DEPARTMENT OF THE ARMY
UNITED STATES MILITARY ACADEMY
WEST POINT, NEW YORK 10996

August 25, 1998

REPLY TO
ATTENTION OF

Directorate of Housing and Public Works

SUBJECT: Final Closure Design for the Motorpool Landfill

Mr. Paul Patel
Division of Solid and Hazardous Materials
Bureau of Hazardous Waste Facilities
New York State Department of
Environmental Conservation
50 Wolf Road
Albany, New York 12233-9240

Dear Mr. Patel:

Enclosed please find the final design analysis report, plans and specifications for the Closure of the Motorpool Landfill at the United States Military Academy.

We appreciate the comments, suggestions and cooperation you have provided throughout this design. We will keep you apprised of the construction which is anticipated to begin in the Spring of 1999. Thanks again for your continuing contribution to the United States Military Academy's restoration program.

Sincerely,

E Rood

Eugene E. Rood, P. E.
Chief, Environmental Management Division

Enclosures

Design Analysis Report
for
U.S. Military Academy
Motor Pool Landfill Closure

Prepared for

U.S. Army Corps of Engineers–Baltimore District
Baltimore, Maryland
DACA31-94-D-0025

Prepared by

EA Engineering, Science, and Technology
15 Loveton Circle
Sparks, Maryland 21152
(410) 771-4950

August 1998 **Project No. 60787.76**

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LIST OF ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Government Industrial Hygienists
ASTM	American Society for Testing and Materials
bgs	Below Grade Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
cf	Cubic Foot/Feet
CFR	Code of Federal Regulations
CHPPM	Center for Health Promotion and Preventative Medicine
cm	Centimeter(s)
DIFP	Digital Instantaneous Floating Point
EPA	Environmental Protection Agency
ft	Foot/Feet
in.	Inch(es)
IR Program	Installation Restoration Program
L	Liter(s)
lb	Pound(s)
LEL	Lower Explosive Limit
LMA	Leachate Management Analysis
MCL	Maximum Contaminant Level
ml	Milliliter(s)
NYSDEC	New York State Department of Environmental Conservation
PCB	Polychlorinated Biphenyls
ppm	Parts Per Million, Volume
PVC	Polyvinyl Chloride
RCP	Reinforced Concrete Pipe
RQD	Rock Quality Density
sec	Second(s)
SVCA®	Soil Vapor Contaminant Assessment
SVOC	Semivolatile Organic Compound

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

TAL	Target Analyte List
TCL	Target Compound List
UEL	Upper Explosive Limit
USACE	United States Army Corps of Engineers
USAEHA	United States Army Environmental Hygiene Agency
USMA	United States Military Academy
VOC	Volatile Organic Compound

1. INTRODUCTION

1.1 PROJECT SCOPE

On 30 September 1997 the U.S. Army Corps of Engineers–Baltimore District (USACE–Baltimore), issued Delivery Order No. 131 under Contract No. DACA31-94-D-0025 to EA Engineering, Science, and Technology. Under this Delivery Order, EA is tasked to develop design documents for the closure of the Motor Pool Landfill at the U.S. Military Academy (USMA), West Point, New York.

This project is being performed in response to recommendations proffered in previous investigations conducted in accordance with provisions of the Installation Restoration (IR) Program, including AR 200-1 Executive Order 12580 and DA PAM 40-578.

This project deliverable comprises a design analysis report, design drawings, specifications, and an engineering cost estimate for improvements to the Motor Pool Landfill. The design concepts incorporated herein have been developed in part from selected recommendations from previous investigations, previous leachate management analyses, and recent pre-design activities conducted under this delivery order.

The design incorporates the following concepts and components based on previous recommendations and EA understanding of the planned future use of the Motor Pool Landfill property.

- Regrade and improve the perimeter drainage course to minimize stormwater run-on/infiltration, thus minimizing its potential contribution to landfill leachate generation.

- Construct landfill cover consisting of new surface pavement system including subgrade improvements as required to stabilize the pavement system. New pavement system will conform to a grading plan designed to promote and manage surface water run-off and minimize infiltration.

- Construct a landfill gas venting/management system for conveyance of landfill gas through the asphalt cap.

- Install a leachate collection trench and tie-in to the exiting sanitary sewer system to convey leachate from a leachate seep location to the USMA Wastewater Treatment Plant.

- Demolish and reuse the existing bituminous pavement.

This Design Analysis Report is based upon new information from pre-design activities and prior investigations and analyses conducted by EA and others as referenced in the documents entitled: *Phase II Leachate Management Analysis of Six Landfills, U.S. Military Academy, West Point, New York* (EA 1996), and *Phase II /Investigation Report of Six Landfills, U.S. Military Academy, West Point, New York* (EA 1995).

1.2 SITE DESCRIPTION/ HISTORY

USMA is adjacent to the Town of Highland Falls in southeastern New York State. USMA consists of the West Point cantonment area, the range areas outside of West Point, Stewart Army Subpost, and Galeville. The Academy is located along the west shore of the Hudson River at the base of several prominent hillsides (Figure 1-1). The area is dissected by several small streams and is the source for many ground-water springs (Frimpter 1970). Much of the original topography has been altered by construction of buildings and roads.

The Academy currently consists of facilities and infrastructure which support USMA's primary training mission. USMA has a population of residents living permanently onsite and additional workers who commute to the Academy.

The Motor Pool Landfill (Figure 1-2) is located on the West Point grounds immediately south of Washington Gate and east of Buildings 719 and 783. The landfill was in use from 1964 to 1969 and is reported to have received primarily sanitary and domestic wastes, although personnel at USMA indicated that wastes (oils, solvents, etc.) from the Motor Pool and/or the nearby dry-cleaning facility may have been placed in the landfill. Aerial photographic sequences from 1965 show landfilling activities. Photographic records from 1974 indicate secession of landfilling activity. The interpreted extent of the landfill shown on Figure 1-2 is based on aerial photos and includes the area adjacent to and east of Building 783, throughout the parking areas. Interviews with West Point operations personnel indicate that trenching was employed but discontinued when compaction proved to be a problem (Meade 1992). Pit and fill methods were then used at

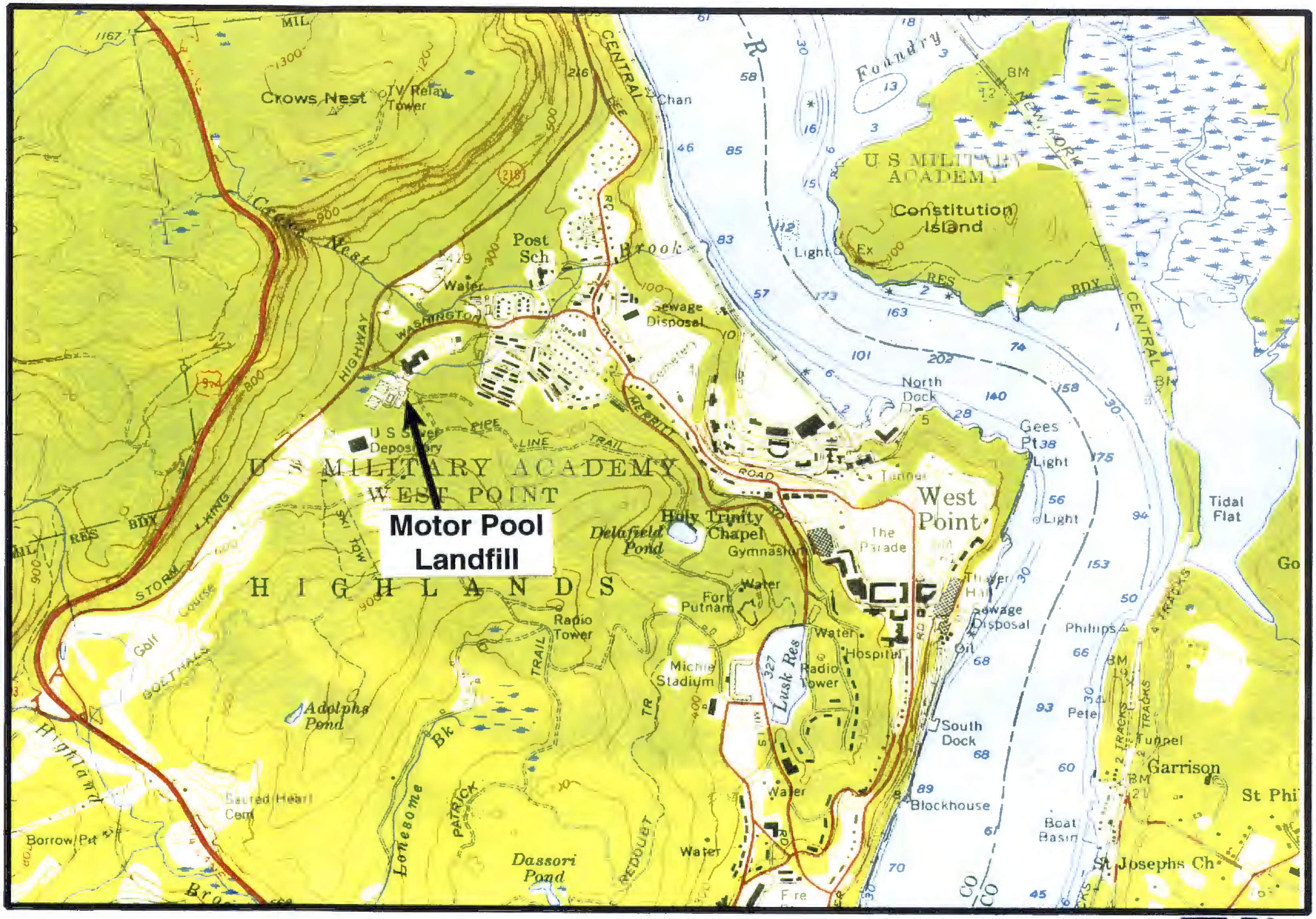
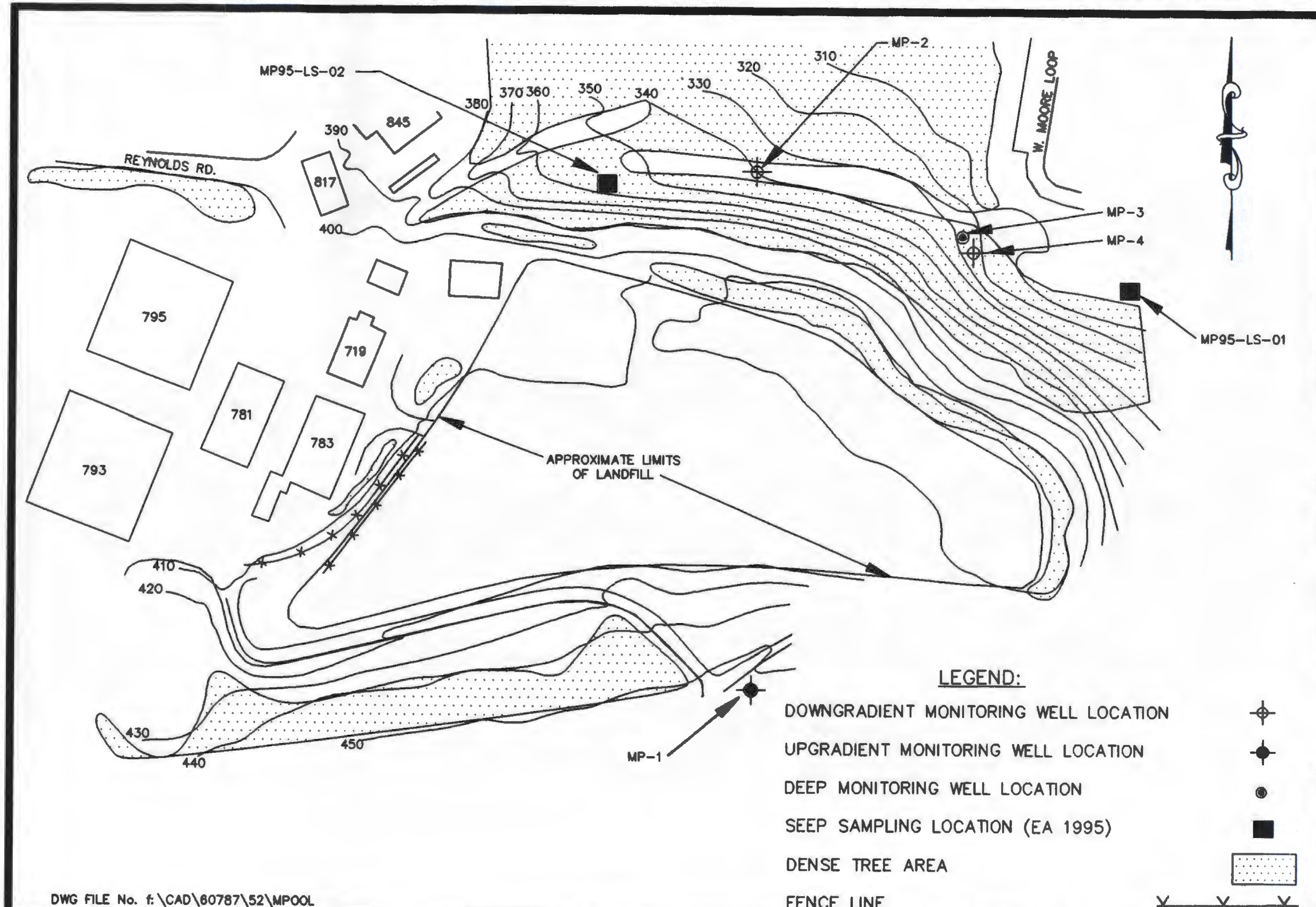


Figure 1-1. Vicinity Map, United States Military Academy, West Point, New York.



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	WEST POINT MILITARY ACADEMY MOTOR POOL LANDFILL CLOSURE WEST POINT, NEW YORK	FIGURE 1-2 SITE LOCATION MAP MOTOR POOL LANDFILL	DESIGNED BY	DRAWN BY SY	DATE 25 JUL 1995	PROJECT NO. 60787.76
			CHECKED BY	PROJECT MGR. JHS	SCALE N.T.S.	FILE NO. MPOOL

the landfill. The landfill was closed by covering with 2 ft of soil and paving. Following the capping and paving of the landfill, the motor pool area was used continuously as a parking and staging area for government vehicles and equipment.

In the 1970s, an odor and leachate problem prompted a study by the U.S. Army Environmental Hygiene Agency (USAEHA) [now the Center for Health Promotion and Preventative Medicine (CHPPM)] at this site. Positive results for methane gas and hydrogen sulfide were obtained at the north end of the landfill. Results of leachate and stream samples indicated that although the leachate contained reportable levels of several metals, there was no measurable degradation to surface water quality (USAEHA 1990). Summaries of more recent site investigations are provided in Chapter 2.

Two seeps were originally sampled in the vicinity of the Motor Pool Landfill in 1988 and are shown on the Existing Conditions and Removal Plan. Seep MP95-LS-01 is on the northeastern slope of the landfill behind Building 523 on S. Moore Loop. Seep MP95-LS-02 is on the northern slope of the landfill, south of the laundry facility, Building 845. The seep discharge points are characterized by orange discoloration.

During pre-design investigations for the current design, a third seep was identified approximately 100 ft east of seep MP95-LS-01. The new seep has been identified as MP98-LS-03 and is shown on the Existing Conditions and Removal Plan.

1.3 EXISTING CONDITIONS

The Motor Pool Landfill, as currently configured, is an elevated triangular parcel encompassing approximately 5 acres. It is bounded on the south by a perimeter drainage swale and further south by steeply rising wooded slopes. The Motor Pool is bounded on the northwest by paved surfaces and a cluster of government buildings including a fuel dispensing facility, warehouses, and other industrial use buildings. The northeastern and eastern landfill boundaries are intermittently wooded but contain landfill debris including metal, construction debris, and household items which protrude from the hillside among boulders and angular rock fragments. The northeastern landfill boundary descends steeply toward the Moore Loop housing cluster. The parking and equipment staging areas are enclosed by chain link fencing. The landfill surface is finished with asphalt paving in some areas, a tar and chip paving system in some areas, and compacted gravel in the remaining areas. A gravel road transits the landfill's northern boundary providing access to two entrance gates. An 18-in. reinforced concrete storm drain transects the central portion of the landfill from south to north. Stormwater is currently directed through and around the landfill, discharging into a stream near Building 817 to the northwest, and into a stream near Building 523 to the east.

1.3.1 Ground-Water Characterization

Ground-water samples were collected from four site monitoring wells during the Phase II Investigation (EA 1996). Ground-water sampling locations included overburden wells MP-1, MP-2, and MP-4, and bedrock well MP-3; these locations are shown on the Existing Conditions and Removal Plan. The wells were installed and sampled during a subsurface investigation conducted by Law Environmental (Law 1994). Samples from the four wells were analyzed for Target Compound List (TCL) volatile organic compounds (VOC), TCL semivolatile organic compounds (SVOC), TCL pesticides/polychlorinated biphenyls (PCB), Target Analyte List (TAL) metals plus cyanide, and 15 water quality parameters. Complete analytical results including data interpretation relative to New York State Department of Environmental Conservation (NYSDEC) Water Quality Regulations for Surface waters and Groundwaters (NYSDEC 1991) are provided in the Phase II investigation Report (EA 1996). The following summarizes the results of the two previous ground-water investigations (Law 1994, EA 1996).

The VOC, SVOC, and water quality parameter analytical results from ground water collected during both the current investigation and the results reported in 1994 suggest that the waste material at the Motor Pool Landfill is not significantly impacting overburden water quality. The Motor Pool Landfill ground water exhibited elevated metals concentrations in the downgradient wells relative to the upgradient wells. Although the NYSDEC Class A standards were exceeded for some compounds, the metals exceeding these standards included aluminum, iron, magnesium, manganese, and sodium, which are parameters associated with taste and odor characteristics relative to drinking water quality and do not have primary drinking water maximum contaminant levels (MCLs).

The four Motor Pool ground-water samples were analyzed for 15 water quality parameters. Comparison of the overburden results from upgradient wells MP-1, MP-2, and MP-4 showed an increasing trend in most of the water quality parameters over the site. All of the parameters, except color, were present at lower concentrations in the bedrock well (MP-3) compared to its nested overburden well (MP-4). None of the reported concentrations exceeded the NYSDEC

Class A ground-water standards. The measured pH in MP-1 slightly exceeded the regulatory range (6.5-8.5) specified in New York State Part V for drinking water.

1.3.2 Leachate Characterization

In order to characterize leachate emanating from two seep locations north of the Motor Pool Landfill, samples were collected during the Law subsurface investigation (Law 1994) and again during the Phase II Investigation (EA 1996). The leachate samples were analyzed for 33 TCL VOC, 64 SVOC, 28 pesticides/PCB, 23 TAL metals plus cyanide, and 15 water quality parameters. Complete analytical results including data interpretation relative to NYSDEC Water Quality Regulations for Surface waters and Groundwaters (NYSDEC 1991) are provided in the Phase II investigation Report (EA 1996). The following summarizes the results of the two previous investigations (Law 1994, EA 1996) for characterization of leachate at the Motor Pool Landfill. Leachate sampling results from several investigations are included in Appendix A.

