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Design Analysis Report
Motor Pool East Landfill Closure
U.S. Military Academy
West Point, New York

Prepared for

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

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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 Ground 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)
EAL	Equivalent Axle Load
EOC	Environment One Corporation
EPA	Environmental Protection Agency
ft	Foot/Feet
gpd	Gallons Per Day
in.	Inch(es)
IR Program	Installation Restoration Program
L	Liter(s)
lb	Pound(s)
LEL	Lower Explosive Limit
LMA	Leachate Management Analysis
m	Meter(s)
MCL	Maximum Contaminant Level
ml	Milliliter(s)
NAD	North American Datum
NYSDEC	New York State Department of Environmental Conservation
PCB	Polychlorinated Biphenyls
ppb_v	Parts Per Billion, Volume
ppm_v	Parts Per Million, Volume
PVC	Polyvinyl Chloride

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

RCP	Reinforced Concrete Pipe
RQD	Rock Quality Density
sec	Second(s)
SVCA®	Soil Vapor Contaminant Assessment
SVOC	Semivolatile Organic Compounds
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 Compounds

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. 132 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 improvement of the Motor Pool East Landfill at the U.S. Military Academy (USMA), West Point, New York.

This design work is being performed in response to findings and 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, technical specifications, a bid form, a price schedule, and a cost estimate for improvements to the Motor Pool East Landfill. The design concepts incorporated herein have been developed in part from previous investigations, and recent pre-design activities conducted under this delivery order.

The design incorporates the following concepts and components based on EA's understanding of the planned future use of the Motor Pool East Landfill property:

- Regrade and improve the perimeter drainage course to minimize stormwater run-on/infiltration into the fill mass, thus minimizing the potential for leachate generation.

- Install new pavement system including subgrade improvements as required for stability and performance. The new pavement system will conform to a grading plan designed to promote and manage surface water run-off and minimize infiltration into the landfill mass.

This Design Analysis Report is based upon information from pre-design activities and prior investigations and analyses conducted by EA and others as referenced in the document entitled: *Expanded RCRA Facility Assessment of Four Landfills, U.S. Military Academy, West Point, New York* (EA 1996).

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 East Landfill is located between Route 218 and Building 793 and 795 near Washington Gate (Figure 1-2). The site is fenced and paved, currently serving as the Motor Pool East Parking Lot. The parking lot occupies an estimated total area of 1.7 acres. An unnamed stream flows along the landfill to the east. A single orange colored seep was observed on the southeast portion of the site along the stream bed (LAW 1994). This site reportedly received garbage, household items, trees, and brush from 1964 to 1969. Sources of the materials were reportedly the USMA and surrounding municipalities. The waste bearing layer may range from 10 to 30 ft below ground surface. It was reportedly USMA practice to place waste material using the pit and fill method with excavated soil used as daily cover. Wastes types (e.g. garbage, wood, metals, and construction materials) were initially segregated and placed into designated areas. However, these materials were reportedly mixed during subsequent regrading activities. The Motor Pool East parking area reportedly received large boulders and blast spoils (from past USMA building construction) as supplemental fill material. Soil cover was placed over the boulders, and a 2-ft sub-base of gravel was placed and graded.

1.3 EXISTING CONDITIONS

The Motor Pool East Landfill is currently paved with asphalt and is used as a parking area for heavy equipment and USMA service vehicles. The pavement system exhibits areas of cracking and disintegration particularly in the west and northwest quadrants. Small isolated areas of surface subsidence are also evident. Surface water includes a stream flowing from south to north along the eastern boundary of the site. A swale located along the northern and western boundaries of the site receives run off from the north and west as well as from a culvert passing

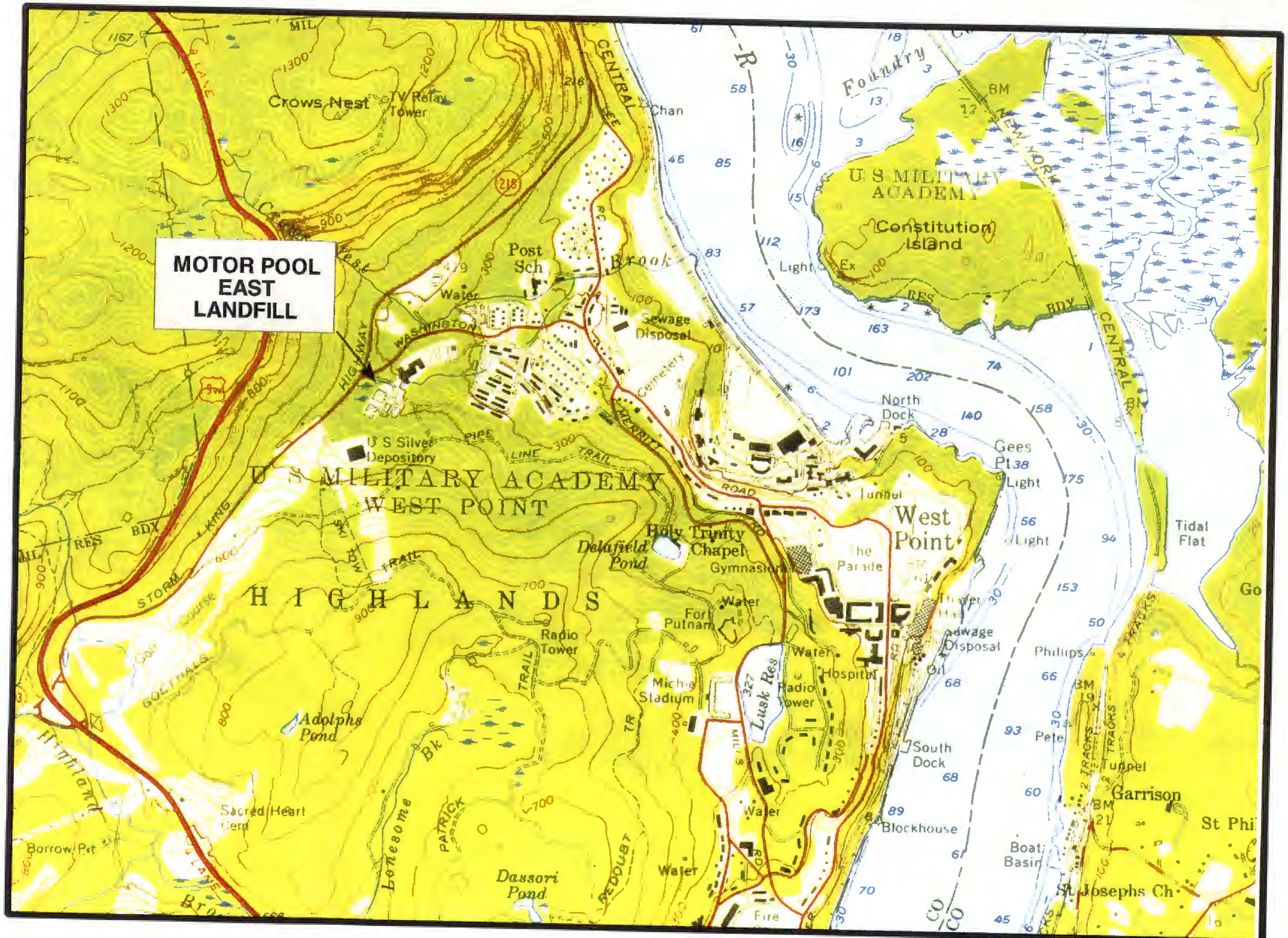
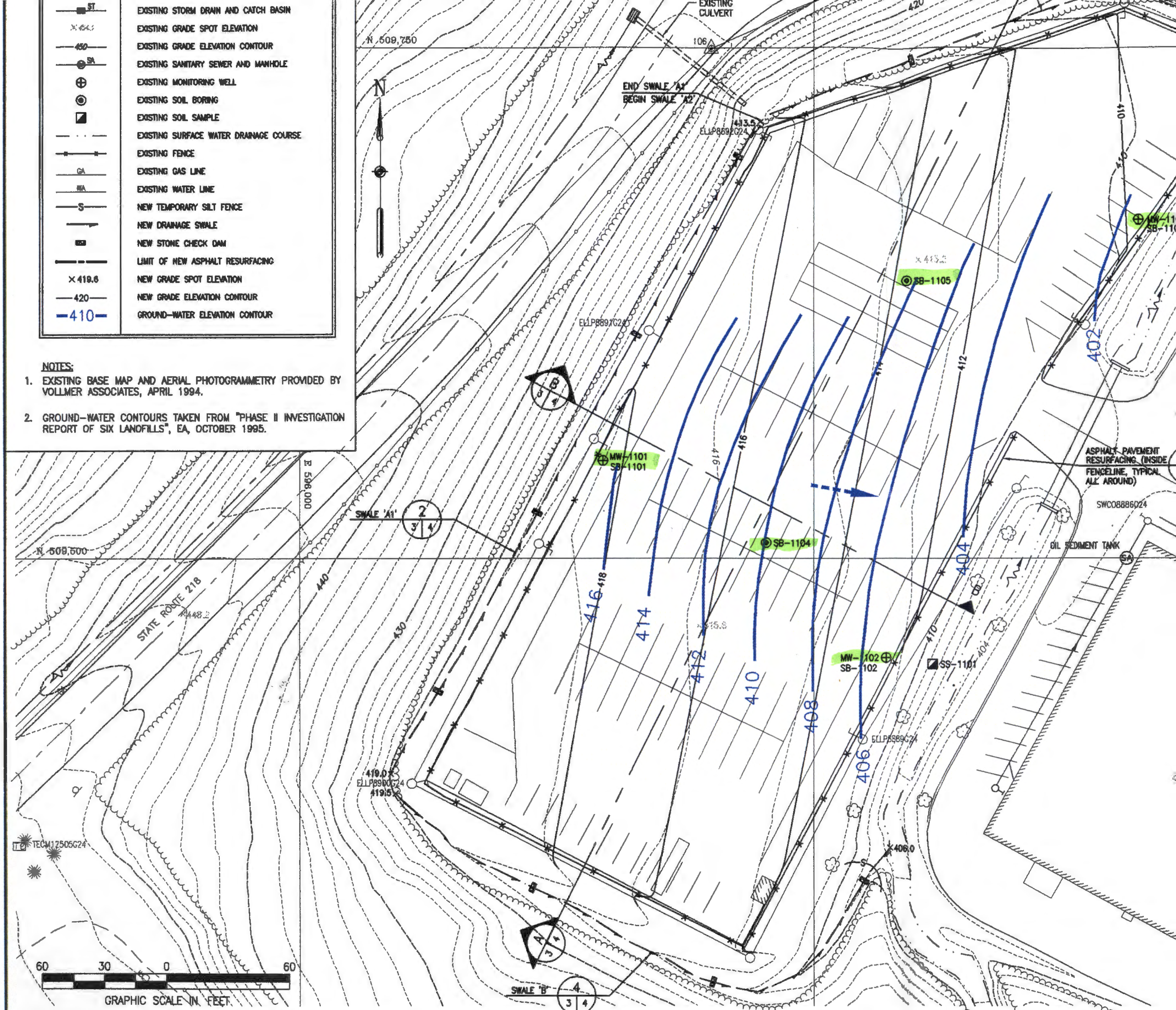


Figure 1-1. Vicinity Map, United States Military Academy, West Point, New York.

ST	EXISTING STORM DRAIN AND CATCH BASIN
× 454.3	EXISTING GRADE SPOT ELEVATION
450	EXISTING GRADE ELEVATION CONTOUR
SA	EXISTING SANITARY SEWER AND MANHOLE
⊕	EXISTING MONITORING WELL
◎	EXISTING SOIL BORING
◪	EXISTING SOIL SAMPLE
	EXISTING SURFACE WATER DRAINAGE COURSE
	EXISTING FENCE
GA	EXISTING GAS LINE
WA	EXISTING WATER LINE
S	NEW TEMPORARY SILT FENCE
	NEW DRAINAGE SWALE
	NEW STONE CHECK DAM
	LIMIT OF NEW ASPHALT RESURFACING
× 419.6	NEW GRADE SPOT ELEVATION
420	NEW GRADE ELEVATION CONTOUR
410	GROUND-WATER ELEVATION CONTOUR

NOTES:

1. EXISTING BASE MAP AND AERIAL PHOTOGRAMMETRY PROVIDED BY VOLLMER ASSOCIATES, APRIL 1994.
2. GROUND-WATER CONTOURS TAKEN FROM "PHASE II INVESTIGATION REPORT OF SIX LANDFILLS", EA, OCTOBER 1995.



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under Route 218. A swale located along the southern boundary of the site receives runoff from the south. Both swales have localized areas where water ponds until it infiltrates into the ground or evaporates.

1.3.1 Ground-Water Characterization

Water quality in the vicinity of the Motor Pool East Landfill was examined during an expanded RCRA Facility Assessment (EA 1996) to determine if landfill waste was contributing to degradation of the surface water or ground water adjacent to the landfill. Figure 1-2 provides relative locations of ground water, and soil boring sampling points used during the RCRA Facility Assessment.

Four ground-water samples were collected from the three monitoring wells (three well samples plus one duplicate) and were analyzed for TCL VOC, TCL SVOC, TCL pesticides/PCB, chlorinated herbicides, TAL metals plus cyanide, and 15 water quality parameters. Samples were collected on 5 and 8 June 1995. There were no VOC, SVOC, pesticides/PCB, or chlorinated herbicides reported in the four samples.

The upgradient well (MW11-01) showed a larger number of inorganic analytes, and analytes at a greater concentration, than observed in the background spring. The 2 downgradient wells showed comparable or slightly lower concentrations of most metals relative to the upgradient location. Downgradient monitoring well MW11-03 showed the lowest overall metal concentrations compared to the other wells.

