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VOLUNTARY CORRECTIVE MEASURES
WORK PLAN
SWMU 123

Holloman Air Force Base
New Mexico

August 2005

Contract No.: DACA45-03-D-0023
Delivery/Task Order No.: 0013
Bhate Project No.: 9050197

Headquarters, Air Combat Command
Langley Air Force Base, Virginia

49 CES/CEV
Holloman Air Force Base, New Mexico
VOLUNTARY CORRECTIVE MEASURES WORK PLAN

SOLID WASTE MANAGEMENT UNIT (SWMU) 123

HOLLOMAN AIR FORCE BASE, NEW MEXICO

Prepared for:
49 CES/CEV
Holloman Air Force Base
New Mexico

Under Contract To:
U.S. Army Corps of Engineers
Omaha District
Omaha, Nebraska

Contract No.
DACA45-03-D0023
Delivery/Task Order No. 0013

August 2005

Prepared by:
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Bhate Project No. 9050197
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VOLUNTARY CORRECTIVE MEASURES WORK PLAN
SOLID WASTE MANAGEMENT UNIT (SWMU) 123
HOLLOMAN AIR FORCE BASE, NEW MEXICO

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G. NMED TPH Screening Guidelines June 24, 2003
H. Komatsu Hydraulic Plate Compactor Specifications
I. ASTM Method D 2922 Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
J. UFGS Section 03307 Concrete for Minor Structures
K. Technical Specification, Item 00434, Flowable Fill
L. ACI 229R-99, Controlled Low-Strength Materials
M. UFGS Section 03300 Cast-In-Place Structural Concrete & UFGS Section 01610 Aggregate for Portland Cement Concrete
N. UFGS Section 02741N Bituminous Concrete Pavement
O. State of New Mexico Department of Transportation Specifications Section 416 Minor Paving
P. Accutest Laboratories, USACE Laboratory Validation Approval, US Department of Army, July 9, 2004
Q. NMED Soil Screening Levels Revision 2.0, February 2004
R. Site-Specific Addendum to the Basewide Quality Assurance Project Plan
S. Site-Specific Addendum to the Basewide Health and Safety Plan
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# ACRONYMS AND ABBREVIATIONS

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<th>Definition</th>
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<tr>
<td>AAF</td>
<td>Army Air Field</td>
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<tr>
<td>ACI</td>
<td>American Concrete Institute</td>
</tr>
<tr>
<td>AFCESA</td>
<td>Air Force Civil Engineer Support Agency</td>
</tr>
<tr>
<td>AF Fm</td>
<td>Air Force Form</td>
</tr>
<tr>
<td>amsl</td>
<td>Above mean sea level</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
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<tr>
<td>bgs</td>
<td>Below ground surface</td>
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<tr>
<td>Bhate</td>
<td>Bhate Environmental Associates, Inc.</td>
</tr>
<tr>
<td>BMP</td>
<td>Best management practices</td>
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<tr>
<td>BTEX</td>
<td>Benzene, toluene, ethylbenzene, and xylenes</td>
</tr>
<tr>
<td>CDW</td>
<td>Construction-derived waste</td>
</tr>
<tr>
<td>CES/CEV</td>
<td>Civil Engineering Squadron/Combat Engineer Vehicle</td>
</tr>
<tr>
<td>CLSM</td>
<td>Controlled low-strength material</td>
</tr>
<tr>
<td>COC</td>
<td>Chain-of-custody</td>
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<tr>
<td>CRZ</td>
<td>Contamination reduction zone</td>
</tr>
<tr>
<td>cu yds</td>
<td>Cubic yards</td>
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<tr>
<td>DPT</td>
<td>Direct push technology</td>
</tr>
<tr>
<td>DRO</td>
<td>Diesel range organics</td>
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<tr>
<td>DQO</td>
<td>Data quality objective</td>
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<tr>
<td>ERPIMS</td>
<td>Environmental Restoration Program Information Management System</td>
</tr>
<tr>
<td>EZ</td>
<td>Exclusion zone</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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</tr>
<tr>
<td>°F</td>
<td>Degrees Fahrenheit</td>
</tr>
<tr>
<td>FID</td>
<td>Flame-ionization detector</td>
</tr>
<tr>
<td>GC</td>
<td>Gas chromatogram</td>
</tr>
<tr>
<td>GRO</td>
<td>Gasoline range organics</td>
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<tr>
<td>HAFB</td>
<td>Holloman Air Force Base</td>
</tr>
<tr>
<td>HASP</td>
<td>Health and Safety Plan</td>
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<tr>
<td>ln ft</td>
<td>Linear feet</td>
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<tr>
<td>mg/kg</td>
<td>Milligrams per kilogram</td>
</tr>
<tr>
<td>MS/MSD</td>
<td>Matrix spike/matrix spike duplicate</td>
</tr>
<tr>
<td>NAVFAC</td>
<td>Naval Facilities Engineering Command</td>
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<tr>
<td>NFA</td>
<td>No Further Action</td>
</tr>
<tr>
<td>NMED</td>
<td>New Mexico Environment Department</td>
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<tr>
<td>NMWQCC</td>
<td>New Mexico Water Quality Commission Criteria</td>
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<tr>
<td>NOD</td>
<td>Notice of Deficiency</td>
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<td>ORO</td>
<td>Oil range organics</td>
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<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
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<tr>
<td>OVA</td>
<td>Organic vapor analyzer</td>
</tr>
<tr>
<td>OWS</td>
<td>Oil/water separator</td>
</tr>
<tr>
<td>PAH</td>
<td>Polynuclear aromatic hydrocarbon</td>
</tr>
<tr>
<td>PCS</td>
<td>Petroleum-contaminated soils</td>
</tr>
<tr>
<td>PID</td>
<td>Photo-ionization detector</td>
</tr>
<tr>
<td>POL</td>
<td>Petroleum, oil, and lubricant</td>
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<tr>
<td>PPE</td>
<td>Personal protective equipment</td>
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Bhate Project No.: 9050197
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<tr>
<th>Acronym</th>
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<td>QA/QC</td>
<td>Quality Assurance/Quality Control</td>
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<td>QAPP</td>
<td>Quality Assurance Project Plan</td>
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<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
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<tr>
<td>SSHO</td>
<td>Site Safety and Health Officer</td>
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<td>SSL</td>
<td>Soil Screening Level</td>
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<td>SWMU</td>
<td>Solid Waste Management Unit</td>
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<tr>
<td>SWPPP</td>
<td>Storm Water Pollution Prevention Plan</td>
</tr>
<tr>
<td>SVOC</td>
<td>Semi-volatile organic compound</td>
</tr>
<tr>
<td>SZ</td>
<td>Support zone</td>
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<tr>
<td>TPH</td>
<td>Total petroleum hydrocarbons</td>
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<tr>
<td>TRPH</td>
<td>Total recoverable petroleum hydrocarbons</td>
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<tr>
<td>UFGS</td>
<td>Unified Facilities Guide Specifications</td>
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<tr>
<td>USACE</td>
<td>United States Corps of Engineers</td>
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<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
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<tr>
<td>UVF</td>
<td>Ultraviolet Fluorometer</td>
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<tr>
<td>VCMs</td>
<td>Voluntary Corrective Measures</td>
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<tr>
<td>VOC</td>
<td>Volatile organic compound</td>
</tr>
<tr>
<td>WRCC</td>
<td>Western Regional Climate Center</td>
</tr>
<tr>
<td>WSMR</td>
<td>White Sands Missile Range</td>
</tr>
<tr>
<td>WWTP</td>
<td>Wastewater treatment plant</td>
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Bhate Project No.: 9050197  August 2005
1 INTRODUCTION

Bhate Environmental Associates, Inc. (Bhate) has been retained by the U.S. Army Corps of Engineers (USACE), under contract DACA45-03-D0023, Delivery/Task Order No. 0013, to conduct Voluntary Corrective Measures (VCMs) at Solid Waste Management Unit (SWMU) 123 at Holloman Air Force Base (HAFB), New Mexico. The VCMs include multiple tasks as outlined in the USACE Scope of Services dated May 5, 2005. This document is to provide a work plan that will serve as the primary working document for the excavation activities at SWMU 123.

This plan provides the relevant site specific information and requirements as outlined in the Scope of Work for remedial activities at SWMU 123. The primary objective of this VCM is to remove, through excavation, and properly dispose of petroleum-contaminated soils (PCS). During this process, required data will be collected to support the closure of the site based on guidance from the New Mexico Environment Department (NMED). The ultimate objective is to achieve approval for site closure from NMED.

This document has been written to provide relevant information on the geologic, hydrologic, and other environmental conditions for HAFB and SWMU 123 as well as the procedures by which the VCM will be completed. Information is provided for the entire Base and its surrounding environment as well as SWMU 123. This VCM calls for the removal of PCS at the site through excavation, with verification of complete PCS removal via confirmation sampling from the excavation.

1.1 HAFB Site Description

HAFB is located in southeastern New Mexico in Otero County, New Mexico, approximately 100 miles north-northeast of El Paso, Texas and six miles west of Alamogordo, New Mexico (Figure 1). HAFB was first established in 1942 as Alamogordo Army Air Field (AAF). From 1942 through 1945, Alamogordo AAF served as the training grounds for over 20 different flight groups, flying primarily B-17s, B-24s, and B-29s. After World War II, most operations had ceased at the base. In 1947, Air Material Command announced the air field would be its primary site for the testing and development of unmanned aircraft, guided missiles, and other research programs. On January 13, 1948, the Alamogordo installation was renamed Holloman Air Force Base, in honor of the late Col. George V. Holloman; a pioneer in guided missile research. In 1968, the 49th Tactical Fighter Wing arrived at HAFB and has remained since. Today, HAFB also serves as the training center for the German Air Force’s Tactical Training Center.