Two Motor Pool leachate seep samples (MP95-LS-01 and MP95-LS-02) exhibited elevated metals concentrations and elevated water quality parameter results relative to the background samples collected from the spring located west of the USMA Washington Gate entrance. Although results of the seep analyses indicate that NYSDEC Class A standards were exceeded, the metals which exceeded the standards included aluminum, iron, magnesium, manganese, and sodium, parameters associated with taste and odor considerations for drinking water quality. Both seeps exhibit iron and manganese flocculation, creating undesirable visual impacts to water and soil. An additional concern associated with MP95-LS-01 is its proximity to the Moore Loop housing cluster. This location affords an increased risk of direct human and animal contact with leachate in soil and water media. During dry periods leachate exists in a relatively undiluted state in pools formed along the course of the intermittent stream that transits the rear of the Moore Loop housing. USMA has expressed a desire to eliminate this condition through design and construction of a leachate intercept and conveyance system, a principal element of this design.

1.3.3 Geology

As reported by Law (1994), the overburden at all four Motor Pool well locations consisted of glacial till or reworked till. The layer of reworked till was typically observed within the upper 5 ft of the overburden. Boulders were encountered in the subsurface at downgradient wells

MP-2 and MP-3, and were evident on the site surface. The overburden composition is generally a fine to medium silty sand with gravel and/or trace clay. However, at well MP-2, a thin (0.6-ft thick) silty clay lens was observed 20 ft below ground surface (bgs), and a thin clayey sand layer was observed at 26 ft bgs. Based upon the site topography and boring logs of the monitoring wells, the overburden is 35 ft thick at cluster MP-3/MP-4, at least 30 ft thick at MP-2, and at least 18 ft thick at MP-1.

Law (1994) also provided an interpretation of the rock core descriptions from samples collected during the installation of well MP-3. The following summarizes the Law interpretation of the rock cores. The bedrock geology consisted predominantly of light gray well foliated biotite-feldspar gneiss (possible biotite-quartz-feldspar) with a thin layer of amphibolite occurring between 36.5 and 39 ft bgs. Bedrock was encountered at about 35 ft bgs at this location. The biotite-feldspar-gneiss contained abundant low angle fractures (20-40 degrees) which occurred throughout the cored section. The average rock quality density (RQD) for the section above the bottom of the steel casing (35-44 ft bgs) was 53 percent. The average RQD for the lower section (44-54 ft bgs) was 60 percent. The fractures in the lower 5 ft of the deeper section exhibited evidence of iron staining.

1.3.4 Hydrogeology

The hydrogeology of the Motor Pool investigative area consists of two hydrostratigraphic units: an unconfined/semi-confined overburden zone and a fractured bedrock zone.

Ground water was observed in the overburden at monitoring wells MP-1, MP-2, and MP-4. Water levels obtained at MP-2 and MP-4 in June 1993 (15.12 and 13.16 ft bgs, respectively) and June 1995 (13.7 and 12.3 ft bgs, respectively) suggest that the overburden thickness may be relatively consistent at these monitoring well locations. In addition, based on the ground-water elevations in the overburden for the Motor Pool lot wells, which were 450.32 ft at well MP-1, 322.88 ft at well MP-2, and 306.60 ft mean sea level at well MP-4, it is apparent that these elevations are a consequence of their topographic setting. The dominant direction of overburden ground-water flow beneath the site is generally to the northeast.

Law (1994) observed iron staining in the lower fractured bedrock zone of well MP-3 and concluded the primary ground-water conduits within the bedrock are within the 44- to 54-ft interval. Based upon the water level measured in well MP-3, which was 7 ft higher than the nested overburden well MP-4 in both the June 1993 and 1995 sampling events, there is an apparent upward ground-water flow component for the fractured bedrock aquifer.

Surface water in the area includes a stream flowing west and north, parallel to South and West Moore Loop. The elevation of the stream surface in the area of wells MP-3/MP-4 is approximately 300-310 ft above mean sea level, which coincides with the measured water elevation for well MP-4. The surface water may receive seasonal recharge from shallow ground water.

2. PREVIOUS INVESTIGATIONS/ PRE-DESIGN ACTIVITIES

This section summarizes previous investigations conducted at the Motor Pool Landfill as well as supplemental pre-design work performed under this delivery order. Previous investigation and pre-design activities at the Motor Pool Landfill have included aerial surveys, Soil Vapor Contaminant Assessment (SVCA®), geophysical surveys, geotechnical investigations, and supplemental surveying. The results of these activities are summarized in this section. Previous investigations by Law (1994) and EA (1996) contain supplemental pre-design information. Applicable portions of previous investigations have been incorporated into this section as cited.

2.1 LEACHATE MANAGEMENT ANALYSIS

As discussed in Chapter 1, the two most recent ground water and leachate quality assessments were performed at the site in June 1993 (Law 1994) and during June 1995. Following chemical characterization, a Leachate Management Analysis (LMA) was conducted (EA 1996) to provide more comprehensive data upon which to base future remedial action. The field aspects of the LMA included soil vapor surveys, preliminary leachate flow estimates, and permeameter testing. Supplementing the collection of field data were interviews with USMA operational personnel, and a review of utility drawings. An economic engineering analysis was performed to explore the most cost-effective short- and long-term alternatives for the management of leachate at the Motor Pool. Leachate volume reduction, collection, conveyance, and disposal/treatment were remedial options presented as alternatives in the LMA. Alternatives proposed in the LMA were based on environmental and aesthetic concerns, economic considerations, and on USMA's overall objectives for the future use of the Motor Pool.

Three principal LMA recommendations are summarized as follows:

- *A leachate collection system should be installed* at seep locations MP95-LS-01 and MP95-LS-02. The collection system should be connected directly to the existing sanitary sewer system located along the southwest side of the South Moore Loop housing cluster.

  The criteria associated with this recommendation were primarily economic, as the sanitary sewer connection offered substantial long-term savings compared to pretreatment or "containerization/pumping /transport" scenarios. The recommended leachate conveyance alternative minimizes space requirements and long-term operations and maintenance costs.

- *Repaving of the surface of the Motor Pool landfill was recommended to achieve leachate source reduction.* This action, while improving Motor Pool aesthetics and function, was recommended to minimize stormwater infiltration through the landfill surface, and waste-bearing layers .

- *The LMA suggested that a landfill gas management plan may also be required* due to the elevated concentrations of methane gas recorded during the field investigation activities. Results of the soil gas survey are presented in following Sections 2.3.

2.2 AERIAL SURVEY

In order to provide an up-to-date topographic map USMA commissioned a base-wide topographic survey. The survey was conducted by Vollmer Associates, New York, using aerial photogrammetry (dated 22 April 1994) and supplemental field-run surveys. The photogrammetric scale was 1 in. = 50 ft. Electronic files of the survey were transferred to EA from USMA to provide the basis for the 30% design drawing set and calculations. Topographic maps were produced using a 2-ft contour interval as specified by USMA. Existing physical features including utility lines, monitoring wells, roads, fences, utility service vaults, buildings, and fences identifiable by the aerial survey were plotted. Horizontal and vertical control points for the aerial survey were provided by USMA staff.

2.3 SOIL VAPOR SURVEY

2.3.1 Field and Analytical Methods

Soil vapor sampling and analysis using an onsite laboratory was performed during the Phase II Investigation from 19 through 22 June 1995. Sorbent trap samples of soil vapor were collected on 25 July 1995. Samples were collected from 34 of the 40 planned locations. Six locations were not sampled due to probe refusal at less than 2 ft. The soil vapor samples were analyzed for methane, five non-chlorinated aromatic VOC (benzene, toluene, ethylbenzene, m/p-xylenes, and o-xylenes), and 2 chlorinated VOC (trichloroethene and tetrachloroethene), using a field gas chromatograph equipped with flame ionization and electron capture detectors.

Sorbent trap samples were analyzed by Envirosystems, Inc., of Columbia Maryland for TCL VOC by EPA Method 8240. Laboratory quality assurance/quality control included the introduction of spiked samples and spiked duplicate samples as well as laboratory control samples and method blanks.

Soil vapor concentrations were calculated using the external standard method applying the following physical/chemical relationship.

$$C_i = CF_i * A_i * V_s / V_{std}$$

where:

C_i = Vapor concentration of analyte of concern (ppm_v)
CF_i = Calibration factor for analyte of concern
A_i = Observed area of targeted analyte
V_s = Vapor volume of sample (ml)
V_{std} = Vapor volume of standard (ml).

CF_i is calculated by dividing the concentration of the target analyte in the calibration standard (ppm_v) by its observed peak area on the gas chromatograph.

2.3.2 Soil Vapor Survey Results

Table 2-1 summarizes the concentrations of the methane, non-chlorinated organics, and chlorinated organics measured during the soil vapor survey. In addition, the results from a previous methane survey performed by Law are incorporated and identified in the table (Law 1994). Law collected nine methane samples.

Methane was detected in seven of nine samples collected by Law, with the average and maximum concentrations of 0.03 and 0.1 percent, respectively. These samples were all collected from the perimeter of the landfill.

Methane was reported in 26 of the 31 samples collected by EA (EA 1996), with average and maximum concentrations of 33.4 and 85.6 percent, respectively. Five of the results exceeded the lower explosive limit (5 percent) and 21 of the results also exceeded the upper explosive limit (15 percent) for methane.

Figure 2-1 presents the spatial analytical results of the methane survey. The highest methane concentrations were reported on the northeastern perimeter of the landfill. The results in Figure 2-1 were derived from geostatistical analysis using kriging as the applied mathematical approach. The output from the kriged results, which yields statistically weighted concentrations, showed concentration isopleths increasing from the approximate center of the landfill toward the northeast corner. Additional detailed description of the geostatistical analysis, interpretive figures, and raw soil gas data tables are presented in the appendixes of the Phase II Investigation Report (EA 1996).

Motor Pool soil vapor samples were also analyzed for two chlorinated and five non-chlorinated VOC using a field gas chromatograph. The analytical results for benzene, toluene, ethylbenzene, m/p-xylene, o-xylene, trichloroethene, and tetrachloroethene are summarized in Table 2-1.

Figure 2-2 presents the spatial analysis of the total benzene, toluene, ethylbenzene, and xylene (BTEX) results. The highest total BTEX concentrations were reported on the western perimeter of the landfill. The output from the kriged results, which yields statistically weighted concentrations, showed concentration isopleths decreasing from the western side of the landfill towards the center of the landfill. Additional detailed description of the geostatistical analysis, interpretive figures, and raw soil gas data tables are presented in the appendixes of the Phase II Investigation Report (EA 1996).

Soil vapor sorbent traps were collected from two locations: one within the center of the landfill and one along the perimeter of the landfill. A volume of 5 L of soil vapor was concentrated on the traps; the traps were analyzed for TCL VOC. Toluene, 4-methyl-2-pentanone, and xylenes were reported in sample MP95-ST-01. These compounds were also detected in the sample collected at the landfill perimeter. The concentrations did not exceed the lower explosive limits or the New York State Ambient Guidance Concentrations.

2.4 GEOPHYSICAL SURVEYS

2.4.1 Ground Conductivity Survey

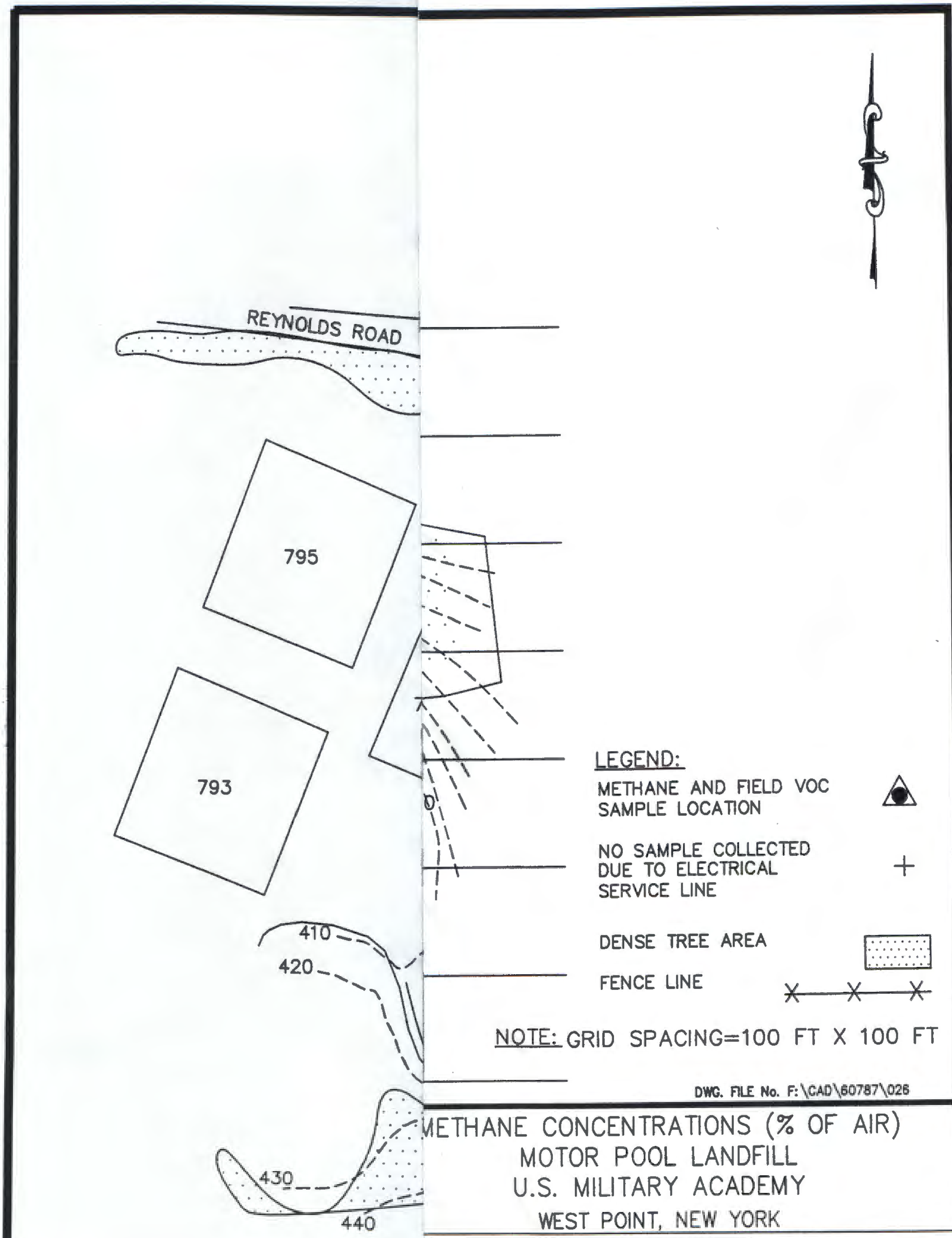
As part of the pre-design activities EA conducted a limited geophysical investigation to estimate the lateral extent of the fill mass at the Motor Pool Landfill. The investigation which included EM-31 ground conductivity and seismic refraction data acquisition was conducted on 13 and 14

TABLE 2-1 SOIL VAPOR RESULTS FROM THE MOTOR POOL LANDFILL

Analyte	Units	Phase I Results(a)			Phase II Results			LEL(c)	UEL(c)
		Range	Frequency	Mean(b)	Range	Frequency	Mean(b)		
Methane	%	0.0-0.1	7/9	0.03	0.0-85.6	26/31	33.4	5(d)	15(d)
Benzene	ppm_v	---(e)			(<1U)-1.8	3/34	0.14	14,000	71,000
Toluene	ppm_v	---(e)			(<1U)-55.0	12/34	3.6	12,700	67,500
Ethylbenzene	ppm_v	---(e)			(<1U)-21.0	10/33	2.9		
m/p-Xylene	ppm_v	---(e)			(<1U)-78.0	21/33	8.7	10,000	60,000
o-Xylene	ppm_v	---(e)			(<1U)-56.0	17/32	8.1		
Trichloroethene	ppm_v	---(e)			(<0.001U)-0.16	25/34	0.03		
Tetrachloroethene	ppm_v	---(e)			(<0.001U)-0.026	23/34	0.006		

(a) Data from the final subsurface investigation report (Law 1994).
(b) Mean calculated by setting non-detects at 0.5*SQL.
(c) Data from American Conference of Governmental Industrial Hygienists (ACGIH) 1995, unless noted.
(d) Data from Weast (1975).
(e) Chlorinated and non-chlorinated volatile organic compounds were not collected as part of the Phase I investigation.

NOTE: LEL = Lower explosive limit; UEL = Upper explosive limit.



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METHANE CONCENTRATIONS (% OF AIR)
MOTOR POOL LANDFILL
U.S. MILITARY ACADEMY
WEST POINT, NEW YORK

FIGURE 2-1

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

3 WASHINGTON CENTER
THE MAPLE BUILDING
NEWBURGH, NEW YORK 12550
(914) 565-8100

PROJECT NUMBER	60787.76
SCALE	N.T.S.
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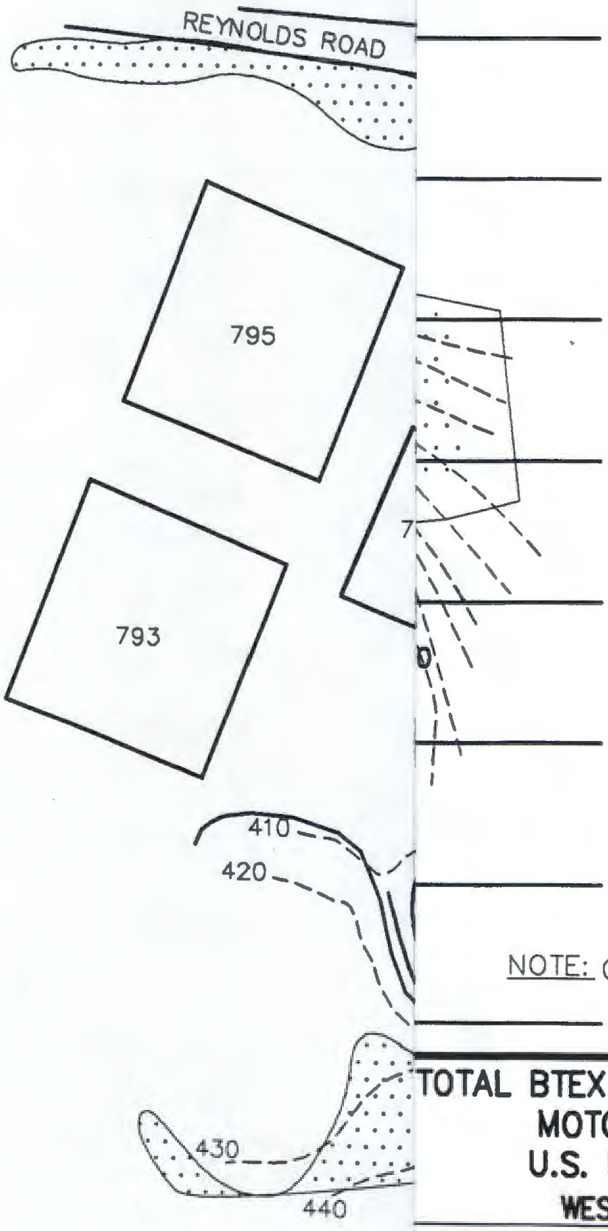

LEGEND:

BTEX SAMPLE LOCATION	▲
NO SAMPLE COLLECTED DUE TO ELECTRICAL SERVICE LINE	+
DENSE TREE AREA	(dotted pattern)
FENCE LINE	—X—X—X—

NOTE: GRID SPACING=100 FT X 100 FT

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TOTAL BTEX CONCENTRATIONS (PPMv)
MOTOR POOL LANDFILL
U.S. MILITARY ACADEMY
WEST POINT, NEW YORK

FIGURE 2-2

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

3 WASHINGTON CENTER
THE MAPLE BUILDING
NEWBURGH, NEW YORK 12550
(914) 565-8100

PROJECT NUMBER	60787.76
SCALE	N.T.S.
FILE NAME	F:\CAD\60787\52
DRAWING NUMBER	BTEXMP
SHEET NUMBER	

January 1998 by Quantum Geophysics, Inc., Phoenixville, Pennsylvania with oversight by EA representatives. The investigation also included work at the Ski Lot Landfill. The geophysical investigation summary report submitted by Quantum Geophysics, Inc. on 28 January 1998 is included in Appendix B.

