects due to the presence of elevated concentrations of several inorganic chemicals. Concentrations of aluminum and copper in Johns Creek and Rutherford Fork of the Obion River also exceeded continuous screening values, indicating the potential for chronic effects to both fish and invertebrates in these waters.

Sediment. Sediment samples were collected at all of the surface water sampling stations as well as at some additional locations. The sediment data were grouped as follows:

- Ditches 1 & 2, Wolf Creek
- Ditches 3,4,5,B & C
- Ditches 6 & 7
- Ditches 8, 9, & 10, Halls Branch
- Johns Creek and Rutherford Fork of the Obion River.

Table 9-31 summarizes the frequency of detection and range of concentrations for chemicals detected in sediment.

EPA Region IV (1991) has developed screening values for most of the chemicals of concern in sediment. Potential impacts associated with sediment contaminants at the site are assessed by comparing measured concentrations with these screening values. For those chemicals for which no screening values are available, sediment toxicity values obtained from the literature are used. Barrick and Beller (1989) reported sediment toxicity in terms of apparent effects thresholds (AETs). An AET is defined as the highest sediment concentrations at which no adverse impacts to a species were observed (similar to a no observed effect concentration (NOEC). Barrick and Beller present AET values for marine benthic invertebrates, amphipods, and oysters; the lowest AET for a chemical is used as the sediment toxicity value if sediment screening values are not available.

Sediment exposure point concentrations for inorganic chemicals exceed sediment screening values in several instances. Results for each surface water group are discussed below.

- Ditches 1 and 2 and Wolf Creek: Concentrations of arsenic, nickel, and zinc exceed the sediment screening values.

- Ditches 3, 4, 5, B, and C: Concentrations of arsenic and chromium exceed the sediment screening values.

- Ditches 6 and 7: The sediment exposure point concentration of silver exceeds the screening value for this chemical.

TABLE 9-31

SUMMARY OF CHEMICALS DETECTED IN SEDIMENT AT MAAP (a)

(Concentrations reported in ug/g)

Chemical (b)	Frequency of Detection (c)	Arithmetic Mean	Range of Detected On-Site Concentrations	Range of Background Concentrations
DITCHES 1 & 2, WOLF CREEK (Depth = 0-1 feet)				
Organics:				
* Acetone (ACET)	2 / 12	0.02	0.3 - 0.085	ND
* Tetrachloroethene (TCLEE)	1 / 12	0.0003	0.002	ND
* Toluene (MEC6H5)	1 / 12	0.004	0.045	ND
Trichlorofluoromethane (CCL3F)	5 / 12	0.01	0.01 - 0.03	0.1
Inorganics:				
* Aluminum (AL)	12 / 12	12,130	8,300 - 19,000	577.7 - 4600
* Arsenic (AS)	12 / 12	14.1	3.3 - 39	1.3 - 15
Barium (BA)	12 / 12	261.4	124 - 1,200	54 - 1200
* Beryllium (BE)	2 / 12	1.8	5.7 - 6.5	ND
* Calcium (CA)	12 / 12	1671	925 - 3,340	196 - 637
Chromium (CR)	4 / 13	14	27.5 - 39	42.1
* Cobalt (CO)	2 / 12	16.5	22.5 - 101	54.2
* Iron (FE)	12 / 12	24,230	9,700 - 60,000	1789.8 - 32000
* Lead (PB)	13 / 13	15.7	2.9 - 30	2.1 - 17
* Magnesium (MG)	12 / 12	1676	946 - 3,190	352 - 519
* Manganese (MN)	12 / 12	2791	235 - 19,000	545.9 - 6690
* Nickel (NI)	1 / 12	10.7	58.6	ND
* Potassium (K)	12 / 12	837.2	569 - 1,140	115.9 - 224
* Selenium (SE)	4 / 12	0.31	0.5 - 0.9	ND
* Silver (AG)	2 / 12	0.02	0.053 - 0.1	ND
* Sodium (NA)	12 / 12	375.9	321 - 448	313 - 346
* Thallium (TL)	2 / 12	29	82.3 - 109	ND
* Vanadium (V)	12 / 12	45.5	22.4 - 96.6	3.9 - 59.9
* Zinc (ZN)	5 / 12	45.2	50 - 133	ND
DITCHES 3, 4, 5, B & C (d)				
Organics:				
* 1,3,5-Trinitrobenzene (135TNB)	1 / 26	0.3	1.6	ND
* Acetone (ACET)	5 / 26	0.0151	0.015 - 0.103	ND
* Fluoranthene (FANT)	1 / 25	0.0377	0.1	ND
* 2-Methylnaphthalene (2MNAP)	1 / 25	0.0266	0.07	ND
* Non-carcinogenic PAHs	1 / 25	0.1	0.5	ND
* Phenanthrene (PHANTR)	1 / 25	0.0229	0.2	ND
* Pyrene (PYR)	1 / 25	0.0181	0.1	ND
* Toluene (MEC6H5)	1 / 26	0.0017	0.035	ND
Trichlorofluoromethane (CCL3F)	13 / 26	0.0079	0.007 - 0.023	0.0
Inorganics:				
* Aluminum (AL)	26 / 26	5087	460 - 16222	577.7 - 4600
* Arsenic (AS)	26 / 26	8.3	0.8 - 33.9	1.3 - 15
Barium (BA)	17 / 26	110.9	66.9 - 500	54 - 1200
* Beryllium (BE)	1 / 26	1	3.5	ND
* Calcium (CA)	26 / 26	764.7	124.1 - 2235.8	196 - 637
* Chromium (CR)	2 / 26	10.9	42.5 - 88.8	42.1
Cobalt (CO)	1 / 26	8.7	38.7	54.2
* Iron (FE)	26 / 26	9392	965 - 47000	1789.8 - 32000
* Lead (PB)	26 / 26	10.3	1.7 - 34	2.1 - 17
* Magnesium (MG)	23 / 26	728.6	63.2 - 2861.8	352 - 519
Manganese (MN)	26 / 26	657.1	86.1 - 3890	545.9 - 6690
* Potassium (K)	22 / 26	341.8	41.3 - 1198.9	115.9 - 224
* Selenium (SE)	3 / 26	0.2	0.3 - 0.7	ND
* Silver (AG)	16 / 26	0.1	0 - 0.7	ND
* Sodium (NA)	25 / 26	323.3	227 - 406.9	313 - 346
* Vanadium (V)	26 / 26	214.2	3.3 - 5000	3.9 - 59.9
* Zinc (ZN)	3 / 26	21	64.3 - 67	ND
DITCHES 6 & 7				
Organics:				
* Acetone (ACET)	1 / 11	0.0168	0.1	ND
* Chloroform (CHCL3)	1 / 11	0.0005	0.001	ND
Trichlorofluoromethane (CCL3F)	5 / 11	0.007	0.0065 - 0.02	0.01
* bis(2-Ethylhexyl)phthalate (B2EHP)	1 / 11	0.4	1.3	ND

See footnotes on the following page.

TABLE 9-31 (Continued)

SUMMARY OF CHEMICALS DETECTED IN SEDIMENT AT MAAP (a)

(Concentrations reported in ug/g)

Chemical (b)	Frequency of Detection (c)	Arithmetic Mean	Range of Detected On-Site Concentrations	Range of Background Concentrations
DITCHES 6 & 7 (Cont.)				
Inorganics:				
* Aluminum (AL)	11 / 11	6561	1938.3 - 13000	577.7 - 4600
* Arsenic (AS)	11 / 11	8.5	2 - 19.8	1.3 - 15
Barium (BA)	10 / 11	196.4	66.2 - 747.9	54 - 1200
* Calcium (CA)	11 / 11	996.3	333.9 - 2460	196 - 637
Chromium (CR)	3 / 11	11.3	23.9 - 26	42.1
Cobalt (CO)	1 / 11	12.4	61.2	54.2
Iron (FE)	11 / 11	12400	2220 - 23374.4	1789.8 - 32000
* Lead (PB)	11 / 11	15.8	4 - 29.3	2.1 - 17
* Magnesium (MG)	11 / 11	820.1	186.9 - 1960	352 - 519
* Manganese (MN)	11 / 11	1946	216.1 - 10906.8	545.9 - 6690
* Potassium (K)	11 / 11	417.8	104.9 - 1130	115.9 - 224
* Selenium (SE)	1 / 11	0.1	0.3	ND
* Silver (AG)	11 / 11	0.3	0.044 - 1.1	ND
* Sodium (NA)	10 / 11	323.9	275.7 - 399	313 - 346
Vanadium (V)	11 / 11	33.1	7.9 - 59.5	3.9 - 59.9
* Zinc (ZN)	2 / 11	33.5	72 - 160.1	ND
DITCHES 8, 9 & 10, HALLS BRANCH				
Organics:				
* 1,1,2,2-Tetrachloroethane (TCLEA)	2 / 18	0.0009	0.003 - 0.004	ND
* Acetone (ACET)	4 / 18	0.0204	0.043 - 0.1	ND
* Chlorobenzene (CLC6H5)	1 / 18	0.0003	0.001	ND
* Toluene (MEC6H5)	1 / 18	0.0003	0.001	ND
Trichlorofluoromethane (CCL3F)	6 / 18	0.0073	0.0075 - 0.024	0.01
Inorganics:				
* Aluminum (AL)	18 / 18	6020	749.2 - 11000	577.7 - 4600
Arsenic (AS)	18 / 18	5.9	0.8 - 10.8	1.3 - 15
Barium (BA)	16 / 18	118.4	57.2 - 578.4	54 - 1200
* Beryllium (BE)	1 / 18	1.1	3.6	ND
* Cadmium (CD)	1 / 18	1.8	6.8	ND
* Calcium (CA)	18 / 18	580.5	224 - 1330	196 - 637
Chromium (CR)	2 / 18	10.2	14.8 - 66.4	42.1
* Copper (CU)	3 / 18	75	117 - 552.9	ND
* Iron (FE)	18 / 18	13420	2013.5 - 61217.6	1789.8 - 32000
* Lead (PB)	18 / 18	16.5	2.1 - 54.5	2.1 - 17
* Magnesium (MG)	18 / 18	874.1	85.7 - 1820	352 - 519
Manganese (MN)	18 / 18	750.8	177.9 - 1588.4	545.9 - 6690
* Mercury (HG)	4 / 18	0.3	0.1 - 3	ND
* Nickel (NI)	1 / 18	8	37.4	ND
* Potassium (K)	17 / 18	344.5	133.7 - 643	115.9 - 224
* Silver (AG)	11 / 18	0.0452	0 - 0.4	ND
* Sodium (NA)	18 / 18	354.6	281 - 450.1	313 - 346
* Thallium (TL)	1 / 18	21	111.3	ND
* Vanadium (V)	18 / 18	26.9	3.5 - 65.5	3.9 - 59.9
* Zinc (ZN)	7 / 18	94.8	59.8 - 569	ND
JOHNS CREEK AND RUTHERFORD FORK OF THE OBION RIVER				
Inorganics:				
* Aluminum (AL)	2 / 2	3280	1088.7 - 5471.4	577.7 - 4600
Arsenic (AS)	2 / 2	4.7	2.3 - 7.1	1.3 - 15
Barium (BA)	1 / 2	49.4	83.9	54 - 1200
Calcium (CA)	2 / 2	290.8	210.3 - 371.3	196 - 637
Iron (FE)	2 / 2	4494	4475.5 - 4511.7	1789.8 - 32000
Lead (PB)	2 / 2	6.2	5.7 - 6.8	2.1 - 17
* Magnesium (MG)	1 / 2	347.5	670	352 - 519
Manganese (MN)	2 / 2	549.1	499.8 - 598.5	545.9 - 6690
Potassium (K)	1 / 2	195	371.2	115.9 - 224
* Silver (AG)	1 / 2	0.1	0.1	ND
* Sodium (NA)	2 / 2	374.7	371.4 - 378.1	313 - 346
Vanadium (V)	2 / 2	16.4	13.6 - 19.2	3.9 - 59.9

* = Chemical of Potential Concern
ND = Not Detected

(a) Except as noted, data presented are for surface sediment from a depth of 0-1 foot.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.
(d) Data for Ditches B and C were collected from a depth of 0-0.5 feet.