1.2 SWMU 123 Site Description

SWMU 123 is identified as a former waste oil tank area and is located in the main petroleum, oil, and lubricant (POL) facility which is located on the eastern perimeter of the southeast corner of the Base off Delaware Road (Figure 2). The size, construction material, and exact location of the waste oil tank at SWMU 123 is unknown as the tank was previously removed and detailed
documentation is not available. The waste oil tank is assumed to have received wash water, waste oil, and fuels from the oil/water separator (OWS) located west of the former waste oil tank (Radian, October 1994). The PCS at SWMU 123 that are scheduled for excavation are located beneath the footprint of an existing wash rack and associated canopy.

1.3 Physiography

HAFB is located within the Sacramento Mountains Physiographic Province on the western edge of the Sacramento Mountains. HAFB is approximately 59,600 acres in area, and is located at a mean elevation of 4,093 feet above mean sea level (amsl). The region is characterized by high tablelands with rolling summit plains; cuesta-formed mountains dipping eastward and of west-facing escarpments with the wide bracketed basin forming the basin and range complex. HAFB is approximately 59,600 acres in area, and is located at a mean elevation of 4,093 feet above sea level. The Base is located in the Tularosa Sub-basin which is part of the Central Closed Basins. The San Andres Mountains bound the basin to the west (about 30 miles) with the Sacramento Mountains approximately 10 miles to the east. At its widest, the basin is about 60 miles east to west and stretches approximately 150 miles north to south.

The ground surface at SWMU 123 is relatively flat and covered with native vegetation, asphalt parking lots, and concrete walkways and driveways.

1.4 Surface Water

The Tularosa Basin contains all of the surface flow in its boundaries. The nearest inflow of surface waters to the Base comes from the Lost River, located in the north-central region of the Base. The upper reaches of the Three Rivers and the Sacramento River are perennial in the basin. HAFB is dissected by several southwest trending arroyos that control the surface drainage. Hay Draw arroyo is located in the far north. Malone and Rita’s Draw, which drain into the Lost River, and Dillard Draw arroyos are located along the eastern perimeter of the Base. Approximately 10,000 years ago, indications are of a much wetter climate. The present day Lake Otero encompassed a much larger area, possibly upwards of several hundred square miles. Its remains are the Alkali Flat and Lake Lucero. Lake Lucero is a temporary feature of merely a few inches in depth during the rainy season.

Ancient lakes and streams deposited water bearing deposits over the older bedrock basement material. Fractures, cracks, and fissures in the Permian and Pennsylvanian bedrock yield small quantities of relatively good quality water in the deeper peripheral. Potable water is only found from a handful of wells near the edges of the basin with more saline water towards the center. Two of the principal sources of potable water are a long narrow area on the upslope sides of Tularosa and Alamogordo with the other in the far southwestern part of the basin. Alamogordo’s water, as well as the Base’s, is supplied from Lake Bonito (which is in the Pecos River Basin).

Within the boundaries of SWMU 123, surface water runoff is controlled by the minimal topographic relief as per the existing grade and landscaping with surface drainage towards the...
adjacent parking area. Appurtenances can be found placed along the perimeter of the parking area to the north and southwest for collection into the Base storm water drainage system. Within the walled area of the site, open non-concrete areas will allow for precipitation to percolate downward and/or evaporate.

1.5 Groundwater

The predominance of the groundwater occurs as an unconfined aquifer in the unconsolidated deposits of the central basin, with the primary source of recharge as rainfall percolation and minor amounts of stream run-off along the western edge of the Sacramento Mountains. Surface water/rainfall migrates downward into the alluvial sediments at the edge of the shallow aquifer near the ranges, and flows downgradient through progressively finer-grained sediments towards the central basin. Because the Tularosa Basin is a closed system, water that enters the area only leaves either through evaporation or percolation. This elevated amount of percolation results in a fairly high water table. Beneath HAFB, groundwater ranges from 5 to 50 feet. Flow for the Base is generally towards the southwest with localized influences from the variations in the topography of the Base. Near the arroyos, groundwater flows directly toward the surface drainage feature.

Groundwater in the area of SWMU 123 flows in a southeast direction with a relatively flat hydraulic gradient (~0.01 feet/feet). The approximate depth to the water table at SWMU 123 is 11 feet.

1.6 Climate

As a whole, New Mexico has a mild, arid to semi-arid continental climate characterized by light precipitation totals, abundant sunshine, relatively low humidity, and relatively large annual and diurnal temperature range (Western Regional Climate Center (WRCC), 2003). The climate of the Central Closed Basins varies with elevation. The Base is found in the low areas and is characterized by warm temperatures and dry air. Daytime temperatures often exceed 100 degrees Fahrenheit (°F) in the summer months and are in the middle 50s in the winter. A preponderance of clear skies and relatively low humidity permits rapid night time cooling resulting in average diurnal temperature ranges of 25 to 35°F. Potential evapotranspiration, at 67 inches per year, significantly exceeds annual precipitation, usually less than 10 inches (Foster Wheeler/Radian, 1995). The very low rainfall amounts resulting in the arid conditions, which with the topographically induced wind patterns combining with the sparse vegetation, tend to cause localized “dust devils”. Much of the precipitation falls during the mid-summer monsoonal period (July and August) as brief, yet frequent, intense thunderstorms culminating to 30 – 40% of the annual total rainfall.

1.7 Geology

The sedimentary rocks which make up the adjacent mountain ranges are between 500 and 250 million years old (White Sands Missile Range (WSMR), 2003). During the period when the area
was submerged under the shallow intra-continental sea, the layers of limestone, shale, gypsum, and sandstone were deposited. In time, these layers were pushed upward through various tectonic forces forming a large bulge on the surface. Approximately 10 million years ago the center began to subside resulting in a vertical drop of thousands of feet leaving the edges still standing (the present day Sacramento and San Andres mountain ranges). In the millions of years following, rainfall, snowmelt, and wind eroded the mountain sediments depositing them in the valley (i.e. Tularosa Basin). Water carrying eroded gypsum, gravel, and other matter continues to flow into the basin.

As the Tularosa Basin is a bolson, which is a basin with no surface drainage outlet, sediments carried by surface water into a closed basin are bolson deposits. The overlying alluvium generally consists of unconsolidated gravels, sands, and clays. Soils in the basin are derived from the adjacent ranges as erosional deposits of limestone, dolomite, and gypsum. A fining sequence from the ranges towards the basin’s center characterizes the area with the near surface soils as alluvial, eolian, and lacustrine deposits. The alluvial fan deposits are laterally discontinuous units of interbedded sand, silt, and clay while the eolian deposits consist primarily of gypsum sands. The eolian and alluvial deposits are usually indistinguishable due to the reworking of the alluvial sediment by eolian processes. The playa, or lacustrine deposits, consist of clay containing gypsum and are contiguous with the alluvial fan and eolian deposits throughout HAFB. There has been the identification of stiff caliche layers, varying in thickness, at different areas of the Base. At the site, soils are predominantly silty sands and interbedded clays.

Lacustrine deposits are observed throughout HAFB. There has been the identification of stiff caliche layers, varying in thickness at HAFB. At SWMU 123, soils are predominantly silty sands and interbedded clays.

In general, subsurface soils at SWMU 123 consist of slightly moist clayey silts with varying amounts of medium to fine sand and caliche to depths ranging from 4 to 5 feet below ground surface (bgs). These soils display low to no plasticity and weak cementation of the caliche fraction. Generally, soils beneath 5 feet are characterized as silty medium to fine sands and sandy silts with occasional layers demonstrating higher percentages of clay content. Soils tend to be moist to saturated below the water table.
2 HISTORICAL DATA REVIEW

2.1 Initial Site Investigations

Previous excavation activities at SWMU 123 have occurred over two phases. The initial phase (Phase I) was conducted to remove PCSs which existed outside of the footprint of the wash rack foundation (and associated canopy) as, based on agreement with NMED and HAFB, soils with total recoverable petroleum hydrocarbons (TRPH) concentrations exceeding 1,000 milligrams per kilogram (mg/kg) that extended under large structures would not require remediation if the soil posed no potential health risk. The second phase of excavation activities (Phase II) was conducted to remove additional PCSs that were not addressed during the Phase I excavation activities.

2.1.1 Phase I Excavation

The initial site reclamation activities at SWMU 123 began in August 1995, and 50 cubic yards of PCS were removed during these activities (Foster Wheeler, April 1999). No tank was identified during the excavation activities and it was then held that the tank had already been removed. There is no known available data regarding confirmation samples collected after or during the removal of the contaminated soil.

2.1.2 Phase II Excavation

In March 1997, an additional 132.5 cubic yards of PCS were removed at SWMU 123. Following the completion of the field excavation, a total of 5 confirmation soil samples were collected and the results are presented in the Final Closure Report Addendum for Phase II Remediation of POL-Contaminated Site (Foster Wheeler, 1997). Four of the confirmation samples, laboratory analysis indicated concentrations of TRPH to be less than 1,000 mg/kg. The 5th sample, collected adjacent to the wash rack (and associated canopy), indicated TRPH concentration at 4,100 mg/kg and a benzene concentration of 33 mg/kg, above the HAFB allowable action limit for benzene of 25 mg/kg. Although the sidewall confirmation sample indicated that contaminated soils still existed, they were under the wash rack and thus unavailable for remediation. HAFB requested No Further Action (NFA) from NMED for the site.

2.1.3 Follow-up Investigation

Based on results of Phases I and II, NMED issued a Notice of Deficiency (NOD) requiring an additional investigation of the potentially contaminated soils beneath the wash rack (and associated canopy). Subsequent soil sampling was performed during January and February 1999 by Foster Wheeler (April 1999), and a total of 9 soil borings were completed beneath the wash rack (and associated canopy) floor/concrete pad. Three of the locations were not sampled as they were located over concrete footers for the surface pad. A total of 13 soil samples were collected from 4 to 9 feet bgs. Of the 13 samples analyzed, 6 had TRPH concentrations above the allowable NMED soil screening level (SSL) for jet fuel of 940 mg/kg. Analytical results for
TRPH ranged from a high of 7,400 mg/kg at 9 feet bgs to a low of less than 10 mg/kg or non-detect at 4 feet bgs. Individual petroleum-related constituents benzene, toluene, ethylbenzene, and xylene (BTEX) were also analyzed at that time. Benzene had a range of non-detect for four of the locations to 1.1 mg/kg and 0.7 mg/kg. None of the 13 soil samples collected exceeded the HAFB allowable benzene concentration of 25 mg/kg.