2.4.1.1 EM-31 Methods

A 20-ft survey grid interval was established across the Motor Pool Landfill using a Warren McKnight Model 1B transit, fiberglass survey tapes, and existing utility (light) poles located at N 509,164 E 596,838 and N 509,196 and E 597,080. State Plane Coordinates were obtained for the light pole locations using the USMA-provided topographic survey basemap (Drawing No. G25.dwg) by Vollmer Associates, New York.

EM-31 ground conductivity instrumentation interfaced with an OmniData 720 Digital Logger was calibrated and phase adjusted in accordance with the manufacturer's operating manual. Quadrature phase (ground conductivity) and in-phase data were acquired on 10-ft stations (at and between adjacent grid nodes) and simultaneously logged.

The combination of EM-31 and in-phase technologies was selected to provide reliable interpretation of the extent of the landfill mass and the location of buried metal debris. EM-31 is the preferred geophysical method for mapping the edges of landfills and the lateral extent of leachate plumes. Leachate-saturated fill will typically be high in total dissolved solids, particularly high dissolved metals concentrations which are distinguishable from surrounding unsaturated, or non-fill material due to high EM-31 response values. In-phase technology is useful in tracing underground metallic piping and electrical conduit, as well steel-reinforced concrete structures and concentrations of buried metal debris.

2.4.1.2 Ground Conductivity and In-Phase Results

Graphical interpretation of EM-31 survey results at the Motor Pool are provide on Figure 1 of Appendix B. It has been noted on the figure that EM-31 data were not interpreted from areas where vehicle or other metal objects (fencing) were present. Generally, the landfill appears to underlie approximately 75-80 percent of the existing Motor Pool parking area. The western and southern boundaries are well defined. The northern and western boundaries are uncertain due to inaccessibility, the result of physical obstructions (recreational vehicles in storage), and EM-31 interference caused by metallic objects on the ground surface. The western landfill boundary is interpreted to fall between grid lines 200 and 210. The southern boundary is undulatory lying between grid station 30 and 120. Data acquisition was not possible south of grid Station -30 due to obstruction by parked vehicles and trailers.

In-phase data interpretation is presented on Figure 2 of Appendix B. Based upon relatively high in-phase results, the northern and western portions of the Motor Pool Landfill may contain a greater volume of buried metal debris. Three specific linear anomalies were detected in the parking lot area and are identified as probable buried utilities/pipes. By reference to USMA-provided utility maps, the western and eastern anomalies are caused by a buried electrical service conduit and an 18-in. reinforced concrete storm drain, respectively.

2.4.2 Seismic Refraction Survey

To aid in characterization of subsurface conditions a seismic refraction survey was conducted along a proposed leachate collection trench location north of the Motor Pool Landfill boundary. The purpose of the survey was to define depth to rock, that is the relative thickness of overburden and rock. The report describing the survey is included in Appendix B.

2.4.2.1 Seismic Refraction Methods

The seismic refraction survey employed digital instantaneous floating point (DIFP) signal tracking technology using a Bison Instrument 9024-24-channel unit. The DIFP signal stacking seismograph included Mark Product spread cables and L-40 40 hz digital grade geophones. Seismic waves were generated by striking a plate coupled to ground surface with a 10-lb steel hammer.

Geophones were spaced at 5-ft intervals with seismic wave generation at the forward and reverse ends, as well as the center of the spread. Relative elevation of the geophones was field-measured using a site level and rod. Orientation of the seismic spread was field-measured relative to true north using a Brunton compass. Field records were maintained as appropriate.

Seismic refraction arrival times were manually picked, tabulated, and incorporated into a time distance plot to determine the number of stratigraphic layers, and assign relative transit times to the interpreted layers. A delay-time technique was employed to process/reduce the seismic refraction data. The resulting interpreted depth profile was constructed using GenericCADD software and printed at a scale of 1 in. = 5 ft.

2.4.2.2 Seismic Refraction Results

Figure 5 in Appendix B depicts the results of the seismic refraction survey conducted along the proposed leachate collection trench north of the Motor Pool Landfill. Ground surface is shown relative to relatively soft overburden (soil), the interpreted top of rock, and consolidated marginal to non-rippable rock.

The results indicate that the top of rock along the proposed trench alignment south of USMA Building No. 845 and north of the Motor Pool Landfill varies from approximately 4 to 5 ft bgs. The rock encountered is characterized by a velocity of approximately 5,000 ft per second and is probably marginally rippable to non-rippable using heavy excavating machinery.

Field observations indicate boulders in the soil profile; oversize rock should therefore be anticipated during trenching activities for the leachate collection trench and conveyance piping along the referenced station line.

2.5 GEOTECHNICAL DATA

2.5.1 Permeameter Testing

Permeameter Testing at the Motor Pool Landfill was conducted during August 1995 as part of the Six Landfills Phase II Investigation (EA 1996). The purpose of this work was to provide a quantitative estimate of the hydraulic conductivity of the in-place landfill cap material. One sample was collected by Parratt-Wolff, Inc. (Syracuse, New York) under the supervision of an EA geologist.

The original Phase II Work Plan specified the use of 3-in. diameter × 30-in.-long Shelby tubes for the collection and retention of geotechnical samples. Resistant sand and gravel cap materials were encountered and a 3-in. diameter × 24-in.-long split-spoon sampler was used instead. The soil sample was tested using ASTM standard methods to determine the characteristics of hydraulic conductivity, moisture content, and density of the cover material.

The sampling indicated composition and thickness of the existing landfill cover and the permeameter testing estimated average hydraulic conductivity of the existing landfill surface material. Results for Motor Pool sample GTS95-MP-01(S-1) (EA 1996) indicate a recovered sample interval from 0.5 to 2.5 ft bgs. The sample moisture content was measured at 10.9 percent of dry weight; density (dry) was 103.6 (lb/cf); density (wet) was 114.9(lb/cf). The average hydraulic conductivity of the remolded sample was measured at 6.12×10^{-5} (cm/sec).

2.5.2 Boring Logs

No geotechnical borings were scoped or conducted in support of the development of the design under this delivery order. Boring Logs from monitoring wells MP-1, MP-2, MP-3, and MP-4 installed by Law in 1994 are included in Appendix C. Overburden and bedrock geological summaries are presented in Section 1.3.3 of this report.

3. SITE DRAINAGE

3.1 SCOPE AND PURPOSE

Site drainage is an important aspect of leachate minimization at the Motor Pool Landfill. Improved drainage will reduce the amount of stormwater infiltrating the landfill and potentially reduce leachate generation. By improving the drainage of the site and controlling stormwater run-off, stormwater will more readily drain to the stormwater drainage swales and surrounding streams, thus allowing less opportunity for infiltration into the landfill. While not all leachate is produced via the infiltration of stormwater into the landfill, reducing the amount of precipitation infiltration decreases the potential for additional leachate generation.

3.2 SITE GRADING

The existing surface of the Motor Pool Landfill does not allow for complete drainage of stormwater due to inconsistent grades and localized subsidence. The center area of the lot has subsided a minimum of 3 ft resulting in a sunken area where water ponds after storm events. Additional localized low spots in various areas throughout the lot also permit water ponding. The existing swale along the southeasterrn perimeter of the site does not have a consistent slope, and therefore does not adequately drain to the surrounding streams.

In order to alleviate these problems, the site will be graded to promote surface water drainage off the cap and into the drainage swales and surrounding streams. The crown of the cap will be oriented in an east-west direction so stormwater discharges to swales along the southern boundary of the site and down the northern slope of the site. Recognizing that the use of the site will remain as a Motor Pool parking lot, the cap will be graded at a minimum 2 percent slope to promote drainage off the cap. The grades are shown on the Final Grading Plan.

3.3 STORMWATER MANAGEMENT

Presently, stormwater drains to a partially asphalt-lined drainage swale on the southern side of the lot which adequately drains to the west but does not adequately drain to the east along the site boundary. There are various areas along the eastern side of this swale on the southern boundary where water ponds. Further, the existing drainage swale near Building 783 to the west of the site exhibits poor drainage characteristics. This swale presently is filled with large vegetation and aquatic animals due to the large amount of water that is ponding in the local area. Additionally, an existing, possibly deteriorated 18-in. reinforced concrete pipe (RCP) storm drainage system traverses the site. Through this storm drainage system, additional water may be entering the landfill and potentially adding to the generation of leachate. Due to the movement of this water, soil material may be "piped" into the storm drainage system producing voids within the landfill. These voids may also be contributing to the subsidence observed at the site.

The total area of the Motor Pool Lot surface is approximately 5.0 acres. The northern 2.6 acres of the lot will drain over the northern slope into the existing stream located to the north of the site. The proposed drainage swales along the southeastern boundary of the Motor Pool Landfill will convey stormwater runoff from the southern 2.4 acres of the lot into streams on the northern and eastern sides of the landfill. The total area designated as the drainage area for the proposed drainage swales is 3.8 acres, which includes the southern area of the lot as well as an additional 1.4 acres south of the swale. Approximately half of this drainage area flows into the swales on the southeastern perimeter (Swales "A" and "B".) The remaining half drains into the existing asphalt lined drainage swale on the southwestern perimeter of the site.

The new drainage swales will collect surface drainage from both the north and south carrying approximately half of the flow to the east. The new drainage swale near Building 783 will improve the drainage characteristics of the existing swale by allowing nearby drainage to drain northward along the western perimeter of the site. The swales are sized to carry the peak discharge of a 24-hour, 10-year frequency storm event at a non-erosive velocity. Surface water drainage calculations in support of the swale design are presented in Appendix D along with the designated drainage areas. The existing 18-in. RCP culvert that traverses the center of the landfill will be excavated and removed to avoid any potential continuing problems caused by the introduction of stormwater into the landfill or increased subsidence that may be caused by soil "piping."

3.4 SEDIMENT CONTROL

Temporary sediment control will be provided during construction. Temporary sediment controls will consist of silt fence located along the north, west, and east perimeters of the landfill, and stone check dams in Swale "B". The silt fence will reduce sediment carried in the run-off, protecting water quality in the streams. The stone check dams will reduce the velocity of flow in the swales, lessening erosion potential and reducing sediment in the run-off. The drainage swales will be either grass-lined (Swale "A") or rip-rap lined (Swale "B" and "C"), therefore reducing the potential for erosion. A rip-rap lined swale is used in the area where grass will not grow due to thick forestation above or high erosive velocities are expected. Inlet and outlet erosion protection will be provided in Swale "C" at the entrance and exit of each existing 18" corrugated metal pipe (CMP) and headwall located along the existing swale. A level spreader will be utilized at the end of Swale "B" to create a non-erosive outlet by converting the concentrated flow into sheetflow and releasing it over the receiving slope. Details of the swales and erosion and sediment controls are shown on the Miscellaneous Detail Sheet.

4. LEACHATE SEEP MANAGEMENT

4.1 SCOPE AND PURPOSE

Three leachate seeps have been identified in the vicinity of the Motor Pool Landfill. Seep MP95-LS-01 is on the northeastern slope of the landfill behind Building 523 on S. Moore Loop. Seeps MP95-LS-02 and MP98-LS-03 are on the northern slope of the landfill, south of the laundry facility, Building 845. The locations of the leachate seeps are shown on the Existing Conditions and Removal Plan. The leachate is a dark orange color due to high concentrations of iron and manganese. Previous sampling of seeps MP95-LS-01 and MP95-LS-02 did not indicate metal concentrations above the MCLs; however, iron and manganese concentrations exceeded secondary MCLs. Secondary MCLs have been established by the Environmental Protection Agency (EPA) to control the taste and odor of drinking water.

The iron- and manganese-rich leachate at these seep locations is discoloring the soil and rock where it surfaces and runs into the nearby streams. Seep MP95-LS-01 is located near base housing units on Moore Loop and it affords an increased risk of direct human and animal contact with leachate in soil and water media. Seep MP95-LS-01 will be collected to reduce discoloration, improve aesthetics, and reduce the potential for human and animal contact with the leachate.

Seeps MP95-LS-02 and MP98-LS-03 are located in a wooded area behind the Laundry Facility and are not visible from Washington Road, the nearest access for the general public. The seeps are also several hundred feet from the nearest base housing units, which limits the potential for human contact with them. For these reasons, seeps MP95-LS-02 and MP98-LS-03 will not be collected or treated. It is also anticipated that the resurfacing of the Motor Pool Landfill and the improvement of perimeter drainage around it will reduce the volume of leachate seeping from the hillside.

An existing leachate seep collection system has been in place since the 1970's and is possibly in poor operational condition. The existing solid vitrified clay pipe will be replaced with a perforated PVC pipe and a new 8" PVC lateral will be placed up the hillside to the east to collect additional leachate that may flow towards the seep locations of MP95-LS-02 and MP98-LS-03.

4.2 SEEP COLLECTION, CONVEYANCE, AND TREATMENT

Seep MP95-LS-01 will be collected through a seep collection trench as shown on the Miscellaneous Detail Sheet. The trench will be constructed along the alignment of the seep at its uphill limits to intercept the leachate before it flows to the ground surface. The trench will be 5-7 ft deep, providing sufficient cover over the pipe for frost protection, where possible. The bottom slope of the trench will match existing topography.

Results from the seismic refraction survey near seep MP95-LS-02 indicate that marginally ripple to non-ripple rock exists at 4-5 ft bgs. Boring logs from nearby monitoring wells MP-3 and MP-4 indicate continuous bedrock is approximately 20-30 ft bgs. Boulders may exist along the trench alignment in the top 5 ft of excavation, but is anticipated that an excavator can remove them.

The collection of seep MP95-LS-01 will be accomplished by placing a 6-in. perforated PVC pipe in the collection trench and backfilling the trench with porous gravel. A woven geotextile will be placed around the gravel trench to reduce infiltration of soil into the gravel. Filter design calculations for the geotextile are shown in Appendix E. The top 1 ft of the trench will be filled with soil and seeded to reduce stormwater infiltration into the trench. A small earth berm will be constructed uphill from the trench to divert stormwater run-off around the trench.

The collected leachate will be conveyed to a nearby sanitary sewer from the seep collection trench through a solid wall 10-in. PVC pipe. A manhole will connect the perforated PVC pipe to the solid-wall pipe at the end of the collection trench. A 1-ft deep collection sump at the bottom of the manhole will act as a sediment trap by allowing suspended solids to settle to the bottom of the sump. The collection sump will decrease the suspended solids in the leachate and reduce the loading on the U.S. Military Academy Wastewater Treatment Plant. The settled solids can be cleaned out through the manhole. Cleanout of the 10-in. PVC pipe can be performed with equipment presently utilized at West Point. The 6-in. perforated pipe can be cleaned from a standpipe cleanout at the end of the collection trench.

The existing sanitary sewer discharges to the U.S. Military Academy Wastewater Treatment Plant. Based upon the Leachate Management Analysis (EA 1996), the Wastewater Treatment Plant has sufficient capacity to handle this small, additional loading.

The existing leachate collection system in the northwest corner of the Motor Pool Lot will be improved. The existing solid-wall vitrified clay pipe will be partially excavated and replaced with a perforated 8-in. PVC pipe. A new manhole will be installed to connect the new 8-in. PVC pipe to the existing vitrified clay pipe which is connected to the sanitary sewer system. A new 8-in. perforated PVC lateral will be added to the system, extending west from the existing manhole. The existing manhole will be replaced and the two existing 6-in. laterals will be cleaned. The improvement of the existing leachate collection system is expected to reduce the amount of leachate seeping from MP95-LS-02 and MP98-LS-03.

5. LANDFILL CAP

5.1 SCOPE AND PURPOSE

The Motor Pool Landfill cap is designed to reduce precipitation infiltration into the landfill and serve as a parking area for USMA vehicles. An asphalt cap is the best alternative to serve this dual purpose. By creating a low permeability barrier between the existing waste and the surrounding environment, there will be a reduction of stormwater infiltration into the landfill and a subsequent reduction in the production of leachate. The flexible pavement landfill cap includes a crushed-graded-aggregate base course, a prime coat, a bituminous intermediate course, a tack coat, and a bituminous final course. A detail of the varying flexible pavement sections is shown on the Miscellaneous Detail Sheet.

5.2 LANDFILL SETTLEMENT

An area in the center of the landfill, near the existing storm drain, has subsided significantly since the Motor Pool was last paved. There are three potential reasons for the subsidence:

- Biological decomposition and settling of the sanitary waste,
- Erosion and piping of the soil around the deteriorating storm drain, and
- Mechanical settlement due to heavy vehicle loading.

Each of these causes will be addressed by the design to reduce future settlement.

Biological decomposition of the waste can be reduced by limiting the amount of oxygen in the waste. Stormwater infiltration is one source of oxygen. By improving the perimeter drainage and repaving the Motor Pool, stormwater infiltration will be reduced.

The catch basins and storm drain traversing the site are deteriorating and water can flow in and out of them. During rainfall events, when water is flowing through the pipe, water leaks out of the pipe and infiltrates the surrounding soil. After a rainfall event, there is less flow through the pipe and the water in the surrounding soil flows back into the pipe. The water flowing into the pipe carries small soil particles with it, creating a piping and subsidence problem. To address this problem, the storm drain and catch basins will be removed from under the pavement.

Two major factors contribute to the mechanical settlement under the Motor Pool: heavy vehicle loads (buses and trucks) and poorly-compacted fill materials (sanitary waste). It appears from the existing Motor Pool grades that the heavy loading has caused approximately 3 ft of settlement. This has compacted the sanitary waste and improved its capacity to carry loads, reducing the potential for future settlement. The design further addresses settlement by bringing the low areas of the site to grade with controlled fill and subgrade reinforcement. To meet the grades shown on the Final Grading Plan, soil will be placed and compacted in controlled lifts, providing a firm subgrade for the asphalt pavement. Additionally, in the center area of the Motor Pool where there has been the greatest amount of subsidence, a geogrid will be placed on top of the subgrade and below the pavement section as reinforcement. These measures will reduce the potential for continued settlement of the Motor Pool.

5.3 PAVEMENT DESIGN

An analysis in accordance with TM 5-822-5, "Pavement Design for Roads, Streets, Walks, and Open Storage Areas," was conducted to design the flexible pavement at the Motor Pool Landfill. The method accounts for vehicular loading based on two factors: the traffic category and the street classification. The traffic category is based on the weight of the mix of vehicles using the pavement. The street classification considers the traffic frequency or repetition of loading. Parking areas are considered Class E. The combination of traffic category and street classification is used to select a pavement design index.

The design method presented in TM 5-822-5 uses the pavement design index and the existing surface soil conditions to define the thickness of the flexible pavement layers. The existing subgrade is best defined as a gravelly sand in Areas 1 and 2 of the lot. A softer subgrade was assumed in Area 3 since the subgrade has not been compacted by large trucks and buses. Additionally, the seasonal frost conditions were evaluated by taking into consideration the Frost-Area Soil Support Indexes for the subgrade soils. Pavement design calculations for the upper (Area 1 and 2) and lower (Area 3) areas of the lot are located in Appendix F.