TABLE 9-32

A COMPARISON OF SEDIMENT EXPOSURE POINT CONCENTRATIONS AND TOXICITY VALUES FOR CHEMICALS OF CONCERN AT MAAP

(Concentrations reported in mg/kg)

Chemical	Exposure Point Concentration (a)	EPA Region IV Screening Value (b)
DITCHES 1 & 2, WOLF CREEK		
Organic Chemicals:		
Acetone	0.085	--
Tetrachloroethene	0.002	>22 (c)
Toluene	0.045	--
Inorganic Chemicals:		
Aluminum	19,000	--
Arsenic	39	33
Beryllium	6.5	--
Calcium	3,340	--
Lead	30	35
Magnesium	3,190	--
Manganese	19,000	--
Nickel	58.6	30
Potassium	1,140	--
Selenium	0.9	--
Silver	0.1	1
Thallium	109	--
Zinc	133	120
DITCHES 3, 4, 5, B & C		
Organic Chemicals:		
Acetone	0.103	--
Fluoranthene	0.1	600
2-Methylnaphthalene	0.07	65
Phenanthrene	0.2	220
Pyrene	0.1	350
Toluene	0.035	--
1,3,5-Trinitrobenzene	1.6	1.8 (c,d)
Inorganic Chemicals:		
Aluminum	16,222	--
Arsenic	33.9	33
Beryllium	3.5	--
Chromium	88.8	80
Lead	34	35
Magnesium	2,862	--
Potassium	1,199	--
Selenium	0.7	--
Silver	0.7	1
Vanadium	5,000	--
Zinc	67	120
DITCHES 6 & 7		
Organic Chemicals:		
Acetone	0.1	--
bis(2-Ethylhexyl)phthalate	1.3	60 (c)
Chloroform	0.001	--
Inorganic Chemicals:		
Aluminum	13,000	--
Arsenic	19.8	33
Calcium	2,460	--
Lead	29.3	35
Magnesium	1,960	--
Potassium	1,130	--
Selenium	0.3	--
Silver	1.1	1
Zinc	160	120

See footnotes on the following page.

TABLE 9-32 (Continued)

A COMPARISON OF SEDIMENT EXPOSURE POINT CONCENTRATIONS AND TOXICITY VALUES FOR CHEMICALS OF CONCERN AT MAAP

(Concentrations reported in mg/kg)

Chemical	Exposure Point Concentration (a)	EPA Region IV Screening Value (b)
DITCHES 8, 9 & 10, HALLS BRANCH		
Organic Chemicals:		
Acetone	0.1	--
Chlorobenzene	0.001	--
1,1,2,2-Tetrachloroethane	0.004	--
Toluene	0.001	--
Inorganic Chemicals:		
Aluminum	11,000	--
Beryllium	3.6	--
Cadmium	6.8	5
Calcium	1,330	--
Copper	553	70
Lead	54.5	35
Magnesium	1,820	--
Mercury	3	0.15
Nickel	37.4	30
Potassium	643	--
Silver	0.4	1
Thallium	111	--
Zinc	569	120
JOHNS CREEK AND RUTHERFORD FORK OF THE OBION RIVER		
Inorganic Chemicals:		
Silver	0.1	1

(a) Value is the maximum detected exposure concentration.
(b) EPA Region IV (1991) except where noted.
(c) Apparent Effects Threshold for marine benthic invertebrates and amphipods reported in Barrick and Beller (1989).
(d) This value is for 1,2,4-trinitrobenzene.

-- = Not available.

- Ditches 8, 9, and 10, and Halls Branch: Concentrations of cadmium, copper, lead, mercury, nickel, and zinc exceed the screening values. The concentration of silver is below the screening value.
- For Johns Creek and Rutherford Fork of the Obion River, the exposure point concentration for silver is below the screening value

At all locations, the exposure point concentrations for organic chemicals are well below screening or toxicity values for these chemicals.

These comparisons suggest that aquatic life impacts associated with inorganic chemicals present in surface water and sediment may be occurring in the intermittent ditches, creeks, and the Rutherford Fork of the Obion River.

9.6 UNCERTAINTY ANALYSIS

As in any risk assessment, there is a large degree of uncertainty associated with the estimates of human health and ecological risks. Consequently, the estimates calculated for MAAP should not be construed as absolute estimates of risk but rather as conditional estimates based on a number of assumptions regarding exposure and toxicity. In general, the main sources of uncertainty in a risk assessment are:

- Environmental sampling and analysis,
- Selection of chemicals for evaluation,
- Fate and transport models used to estimate exposure point concentrations,

- Exposure parameter estimation, and
- Toxicological data.

A complete understanding of the uncertainties associated with the risk estimates is critical to understanding the true nature of the predicted risks and to placing the predicted risks in proper perspective. Some of the key sources of uncertainty associated with the estimates of risk for the MAAP study area are summarized below.

9.6.1 Uncertainties Associated with Selection of Chemicals for Evaluation

Chemicals that were selected as chemicals of potential concern in the soil, groundwater, surface water, and sediment may be present at naturally occurring concentrations. The ability to determine with any confidence whether a site-related chemical is present at levels in excess of background concentrations is dependent on the availability of sufficient data to characterize background.

In cases where there are few background data (as was the case with most media), it is difficult to adequately characterize whether or not on-site chemical concentrations are truly site-related or whether they fall within a range background concentrations. Although many inorganic chemicals were detected at low concentrations in the various media, and could be present within true background ranges, they were nevertheless retained as chemicals of potential concern, which could possibly result in an over-estimation of risk. For example, in several cases, exposure point concentrations for the inorganic chemicals were low, but these inorganics nevertheless accounted for elevated risks (e.g., arsenic for the ingestion of groundwater, and chromium for inhalation exposures). All organic chemicals also were retained as chemicals of potential concern, even though in some cases, they may be laboratory sampling artifacts.

9.6.2 Uncertainties Associated with Exposure Concentration Estimates

There is uncertainty associated with calculating exposure point concentrations for estimating CDIs. The 95% upper confidence limit of the population mean was used to represent the exposure point concentration over the duration of the exposure period. It should be noted that the statistical procedure developed for estimating this parameter is very sensitive to small sample sizes (i.e., less than 20 samples for a particular parameter) and to distributions that are extremely positively skewed (USEPA, 1989e; Land, 1971). Skewed distributions often result when a chemical is detected in only a few samples while the majority of the samples are non-detects. In cases where the upper confidence limit exceeds the maximum detected concentration, the maximum concentration was used to derive risk (USEPA, 1989).

In this risk assessment, the non-detects were included in the calculation of the 95% upper confidence limit of the population mean concentration at one-half the reported detection limits. While this approach is commonly accepted in Superfund site risk assessments, it is associated with some uncertainty. This is because the actual chemical concentration in a non-detect sample may range from zero to a value just below the reported detection limit.

There is some uncertainty associated with concentrations of certain chemicals in groundwater. In one particular case, concentrations of chromium in unfiltered samples were lower than the concentrations in filtered samples (for current off-site groundwater samples), which is indicative of sampling or handling error.

There is uncertainty associated with sampling results from off-site wells. For this risk assessment, it was assumed that cadmium and chromium detected in the off-site wells are site-related chemicals, because they exceeded available background concentrations. However, in 1990, the University of Tennessee conducted groundwater sampling at the off-site wells, during which neither cadmium nor chromium exceeded background concentrations. During sampling for this RI, concentrations of cadmium and chromium exceeded background levels only in the new off-site monitoring wells, and not in the two existing residential wells. As mentioned earlier, this could possibly be because the new monitoring wells had been sampled before they fully stabilized. Due to the uncertainty associated with these sampling results, resampling of these monitoring wells is recommended to determine whether cadmium and chromium are indeed elevated above background levels.

There are uncertainties associated with the groundwater modeling, which could affect the estimation of groundwater exposure point concentrations. Although the groundwater direction and flow rates in the MAAP area have been well characterized, there is uncertainty associated with contaminant transport in the O-Line and OBG/ADA plumes. This is related to assumptions used for dispersion of contaminants in the groundwater plumes to the northern and northwestern boundaries. Since the dispersivity associated with contamination migration in this aquifer was unknown, the plume migration was calibrated to the plume size, as indicated by the most current groundwater data. In addition, the contamination loading was unknown, so the source strength was assumed by analyzing soil and groundwater data for contamination at the O-Line ponds and the OBG/ADA. The retardation factors used in the model are based on laboratory data. However, by running the transport model until no further change at the boundary was occurring, the results are fairly insensitive to an error in the retardation factor. Constant loading for 100 years was assumed, and no degradation or dilution of contamination was assumed to occur over time. Finally, although all known sources were included in the modeling, there may be other sources (e.g., at select ditches or sumps) for which no sampling data were collected. However, this is unlikely to greatly under-estimate exposure point concentrations in groundwater since it is assumed that the modeling did incorporate the most significant sources of contamination.

Since only cadmium and explosives concentrations were modeled for the ingestion of groundwater scenario, reasonable maximum exposure concentrations (the lower of the 95% upper confidence limit on the population mean and the maximum detected value) were used for the remaining chemicals of potential concern. Using these RME concentrations does not take into consideration any dilution or reduction in concentrations, and therefore these concentrations are likely to be over-estimated. Conversely, the concentrations of degradation products will be under-estimated.