2.2 Subsequent Site Investigation

In April 2004, Bhate performed an additional site investigation to complete the delineation of the subsurface hydrocarbon contamination at SWMU 123. A total of five soil borings and nine direct push technology (DPT) locations were advanced during this investigation. The five soil borings were subsequently completed as 2-inch flush mount monitoring wells.

A total of 31 soil samples from 14 soil borings, including three duplicate samples, were submitted to the laboratory for analysis. One sample location (SB01), from 10 to 11 feet bgs, exhibited concentrations that exceeded applicable NMED residential SSLs for volatile organic compounds (VOCs). At this location, 1,2,4-trimethylbenzene was detected at 53.7 mg/kg and total xylenes were detected at 170 mg/kg. Their SSLs are 52.2 mg/kg and 132 mg/kg, respectively. Three semi-volatile organic compounds (SVOCs) were detected in the soil samples: 2-methylnaphthalene, naphthalene, and diethylphthalate. None of the SVOCs detected exceeded any applicable SSLs. Seven soil sampling locations contained detectable total petroleum hydrocarbons (TPH) concentrations: SB01, DP02, DP03, DP04, DP05, DP06, and DP08. Of these locations, the detectable concentrations for total TPH ranged from a low of 20.5 to a high of 3,940 mg/kg. Locations SB01 and DP04 were the only locations to have the total TPH concentrations that exceed the NMED SSL for jet fuel of 940 mg/kg.

Based on the findings of the investigation, the following conclusions and recommendations were developed (Bhate, November 2004):

- Groundwater hydrocarbon contamination in excess of New Mexico Water Quality Commission Criteria (NMWQCC) standards exists at the site in the proximity of monitoring wells MW-1, MW-2, and MW-3. The plume has a southeasterly trajectory and is predicted to be relatively narrow due the non-detect results for the adjacent monitoring well MW-5 and only trace amount in MW-3 groundwater samples. The farthest southerly extent of the contamination is unknown as there is no definitive end-point or non-detect determined for the southern projection of the plume. An additional downgradient well installation would fill the data gap.

- Free product was found in MW-1 with an initial measured thickness of 1.41 feet. This product thickness has been reduced to 0.11 feet and will require continued removal using conventional pumping/skimming methods.

- Soil contamination in the form of TPH concentrations greater that the NMED SSL of 880 mg/kg (for diesel-crankcase oil) is confined to a relatively small area centered at DP04 and...
SB01. The contamination is estimated to occur just above the water table (12 feet bgs) to approximately 9 feet bgs with an estimated volume of impacted soil of less than 250 cubic yards.

The NMED allowable limit for benzene is 27 mg/kg (NMED, February 2004). The results of the April 2004 (from the November 2004 Bhate report) investigation are summarized in the tables attached as Appendix A.
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3 EXCAVATION PROCEDURES

The objective of the soil excavation at SWMU 123 is to excavate, transport, and dispose of impacted subsurface soils that either have TPH levels exceeding 880 mg/kg (the NMED SSL for diesel-crankcase oil) or soils posing a risk due to exposure to VOCs and/or SVOCs as established by the NMED soil screening guidance. Contaminated soils will be removed to approximately 15 feet below the site's existing concrete slab grade. This depth will ensure complete removal of PCS and account for any potential smear zone. Horizontally, the excavation will be completed based upon TPH levels greater than 880 mg/kg as determined by confirmation soil samples collected from the excavation and analyzed by Accutest Laboratories. The estimated extent of soils to be removed is shown in Figure 3.

At this time, excavation is proposed to extend 12 feet beyond the north and east building line and will not extend beyond the building line on the west and south sides. Except where noted below, the excavation activities will prescribe to the procedures outlined in Unified Facilities Guide Specifications (UFGS) Section 02111 Excavation and Handling of Contaminated Material, September 2003 (Appendix B). The UFGS are a joint effort of the USACE, the Naval Facilities Engineering Command (NAVFAC), and the Air Force Civil Engineer Support Agency (AFCESA). The UFGS are for use in providing construction specifications and guidelines for the military services.

3.1 Pre-Excavation Activities

The construction general permit requires a project Storm Water Pollution Prevention Plan (SWPPP) to be submitted for excavation sites which will disturb greater than one acre of surface soils. For the planned activities, inclusive of the temporary clean soil stockpiles, the total area of disturbance and/or excavation is less than one acre. Therefore, a project SWPPP will not be prepared and submitted.

Before excavation and other site activities can begin, there are several pre-construction documents and approval requirements to be met, including: Air Force Form (AF Fm) 332 approval, dig permit with utility clearances, site security measures, and facility manager notification of the intended operations. Bhate will coordinate project requests for Base installation support services through the 49th Civil Engineering Squadron/Combat Engineer Vehicle (CES/CEV). Pertinent to the start of activities, a pre-construction meeting and site walkthrough will be conducted with the USACE Resident Engineer, HAFB personnel, and the Bhate Site Manager to inspect site conditions for site/equipment access, equipment staging area(s), soil stockpile areas, potential site hazards, and emergency evacuation routes. Also reviewed at this time will be project procedures in accordance with the schedule and planned activities.

3.1.1 AF Form 332

The completed and approved AF Fm 332 for this site, included as Appendix C, authorizes construction work at HAFB and is required for the initiation of any construction work. This
work order describes what activities will take place at the location. Also, the AF Fm 332 is the mechanism by which the utility clearance/dig permit is authorized. Both the AF Fm 332 and dig permit were reviewed by the appropriate Base utility group for approval to begin work at the excavation site. Prior to the submittal of AF Fm 332, the area of excavation was clearly delineated with marker flags, stakes, or paint, as appropriate to the surface material.

3.1.2 Dig Permit/Utility Clearances

As noted above, utility clearance approvals will be completed by the appropriate HAFB utility office. Upon receipt of the approved dig permit with the utility clearances, the Bhate Site Manager or other authorized project personnel will complete a site walk-through confirming the dig permit authorizations and make any required changes.

Any utilities adjacent to the planned excavation boundary noted during the site reconnaissance will be properly identified and located. All necessary measures to secure the utility from potential damage and/or service interruption will be implemented prior to excavation.

3.1.3 Excavation Area Site Safety

As an Occupational Safety and Health Administration (OSHA) Class II excavation, site safety is concerned with the excavation and the areas around the excavation. Concerns include: the proper designation and demarcation of construction boundaries (i.e. exclusion zone [EZ], contamination reduction zone [CRZ], and support zone [SZ]), compliance with excavation requirements, posting of potential hazards, and control of un-authorized site personnel. This is discussed in the 2003 Basewide Health and Safety Plan (HASP) (Bhate, December 2003). Notification of the excavation activities will be provided to the appropriate personnel with the POL Yard prior to the initiation of any field activities.

At a minimum, the site will be secured with caution tape surrounding the perimeter of the site delineating the outer boundary of the SZ. This is essential in the utility clearance process and it serves as the demarcation of the site for both project and non-project persons. A CRZ and/or EZ will be established as guided by the HASP and prevailing site conditions. The depth to the bottom of the excavation will extend to the water table and is expected to reach 15 feet below grade. At the immediate edge of the excavation, a temporary construction fence will be erected completely around the excavation site. Postings will indicate the excavation hazard as well.

3.2 Decontamination Procedures

Small equipment, such as sampling tools, will be decontaminated in accordance with the Basewide Quality Assurance Project Plan (QAPP) (Bhate, November 2003). Heavy equipment, such as the backhoe, trackhoe, etc., will be decontaminated at a temporary decontamination pad set up at the site.
3.3 Excavation Activities

3.3.1 Excavation Boundary

The approximate limit of the area to be excavated during activities outlined under this VCM Work Plan is shown on the Shoring Plan on Figure 4. Based upon the estimated horizontal extent of contamination, an estimated 2,700 cubic yards (cu yds) of overburden will be required to be removed. This material will be directly loaded into a dump truck for immediate delivery to FT-31 Landfarm for treatment or stockpiling.

Prior to the excavation of overburden, the concrete drive-up pad, three concrete utility pads, and approximately 8 feet of asphalt paving will be removed. All construction debris will be disposed of at the Base re-use area for processing.

3.3.2 Canopy Shoring

Prior to any excavation activities, the existing pre-fabricated metal building under which the excavation activities will be performed will require the installation of a modular frame shoring system. The modular shoring system will be erected in accordance to the shoring specifications of Patent Construction Systems (see Figures 5, 6, and 7). The shoring system consists of 4-foot wide shoring frames, 24-inch adjustable screw jacks, base plates, cross braces, stringer beams, soldier beams, and the required hardware to clamp the shoring system to the existing building. The Shoring Plan is shown on Figure 4. Three of the four girder beams on the north side of the canopy will require the installation of the shoring system to support the weight of the wash rack (and associated canopy) (Figure 5). To properly support the canopy during the excavation activities, which requires the removal of soils beneath the north side building foundation, there will be a separate shoring unit placed at each building girder with each unit able to support a maximum allowable load of 41,000 pounds as shown in Figures 6 and 7.

Once all canopy shoring has been installed, an elevation survey of the top of each canopy support column foundation will be performed to establish existing top elevations. As excavation commences and soils are removed from beneath the building foundation, elevation surveys will be performed a minimum of twice per shift to assure that the existing foundation does not settle (see Appendix D for foundation plan drawings that were prepared by the CES). Major settling is not anticipated. If elevation surveys determine that the shoring system does not properly support the building despite attempts to adjust the shoring system, immediate measures will be taken to replace removed soils from beneath the building foundation and alternate shoring or stabilization methods will be evaluated and implemented including but not limited to additional shoring.