The entire Motor Pool Lot will receive a new bituminous intermediate course, a tack coat, and a bituminous final course; however, not all areas will receive the same amount of base course. For design purposes, the existing Motor Pool Landfill has been segmented into four distinct areas based on present use and existing surface conditions. These areas are indicated on the Construction Phasing Plan.

The west end of the lot, Area 4, is presently paved and shows few signs of settlement relative to the other areas of the lot. The existing pavement has small "alligator" cracks due to pavement fatigue and thus needs to be repaired. This region of the lot will be remedied by covering the entire surface first with a woven geotextile to supply reinforcement and next with an overtopping pavement consisting of a new bituminous intermediate course, a tack coat, and a bituminous final course section. Area 4 and Area 2 will be joined together at the same grade by cutting the adjoining area within the center area of the lot as shown on the Miscellaneous Detail Sheet.

The east end of the lot, Area 1, is presently covered with a gravel surface and shows few signs of settlement. This area will receive 10-in. of aggregate base course, 2-in. of bituminous intermediate course, a tack coat, and 1.5-in. of bituminous final course as shown on the Miscellaneous Detail Sheet. The intersection of this area with Area 2 will be joined together at equal grades.

Area 2 has suffered from substantial settlement and cracking and will receive the same pavement section as Area 1, with exception to the center area. The varying sections of Area 2 are shown on the Miscellaneous Detail Sheet. The pavement surface will be demolished and left in place as subgrade material. The subgrade will be proof-rolled to locate soft spots in the existing aggregate base course, and identified soft spots will be undercut and filled in a controlled manner. Soft spots that extend into the sanitary waste will only be undercut to the top of the waste. The area will be brought to grade by placing and compacting fill in a controlled manner. Additionally, in the area of greatest settlement, a geogrid will be installed beneath the graded-crushed-aggregate base course. The geogrid will partially carry the traffic loadings over this area and reinforce the pavement section. The extent of the placement of the geogrid is shown on the Final Grading Plan.

The northwest region of the lot Area 3 is currently unpaved and is used to park smaller vehicles and 2-axle trucks. The area used for parking vehicles will receive 6 in. of aggregate base course, 2 in. of bituminous intermediate course, a tack coat, and 1.5 in. of bituminous final course as shown on the Miscellaneous Detail Sheet. The roadway adjacent to this area has continued use by a combination of heavy trucks and buses and will therefore receive the same pavement section as Area 1, as shown on the Miscellaneous Detail Sheet.

6. LANDFILL GAS MANAGEMENT

6.1 SCOPE AND PURPOSE

The generation of landfill gas occurs when sanitary waste undergoes natural aerobic and anaerobic decomposition. Landfill gas at the Motor Pool Landfill has caused cracking of the existing asphalt surface and odors observed primarily during warm weather periods. To reduce cracking in the landfill cap caused by gas pressure and to control odor, a passive landfill gas venting system will be installed.

6.2 LANDFILL GAS GENERATION

Areas of landfill gas generation at the Motor Pool Landfill have been identified by two methods. A soil gas survey and a conductivity survey were conducted as described previously in Chapter 2. The soil gas survey consisted of sampling soil gas near the ground surface of the Motor Pool and measuring the concentration of methane in the gas. The results of the soil gas survey identified areas below the existing asphalt surface where landfill gas is concentrated. The conductivity survey identified subsurface areas with high conductivity, indicative of leachate from sanitary waste. The presence of sanitary waste indicates the potential for landfill gas generation. The results of these surveys have been used to determine the approximate limits of landfill/gas generation in the landfill. The estimated limit of gas generation is shown on Figure 6-1.

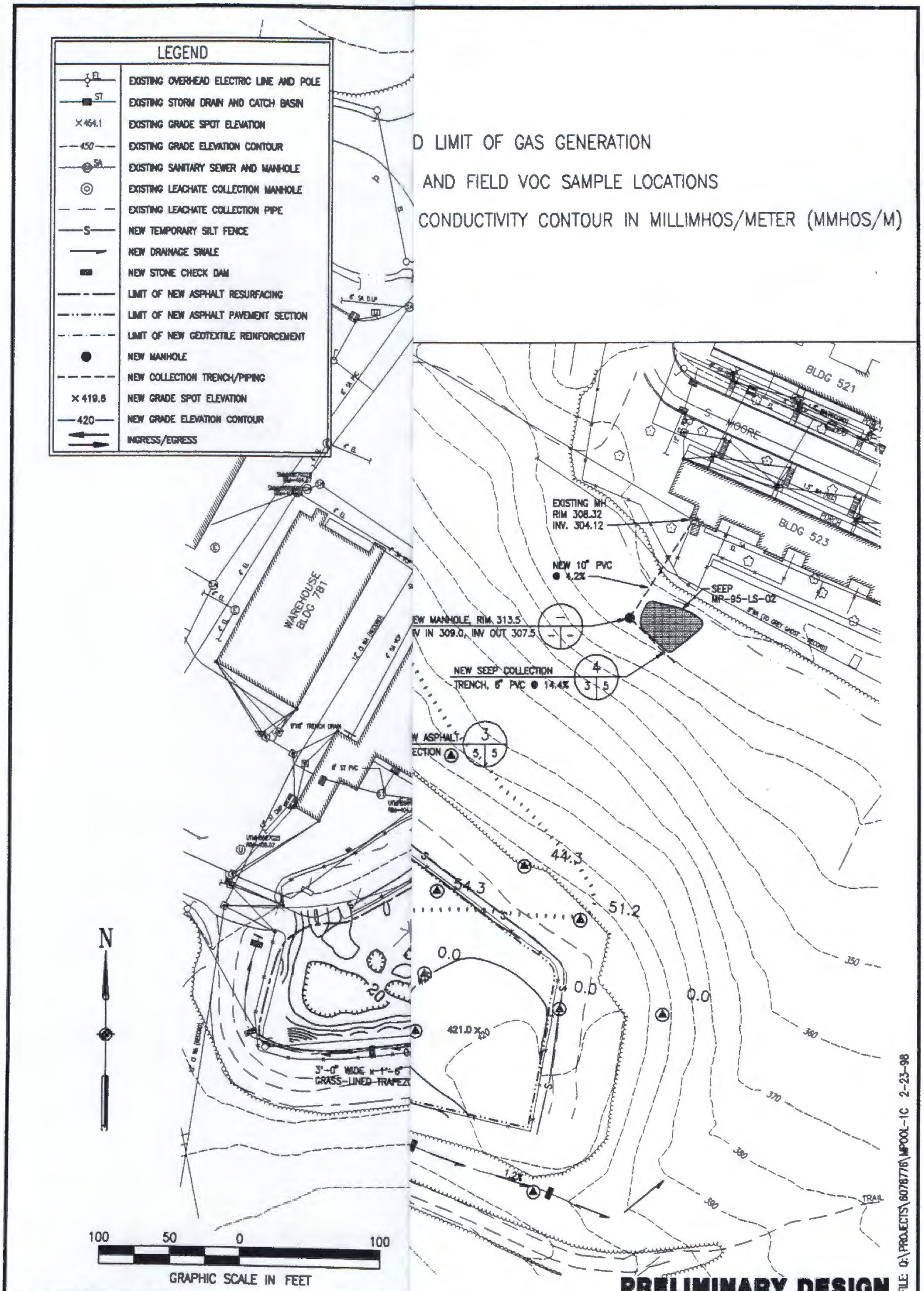
6.3 LANDFILL GAS COLLECTION/VENTING

A passive gas venting system will be installed with the asphalt cap. Passive systems are less expensive and easier to implement than active systems. The landfill gas generation rates are expected to have decreased since the landfill was closed, and a passive system is appropriate for controlling gas emissions at the site. For the purpose of determining the method of landfill gas venting (passive or active), 40 CFR Parts 51, 52, and 60 were utilized. Since the landfill was closed in 1969 and did not operate on or after 30 May 1991, these regulations do not apply.

The gas venting system is necessary for removing landfill gas which would be trapped under the low-permeability barrier layers and for controlling odor. The gas will flow laterally through the aggregate base course and subgrade soils to the passive landfill gas vents, which will transmit the gas through the cap and into the atmosphere. This will reduce buildup of gas beneath the cap and subsequent cracking.

The passive gas vents consist of a perforated PVC pipe set vertically in a shallow, gravel-filled excavation. At the base of the asphalt pavement, the pipe is coupled to a solid-wall PVC pipe. The pipe riser has a turbine ventilator on top to increase the upward draw of landfill gas into the atmosphere. A detail of the passive gas vents is shown on the Miscellaneous Detail Sheet. The gas will be vented 8 ft above the ground surface to reduce odor problems and reduce the potential for explosive levels of methane coming in contact with open flames. Depending on the location of the gas vent, either bollards or wheel stops will be used to protect the vents. The Miscellaneous Details Sheet specifies which gas vent protection is utilized.

Landfill gas is less dense than air and will rise to the highest elevation of the landfill cap. The gas collection system is designed to make use of this property by collecting the gas after it rises into the gravel base course and subgrade soils and subsequently follows these layers to the ridge line. Gas vents will be placed as close to the ridge line as possible without obstructing the flow of traffic on the Motor Pool. Vents will also be placed along the northern perimeter of the cap in two areas where gas production is high. This will reduce the volume of gas reaching the ridge line and will further reduce the chances of cracking of the asphalt surface. Passive gas vent locations are shown on the Final Grading Plan.



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ESTIMATED LIMIT OF GAS GENERATION

7. SCHEDULE

The anticipated construction schedule for accomplishing the work is shown in Figure 7-1. The significant activities of the schedule are discussed in the following sections. A Sequence of Construction Operations is shown on the Construction Phasing Plan Sheet.

7.1 EROSION AND SEDIMENT CONTROL

Erosion and sediment control devices will be installed prior to construction activities to ensure that sediment loss and erosion is minimized. Silt fencing will be installed downgradient of construction activity locations along the northern, western, and eastern perimeters of the Motor Pool. Temporary check dams will be placed in the new surface drainage swale along the southeastern perimeter of the site. Inlet and Outlet protection will be provided for the protection of the existing and proposed swale near Building 783. Either vegetative stabilization or rip-rap will be used in the new surface drainage swales to minimize the transport of sediment offsite.

7.2 SWALE AND DRAINAGE IMPROVEMENTS

A new surface drainage swale will be graded on the southeastern perimeter of the Motor Pool and the western perimeter near Building 783 to improve surface drainage. The swale has its highpoint near the center of the southern perimeter such that it drains both to the east and west of the site.

7.3 ASPHALT CAP

The construction of the new asphalt cap will consist of four phases to permit continuing operation of the Motor Pool. The four phases are illustrated on the Construction Phasing Plan, where a detailed description of them is included. The phases are described below:

a) Phase 1 will consist of cutting and filling to bring the area to grade. A complete new asphalt pavement section will be provided on top of the subgrade in Area 1.

b) Phase 2 will consist of removing the existing catch basins and existing RCP that traverse the site and sealing the end of the pipe with brick and grout. The necessary areas will be cut and filled to bring the existing grade up to subgrade and a complete new asphalt pavement section will be provided on top of the subgrade in Area 2.

c) Phase 3 will consist of providing a new pavement section in Area 3.

d) Phase 4 will consist of providing a new asphalt pavement surface over the existing pavement surface in Area 4.

7.4 LANDFILL GAS MANAGEMENT

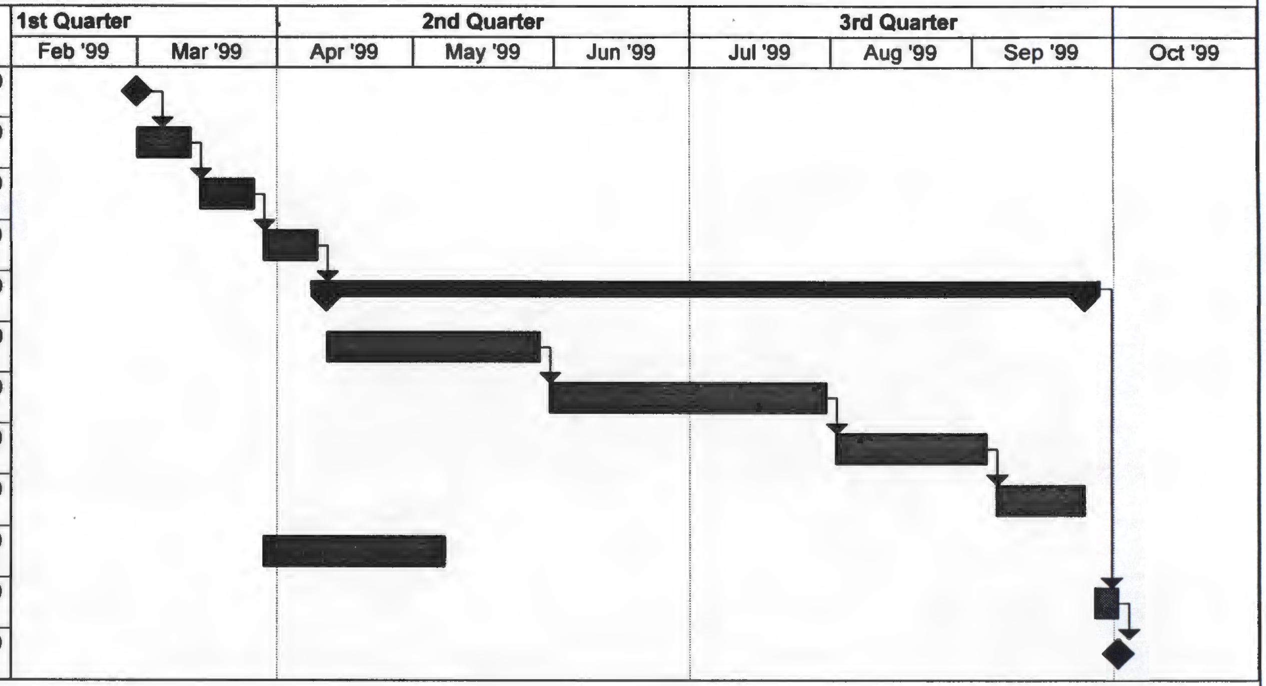
Eleven passive gas vents will be installed along the crown and along the northwest and northeast perimeter of the Motor Pool during the construction of the asphalt cap. Since the installation of the passive gas vents will be an integral part of the asphalt cap construction, the construction schedule shown on Figure 7-1 includes the addition of these vents as part of each of the four phases of the cap construction.

7.5 LEACHATE SEEP COLLECTION

The leachate seep collection trenches will be installed along with new manholes and piping to convey the seeps to the existing sanitary sewer. The leachate seep collection trenches can be installed concurrently with the construction of the new asphalt cap.

Anticipated Construction Schedule

ID	Task Name	Duration	Start	Finish
1	Notice to Proceed	0d	3/1/99	3/1/99
2	Mobilization	2w	3/1/99	3/12/99
3	Install Erosion and Sediment Contro	2w	3/15/99	3/26/99
4	Swale and Drainage Improvements	2w	3/29/99	4/9/99
5	**Asphalt Cap**	**120d**	**4/12/99**	**9/24/99**
6	Phase 1	7w	4/12/99	5/28/99
7	Phase 2	9w	5/31/99	7/30/99
8	Phase 3	5w	8/2/99	9/3/99
9	Phase 4	3w	9/6/99	9/24/99
10	Leachate Seep Collection	6w	3/29/99	5/7/99
11	Demobilization	1w	9/27/99	10/1/99
12	Substantial Completion	0d	10/1/99	10/1/99



Project: Motor Pool Landfill- West Poi
Date: 8/13/98

Task | Summary | Rolled Up Progress
Progress | Rolled Up Task
Milestone | Rolled Up Milestone

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Figure 7-1

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APPENDIX A

LEACHATE SAMPLING RESULTS

TABLE 1-8 HISTORICAL LEACHATE SAMPLE RESULTS FROM MOTOR POOL LANDFILL

Parameter	Units	EOC (1989d)	USAEHA (1989)	LAW (1994)		
				MPLE-1	MPLE-1 Dup	MPLE-2
Collection Date		6/89	12/13/88	6/93	6/93	6/93
VOLATILE ORGANICS	µg/L	ND	ND	ND	ND	ND
SEMIVOLATILE ORGANICS	µg/L	ND	ND	ND	ND	ND
PESTICIDE/POLYCHLORINATED BIPHENYLS	µg/L	ND	ND	ND	ND	ND
INORGANICS						
Arsenic	mg/L	NA	(<0.001U)	0.008	0.011	(<0.005U)
Barium	mg/L	NA	0.114	NA	NA	NA
Boron	mg/L	NA	NA	(<0.10U)	0.24	(<0.10U)
Cadmium	mg/L	(<0.002U)	(<0.0005U)	NA	NA	NA
Calcium	mg/L	32	109	NA	NA	NA
Chromium	mg/L	NA	(<0.020U)	NA	NA	NA
Copper	mg/L	NA	(<0.020U)	NA	NA	NA
Iron	mg/L	7.1	29.9	4.8	6.0	15.6
Lead	mg/L	(<0.03U)	(<0.001U)	NA	NA	NA
Magnesium	mg/L	9.54	23.8	NA	NA	NA
Manganese	mg/L	2.02	7.09	3.9	4.3	3.1
Mercury	mg/L	NA	(<0.0002U)	NA	NA	NA
Potassium	mg/L	2.9	NA	NA	NA	NA
Nickel	mg/L	NA	NA	0.036	0.067	(<0.004U)
Selenium	mg/L	NA	(<0.001U)	NA	NA	NA
Silver	mg/L	NA	(<0.020U)	NA	NA	NA
Sodium	mg/L	46.8	133	NA	NA	NA
Zinc	mg/L	NA	(<0.020U)	NA	NA	NA

NOTE: NA = Not analyzed; ND = None detected.

Parameter	Units	EOC (1989d)	USAEHA (1989)	LAW (1994)		
				MPLE-1	MPLE-1 Dup	MPLE-2
Collection Date		6/89	12/13/88	6/93	6/93	6/93
MISCELLANEOUS						
Alkalinity	mg/L	200	360	258	270	270
Ammonia	mg/L	1.68	NA	0.81	1.2	2.7
Biochemical Oxygen Demand	mg/L	NA	NA	2.2	(<2U)	(<2U)
Chemical Oxygen Demand	mg/L	23.5	NA	(<5U)	16.4	221
Chloride	mg/L	69	200	43.6	48.3	195
Cyanide, total	mg/L	NA	0.01	NA	NA	NA
Color	Color Units	NA	700	40	30	5
Conductivity	μmhos/cm	NA	1,400	NA	NA	NA
Fluoride	mg/L	NA	(<0.10U)	NA	NA	NA
Hardness	mg/L	300	NA	306	281	364
MBAS	mg/L	NA	0.08	NA	NA	NA
Nitrite+Nitrate (as N)	mg/L	0.1	0.15	0.54	0.54	0.13
pH		NA	7.9	NA	NA	NA
Sulfate	mg/L	9.5	6.0	22.1	12.9	9.3
Total Dissolved Solids	mg/L	314	720	395	387	657
Total Kjeldahl Nitrogen	mg/L	NA	NA	1.2	1.1	3.1
Total Organic Carbon	mg/L	5	7.8	4.2	4.8	10.9
Total Phenols	mg/L	(<0.002U)	NA	NA	NA	NA
Turbidity	JTU	150	330	NA	NA	NA

TABLE 8-8 SUMMARY OF ANALYTICAL RESULTS FOR ORGANIC ANALYSES PERFORMED ON LEACHATE SEEPS COLLECTED AT THE MOTOR POOL LANDFILL

Analyte	MP95-LS-01 WP6507 South side	MP95-LS-02 WP6508 West side	MP95-GWTB-01 QC-Trip Blank	NYSDEC Class A Standard[a]
VOLATILE ORGANICS[b]				
Chloroform	(<1U)	(<1U)	5	7
Methylene chloride	(<1U)	(<1U)	2	5
SEMIVOLATILE ORGANICS[c]				
Bis(2-ethylhexyl)phthalate	4 BJ	(<7U)	(<7U)	4/0.6[d]
PESTICIDE/PCB ORGANICS[e]				
Endosulfan II	0.0094 P	(<0.006U)	(<0.006U)	0.009[d]
Endosulfan sulfate	0.0080 P	(<0.006U)	(<0.006U)	
Endrin	0.022 P	(<0.004U)	(<0.004U)	0.02/0.002[d]

(a) Class A Standards (protection for human consumption) from NYSDEC (1993).
(b) See Table G-56 for detailed results.
(c) See Table G-57 for detailed results.
(d) Class A standard for wildlife protection (NYSDEC 1993).
(e) See Table G-58 for detailed results.