There are several uncertainties affecting emissions estimation and air dispersion modeling. First, uncertainties are associated with the Cowherd model, which was used to estimate emissions due to wind erosion. Due to limitations of the model, a particle size was assumed, instead of using site-specific data on particle size distribution. This may under-estimate actual emissions occurring as a result of wind erosion. Another assumption used in the air modeling was that precipitation occurs 30% of the time, and that erosion therefore occurs during the remaining 70% of the time. Second, the Box model, which was used to estimate air concentrations at the OBG, conservatively assumed that concentrations remain the same in the box for 8 hours per day, each working day. Thus site personnel are working in the area encompassed in the Box for this entire time period. Since site personnel only work in select areas of the OBG (not all of which are located in the Box), it is unlikely that they would be exposed for the entire work day to concentrations estimated in the Box model. This will likely over-estimate worker exposure estimates.

Uncertainties are associated with the modeling uptake of chemicals in deer. Because surface water was the only media for which there was adequate sampling data, only exposures via ingestion of surface water were assumed. However, because deer could be exposed to chemicals of concern in soils or plants, while foraging, exposures to deer could be under-estimated. However, since areas for which adequate surface soil data were collected (i.e., known source areas), generally do not provide good habitat for deer, deer exposures are unlikely to be significantly under-estimated. There also is uncertainty associated with the bioaccumulation of chemicals in deer. Although many of the chemicals that were modeled for deer uptake are volatile organic chemicals, and are unlikely to bioaccumulate, this was nevertheless modeled. In addition, using transfer coefficients designed for beef bioaccumulation also could result in some uncertainty.

9.6.3 Uncertainties Associated with Assumptions Used to Estimate Exposures

There are uncertainties associated with the combination of upper-bound exposure parameter values with the 95% upper confidence limit on the population mean to estimate exposures (which EPA has defined as the 95th percentile of the distribution of potential exposures). Combining upper-bound estimates using the simple intake formula recommended by USEPA (1989e) would result in exposure estimates that would exceed the 95th percentile of the distribution of potential exposures. An in-depth simulation model would have to be performed to adequately quantify percentiles of the exposure distribution.

With respect to the exposure pathways evaluated in this risk assessment, there are several uncertainties in the parameters used for each scenario. These parameters are used to estimate chronic daily intakes (CDIs), which are then combined with toxicological information to assess potential risks. For example, several of the standard EPA assumptions that are used throughout this assessment (e.g., ingestion of 1.9 liters of groundwater per day, 70 kg or 48 kg average body weight, and 70 year lifetime) are assumed to represent upper-bounds of potential exposures, and are used when site-specific data are not available. Some of other assumptions for human intakes are also associated with uncertainty. For example, it was conservatively assumed that one person consumes 75 pounds of venison from a deer over the period of one year. Risks for certain individuals within an exposed population may be higher or lower (although they are more likely to be lower) depending on their actual drinking water intakes, body weights, etc. In addition, exposure point concentrations were assumed to be constant throughout the period of exposure.

It was assumed for all pathways that exposures would occur in the same time frame. However, for ingestion of groundwater, the modeled concentrations of explosives and cadmium are unlikely to attain their respective maximum concentrations at the same time. Because the modeled concentrations take into account different rates of migration for each of the chemicals of concern, each will reach its RME concentration at the border at a different time. For example, HMX is expected to attain its RME concentration at the northern in roughly 60 years, while 2,4,6-TNT is expected to reach its RME concentration at the northern border in about 200 years. In the assessment, it was assumed that the receptor populations would be exposed to the RME concentrations of the chemicals of concern at the same time, thereby over-estimating potential risks.

There are uncertainties associated with the assumption that a certain type of exposure would occur at all, which is particularly relevant for hypothetical future exposure scenarios. For example, it was assumed that groundwater could be used by residents at the northern and northwestern boundaries of MAAP. As mentioned earlier, however, the northern boundary of MAAP is in a floodplain, and it is unlikely that people would build there. Thus exposures at the northern boundary of MAAP are considered unlikely.

Finally, there is uncertainty associated with only qualitatively assessing potential exposures, rather than conducting a quantitative evaluation. This is the case with potential dermal exposures to chemicals of concern in surface soil and in groundwater. As noted in Section 9.2.2.1, the potential for contact with surface soils is greatest in the OBG and ADA. Dermal exposures would not occur in the ADA since no chemicals of concern were detected there, while in the OBG, workers are present on a daily basis, but only come into contact with surface soils on an infrequent basis. As a result, dermal exposures are expected to be minimal and infrequent. As explained in Section 9.2.2.3, no organic chemicals were detected in groundwater from potable production wells. With the exception of one well used for non-potable purposes, at which 2,4-DNT was detected at 1 µg/L, no organic chemicals were detected. Thus, it is considered unlikely that dermal exposures would occur. As a result, although there are uncertainties associated with not quantitatively evaluating dermal exposures, it is considered unlikely that significant dermal exposures would occur as a result of exposures to chemicals of concern at MAAP.

9.6.4 Uncertainties in the Toxicity Assessment

In most risk assessments, one of the largest sources of uncertainty is in health criteria values. Health criteria for evaluating long-term exposures such as risk reference doses or cancer slope factors are based on concepts and assumptions which bias an evaluation in the direction of over-estimation of health risk. As EPA notes in its Guidelines for Carcinogenic Risk Assessment (USEPA, 1986a):

> There are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to genetic constitution, diet, occupational and home environment, activity patterns and other cultural factors.

These uncertainties are compensated for by using upper-bound 95th percentile upper confidence limits or maximum likelihood estimates for cancer slope factors for carcinogens, and safety factors for reference doses for noncarcinogens. The assumptions used here provide a rough but plausible estimate of the upper limit of risk.

EPA-approved health effects criteria are not available for most of the chemicals of potential concern for the inhalation pathway and several chemicals associated with the oral exposure pathways; thus risks associated with these chemicals could not be estimated. It is important to note that several of the chemicals that are known carcinogens by the oral route have no toxicity data for the inhalation route (2,4- and 2,6-DNT, RDX, 2,4,6-TNT). Although carcinogenicity via the oral route does not necessarily indicate that the same chemicals via the inhalation route are carcinogenic, it nevertheless suggests that a chemical without inhalation toxicity criteria may be of concern, and that risk for the inhalation pathways may be under-estimated.

There are varying degrees of confidence in the weight of evidence for carcinogenicity of a given chemical. EPA's (1986a) weight-of-evidence classification provides information which can indicate the level of confidence or uncertainty in the data obtained from studies in humans or experimental animals. For example, seven chemicals that were evaluated are Class C chemicals, possible human carcinogens, for which there is limited evidence of carcinogenicity in animals. Specifically, RDX and 2,4,6-TNT, both Class C carcinogens, contributed significantly to the risks in the ingestion of groundwater pathways. The summation of the risks associated with all potential carcinogens tends to over-estimate risk by including probable human carcinogens with demonstrated human carcinogens (Class A).

When deriving RfDs, the current EPA methodology (USEPA, 1990c) recommends that a maximum uncertainty factor of 3,000 be used when four areas of uncertainty are associated with a toxicity study. However, RfDs calculated before the current methodology came into effect, may include an uncertainty factor of greater than 3,000, and therefore may be more conservative than more recently developed RfDs. Several of the chemicals in this assessment had uncertainty factors greater than 3,000.

In general, toxicity criteria are very uncertain and usually very conservative, but the sources of uncertainty differ among the chemicals.. For inorganic chemicals, including arsenic and cadmium, the major sources of uncertainty are limitations in the data based on the human epidemiological studies and the uncertainty about the physical and chemical forms of the inorganic chemicals in the workplace (mostly smelters) from which the data were derived. The cancer slope factor for chromium is conservatively associated with only the hexavalent form which is not expected to be prevalent at the site.

There is also a great deal of uncertainty in assessing the risks due to exposure to a mixture of chemicals. In this assessment, the effects of exposure to each of the chemicals of concern have initially been considered separately within each pathway. However, these substances occur together at the site, and individuals may be exposed to mixtures of the chemicals. Prediction of how these mixtures of toxicants will interact must be based on an understanding of the mechanisms of such interactions. The interactions of the individual components of chemical mixtures may occur during absorption, distribution, metabolism, excretion, or activity at the receptor site. Individual compounds may interact chemically, yielding a new toxic component or causing a change in the biological availability of an existing component, or may interact by causing different effects at different receptor sites.

Suitable data are not currently available to rigorously characterize the effects of chemical mixtures. Consequently, as recommended in EPA's Risk Assessment Guidance for Superfund (USEPA, 1989e) and in EPA's Guidelines for Health Risk Assessment of Chemical Mixtures (USEPA, 1986c), chemicals present in the various media to which people could be exposed were assumed to act additively, and potential health risks were evaluated by summing risks and hazard indices for chemicals of potential concern. This approach to assessing potential risks associated with mixtures of chemicals assumes that there are no synergistic or antagonistic interactions among the chemicals considered and that all chemicals have the same toxic end points and mechanisms of action. To the extent that these assumptions are incorrect, the estimated risks could under- or over-estimate actual risks.

As a result of the uncertainties described above, this risk assessment should not be construed as presenting absolute estimates of risks to human populations. Rather, it is a conservative analysis for the no-action alternative intended to indicate the potential for adverse impacts to occur.

9.7 SUMMARY AND CONCLUSIONS

Past activities at MAAP have resulted in significant contamination of groundwater, surface soil, and sediment and to a lesser extent, contamination of subsurface soils and surface water. This section summarizes the significant findings of the risk assessment associated with this contamination.

9.7.1 Chemicals of Potential Concern

In this assessment, a set of chemicals of potential concern was selected for detailed evaluation based on the RI sampling results. Using a conservative selection procedure, chemicals were selected for five media (groundwater, surface soil, subsurface soil, surface water and sediment). A variety of organic and inorganic chemicals have been detected at MAAP, in addition to the explosive compounds and the four metals that were the focus of the field investigation. The explosive chemicals and several organic chemicals that are solvents most likely associated with manufacturing and production at the LAP lines were detected in each medium. Many inorganic chemicals also were detected in each medium. Because so few background samples were collected in each of the sampled media, background levels of chemicals of concern have not been well characterized. Nevertheless, many of the inorganic chemicals detected at low concentrations were retained as chemicals of concern, although they could be well within background levels.

9.7.2 Exposure Assessment

To evaluate the potential human health risks, several exposure pathways were selected for detailed evaluation. The exposure pathways that were quantitatively and qualitatively evaluated were:

- Residential drinking water exposures of future groundwater users at the northern and northwestern boundaries of MAAP, and of current users of off-site wells (quantitative);
- Residential inhalation and dermal exposures during in-home use of groundwater (qualitative);
- Inhalation exposures of workers and nearby residents of chemicals adsorbed onto wind-generated dust from surface soils at the OBG (quantitative); and
- Ingestion of deer killed at MAAP (quantitative).