3.3.3 Excavation Shoring

During excavation activities, the excavation will be benched to provide access for hand work and density testing. Excavation activities associated with previous investigations at different locations on HAFB indicate native soils demonstrate significant stability, achieving near vertical
walls, during excavations. The soils surrounding SWMU 123 are considered native soils to within 4 feet of the building limits. Inside 4 feet from the building limits and under the building concrete foundations and pad the soils are considered structural fill to a depth of 4 feet and native soil from 4 feet below grade to the excavation depth limit. At this time, stabilization of the excavation sidewalls is not intended; however, monitoring of the excavation sidewalls will be performed as the excavation progresses. If any slumping or sidewall failure is evident, then alternate stabilization methods will be evaluated and implemented including but not limited to sloping, benching, or shoring.

3.3.4 Soil Excavation

Excavation activities will utilize the appropriate excavation equipment and a wheel loader to assist with soil management and will be performed in accordance with UFGS Section 02315 Excavation, Filling and Backfilling for Buildings (see Appendix E). All overburden soils will be directly loaded into a dump truck and hauled to the FT-31 overburden stockpile. All overburden soils will be directly loaded into a dump truck and hauled to the FT-31 overburden stockpile. Soil (backfill) stockpiles will be managed as to not allow for any material to be removed or transported off-site via wind or precipitation (see Section 6 of this Work Plan, Waste Management).

The contaminated subsurface smear zone is estimated to begin directly below the bottom of concrete. All contaminated soils will be directly loaded and transported to FT-31 Landfarm for management. Applicable procedures and safety measures for completing the excavation are located in the Basewide Health and Safety Plan (Bhate, December 2003) will be followed. Applicable HAFB Standard Operating Procedures (SOPs) for completing the sampling associated with this excavation are located in Appendix A of the Basewide Quality Assurance Project Plan (Bhate, November 2003).

3.3.4.1 Soil Screening

Throughout the excavation, observation of discoloration and unusual odors will be documented. Potential PCS will be field screened for petroleum hydrocarbon contamination using the SiteLAB® Analytical Test Kit Ultraviolet Fluorometer (UVF) 3100A in accordance with the U.S. Environmental Protection Agency (USEPA) Field Measurement Technologies for Total Petroleum Hydrocarbons in Soil guideline (see Appendix F of this Work Plan). Excavated soil will be segregated in the field based on visual observation, headspace readings, and onsite analysis of TPH with laboratory confirmation. Soils that demonstrate a field screened TPH concentration above 880 mg/kg exceed the action limit for PCS and will be managed in accordance with Section 6 of this Work Plan. Soils demonstrating a concentration below 880 mg/kg will be stockpiled for backfill once the excavation is complete. The excavation sampling quantities and analyses are summarized in Table 3-1.

The field screening incorporates the initial screening for the segregation of the excavated soils between contaminated and un-contaminated and the corresponding Quality Assurance/Quality
Control (QA/QC) confirmation and validation analyses. The soil screening is comprised of three phases: 1) initial field screening, 2) field confirmatory, and 3) laboratory validation. These steps are detailed in Section 4, *Soil Sampling and Analysis*, of this Work Plan.

### 3.3.4.2 Soil Segregation

The 880 mg/kg action level for PCS is found listed in Table 2 of the residential direct exposure limit for diesel fuel in the *NMED TPH Screening Guidelines*, June 24, 2003 (Appendix G). This cleanup level is part of a previous agreement between HAFB and NMED. The concentrations for the TPH carbon fractions will be summed for the total TPH value as the comparison to the NMED TPH allowable limit of 880 mg/kg for diesel contaminated PCS.

The un-impacted soils are the overburden soils which have historically demonstrated no contamination and the source of the contamination is not from a surface release. These soils are from the surface to an approximate depth of 4 feet bgs, approximately 400 cu yds. Suspected contaminated soils are those primarily within the smear zone. These are typically contained in a 1 to 2 foot zone above the contaminated soils. They will be found in the depth range from 3 to 5 feet bgs with an approximate volume of 200 cu yds. The contaminated soils are those that are definitively contaminated as validated by laboratory analytical data. These soils are typically the lower 3 feet just above the water table, in a depth range from 5 to 8 feet bgs, approximately 300 cu yds. Due to the small size of this site, suspected contaminated soils will be handled as though they are contaminated, directly loaded and transported to the FT-31 Landfarm for treatment or stockpiling.

### 3.3.4.3 Confirmation Soil Sampling

After the excavation is complete and all suspected petroleum contaminated soils have been removed, sidewall confirmation samples will be collected. Samples will be collected using the bucket of the back-hoe. A soil sample will be obtained from the interior of the bucket to minimize the potential for outside source contamination. Samples will be collected at a frequency of 1 per 20 linear feet (in ft) per side wall at mid-depth of the contamination zone. At a minimum, 1 sample per side wall will be collected.

### 3.3.5 Excavation Backfilling and Compaction

Clean soils will be obtained for backfill as needed from a local sand/gravel provider. In areas not directly under an existing foundation, below 6 feet bgs, the backfill will be placed in 24-inch lifts and compacted using a remote controlled hydraulic plate compactor lowered into the excavation by heavy equipment (see Appendix H of this Work Plan) to at least 18 inches. For depths from 6 feet bgs to 1 feet bgs, the excavation will be backfilled in 9-inch lifts with compaction to at least 6 inches.

For areas directly under foundations, below 6 feet bgs, the backfill will be placed in 24-inch lifts and compacted to at least 18 inches using a remote controlled hydraulic plate compactor lowered into the excavation by heavy equipment. For depths from 6 feet bgs to approximately 3 feet bgs...
depending on the height of the remote controlled compactor, the excavation will be backfilled in 9-inch lifts with compaction to at least 6 inches. The remaining fill required to reach the bottom of the existing foundation will be controlled low-strength material (CLSM) more commonly referred to as flowable fill.

The compaction of the two base soils lifts in all areas will be confirmed by determination of the soil density via an in-place nuclear densitometer, or similar test per American Society for Testing and Materials (ASTM) Method D 2922 (see Appendix I of this Work Plan).

The final 12-inches of backfill in areas not directly beneath foundations will adhere to the specifications of subgrade preparation found in UFGS Section 03307 Concrete for Minor Structures (see Appendix J of this Work Plan) and as discussed in Section 3.3.7.1 of this Work Plan, Minor Concrete Reconstruction.

In areas directly beneath foundations, the final backfill, CLSM, will be designed in accordance with the flowable fill specifications in Appendix K of this Work Plan and placed according to American Concrete Institute (ACI) publication, ACI 229R-99 (see Appendix L of this Work Plan).

While major settling is not anticipated, the loss of approximately 1/4-inch in elevation during the curing of the CLSM is expected to occur, as the CLSM will shrink approximately 1/8-inch per foot of depth.

3.3.6 Soil Disposal

Contaminated soils will be transported to the permitted FT-31 Landfarm for treatment/processing or stockpiling. Soils will be handled, transported, and managed in accordance with the NMED guidelines and the facility's requirements.

3.3.7 Site Restoration

Upon completion of site excavation and backfill activities, the site will be restored to its original appearance. Construction equipment and debris will be removed. The site will be canvassed for trash, debris, etc. Final grade for areas of the site which will not have a surface improvement upon them will allow for positive drainage in accordance with the surrounding area.

3.3.7.1 Minor Concrete Reconstruction

The section(s) of minor concrete which have been removed or damaged during the excavation will be replaced in similar construction and match in appearance to that which was removed. The design and construction, inclusive of materials, will be completed in accordance with the UFGS specifications for minor structures, Section 03307 Concrete for Minor Structures, August 2004 (see Appendix J of this Work Plan). Matching of the new minor concrete structures to the existing structures has primacy over the UFGS guideline. The guideline should be adhered to utilizing best management practices and holding to the intent of the guideline.
3.3.7.2 Structural Concrete Restoration

The section(s) of structural concrete which have been removed or damaged during the excavation will be replaced in similar construction and match in appearance to that which was removed. The design and construction, inclusive of materials, will be completed in accordance with the UFGS specifications for cast-in-place structural concrete, Section 03300 Cast-in-Place Structural Concrete, January 2005, and the UFGS specification Section 01610 Aggregate for Portland Cement Concrete (see Appendix M of this Work Plan). Matching of the new structural concrete to the existing concrete has primacy over the UFGS guideline. The guideline should be adhered to utilizing best management practices and holding to the intent of the guideline.

3.3.7.3 Landscaped Areas

The areas of landscape material which are removed or damaged during the excavation will be replaced with similar design and match in appearance to that which was removed.

3.3.7.4 Asphalt Parking Area

The area of vehicle parking or traffic which is removed or damaged during the excavation will be replaced in similar construction and match in appearance to that which was removed. The design and construction, inclusive of materials, will be completed in accordance with the UFGS guideline for asphalt paved areas, Section 02741N Bituminous Concrete Pavement, September 1999 (see Appendix N of this Work Plan). Matching of the new paved area to the existing paved area has primacy over the UFGS guideline. The guideline should be adhered to utilizing best management practices and holding to the intent of the guideline. The UFGS guideline allows for references to the specific State of which construction is to be completed for the design specifications. The New Mexico Highway Department State Highway Specifications, specifically Division 416 Minor Paving, provides the applicable guidelines for completion of repaving a vehicle parking area (see Appendix O of this Work Plan). This UFGS shall be implemented in its entirety except for the following parts and/or subparts:

- Sections 1.1 and 1.2
- Sections 3.0 through 3.2
- Sections 2.0 through 2.10
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4 SOIL SAMPLING AND ANALYSIS

The project soil sampling requirements, detailed in Table 3-1, include field screening samples, stockpile samples, and confirmation samples. Table 4-1 provides the sample collection information inclusive of the container type, quantity, and holding times.