The analytical results were also compared to the NYSDEC Class GA standards and guidance values (NYSDEC 1993a). Chromium in well MW11-02 (60.8 μg/L) exceeded the Class GA standard (50 μg/L) for this parameter. However, this exceedance may be an artifact of the solids present in the sample, since the duplicate collected from this well (MW11-02 Dup) showed a chromium concentration (21.3 μg/L) that was lower and less than the class GA standard. Iron, manganese, and sodium exceeded their respective Class GA standards or guidance values in all four ground-water samples (three wells plus one duplicate), while zinc exceeded the Class GA standards in all wells except MW11-03. The iron and manganese Class GA standards are secondary standards based upon the aesthetic properties (e.g., taste and color) of these inorganics in potable water.

Comparison of the upgradient and downgradient water quality parameter results showed that higher concentrations were noted in the upgradient sample for 2 water quality parameters (pH and nitrate) relative to the downgradient samples. Higher concentrations were noted downgradient relative to the upgradient station for 11 water quality parameters (alkalinity, ammonia, color, chemical oxygen demand, biological oxygen demand, dissolved organic carbon, chloride, total suspended solids, hardness, sulfate, and total Kjeldahl nitrogen). None of the observed concentrations exceeded the NYSDEC Class GA standards or guidance values, except for chloride in the original and duplicate samples collected from well MW11-02.

1.3.2 Surface Water Characterization

Four surface water samples were collected from the stream adjacent to the landfill (three samples plus one duplicate) and were analyzed for TCL VOC, TCL SVOC, TCL pesticides/PCB, chlorinated herbicides, TAL metals plus cyanide, and 15 water quality parameters. Samples were collected on 6 June 1995 (EA 1996). There were no VOC or SVOC reported in the four samples.

There were no detectable pesticides/PCB or herbicides in Sample SW11-01. Dieldrin was reported above the NYSDEC Class A standard for 2 samples as well as the sample duplicates (SW11-02, SW11-02 Dup, and SW11-03). Although the reported concentrations were above the Class GA standard for this compound, the results are suspect since in all cases the results were flagged with a "P" by the laboratory indicating poor duplication between the two analytical columns used for sample analysis.

Comparison of the upstream and downstream results showed that higher concentrations were noted in the upstream sample for 11 TAL metals (aluminum, barium, calcium, chromium, iron, lead, magnesium, manganese, potassium, sodium, and vanadium) relative to the downstream samples. Higher concentrations were noted downstream relative to the upstream station for three TAL metals (antimony, copper, and zinc). The upstream sample was collected just upstream of the small rust-colored seep emanating from the perimeter of the landfill. The surface water quality at this location may be influenced by this seep, but also from a seep from the adjacent Ski Lot Landfill, which discharges to a feeder tributary to this stream.

The analytical results were also compared to the NYSDEC Class A standards for human and wildlife protection. The upstream results (SW11-01) for two inorganics (iron and manganese) were above the NYSDEC Class A standard for human protection. The downstream results were less than the NYSDEC Class A standard for human protection.

The upstream results (SW11-01) for five inorganics (aluminum, iron, lead, manganese, and zinc) were above the NYSDEC Class A standards for wildlife protection. The most downstream sampling location (SW11-03) exceeded the NYSDEC Class A standards for wildlife protection for two inorganics (iron and zinc). The mid-point downstream station (and its duplicate) showed all inorganic concentrations less than the NYSDEC Class A standards for wildlife protection.

The three surface water samples (plus one duplicate) were analyzed for the 15 water quality parameters. Comparison of the upstream and downstream results showed that higher concentrations were noted in the upstream sample for eight water quality parameters (alkalinity, chloride, pH, chemical oxygen demand, dissolved organic carbon, total suspended solids, hardness, and sulfate) relative to the downstream sample. Higher concentrations were noted downstream relative to the upstream station for three water quality parameters (ammonia, color, and nitrate). None of the observed concentrations exceeded the NYSDEC Class A surface water standards for either human consumption or wildlife protection.

1.3.3 Stream Sediment Characterization

Stream sediment samples were collected at three locations from the stream adjacent to the Motor Pool East Landfill, and were analyzed for TCL SVOC, TCL pesticides/PCB, chlorinated herbicides, TAL metals plus cyanide, and total organic carbon.

The upstream sample (SD11-01) was free of detectable SVOC. One phthalate compound (bis[2-ethylhexyl]phthalate) and 15 polycyclic aromatic hydrocarbons (PAH) were identified in one or more of the downstream samples. The duplicate collected from location SD11-02 showed the highest overall PAH concentration. PAH are commonly found in road surface runoff. The proximity of the stream to the Motor Pool East access road and parking lot suggests that this was the likely source of PAH contamination in the sediments.

The observed SVOC concentrations to the four guidance criteria (Human Health Bioaccumulation, Benthic Aquatic Life Acute Toxicity, Benthic Aquatic Life Chronic Toxicity, and Wildlife Bioaccumulation) listed in the NYSDEC Technical Guidance for Screening Contaminated Sediments (NYSDEC 1993b). These values were calculated using the average observed total organic carbon concentration (26,425 mg/Kg) observed in the sediment samples, and the organic carbon normalized concentrations presented in NYSDEC (1993b). Reported concentrations of benzo[a]anthracene in sample SD11-02 and three analytes (benzo[a]pyrene, benzo[k]fluoranthene, and benzo[a]anthracene) in duplicate sample SD11-02 Dup exceeded guidance criteria for Human Health Bioaccumulation. Phenanthrene concentration in duplicate sample SD11-02 Dup exceeded guidance criteria for Benthic Aquatic Life Chronic Toxicity.

The three stream sediment samples (plus one duplicate sample), and one rinsate blank were analyzed for the 28 TCL pesticides/PCB and chlorinated herbicides. Comparison of the upstream and downstream results showed that higher concentrations were noted in the upstream sample (SD11-01) for three analytes (4,4'-DDD, 4,4'- DDE, and *gamma*-chlordane) relative to the downstream samples. Higher concentrations were noted downstream relative to the upstream station for eight analytes (aldrin, Aroclor-1254, Aroclor-1260, dieldrin, endosulfan I, endosulfan sulfate, heptachlor epoxide, and methoxychlor).

Comparison of the results to the sediment criteria (NYSDEC 1993b) showed that all of the observed concentrations were below those concentrations which may induce acute or chronic toxic effects in benthic organisms. All of the pesticide results were also below the concentrations which may result in significant bioaccumulation of the chemicals by wildlife. Aroclor-1254 in the duplicate sample (SD11-02 Dup) and Aroclor-1260 in three samples (SD11-01, SD11-02, and SD11-02 Dup) were above the concentration which may result in bioaccumulation by wildlife.

With the exception of aldrin and dieldrin, the observed pesticide and PCB concentrations were above the concentrations which may result in significant bioaccumulation of the chemicals by humans, if the biota are used as a food source.

Three stream sediment samples, one duplicate sample, and one rinsate blank were analyzed for the 25 TAL metals plus cyanide. Comparison of the upstream and downstream results showed that higher concentrations were noted in the upstream sample for cyanide and 15 TAL metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, lead, manganese, nickel, potassium, selenium, vanadium, and zinc) relative to the downstream samples. Higher concentrations were noted downstream relative to the upstream station for six TAL metals (cobalt, copper, iron, magnesium, silver, and sodium). Downstream concentrations for chromium were less than the upstream station except for Sample SD11-03 which had the same concentration.

The observed concentrations were generally consistent with anticipated background concentrations for the 10 analytes that background data were available. None of the observed chromium or zinc concentrations were greater than the NYSDEC lower effect limits or severe effect limits (NYSDEC 1993a). The upstream sample result for antimony exceeded the lower effect limit but was less than the severe effect limit. The cadmium, iron, and manganese concentrations in all four sample results (three samples plus the duplicate) were greater than the lower effect limit, and the cadmium and iron results were all less than the severe effect limits. The upstream sample also exceeded the severe effect limit. The copper and nickel results were above the lower effect limit in the three samples (but not the duplicate), and were all less than the severe effect limit. The lead concentration in the upstream sample was above the severe effect limit with the proximal downstream station (SD11-02 and SD11-02 Dup) exceeding the lower effect limit.

1.3.4 Leachate Seep Characterization

A single leachate sample was collected from the seep located approximately 15 ft south of monitoring well MW11-02, along the edge of the stream. The leachate seep sample was analyzed for the 33 TCL VOC, 64 TCL SVOC, 28 TCL pesticides/PCB, and two chlorinated herbicides. None of these compounds were detected in the sample.

The leachate seep sample was also analyzed for the 23 TAL metals plus cyanide. A total of 15 metals were detected in these samples. Comparison of the results to the NYSDEC Class GA standards showed that only iron and sodium were present above this standard. The observed iron concentration was also above the Class A standard for human consumption and wildlife protection.

The leachate seep analysis also included 15 water quality parameters. A total of 11 water quality parameters were detected. None of the reported results exceeded the NYSDEC Class GA standards, Class A standards for human consumption, or Class A standards for wildlife protection.

1.3.5 Geology

The regional geology in the vicinity of the USMA consists of a crystalline base overlain by glacial deposits. Most of the site bedrock is comprised of Pre-Cambrian granite with some gneiss. Within the bedrock, quartz, feldspar, and mica occur in a medium-grained configuration. The Pleistocene glacial deposits are composed of a mixture of clay, sand, and gravel with boulders prevalent. In some areas, the glacial deposits are more fine-grained and act to confine ground-water movement (USAEHA 1990). Fracture systems recorded within the West Point topographic quadrangle indicate that the rock strata contain joint systems, generally dipping 60 degrees to vertical (Isachsen and McKendree 1977; USGS 1967a). This joint orientation may have environmental relevance, as it could provide potential pathways for ground-water flow.

The dominant soil type at the USMA is Hollis-Rock outcrop (USDA 1981). The Hollis series consists of shallow, well drained gently sloping to very steep soil overlying schist, granite, and gneiss bedrock in mountainous uplands. The soil units mapped in the area, described as glacial till deposits, are composed of a heterogeneous mixture of very large boulders, cobbles, gravel, silt, sand, and clay. The maximum depth of frost penetration in these types of soil is approximately 60 in. (Sowers and Sowers 1970). Particle size segregation is typically confined to glacial features or modern stream development. Very large boulders, up to 10 ft in diameter, are common in the area.

Specific to the Motor Pool East Landfill and parking area, waste fill material was encountered just below ground surface in six soil borings. Waste was identified as predominantly wood chips, weeds, and other organic material. The vertical extent of the waste material was undetermined in the borings since the borehole depths were not extended into native soil, and also due to auger refusal. Boulders were encountered at depths ranging from 4 ft to 32 ft. The cap material placed atop the fill material as final cover consists of fine-coarse sand, silty clay, and gravel and boulder mixtures. All of the soil boring locations were overlain with macadam.

1.3.6 Hydrogeology

The hydrogeology of the Motor Pool East investigative area consists of an unconfined overburden zone. Ground-water elevations recorded in the 3 site overburden monitoring wells suggest that the overburden thickness may be relatively consistent and that existing ground-water elevations are a consequence of the localized topographic setting. The dominant direction of overburden ground-water flow beneath the site is generally to the southeast. Figure 1-2 provides the interpreted direction of ground-water flow in overburden soil around the Motor Pool East parking area.

1.3.6.1 Hydrogeologic Linkage of Ski Lot and Motor Pool East Landfills

The analytical results from the overburden monitoring wells at the Motor Pool East Landfill suggest that the upgradient well exhibits higher relative concentrations of metals when compared to the downgradient wells. This landfill is adjacent to the Ski Lot Landfill which exhibited elevated downgradient concentrations of metals (EA 1996). In addition, there is a seep located between the Ski Lot Landfill and Motor Pool East Landfill which drains to the swale between the two landfills.

The comparison of the ground-water elevations of the overburden wells from the Motor Pool East Landfill (EA 1996) and the adjacent Ski Lot Landfill (EA 1995) showed that the unconfined overburden zone within the Motor Pool East Landfill was linked to the Ski Lot Landfill unconfined overburden aquifer. The intermittent seeps located between the two landfills and from the Motor Pool East Landfill are in areas where the interpreted ground-water surface can intercept the ground surface. Seasonal fluctuations in the ground-water elevation result in the seeps discharging to the surface. The hydrogeologic interpretation, combined with the analytical results and absence of any metallic debris based on the geophysical survey, suggests that the metals present in the ground water at the Motor Pool East Landfill are not attributable to waste fill mass, but rather ground water that is migrating from the Ski Lot Landfill.

2. PREVIOUS INVESTIGATIONS/ PRE-DESIGN ACTIVITIES

This section summarizes previous investigations conducted at the Motor Pool East Landfill as well as supplemental pre-design work performed under this delivery order. Previous investigation and pre-design activities at the Motor Pool East Landfill have included an aerial survey, magnetometer survey, and installation of a soil boring/monitoring well network. Previous USMA investigations contain supplemental pre-design information. Applicable portions of previous investigations have been incorporated into this section as cited, and into the overall concept design as applicable.

2.1 PREVIOUS U.S. MILITARY ACADEMY INVESTIGATIONS

The following previous investigations were reviewed and cited for their applicability to the RCRA Facility Assessment. As cited in this document, these investigations provide supplemental information on soil lithology, water quality, hydrogeology, and other related RCRA Facility Assessment objectives. Several of the previous investigations were performed on property adjacent to the four RCRA Facility Assessment areas of concern, including the Motor Pool East Landfill.

- EA Engineering, Science, and Technology. September 1996. *Expanded RCRA Facility Assessment of Four Landfills, U.S. Military Academy, West Point New York.*

- Woodward-Clyde Federal Services. November 1994. *West Point RCRA Facility Assessment Investigation at 10 Landfills, Final Progress Report.*

- Paulus, Sokolowski, and Sartor (PSS). 1985. *Analysis of Existing Facilities, Draft Environmental Assessment Report.* United States Military Academy, West Point, New York. Warren, New Jersey. February.

- Metcalf and Eddy. 1992. *One Stop Shopping Area Feasibility Study Pilot Geotechnical Report.* September.