NOTE: U = Not detected. Sample quantitation limits shown as (<_U).
P = Duplicate analytical column results outside the control limit.
Results reported in μg/L.

TABLE 8-9 SUMMARY OF ANALYTICAL RESULTS OF INORGANIC ANALYSES PERFORMED ON LEACHATE SEEPS COLLECTED AT THE MOTOR POOL LANDFILL

Analyte	MP95-LS-01 WP6507 South Side	MP95-LS-02 WP6508 West Side	NYSDEC Class A Standard[a]
Aluminum	11,400	382	100
Arsenic	30.7	(<1.0U)	50/190[b]
Barium	241	83.8 B	1,000
Calcium	128,000	69,500	
Chromium	13.0	(<5 U)	50/410.1[c]
Cobalt	26.2 B	(<9 U)	
Copper	23.4 B	8.0 B	200/24.2[c]
Iron	44,700	12,300	300
Lead	16.1	1.8 B	50/9.3[c]
Magnesium	33,500	15,200	
Manganese	22,700	5,640	300
Nickel	21.7 B	(<9 U)	180.6[c]
Potassium	8,100	5,120	
Sodium	58,600	83,000	
Thallium	6.5 BW	(<2 U)W	4/8[b]
Vanadium	28.5 B	(<4 U)	14
Zinc	67.1	16.5 B	30

(a) Class A Standards (protection for human consumption) from NYSDEC (1993).
(b) Value shown is for protection of wildlife.
(c) Value shown is for protection of wildlife. Calculated from average hardness of 231 mg/L.

NOTE: U = Not detected. Sample quantitation limits shown as (<_U).
B = Reported concentration less than the Contract Required Detection Limit.
N = Sample spike recovery outside of the control limits.
W = Furnace analytical spike recovery outside of the control limits.
E = Serial dilution outside of the control limits.
See Table G-59 for detailed results.
Results reported in $\mu g/L$.

TABLE 8-10 SUMMARY OF WATER QUALITY PARAMETER ANALYTICAL RESULTS FROM LEACHATE SEEPS COLLECTED AT THE MOTOR POOL LANDFILL

Analyte	Units	MP95-LS-01 WP6507 South Side	MP95-LS-02 WP6508 West Side	NYSDEC Class A Standard[(a)]
Alkalinity	mg/L	407	230	
Ammonia	mg/L	2.9	2.1	2
Biochemical oxygen demand	mg/L	6.8	1.2	
Chemical oxygen demand	mg/L	125	15.1	
Chloride	mg/L	70.3	171	250
Color	Color Units	20	30	
Dissolved organic carbon	mg/L	23.9	23	
Hardness	mg/L	520	271	
Nitrate	mg/L	0.07	0.34	10
pH		7.1	7.2	6.5-8.5
Sulfate	mg/L	(<4 U)	3.6	250
Total Kjeldahl nitrogen	mg/L	3.1	0.43	
Total suspended solids	mg/L	1,570	39.0	

(a) Class A Standards (protection for human consumption) from NYSDEC (1993).

NOTE: U = Not detected. Sample quantitation limits shown as (<_U).
See Appendix Table G-60 for detailed results.

APPENDIX B

GEOPHYSICAL INVESTIGATION

QUANTUMGEOPHYSICS, INC.
Engineering, Groundwater & Environmental Geophysics

January 28, 1998

Kurt Ilker
EA Engineering, Science and Technology
The Maple Building
3 Washington Center
Newburgh, New York 12550

Re: Report
Geophysical Investigation
Motorpool and Ski Lot Landfills
West Point Military Academy
West Point, New York

Dear Mr. Ilker:

This report presents the findings of Quantum Geophysics, Inc's geophysical investigation of the motorpool and ski lot landfills located at the West Point Military Academy, West Point, New York. The investigation incorporated an EM31 ground conductivity survey to map the lateral extent of the landfills and a seismic refraction survey to identify top of rock along a proposed leachate collection trench located between the laundry building and the eastern end of the motorpool parking lot.

The landfills have been paved-over and are currently being used as parking lots. Where possible, vehicles were moved by facility personnel in advanced of the geophysical surveys. The surveys were conducted January 13 and 14, 1998 by Quantum's principal geophysicist Richard Lee and staff geophysicist Scott Dietrich.

This report continues with a brief description of our technical approach followed by a detail discussion of the geophysical findings with respect to the lateral extent of the landfills and top of rock along the proposed trench alignment.

TECHNICAL APPROACH

SURVEY GRID

A 20 x 20-foot survey grid was constructed over the motorpool and ski lot parking lots using a Warren McKnight 1B transit, 300-foot fiberglass survey tapes, and fluorescent spray paint. The ski lot survey grid was tied to the 2 wooden light posts located at N509,117 E595,808 and N509,147 E595,875. The motorpool survey grid was referenced to the light posts located at N509,164 E596,838 and N509,196 E597,080. State plan coordinates for the light posts were obtained from the basemap G25.DWG dated 1-21-98 by EA Engineering, Science and Technology.

EM31 SURVEY

The EM31 was taken to a metal-free location, assembled, interfaced with an OmniData 720 digital data logger, the battery condition checked, and the sensitivity and phasing adjusted following procedures outlined in the operating manual

. Quadrature phase (ground conductivity) and in-phase data were acquired on 10-foot stations (at and between adjacent grid nodes) and then downloaded onto a PC at the end of each field day.

In the office, the data were entered into the surface applications program ***Surfer for Windows***, gridded using the Kriging Method with an octant search, contoured at 5 millimhos/meter (ground conductivity) and 2 parts per thousand (in-phase), exported to ***GenericCADD***, annotated, merged with basemap G25.DWG, and printed by a Hewlett Packard (HP) 660C color deskjet printer at a scale of 1 inch = 100 feet.

SEISMIC REFRACTION SURVEY

The seismic refraction survey incorporated a Bison Instrument 9024 24-channel digital instantaneous floating point (DIFP) signal stacking engineering seismograph with Mark Product spread cables and L-40 40 Hz digital grade geophones. Seismic waves were generated by striking a plate coupled to the ground surface with a 10-lbs. sledge hammer.

Data were acquired with a geophone spacing of 5 feet. Seismic waves were generated at the forward and reverse ends of the spread and in the middle of the spread. The relative elevation of each geophone location was hand-leveled and recorded in a fieldbook. The orientation of the seismic spread was noted with respect to true north using a Brunton compass a entered into the fieldbook.

Arrival times were manually picked, tabulated, and used to construct a time-distance plot to: 1) determine the number of layers, and 2) assign travel times to layers. The data were then processed using the delay-time technique described by Redpath, B. (1973).[1] The interpreted depth profile was constructed using GenericCADD and printed by the HP 660C printer at a scale of 1 inch = 5 feet (horizontal and vertical scale).

The data processing sheet is provided in Appendix A.

FINDINGS

Fully annotated ground conductivity and in-phase contour maps for the motorpool landfill and the ski lot landfill are shown in Figures 1 through 4, respectively. The interpreted seismic refraction profile is shown in Figure 5. Based upon the geophysical data:

- The motorpool landfill is best expressed in the ground conductivity data (Figure 1). It is characterized by closely spaced contours in excess of 15 to 20 millimhos/meter (mmhos/m). Where observed, and assuming it is present where no data could be obtained or recorded because of parked vehicles and trailers, the landfill appears to underlie about 75% to 80% of the parking lot. The western and southern boundaries are fairly well defined. The northern and eastern boundaries are uncertain because of inaccessibility.

  The western boundary falls somewhere between Lines 200 and 210, and is equivalent to E596,820 to E596,830. The southern boundary is undulatory and lies between Station -30 and Station 120. The state plan equivalent is N509,190 and N509,300. Data suggest that the southern boundary may extend further south than N509,190 (south of Station -30) where the survey was obstructed by parked vehicles and trailers.

  The northern and western portions of the motorpool landfill may contain a greater amount of buried metal debris as indicated by substantially higher in-phase measurements (Figure 2).

[1]Redpath, B. B., 1973, Seismic Refraction Exploration for Engineering Site Investigation. Explosive Excavation Research Laboratory, Livermore, California. Published by NTIS.

- Three (3) linear anomalies were detected in the motorpool parking lot and are identified as probable buried pipes/utilities (Figures 1 and 2). The basemap indicates that the western and eastern anomalies are caused by a buried electrical line and an 18-inch stormwater reinforced concrete pipe (RCP), respectively. The basemap does not indicate an origin for the probable pipe/utility located to the north.

- The ski lot landfill is also best expressed in the ground conductivity data (Figure 3). It is characterized by closely spaced contours greater than 15 to 25 mmhos/m. It is a fairly well defined, oblong-shaped feature that measures approximately 150 x 370 feet. The southern boundary backs-up to the slope break at the edge of the parking lot.

  Elevated in-phase measurements suggest that the ski lot landfill may contain a significant amount of buried metal debris (Figure 4). Buried metal debris may also be located just north of the landfill as shown in Figure 4.

- The top of rock along the proposed trench alignment between the laundry building and the motorpool varies from approximately 4 to 5 feet below ground surface. The rock is characterized by a velocity of roughly 5,000 feet per second (fps) and is most likely marginally rippable to non-rippable using heavy earth-moving machinery.

  Field observations indicate possible boulders in the soil profile. Oversize rock should therefore be anticipated during construction.

Quantum appreciates this opportunity to be of service to EA Engineering, Science and Technology at the West Point Military Academy, West Point, New York. Please call if you have any questions or if we can be of further assistance.

Sincerely,

Richard K. Lee

Richard K. Lee, R. GP. and P. G.
President and Principal Geophysicist

RKL/jas

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LEGEND

20	Ground Conductivity Contour in Millimhos/Meter (mmhos/m). Contour Interval = 5 mmhos/m.
	Probable Buried Landfill.
	Probable Buried Landfill Based on Elevated Readings Observed While Walking Between Rows of Vehicles and Trailers.
	Probable Buried Pipe/Utility.
	Ground Elevation in Feet.

Base Map Source: G25.DWG dated 1-21-98 by EA Engineering, Science and Technology.

QUANTUM GEOPHYSICS, INC.

ENGINEERING, ENVIRONMENTAL, AND GROUNDWATER GEOPHYSICS
29 RICHARD LEE LANE, PHOENIXVILLE, PA 19460

GROUND CONDUCTIVITY CONTOUR MAP
MOTORPOOL LANDFILL
WEST POINT MILITARY ACADEMY
WEST POINT, NEW YORK

For:	EA Engineering, Science and Technology			Figure
Date: 1-23-98	Drawn: CAS	Approved: RKL		1
Project: 98-1003	File: D:\EA-ENG\MTRPOOLQ.DWG			

LEGEND

In-Phase Contour in Parts Per Thousand (ppt).
Contour Interval = 2 ppt.

Probable Buried Landfill Based Upon Ground Conductivity Data.

Probable Buried Landfill Based on Elevated Readings Observed While Walking Between Rows of Vehicles and Trailers.

Probable Buried Pipe/Utility.

Ground Elevation in Feet.

Base Map Source: G25.DWG dated 1-21-98 by EA Engineering, Science and Technology.

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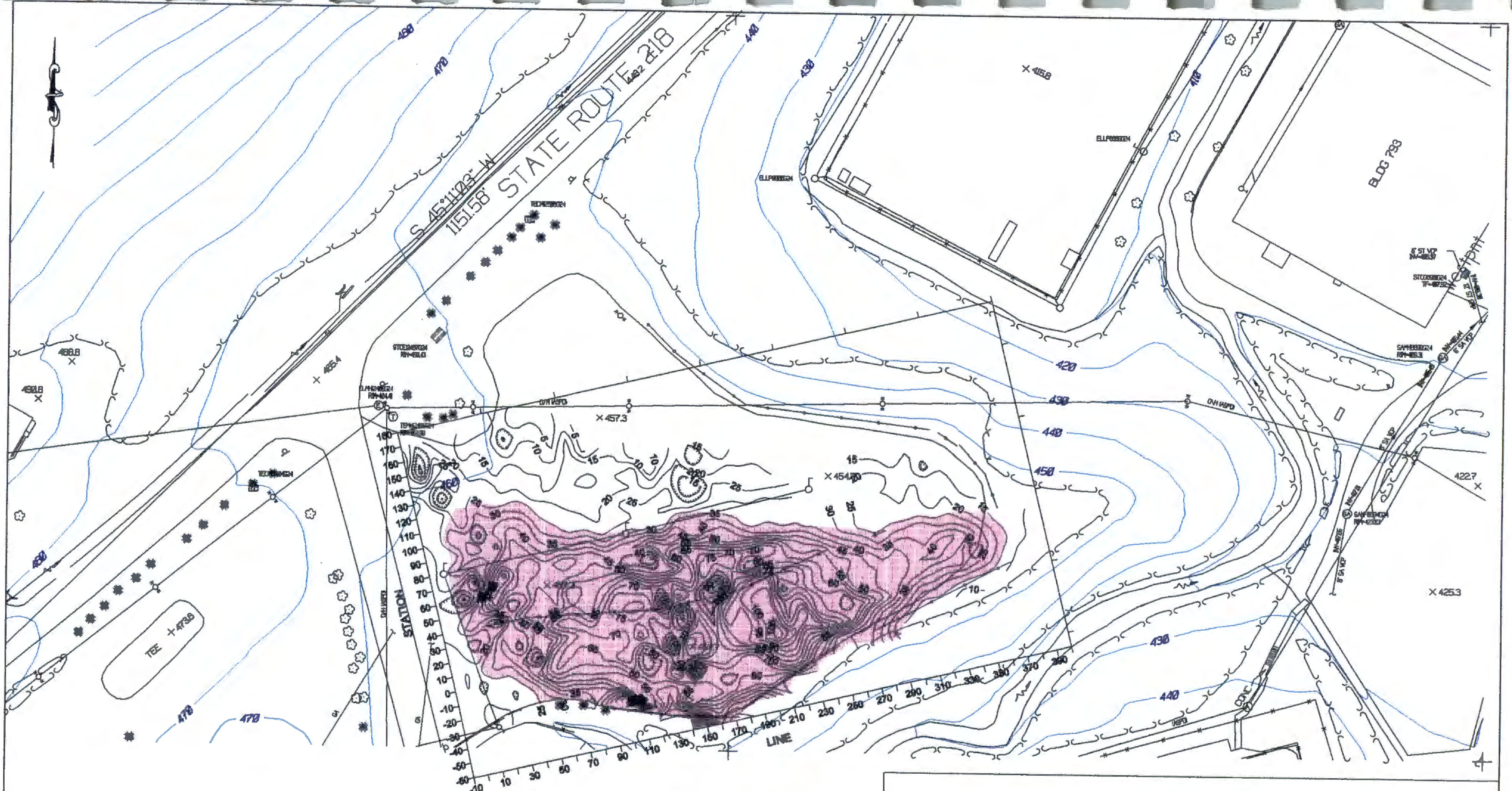
IN-PHASE CONTOUR MAP
MOTORPOOL LANDFILL
WEST POINT MILITARY ACADEMY
WEST POINT, NEW YORK

For: EA Engineering, Science and Technology			Figure 2
Date: 1-23-98	Drawn: CAS	Approved: RKL	
Project: 98-1003	File: D:\EA-ENG\MTRI.DWG		



50 25 0 50 100
GRAPHIC SCALE IN FEET

LEGEND

Ground Conductivity Contour in Millimhos/Meter (mmhos/m).
Contour Interval = 5 mmhos/m.

Probable Buried Landfill.

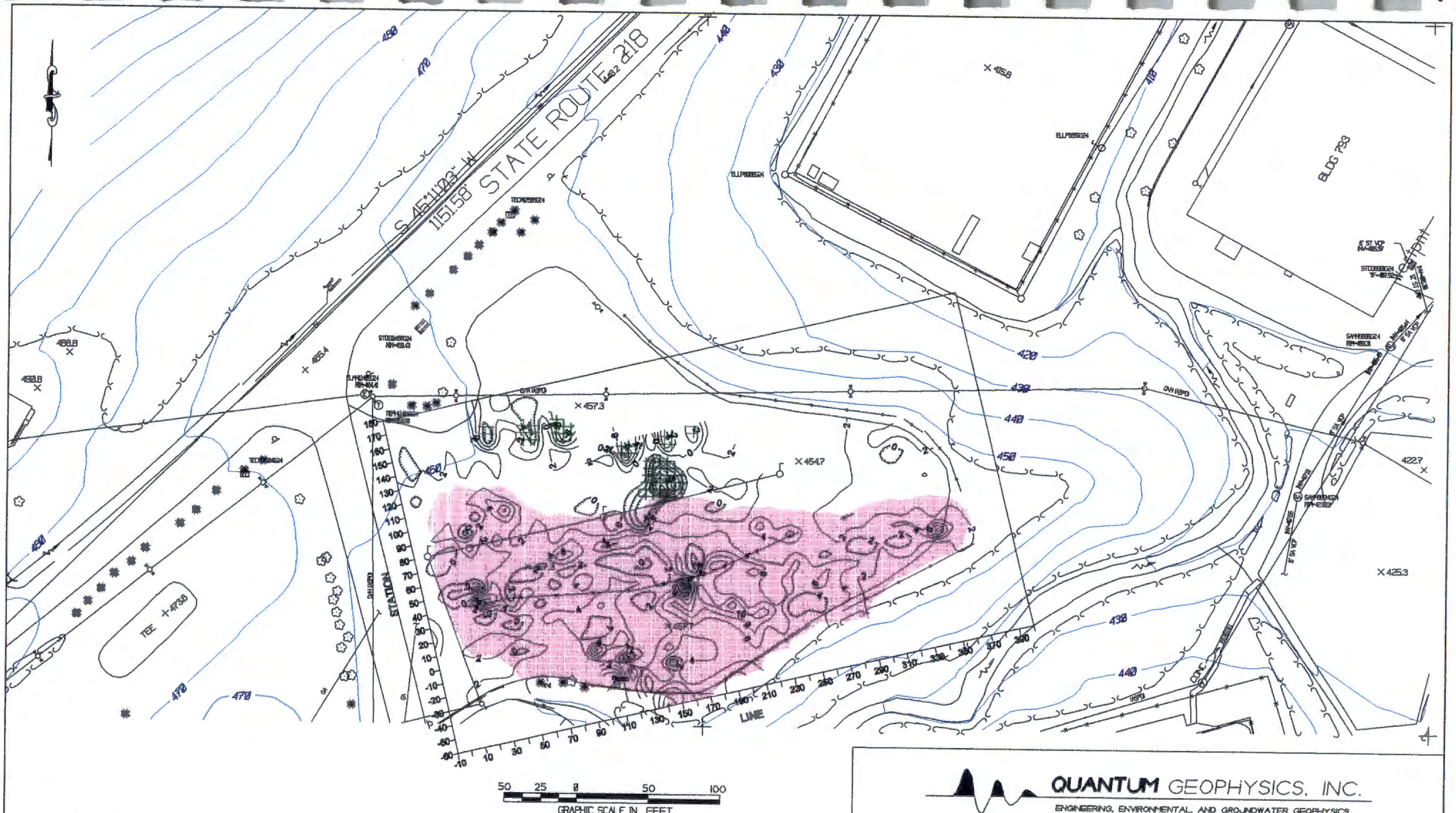
Ground Elevation in Feet.