Due to institutional controls at MAAP, drinking water ingestion exposures for potable water were not evaluated for those who work and live there. Several wells at MAAP are used for non-potable water, and dermal exposures and exposures from inhalation of chemicals that have volatilized during use could occur. These exposures are not expected to be significant, as few volatile chemicals were detected in groundwater, and those that were, were detected at low concentrations. Nevertheless, since these wells are not currently monitored, it is recommended that the water from non-potable wells be monitored on a somewhat consistent basis.

Exposure scenarios for each of the potential exposure pathways that was quantitatively evaluated were developed, and exposure point concentrations and chronic daily intakes (CDIs) of exposed populations were made. In this assessment, the reasonable maximum exposure (RME) case was evaluated in accordance with EPA guidance on conducting risk assessments at Superfund sites. For the pathways that were quantitatively evaluated, it was assumed that chemical concentrations in the environmental media sampled (or modeled) would remain constant over the duration of the exposure period assumed. In the absence of any site-specific information to the contrary, other exposure parameters used to estimate potential intakes for potentially exposed populations were based on EPA standard assumptions and/or professional judgement.

9.7.3 Risk Characterization

Quantitative risk assessment involves combining intakes for exposed populations with reference doses (RfDs, defined as acceptable daily doses for noncarcinogens) or slope factors (for carcinogens) to derive estimates of noncarcinogenic hazard, or excess lifetime cancer risks, of the potentially exposed populations. For carcinogens, potential risks are presented as the product of the CDI and slope factors. Risks were compared to EPA's target risk range of 10^{-4} to 10^{-6}. For noncarcinogens, potential hazards are presented as the ratio of the CDI to the reference dose (CDI:RfD), and the sum of the ratios is referred to as the hazard index. In general, hazard indices that are less than one are not likely to be associated with adverse health effects, and are therefore less likely to be regulatory concern than hazard indices greater than one. The risk estimates for each of the selected pathways are presented below.

9.7.3.1 Groundwater Ingestion. For the receptor populations at the northern and northwestern boundaries of MAAP, risks exceeded the 10^{-6} risk level, primarily due to arsenic, RDX, and 2,4,6-TNT. However, it is important to note that RDX and 2,4,6-TNT are Class C carcinogens, and that carcinogenic risks could thus be over-estimated. In addition, arsenic was present in low concentrations and may well be within background levels, and so risks due to arsenic also could be over-estimated. The total hazard indices for groundwater ingestion exceed 1, primarily due to manganese, 1,3,5-TNB, 2,4,6-TNT, and vanadium. For current users of groundwater northwest of MAAP, the hazards associated with ingestion of groundwater exceeded one for cadmium. This could be due to problems in sampling, and therefore, there is uncertainty in the results.

Potential residents in the future could be exposed to organic chemicals of concern via inhalation of chemicals that have volatilized during use, and via dermal absorption. Inhalation and dermal exposures to chemicals in groundwater are not expected to be significant, relative to those associated with ingestion exposures.

For the potential future drinking water exposures, it should be noted that it may not be appropriate to sum risks for all the chemicals of concern in the O-Line pond and OBG/ADA plumes of contamination, because the organic and inorganic chemicals are travelling at different rates (i.e., most inorganic chemicals are travelling at a slower rate than most organic chemicals). Therefore, it is unlikely that a potential receptor could be exposed to RME concentrations of all the chemicals at one time.

9.7.3.2 Inhalation Exposures. Inhalation risks were evaluated for workers at the OBG and for residents who live downwind from the OBG. The upper-bound excess lifetime cancer risks for workers was 1×10^{-5}, primarily due to chromium, while the risks for off-site residents was 2×10^{-6}, also due to chromium. As noted earlier, it was conservatively assumed that all chromium at the OBG was in the hexavalent form, a known inhalation carcinogen. However, it is more likely that most of the chromium in surface soil is in the trivalent (noncarcinogenic) form, as this form is readily adsorbed or complexed to soil particles, metal oxides and organic matter.

The hazard index for the workers was one, due to chromium, while the hazard index for residents was less than one. Again, because it was assumed that all chromium was in the form Chromium VI, whose RfD is 200 times greater than the RfD for Chromium III, the hazards associated with inhalation exposures may be over-estimated.

Inhalation exposures of lead were not evaluated in the same manner as the other chemicals of potential concern. A comparison was made with the NAAQS for both worker and residential exposures, and with TLVs for worker exposures. According to modeled estimates of ambient air concentrations of lead on- and off-site, both worker and residential exposures would be well within acceptable levels.

9.7.3.3 Ingestion of Venison. Risks associated with ingestion of venison were calculated for those who consume deer killed at MAAP. Risks for ingestion of venison were $8x10^{-8}$, while hazards were less than one, indicating that neither carcinogenic or noncarcinogenic effects are likely to occur.

9.7.4 Ecological Impacts

In this assessment, potential ecological impacts associated with the chemicals of potential concern at the MAAP site were evaluated. Potential impacts on plants, terrestrial wildlife, and aquatic life were evaluated either qualitatively or quantitatively, depending upon the availability of exposure and toxicity information and the likelihood of significant exposure. The conclusions of the environmental assessment are as follows:

> Terrestrial wildlife. Potential impacts were evaluated for wildlife exposed to chemicals of potential concern in soil, surface water and food. Impacts to deer, the indicator species for terrestrial wildlife, from ingestion of surface water are not predicted based on the available toxicity data.
>
> Exposure of terrestrial wildlife and livestock to chemicals in food also are not expected to result in significant impact due to the localized nature of the contamination at MAAP relative to the available foraging habitat.
>
> Aquatic Life. Impacts to aquatic invertebrates and fish were evaluated by comparing surface water and sediment concentrations in various surface waters with ambient water quality criteria (AWQC), State water quality standards, and other toxicity data. Based on these comparisons it is apparent that aquatic life at MAAP may be adversely impacted by elevated concentrations of inorganic chemicals in surface water and sediment.

9.7.5 Data Needs

As in any risk assessment, there is a great deal of uncertainty associated with the estimates of risk. Some of the uncertainties associated with the risk assessment can be addressed by additional sampling. Specific data needs are as follows:

- Additional background sampling data are needed so that the site-relatedness of inorganic chemicals can be determined with more certainty for all media;
- If the chromium in OBG surface soils is determined to be site-related, its oxidation state should be determined so that potential inhalation risks can be evaluated more accurately;
- Off-site monitoring wells should be resampled to determine whether or not the levels of cadmium and chromium detected during the RI are a sampling artifact;

- City of Milan wells should be sampled to determine if contaminants have migrated to these wells;
- Periodic monitoring of non-potable supply wells would be useful in determining the potential for future exposure of MAAP personnel using water from these wells; and
- Air monitoring at or near the OBG during episodic events (e.g., bulldozer operations, detonations, high winds) would be useful in determining the potential magnitude of short-term exposures of workers at the OBG.

10.0 IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

USATHAMA tasked the Chemical Hazard Evaluation Program at Oak Ridge National Laboratory to develop a list of potential Applicable or Relevant and Appropriate Requirements (ARARs) for MAAP. Information from the Draft Final ARARs Assessment document (ORNL, 1990) was used as a starting point for the determination of ARARs as discussed below. Regulatory guidance documents from Federal and State agencies were also used for the development of potential ARARs for MAAP. This chapter identifies chemical-, location-, and action-specific ARARs from Federal, State, and local regulations, and discusses potential human health ARARs and other guidance values. Of the chemicals detected at MAAP, guidance values are available for chemicals in soil, groundwater, surface water and air. Guidance values are not currently available for chemicals detected in sediment (six non-ionic organic chemical criteria for sediments will be published in the Federal Register by the end of FY 91). The regulatory requirements identified in this section are potential ARARs only. The final determination of ARARs will be made by the regulatory agencies overseeing work at the site.

Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that remedial actions at Superfund sites comply with requirements or standards under Federal or State environmental laws that are "applicable" or "relevant and appropriate" (ARAR) to the hazardous substances, pollutants, or contaminants at a site or the circumstances of the release. ARARs are defined as cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a Superfund site. Because the O-Line Pond area is a Superfund site, the investigation was performed using the technical approach outlined in CERCLA/SARA and the NCP.

"Applicable" requirements specifically address the existing site conditions, while "relevant and appropriate" requirements address conditions significantly similar to those encountered at the site that their use may be pertinent. The determination that a requirement is relevant and appropriate involves the comparison of a number of site specific factors with those addressed in the regulatory requirements, including the characteristics of the remedial action, the hazardous substances present at the site, or the physical circumstances of the site. To-be-Considered materials (TBCs) are non-promulgated advisories or guidance issued by Federal or State government that are not legally binding and do not have the status of potential ARARs. TBCs may be used in conjunction with ARARs to determine the necessary level of cleanup for protection of health and the environment.

The approach in determining how protective a remedial action will be to human health involves risk assessment. Consideration of both ARARs and To-Be-Considered materials (TBCs) are used in determining the level of risk posed to the environment. The risk assessment includes consideration of site specific factors such as types of hazardous substances present, potential for exposure, and presence of sensitive populations. Acceptable exposure levels are generally determined by applicable or relevant and appropriate Federal and State environmental requirements.

Selection of ARARs is dependent on the hazardous substances present at the site, the site characteristics and location, and the actions selected for a remedy. Thus, these requirements may be chemical-, location-, or action-specific. Chemical-specific ARARs are health- or risk-based concentration limits set for specific hazardous substances, pollutants, or contaminants. Location-specific ARARs address such circumstances as the presence of an endangered species on the site, or the location of the site in a 100-year floodplain. Action-specific ARARs control or restrict particular types of remedial actions selected as alternatives for cleanup of the site. The regulatory agencies responsible for the site make the final determination on the applicability or relevance and appropriateness of a requirement based on such factors as the characteristics of the remedial action and physical circumstances of the site.

10.1 CHEMICAL-SPECIFIC ARARs

The chemicals of concern, or "Indicator Chemicals", are determined as part of the Superfund public health evaluation process, which is composed of two phases: 1) the baseline public health evaluation and 2) the development of health-based performance goals for proposed remedial alternatives. The process is fully described in the EPA Superfund Public Health Evaluation Manual (SPHEM) (USEPA, 1986e). Selection of indicator chemicals is the first step in the baseline public health evaluation process. The identification of chemicals that pose the greatest potential public health risk is based on site monitoring data, chemical toxicity information in the form of toxicity constants developed by EPA, and environmental persistence and mobility of the chemicals. Chemical-specific ARARs or TBC guidance values are subsequently selected for health-based performance goals (cleanup levels for contaminated soils and groundwater) for these chemicals in contaminated media.

10.1.1 Groundwater Criteria

EPA has developed chemical-specific criteria that may be considered ARARs at MAAP. These criteria are the National Primary Drinking Water Standards (NPDWS), which are codified in 40 CFR Part 141. The NPDWS include maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs). Other guidance established by EPA include secondary maximum contaminant levels (SMCLs), and Health Advisories. Appendix M lists the potential Federal ARARs and other guidance values for chemicals in groundwater. The criteria for contaminants of concern at MAAP are listed in Table 10-1.