4.1 Field Screening Sampling

Soils will be periodically field screened using soil-headspace screening techniques via a field organic vapor analyzer (OVA). Confirmatory field TPH analysis of the OVA headspace samples will be performed with the field fluorometer in accordance with the USEPA Innovative Technology Verification Report: Field Measurement Technologies for Total Petroleum Hydrocarbons in Soil, September 2001 guideline (see Appendix F of this Work Plan). From these samples, final QA confirmation analysis in accordance with the NMED specified gas chromatogram (GC) methods will be accomplished via a fixed-base laboratory.

4.1.1 Initial Field Screening

HAFB excavation guidelines for PCS require initial field screening via headspace analysis every 100 cubic yards. This sampling scheme would allow for only 3 field screening samples and a single field confirmatory sample. To improve the accuracy of the screening of the excavated soils, field screening frequency will increase to one sample per 50 cubic yards removed for a total of 6 samples to be screened via the OVA.

4.1.2 Field Confirmatory Sampling

A field confirmatory frequency of 50% with the SiteLAB® Analytical Test Kit UVF-3100A will be implemented instead of the normal 10% per the USACE and USEPA (SW846) guidelines for QA/QC requirements of site investigations for contamination. The adjusted resulting quantity is a total of 3 of the 6 samples to be field checked with the SiteLAB®. This test uses a 10-gram sample of soil where petroleum compounds are extracted with methanol. The extract is decanted into a quartz cuvette and placed in the chamber of the UVF and the TPH concentration is displayed. Although the NMED clean-up level is 880 mg/kg, soils resulting in a headspace reading with the UVF above 790 mg/kg will be designated TPH contaminated, allowing for a 10% instrument error and variability between the screening method and the USEPA Method analyses.

4.1.3 Laboratory Validation

Laboratory validation frequency of the UVF screening samples will be at 10%, or 1 sample per site minimum. Laboratory validation will be completed using USEPA Method 8015M for TPH-gasoline range organics (TPH-GRO) [C₆-C₁₀], TPH-diesel range organics (TPH-DRO) [C₁₀-C₂₂], and TPH-oil range organics (TPH-ORO) [C₂₂-C₃₆]. Laboratory analyses will be completed at an expedited turn-around-time of 24 hours.
4.2 Excavation Confirmation Sampling

Excavation confirmation samples will be collected at the frequency of one per 20 linear feet of each sidewall within the contamination zone at mid-depth. Analytical confirmation sampling from the bottom of the excavation is not required because excavation will be terminated at one foot below the water table. Samples will be analyzed by a fixed-base laboratory for TPH, TPH-DRO, and TPH-GRO, using USEPA Method 8015M, VOCs (USEPA Method 8260B), and SVOCs (USEPA Method 8270C). If any single sample demonstrates a TPH level above the NMED soil value for TPH of 880 mg/kg, excavation will continue along that face until field screening deems termination with re-evaluation via laboratory confirmation analysis. Data will adhere to project data quality objectives (DQO) requirements, method reporting limits, duplicate field samples, and QC samples as established within the Basewide Quality Assurance Project Plan (Bhate, November 2003). Sample quantities, containers, methods of preservation, and holding times will be consistent with the requirements of associated method protocols. Laboratory analyses will be completed at a rush turn-around-time, 24-hours.

4.2.1 Stockpile Sampling

Stockpiled overburden soils will be sampled every 500 cu yds. Laboratory analyses will be completed at an expedited turn-around-time, 24 hours with analysis for TPH, -DRO and -GRO, using USEPA Method 8015M, VOCs (USEPA Method 8260B), and SVOCs (USEPA Method 8270C).

4.2.2 Analytical Methods

Each laboratory soil sample (including the field duplicates) will be analyzed for their respective analytes in accordance with Table 4-2. Samples will be analyzed for BTEX, as VOCs, by Method 8260B, polynuclear aromatic hydrocarbons (PAHs), as SVOCs, by Method 8270C, TPHs and carbon fractions (Table 4-3) by Method 8015M.

Laboratory analyzed samples will be completed by Accutest Laboratories in Orlando, Florida. A copy of their USACE validation is included in Appendix P of this Work Plan.
5 RISK BASED CLEAN-UP APPROACH

The objective of the excavation activities presented is to remove contaminated soil from the site to support closure of the site. Data collected as a result of field screening will be evaluated based on the DQOs of the project. The results from the off-site laboratory confirmation samples from the sidewalls of the excavation will be evaluated to determine whether excavation activities at the site have removed the contaminated soil to the point where there is an acceptable risk given possible exposure at the site. If the completed evaluation indicates an acceptable risk, then no further excavation will be required and the site can be considered for closure with no further action.

5.1 Evaluation of TPH

Based on the direction provided by NMED pertaining to the remediation of petroleum-impacted sites at HAFB, a TPH screening level of 880 mg/kg will be used to evaluate the data provided by the off-site analytical laboratory. As discussed in Section 4 of this Work Plan, Soil Sampling and Analysis, the 880 mg/kg action level for PCSs is the Residential Direct Exposure Limit for diesel fuel, listed in Table 2 of the NMED TPH Screening Guidelines, June 24, 2003 (see Appendix G of this Work Plan).

5.2 Evaluation of VOCs and SVOCs

For any VOCs or SVOCs that are detected in soil, the concentration will be evaluated against the screening levels provided in Appendix A of the revised NMED guidance document Technical Background Document for Development of Soil Screening Levels, Revision 2.0, February 2004 (NMED, 2004). Tables containing the SSLs from this guidance document are provided in Appendix Q of this Work Plan. The laboratory data for each collected soil sample will be compared to these SSLs.
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6 WASTE MANAGEMENT

Construction-derived waste (CDW) generated by the activities of this excavation may include excavated soil, decontamination residuals, and personal protective equipment (PPE) (see Table 6-1). Each of these waste streams will be managed and characterized according to the guidelines discussed below. Waste containers and the decontamination pad will be managed in a secure area.

6.1 Excavated Soil

6.1.1 Clean Soils – Stock Piles

The clean soil stockpiles will be constructed in accordance with best management practices (BMPs) to mitigate soil loss due to erosion, wind, and run-off. These BMPs may include the use of a plastic liner, straw bales for berming or silt fencing, and a cover. Soils will be placed on thick plastic sheeting within a constructed berm for protection from off-site transportation by wind and rain until characterization is complete. If laboratory analysis indicates concentrations are below the SSL for TPH of 880 mg/kg, and the SSL for each individual VOC and SVOC constituent, the stockpiled soil will be used as backfill once the excavation activities are complete.

6.1.2 Contaminated Soils – Base Landfarm

Excavated contaminated soils will be handled in accordance with Sections 3 and 4 of this Work Plan. Contaminated soils will be directly loaded and transported to the selected location for treatment and/or disposal at either the FT-31 Landfarm or an off-site subcontractor location.

6.2 Decontamination Water

Decontamination water is anticipated to be non-hazardous and as such, can be disposed of through the HAFB wastewater treatment plant (WWTP). When feasible, decontamination water will be allowed to evaporate from the decontamination pad area. Sediment remaining in the decontamination pad area after the water has either evaporated or has been discharged to the WWTP will be combined with the excavated contaminated soil for disposal.

6.3 Personal Protective and Disposable Sampling Equipment

PPE and other site non-hazardous debris/waste shall be placed in plastic trash bags and disposed in a standard trash dumpster or receptacle as directed by HAFB personnel.
6.4 Construction Debris

Unless visibly stained, all construction debris will be assumed to be uncontaminated and non-hazardous and will be disposed of accordingly at the Base re-use facility. Stained construction debris will be disposed of in accordance with HAFB procedures.
7 PROJECT QUALITY ASSURANCE

The laboratory performing the chemical sample analysis will follow the Site Specific Addendum to the Basewide QAPP (Bhate, August 2005) provided as Appendix R to this Work Plan.

7.1 Standard Operating Procedures

Applicable SOPs for completing the sampling associated with excavation at SWMU 123 are located in Appendix A of the Basewide QAPP (Bhate, November 2003).

7.2 Sample Identification

Each sample will be identified on the sample label and chain-of-custody (COC) records for each sample collected, regardless of type. Field duplicates will be paired with another sample and will be classified as blind samples. The duplicate samples will appear in sequence with the regular samples. Sample nomenclature will adhere to the procedures and guidelines established in the Basewide QAPP. Sample labeling will adhere to the format provided in the Basewide QAPP and/or QAPP project addendum.

7.3 Project Documentation

The field operations documentation will provide consistent procedures and formats for documentation and management of field records and collected samples.

7.3.1 Sample Documentation

Sample documentation, identification, and tracking will adhere to the prescribed methods found in the Basewide QAPP and/or its respective project-specific addendum. All sampling activities will include documentation of significant activities, potential environmental influences during sampling, field variances, and sample identification information. At a minimum, field logbooks will be utilized to record dates and times, sampling protocols, project numbers, and sampler’s name. Daily Quality Assurance Reports will be completed and submitted weekly to the HAFB Project Manager. Other pertinent information will include COC numbers and air bill tracking numbers. COC forms will be completed and included with each sample shipment; one COC per cooler.

At a minimum, the following sample collection information will be logged in the field book:

- Date and time
- Sample identification number
- Project number
- Sampler name
- Preservative (if any)
7.3.2 Field Logbook

Personnel will use only bound field logbooks for field records. The Project Manager will ensure that all field notes can be efficiently traced, filed, and retrieved. All entries will be recorded in indelible, waterproof ink. If errors are made, corrections will be made by crossing a single line through the error, correcting the information, and initialing and dating the correction. Entries will be made as described below.

Documentation and reporting of events and activities will be made in chronological order on the right page of the logbook. All entries will be dated and time of entry recorded. At the beginning of each day, the first two entries will be “personnel/contractors on site” and “weather”. At the end of each day’s entry, the personnel will draw a diagonal line originating from the bottom left corner of the page to the conclusion of the entry and sign along the line indicating the conclusion of the entry or the day’s activity. Once completed, the field logbooks become documents that can be used to account for project activities and will be maintained as part of the project files.