- LAW Environmental Inc. 1994. *Subsurface Investigation Report for Subsurface Investigation, USMA, West Point, New York.*

- Bionetics Corporation. 1984. *Installation Assessment, U.S. Military Academy, West Point, New York.* Report No. TS-PIC-84001. April. 15 pp.

2.1.1 RCRA Facility Assessment

The principle source for recent Motor Pool East site investigation data is the *Expanded RCRA Facility Assessment of Four Landfills, U.S. Military Academy, West Point New York* (EA 1996). This investigation was designed to gather and assess site-specific data relative to:

- Presence of buried ferrous material at the Motor Pool East Landfill.
- Characterization of the lithology of surface and subsurface soil.
- Examination of ground-water and surface-water quality at the Motor Pool East and adjacent landfills where ground water may be impacted.
- Characterization of stream sediment samples.
- Analysis of aqueous sample collected from apparent seep at Motor Pool East Landfill.

2.2 AERIAL SURVEY

In order to provide an up-to-date topographic map USMA commissioned a basewide 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 of the Motor Pool East landfill and adjacent properties 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 MAGNETOMETER SURVEY

An orange-colored seep is located on the southeastern side of the Motor Pool East Landfill. Historical records indicate that buried ferrous materials are the probable source of the discolored seep located on the southeastern side of the Motor Pool East Landfill. A magnetometer survey was used as a non-invasive technique to define the approximate locations of the buried ferrous materials.

2.4 GEOTECHNICAL DATA

Geotechnical data cited in this section is summarized from previous investigation by LAW (1994) and EA (1996). No additional pre-design geotechnical data was collected under this delivery order.

2.4.1 Ground Conductivity Survey

During the RCRA Facility Assessment (EA 1995), EA directed a limited geophysical investigation to estimate the lateral extent of the fill mass at the Motor Pool East Landfill. The investigation which included EM-31 ground conductivity and in-phase data acquisition was conducted on 23 and 24 May 1995 by Quantum Geophysics, Inc., Phoenixville, Pennsylvania.

A 20-ft survey grid interval was established across the Motor Pool East Landfill using a Warren McKnight Model 1B transit, fiberglass survey tapes, and existing fence poles for points of origin. 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.

2.4.1.1 Ground Conductivity and In-Phase Results

Appendix A, Figure A-2 presents the ground conductivity (EM-31) contour map for Motor Pool East Landfill. Figure A-3 presents the in-phase contour map for the landfill. The ground conductivity data suggest that two probable landfill cells exist at the Motor Pool East Landfill: one cell has dimensions of approximately 55 ft × 90 ft; the limit and approximate dimensions of the other cell could not be established due to the presence of nearby immovable vehicles. However, due to the absence of corresponding elevated in-phase measurements, it is likely that both landfill cells contain mostly non-metallic, electrically conductive material.

2.4.2 Soil Boring/Monitoring Well Network

As reported by EA (1995), 6 soil borings were completed at the Motor pool East, 3 of which were completed as monitoring wells. Relative locations of the monitoring wells are provided in Figure 1-3. Results of the soil boring work indicate that the Motor Pool East landfill overburden at all 3 monitoring well locations consists 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 monitoring wells MW11-01 and MW11-03, and were evident on the site surface. The overburden composition is generally a fine to medium silty sand with gravel and/or trace clay. The vertical extent of the overburden material is undetermined, since the borehole depths were not extended into native soil. Four soil borings advanced to 19-22 ft below ground surface exhibited saturated fill at the completion depth. The Motor Pool East parking area is entirely overlain with a pavement layer consisting of an estimated 2-in. thickness of asphalt underlain by a stone subbase layer estimated at 12-in. thickness (as exhibited in soil boring SB-11-04A). The subbase layer is underlain by a fine-coarse sand, silty clay, and gravel and boulder mixture. Logs of borings are provided in Appendix B for six soil borings installed during the subsurface investigation.

3. SITE DRAINAGE

3.1 SCOPE AND PURPOSE

Site drainage is an important aspect of leachate minimization at the Motor Pool East 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-on and 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 East Landfill does not allow for complete drainage of stormwater due to inconsistent grades, localized subsidence, and cracking of the existing pavement. The lot contains localized low spots which permit water ponding after storm events. The existing swales along the southern, western, and northern perimeters of the site do not have consistent slopes, and therefore do not adequately drain to the surrounding stream.

In order to alleviate these problems, the site will be graded to promote surface water drainage from the cap surface and into the drainage swales and surrounding stream. Recognizing that USMA anticipates continued use of the Motor Pool East Landfill as a parking area, the present grades will be generally maintained; however, they will be made more consistent over the area of the lot. The lot will therefore be graded at a minimum 3 percent slope to promote drainage off the cap. The grades are shown on the Final Grading Plan.

3.3 STORMWATER MANAGEMENT

Presently, stormwater from the Motor Pool East pavement drains to the stream east of the site. Stormwater from the north, south, and west of the site is collected by swales to prevent run-on to the parking lots. The swales discharge to the stream east of the site.

The total area of Motor Pool East surface is approximately 1.7 acres. The pavement is graded to drain to the stream east of the site. Currently, erosion rills exist on the stream bank where the water flows off of the pavement down into the stream. An asphalt curb will be constructed along the eastern side of the parking lot to collect runoff and direct it into gabion downchutes down into the stream. This will alleviate the erosion problem along the stream bank.

Swales collecting run-off from the drainage areas north, south, and west of Motor Pool East will be improved. Based on the surrounding topography, a limited amount of rock excavation may be necessary during the excavation and improvement of the existing drainage swales. Swale "A1" will receive flow from west and north of the site. Swale "A2" will receive flow from swale "A1," from west of the site, and from the culvert under Route 218. Swale "B" will receive flow from south of the site. The swales will carry surface run-off water to the stream east of the site.

The new drainage 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 C along with a figure of the designated drainage areas.

3.4 SEDIMENT CONTROL

Temporary sediment control will be provided during construction, consisting of silt fence located at the swale outlets, and stone check dams in the swales. The silt fence will reduce sediment carried in the runoff, protecting water quality in the stream. The stone check dams will reduce the velocity of flow in the swales, minimizing erosion potential and reducing sediment in the runoff.

4. LANDFILL CAP

4.1 SCOPE AND PURPOSE

The Motor Pool East Landfill cap has been 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 existing flexible pavement landfill cap includes approximately 10 in. of aggregate sub-base and 2-in. of bituminous surface course, based on information provided in the 1995 Boring Logs (Appendix B.) The existing asphalt is cracked and has subsided locally in various locations. Two varying pavement sections will be provided based on the current conditions and expected future uses of the lot. In both cases, the lot will be resurfaced to seal out rain water. Details of the flexible pavement sections are discussed below and illustrated on the Details and Cross-Sections Sheet.

4.2 PAVEMENT DESIGN

The existing asphalt surface is cracked across the entire lot and has subsided in some areas. The condition of the existing pavement surface of the lot was evaluated and was determined to exhibit obvious cracking within the common driving lanes as well as around the perimeter of the lot. Additionally, the pavement along the north and west side of the lot is expected to be fairly wet due to the ponding of stormwater. This may be compromising the integrity of the existing pavement system.

For design purposes, the existing Motor Pool East Landfill has been segmented into two distinct areas based on these existing surface conditions. Only the areas exhibiting obvious cracking, as designated on the Existing Conditions Plan, will receive a complete flexible pavement section, as shown on the Final Conditions Plan. The central area of the lot, however, shows few signs of settlement relative to the other areas of the lot. The existing pavement in this area has small "alligator" cracks due to pavement fatigue and thus needs to be repaired. The central region of the lot will be remedied by covering the entire surface first with a new tack coat and a woven geotextile to supply reinforcement. Next, the area will be finished with an overtopping pavement consisting of a 1.5-in. layer of new bituminous final course.

Due to the extent of the cracking, the suspected wet subbase, and the localized subsidence in the surrounding areas of the lot, the existing pavement and underlying subbase in these areas will be demolished and removed. Upon arriving at the final excavation grades shown on the Details and Cross-Sections Sheet, the subgrade shall be scarified to a minimum depth of 4-in. The existing subgrade will also be proof-rolled to locate soft spots. 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 complete flexible pavement section that this area will receive consists of: 11-in. of aggregate base course, a prime coat, 2-in. of bituminous intermediate course, a tack coat, and 1.5-in. of bituminous final course, as shown on the Details and Cross-Sections Sheet. The two differing pavement sections will be joined together at the same grade by transitioning the adjoining areas together as shown on the Detail Sheet.

This total approach addresses three factors of the pavement strength and permeability:

- The existing subbase can be dried in areas where it is wet due to the infiltration of the ponded stormwater in the north and west regions of the lot.
- The subbase can be recompacted to provide a better foundation for the asphalt.
- The subbase can be regraded to smooth out areas where localized subsidence has occurred and to promote drainage off of the finished pavement.

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 East 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 sandy-gravelly soil with a significant amount of fines. 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 lot are located in Appendix D.

4.3 GAS MANAGEMENT

A soil vapor survey was not performed at the Motor Pool East Landfill as part of the pre-design investigations or the previously performed Six Landfills Investigation. Based on discussions with the site manager, Russ Goodrich, there has not been an odor problem or noticeable vapors emanating from the Motor Pool East Landfill. No evidence of stressed vegetation or surface cracking of the grassed areas surrounding the Motor Pool East Landfill was observed, indicating that landfill gas generation is not significant at the site. Paving of the lot is expected to reduce stormwater infiltration into the fill mass and further reduce what limited gas generation is occurring. For this reason, vents will not be placed in the parking area.

Although no evidence of gas generation has been observed at the site, some gas generation may be expected because of the nature of the fill (refer to Chapter 1). The asphalt surface is graded so the high point of the pavement is at the pavement's edge. Therefore, small amounts of gas that may be generated will pass through the aggregate subbase and will be vented to the atmosphere along the western edge of the pavement. This will reduce the chance of the pavement cracking due to gas pressure building up beneath it.

5. SCHEDULE

The anticipated construction schedule for accomplishing the work is shown in Figure 5-1. Major scheduling milestone activities are discussed in the following sections.

5.1 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 along the eastern perimeter of the Motor Pool East Lot and temporary check dams will be placed in the new surface drainage swales.

5.2 SWALE AND DRAINAGE IMPROVEMENTS

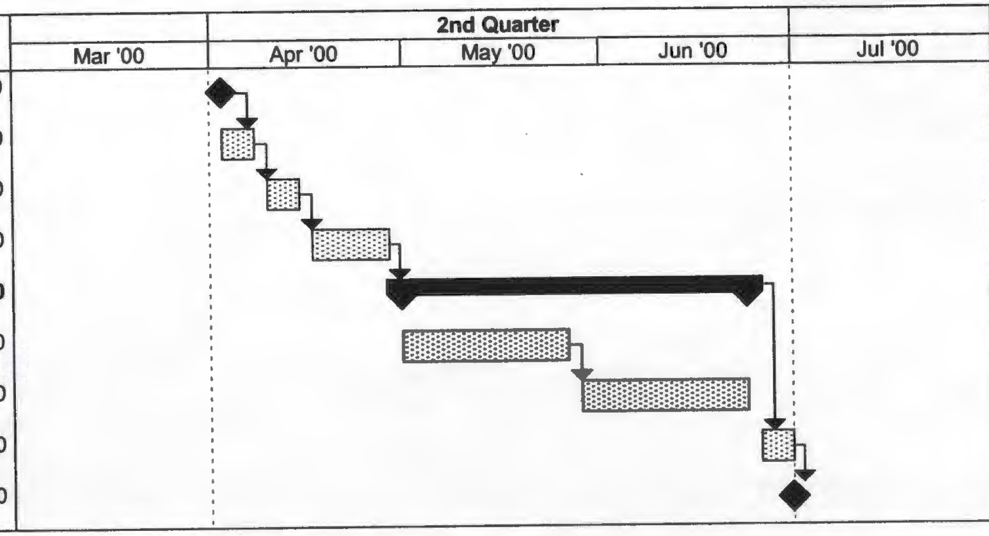
The existing perimeter swales will be improved to increase their capacity and reduce ponding around the Motor Pool East.

5.3 ASPHALT CAP

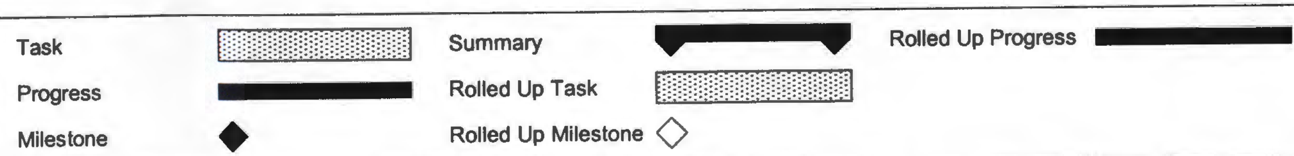
The construction of the new asphalt cap will consist of two phases to permit continuing operation of the Motor Pool East. The two phases are illustrated on the Construction Phasing Plan, where a detailed description of them is included.

Anticipated Construction Schedule

ID	Task Name	Duration	Start	Finish
1	Notice to Proceed	0d	4/3/00	4/3/00
2	Mobilization	1w	4/3/00	4/7/00
3	Install Erosion and Sediment Contro	1w	4/10/00	4/14/00
4	Swale and Drainage Improvements	2w	4/17/00	4/28/00
5	**Asphalt Cap**	**40d**	**5/1/00**	**6/23/00**
6	Phase 1	4w	5/1/00	5/26/00
7	Phase 2	4w	5/29/00	6/23/00
8	Demobilization	1w	6/26/00	6/30/00
9	Substantial Completion	0d	6/30/00	6/30/00



Project: Proposed Schedule for Motor Pool East Landfill - West Point
Date: 6/14/99



F:\6078777\reports\desanal\schedule.mpp

Figure 5-1

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Appendix A

Geophysical Investigation

QUANTUMGEOPHYSICS, INC.