MCLGs were developed under the Safe Drinking Water Act as chemical-specific health goals used in setting enforceable drinking water standards for public water supply systems. MCLGs are based entirely on health considerations and do not take cost or feasibility into account. As health goals, MCLGs are set at levels where no known or anticipated health effects may occur, including an adequate margin of safety. EPA is required to set MCLs as close as feasible to the respective MCLG, taking into consideration the best technology, treatment techniques, and other factors (including cost). However, as the standard for public water supplies, MCLs are fully protective of human health and (for carcinogens) fall within the acceptable risk range of 10^{-4} to 10^{-7}. Furthermore, for noncarcinogens, which are the majority of contaminants, MCLs are almost always set at the same level as the respective MCLGs. Also, these standards assure that even sensitive populations will experience no adverse health effects (52 Federal Register 33499).

The use or potential use of the groundwater (potable or potentially potable) must be considered in determining potential ARARs. According to the previously cited guidance, MCLs will generally be considered ARARs for all Federal Class I and Class II groundwater or surface water that is or may be used for drinking water.

Secondary Maximum Contaminant Levels (SMCLs) were developed under the Safe Drinking Water Act as chemical-specific reasonable goals for drinking water quality. They apply to any contaminant in drinking water which may adversely affect the odor, aesthetics or appearance. SMCLs are regarded as "other guidance".

In addition to MCLs and MCLGs, EPA provides drinking water suppliers with guidance on various chemicals that may be encountered in a water system which are known as health advisories. The Office of Drinking Water's nonregulatory health advisories (HAs) are concentrations of contaminants in drinking water at which adverse effects would not be anticipated to occur. A margin of safety is included to protect sensitive members of the population. The health advisory numbers are developed from data describing noncarcinogenic end-points of toxicity. They do not incorporate quantitatively any potential carcinogenic risk from such exposure. Lifetime health advisories are calculated for a 70-kg adult assumed to drink 2 liters of water per day.

TABLE 10-1
Potential ARARs For Contaminants of Concern in Groundwater

Analyte	State of Tennessee[1]		Federal				U.S. Army Surgeon General Permissible Drinking Water Criteria (mg/L)	Proposed by the U.S. Army (Etnier, 1987) 10^{-6} risk (mg/L)
	Groundwater Standard (mg/L)	Public Water Supply Standard (mg/L)	MCL (mg/L)	MCLG (mg/L)	Lifetime Health Advisory[2] (mg/L)	Secondary Maximum Contaminant Levels		
Acetone	--	--	--	--	--	--	--	--
bis(2-ethylhexyl) phthalate	--	--	--	--	--	--	--	--
Chloroform	--	--	0.10 (a,j)	--	--	--	--	--
Ethylbenzene	--	--	0.70 (b)	0.70 (b)	0.68 (e)	0.03 (P,g)	--	--
2-Propanol	--	--	--	--	--	--	--	--
Toluene	--	--	1.0 (b)	1.0 (b)	2.42 (e)	0.04 (P,g)	--	--
Xylenes (total)	--	--	10 (b)	10 (b)	0.4 (e)	0.02 (P,g)	--	--
Aluminum	--	--	--	--	--	50-200 (b)	--	--
Arsenic	0.05	0.05	0.05 (a)	0.05 (P,h)	--	--	--	--
Barium	--	1.0	1.0 (a)	2.0 (P,i)	1.5 (e)	--	--	--
Cadmium	0.01	0.01	0.005 (b)	0.005 (b)	0.005 (b)	--	--	--
Calcium	--	--	--	--	--	--	--	--
Chromium	0.05	0.05	0.1 (b)	0.1 (b)	--	--	--	--
Cobolt	--	--	--	--	--	--	--	--
Copper	--	1.0	1.3 (P,k)	1.3 (P,k)	--	1.0 (f)	--	--
Iron	--	0.3	--	--	--	0.3 (f)	--	--
Lead	0.05	0.05	0.05 (a) 0.005 (P,k)	0.0 (P,k)	--	--	--	--

TABLE 10-1 (Cont'd)
Potential ARARs for Contaminants of Concern in Groundwater (Cont'd)

Analyte	State of Tennessee[1]		Federal				U.S. Army Surgeon General Permissible Drinking Water Criteria (mg/L)	Proposed by the U.S. Army (Etnier, 1987) 10^{-6} risk (mg/L)
	Groundwater Standard (mg/L)	Public Water Supply Standard (mg/L)	MCL (mg/L)	MCLG (mg/L)	Lifetime Health Advisory[2] (mg/L)	Secondary Maximum Contaminant Levels		
Magnesium	--	--	--	--	--	--	--	--
Manganese	--	0.05	--	--	--	0.05 (f)	--	--
Mercury	0.002	0.002	0.002 (b)	0.002 (b)	0.001 (e)	--	--	--
Nickel	--	--	0.1 (P,c)	0.1 (P,c)	0.15 (e)	--	--	--
Potassium	--	--	--	--	--	--	--	--
Silver	0.05	0.05	0.05 (a)	--	--	0.1 (b)	--	--
Sodium	--	--	--	--	--	--	--	--
Vanadium	--	--	--	--	--	--	--	--
Zinc	--	5.0	--	--	--	5.0 (f)	--	--
1,3,5-TNB	--	--	--	--	--	--	--	--
2,4,6-TNT	--	--	--	--	0.002 (ac)	--	0.044	--
RDX	--	--	--	--	0.002 (ab)	--	0.035	--
HMX	--	--	--	--	0.4 (z)	--	--	--
NB	--	--	--	--	--	--	--	--
TETRYL	--	--	--	--	--	--	--	--
1,3-DNB	--	--	--	--	--	--	--	--
2,4-DNT	--	--	--	0	--	--	--	0.00017
2,6-DNT	--	--	--	0	--	--	--	0.0000068

TABLE 10-1 (Cont'd)
Potential ARARs for Contaminants of Concern in Groundwater (Cont'd)

[1] Rules of the Tennessee Department of Health and the Environment, Chapter 1200-5-1-.06, as amended.

[2] Lifetime Health Advisory adjusted for 100% relative source contribution from ingestion of drinking water only.

-- = Standard not developed for this chemical.

(P) = Proposed.

(a) 40 CFR, Part 141-National Primary Drinking Water Regulations. 559-563, 620-621.

(b) Environmental Protection Agency (EPA). 1991. National Primary Drinking Water Regulations; Final Rule. Federal Register. Vol. 56, No. 20, Wednesday, January 30, 1991. 3526-3597.

(c) Environmental Protection Agency (EPA). 1990. National Primary and Secondary Drinking Water Regulations; Synthetic Organic Chemicals and Inorganic Chemicals. Proposed Rule. Federal Register. Vol. 53, No. 143, Wed. July 25, 1990.

(e) Environmental Protection Agency (EPA). 1987. Health Advisories. Office of Drinking Water. Washington, D.C. March 31, 1987.

(f) 40 CFR, Part 143-National Secondary Drinking Water Regulations. 674.

(g) Environmental Protection Agency (EPA). 1989. National Primary and Secondary Drinking Water Regulations; Proposed Rule. Federal Register. Vol. 54, No. 97, Monday, May 22, 1989. 22062-22160.

(h) Environmental Protection Agency (EPA). 1985. National Primary Drinking Water Regulations. Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms. Proposed Rule. Federal Register, Vol. 50, No. 219, Wednesday, November 13, 1985. 46935-47025.

(i) Environmental Protection Agency (EPA). 1991. National Primary Drinking Water Regulations - Monitoring for Synthetic Organic Chemicals; MCLGs and MCLs for Aldicarb, Aldicarb Sulfoxide, Aldicarb Sulfone, Pentachlorophenol, and Barium; Proposed Rule. Federal Register. Vol. 56, No. 20, Wednesday, January 30, 1991. 3600-3614.

(j) The value of 100 μg/liter is for total trihalomethanes (i.e., the sum of chloroform, bromochloromethane, and bromoform).

(k) Environmental Protection Agency (EPA). 1988. Drinking Water Regulations; Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper; Proposed Rule. Federal Register. Vol. 53, No. 160, 31515-31578, Thursday, August 18, 1988.

(z) Environmental Protection Agency (EPA). 1988. Health Advisory for Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). Office of Drinking Water. Washington, D.C. November, 1988.

(ab) Environmental Protection Agency (EPA). 1988. Health Advisory for Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX). Office of Drinking Water. Washington, D.C. November, 1988.

(ac) Environmental Protection Agency (EPA). 1988. Health Advisory for 2,4,6-Trinitrotoluene (TNT). Office of Drinking Water. Washington, D.C. November, 1988.

The environmental media at MAAP were analyzed for TAL/TCL constituents, munitions compounds, and select metals. Table 10-1 lists the chemicals currently considered to be of concern in groundwater at MAAP. National Primary Drinking Water Standards established in 40 CFR Part 141 are Federal ARARs for chemicals of potential concern in groundwater at MAAP. The State of Tennessee ARARs for groundwater and the Public Water Supply are from Chapter 1200-5-1-.06 of the Rules of the Tennessee Department of Health and Environment, as amended. The proposed rules are dated January 10, 1991. The State MCLs for public water systems are similar to the Federal MCLs with the exception of cadmium and chromium. The State MCLs for cadmium and chromium are not as restrictive as the Federal MCLs.

Other TBC guidance values have been established by the U.S. Army for some explosive compounds that are known carcinogens. 2,4- and 2,6-Dinitrotoluene were considered chemicals of potential concern based on the following information. The mixture of 2,4- and 2,6-DNT is classified as a B2 carcinogen (probable human carcinogen), as is 2,4-DNT alone (USEPA, 1988). However, recent studies have shown that the 2,6-isomer is a potent hepatocarcinogen (Leonard et al., 1983, 1987); therefore, both isomers are considered to be high risk chemicals at MAAP. The primary munitions compounds (2,4,6-Trinitrotoluene (TNT), RDX, HMX, nitrobenzene (NB), and tetryl) and degradation products (1,3,5-Trinitrobenzene (TNB), and 1,3-DNB) that occur in environmental media are also listed in Table 10-1.

10.1.2 Surface Water Criteria

Federal ambient water quality criteria (AWQC) for the protection of freshwater organisms are available for both organic and inorganic contaminants. These may be considered relevant and appropriate for cleanup of surface water at MAAP if environmental impact is considered as well as human health. Table 10-2 lists the appropriate AWQC for chemicals detected in surface waters at MAAP.

Under the Tennessee Water Quality Control Act (Chapter 1200-4-3 of the Rules of the TDHE, 1991), the Tennessee Water Quality Control Board has classified the Rutherford Fork of the Obion River, the East Fork of Wolf Creek, and Wolf Creek for the following uses: fish and aquatic life, recreation, irrigation and livestock watering, and wildlife. These water bodies were not classified for use as domestic or industrial water supplies (TDHE, 1987). Specific water quality standards for each use designation category are promulgated for surface water and groundwater.