The following general requirements apply to field logbooks:

- The left page of the logbook will be used for auxiliary reporting such as sketches, tables, etc.
- The date will be recorded in the top, left-hand corner of each right page.

The time of entry recordings will be in columnar form down the left-hand side of the right page.

7.3.3 Field Analytical Data

The field analytical data collected at the site will include the field screening readings for selection of PPE, as well as field screening for headspace analysis. The breathing zone of the site will be screened for VOCs in the field at the time of sample collection utilizing an OVA. If a high humidity condition exists at the time of sample collecting, a flame-ionization detector (FID) is recommended since a photo-ionization detector (PID) is not a completely reliable screening instrument under these conditions. The field screening data will be recorded in the field logbook.
7.3.4 Data Reporting

Data obtained during the excavation, through confirmation or field screening samples, will be reported according to the Basewide QAPP (Bhate, November 2003). In accordance with USACE EM200-1-6, the investigative data is classified as definitive data. The data will be generated using rigorous, analyte-specific analytical methods where analyte identifiers and quantitations are confirmed and QA/QC requirements have been satisfied. For this project, regular, field duplicate and matrix spike/matrix spike duplicate (MS/MSD) samples are to be collected concurrently. The data meet the objectives of the project for level of accuracy and precision required, intended use of the data, analytical methods, time constraints, and allowable decision errors. Risk evaluation and sampling results will be tabulated and summarized in the VCM report for the site. An Environmental Restoration Program Information Management System (ERPIMS) submittal is not required for this project.
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8 HEALTH AND SAFETY REQUIREMENTS

Project health and safety practices during the excavation activities will adhere to the Basewide Health and Safety Plan (HASP) (Bhate, December 2003) and the Site Specific Addendum to the Basewide HASP, included in Appendix S of this Work Plan. It is anticipated that no greater than modified level D PPE will be required to complete the site inspection and sampling activities. This includes: OSHA-approved safety shoes, American National Standards Institute (ANSI) approved safety glasses (Z87.1) and hard hat (Z89.1-1997: Type I), long-sleeved shirt and long pants, and as required, hearing protection, leather work gloves, and/or nitrile gloves.

The site must also be secured to further ensure safety at the site. Of concern is the proper designation and demarcation of the excavation boundaries (i.e., SZ, CRZ, and EZ), as appropriate. Likewise, compliance with any intrusive work requirements, posting of potential hazards, and control of unauthorized site personnel will be completed as directed in the Basewide HASP. At a minimum, the site will be secured with caution tape surrounding the perimeter of the site and delineating the outer boundary of the SZ. This is essential in the utility clearance process and it serves as the demarcation of the site for both project and non-project-related individuals. A CRZ and/or EZ will be established as guided by the HASP and site prevailing conditions.

Excavation depths are expected to exceed 15 feet. Sidewall benching will not be completed.
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9 ORGANIZATION AND SCHEDULE

During the corrective measures activities at the site, Mr. John Hymer will serve as the Bhate Site Manager overseeing and directing all investigation sampling activities. Mr. Hymer will also provide on-site management of any subcontractors for the project. Mr. Frank Gardner is the Bhate Program Manager and will ensure required project documents, permits, contractual agreements, and other program tasks are completed. Key project personnel are listed in Table 9-1. Activities associated with this Work Plan are anticipated to begin at the end of August and last approximately 2 weeks.
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10 REFERENCES


NMED. February 2004. Soil Screening Levels Revision 2.0.


State of New Mexico Department of Transportation Specifications Section 416 Minor Paving.


UFGS. Guide Specification for Construction, Section 01610 *Aggregate for Portland Cement Concrete.*

UFGS. Guide Specification for Construction, Section 03300 *Cast-in-Place Structural Concrete.*


FIGURES
NOTE: This information is depicted to provide visual aid within the context of this workplan and should not be used as a sole reference in distances and locations of features indicated.
Figure 2

VCM Work Plan
SWMU 123
Holloman Air Force Base
Alamogordo, New Mexico
LEGEND:

- OPT LOCATION (CONCENTRATION)

- SOIL BORING/MONITORING WELL (CONCENTRATION)

- TPH > 940mg/kg (IMPACTED SOIL)

- EXTENT OF IMPACTED SOILS

- SWMU 123

VCM Work Plan
SWMU 123
Holloman Air Force Base
Alamagordo, New Mexico

Figure 3
NOTE:
INCLINED LEG
LOAD = 5125 LBS

PLAN: 10K RESHORING LAYOUT
SCALE: 1/8" = 1'0"

EXISTING ORDER (TYP.)
MAX. ALLOWABLE
LOAD= 41000 LBS

NOTE:
INDUCED LEG
LOAD= 5125 LBS

WEDGE AS REQ'D
BY CONTR.
TWO(2) 8'-10" LC
SOLDER BEAMS
TWO(2) 7'-10" LC
DUAL ALUM. BEAMS
BEAM CLIP
TWO(2) 5' LG. 7.25"
ALUM. STGRS.
BX8 U-HEAD
24" ADJ. SCREWED

UNIVERSAL CLAMP
(TYP.)

4"WX8' FRM.

TUBELOX STABILITY BRACING
ATTACHED TO LEGS WITH
RA CLAMPS (TYP.)

CONNECTOR PIN

4"WX8' FRM.

24" ADJ. SCREWED

BASE PLATE

SILL AS RED'D.
BY CONTR.

SECTION A
SCALE: 3/8" = 1'0"

ENGINEERING, SCIENCE AND CONSTRUCTION

CANOPY RESHORING LAYOUT

SECTION A

VCM Work Plan
SWMU 123
Holloman Air Force Base
Alamagordo, New Mexico

Source: Patent Construction Systems

Figure 6
VOLUNTARY CORRECTIVE MEASURES WORK PLAN

SWMU 123

HOLLOMAN AFB, NEW MEXICO

TABLES
Table 3-1. Excavation Sampling Quantities and Analysis

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Contamination Profile</th>
<th>Purpose</th>
<th>Frequency</th>
<th>Estimated Quantity</th>
<th>Method/Analyses</th>
<th>Requested Analyses Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Screening</td>
<td>Un-impacted Soils</td>
<td>Initial Field Screening</td>
<td>Every 50 cu yds</td>
<td>6</td>
<td>OVA: VOCs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field Confirmatory</td>
<td>Every 100 cu yds</td>
<td>3</td>
<td>UVF: TPH</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laboratory Validation</td>
<td>Every 100 cu yds</td>
<td>1</td>
<td>Laboratory: TPH, VOCs, and SVOCs</td>
<td>24 hrs</td>
</tr>
<tr>
<td></td>
<td>Suspected Contaminated and Contaminated Soils (contamination zone)</td>
<td>Initial Field Screening</td>
<td>Every 50 cu yds</td>
<td>6</td>
<td>OVA: VOCs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field Confirmatory</td>
<td>Every 100 cu yds</td>
<td>3</td>
<td>UVF: TPH</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laboratory Validation</td>
<td>Every 300 cu yds</td>
<td>1</td>
<td>Laboratory: TPH</td>
<td></td>
</tr>
<tr>
<td>Stock Pile</td>
<td>Un-impacted Soils</td>
<td>Backfill Characterization</td>
<td>Every 500 cu yds</td>
<td>2</td>
<td>Laboratory: TPH, VOCs, and SVOCs</td>
<td>24 hrs</td>
</tr>
<tr>
<td>Excavation Confirmation</td>
<td>Un-impacted Soils</td>
<td>Closure</td>
<td>Every 20 ln ft, at mid-depth within contamination zone, minimum of 1 per side wall</td>
<td>4</td>
<td>Laboratory: TPH, VOCs, and SVOCs</td>
<td>7 days</td>
</tr>
</tbody>
</table>

NOTES: cu yds = Cubic yards; ln ft = Linear feet; TPH = Total Petroleum Hydrocarbons; VOCs = Volatile organic compounds; SVOCs = Semi-volatile organic compounds; hrs = Hours; UVF = Ultraviolet fluorometer; OVA = Organic vapor analyzer
Table 4-1. Sample Collection Information

<table>
<thead>
<tr>
<th>Soil Collection Information</th>
<th>VOC (8260B)</th>
<th>SVOC (8270C)</th>
<th>TPH (8015M)</th>
<th>Soil Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container</td>
<td>Encore</td>
<td>4 oz glass jar</td>
<td>Non-preserved 40-mL vial (Terra-core)</td>
<td>8 oz glass jar</td>
</tr>
<tr>
<td>Container Quantity</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Holding Time</td>
<td>24 hrs</td>
<td>7 days</td>
<td>7 days</td>
<td>14 days</td>
</tr>
</tbody>
</table>

**NOTES:** hrs = Hours; oz = Ounce; mL = Milliliter; TPH = Total petroleum hydrocarbons; VOCs = Volatile organic compounds; SVOCs = Semi-volatile organic compounds
### Table 4-2. Sample Analytes and Methodologies

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTEX (VOCs)</td>
<td>EPA Method 8260B</td>
</tr>
<tr>
<td>PAH (SVOCs)</td>
<td>EPA Method 8270C</td>
</tr>
<tr>
<td>TPH (GRO/DRO/ORO)</td>
<td>EPA Method 8015M</td>
</tr>
</tbody>
</table>

**NOTES:** TPH = Total petroleum hydrocarbons; VOCs = Volatile organic compounds; SVOCs = Semi-volatile organic compounds; GRO = Gasoline range organics; DRO = Diesel range organics; ORO = Oil range organics; PAH = Polynuclear aromatic hydrocarbons; EPA = Environmental Protection Agency; BTEX = Benzene, toluene, ethylbenzene, and xylenes
### Table 4-3. Carbon Fractions for Petroleum Hydrocarbons