Engineering, Groundwater & Environmental Geophysics

June 1, 1995

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

**RE: REPORT
EM31 SURVEY
UNITED STATES MILITARY ACADEMY
WEST POINT, NEW YORK**

Dear Mr. Samuelian,

This report presents the findings of Quantum Geophysics, Inc.'s EM31 survey at the United States Military Academy, West Point, New York. The survey was conducted to identify anomalous subsurface conditions at 3 suspected landfills: WSTPT-12 (Building 917), WSTPT-11A (Motor Pool), and WSTPT-48 (Building 706).

The survey was carried-out on May 23 and 24, 1995 by Quantum's principal geophysicist Richard K. Lee. A partially constructed 10 x 20-foot survey grid by EA Engineering, Science, and Technology was used to guide the EM31 survey.

The remainder of this report briefly describes our technical approach and then details the geophysical findings with respect to anomalous subsurface conditions at the 3 suspected landfills. Included in this report, under separate cover, is a 3.5 inch high density diskette with .DWG files of fully annotated contour maps of the geophysical data and findings.

TECHNICAL APPROACH

A. EM31

The electromagnetic survey incorporated a Geonics Limited EM31 ground conductivity meter coupled to an OmniData Polycorder 720 digital programmable data logger and supported by Geonics' data acquisition and processing program ***DAT31*** and a Dell 386 laptop computer.

19 East Central Avenue Paoli, PA 19301 Telephone (610) 651-0229 Fax (610) 651-0256

The EM31 is a battery-operated instrument that works on the principal of induction. It is constructed of 2 circular coils, a transmitter and receiver, mounted in the ends of a 13-foot-long PVC boom and interfaced with a measurement console. The transmitter coil is energized with an alternating current which induces a "primary magnetic field". This field causes very small electric currents to flow through the earth and they in turn induce a "secondary magnetic field". Both the primary and secondary fields are sensed by the receiver coil.

The intensity of the secondary field is a function of intercoil spacing, operating frequency, and soil conductivity. The EM31 is designed so that these factors are incorporated into it and the secondary field is a simple function of soil conductivity.

The EM31 measures 2 components of the induced field: 1) quadrature phase, and 2) in-phase. The quadrature phase is related to ground conductivity. It is measured in millimhos/meter (mmhos/m) and is equivalent to millisiemens/meter. The in-phase component is more sensitive to metal (compared to the quadrature phase) and is measured in parts per thousand (ppt).

In most cases, the ratio of the secondary and primary fields is linearly proportional to ground conductivity. In the presence of massive conductors such as drums, fences, and buildings, the induction principal "breaks-down" and the ratio of the 2 fields is no longer proportional to ground conductivity. **Under such circumstances, rapidly changing readings as well as negative values can be expected. Such readings indicate the presence of metal and are not related to ground conductivity.**

The EM31 is sensitive to both ferrous and non-ferrous metal.

The EM31 was taken to a metal-free environment, assembled, interfaced with the data logger, the battery condition checked, and the sensitivity and phasing adjusted following procedures outlined in the operating manual. Both the quadrature phase and in-phase data were collected with the instrument in the vertical dipole orientation for a depth of exploration of roughly 18 feet below the ground surface.

The EM data were downloaded onto the laptop computer for storage at the end of each field day. In the office, the EM data were entered into ***SURFER for Windows***, gridded using the Kriging Method, contoured at appropriate contour intervals, written to .DXF files, imported into ***GenericCADD***, annotated, printed by a Panasonic KX-P4420 laser printer and saved as .DWG files.

FINDINGS

A. WSTPT-12 (BUILDING 917)

Contour maps of the ground conductivity and in-phase data collected at WSTPT-12 are paneled and shown in Figure 1. The data indicate:

- A 30 x 50-foot lobate-shaped ground conductivity anomaly (55 to 75+ mmhos/m) identified as a possible landfill cell or septic leach field. It is centered roughly 45 feet from Building 917. A linear trend in the conductivity data suggests that there is an underground pipe that most likely extends from Building 917 into the landfill cell or leach field. The pipe's appearance in the conductivity data and its' absence in the in-phase data indicate that it is a non-metallic pipe that contains water or other electrically conductive material.

- The in-phase data indicate at least 2 underground pipes leading into/out-of several ground valves located roughly 25 feet from Building 917, near the southeast corner of the building. They appear to be constructed of metal. A site location map provided by EA Engineering, Science, and Technology (Figure 1-5) shows a UST at where the valve covers are located. The absence of a large, geometric-shaped anomaly at this location suggests that the UST, if present, is probably located immediately adjacent to or inside the building.

B. WSTPT-11A (MOTOR POOL)

Contour maps of the ground conductivity and in-phase data collected at WSTPT-11A are shown in Figures 2 and 3, respectively. The data show:

- Two (2) probable landfill cells, based upon the ground conductivity data. One is lobate-shaped, measures roughly 55 x 90 feet, is characterized by ground conductivities of about 30 to 50+ mmhos/m, and is centered at Line 260 station 100.

The other probable cell is irregular-shaped, is characterized by ground conductivities of 25 to 45+ mmhos/m, and is located between Lines 320 and 380. It's southern limit is uncertain because no data were collected in this location as a result of non-moveable vehicles.

The absence of corresponding elevated in-phase measurements suggest that the 2 landfill cells contain mostly non-metallic, electrically conductive material.

- Low ground conductivity values of 10 mmhos/m and less between Lines 40 and 120, stations 60 and 140, most likely indicate relatively shallow depth to bedrock.

C. WSTPT-48 (BUILDING 706)

WSTPT-48 consists of 2 parts, an area located west of Building 706 which we have designated WSTPT48A, and a smaller area adjacent to Building 706 designated WSTPT48B.

WSTPT48A

Contour maps of the ground conductivity and in-phase data collected at WSTPT48A are paneled and shown in Figure 4. The data indicate:

- Two (2) probable landfill cells. One is rectangular-shaped, measures roughly 30 x 50-feet, and is centered at Line 40 station 100. It comprises several anomalies which may be caused by metal debris. One anomaly, centered at Line 60 station 90, is characterized by ground conductivities as great as 121 mmhos/m and in-phase values as high as 49 ppt. It has a geometric shape which, along with the "dramatic" response in the data, suggest that the anomaly may be caused by a UST. It is located beneath and very close to the edge of the concrete slab.

  The interpretation of a UST is reasonable considering that the reinforced slab appears to have been constructed as a parking area as opposed to being the floor slab of a razed building. Building foundations are generally supported by reinforced footers which, in turn, cause regularly-spaced and, oft times, small "bulls' eye-shaped" targets in the data. Regularly-spaced, small bulls eye-shaped targets are not associated with the anomaly caused by the slab at WSTPT48A. The suspected UST probably fueled vehicles that were assigned or parked on the concrete slab.

The other landfill cell wraps around the southeast corner of the slab. It is characterized by ground conductivities of 30 to 80+ mmhos/m and in-phase values of 5 to 10+ ppts. Buried metal debris is suspected where in-phase values are elevated, specifically in the immediate area of Line 140 station 60.

WSTPT48B

Contour maps of the ground conductivity and in-phase data collected at WSTPT48B are also paneled and are shown in Figure 5. The data show:

- A lobate-shaped ground conductivity anomaly centered at Line 120 station 100. It is characterized by ground conductivities of 20 to 50+ mmhos/m and is probably the leach field indicated in EA Engineering, Science, and Technology Figure 1-6 (Site Location Map, WSTPT-48, Building 706, Parking Lot Landfill). It is located about 60 feet west of Building 706.

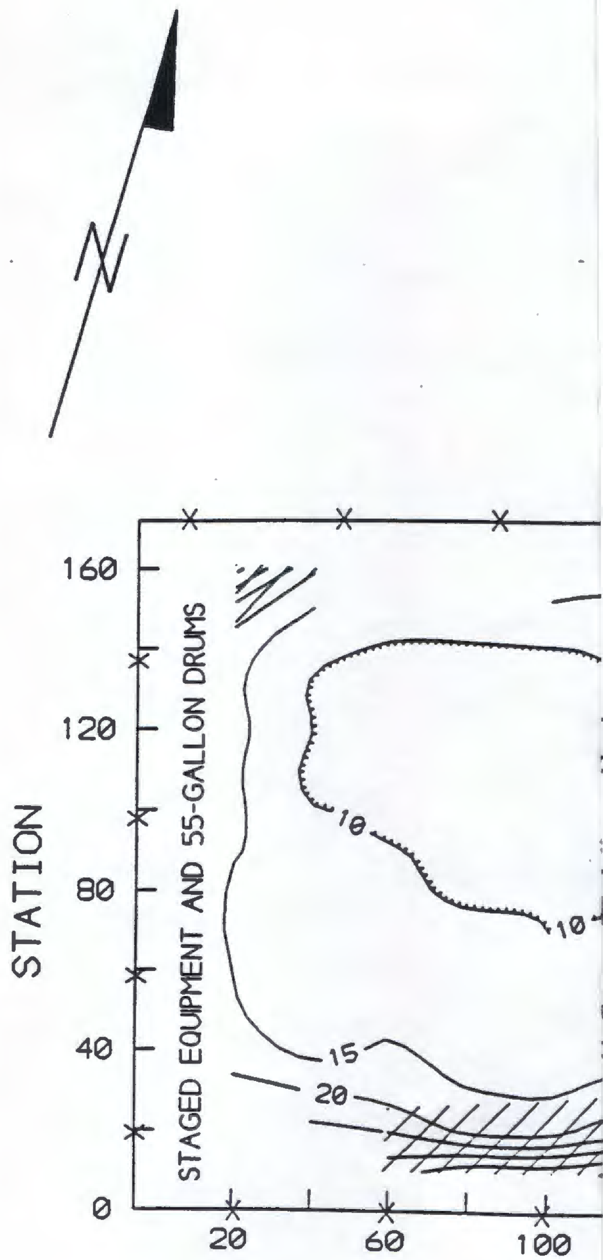
Quantum appreciates the opportunity to be of service to EA Engineering, Science, and Technology at the U.S. Military Academy, West Point, New York. Please call if you have any questions or if we can be of further assistance.

Sincerely,

Richard K. Lee

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

RKL/jas



ound Conductivity in Millimhos/Meter (mmhos/m).
ontour Interval - 5 mmhos/m.

obable Landfill Cell. Querried
here Unknown.

evated Readings Caused By Fence or
on-Moveable Vehicles and Equipment.

NOTE: Motor Pool continues roughly 30 to
where no data were collected beca
and vehicles.

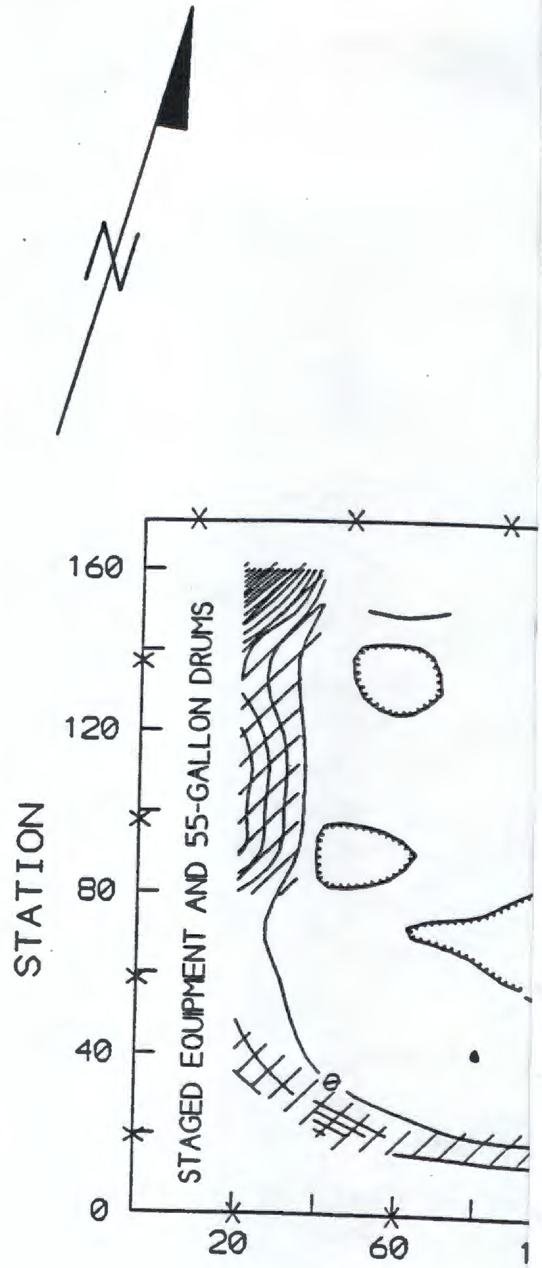
QUANTUM GEOPHYSICS. INC.

Engineering, Groundwater, and Environmental Geophysics
19 E. Central Ave., Paoli, PA 19301

UND CONDUCTIVITY CONTOUR MAP
TIIA (MOTOR POOL)
ED STATES MILITARY ACADEMY
T POINT. NEW YORK

ERING. SCIENCE AND TECHNOLOGY

95	Drawn: CAS	Approved: RKI	Figure A-2



In-Phase in Parts Per Thousand (ppt).
Contour Interval = 1 ppt.

Elevated Readings Caused By Fence or Non-Moveable Vehicles and Equipment.

NOTE: Motor Pool continues roughly where no data were collecte[d] and vehicles.