The TDHE classification rule provides that stream segments designated for recreational use will be regulated by numerical toxic limits based on Federal AWQC for the protection of humans from the consumption of contaminated fish alone. The TDHE has established criteria in their water quality standards for cadmium, chromium III and VI, and lead, which may be applicable for cleanup standards of surface waters around MAAP. Effluent from industrial and sewage treatment plants at MAAP are regulated under the Clean Water Act. The EPA has adopted effluent limitations and guidelines for existing sources and standards of performance for new sources pursuant to Sections 301, 304, and 306 of the Federal Water Pollution Control Act as amended, PL92-500. Table 10-3 shows the available effluent limitations of industrial wastewater treatment plants established under Section 70-330, Tennessee Code Annotated and Rule 12-4-5 (TDHE, 1977) for the chemicals of concern at MAAP.

Industrial treatment units, including those at MAAP, are required to achieve as a minimum the concentration provided in Table 10-3 as a maximum effluent limitation when such contaminants are present. Permits developed under the NPDES program for discharges to effluent-limited segments contain limitations and standards in accordance with these guidelines. Depending on the conditions of receiving waters and pollutants involved, individually specified effluent limitations may apply. The NPDES permit issued for MAAP includes an effluent limitation for an additional pollutant, defined as total nitrobodies, of 1 mg/L (Appendix A).

TABLE 10-2
Potential ARARs for Surface Water

Analyte	State of Tennessee[1]			Federal Water Quality Criteria[2]			
	Surface Water Standard for Freshwater Fish and Aquatic Life (μg/L)		Recreation (10^{-5} risk factor for carcinogens) Organisms Only (μg/L)	Acute Criteria for Protection of Aquatic Life[(a)] (μg/L)	Chronic Criteria for Protection of Aquatic Life[(b)] (μg/L)	Water and Fish Ingestion, Protection of Human Health (μg/L)	Fish Consumption Only, Protection of Human Health (μg/L)
	Criterion Maximum Concentration	Criterion Continuous Concentration					
Cadmium, total recoverable	--	--		--	--	--	--
Aluminum	--	--	--	--	--	--	--
Silver	$e^{(1.72[\ln(\text{hardness})] -6.52)}$	--	--	$e^{(1.72[\ln(\text{hardness})]- 6.52)}$	0.12	50	--
Arsenic	--	--	--	--	--	0.0000022	0.0000175
Barium	--	--	--	--	--	10	--
Calcium	--	--	--	--	--	--	--
Iron	--	--	--	--	--	1,000	30
Potassium	--	--	--	--	--	--	--
Magnesium	--	--	--	--	--	--	--
Sodium	--	--	--	--	--	50	100
Manganese	--	--	--	--	--	--	--
Zinc	$e^{(.8473[\ln(\text{hardness})] +0.8604)}$	$e^{(.8473[\ln(\text{hardness})] +0.7614)}$	--	$e^{(.8473[\ln(\text{hardness})] +0.8604)}$	$e^{(.8473[\ln(\text{hardness})] +0.7614)}$	--	--
Copper	$e^{(.9422[\ln(\text{hardness})]- 1.464)}$	$e^{(.8545[\ln(\text{hardness})]- 1.465)}$	--	$e^{(.9422[\ln(\text{hardness})]- 1.464)}$	$e^{(.8545[\ln(\text{hardness})]- 1.465)}$	--	--
Cobalt	--	--	--	--	--	--	--
Vanadium	--	--	--	--	--	--	--
Acetone	--	--	--	--	--	--	--
Trichlorethylene	--	--	807	45,000	21,900	2.7	90.7
Toluene	--	--	300,000	17,500	--	143	4,240
2-Propanol	--	--	--	--	--	--	--
Di-N-octylphthalate	--	--	--	--	--	--	--
Diethylphthalate	--	--	120,000	--	--	3,500	1,000

TABLE 10-2 (Cont'd)
Potential ARARs for Surface Water

Analyte	State of Tennessee[1]			Federal Water Quality Criteria[2]			
	Surface Water Standard for Freshwater Fish and Aquatic Life (μg/L)		Recreation (10^{-5} risk factor for carcinogens) Organisms Only (μg/L)	Acute Criteria for Protection of Aquatic Life[(a)] (μg/L)	Chronic Criteria for Protection of Aquatic Life[(b)] (μg/L)	Water and Fish Ingestion, Protection of Human Health (μg/L)	Fish Consumption Only, Protection of Human Health (μg/L)
	Criterion Maximum Concentration	Criterion Continuous Concentration					
Bromodichloromethane	--	--	--	--	--	--	--
Dibromochloromethane	--	--	4,700	--	--	--	--
Bromomethane	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	420	--	9,400	0.6	41.8
1,1,2,2-Tetrachloroethane	--	--	110	--	2,400	0.17	10.7
Carbon disulfide	--	--	--	--	--	--	--
2-Cyclohexene-1-one	--	--	--	--	--	--	--
Cadmium, dissolved	$e^{(1.128[\ln(\text{hardness})]-3.828)}$	$e^{(.7852[\ln(\text{hardness})]-3.490)}$		--	$e^{(.7852[\ln(\text{hardness})]-3.490)}$	10	--
Chromium (hexavalent), total recoverable	16	11		16	11	50	--
Chromium (trivalent), total recoverable	--	--		--	$e^{(0.819[\ln(\text{hardness})]-4.661)}$	170,000	3,433,000
Lead, total recoverable	$e^{(1.273[\ln(\text{hardness})]-1.460)}$	$e^{(1.273[\ln(\text{hardness})]-4.705)}$		--	$e^{(1.266[\ln(\text{hardness})]-4.661)}$	50	--
Mercury, total recoverable	2.4	0.012		2.4	0.012	0.144	0.146
RDX	--	--		--	300	--	--
2,4,6-TNT	--	--		--	60 (approximate due to insufficient data)	--	--
2,4-DNT	--	--		--	230	0.11	0.91

[1] Source: Rules of the Tennessee Department of Health and Environment, Bureau of Environment, Division of Water Pollution Control, Chapter 1200-4-3, General Water Quality Criteria, January 1991

[2] U.S. EPA, Office of Water Regulations and Standards, Washington, DC, Quality Criteria for Water, 1986, EPA 440/5-86-001

(a) 1-hour average concentration, not to be exceeded more than once every 3 years on the average

(b) 4-day average concentration, not to be exceeded more than once every 3 years on the average

TABLE 10-3
Effluent Limitations and Guidelines

Tennessee Effluent Limitations for Industrial Wastewater Treatment Plants[1]	
Chemical	Daily Maximum Concentration (mg/L)
Aluminum	250
Arsenic	1.0
Barium	5.0
Cobalt	10.0
Copper	1.0
Iron (total)	10.0
Manganese	10.0
Silver	0.05
Zinc	2.0
Cadmium	0.01
Chromium (total)	3.0
Lead	0.1
Mercury	0.05

[1] Source: TDHE, 1977

10.1.3 Soil Criteria

The chemicals of concern in contaminated soils at MAAP are the explosive compounds, chromium, cadmium and lead. There are no set maximum allowable residual levels for these chemicals in soils under Federal law or Tennessee law. However, EPA has proposed health-based chemical concentration criteria for action levels that have undergone extensive scientific review, but which have not been formally promulgated. Proposed guidance levels are available for selected hazardous constituents in water, soil and air. The TDC has proposed soil clean-up levels which, if applicable, may be ARARs for the site. Table 10-4 lists the guidance values proposed by EPA and the TDC for chemicals of concern in soils at MAAP.

EPA has recommended cleanup values for lead in soils based on studies of blood lead levels in exposed children. The EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9355.2 suggests a cleanup level for lead in soil of 500-1000 ppm.

RCRA has addressed land disposal of treated hazardous wastes in its land disposal restrictions (40 CFR 268). However, the applicability of these cleanup standards to cleanup of CERCLA sites is an issue EPA is currently addressing (54 FR 41566, October 10, 1989). EPA is investigating the need to set separate treatment standards for soil and debris [Notice of Proposed Rulemaking (NPRM) expected 12/90; final rule expected 10/91]. When promulgated, these standards may be ARARs for cleanup of contaminated soil at MAAP.

10.1.4 Other Guidance to be Considered

In the absence of Federal or State-promulgated ARARs, EPA states a preference for Office of Drinking Water Health Advisories and Reference Doses (RfDs) for systemic toxicants, and carcinogen potency factors (CPFs) for carcinogens (53 FR 51394, December 21, 1988). RfDs and CPFs are available from the EPA "Integrated Risk Information System (IRIS), and are listed in Table 10-5 for the indicator chemicals at MAAP. Where promulgated Federal and State standards have not been developed, for the chemicals of concern at MAAP, health-based guidance values have been calculated and are shown in Table 10-5.

2,4,6-TNT and RDX. EPA has set drinking water health advisories of 0.002 mg/L for 2,4,6-TNT and RDX (USEPA, 1989b). The value was calculated assuming that an individual receives 80% of his exposure from sources other than drinking water.

2,4- and 2,6-DNT. The U.S. Army Biomedical Research and Development Laboratory (USABRDL) has available ambient water quality criteria for the protection of human health for 2,4- and 2,6-DNT. These values are 0.00018 mg/L and 0.0000072 mg/L, respectively, and represent that concentration in water that will result in one excess cancer in one million individuals (a 10^{-6} risk) following a lifetime ingestion of 2 liters of water/day (Etnier, 1987).

1,3,5-Trinitrobenzene. The guidance value is derived from an oral Reference Dose (RfD) of 0.00005 mg/kg/day (USEPA, 1988b). Using the EPA methodology for deriving health advisories, an acceptable concentration (C_w) in drinking water of 0.0004 mg/L can be calculated in the following manner:

$$C_w = \frac{RfD \times BW}{IR} \times 0.2 \qquad (1)$$

where:

C_w = concentration in water that will result in no adverse health effects following ingestion of contaminated drinking water alone (mg/L)
RfD = Reference Dose (mg/kg-day)

TABLE 10-4
EPA Guidance Values for Chemicals in Soil

Concentrations Meeting Criteria for Action Levels[1]	
Chemical	Concentration in Soil (mg/kg)
1,3-DNB	8.0
Cadmium	40.0
Chromium (VI)	400.0
Mercury (inorganic)	20.0

[1] Environmental Protection Agency, 40 CFR Section 264.521 (a)(2)(I-IV)

TABLE 10-5
Office of Drinking Water Health Advisories and Reference Doses

TBC guidance Values for Indicator Chemicals at MAAP[1]			
Indicator Chemical	Rfd[2] (mg/kg/day)	CPF[3] $(mg/kg/day)^{-1}$	TBC[4] Guidance
2,4-Dinitrotoluene	--	0.19[5]	0.00018[6]
2,6-Dinitrotoluene	--	0.48[5]	0.0000072[6]
1,3,5-Trinitrobenzene	0.00005	--	0.0004
2,4,6-Trinitrotoluene	0.0005	--	0.002[8]
RDX	0.003	--	0.002[8]
Total Nitrates	1.0	--	--
Cadmium	0.0005	--	--
Total Chromium[9]	0.005	--	--
Lead	NA[10]	NA	--
Mercury (inorganic)	0.0003	--	--

[1] All values from the Integrated IRIS unless otherwise noted.