Base Map Source: G25.DWG dated 1-21-98 by EA Engineering, Science and Technology.

QUANTUM GEOPHYSICS, INC.
ENGINEERING, ENVIRONMENTAL, AND GROUNDWATER GEOPHYSICS
29 RICHARD LEE LANE, PHOENIXVILLE, PA 19460

GROUND CONDUCTIVITY CONTOUR MAP
SKI LOT LANDFILL
WEST POINT MILITARY ACADEMY
WEST POINT, NEW YORK

For:	EA Engineering, Science and Technology			Figure
Date:	1-23-98	Drawn: CAS	Approved: RKL	3
Project:	98-1003	File: D:\EA-ENG\SKIQ.DWG		



LEGEND

In-Phase Contour in Parts Per Thousand (ppt). Contour Interval = 2 ppt.

Probable Buried Landfill Based Upon Ground Conductivity Data.

Probable Buried Metal Debris Outside of Landfill.

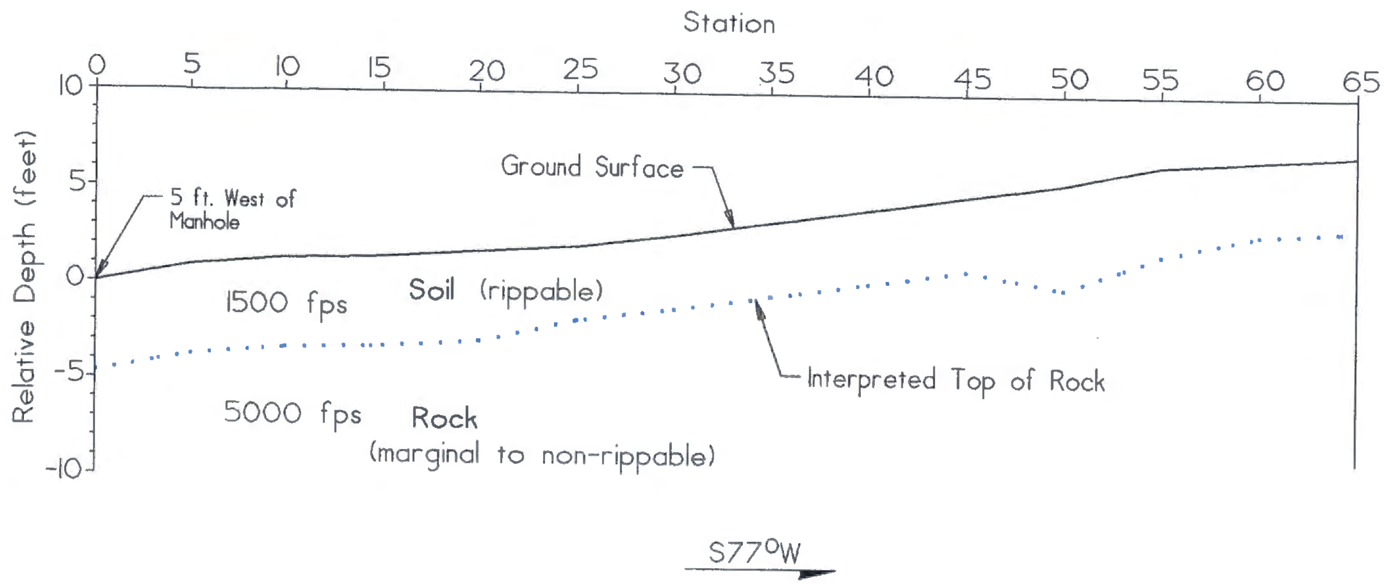
470 — Ground Elevation in Feet.

Base Map Source: G25.DWG dated 1-21-98 by EA Engineering, Science and Technology.

QUANTUM GEOPHYSICS, INC.
ENGINEERING, ENVIRONMENTAL, AND GROUNDWATER GEOPHYSICS
29 RICHARD LEE LANE, PHOENIXVILLE, PA 19460

IN-PHASE CONTOUR MAP
SKI LOT LANDFILL
WEST POINT MILITARY ACADEMY
WEST POINT, NEW YORK

For: EA Engineering, Science and Technology			Figure 4
Date: 1-23-98	Drawn: CAS	Approved: RKL	
Project: 98-1003	File: D:\EA-ENG\SKI.DWG		



NOTES

1. Seismic Survey Conducted 1-14-98 Using a Bison Instrument 9024 Seismograph with a Hammer and Plate Source.
2. Geophone Spacing = 5 Feet.
3. Data Processed Using the Delay-Time Technique.
4. Soil May Contain Boulders Based Upon Field Observations.

QUANTUM GEOPHYSICS, INC.
ENGINEERING, ENVIRONMENTAL, AND GROUNDWATER GEOPHYSICS
29 RICHARD LEE LANE, PHOENIXVILLE, PA 19460

SEISMIC REFRACTION SURVEY
PROPOSED LEACHATE COLLECTION TRENCH
WEST POINT MILITARY ACADEMY
WEST POINT, NEW YORK

For: EA Engineering, Science and Technology			Figure 5
Date: 1-26-98	Drawn: CAS	Approved: RKL	
Project: 98-1003	File: D:\EA-ENG\SEISMIC.DWG		

APPENDIX A

Seismic Refraction Processing Sheet

QUANTUM GEOPHYSICS, INC.
SEISMIC REFRACTION DATA SHEET - 2 LAYER CASE

Geophone Location ( )	Observed Arrival Times SP1 (sec)	Observed Arrival Times SP2 (sec)	Observed & Phantomed Arrival Times for V_2 SP1 (sec)	Observed & Phantomed Arrival Times for V_2 SP2 (sec)	Delay Times $T_D = (T_{SP1} + T_{SP2} - T_{Total})/2$ (sec)	Depth to V_2 Layer $D = T_D{*}V_1/\cos(\sin^{-1} V_1/V_2)$
0	0	18	6	18	.003	4.7
5	4	17	7	17	.003	4.7
10	8	16	8	16	.003	4.7
15	9	15	9	15	.003	4.7
20	10	14	10	14	.003	4.7
25	10	13	10	13	.0025	3.9
30	11	12	11	12	.0025	3.9
35	12	11	12	11	.0025	3.9
40	13	10	13	10	.0025	3.9
45	14	9	14	9	.0025	3.9
50	15	10	15	10	.0035	5.5
55	16	8	16	8	.003	4.7
60	17	3	17	6	.0025	3.9
65	18	0	18	5	.0025	3.9

From T-D Plots:

V_1 = 1500 fps
T_{Total} = 18 msec
V_1 =
V_1 =
V_{2U} = 5000 fps
V_{2D} = 5000 fps

Dip Angle (@) = $1/2\ [\sin^{-1}(V_1/V_{2D}) - \sin^{-1}(V_1/V_{2U})]$

True V_2 = $[2(V_{2U} * V_{2D})/(V_{2U} + V_{2D})]\cos @$

APPENDIX C

MONITORING WELL BORING LOGS (1994)

HTW DRILLING LOG

HOLE No. MP-1

SHEET 1 OF 3

1. COMPANY NAME: Law Environmental, Inc.	2. DRILLING SUBCONTRACTOR: Parratt-Wolff
3. PROJECT: West Point Subsurface Investigation	4. LOCATION: West Point - Motor Pool Lot
5. NAME OF DRILLER: Mark Beck	6. MANUFACTURER'S DESIGNATION OF DRILL: CME-55
7. SIZE AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: CME 55; 140 lb. hammer, 30" drop; 2' spoon, 2" diameter; 4 1/4" augers	8. HOLE LOCATION: Motor Pool- Location 1
	9. SURFACE ELEVATION: 454.00
	10. DATE STARTED: 6-9-93 / 11. DATE COMPLETED: 6-10-93
12. OVERBURDEN THICKNESS: 16 ft. +	15. DEPTH GROUNDWATER ENCOUNTERED: ~10 ft.
13. DEPTH DRILLED INTO ROCK: 0	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 2.9 ft. BGS; 18 hours
14. TOTAL DEPTH OF HOLE: 16 ft. augers 18 ft. spoon	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): 3.64 BGS 7-8-93

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
9, 10-12 ft., 12-14 ft.	√	—	—

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %
—	—	—	—	—	—	—

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
Installed well		√		

24. CHECKED BY:

25. NAME OF INSPECTOR: J. Ronald Sides

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
	0–2.0	Very Loose Brown Clayey Graveley Silty SAND, 20% Pebbles, Poorly sorted; Damp	— 2.0 ppm	0-2	—	2 1 2 4	12:40, 6-9-93
	2.0–4.0	Very Loose Brown Clayey Silty SAND Minor Gravel, Poorly sorterd; Moist	— 1.4 ppm	2-4	—	6 2 1 1	Very Moist
	4.0–5.0	Very Stiff Silty, Sandy CLAY, Brown to Reddish Brown; Moist	—	4-6	—	11 8 8 9	

HTW DRILLING LOG

HOLE No.	MP-1
PROJECT	West Point Subsurface Investigation
INSPECTOR	J. Ronald Sides
SHEET	2 OF 3

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
			0.6 ppm				
	6.0	Very Stiff to Hard, Reddish-Brown Silty, Sandy CLAY, Some Gray Mottling; Moist	—	6-8	—	7 8 12 21	
	7.0						
	8.0		— 1.2 ppm	8-10	—	8 30 16 12	
	9.0						
	10.0	Very Dense, Brown, Very Clayey Silty SAND. Small Metamorphic Cobble in Tip; Wet	— 1.1 ppm	10-12	—	9 12 52 57	
	11.0						
	12.0	Very Stiff, Brown, Very Sandy, Silty CLAY; Wet	—	12-14	—	7 9 15 12	14:20 6-9-93 Stopped, storm
	13.0						
	14.0						

HTW DRILLING LOG

HOLE No.	MP-1
SHEET	3
OF	3

PROJECT: West Point Subsurface Investigation

INSPECTOR: J. Ronald Sides

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Very Stiff Brown Silty CLAY with Trace of Sand, Lower 6" has 10% coarse sand and rock fragments	—	14-16	—	8 14 10 12	7:47, 6-10-93
	15.0						
	16.0						Auger TD
		Hard Brown Sandy and Silty CLAY, Uniform texture, 10% rock fragments, Lower 1 ft. very stiff with 50%; Moist metamorphic rock fragments	—	16-18	—	8 16 34 21	
	17.0						
	18.0						8:45, 6-10-93 Spoon TD
	19.0						
	20.0						
	21.0						
	22.0						
	23.0						

HTW DRILLING LOG

HOLE No.	MP-2
SHEET 1 OF 4	
1. COMPANY NAME	Law Environmental, Inc.
2. DRILLING SUBCONTRACTOR	Parratt-Wolff
3. PROJECT	West Point Subsurface Investigation
4. LOCATION	West Point - Motor Pool Lot
5. NAME OF DRILLER	Mark Beck
6. MANUFACTURER'S DESIGNATION OF DRILL	CME-55
7. SIZE AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	CME 55 140 lb. hammer, 30" drop 2' spoon, 2" diameter 4 1/4" augers
8. HOLE LOCATION	Motor Pool - Location 2
9. SURFACE ELEVATION	335.86
10. DATE STARTED	6-18-93
11. DATE COMPLETED	6-18-93
12. OVERBURDEN THICKNESS	30 ft.
13. DEPTH DRILLED INTO ROCK	0 ft.
14. TOTAL DEPTH OF HOLE	30 ft.
15. DEPTH GROUNDWATER ENCOUNTERED	24-26' (Semi-Confined?)
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	~8.5; 13.5 hours
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	10.92 BGS 7-8-93

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
14, 24-26 ft.	√		—

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %
NO	—	—	—	—	—	

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
Installed well		√		

24. CHECKED BY:	25. NAME OF INSPECTOR
	J. Ronald Sides

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Very Stiff, Brown Gravelly, Very Sandy Silty CLAY, Damp	0 ppm	0-1.6	—	12 16 20 50/.2	7:45, 6-18-93 Spoon refusal
	1.0						
		No sample, auger					
	2.0	Very Dense to firm, Brown, Clayey to Slightly Clayey, Silty Medium SAND, Minor gravel, Damp	0 ppm	2-4	—	12 23 34 23	
	3.0						
	4.0		0 ppm	4-6	—	8 14 12 14	
	5.0						

HTW DRILLING LOG

HOLE No.	MP-2

PROJECT	INSPECTOR	SHEET 2 OF 4
West Point Subsurface Investigation	J. Ronald Sides	

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
	6.0		0 ppm	6-8	—	11 7 5 11	
	7.0						
	8.0	Very Dense, Moist, Same lithology as 2-8 ft.but 25% rock fragments near base (lower 1')	0 ppm	8-9.7	—	17 18 45 5/.2	
	9.0						Spoon refusal
	10.0						
	11.0						
	12.0	Dense, Reddish Tan Medium SAND. Poorly sorted. Average Medium Grained. 50% highly altered metamorphic rocks, high feldspar and mica content; Moist	0 ppm	12-14	—	25 18 24 16	
	13.0						
	14.0						

HTW DRILLING LOG

PROJECT	INSPECTOR	HOLE No.
West Point Subsurface Investigation	J. Ronald Sides	MP-2
		SHEET 3 OF 4

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Very Firm to Very Dense, Light Brown Clayey SAND. Poorly sorted. Medium. High Mica and Feldspar content. 20% altered rocks; Moist	0 ppm	14-16	—	8 16 15 18	
	15.0						
	16.0		0 ppm	16-18	—	18 42 64 60	
	17.0						
	18.0	Very Dense, Light Brown to Red Brown Clayey SAND. Poorly Sorted. High Mica and Feldspar Content. 30% highly altered rock fragments	0 ppm	18-20	—	8 24 34 32	
	19.0						
	20.0	Hard, Brown Sandy, Silty CLAY; Wet		20-21.4		24 48	
		Highly Altered Metamorphic Rock, High in Feldspar and Biotite. Very Dense	0 ppm			125/.4	
	21.0						
	22.0	Brown to Reddish Brown, Very Dense Sandy Soil Composed Mostly of Highly Altered Metamorphic Rock; Wet	0 ppm	22-24	—	24 52 36 18	Spoon through augers
	23.0						

HTW DRILLING LOG

HOLE No. MP-2

PROJECT: West Point Subsurface Investigation | INSPECTOR: J. Ronald Sides | SHEET 4 OF 4

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
	24.0	Very Firm, Brown Clayey Silty SAND. Poorly Sorted; Medium , Wet	0 ppm	24-26	—	6 12 18 22	Note: Rapid H_20 rise at TD=26' to ~14' Below Surface
	25.0						
	26.0		0 ppm	26-26.3		100	100% Refusal
	27.0						
	28.0	Auger					Refusal immediate No Sample
	29.0						
		Possible Bedrock					Auger Refusal
	30.0						TD 14:40-6-18-93 Attempt to sample past 30' Immediate refusal Probable rock
	31.0						
	32.0						

MRK FORM JUN 89 55-2
0660-0817.02

PROJECT NAME & NO. West Point 11-0660-0817

HOLE No. MP-2

HTW DRILLING LOG

HOLE No. MP-3 | SHEET 1 OF 7

1. COMPANY NAME: Law Environmental, Inc.	2. DRILLING SUBCONTRACTOR: Parratt-Wolff
3. PROJECT: West Point Subsurface Investigation	4. LOCATION: West Point – Motor Pool Lot
5. NAME OF DRILLER: Ron Bush	6. MANUFACTURER'S DESIGNATION OF DRILL: CME-75
7. SIZE AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4 1/4 HSA; S-type Casing; HX core; 5-7/8 Tricone Roller Bit	8. HOLE LOCATION: Motor Pool LF
	9. SURFACE ELEVATION: 317.91
	10. DATE STARTED: 7-26-93 / 11. DATE COMPLETED: 8-9-93
12. OVERBURDEN THICKNESS: 27.2 ft.	15. DEPTH GROUNDWATER ENCOUNTERED: 10 ft. upper zone
13. DEPTH DRILLED INTO ROCK: 26.8 ft.	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 7.39 8-12-93
14. TOTAL DEPTH OF HOLE: 54.0 ft.	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
11			4

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %
N/A	N/A	N/A	N/A	N/A	N/A	

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
Completed well	N/A	√	N/A	

24. CHECKED BY:	25. NAME OF INSPECTOR: Ian J. Grassie

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		No samples to 5.0 ft., Dry cuttings, Light Brown Silty SAND and Gravel	0 ppm	N/A	N/A	N/A	0-2 cuttings 0 ppm HNU (Dry)
	1.0						
	2.0						
	3.0						
	4.0						
	5.0						

HTW DRILLING LOG

HOLE No. MP-3

PROJECT: West Point Subsurface Investigation

INSPECTOR: IJG

SHEET 2 OF 7

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Dense to Very Dense Light Brown Silty Fine SAND and Gravel (Dry) Fill		5-7 ft.	N/A	21 21 29 16	REC 75%
	6.0						
	7.0			7-9 ft.	N/A	21 30 39 44	REC 20% (Rock in tip of spoon)
	8.0						
	9.0	Boulder, No sample	N/A	N/A	N/A	N/A	N/A
	10.0	Very Firm Light Brown Silty Fine SAND with some Gravel; Wet		10-12 ft.	N/A	14 12 14 17	REC 75%
	11.0						
	12.0			12-14 ft.	N/A	18 24 25 42	REC 80%
	13.0	Very Dense Silty Fine SAND with some Clay; Damp					
	14.0						

HTW DRILLING LOG

HOLE No. MP-3

PROJECT: West Point Subsurface Investigation | INSPECTOR: IJG | SHEET 3 OF 7

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Dense to Very Dense Light Brown Silty SAND and Gravel; Damp		14-16 ft.	N/A	12 13 25 24	REC 85%
	15.0						
	16.0			16-18 ft.	N/A	36 42 30 33	REC 100%
	17.0						
	18.0	Very Dense Light Brown Silty SAND and Gravel; Minor Clay; Upper 1 ft. wet, Lower .6 damp		18-20 ft.	N/A	26 48 41 55	REC 78%
	19.0						
	20.0	Very Dense Light Brown Silty Fine SAND and Gravel; Damp		20-28.8 ft.	N/A	59 53	REC 50%
	21.0	Boulder, no sample		N/A	N/A	N/A	
	22.0			22-22.3 ft.	N/A	50/.3	REC 100%
	23.0			End 7-26-93			