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-PHASE CONTOUR MAP
STPTIIA (MOTOR POOL)
NITED STATES MILITARY ACADEMY
EST POINT, NEW YORK

NEERING, SCIENCE AND TECHNOLOGY			Figure A-3
1995	Drawn: CAS	Approved: RKL	
5-1021	C:\CADD6\WPII.GCD		

Appendix B

Boring Logs (1995)

EA Engineering, Science, and Technology

LOG OF SOIL BORING

Coordinates:	N 509548.13: E 596147.80
Surface Elevation:	418.20
Casing Below Surface:	417.78
Reference Elevation:	Top of PVC casing
Reference Description:	Permanent marker

Job. No.	Client	Location
60787.50	U.S. Army Corps of Engineers	West Point 11A

Drilling Method: Diedrich D-50 drill rig 4 1/4 in. ID hollow stem auger

Boring No.: SB11-01

Sampling Method: 2 in. OD split barrel, 2 ft length 140-lb hammer falling 30 in.

Sheet 1 of 1

Water Lev.	0.71	0.80		
Time				
Date	04/27/95	06/05/95		
Reference	TOC	TOC		

Drilling	Start	Finish
Time	1050	1230
Date	18 April 1995	18 April 1995

Surface Conditions: North end of asphalt parking lot, upgradient to the landfill.

Sample Type	Inches Drvn/In. Recvrd.	Depth Casing	Samp. # /samp. depth	PID (ppm) HNu	Blows per 6 in.	Depth in Feet	USCS Log	Description
SS	24		1		8	0		Top 1 in. asphalt fragments
	12	0	2	0.6	12		FILL	Middle 2 in. brown fine sand; loose; dry
					14	1		Bottom 9 in. brown - grey clayey SAND with numerous rock fragments; medium dense; dry
					17			
SS	6		2		35	2		Brown - grey silty SAND; dense; moist
	4	0	2.4	0.0	50/0.1		FILL	Rock fragments (quartz) at bottom of spoon
						3		
						4		Hit something hard at 4 ft. No split barrel sample, augered through
						5		
SS	24		3		6	6		Brown silty SAND with fragments of fine gravel; loose; wet
	1	6	8	0.0	7			Water table at 6.5 ft
					11	7	FILL	
					10			
SS	24		4		3	8		Brown silty SAND with fragments of fine gravel; loose; wet
	16	8	10	0.0	4			
					6	9		
					6			
						10		
						11		
						12		
						13		
						14		
SS	24		5		10	15		Top 2 in. brown-grey fine SAND and silty CLAY; loose; saturated
	12	15	17	0.0	32		FILL	Middle 6 in. grey wheathered shale
					22	16		Bottom 4 in. brown-grey fine SAND and silty CLAY; medium dense; saturated
					20			
						17		End of boring 16 ft
						18		
						19		
						20		SS = Split barrel sampler

Logged by: Suzanne Chase — Date: 18 April 1995

Drilling Contractor: Parratt Wolff, Inc. — Driller: Ronald Bush

WELL SPECIFICATIONS:

Diam of casing:	2 in.	Screen Interval:	4.5 ft - 15 ft	Filter Pack:	4.0 ft - 16.0 ft	Grout:	0.0 ft - 3.0 ft
BOH:	16 ft	Riser Interval:	0.0 ft - 4.5 ft	Bentonite:	3.0 ft - 4.0 ft	Cover:	8 in. bolt down curb box

EA Engineering, Science, and Technology®

LOG OF SOIL BORING

Coordinates:	N 509451.36: E 596285.41
Surface Elevation:	412.67
Casing Below Surface:	412.17
Reference Elevation:	Top of PVC casing
Reference Description:	Permanent marker

Job. No.	Client	Location
60787.50	U.S. Army Corps of Engineers	West Point 11A
Drilling Method: Diedrich D-50 drill rig 4 1/4 in. ID hollow stem auger		Boring No. SB11-02
Sampling Method: 2 in. OD split barrel, 2 ft length 140-lb hammer falling 30 in.		Sheet 1 of 1

					Drilling Start	Drilling Finish
Water Lev.	8.85	6.73				
Time					1510	1600
Date	04/27/95	06/05/95			18 April 1995	18 April 1995
Reference	TOC	TOC				

Surface Conditions: South end of asphalt parking lot, adjacent to seep area, north of stream.

Sample Type	Inches Drvn/In. Recvrd.	Depth Casing	Samp. # /samp. depth	PID (ppm) HNu	Blows per 6 in.	Depth in Feet	USCS Log	Description
SS	24		1		13	0		Top 2 in. asphalt fragments
	12	0	2	0.0	10		FILL	Brown silty SAND with some gravel (up to 0.5 in. diameter); loose; moist
					9	1		
					5			
SS	24		2		11	2		Top 2 in. brown silty SAND; loose; moist - wet
	14	0	4	0.0	16			Grey fine-silty SAND with some gravel and little clay; dense; moist
					54	3		
					7			
SS	24		3		2	4	FILL	Grey fine silty SAND with fragments of wood, weeds, and gravel; very loose; moist
	22	4	6	0.0	2			Band of dark brown SAND with roots and wood at 5.5 ft
					3	5		
					4			
SS	23		4		3	6		Top 2 in. loose; wet
	6	4	7	0.0	6		FILL	Bottom 4 in. loose; moist
					54/0.3	7		Dark grey silty SAND with some clay; gravel at bottom 2 in.
SS	24		5		5	8		Brown silty CLAY with some gravel and rock fragments (quartz and muscuvite); loose; moist
	6	8	10	0.7	5			
					4	9		Water table at 9.0 ft
					8			
SS	24		6		6	10		Brown silty CLAY with gravel, muscuvite, and iron staining; loose; wet
	12	10	12	1.1	6		FILL	
					6	11		
					6			
SS	24		7		3	12		Top 6 in. brown silty CLAY with gravel; loose; wet
	21	10	14	1.3	5			Grey silty CLAY with iron staining and gravel; loose; wet
					8	13		
					16			
SS	24		8		3	14		Top 6 in. brown fine-medium SAND; very loose; wet
	14	14	16	0.0	4		FILL	Brown fine-silty CLAY with some gravel; loose; wet
					6	15		
					6			
SS	24		9		10	16		Top 20 in. brown fine-medium SAND with some gravel; loose; wet
	24	14	18	0.0	12			Band of brown fine-silty CLAY 17.0-17.2 ft
					14	17		Bottom 4 in. brown fine-silty CLAY; loose; wet
					8			
						18		
						19		End of boring 19 ft
						20		
								SS = Split barrel sampler

Logged by: Jeanette Scalzo Date: 18 April 1995

Drilling Contractor: Parratt Wolff, Inc. Driller: Ronald Bush

WELL SPECIFICATIONS:

Diam of casing:	2 in.	Screen Interval:	5.0 ft - 18 ft	Filter Pack:	4.0 ft - 19.0 ft	Grout:	0.0 - 3.0 ft
BOH:	19 ft	Riser Interval:	0.0 ft - 5.0 ft	Bentonite:	3.0 ft - 4.0 ft	Cover:	8 in. bolt down curb box

EA Engineering, Science, and Technology

LOG OF SOIL BORING

Job. No.	60787.50
Client	U.S. Army Corps of Engineers
Location	West Point 11A
Drilling Method:	Diedrich D-50 drill rig 4 1/4 in. ID hollow stem auger
Boring No.	SB11-03
Sampling Method:	2 in. OD split barrel, 2 ft length 140-lb hammer falling 30 in.
Sheet	1 of 2

[C]oordinates:	N 509666.07: E 596408.18	
[S]urface Elevation:	409.52	
Casing Below Surface:	409.12	
[R]eference Elevation:	Top of PVC casing	
[R]eference Description:	Permanent marker	

Water Lev.	7.38	7.35		
Time				
Date	04/28/95	06/08/95		
Reference	TOC	TOC		

Drilling	Start	Finish
Time	830	1110
Date	19 April 1995	19 April 1995

Surface Conditions: South end of asphalt parking lot, north of Bldg. 795

[S]ample Type	Inches Drvn/In. Recvrd.	Depth Casing	Samp. # /samp. depth	PID (ppm) HNu	Blows per 6 in.	Depth in Feet	USCS Log	Description
SS	24		1		7	0		Top 2 in. asphalt fragments
	16	0	2	0.0	5		FILL	Middle 10 in. brown silty SAND with some gravel; loose; moist
					6	1		Bottom 4 in. yellow brown fine-medium SAND with some gravel; loose; wet
					6			
SS	24		2		6	2		Top 1 in. gravel
	18	0	4	0.0	11			Middle 12 in. increasing brown SAND with some silt; medium dense; wet
					15	3		Bottom 5 in. dark grey silty CLAY with some gravel and sand; cohesive; wet
					18		FILL	
SS	18		3		50/0.4	4		Grey CLAY with some sand and gravel; dense; wet
	5	4	4.4	0.0				Bottom 2 in. rock fragments (quartz); noncohesive
						5		
						6		
						7		
[S]S	11		4		16	8		Top 8 in. dark grey silty CLAY with wood and seed type particles; wet
	11	8	8.9	0.0	50/0.4		FILL	Bottom 3 in. rock fragments (quartz)
						9		Auger refusal 9 ft.
								Moved drill rig 10' west
						10		
						11		
						12		
						14		
[S]S	24		5		3	15		Brown SAND with some gravel; loose; wet
	20	15	17	0.0	4		FILL	Bottom 6 in. silty CLAY with a trace of gravel; loose; wet
					8	16		
					8			
						17		
						18		
						19		
						20		SS = Split barrel sampler

Logged by: Jeanette Scalzo

Date: 19 April 1995

[D]rilling Contractor: Parratt Wolff, Inc.

Driller: Ronald Bush

[W]ELL SPECIFICATIONS:

Diam of casing:	2 in.	Screen Interval:	8.0 - 22.0 ft	Filter Pack:	6.0 - 23.0 ft	Grout:	0.0 - 3.0 ft
[B]OH:	23 ft	Riser Interval:	0.0 - 8.0 ft	Bentonite:	3.0 -6.0 ft	Cover:	8 in. bolt down curb box

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LOG OF SOIL BORING

Job. No.	60787.50
Client	U.S. Army Corps of Engineers
Location	West Point 11A
Drilling Method:	Diedrich D-50 drill rig 4 1/4 in. ID hollow stem auger
Boring No.	SB11-03
Sampling Method:	2 in. OD split barrel, 2 ft length 140-lb hammer falling 30 in.
Sheet	2 of 2

Coordinates:
Surface Elevation:
Casing Below Surface:
Reference Elevation: Top of PVC casing
Reference Description: Permanent marker

Water Lev.					
Time					
Date					
Reference					

Drilling	Start	Finish
Time	830	1110
Date	19 April 1995	19 April 1995

Surface Conditions: South end of asphalt parking lot, north of Bldg. 795

Sample Type	Inches Drvn/In. Recvrd.	Depth Casing	Samp. # /samp. depth	PID (ppm) HNu	Blows per 6 in.	Depth in Feet	USCS Log	Description
SS	24 / 24	20	6 / 22	0	3	20	FILL	Dark grey silty CLAY with medium brown sand layers; very loose; wet
					3			Bottom 6 in. yellow brown silty SAND; loose; wet
					4	21		
					4			End of boring 23 ft
						22		
						23		
						24		
						25		
						26		
						27		
						28		
						29		
						30		
						31		
						32		
						33		
						34		
						35		
						36		
						37		
						38		
						39		
						40		SS = Split barrel sampler

Logged by: Jeanette Scalzo
Date: 19 April 1995
Drilling Contractor: Parratt Wolff, Inc.
Driller: Ronald Bush

WELL SPECIFICATIONS:

Diam of casing: 2 in.
BOH: 23 ft
Screen Interval: 8.0 - 22.0 ft
Riser Interval: 0.0 - 8.0 ft
Filter Pack: 6.0 - 23.0 ft
Bentonite: 3.0 -6.0 ft
Grout: 0.0 - 3.0 ft
Cover: 8 in. bolt down curb box

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LOG OF SOIL BORING

Job. No.	60787.50
Client	U.S. Army Corps of Engineers
Location	West Point 11A
Drilling Method:	Diedrich D-50 drill rig 4 1/4 in. ID hollow stem auger
Boring No.	SB11-04
Sampling Method:	2 in. OD split barrel, 2 ft length 140-lb hammer falling 30 in.
Sheet	1 of 1

Coordinates:
Surface Elevation:
Casing Below Surface:
Reference Elevation: Top of PVC casing
Reference Description: Permanent marker

Water Lev.				
Time				
Date				
Reference				

Drilling	Start	Finish
Time	1340	1645
Date	20 April 1995	20 April 1995

Surface Conditions: Middle of asphalt parking lot between SB11-01 and SB11-02

Sample Type	Inches Drvn/In. Recvrd.	Depth Casing	Samp. # /samp. depth	PID (ppm) HNu	Blows per 6 in.	Depth in Feet	USCS Log	Description
SS	24		1		12	0		Top 2 in. asphalt
	11	0	2	0.0	6		FILL	Middle 3 in. grey, reddish brown SAND and GRAVEL (up to 2 in. diameter); loose
					7	1		Bottom 6 in. fine-medium SAND with some gravel; yellow and brick color staining; loose; moist
					6			
SS	24		2		5	2		Grey fine SAND with a trace of silt; large gravel (up to 2 in. diameter)
	12	0	4	0.0	6		FILL	with some coarse sand; loose; dry
					7	3		
					7			
						4		Auger refusal 4-5 ft; moved south 5 ft
								Water table 4.5 ft
SS	24		3		10	5		Grey brown SILT with some sand and gravel (up to 2 in. diameter); dark grey greenish and
	13	5	7	0.0	14			yellowish brown lenses; loose; wet
					9	6		
					8			
						7	FILL	
SS	24		4		12	8		Top 3 in. yellow brown SAND and GRAVEL (up to 3/4 in. diameter) with some silt; loose; wet
	11	8	10	0.0	9			Middle 2 in. coarse SAND with iron staining; loose; wet
					8	9		Bottom 6 in. yellow brown SAND and GRAVEL (up to 3/4 in. diameter) with some silt; loose; wet
					8			
SS	24		5		5	10		Grey fine-medium SAND with trace of gravel and some clay; yellowish brown lenses; loose; wet
	13	10	12	0.5	5			Bottom 2 in. brick color rock framents and quartz fragments
					5	11		
					6			
SS	24		6		6	12		Top 3 in. grey SAND and GRAVEL; dense; wet
	13	12	14	0.5	11		FILL	Middle 5 in. brown silty fine SAND with little clay; gravel (up to 1.5 in. diameter); loose; wet
					6	13		Bottom 2 in. large GRAVEL (gamite and pyrite); loose; wet
					8			
SS	24		7		5	14		Brown sandy CLAY; loose; wet
	10	14	16	0.5	2			Bottom 2 in. angular GRAVEL; dark brown CLAY; dense; wet
					5	15		
					11			Bottom 2 in. angular GRAVEL; dark brown CLAY; dense; wet
SS	24		5		14	16		
	24	16	18	0.0	50/0.3			
						17		
						18		
								Auger refusal
						19		End of boring 19.6 ft
						20		
								SS = Split barrel sampler