<table>
<thead>
<tr>
<th>Aliphatics</th>
<th>Aromatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>C6</td>
<td>C7-C8</td>
</tr>
<tr>
<td>C6-C8</td>
<td>C8-C10</td>
</tr>
<tr>
<td>C8-C10</td>
<td>C10-C12</td>
</tr>
<tr>
<td>C10-C12</td>
<td>C12-C16</td>
</tr>
<tr>
<td>C12-C16</td>
<td>C16-C21</td>
</tr>
<tr>
<td>C16-C35*</td>
<td>C21-C35*</td>
</tr>
</tbody>
</table>

**NOTES:**

- **Aliphatics** = compounds containing only carbon and hydrogen which do not contain a benzene ring and they can be straight-chain, branched chain, or cyclic molecules.
- **Aromatics** = any of a large class of hydrocarbon compounds, that includes benzene and compounds that resemble benzene in certain of their chemical properties, that have one or more benzene rings. Common aromatic compounds other than benzene include toluene, naphthalene, and anthracene (the polynuclear aromatic hydrocarbons).
<table>
<thead>
<tr>
<th>Activity</th>
<th>PPE</th>
<th>Soil</th>
<th>Water</th>
<th>Debris</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Decontamination</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Excavation</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
Table 9-1. Key Personnel and Responsibilities

<table>
<thead>
<tr>
<th>Name</th>
<th>Project Title/Assigned Role</th>
<th>Phone Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. John Hymer</td>
<td>Site Manager/SSHO</td>
<td>Work: (505) 679-2100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cell: (505) 491-9171</td>
</tr>
<tr>
<td>To be determined</td>
<td>Field Team Leader</td>
<td></td>
</tr>
<tr>
<td>Mr. Frank Gardner</td>
<td>Bhate Program Manager</td>
<td>Work: (970) 216-7819</td>
</tr>
<tr>
<td>Ms. Karen Niebuhr</td>
<td>Senior Engineer/Project Manager</td>
<td>Work: (205) 918-4024</td>
</tr>
<tr>
<td>Ms. Judy McBride</td>
<td>Health and Safety Specialist</td>
<td>Home: (205) 871-9215</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cell: (205) 586-6200</td>
</tr>
</tbody>
</table>

NOTE: SSHO = Site Safety and Health Officer
APPENDIX A

TABLES FROM SITE INVESTIGATION REPORT
SWMU 123
BHATE ENVIRONMENTAL ASSOCIATES, INC.
NOVEMBER 2004
Table 5-1 Water Levels and Free Product Levels

<table>
<thead>
<tr>
<th>WELL ID</th>
<th>Top Casing Elevation (ft amsl)</th>
<th>Depth to Groundwater (ft)</th>
<th>Groundwater Elevation (ft amsl)</th>
<th>Depth to Free Product (ft)</th>
<th>Measured Product Thickness (ft)</th>
<th>True Product Thickness ¹ (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW-1</td>
<td>4092.17</td>
<td>10.73</td>
<td>4081.44</td>
<td>10.26</td>
<td>0.11</td>
<td>0.02</td>
</tr>
<tr>
<td>MW-2</td>
<td>4092.27</td>
<td>11.24</td>
<td>4081.03</td>
<td>NFP</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>MW-3</td>
<td>4091.98</td>
<td>10.70</td>
<td>4081.28</td>
<td>NFP</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>MW-4</td>
<td>4092.67</td>
<td>11.02</td>
<td>4081.55</td>
<td>NFP</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>MW-5</td>
<td>4091.95</td>
<td>10.88</td>
<td>4081.07</td>
<td>NFP</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* ft = feet; ft amsl = feet above mean sea level; NFP = no free product

¹ True Product Thickness Calculation (after Pastrovich 1979)

\[
H_t = \frac{H_o (P_w - P_o)}{P_o}
\]

Where:
- \(H_t\) = thickness of hydrocarbon liquid in adjacent formation
- \(H_o\) = hydrocarbon thickness measured in well (0.11 ft = 3.3528 cm
- \(P_w\) = density of water (1.0 gm/cm³)
- \(P_o\) = density of hydrocarbon (0.84 gm/cm³, after Abdul et al. (1989))

\[
H_t = 0.638628571\ \text{cm}
\]

\[
H_t = 0.0209524\ \text{ft}
\]
Table 5-2. Free Product Removal Summary

<table>
<thead>
<tr>
<th>Date</th>
<th>Bailing Duration</th>
<th>Free Product Thickness</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/22/2004</td>
<td>15 mins</td>
<td></td>
<td>0.36 ft</td>
<td></td>
</tr>
<tr>
<td>9/23/2004</td>
<td>15 mins</td>
<td></td>
<td>0.53 ft</td>
<td>0.08 ft</td>
</tr>
<tr>
<td>9/24/2004</td>
<td>15 mins</td>
<td></td>
<td>0.17 ft</td>
<td>0.09 ft</td>
</tr>
<tr>
<td>9/27/2004</td>
<td>15 mins</td>
<td></td>
<td>0.27 ft</td>
<td>0.14 ft</td>
</tr>
<tr>
<td>10/6/2004</td>
<td>-</td>
<td></td>
<td>0.11 ft</td>
<td></td>
</tr>
</tbody>
</table>

**ft = feet; mins = minutes**
### Table 5-3 Total Dissolved Solids in Groundwater

<table>
<thead>
<tr>
<th>Location (MW)</th>
<th>Groundwater Total Dissolved Solids Concentrations (mg/L)</th>
<th>Date Sampled</th>
<th>Method (160.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW-1</td>
<td>3.010</td>
<td>7/18/04</td>
<td>160.1</td>
</tr>
<tr>
<td>MW-2</td>
<td>3.640</td>
<td>7/18/04</td>
<td>160.1</td>
</tr>
<tr>
<td>MW-3</td>
<td>3.230</td>
<td>7/18/04</td>
<td>160.1</td>
</tr>
<tr>
<td>MW-4</td>
<td>5.720</td>
<td>7/18/04</td>
<td>160.1</td>
</tr>
<tr>
<td>MW-5</td>
<td>6.050</td>
<td>7/18/04</td>
<td>160.1</td>
</tr>
<tr>
<td>Average</td>
<td>4.330</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*mg/L = milligrams per liter, NMWQCC = New Mexico Water Quality Control Commission, MW = Monitoring Well, AFB = Air Force Base.*
### Groundwater Screening Levels

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Groundwater Screening Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NV</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.01</td>
</tr>
<tr>
<td>Benzene</td>
<td>50</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.01</td>
</tr>
<tr>
<td>Copper</td>
<td>10</td>
</tr>
<tr>
<td>Lead</td>
<td>0.05</td>
</tr>
<tr>
<td>Hexadecane</td>
<td>0.01</td>
</tr>
<tr>
<td>Xylenes</td>
<td>0.01</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.2</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.1</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>0.1</td>
</tr>
<tr>
<td>Chlorinated solvents</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Table 5-1: Groundwater Analytical Results**

| Chemical | SWMU 123 | APM C | SWMU 200 | APM C | SWMU 205 | APM C | SWMU 208 | APM C | SWMU 210 | APM C | SWMU 211 | APM C | SWMU 213 | APM C | SWMU 215 | APM C | SWMU 217 | APM C | SWMU 219 | APM C | SWMU 220 | APM C | SWMU 221 | APM C | SWMU 222 | APM C | SWMU 223 | APM C |
|----------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|----------|--------|
| As       | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   | 0.43     | 0.58   |
| BTEX     | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   |
| THM      | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   | 1.00     | 1.00   |

**Note:** The values are not applicable. (NA)
## Table 5-5. Soil Boring Analytical Results

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Soil Screening Levels</th>
<th>SDG No.</th>
<th>Date Sampled</th>
<th>Data Record</th>
<th>TP/H (mg/kg)</th>
<th>JHH-100</th>
<th>JHH-1000</th>
<th>JHH-10000</th>
<th>JHH-100000</th>
<th>JHH-1000000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sample 1</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample 2</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample 3</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample 4</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample 5</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample 6</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
<td>10/10/13</td>
</tr>
</tbody>
</table>

### Notes:
- **SDG** = Sample Delivery (grams) + milligrams per kilogram.
- **VOCs** = Volatile Organic Compounds.
- **SVOCs** = Semi-Volatile Organic Compounds.
- **SB** = Soil Boring.
- **AFB** = Air Force Base.
- **ANR** = Analysis Not Requested.
- **NR** = No Value.
- **ND** = Not Detected.
- **mg/kg** = milligrams per kilogram.

**NOTE:** SDG 1386-4 was collected to replace sample. All samples in this SDG replace those from earlier SDGs. Sampled 5-8, 6-11, 5-10, and 6-11.

### Table 5-5a. Summary Statistics for Soil, Upper Tolerance Limit (UTL)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>UTL (mg/kg)</th>
<th>SDG No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sample 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample 2</td>
</tr>
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<td></td>
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<td>Sample 3</td>
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<td>Sample 4</td>
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<td></td>
<td></td>
<td>Sample 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample 6</td>
</tr>
</tbody>
</table>

### Notes:
- **SDG** = Sample Delivery (grams) + milligrams per kilogram.
- **VOCs** = Volatile Organic Compounds.
- **SVOCs** = Semi-Volatile Organic Compounds.
- **SB** = Soil Boring.
- **AFB** = Air Force Base.
- **ANR** = Analysis Not Requested.
- **NR** = No Value.
- **ND** = Not Detected.
- **mg/kg** = milligrams per kilogram.

**NOTE:** SDG 1386-4 was collected to replace sample. All samples in this SDG replace those from earlier SDGs. Sampled 5-8, 6-11, 5-10, and 6-11.
APPENDIX B

UFGS SECTION 02111 EXCAVATION AND HANDLING OF CONTAMINATED MATERIAL
SEPTEMBER 2003
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DIVISION 02 - SITE CONSTRUCTION

SECTION 02111

EXCAVATION AND HANDLING OF CONTAMINATED MATERIAL

09/03

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-- End of Section Table of Contents --
NOTE: This guide specification covers the requirements for excavation, handling, and temporary storage of contaminated material.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

PART 1 GENERAL

NOTE: The following information should be shown on the project drawings:

a. Overall site plan, borrow areas, stockpile areas, storage areas, security requirements, special shoring requirements, boring logs, and access routes.

b. Individual site plans of each area of contamination with site features such as buildings, roads, utilities, topography, trees, shrubs, surface conditions, etc.

c. Limits of pavement removal, fence removal, and the location of ancillary equipment to be removed.