HTW DRILLING LOG

HOLE No. MP-3

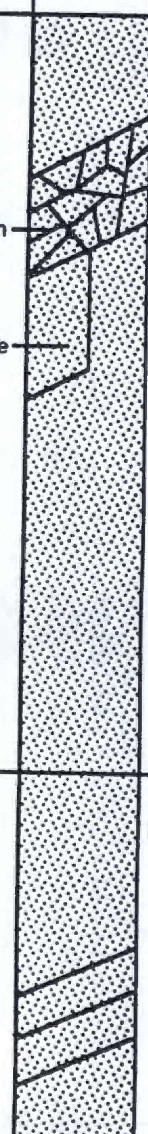
PROJECT	INSPECTOR	SHEET 4 OF 7
West Point Subsurface Investigation	IJG	

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Boulder (No water loss)	N/A	N/A	N/A	N/A	No sample
	24.0	Very Dense Light Brown Fine Silty SAND, Minor Clay; Damp		24-25.3	N/A	34 50/.5 50/.3	REC 65%
	25.0	Boulder	N/A	N/A	N/A	N/A	No sample
	26.0	Very Dense Greenish Gray to Light Brown, Very Dense Fine Very Silty SAND		26-27.15	N/A	35 43 50/.15	REC 45%
	27.0	Boulder	N/A	N/A	N/A	N/A	No sample
	28.0						
		Boulder, Light Gray Biotite Granitic Gneiss, Well Foliated		Core Box 1			Cored with DX Bit
	29.0						
	30.0						
	31.0						
	32.0						

HTW DRILLING LOG

PROJECT	INSPECTOR	HOLE No.	SHEET
West Point Subsurface Investigation	IJG	MP-3	SHEET 5 OF 7

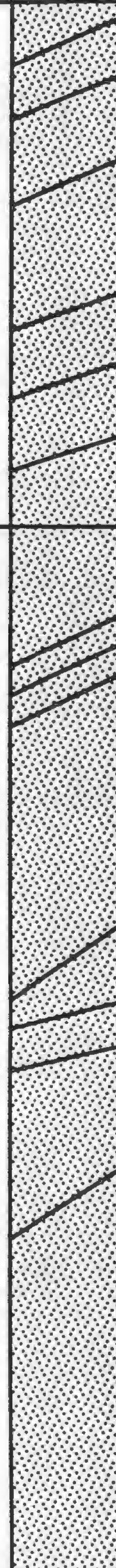
ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
			0 ppm	N/A	N/A	N/A	No water loss
	33.0	Boulders				50/0.1	Spin S-type Casing End 7-27-93 Start 7-28-93
	34.0	Start coring				N/A	
	35.0	Light Gray Biotite Granitic Gneiss, Very Well Foliated	1.5 ppm Not sustained	Core Box 2 Run #2	N/A		DX Coring REC 100% RQD 65%
	36.0–37.0–38.0	Amphibolite					
	39.0–40.0–41.0	Light Gray to Gray Biotite Feldspar Gneiss, Very Well Fractured, Well Foliated	0 ppm	Core Box 3 Run #3	N/A		REC 100% RQD 30%



HTW DRILLING LOG

PROJECT West Point Subsurface Investigation	INSPECTOR IJG	HOLE No. MP-3	SHEET 6 OF 7

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
			0 ppm		N/A		
					30-40° fracture		
	42.0						
	43.0						
		Set 4" casing to 44'					End 7-28-93
	44.0	Gray Biotite Feldspar Gneiss, Very Well Foliated; Slight Iron Stain	1 ppm	Core Box 4 Run #4			Start 8-9-93 REC 100% RQD 75%
					30°		
	45.0						
	46.0						
					35° 20° 20°		
	47.0						
					35°		
	48.0						
	49.0			Run #5			No water loss this run
	50.0						



MRK FORM JUN 89 55-2
0660-0817.02

PROJECT NAME & NO.
West Point 11-0660-0817

HOLE No. MP-3

HTW DRILLING LOG

HOLE No. MP-3

PROJECT: West Point Subsurface Investigation

INSPECTOR: IJG

SHEET 7 OF 7

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Light Gray Biotite Feldspar Gneiss, Well Foliated and Well Fractured, Iron Staining in Fractures	0 ppm		Low angle fractures; fragments		REC 100% RQD 45%
	51.0						
	52.0						
	53.0				15°		
					15°		
	54.0						20 gallon water loss
							TD
	55.0						
	56.0						
	57.0						
	58.0						
	59.0						

HTW DRILLING LOG

HOLE No.	MP-4
SHEET	1 OF 3
1. COMPANY NAME	Law Environmental, Inc.
2. DRILLING SUBCONTRACTOR	Parratt-Wolff
3. PROJECT	West Point Subsurface Investigation
4. LOCATION	West Point – Motor Pool Lot
5. NAME OF DRILLER	Ron Bush
6. MANUFACTURER'S DESIGNATION OF DRILL	CME-75
7. SIZE AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	HSA 4 1/4
8. HOLE LOCATION	Motor Pool-Location 4
9. SURFACE ELEVATION	317.94
10. DATE STARTED	8-10-93
11. DATE COMPLETED	8-10-93
12. OVERBURDEN THICKNESS	20 ft.
15. DEPTH GROUNDWATER ENCOUNTERED	≈9 ft. damp wet at 10.5 to 12
13. DEPTH DRILLED INTO ROCK	0
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	12.94 8-12-93
14. TOTAL DEPTH OF HOLE	20 ft.
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
2, 2-4 ft.			0

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %
N/A	N/A	N/A	N/A	N/A	N/A	

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
Installed well	N/A	√	N/A	

24. CHECKED BY:	25. NAME OF INSPECTOR
	J. Ronald Sides

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Light Brown to Rusty Brown Silty Fine SAND and Gravel; Dry; Description made from cuttings	0 ppm	N/A	N/A	N/A	No sample
	1.0						
	2.0						
	3.0						
	4.0						
	5.0						

HTW DRILLING LOG

HOLE No. MP-4

PROJECT	INSPECTOR	SHEET 2 OF 3
West Point Subsurface Investigation	J. Ronald Sides	

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Light Brown Silty SAND and Gravel; Dry	0 ppm	N/A	N/A	N/A	
	6.0						
	7.0						
	8.0	Boulders					
	9.0	Very Dense Rusty to Light Brown Slightly Silty Medium to Coarse SAND and Gravel; Dry to Damp	0 ppm	N/A	N/A	11 23 68 35	REC 50%
	10.0						
	11.0	Very Dense Light Brown Medium Slightly Silty SAND; Damp; Wet at ≈ 11 ft.	0 ppm	N/A	N/A	29 40 31 44	REC 75%
	12.0						
	13.0						
	14.0						

HTW DRILLING LOG

HOLE No. MP-4

PROJECT	INSPECTOR	SHEET 3 OF 3
West Point Subsurface Investigation	J. Ronald Sides	

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX No. e	ANALYTICAL SAMPLE No. f	BLOW COUNTS g	REMARKS h
		Light Brown Medium to Fine Silty SAND and Gravel; Wet	0 ppm	N/A	N/A	N/A	
	15.0						
	16.0						
	17.0						
	18.0						
	19.0						
	20.0						TD
	21.0						
	22.0						
	23.0						

APPENDIX D

DRAINAGE CALCULATIONS AND SWALE DESIGN

EA Engineering, Science, and Technology

Project: West Point - Motor Pool L.F.
Project #: 60787.76
Task:
Calculated: JDM Date: 02-Mar-98
Checked: MJA Date: 3/2/98

TR-55 Worksheet #2: Runoff Curve Number and Runoff

Stage of Development: Proposed swale improvements
Drainage Area Description: South side of site draining to proposed swale along southern fence line - Easterly flowing swale

Soil Name and Hydrologic Group		Cover Description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN Table 2-2	CN Fig. 2-3	CN Fig. 2-4	Area (acres)	CN*Area
Asphalt	C	Paved Parking Lot	98			1.1	107
	C	Woods, good condition	70			1.1	76
	0	0	0	0	0	0.0	0
							0
							0
							0
							0
							0
							0
							0
					Totals	2.2	183

Use CN = 84

	Storm #1	Storm #2	Storm #3	Storm #4	Storm #5
Frequency (years)	2	5	10	25	0
24 Hour Rainfall, P (in)	3.5	4.5	5	5.5	0
Runoff, Q (in) (use P and CN with Table 2-1, Fig. 2-1, or Eqn. 2-3 and 2-4)	1.94	2.82	3.27	3.73	0.00

F:\6078776\CALCS\TR55RUN1.WB2

EA Engineering, Science, and Technology

Project:	West Point - Motor Pool L.F.
Project #:	60787.76
Task:	
Calculated:	JDM	Date: 02-Mar-98
Checked:	MA	Date: 3/2/98

TR-55 Worksheet #3: Time of Concentration (Tc) or Travel Time (Tt)

Sheet Flow	Segment	A1B1			
1 Surface Description (Table 3-1)		light underb			
2 Manning's Roughness Coeff., n (Table 3-1)		0.4			
3 Flow Length, L (total L <= 300 ft)	ft	100			
4 Two year 24 hour Rainfall, P2	in	3.5			
5 Land Slope, s	ft/ft	0.160			
6 Tt	hr	0.149	0.000	0.000	0.149

Shallow Concentrated Flow	Segment	B1C1	0	0	
7 Surface Description (1=paved, 2=unpaved)		2	0	0	
8 Flow Length, L	ft	70	0	0	
9 Watercourse Slope, s	ft/ft	0.286	0.000	0.000	
10 Average Velocity, V (Fig. 3-1)	ft/s	8.63	0.00	0.00	
11 Tt	hr	0.002	0.000	0.000	0.002

Channel Flow	Segment	C1D1			
Bottom width of trapezoidal channel	ft	2			
Depth of trapezoidal channel	ft	1			
Side slopes of trapezoidal channel (?H:1V)		3			
12 Cross Sectional Flow Area, a	sq ft	5.00	0.00	0.00	
13 Wetted Perimeter, pw	ft	8.32	0.00	0.00	
14 Hydraulic Radius, r	ft	0.601	0.000	0.000	
15 Channel Slope, s	ft/ft	0.012			
16 Manning's Roughness Coeff., n		0.15			
17 V	ft/s	0.775	0.000	0.000	
18 Flow Length, L	ft	485			
19 Tt	hr	0.174	0.000	0.000	0.174
				Tc =	0.325

TR-55 Worksheet #4: Graphical Peak Discharge Method

1 Drainage Area, Am	sq mi	0.003
Runoff Curve Number, CN (worksheet #2)		84
Time of Concentration, Tc (worksheet #3)	hr	0.325
Rainfall Distribution Type (I, IA, II, III)		II
Pond and Swamp Areas Spread Throughout Watershed	% Am	0

		Storm #1	Storm #2	Storm #3	Storm #4	Storm #5
2 Frequency	yr	2	5	10	25	0
3 Rainfall, P (24 hour)	in	3.5	4.5	5.0	5.5	0.0
4 Initial Abstraction, Ia (Table 4-1)	in	0.381	0.381	0.381	0.381	0.000
5 Ia/P		0.109	0.085	0.076	0.069	0.000
6 Unit Peak Discharge, qu (Exhibit 4-II)	csm/in	647.3	652.1	652.1	652.1	0.0
7 Runoff, Q (worksheet 2)	in	1.94	2.82	3.27	3.73	0.00
8 Pond & Swamp Adjustment Factor, Fp (Table 4-2, Fp = 1.0 for none)		1	1	1	1	1
9 Peak Discharge, qp	cfs	4.3	6.3	7.3	8.3	0.0

TRAPEZOIDAL SWALE

Channel Characteristics:

Flow Rate, Q =	7.30	cfs
Bottom width, B =	2.0	ft
Side slope, Z =	2.0	?H:1V
Side slope, Z =	2.0	?H:1V
Manning roughness, n =	0.15	
Channel slope, S =	0.012	ft/ft
Rock filter height, H =	0.0	ft
Flow Depth, D =	1.5	ft
Top width =	8.00	ft
Flow area, A =	7.50	sq ft
Wetted perimeter, P =	8.71	ft
Mean depth, Dm =	0.938	ft
Hydraulic radius, R =	0.861	ft
Velocity, V =	0.97	fps

	Flow Depth* (ft)	Hydraulic Radius (ft)	Velocity (fps)	Hydraulic Radius (ft)	Difference	
	0.1	0.090	33.2	169.545	-169.455	
	0.2	0.166	15.2	52.609	-52.443	
	0.3	0.233	9.4	25.397	-25.163	
	0.4	0.296	6.5	14.760	-14.465	
	0.5	0.354	4.9	9.523	-9.169	
	0.6	0.410	3.8	6.576	-6.166	
	0.7	0.464	3.1	4.765	-4.301	
	0.8	0.516	2.5	3.580	-3.063	
	0.9	0.568	2.1	2.766	-2.199	
	1.0	0.618	1.8	2.187	-1.569	
	1.1	0.668	1.6	1.762	-1.094	
	1.2	0.717	1.4	1.442	-0.725	
	1.3	0.765	1.2	1.196	-0.431	
	1.4	0.813	1.1	1.004	-0.191	
>	1.5	0.861	1.0	0.852	0.009	<
	1.6	0.909	0.9	0.729	0.180	
	1.7	0.956	0.8	0.629	0.327	
	1.8	1.003	0.7	0.547	0.456	
	1.9	1.050	0.7	0.478	0.572	
	2.0	1.096	0.6	0.421	0.676	
	2.1	1.143	0.6	0.372	0.771	
	2.2	1.189	0.5	0.331	0.858	
	2.3	1.236	0.5	0.296	0.940	
	2.4	1.282	0.4	0.265	1.016	
	2.5	1.328	0.4	0.239	1.089	
	2.6	1.374	0.4	0.216	1.158	
	2.7	1.420	0.4	0.196	1.224	
	2.8	1.465	0.3	0.178	1.287	
	2.9	1.511	0.3	0.163	1.348	
	3.0	1.557	0.3	0.149	1.408	
	3.1	1.602	0.3	0.137	1.466	
	3.2	1.648	0.3	0.126	1.522	
	3.3	1.694	0.3	0.116	1.578	
	3.4	1.739	0.2	0.107	1.632	
	3.5	1.784	0.2	0.099	1.685	
	3.6	1.830	0.2	0.092	1.738	
	3.7	1.875	0.2	0.085	1.790	
	3.8	1.921	0.2	0.079	1.841	
	3.9	1.966	0.2	0.074	1.892	
	4.0	2.011	0.2	0.069	1.942	
	4.1	2.056	0.2	0.065	1.992	
	4.2	2.102	0.2	0.061	2.041	
	4.3	2.147	0.2	0.057	2.090	
	4.4	2.192	0.2	0.053	2.139	
	4.5	2.237	0.1	0.050	2.187	

* Actual flow depth (D) is where hydraulic radii match (smallest "difference")

EA Engineering, Science, and Technology

Project: West Point - Motor Pool L.F.
Project #: 60787.76
Task:
Calculated: JDM   Date: 26-Feb-98
Checked: MJd   Date: 3/2/98

TR-55 Worksheet #2: Runoff Curve Number and Runoff

Stage of Development: Proposed swale improvements
Drainage Area Description: South side of site draining to proposed swale along southern fence line - Westerly flowing swale

Soil Name and Hydrologic Group		Cover Description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN Table 2-2	CN Fig. 2-3	CN Fig. 2-4	Area (acres)	CN*Area
Asphalt	C	Paved Parking Lot	98			1.3	123
	C	Woods - grass combination, good conditio	72			0.4	27
	0	0	0	0	0	0.0	0
							0
							0
							0
							0
							0
							0
							0
					Totals	1.6	150

Use CN = 92

	Storm #1	Storm #2	Storm #3	Storm #4	Storm #5
Frequency (years)	2	5	10	25	0
24 Hour Rainfall, P (in)	3.5	4.5	5	5.5	0
Runoff, Q (in) (use P and CN with Table 2-1, Fig. 2-1, or Eqn. 2-3 and 2-4)	2.63	3.60	4.08	4.57	0.00

EA Engineering, Science, and Technology

Project: West Point - Motor Pool L.F.
Project #: 60787.76
Task:
Calculated: JDM Date: 26-Feb-98
Checked: [handwritten initials] Date: 3/2/98

TR-55 Worksheet #3: Time of Concentration (Tc) or Travel Time (Tt)

Sheet Flow	Segment	A2B2			
1 Surface Description (Table 3-1)		dense gras			
2 Manning's Roughness Coeff., n (Table 3-1)		0.24			
3 Flow Length, L (total L <= 300 ft)	ft	55			
4 Two year 24 hour Rainfall, P2	in	3.5			
5 Land Slope, s	ft/ft	0.218			
6 Tt	hr	0.054	0.000	0.000	0.054
Shallow Concentrated Flow	Segment	B2C2	0	0	
7 Surface Description (1=paved, 2=unpaved)		2	0	0	
8 Flow Length, L	ft	50	0	0	
9 Watercourse Slope, s	ft/ft	0.260	0.000	0.000	
10 Average Velocity, V (Fig. 3-1)	ft/s	8.23	0.00	0.00	
11 Tt	hr	0.002	0.000	0.000	0.002
Channel Flow	Segment	C2D2			
Bottom width of trapezoidal channel	ft	3			
Depth of trapezoidal channel	ft	1.5			
Side slopes of trapezoidal channel (?H:1V)		2			
12 Cross Sectional Flow Area, a	sq ft	9.00	0.00	0.00	
13 Wetted Perimeter, pw	ft	9.71	0.00	0.00	
14 Hydraulic Radius, r	ft	0.927	0.000	0.000	
15 Channel Slope, s	ft/ft	0.008			
16 Manning's Roughness Coeff., n		0.15			
17 V	ft/s	0.845	0.000	0.000	
18 Flow Length, L	ft	620			
19 Tt	hr	0.204	0.000	0.000	0.204
				Tc =	0.260

TR-55 Worksheet #4: Graphical Peak Discharge Method

1 Drainage Area, Am	sq mi	0.003
Runoff Curve Number, CN (worksheet #2)		92
Time of Concentration, Tc (worksheet #3)	hr	0.260
Rainfall Distribution Type (I, IA, II, III)		II
Pond and Swamp Areas Spread Throughout Watershed	% Am	0

		Storm #1	Storm #2	Storm #3	Storm #4	Storm #5
2 Frequency	yr	2	5	10	25	0
3 Rainfall, P (24 hour)	in	3.5	4.5	5.0	5.5	0.0
4 Initial Abstraction, Ia (Table 4-1)	in	0.175	0.175	0.175	0.175	0.000
5 Ia/P		0.050	0.039	0.035	0.032	0.000
6 Unit Peak Discharge, qu (Exhibit 4-II)	csm/in	719.6	719.6	719.6	719.6	0.0
7 Runoff, Q (worksheet 2)	in	2.63	3.60	4.08	4.57	0.00
8 Pond & Swamp Adjustment Factor, Fp (Table 4-2, Fp = 1.0 for none)		1	1	1	1	1
9 Peak Discharge, qp	cfs	4.8	6.6	7.5	8.4	0.0

TRAPEZOIDAL SWALE

Channel Characteristics:

Flow Rate, Q =	7.50	cfs
Bottom width, B =	3.0	ft
Side slope, Z =	2.0	?H:1V
Side slope, Z =	2.0	?H:1V
Manning roughness, n =	0.15	
Channel slope, S =	0.008	ft/ft
Rock filter height, H =	0.0	ft
Flow Depth, D =	1.5	ft
Top width =	9.00	ft
Flow area, A =	9.00	sq ft
Wetted perimeter, P =	9.71	ft
Mean depth, Dm =	1.000	ft
Hydraulic radius, R =	0.927	ft
Velocity, V =	0.83	fps