[2] RfD = Reference dose.

[3] CPF = Carcinogen potency factor.

[4] To-Be-Considered guidance.

[5] Value from Etnier, 1987.

[6] Estimated from a carcinogen potency factor. The concentration in water which will result in one excess cancer risk in 1×10^6 people following a lifetime exposure to contaminated drinking water.

[7] Estimated from a Reference Dose. The concentration in drinking water that is assumed to result in no adverse health effects following daily ingestion for a lifetime; assumes a 20% contribution of drinking water to total exposure.

[8] Drinking water health advisory (assuming a 20% contribution of drinking water to total exposure).

[9] RfD for chromium VI.

[10] Not available.

BW = assumed body weight of an adult (70 kg)

IR = assumed daily water ingestion rate of an adult (2 L/day)

0.2 = the relative source contribution of drinking water to total exposure

10.2 LOCATION-SPECIFIC ARARs

Location-specific ARARs set restrictions on remedial action activities depending on the characteristics of a site or its immediate environs. Much of the information regarding characteristics of MAAP was provided by officials from the State of Tennessee. Table 10-6 lists regulations that may be considered ARARs for MAAP.

10.2.1 Faults

There are no faults in the immediate area of MAAP (Tennessee Geologic Survey, 1978). However, the primary concern at the installation is its proximity to the New Madrid Seismic Zone, one arm of which extends almost to Dyersburg, Tennessee, 40 miles northeast of the plant (Stevens, 1989). The Tennessee Earthquake Center records an average of 150 earthquakes a year in this zone; consequently, Milan is in close proximity to major seismic activity (Algermissen and Hopper, 1984).

The Earthquake Center recently defined the seismic zone in which MAAP is located. The plant is located in Seismic Zone 2, which is at moderate risk from a large earthquake in the New Madrid Seismic Zone (Stevens, 1989). If any remedial action alternatives requiring site modification are selected, the RCRA regulation governing placement of hazardous wastes in fault zones may be relevant and appropriate requirements.

10.2.2 Wilderness Areas, Wildlife Refuges, and Scenic Rivers

There are no wilderness areas, wildlife refuges, or wild or scenic rivers inside of the plant boundaries (Hurst, 1989); however, under the Tennessee Water Quality Control Act, the Tennessee Water Control Board has designated the three primary streams in and near MAAP (the Rutherford Fork of the Obion River, the East Fork, and Wolf Creek) for the following uses: fish and aquatic life, recreation, irrigation and livestock watering and wildlife (TDHE, 1991). If any remedial actions are contemplated that would impact these areas, the regulation found in the Fish and Wildlife Coordination Act may be ARARs.

10.2.3 Wetlands and Floodplains

Three major watersheds (the Middle Fork of the Forked Deer River, Wolf Creek, and Rutherford Fork of the Obion River) and one minor watershed (Hall Branch of Johns Creek) drain MAAP (Blaylock, 1978; USATHAMA, 1988). Areas at MAAP subject to flooding after heavy rains, generally four inches or more in twelve hours or less, include portions of Hall's Branch and Wolf Creek (Blaylock, 1978; USACE, 1978). Flooding of the installation that occurs during rainy seasons could cause the off-post migration of surface soil contamination (USATHAMA, 1988; USACE, 1978).

The Flood Hazard Boundary Map and Flood Insurance Rate Maps, maintained by the Flood Emergency Management Agency (FEMA), indicate that there are some areas of MAAP that are located within the approximate 100-year floodplain (FEMA 1988a; FEMA 1988b). The Flood Plain Information Report (USACE, 1974) also identifies some additional areas at MAAP that are subject to flooding during a 100-year flood (ORNL, 1990). Therefore, the regulation prohibiting site modifications in a 100-year floodplain may be an ARAR for MAAP.

TABLE 10-6
Location-Specific ARARs

Selected Location-Specific ARARs for Milan Army Ammunition Plant			
Location	Requirement	Prerequisite(s)	Citation
Within 61 meters (200 feet) of a fault displaced in Holocene time	Prohibits new treatment, storage or disposal of hazardous waste	RCRA hazardous waste; treatment, storage, or disposal	EPA Regulations for Owners and Operators of Permitted Hazardous Waste Facilities, 40 CFR 264.18
Within 100-year floodplain	Facility must be designed, constructed, operated, and maintained to avoid washout by a 100-year floodplain	RCRA hazardous waste; treatment, storage, or disposal	EPA Regulations for Owners and Operators of Permitted Hazardous Waste Facilities, 40 CFR 264.18
Within floodplain	Must take action to avoid adverse effects, minimize floodplain destruction, restore and preserve natural and beneficial values, and minimize impact of floods on human safety, health, and welfare	Action of Federal agencies pertaining to: acquiring, managing, and disposing of lands and facilities; construction or improvements; and conducting activities and programs affecting land use in flood-prone areas	Executive Order 11988; Floodplain Management (40 CFR 6, Appendix A)
Wetland	Action to avoid adverse impact, minimize potential harm, and to preserve and enhance wetlands to the extent possible	Wetland as defined 40 CFR 6, Appendix A Section 4; Action by Federal agencies involving construction of facilities or management of property in wetland areas	Executive Order 11990; Protection of Wetlands (40 CFR 6, Appendix A)
Within area where action may cause irreparable harm, loss, or destruction of significant artifacts	Must take action to recover and preserve artifacts	Alteration of terrain that threatens significant scientific, prehistorical, historical, or archaeological data	National Archaeological and Historic Preservation Act (16 USC 469); National Historic Landmarks Program (36 CFR 65)
Historic project owned or controlled by Federal agency	Must take action to preserve historic properties; planning of action to minimize harm to National Historic Landmarks	Federal agencies must get approval for actions that affect property included in, or eligible for the National Register of Historic Places	National Historic Preservation Act Section 106 (16 USC 470 et seq.); 36 CFR 800.1 National Historic Landmarks Program (35 CFR 65)

TABLE 10-6 (Cont'd)
Location-Specific ARARs

Selected Location-Specific ARARs for Milan Army Ammunition Plant			
Location	Requirement	Prerequisite(s)	Citation
Critical habitat upon which endangered or threatened species depends	Action to conserve endangered or threatened species; must not destroy or adversely modify critical habitat; consultation with Department of Interior	Determination of presence of endangered or threatened species	Endangered Species Act of 1973 (16 USC 1531 et seq.); 50 CFR 402
Within area affecting stream or river	Must take action to protect affected fish or wildlife resources; prohibits diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife	Presence of fish and wildlife resources	Fish and Wildlife Coordination Act (16 USC 661 et seq.)

Wetlands occur throughout the 18,000 acres of the site (Powers, 1989). The State of Tennessee State Conservation Department classifies wetlands as areas having hydric soils and woody vegetation, therefore meeting the requirements defining a wetland according to the U.S. Department of Agriculture (Ellis, 1991). If any remedial actions are contemplated that would impact wetland areas, the regulations found in Executive Order 11988 and Executive Order 11990 may be ARARs.

10.2.4 Historic Sites and Archaeological Findings

There are three known archaeological sites at MAAP located on high ground overlooking Wolf Creek (Blaylock, 1978). One site is located in a cultivated area. Materials consist mostly of middle Archaic artifacts. The sites have not been extensively examined and therefore, their exact importance is unknown (Blaylock, 1978). An archaeological overview and management plan has been developed for MAAP; however, it does not provide conclusive information and a complete archaeological investigation needs to be conducted (Smith, 1989).

There is one historical structure of significance on MAAP, the Browning House, childhood home of Gordon Browning who was governor of Tennessee in 1937-38 and 1942-52 (MacDonald and Mack Partnership, 1984). The building is located adjacent to Line Z in the northwest portion of the installation. The Browning House has been entered in the National Register of Historic Places as provided for in the National Historic Preservation Act of 1966 (MacDonald and Mack Partnership, 1984). If any remedial actions are considered that would impact the archaeological sites or the historic home, the regulations listed in Table 10-6 may be an ARAR.

10.2.5 Rare, Threatened or Endangered Species

Rare or endangered species of animals have not actually been observed at MAAP; however, a 1978 report prepared by the Department of the Army recommends that four species of birds should be actively investigated to establish their status at the site. These species include: Sharp-shinned Hawk (Accipiter striatus velox), Cooper's Hawk (Accipiter cooperi Bonaparte), BeWick's Wren (Thryomanes bewickii), and the Grasshopper Sparrow (Ammodramus savannarum pratensis). These species appear on the State and Federal endangered list and the National Audubon Society's Blue List. Several endangered, threatened, rare, and special concern species occur in Gibson and Carroll County, Tennessee; however, further site study is needed to determine their status at MAAP and in the surrounding areas (Tennessee Department of Conservation, 1989a; Pitts, 1989).

One State-listed threatened plant, the Compass Plant (Silphium laciniatum), has been observed near the roadside by the boundary fence, on the southeast corner of MAAP (Eagar, 1989; Tennessee Department of Conservation 1989b). The Compass Plant has also been observed on the extreme southern edge of MAAP within a few hundred feet of the boundary fence (Blaylock, 1978).

If remedial action alternatives requiring site modifications are selected, regulations found in the Endangered Species Act of 1973 may be relevant and appropriate. In addition, any regulation cited in the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act (in Tennessee Code Annotated Section 70.8101) may be relevant and appropriate.

10.2.6 Air Quality

MAAP has used a burning ground to treat or dispose of some of its wastes. Approximately 370 acres have been used for the destruction and disposal of out-of-specification ordnance items and explosive-contaminated wastes since about 1942. A description of the burning grounds and activities conducted in these areas are presented in Section 2.3.2.

The ambient air quality at MAAP is considered good according to the most recent documentation of air monitoring conducted at MAAP (Blaylock, 1978). Air quality monitoring stations were constructed at MAAP but were later dismantled. The State of Tennessee does not specify that ambient air monitoring is required for the site.

The Tennessee Air Pollution Control Regulations, Chapter 1200-3-8, provide guidelines for the generation and control of fugitive dust. According to the established guidelines the emission of fugitive dust is not permitted to exceed five minutes per hour or twenty minutes per day as to produce a visible emission beyond the property line on which the emission originates. Based on past disposal practices conducted in the burning grounds Tennessee Air Pollution Control regulations concerning fugitive dust may be ARAR for the site.