Logged by: Jeanette Scalzo
Date: 20 April 1995
Drilling Contractor: Parratt Wolff, Inc.
Driller: Ronald Bush

EA Engineering, Science, and Technology

LOG OF SOIL BORING

Coordinates:	
Surface Elevation:	
Casing Below Surface:	
Reference Elevation:	Top of PVC casing
Reference Description:	Permanent marker

Job. No.	Client	Location
60787.50	U.S. Army Corps of Engineers	West Point 11A
Drilling Method: Diedrich D-50 drill rig 4 1/4 in. ID hollow stem auger		Boring No. SB11-04A
Sampling Method: 2 in. OD split barrel, 2 ft length 140-lb hammer falling 30 in.		Sheet 1 of 1

Water Lev.					Drilling	
Time					Start	Finish
Date					730	1100
Reference					21 April 1995	21 April 1995

Surface Conditions: Middle of asphalt parking lot between SB11-01 and SB11-02, approximately 10' east of the first attempt, SB11-04

Sample Type	Inches Drvn/In. Recvrd.	Depth Casing	Samp. # /samp. depth	PID (ppm) HNu	Blows per 6 in.	Depth in Feet	USCS Log	Description
SS	24		1		21	0		Top 2 in. asphalt
	6	0	2	0.0	10			Brown fine-medium SAND with gravel; loose; moist
					15	1		Bottom 2 in. large GRAVEL
					18		FILL	
SS	24		2		27	2		Top 1 in. large GRAVEL; dense; dry
	5	0	4	0.0	26			Brown fine SAND with some silt and gravel; green staining; dense; moist
					27	3		
					22			
SS	24		3		5	4		Greenish grey silty SAND with large gravel, wood, and slate fragments; loose; moist
	14	4	6	1.8	4			Bottom 2 in. brown yellowish staining
					5	5	FILL	
					6			
SS	24		4		3	6		Top 2 in. greenish grey silty SAND with large gravel, wood, and slate fragments; loose; moist
	14	4	8	0.0	3			Middle 4 in. light grey silty CLAY with a large wood fragment; loose; moist
					6	7		Bottom 8 in. dark grey silty SAND with some clay; wood; large gravel; moist
					8			Water table at 7 ft
SS	24		5		6	8		Top 3 in. grey CLAY; medium dense; wet
	4	8	10	0.0	11			GRAVEL (up to 1 in. diameter) with some clay; medium dense; wet
					17	9	FILL	
					10			
SS	24		6		10	10		No recovery in split spoon; pushed spoon down and recovered 2 in.
	2	10	12	0.0	19			Brown-dark yellow fine-medium SAND with some clay, silt and gravel; medium dense; saturated
					18	11		
					15			
SS	24		7		7	12		Top 2 in. brown-dark yellow fine-medium SAND with some clay, silt and gravel;
	3	10	14	0.0	17			medium dense; saturated
					15	13		Bottom 1in. large GRAVEL
					12		FILL	
SS	24		8		17	14		Brown silty CLAY with some gravel; cohesive; medium dense; wet
	12	14	16	0.2	19			
					16	15		
					22			
SS	24		9		20	16		Top 2 in. brown silty CLAY with some gravel; cohesive; medium dense; wet
	20	14	18	0.2	22			Middle 2 in. large GRAVEL
					24	17		Bottom brown reddish fine-medium SAND with some silt and clay;
					20		FILL	large gravel (up to 1 in. diameter); slate; iron staining; medium dense; wet
SS	21		10		14	18		
	12	18	19.3	0.3	17			Brown fine-medium SAND with some gravel; reddish orange staining; medium dense; wet
					18	19		Auger refusal
					50/0.3			End of boring 19.3 ft
						20		
								SS = Split barrel sampler

Logged by: Jeanette Scalzo — Date: 21 April 1995

Drilling Contractor: Parratt Wolff, Inc. — Driller: Ronald Bush

EA Engineering, Science, and Technology

LOG OF SOIL BORING

Coordinates:	
Surface Elevation:	
Casing Below Surface:	
Reference Elevation:	Top of PVC casing
Reference Description:	Permanent marker

Job. No.	Client	Location
60787.50	U.S. Army Corps of Engineers	West Point 11A
Drilling Method: Diedrich D-50 drill rig 4 1/4 in. ID hollow stem auger		Boring No. SB11-05
Sampling Method: 2 in. OD split barrel, 2 ft length 140-lb hammer falling 30 in.		Sheet 1 of 2

Water Lev.					Drilling Start	Drilling Finish
Time					1600	1100
Date					19 April 1995	20 April 1995
Reference						

Surface Conditions: Middle of asphalt parking lot, north of the northest corner of Bldg. 795

Sample Type	Inches Drvn/In. Recvrd.	Depth Casing	Samp. # /samp. depth	PID (ppm) HNu	Blows per 6 in.	Depth in Feet	USCS Log	Description
SS	24		1		22	0		Top 2 in. asphalt fragments
	15	0	2	0.0	11		FILL	Brown reddish SAND with some gravel; dense; dry
					9	1		
					8			
SS	24		2		11	2		Top 14 in. brown reddish SAND with some gravel; dense; dry
	20	0	4	0.0	17			Grey silty SAND with some gravel up to 1"; dry
					25	3	FILL	
					32			
						4		
								Auger refusal 4.5 ft; moved approximately 4 ft south towards Bldg. 795
SS	24		3		3	5		Water table at 5.5 ft
	19	5	7	0.2	6			Grey fine SAND with some silt and gravel; wood ; loose; moist
					5	6		
					4			
SS	24		4		5	7		Grey fine SAND with silt and gravel; noncohesive; loose; moist
	24	6	9	0.0	7			Bottom 4 in silty CLAY with organic matter; cohesive; loose; wet
					6	8	FILL	
					5			
SS	12		5		2	9		Grey sandy SILT with some gravel (up to 1/2 in. diameter); cohesive; medium dense; wet
	8	8	10	0.0	2			Bottom 3 in. greyish brown CLAY and SAND; medium dense; wet
SS	12		6		16	10		
	12	8	11.2	0.0	20			Greyish brown silty SAND with some clay; cohesive; dense; wet
					50/0.2	11		
SS	24		7		4	12		Grey fine-medium SAND with some gravel; loose; saturated
	10	10	14	0.0	7		FILL	
					8	13		
					8			
SS	24		8		5	14		Tan-brown coarse SAND with iron staining; large gravel; loose; saturated
	12	10	16	0.0	6			
					8	15		
					6			
SS	24		5		7	16		Brown well sorted silty SAND; loose; saturated
	24	16	18	0.0	6		FILL	Bottom 3" coarse gravel up to 3"; loose; saturated
					6	17		
					7			
SS	24		6		6	18		Brown CLAY with fine sand lens; cohesive; loose; wet
	16	18	20		6			
					8	19		
					8			
						20		
								SS = Split barrel sampler

Logged by: Jeanette Scalzo — Date: 19 - 20 April 1995

Drilling Contractor: Parratt Wolff, Inc. — Driller: Ronald Bush

EA Engineering, Science, and Technology

LOG OF SOIL BORING

Job. No.	60787.50
Client	U.S. Army Corps of Engineers
Location	West Point 11A
Drilling Method:	Diedrich D-50 drill rig 4 1/4 in. ID hollow stem auger
Boring No.	SB11-05
Sampling Method:	2 in. OD split barrel, 2 ft length 140-lb hammer falling 30 in.
Sheet	2 of 2

Coordinates:
Surface Elevation:
Casing Below Surface:
Reference Elevation: Top of PVC casing
Reference Description: Permanent marker

Water Lev.				
Time				
Date				
Reference				

Drilling	Start	Finish
Time	1600	1100
Date	19 April 1995	20 April 1995

Surface Conditions: Middle of asphalt parking lot, north of the northest corner of Bldg. 795

Sample Type	Inches Drvn/In. Recvrd.	Depth Casing	Samp. # /samp. depth	PID (ppm) HNu	Blows per 6 in.	Depth in Feet	USCS Log	Description
SS	24		7		5	20		Brown CLAY with fine sand lens; cohesive; loose; wet
	14	20	22	0.0	8			Bottom 3" brown coarse SAND with some gravel and slate fragments; medium dense; saturated
					7	21	FILL	
					11			
SS	24		8		15	22		Brown coarse SAND with gravel; medium dense; saturated
	20	20	24	0.0	12			Bottom 6 in. rock fragments (quartz); coarse SAND with gravel; medium dense; saturated
					10	23		
					17			
SS	24		9		69	24		Brown fine-coarse SAND; medium dense; wet
	10	24	26	0.0	60			Bottom 6 in. finer SAND with rock fragments (up to 2 in. diameter)
					30	25	FILL	
					27			
SS	24		10		18	26		Brown fine-medium SAND; medium dense; saturated
	22	24	28	0.0	10			Bottom 2 in. coarse SAND with gravel; medium dense; saturated
					13	27		
					13			
SS	24		11		6	28		Brown fine-medium SAND with large gravel; loose; saturated
	20	28	30	0.0	5			
					8	29		
					9			
SS	24		12		6	30	FILL	Top 4 in. brown fine-medium SAND with gravel; medium dense; wet
	16	30	32	0.0	10			Fine SAND with little silt and some gravel; slate fragments; dense; wet
					28	31		
					31			
SS	24		13		13	32		Brown fine-medium SAND with gravel; dense; wet
	11	30	33.5	0.0	31			Bottom 2 in. banded rock fragments (slate, quartz)
					65/0.5	33		Auger refusal 32 ft
						34		End of boring 33.5 ft
						35		
						36		
						37		
						38		
						39		
						40		SS = Split spoon sampler

Logged by: Jeanette Scalzo

Date: 19 - 20 April 1995

Drilling Contractor: Parratt Wolff, Inc.

Driller: Ronald Bush

Appendix C

Drainage Calculations and Swale Design

SWALE "A_1"	Flow from drainage area (TR-55 calculations) provides 4 cfs to swale. **Existing:** Length of Swale until union with Swale A_2 = 370' Top of Swale @ beginning = 419.5' Top of Swale @ end = 416' Existing Slope = approximately .8% **Proposed:** Slope = 1.3% Grass Lined; n=.035 Depth = 1' Bot. Width = 2' Side Slope = 2:1 on both sides (H:V) Top of Swale @ end = 414.8' Bot. of Swale @ end = 413.8'
SWALE "A_2"	Assume that the existing 30" RCP at the existing slope will have a maximum flow of 80 cfs during a 10-year storm event. Additional flow from Swale A_1 and drainage area (TR-55 calculations) provides 6 cfs. Total flow to swale = 86 cfs. **Existing:** Length of swale to stream (terminating at existing 404' contour line) = 285' Top of Swale @ beginning = 416' Top of Swale @ end = 403' Existing Slope = approximately 4.5% **Proposed:** Slope = 3.7% Grass Lined; n=.035 Depth = 2' Bot. Width = 2' Side Slope = 2:1 both slopes (H:V)

Project	WEST POINT - MOTOR POOL EAST LANDFILL
Subject	Swale Calculations and Assumptions
Project No.	60787.77
Sheet No.	2 of 2
Drawing No.	
Computed by	JDM
Date	3/26/99
Checked by	
Date	

	Top of Swale @ beginning = 415.8' Bot. of Swale @ beginning = 413.8' Top of Swale @ end = 406.0' Bot. of Swale @ end = 404.0'
SWALE "B"	Assume that existing 36" RCP at the existing slope will have a maximum flow of 50 cfs during a 10-year storm event. Additional flow from drainage area (TR-55 calculations) provides 13 cfs. Total flow to swale = 63 cfs. **Existing:** Length of swale to stream = 305' Top of Swale - beginning = 419.5' Top of Swale - end = 406' Existing Slope = approximately 4.5% **Proposed:** Slope = 4.0% Grass Lined; n=.035 Depth = 1.5' Bot. Width = 3' Side Slope = 2:1 on both sides (H:V) Top of Swale - end = 417.3' Bot. of Swale - end = 406'

EA Engineering, Science, and Technology

Project: West Point - Motor Pool East
Project #: 60787.77
Task: 0001
Calculated: JDM   Date: 18-Jun-99
Checked: Date:

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

Stage of Development: Post-Development
Drainage Area Description: Drainage to Swale "A1"

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
C	woods, good condition	70			0.92	64
						0
						0
						0
						0
						0
						0
						0
						0
						0
				Totals	0.92	64

Use CN = 70

	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)	1.01	1.67	2.04	2.41	0.00

EA Engineering, Science, and Technology

Project: West Point - Motor Pool East
Project #: 60787.77
Task: 0001
Calculated: JDM Date: 18-Jun-99
Checked: Date:

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

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

Shallow Concentrated Flow	Segment	B2C2			
7 Surface Description (1=paved, 2=unpaved)		2			
8 Flow Length, L	ft	90			
9 Watercourse Slope, s	ft/ft	0.267			
10 Average Velocity, V (Fig. 3-1)	ft/s	8.34	0.00	0.00	
11 Tt	hr	0.003	0.000	0.000	0.003