	Flow Depth* (ft)	Hydraulic Radius (ft)	Velocity (fps)	Hydraulic Radius (ft)	Difference	
	0.1	0.093	23.4	136.417	-136.324	
	0.2	0.175	11.0	44.038	-43.864	
	0.3	0.249	6.9	22.002	-21.753	
	0.4	0.317	4.9	13.177	-12.860	
	0.5	0.382	3.8	8.731	-8.349	
	0.6	0.443	3.0	6.173	-5.730	
	0.7	0.502	2.4	4.568	-4.066	
	0.8	0.559	2.0	3.498	-2.939	
	0.9	0.615	1.7	2.750	-2.135	
	1.0	0.669	1.5	2.209	-1.540	
	1.1	0.722	1.3	1.805	-1.083	
	1.2	0.775	1.2	1.497	-0.723	
	1.3	0.826	1.0	1.257	-0.431	
	1.4	0.877	0.9	1.067	-0.190	
>	1.5	0.927	0.8	0.915	0.012	<
	1.6	0.977	0.8	0.790	0.186	
	1.7	1.026	0.7	0.688	0.338	
	1.8	1.075	0.6	0.603	0.472	
	1.9	1.124	0.6	0.532	0.592	
	2.0	1.172	0.5	0.471	0.701	
	2.1	1.220	0.5	0.420	0.800	
	2.2	1.268	0.5	0.376	0.892	
	2.3	1.316	0.4	0.338	0.978	
	2.4	1.363	0.4	0.305	1.058	
	2.5	1.410	0.4	0.276	1.134	
	2.6	1.458	0.4	0.251	1.207	
	2.7	1.505	0.3	0.229	1.276	
	2.8	1.551	0.3	0.209	1.342	
	2.9	1.598	0.3	0.192	1.407	
	3.0	1.645	0.3	0.176	1.469	
	3.1	1.691	0.3	0.162	1.529	
	3.2	1.738	0.2	0.150	1.588	
	3.3	1.784	0.2	0.138	1.645	
	3.4	1.830	0.2	0.128	1.702	
	3.5	1.876	0.2	0.119	1.757	
	3.6	1.923	0.2	0.111	1.812	
	3.7	1.969	0.2	0.103	1.865	
	3.8	2.015	0.2	0.097	1.918	
	3.9	2.061	0.2	0.090	1.970	
	4.0	2.106	0.2	0.085	2.022	
	4.1	2.152	0.2	0.079	2.073	
	4.2	2.198	0.2	0.075	2.124	
	4.3	2.244	0.2	0.070	2.174	
	4.4	2.290	0.1	0.066	2.223	
	4.5	2.335	0.1	0.062	2.273	

* Actual flow depth (D) is where hydraulic radii match (smallest "difference")

Project W. Point L.F. Project No.
Subject MOTOR POOL, DRAINAGE AREAS Sheet No. 1 of 2
Drawing No.
Computed by: JDM Date 2/3/98 Checked by M J Date 3/2/98

MOTOR POOL - DRAINAGE AREAS

*Using Planimeter

East Area

$PAVED_1$ = 1.09 Ac (47,394 ft^2)

$WOODS_1$ = 1.09 Ac (47,394 ft^2)

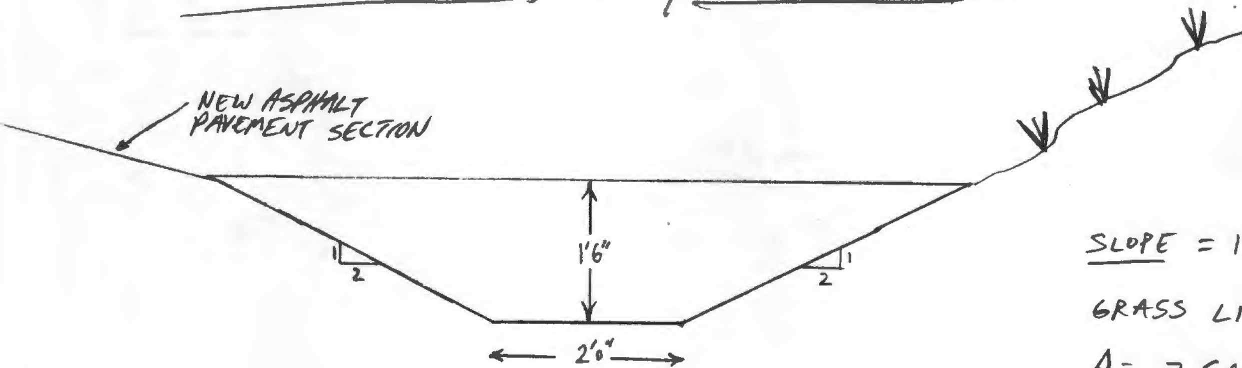
West Area

$PAVED_2$ = 1.25 Ac (54,720 ft^2)

GRASS/WOODS = .38 Ac (16,560 ft^2)

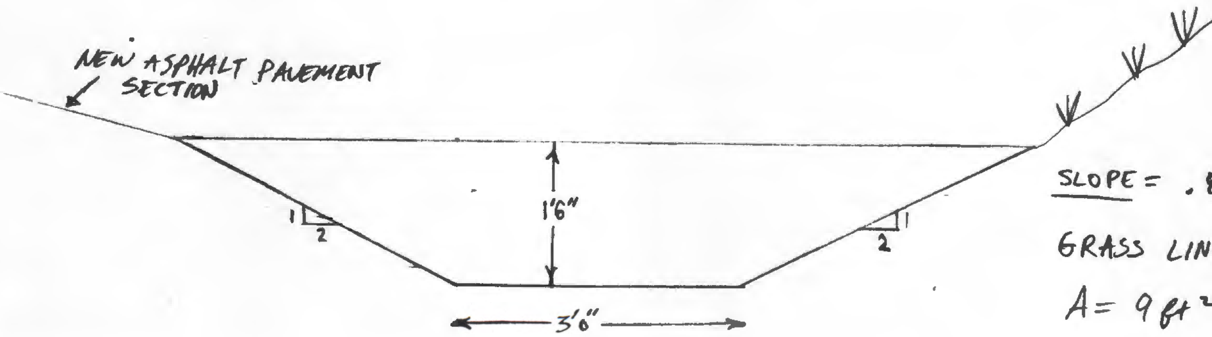
Project W. Point
Subject MOTOR POOL L.F.
Computed by: JDM Date 2/3/98
Project No.
Sheet No. 2 of 2
Drawing No.
Checked by MJD Date 3/2/98

SWALE – EASTERLY FLOW / SOUTHERN PERIMETER

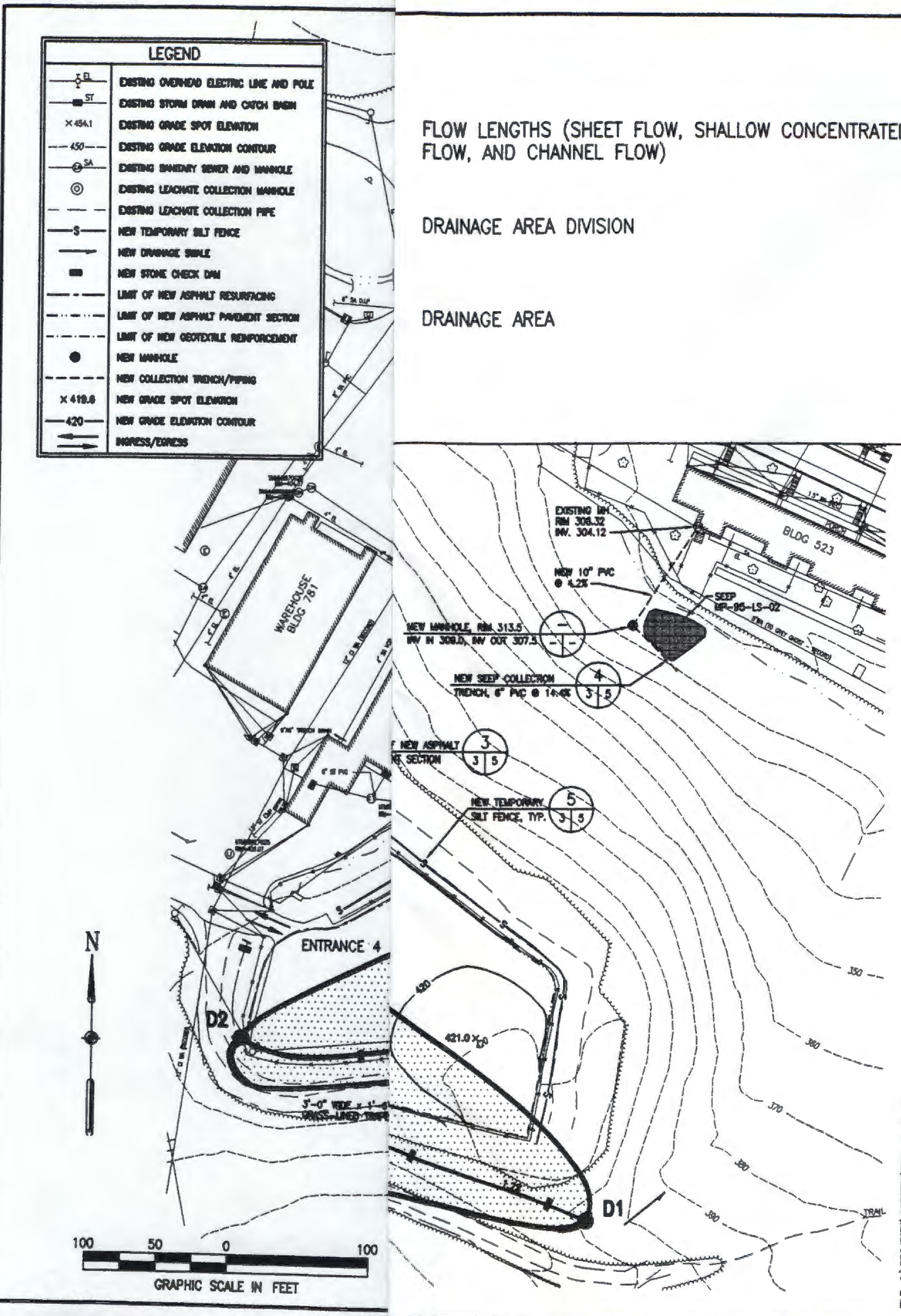


SLOPE = 1.2%
GRASS LINED
$A = 7.5 ft^2$

SWALE – WESTERLY FLOW / SOUTHERN PERIMETER



SLOPE = .8%
GRASS LINED
$A = 9 ft^2$



EA ENGINEERING, SCIENCE, AND TECHNOLOGY

DRAINAGE AREAS

APPENDIX E

GEOTEXTILE FILTER DESIGN

OBJECTIVE:

Design the geotextile filter in the leachate seep collection trench to retain the surrounding soil and pass the leachate. Determine permittivity and apparent opening size (AOS) criteria for the geotextile.

Koerner, *Designing With Geosynthetics*

PROCEDURE:

1. Calculate the required permittivity (Ψ) of the geotextile.

$$\Psi = \frac{q}{\Delta h \times A}$$

where:

EA. 1996. *Final Phase II Leachate Management Analysis of Six Landfills, U.S. Military Academy, West Point, New York.*

q = flow (cfs) = 113 gpd = 0.000175 cfs
Δh = head difference across geotextile (ft)
A = area of flow through geotextile (ft^2)

$$\Psi = \frac{0.000175}{0.5 \times (1 \times 15)} = 0.0000233 \text{ sec}^{-1}$$

Koerner, *Designing With Geosynthetics*

2. Using a global factor of safety of 100, determine the allowable permittivity.

$$\Psi_{allow} = F.S. \times \Psi_{req'd} = 100 \times 0.0000233 = 0.00233 \text{ sec}^{-1}$$

3. Based on partial factors of safety for flow, determine the ultimate permittivity of the geotextile.

$$\Psi_{ult} = F.S._{SCB} \times F.S._{CR} \times F.S._{IN} \times F.S._{CC} \times F.S._{BC} \times \Psi_{allow}$$

where:

$F.S._{SCB}$ = F.S. for soil clogging and blinding
$F.S._{CR}$ = F.S. for creep reduction of void space
$F.S._{IN}$ = F.S. for adjacent materials intruding in geotextile voids
$F.S._{CC}$ = F.S. for chemical clogging
$F.S._{BC}$ = F.S. for biological clogging

Koerner, *Designing With Geosynthetics*

$$\Psi_{ult} = 8.0 \times 1.2 \times 1.5 \times 4.0 \times 4.0 \times 0.00233 = 0.538 \text{ sec}^{-1}$$

Project	West Point – Motor Pool Landfill	Project No.	60787.76
Subject	Leachate Seep Collection Trench Geotextile Filter Design	Sheet No.	2 of 2
		Drawing No.	
Computed by MJG	Date 5/19/98	Checked by GAT	Date 5/20/98

Carroll. 1983. *Geotextile Filter Criteria*

Based on boring logs from MP-3 and MP-4 which indicate silty SAND and gravel

4. Calculate the largest AOS (O_{95}) which will retain the surrounding soil.

$$O_{95} \leq 2\, d_{85}$$

where:

O_{95} = apparent opening size (AOS)

d_{85} = 85% of the soil is smaller than this diameter (mm) = 0.5mm

$$O_{95} \leq 2\,(0.5\text{mm}) \leq 1.0\text{mm}$$

5. Select a geotextile with this permittivity and AOS.

Synthetic Industries Erosion V, X, and XV meet the permittivity and AOS requirements.

RESULTS:

Use a woven geotextile with a minimum permittivity of 0.54 sec^{-1} and a maximum AOS of 1mm.

APPENDIX F

FLEXIBLE PAVEMENT DESIGN

Project	West Point – Motor Pool Landfill	Project No.	60787.76
Subject	Upper Motor Pool Pavement Design (TM 5-822-5)	Sheet No.	1 of 2
		Drawing No.	
Computed by MJG	Date 5/12/98	Checked by GAT	Date 5/12/98

OBJECTIVE:

Design the pavement cross-section at the Motor Pool Landfill to serve the mix of cars, trucks, buses, and military vehicles which are stored in the upper Motor Pool parking area. Utilize the design method presented in "Pavement Design for Roads, Streets, Walks, and Open Storage Areas" (TM 5-822-5).

TM 5-822-5

PROCEDURE:

1. Quantify the types of vehicles which utilize the Motor Pool to determine the traffic category.

Site visit – Spring 1997

Assume 80 cars and small vans and trucks, and 60 3-axle trucks and buses utilize the Motor Pool.

This corresponds to traffic category IVA – more than 25% trucks.

2. Determine the class of the parking area.

TM 5-822-5, 3-2c(1)

Vehicular parking areas are class E.

3. Based on (1) and (2) above, identify the pavement design index.

TM 5-822-5, Table 3-1

The pavement design index is 5.

4. Determine the subgrade compaction depth below the top of pavement.

TM 5-822-5, Table 4-1

Assuming the subgrade is compacted to 95% Modified Proctor density and it is cohesionless, a minimum of 12-in. of material compacted to 100% Modified Proctor density is required on top of existing subgrade and below the top of the pavement.

5. Using the pavement design index and the CBR of the base course, find the minimum thicknesses of the pavement and the base course.

TM 5-822-5, Table 6-1

Assume the base course will be graded crushed aggregate with a CBR of 100. The required pavement thickness is 2 in. and the base course thickness is 4 in. The pavement and base course are 6-in. thick.

6. Determine the thickness of the subbase material.

TM 5-822-5, Figure 8-1

Based on a subgrade CBR of 15 for gravelly-sand and a pavement design index of 5, the total pavement section must be a minimum of 8-in. thick. Based on the suspected Proctor density of the subgrade (from step 4), the total pavement section must be a minimum of 12-in. thick.

The suspected density of the subgrade controls this design and the thickness of the subbase material. The subbase material must be 6-in. thick to provide a total of 12 in. of material compacted to 100% Modified Proctor density on top of the subgrade.

RESULTS:

The following flexible pavement section will be constructed on the Motor Pool Landfill to serve the current Motor Pool vehicles:

Asphalt pavement = 2 in.
Base course = 4 in.
Subbase course = 6 in.

The following assumptions were used to develop this pavement cross-section:

- Approximately 80 2-axle and 50 3-axle vehicles use the Motor Pool.
- The subgrade is cohesionless, compacted to a minimum of 95% Modified Proctor density, and has a minimum CBR of 15.
- The base and subbase courses will be compacted to a minimum of 100% Modified Proctor density.
- The base course will be a graded crushed aggregate with a minimum CBR of 100.

Project	West Point – Motor Pool Landfill	Project No.	60787.76
Subject	Lower Motor Pool Pavement Design (TM 5-822-5)	Sheet No.	1 of 2
		Drawing No.	

Computed by MJG Date 5/12/98 Checked by GAT Date 5/12/98

OBJECTIVE:

Design the pavement cross-section at the Motor Pool Landfill to serve the mix of cars and small trucks which are stored in the lower Motor Pool parking area. Utilize the design method presented in "Pavement Design for Roads, Streets, Walks, and Open Storage Areas" (TM 5-822-5).

TM 5-822-5

PROCEDURE:

1. Quantify the types of vehicles which utilize the lower Motor Pool parking area to determine the traffic category.

Site visit – Spring 1997

Assume 50 cars, small vans, and pickup trucks utilize the lower Motor Pool parking area north of the main parking area.

This corresponds to traffic category I – less than 1% 2-axle trucks.

2. Determine the class of the parking area.

TM 5-822-5, 3-2c(1)

Vehicular parking areas are class E.

3. Based on (1) and (2) above, identify the pavement design index.

TM 5-822-5, Table 3-1

The pavement design index is 1.

4. Determine the subgrade compaction depth below the top of pavement.

TM 5-822-5, Table 4-1

Assuming the subgrade is compacted to 95% Modified Proctor density and it is cohesionless, a minimum of 7-in. of material compacted to 100% Modified Proctor density is required on top of existing subgrade and below the top of the pavement.

5. Using the pavement design index and the CBR of the base course, find the minimum thicknesses of the pavement and the base course.

TM 5-822-5, Table 6-1

Assume the base course will be graded crushed aggregate with a CBR of 50. The required pavement thickness is 2 in. and the base course thickness is 4 in. The pavement and base course are 6-in. thick.

6. Determine the thickness of the subbase material.

TM 5-822-5, Figure 8-1

Based on a subgrade CBR of 10 and a pavement design index of 1, the total pavement section must be a minimum of 6-in. thick. Based on the suspected Proctor density of the subgrade (from step 4), the total pavement section must be a minimum of 7-in. thick.

The suspected density of the subgrade controls this design and the thickness of the subbase material. The subbase material will be 2-in. thick (use a 2-in. minimum thickness for constructability) to provide a total pavement thickness of 8 in. on top of the subgrade.

RESULTS:

The following flexible pavement section will be constructed on the Motor Pool Landfill to serve the current Motor Pool vehicles:

Asphalt pavement = 2 in.
Base course = 4 in.
Subbase course = 2 in.

The following assumptions were used to develop this pavement cross-section:

- Approximately 50 2-axle passenger vehicles use the lower Motor Pool parking area.
- The subgrade is cohesionless, compacted to a minimum of 95% Modified Proctor density, and has a minimum CBR of 10.
- The base and subbase courses will be compacted to a minimum of 100% Modified Proctor density.
- The base course will be a graded crushed aggregate with a minimum CBR of 50.