10.3 ACTION-SPECIFIC ARARs

Remedial alternatives have not been evaluated or selected for MAAP, and therefore action-specific ARARs have not been developed at this time.

11.0 CONCLUSIONS AND RECOMMENDATIONS

This section presents a summary listing of the results obtained, conclusions reached, and unknowns or uncertainties remaining as a result of the RI conducted at MAAP during 1990-91. The findings are reproduced directly or are abstracted from the information contained in preceding Sections 1-10, and are presented here without supporting details or framework. The conclusions provide general and comparative interpretations of the findings, in terms of the general objectives of the RI, and also list the major uncertainties regarding the adequacy of site characterization. Recommendations are made for broad approaches to the potential problems evident at the site.

11.1 FINDINGS

Results of a site-wide or long-term nature are presented below, followed by a summary of findings impacting the RI/FS process at each of the major areas investigated.

11.1.1 General Results

- A broad range of chemicals were found in the environmental media, nearly all of which were found to be related to past or current use at the site. Several types of contamination related to munitions manufacturing and destruction processes at the site, including explosive compounds, metals, and various semivolatile and volatile organic compounds, were observed in surface and subsurface soils, surface water and sediments, and/or groundwater existing within or emanating from the vicinity of major suspected source areas.

- No evidence was found that contamination at levels posing imminent health hazards is migrating from the site via air and surface pathways. For the surface pathways, the evidence suggests that no non-recoverable or long-term environmental impacts has occurred or will occur.

- Groundwater is contaminated at the site perimeter and a potential was found for human exposures above acceptable limits, resulting in risk estimates that dictate consideration of potential remedial or corrective actions. However, the sources contributing to the observed contamination near the site boundary were not completely characterized during this investigation.

- Contamination at levels of concern was found in groundwater at the limits of the study area established for the RI; thus, the full extent of contamination is not known for this pathway.

- Although the transmissivity of the aquifer (27 ft/day) is quite high, the very small horizontal groundwater gradient (0.0015 ft/ft) results in a low (on the order of 0.2 ft/day) groundwater velocity. Vertical gradients were found to be on the order of 0.004 ft/ft and appear to vary across the site. These flow conditions, along with the presence of multiple source areas and variable infiltration characteristics, contribute to the complex three-dimensional pattern of contamination observed. Two-dimensional hydrodynamic modeling attempts were unsuccessful in reproducing the observed groundwater flow parameters.

- The observed vertical gradient at the northern boundary and the presence of contamination predominantly in the lower portion of the aquifer strongly suggests that only a small fraction of contaminated groundwater discharges to the Rutherford Fork of the Obion River.

- High aquifer yields and broad, three-dimensionally diffuse contaminant plumes were found. Thus, the feasibility of simple comprehensive remedial measures, such as interception of contaminated groundwater at the site perimeter, is not assured.

- The data show that several unit sources are releasing or have released pollutants; however, the exact source-pathway-transport relationships to reproduce the complex patterns observed could not be discerned from available data.

- Flow measurements made in Ditches B and C show that infiltration of surface water in the ditch systems occurs to a significantly greater degree than would be expected in areas which are not drainage ways. Except during periods of high and extended loading, a large percentage of the runoff (or wastewater discharge) collected by these ditches will infiltrate (or has infiltrated) prior to discharge into the Rutherford Fork of the Obion River.

11.1.2 O-line Ponds Source Area

- No evidence was found that contamination emanating from the closed O-Line Pond unit is resulting in direct and immediate human health impacts. Groundwater contamination problems associated with current or recent releases from the O-line Ponds were found to pose a future threat which does not require immediate corrective action. However, releases during the operational period of this unit which migrated via surface routes prior to infiltration through the soil underlying the ditches apparently have caused groundwater contamination of a more immediate concern.

- There is a potential for future impact from groundwater contamination observed in the vicinity of the O-Line Ponds. It is possible that residual contamination beneath the closed unit could result in releases to groundwater for a considerable period of time, and ultimately pose unacceptable health or environmental risks.

- The total explosives-compound loading to groundwater from sources related to the O-line Ponds was estimated to be on the order of 1.5 lbs/day.

11.1.3 OBG and ADA Source Areas

- No conclusive evidence was found that sources within the demolition and disposal areas pose unacceptable short-term health or environmental risks. Contamination currently or previously observed in groundwater at the boundary of the installation was shown not to have originated within these areas. However, evidence suggests that contaminants are being released from these areas into groundwater, with potential longer-term effects.

- Little additional evidence was obtained regarding specific source areas or release potentials from sources within the OBG and ADA complex. However, the lack of uniformity in results obtained from subsurface sampling over a fixed grid verifies that contamination is restricted to specific source areas.

- Evidence from sampling of the RCRA wells suggests that contamination entering the groundwater from sources in the OBG and ADA Areas is transported quickly to the lower portion of the aquifer.

- The total explosives compound loading to groundwater for this area was estimated to be on the order of 0.3 lbs/day.

11.1.4 Load Line Sumps

- Explosives-compound contamination exists within the soil column beneath and near most of the wastewater sumps at the Load Lines, but the levels attenuate rapidly with depth. No contamination was found at depths more than 15 feet below the ground surface and the sumps do not appear to pose imminent health or environmental hazards. However, the available data are not adequate to determine the extent of contaminant migration.

- Lead and cadmium contamination was detected in some of the soils near sumps, and/or in nearby groundwater wells. It is not known whether the metals contamination in groundwater arises from releases of the sumps or from other adjacent sources.

- Sumps and/or sludge pits at Line K were not investigated to an extent commensurate with past practices identified and the level of contaminants found in groundwater nearby.

11.1.5 Drainage Ditches

- There is strong evidence that at least the drainage ditches near the O-Line Ponds are line sources for groundwater contamination. Data supporting this conclusion include calculated groundwater flow velocities, observed contamination patterns, measured surface-water flow parameters, and reported wastewater disposal practices and rates. Because of rapid infiltration and very high historical loading of the ditches by explosives-laden wastewater, at least some portions of the ditches appear to act as major sources of groundwater contamination.

- Evidence suggests that the ditch running north from Line Z is the source for groundwater contamination previously reported in off-site residential wells. No off-site contamination by explosives was found in this area during the present study.

- The Ditch 1 drainage system has received wastewater from LAP Lines A and X. Flow from this system enters Wolf Creek near the facility boundary and continues north. It is possible that the soil underlying Ditch 1 and Wolf Creek has retained contaminants contributed by past disposal activities and that groundwater quality has been or is being impacted by these areas. Because the City of Milan water supply wells are located approximately 2,000 feet west of Wolf Creek, it is recommended that a system of regular monitoring be implemented, and that further work be done to characterize Ditch 1 and Wolf Creek as potential sources.

- Explosives contamination found in the shallow sediment of the drainage ditches is at or below the levels attributable to permitted discharges. Metals contamination occurs at some locations at levels below regulatory or risk-based limits. No site-related contamination of concern was found in the perennial streams below the outfalls of the ditches.

11.1.6 Other Potential Source Areas

- Results show that the Former Burn Out Area is not a significant source of contamination.

- No evidence was obtained suggesting that the Present Landfill is a source of explosives or select metals contamination.

- The near-surface soil in and groundwater near the Closed Landfill was found to be contaminated with explosives and metals. The data are insufficient to determine the extent of soil contamination or whether the landfill is the source of observed groundwater contamination.

- Various site-related volatile and semivolatile organic compounds were found in soil borings at the Former Borrow Pit, indicating that this area was the site of past waste disposal. No evidence was found that releases from this unit to groundwater have occurred.

- Evidence suggests that the Salvage Yard is not a major source of soil or groundwater contamination.

11.2 CONCLUSIONS AND UNCERTAINTIES

In summary form, the major conclusions of this study are as follows:

- Groundwater contamination along a broad expanse and arising from several contributing sources is the problem of greatest concern at MAAP. The contaminated groundwater plumes extend toward off-site receptors, and the potential health threat is unacceptably large. Further data collection and/or an analysis of potentially feasible remedial or corrective measures is required. In order of decreasing availability to receptors with secondary consideration for chemical toxicity, known source strength, and release potential, the predominant source areas contributing to groundwater contamination are:
    - the ditches north of the O-line Ponds Area;
    - the closed O-line Ponds;
    - the OBG/ADA;
    - sumps, ditches, and wastewater ponds at several load lines;
    - the Closed Landfill;
    - the Former Borrow Pit; and
    - other areas investigated during this RI.
- Areas with relatively low or no observed problems and requiring no further action include:
    - the Former Burn Out Area;
    - the Present Landfill; and
    - the Salvage Yard.
- A significantly more complex set of hydrologic, chemical, and source identification questions were raised than can be resolved by available data. Many findings cannot be rationalized with the previously held concepts of release and transport from known sources at the site, and critical data for several areas are not available to isolate sources of concern. Because a single comprehensive remedy (e.g., groundwater extraction and treatment at the boundary) may be infeasible, data are needed prior to initiation of remedial or corrective actions to determine:
    - the source of groundwater contamination in wells west-northwest of the load lines, and north-northeast of the O-Line Ponds;
    - the source strength and release potential of soil contamination at the load line sumps;
    - the location and strength of specific sources within the OBG/ADA which are causing the observed down-gradient contamination;
    - a complete correlation of observed contamination with specific sources in the north-central portion of the site;
    - the full extent of contaminant migration toward the north and northwest, preferentially related to specific sources;

- a comprehensive inventory of, as well as the full nature and extent of contaminant release and transport for many types of site-related chemicals other than explosives and select metals;
- the nature and extent of contamination sources near Line K and/or in areas where sludge may have been disposed (including cyanide wastes);
- the full extent of both lateral and longitudinal contamination due to potential releases from the ditches, both near the load lines and along the northern portions of major ditches B and C; and
- a better understanding of the groundwater hydrology adequate for analyzing findings and making predictions of future events.

Many of these uncertainties are due to the inadequacy of available information toward understanding of hydrologic and transport processes, and to the presence of multiple contamination sources. Thus, for many of the areas the site characterization phase has not progressed to the point where the feasibility of remedial options can be evaluated.

- The area where data are sufficient to proceed to a feasibility study phase, with concurrent additional data collection as necessary, is the O-Line Ponds Area, where additional data requirements can be related to needs for remedy selection and alternatives analysis.

11.3 RECOMMENDATIONS

- It is recommended that a comprehensive additional remedial investigation be performed to fully characterize site features relevant to determining the need for and nature of potential remedial actions. A considerable volume of additional multi-level hydrologic and chemical data and a more complete investigation of source strengths and release potential are needed to develop an understanding of source, transport, and fate processes at the site.
- It is recommended that a program to remedy (if required) and close selected units be implemented. Unit-specific data collection should be performed as needed to evaluate the feasibility of potential remedial actions in terms of risk abatement, implementability, and other criteria listed in the National Contingency Plan.

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