Channel Flow	Segment	A2B2	C2D2		
Bottom width of trapezoidal channel	ft	2	2		
Depth of trapezoidal channel	ft	1	1		
Side slopes of trapezoidal channel (?H:1V)		1	2		
12 Cross Sectional Flow Area, a	sq ft	3.00	4.00	0.00	
13 Wetted Perimeter, pw	ft	4.83	6.47	0.00	
14 Hydraulic Radius, r	ft	0.621	0.618	0.000	
15 Channel Slope, s	ft/ft	0.030	0.013		
16 Manning's Roughness Coeff., n		0.025	0.035		
17 V	ft/s	7.517	3.522	0.000	
18 Flow Length, L	ft	420	220		
19 Tt	hr	0.016	0.017	0.000	0.033
				Tc =	0.036

TR-55 Worksheet #4: Graphical Peak Discharge Method

1 Drainage Area, Am	sq mi	0.001
Runoff Curve Number, CN (worksheet #2)		70
Time of Concentration, Tc (worksheet #3)	hr	0.036
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	0.857	0.857	0.857	0.857	0.000
5 Ia/P		0.245	0.190	0.171	0.156	0.000
6 Unit Peak Discharge, qu (Exhibit 4-II)	csm/in	1304.8	1286.9	1280.7	1275.7	0.0
7 Runoff, Q (worksheet 2)	in	1.01	1.67	2.04	2.41	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	1.89	3.10	3.75	4.43	0.00

SWALE "A1" (Path A2B2)

Channel Characteristics:

Flow Rate, Q =	3.75	cfs
Bottom width, B =	0.5	ft
Side slope, Z =	1.0	?H:1V
Side slope, Z =	1.0	?H:1V
Manning roughness, n =	0.03	
Channel slope, S =	0.052	ft/ft
Rock filter height, H =	0.0	ft
Flow Depth, D =	0.6	ft
Top width =	1.70	ft
Flow area, A =	0.66	sq ft
Wetted perimeter, P =	2.20	ft
Mean depth, Dm =	0.388	ft
Hydraulic radius, R =	0.300	ft
Velocity, V =	5.68	fps

	Flow Depth* (ft)	Hydraulic Radius (ft)	Velocity (fps)	Hydraulic Radius (ft)	Difference	
	0.1	0.077	62.5	13.052	-12.976	
	0.2	0.131	26.8	3.662	-3.531	
	0.3	0.178	15.6	1.632	-1.454	
	0.4	0.221	10.4	0.888	-0.667	
	0.5	0.261	7.5	0.543	-0.281	
>	0.6	0.300	5.7	0.358	-0.057	<
	0.7	0.339	4.5	0.249	0.090	
	0.8	0.376	3.6	0.181	0.196	
	0.9	0.414	3.0	0.136	0.278	
	1.0	0.451	2.5	0.104	0.346	
	1.1	0.487	2.1	0.082	0.405	
	1.2	0.524	1.8	0.066	0.458	
	1.3	0.560	1.6	0.054	0.507	
	1.4	0.596	1.4	0.044	0.552	
	1.5	0.633	1.2	0.037	0.596	
	1.6	0.669	1.1	0.031	0.637	
	1.7	0.705	1.0	0.027	0.678	
	1.8	0.740	0.9	0.023	0.718	
	1.9	0.776	0.8	0.020	0.757	
	2.0	0.812	0.7	0.017	0.795	
	2.1	0.848	0.7	0.015	0.833	
	2.2	0.884	0.6	0.013	0.870	
	2.3	0.919	0.6	0.012	0.908	
	2.4	0.955	0.5	0.010	0.945	
	2.5	0.991	0.5	0.009	0.981	
	2.6	1.026	0.5	0.008	1.018	
	2.7	1.062	0.4	0.008	1.054	
	2.8	1.097	0.4	0.007	1.091	
	2.9	1.133	0.4	0.006	1.127	
	3.0	1.169	0.4	0.006	1.163	
	3.1	1.204	0.3	0.005	1.199	
	3.2	1.240	0.3	0.005	1.235	
	3.3	1.275	0.3	0.004	1.271	
	3.4	1.311	0.3	0.004	1.307	
	3.5	1.346	0.3	0.004	1.343	
	3.6	1.382	0.3	0.003	1.378	
	3.7	1.417	0.2	0.003	1.414	
	3.8	1.453	0.2	0.003	1.450	
	3.9	1.488	0.2	0.003	1.485	
	4.0	1.524	0.2	0.003	1.521	
	4.1	1.559	0.2	0.002	1.557	
	4.2	1.595	0.2	0.002	1.592	
	4.3	1.630	0.2	0.002	1.628	
	4.4	1.665	0.2	0.002	1.664	
	4.5	1.701	0.2	0.002	1.699	

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

SWALE "A1" (Path C2D2)

Channel Characteristics:

Flow Rate, Q =	3.75	cfs
Bottom width, B =	2.0	ft
Side slope, Z =	2.0	?H:1V
Side slope, Z =	2.0	?H:1V
Manning roughness, n =	0.035	
Channel slope, S =	0.013	ft/ft
Rock filter height, H =	0.0	ft
Flow Depth, D =	0.5	ft
Top width =	4.00	ft
Flow area, A =	1.50	sq ft
Wetted perimeter, P =	4.24	ft
Mean depth, Dm =	0.375	ft
Hydraulic radius, R =	0.354	ft
Velocity, V =	2.50	fps

	Flow Depth* (ft)	Hydraulic Radius (ft)	Velocity (fps)	Hydraulic Radius (ft)	Difference	
	0.1	0.090	17.0	6.626	-6.536	
	0.2	0.166	7.8	2.056	-1.890	
	0.3	0.233	4.8	0.993	-0.759	
	0.4	0.296	3.3	0.577	-0.281	
>	0.5	0.354	2.5	0.372	-0.018	<
	0.6	0.410	2.0	0.257	0.153	
	0.7	0.464	1.6	0.186	0.278	
	0.8	0.516	1.3	0.140	0.376	
	0.9	0.568	1.1	0.108	0.460	
	1.0	0.618	0.9	0.085	0.533	
	1.1	0.668	0.8	0.069	0.599	
	1.2	0.717	0.7	0.056	0.660	
	1.3	0.765	0.6	0.047	0.719	
	1.4	0.813	0.6	0.039	0.774	
	1.5	0.861	0.5	0.033	0.828	
	1.6	0.909	0.5	0.028	0.880	
	1.7	0.956	0.4	0.025	0.931	
	1.8	1.003	0.4	0.021	0.982	
	1.9	1.050	0.3	0.019	1.031	
	2.0	1.096	0.3	0.016	1.080	
	2.1	1.143	0.3	0.015	1.128	
	2.2	1.189	0.3	0.013	1.176	
	2.3	1.236	0.2	0.012	1.224	
	2.4	1.282	0.2	0.010	1.271	
	2.5	1.328	0.2	0.009	1.318	
	2.6	1.374	0.2	0.008	1.365	
	2.7	1.420	0.2	0.008	1.412	
	2.8	1.465	0.2	0.007	1.458	
	2.9	1.511	0.2	0.006	1.505	
	3.0	1.557	0.2	0.006	1.551	
	3.1	1.602	0.1	0.005	1.597	
	3.2	1.648	0.1	0.005	1.643	
	3.3	1.694	0.1	0.005	1.689	
	3.4	1.739	0.1	0.004	1.735	
	3.5	1.784	0.1	0.004	1.781	
	3.6	1.830	0.1	0.004	1.826	
	3.7	1.875	0.1	0.003	1.872	
	3.8	1.921	0.1	0.003	1.917	
	3.9	1.966	0.1	0.003	1.963	
	4.0	2.011	0.1	0.003	2.009	
	4.1	2.056	0.1	0.003	2.054	
	4.2	2.102	0.1	0.002	2.099	
	4.3	2.147	0.1	0.002	2.145	
	4.4	2.192	0.1	0.002	2.190	
	4.5	2.237	0.1	0.002	2.235	

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

EA Engineering, Science, and Technology

Project: West Point - Motor Pool East
Project #: 60787.77
Task: 0001
Calculated: JDM Date: 26-Mar-99
Checked: Date:

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

Stage of Development: Post-Development
Drainage Area Description: Drainage to Swale "A2"

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
C	woods, good condition	70			0.50	35
						0
						0
						0
						0
						0
						0
						0
						0
						0
				Totals	0.50	35

Use CN = 70

	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)	1.01	1.67	2.04	2.41	0.00

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Project: West Point - Motor Pool East
Project #: 60787.77
Task: 0001
Calculated: JDM   Date: 26-Mar-99
Checked: Date:

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

Sheet Flow	Segment				
1 Surface Description (Table 3-1)					
2 Manning's Roughness Coeff., n (Table 3-1)					
3 Flow Length, L (total L <= 300 ft)	ft				
4 Two year 24 hour Rainfall, P2	in				
5 Land Slope, s	ft/ft				
6 Tt	hr	0.000	0.000	0.000	0.000
Shallow Concentrated Flow	Segment	A3B3			
7 Surface Description (1=paved, 2=unpaved)		2			
8 Flow Length, L	ft	35			
9 Watercourse Slope, s	ft/ft	0.400			
10 Average Velocity, V (Fig. 3-1)	ft/s	10.20	0.00	0.00	
11 Tt	hr	0.001	0.000	0.000	0.001
Channel Flow	Segment	B3C3			
Bottom width of trapezoidal channel	ft	2			
Depth of trapezoidal channel	ft	2			
Side slopes of trapezoidal channel (?H:1V)		2			
12 Cross Sectional Flow Area, a	sq ft	12.00	0.00	0.00	
13 Wetted Perimeter, pw	ft	10.94	0.00	0.00	
14 Hydraulic Radius, r	ft	1.096	0.000	0.000	
15 Channel Slope, s	ft/ft	0.035			
16 Manning's Roughness Coeff., n		0.035			
17 V	ft/s	8.469	0.000	0.000	
18 Flow Length, L	ft	285			
19 Tt	hr	0.009	0.000	0.000	0.009
				Tc =	0.010

TR-55 Worksheet #4: Graphical Peak Discharge Method

1 Drainage Area, Am	sq mi	0.001
Runoff Curve Number, CN (worksheet #2)		70
Time of Concentration, Tc (worksheet #3)	hr	0.010
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	0.857	0.857	0.857	0.857	0.000
5 Ia/P		0.245	0.190	0.171	0.156	0.000
6 Unit Peak Discharge, qu (Exhibit 4-II)	csm/in	1624.2	1512.0	1474.5	1444.6	0.0
7 Runoff, Q (worksheet 2)	in	1.01	1.67	2.04	2.41	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	1.28	1.98	2.35	2.72	0.00

SWALE "A2"

Channel Characteristics:

Flow Rate, Q =	86.40	cfs
Bottom width, B =	2.0	ft
Side slope, Z =	2.0	?H:1V
Side slope, Z =	2.0	?H:1V
Manning roughness, n =	0.035	
Channel slope, S =	0.037	ft/ft
Rock filter height, H =	0.0	ft
Flow Depth, D =	1.8	ft
Top width =	9.20	ft
Flow area, A =	10.08	sq ft
Wetted perimeter, P =	10.05	ft
Mean depth, Dm =	1.096	ft
Hydraulic radius, R =	1.003	ft
Velocity, V =	8.57	fps

	Flow Depth* (ft)	Hydraulic Radius (ft)	Velocity (fps)	Hydraulic Radius (ft)	Difference	
	0.1	0.090	392.7	334.403	-334.313	
	0.2	0.166	180.0	103.763	-103.597	
	0.3	0.233	110.8	50.091	-49.858	
	0.4	0.296	77.1	29.112	-28.817	
	0.5	0.354	57.6	18.783	-18.429	
	0.6	0.410	45.0	12.970	-12.560	
	0.7	0.464	36.3	9.398	-8.934	
	0.8	0.516	30.0	7.060	-6.544	
	0.9	0.568	25.3	5.456	-4.888	
	1.0	0.618	21.6	4.313	-3.695	
	1.1	0.668	18.7	3.475	-2.807	
	1.2	0.717	16.4	2.844	-2.127	
	1.3	0.765	14.4	2.360	-1.594	
	1.4	0.813	12.9	1.981	-1.167	
	1.5	0.861	11.5	1.680	-0.819	
	1.6	0.909	10.4	1.438	-0.529	
	1.7	0.956	9.4	1.241	-0.285	
>	1.8	1.003	8.6	1.078	-0.075	<
	1.9	1.050	7.8	0.943	0.107	
	2.0	1.096	7.2	0.830	0.266	
	2.1	1.143	6.6	0.734	0.408	
	2.2	1.189	6.1	0.653	0.536	
	2.3	1.236	5.7	0.583	0.652	
	2.4	1.282	5.3	0.523	0.758	
	2.5	1.328	4.9	0.471	0.856	
	2.6	1.374	4.6	0.426	0.948	
	2.7	1.420	4.3	0.386	1.033	
	2.8	1.465	4.1	0.352	1.114	
	2.9	1.511	3.8	0.321	1.190	
	3.0	1.557	3.6	0.293	1.263	
	3.1	1.602	3.4	0.269	1.333	
	3.2	1.648	3.2	0.248	1.400	
	3.3	1.694	3.0	0.228	1.465	
	3.4	1.739	2.9	0.211	1.528	
	3.5	1.784	2.7	0.195	1.589	
	3.6	1.830	2.6	0.181	1.649	
	3.7	1.875	2.5	0.168	1.707	
	3.8	1.921	2.4	0.157	1.764	
	3.9	1.966	2.3	0.146	1.820	
	4.0	2.011	2.2	0.136	1.875	
	4.1	2.056	2.1	0.128	1.929	
	4.2	2.102	2.0	0.120	1.982	
	4.3	2.147	1.9	0.112	2.035	
	4.4	2.192	1.8	0.105	2.087	
	4.5	2.237	1.7	0.099	2.138	

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

EA Engineering, Science, and Technology

Project: West Point - Motor Pool East
Project #: 60787.77
Task: 0001
Calculated: JDM   Date: 29-Sep-98
Checked: MJD   Date: 10/1/98

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

Stage of Development: Post-Development
Drainage Area Description: Drainage to Swale "B"

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			0.95	93
	C	woods, good condition	70			1.20	84
							0
							0
							0
							0
							0
							0
							0
							0
					Totals	2.15	177

Use CN = 82

	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)	1.81	2.67	3.11	3.57	0.00

EA Engineering, Science, and Technology

Project: West Point - Motor Pool East
Project #: 60787.77
Task: 0001
Calculated: JDM Date: 29-Sep-98
Checked: MDS Date: 10/1/98

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

Sheet Flow	Segment	A1B1			
1 Surface Description (Table 3-1)		asphalt			
2 Manning's Roughness Coeff., n (Table 3-1)		0.011			
3 Flow Length, L (total L <= 300 ft)	ft	200			
4 Two year 24 hour Rainfall, P2	in	3.5			
5 Land Slope, s	ft/ft	0.070			
6 Tt	hr	0.020	0.000	0.000	0.020
Shallow Concentrated Flow	Segment	B1C1			
7 Surface Description (1=paved, 2=unpaved)		2			
8 Flow Length, L	ft	140			
9 Watercourse Slope, s	ft/ft	0.214			
10 Average Velocity, V (Fig. 3-1)	ft/s	7.46	0.00	0.00	
11 Tt	hr	0.005	0.000	0.000	0.005
Channel Flow	Segment	C1D1			
Bottom width of trapezoidal channel	ft	3			
Depth of trapezoidal channel	ft	1.4			
Side slopes of trapezoidal channel (?H:1V)		2			
12 Cross Sectional Flow Area, a	sq ft	8.12	0.00	0.00	
13 Wetted Perimeter, pw	ft	9.26	0.00	0.00	
14 Hydraulic Radius, r	ft	0.877	0.000	0.000	
15 Channel Slope, s	ft/ft	0.043			
16 Manning's Roughness Coeff., n		0.035			
17 V	ft/s	8.087	0.000	0.000	
18 Flow Length, L	ft	225			
19 Tt	hr	0.008	0.000	0.000	0.008
				Tc =	0.033

TR-55 Worksheet #4: Graphical Peak Discharge Method

1 Drainage Area, Am	sq mi	0.003
Runoff Curve Number, CN (worksheet #2)		82
Time of Concentration, Tc (worksheet #3)	hr	0.033
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	0.428	0.428	0.428	0.428	0.000
5 Ia/P		0.122	0.095	0.086	0.078	0.000
6 Unit Peak Discharge, qu (Exhibit 4-II)	csm/in	1279.3	1270.5	1270.5	1270.5	0.0
7 Runoff, Q (worksheet 2)	in	1.81	2.67	3.11	3.57	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	7.78	11.39	13.29	15.22	0.00

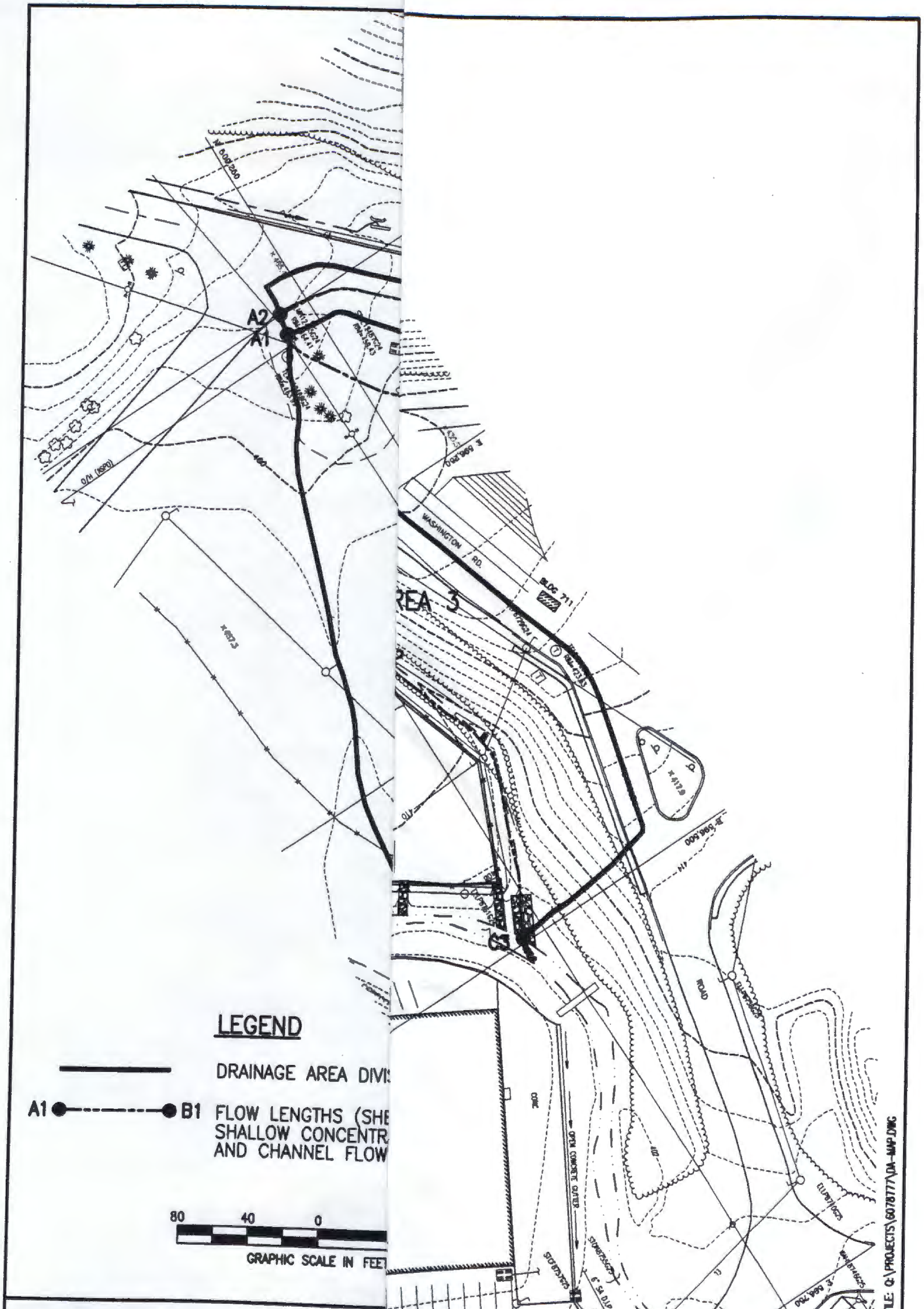
SWALE "B"

Channel Characteristics:

Flow Rate, Q =	63.00	cfs
Bottom width, B =	3.0	ft
Side slope, Z =	2.0	?H:1V
Side slope, Z =	2.0	?H:1V
Manning roughness, n =	0.035	
Channel slope, S =	0.043	ft/ft
Rock filter height, H =	0.0	ft
Flow Depth, D =	1.4	ft
Top width =	8.60	ft
Flow area, A =	8.12	sq ft
Wetted perimeter, P =	9.26	ft
Mean depth, Dm =	0.944	ft
Hydraulic radius, R =	0.877	ft
Velocity, V =	7.76	fps

Flow Depth* (ft)	Hydraulic Radius (ft)	Velocity (fps)	Hydraulic Radius (ft)	Difference
0.1	0.093	196.9	106.040	-105.947
0.2	0.175	92.6	34.232	-34.057
0.3	0.249	58.3	17.102	-16.854
0.4	0.317	41.4	10.243	-9.926
0.5	0.382	31.5	6.787	-6.405
0.6	0.443	25.0	4.798	-4.355
0.7	0.502	20.5	3.551	-3.049
0.8	0.559	17.1	2.719	-2.160
0.9	0.615	14.6	2.138	-1.523
1.0	0.669	12.6	1.717	-1.048
1.1	0.722	11.0	1.403	-0.681
1.2	0.775	9.7	1.164	-0.389
1.3	0.826	8.7	0.977	-0.151
> 1.4	0.877	7.8	0.830	0.047 <
1.5	0.927	7.0	0.711	0.216
1.6	0.977	6.4	0.614	0.362
1.7	1.026	5.8	0.535	0.491
1.8	1.075	5.3	0.469	0.606
1.9	1.124	4.9	0.413	0.710
2.0	1.172	4.5	0.366	0.806
2.1	1.220	4.2	0.326	0.894
2.2	1.268	3.9	0.292	0.976
2.3	1.316	3.6	0.263	1.053
2.4	1.363	3.4	0.237	1.126
2.5	1.410	3.1	0.215	1.196
2.6	1.458	3.0	0.195	1.263
2.7	1.505	2.8	0.178	1.327
2.8	1.551	2.6	0.162	1.389
2.9	1.598	2.5	0.149	1.449
3.0	1.645	2.3	0.137	1.508
3.1	1.691	2.2	0.126	1.565
3.2	1.738	2.1	0.116	1.621
3.3	1.784	2.0	0.108	1.676
3.4	1.830	1.9	0.100	1.730
3.5	1.876	1.8	0.093	1.784
3.6	1.923	1.7	0.086	1.836
3.7	1.969	1.6	0.080	1.888
3.8	2.015	1.6	0.075	1.940
3.9	2.061	1.5	0.070	1.990
4.0	2.106	1.4	0.066	2.041
4.1	2.152	1.4	0.062	2.091
4.2	2.198	1.3	0.058	2.140
4.3	2.244	1.3	0.054	2.189
4.4	2.290	1.2	0.051	2.238
4.5	2.335	1.2	0.048	2.287

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



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DRAWN BY	DATE	PROJECT NO.	FILE NAME
FDV	APRIL 1999	60787.77	DA-MAP
PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
GAT	AS SHOWN	–	–

Appendix D

Pavement Design

OBJECTIVE:

Design the pavement cross-section at the Motor Pool East Landfill to serve the mix of cars and military trucks that are stored within the parking lot 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 that utilize the lower Motor Pool East Landfill parking area to determine the traffic category.

Site visit – Winter 1999

Based on dimensions of the available parking area, assume 100 military trucks (2-axle) and passenger vehicles, along with a few 3-axle trucks utilize the Motor Pool East parking area.

This corresponds to traffic category III – traffic containing as much as 15 percent trucks, but with not more than 1 percent of the total traffic composed of trucks having 3 or more axles.

2. Determine the class of the parking area.

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

Vehicular parking areas are considered a class E road and street.

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

TM 5-822-5, Table 3-1

The pavement design index is 3.

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

TM 5-822-5, Table 4-1

Assuming the existing subgrade is compacted to 95% Modified Proctor density and that it is cohesionless, a minimum of 9-in. of material compacted to 100% Modified Proctor density is required on top of the 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 provided base course will be graded crushed aggregate with a CBR of 50. Typically, a base course of 50-CBR will only be used for Class E road and street. The required pavement thickness is 2.5-in. minimum and the base course thickness is 4-in. minimum.

Based on experience, a final bituminous wearing course of 1.5-in. minimum should be placed above an intermediate bituminous course of 2-in. minimum. Therefore, the total pavement thickness will be increased from 2.5-in. to 3.5-in. The total pavement and base course section is 7.5-in. thick - without including the underlying subbase material.

6. Determine the thickness of the subbase material, underlying the base course.

TM 5-822-5, Figure 8-1

Based on an existing subgrade CBR of 7 and a pavement design index of 3, the *total* pavement section (pavement, base course, and subbase) must be a minimum of 13-in. thick. Based on the suspected Proctor density of the subgrade (from step 4), the total pavement section must be a minimum of 9-in. thick.

Therefore, the suspected density of the subgrade controls the design of the subbase material. The subbase material will be 5-in. thick to provide a *total* pavement thickness of 12.5-in. above the existing subgrade.

Note that in this design, the subbase course and base course materials will be the *same* select material; thereby providing a total of 9-in of subbase/base course below the 3.5-in asphalt section. The 9-in. of subbase/base course will be placed in a single lift and compacted

7. Check total pavement thickness against possible detrimental effects of frost action in subsurface soils.

TM 5-822-5, Table 18-2

Based on the Reduced Subgrade Strength design method, the frost group of the subgrade soil is F-2 and S-2, which are sandy-gravelly soils with 10-20% fines by weight. Using this frost group, the frost-area soil support index is 6.5. This frost-area soil support index can be equated to the CBR of the subgrade and used to determine the total thickness of the subbase material (as in step 6).

TM 5-822-5, Table 18-3

Recalculating the total minimum thickness using a CBR of 6.5 indicates that the total pavement section must be a minimum of 14-in. thick. The pavement section must be increased from 12.5-in. to a minimum of 14-in. thick, to take frost action into account.

RESULTS:

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

- Asphalt pavement = 3.5-in. (2-in. intermediate course and 1.5-in. final wearing course)
- Base course = 4-in.
- Subbase course = 7-in. (Combined Base course and Subbase = 11-in., placed and compacted in a single lift.)

- **Total Flexible Pavement Section = 14.5-in.**

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

- The representative traffic utilizing the Motor Pool East parking area contains as much as 15 percent trucks, with not more than 1 percent composed of trucks having 3 or more axles.
- The subgrade is cohesionless, compacted to a minimum of 95% Modified Proctor density, and has a minimum CBR of 7.
- The subgrade frost design soil classification is sandy-gravelly soils with 10-20% fines by weight with a frost-area soil support index (CBR) of 6.5. This CBR is lower and controls the design.
- The base and subbase courses will be compacted to a minimum of 100% Modified Proctor density.
- Both the subbase and base courses will be a graded crushed aggregate with a minimum CBR of 50.