All specific chemical testing procedures (including air emissions analysis) should be addressed in the Sampling and Analysis Plan required by Section 01450 CHEMICAL DATA QUALITY CONTROL.
When applicable, the use of onsite field screening or field analysis (supported at a prescribed frequency by fixed laboratory analysis) should be encouraged to avoid prolonged delays or equipment downtime. Details on the appropriate application and use of field analyses can be found in Appendix H of EM 200-1-3.

1.1 REFERENCES

NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D 1556 (2000) Density and Unit Weight of Soil in Place by the Sand-Cone Method

ASTM D 1557 (2002) Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/cu. ft. (2,700 kN-m/cu.m.))

ASTM D 2167 (1994; R 2001) Density and Unit Weight of Soil in Place by the Rubber Balloon Method

ASTM D 2487 (2000) Soils for Engineering Purposes (Unified Soil Classification System)

ASTM D 2922 (2001) Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

ASTM D 422 (1963; R 2002) Particle-Size Analysis of Soils

ASTM D 5434 (1997; R 2003) Field Logging of Subsurface Explorations of Soil and Rock

ASTM D 698 (2000a) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu. ft. (600 kN-m/cu. m.))

U.S. ARMY CORPS OF ENGINEERS (USACE)

1.2 MEASUREMENT AND PAYMENT

**************************************************************************
NOTE: These paragraphs should be deleted if the
work is in one lump-sum contract price. Coordinate
requirements of these paragraphs with the bidding
schedule.
**************************************************************************

1.2.1 Measurement

**************************************************************************
NOTE: Modify this paragraph if the method of
payment will be on a weight basis.
**************************************************************************

Measurement for excavation and on-site transportation shall be based on the
actual number of cubic meters yards of contaminated material in-place prior
to excavation. Determination of the volume of contaminated material
excavated shall be based on cross-sectional volume determination reflecting
the differential between the original elevations of the top of the
contaminated material and the final elevations after removal of the
contaminated material. Measurement for backfilling of excavated areas
shall be based on in-place cubic meters yards of compacted fill.
Measurement for construction of stockpile areas shall be based on the
number of square meters yards of stockpile liner constructed.

1.2.2 Payment

1.2.2.1 Excavation and Transportation

Compensation for excavation and on-site transportation of contaminated
material will be paid as a unit cost. This unit cost shall include any
other items incidental to excavation and handling not defined as having a
specific unit cost.

1.2.2.2 Backfilling

Compensation for backfill soil, transportation of backfill, backfill soil
conditioning, backfilling, compaction, and geotechnical testing will be
paid as a single unit cost.

1.2.2.3 Stockpiling

Compensation for construction of stockpile areas will be paid for as a unit
cost. This unit cost shall include all aspects of grading, preparation,
handling, placement, maintenance, removal, treatment, and disposal of
stockpile cover materials and liner materials and all other items
incidental to construction of stockpiles.
NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Surveys; G, [___]

Separate cross-sections of each area before and after excavation and after backfilling.

SD-03 Product Data

Work Plan; G, [___]

Work Plan within [30] [___] calendar days after notice to proceed. No work at the site, with the exception of site inspections and surveys, shall be performed until the Work Plan is approved. The Contractor shall allow [30] [___] calendar days...
in the schedule for the Government's review. No adjustment for time or money will be made if resubmittals of the Work Plan are required due to deficiencies in the plan. At a minimum, the Work Plan shall include:

a. Schedule of activities.
b. Method of excavation and equipment to be used.
c. Shoring or side-wall slopes proposed.
d. Dewatering plan.
e. Storage methods and locations for liquid and solid contaminated material.
f. Borrow sources and haul routes.
g. Decontamination procedures.
h. Spill contingency plan.

Closure Report; G, [____]

[____] copies of the Closure Report within [14] [____] calendar days of work completion at the site.

SD-06 Test Reports

Backfill; G, [____]
Surveys; G, [____]
Confirmation Sampling and Analysis; G, [____]
Sampling of Stored Material; G, [____]
Sampling Liquid; G, [____]
Compaction; G, [____]

Test results.

1.4 SURVEYS

Surveys shall be performed immediately prior to and after excavation of contaminated material to determine the volume of contaminated material removed. Surveys shall also be performed immediately after backfill of each excavation. The Contractor shall provide cross-sections on [7.6] [____] meter [25] [____] foot intervals and at break points for all excavated areas. Locations of confirmation samples shall also be surveyed and shown on the drawings. Surveys shall be performed in accordance with Section: [____].

1.5 REGULATORY REQUIREMENTS

1.5.1 Permits and Licenses

**************************************************************************
NOTE: Include additional site specific requirements in this paragraph.
**************************************************************************

The Contractor shall obtain required federal, state, and local permits for
excavation and storage of contaminated material. Permits shall be obtained at no additional cost to the Government.

1.5.2 Air Emissions

**************************************************************************
NOTE: An air pathway analysis should be performed during design to determine what air monitoring and controls are required. Guidance on air pathway analyses is provided in EP 1110-1-21 Air Pathway Analysis for the Design of Hazardous, Toxic, and Radioactive Waste (HTRW) Remedial Action Projects. Specify perimeter air monitoring requirements in Section 01355 ENVIRONMENTAL PROTECTION.
**************************************************************************

Air emissions shall be monitored and controlled in accordance with Section 01355.

1.6 DESCRIPTION OF WORK

**************************************************************************
NOTE: Include any pertinent information regarding project/site conditions in this paragraph, the appendices to the specifications, or on the drawings.

If oversize material such as debris and foundations are present, the specification should describe treatment, handling, and disposal requirements for this material. Measurement and payment procedures should also be described for this material.

If clean soil overlies the contaminated material, the specification should describe how this material will be measured, removed, stored, and tested to verify they are clean.
**************************************************************************

The work shall consist of excavation and temporary storage of approximately [_____] cubic meters yards of contaminated material. Approximate locations of contaminated material are shown on the drawings. Characterization data on the nature and extent of the contaminated material is shown in Appendix [______]. Subsurface conditions are shown [on the drawings] [in Appendix [______]]. The Contractor shall submit a Work Plan as specified in the Submittals paragraph. The Contracting Officer shall be notified within [24] [_____] hours, and before excavation, if contaminated material is discovered that has not been previously identified or if other discrepancies between data provided and actual field conditions are discovered. Backfill material is [not available onsite] [available onsite and typically consists of [______]]. Ground water is approximately [_____] meters feet below pre-excavation ground surface.

1.7 CHEMICAL TESTING

Required sampling and chemical analysis shall be conducted in accordance with Section 01450A CHEMICAL DATA QUALITY CONTROL.
1.8 SCHEDULING

The Contractor shall notify the Contracting Officer [_____] calendar days prior to the start of excavation of contaminated material. The [Contracting Officer will] [Contractor shall] be responsible for contacting regulatory agencies in accordance with the applicable reporting requirements.

PART 2 PRODUCTS

2.1 BACKFILL

**************************************************************************
NOTE: If contaminated material removal is part of a larger project and a backfilling specification is needed for the project as a whole, refer to another specification such as Section 02315 EXCAVATION, FILLING AND BACKFILLING FOR BUILDINGS for Buildings, for backfill requirements and delete the following paragraphs.

In many cases, the degree of engineering control of the materials used as backfill may not need to be as stringent as described in this paragraph. In other cases, such as under pavements, special compaction and material requirements may apply and the specification will need to be revised to address these special requirements or another specification section should be referenced.

Backfill and topsoil brought in from offsite is usually tested to verify the material is clean. Quality assurance samples taken by the Government may also be prudent to verify the seller's claims by analyzing for target analytes. Backfill is commonly tested for the site specific contaminants being cleaned up and/or is based on suspicion of contamination at the site from which the backfill is originating.

At some sites, previously contaminated material which has been removed from the excavation is reused as backfill following treatment to remove the contaminant of concern.

**************************************************************************

Backfill material shall be obtained from [the location indicated on the drawings] [offsite sources approved by the Contracting Officer]. Backfill shall be classified in accordance with ASTM D 2487 as GW, GP, GM, GC, SW, SP, SM, SC, ML, MH, CL, or CH and shall be free from roots and other organic matter, trash, debris, snow, ice or frozen materials. Backfill material shall be tested for the parameters listed below at a frequency of once per [3000] [_____] cubic meters yards. A minimum of one set of classification tests shall be performed per borrow source. [One] [_____] backfill sample per borrow source shall also be collected and tested for the chemical parameters listed below.
### Physical Parameter

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Size</td>
<td>ASTM D 422</td>
</tr>
<tr>
<td>Compaction</td>
<td>ASTM D 698</td>
</tr>
</tbody>
</table>

### Chemical Parameter

<table>
<thead>
<tr>
<th>Test Frequency</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Backfill shall not be used until borrow source chemical and physical test results have been submitted and approved.

#### 2.2 SPILL RESPONSE MATERIALS

The Contractor shall provide appropriate spill response materials including, but not limited to the following: containers, adsorbents, shovels, and personal protective equipment. Spill response materials shall be available at all times when contaminated materials/wastes are being handled or transported. Spill response materials shall be compatible with the type of materials and contaminants being handled.

#### PART 3 EXECUTION

### 3.1 EXISTING STRUCTURES AND UTILITIES

No excavation shall be performed until site utilities have been field located. The Contractor shall take the necessary precautions to ensure no damage occurs to existing structures and utilities. Damage to existing structures and utilities resulting from the Contractor’s operations shall be repaired at no additional cost to the Government. Utilities encountered that were not previously shown or otherwise located shall not be disturbed without approval from the Contracting Officer.

### 3.2 CLEARING

**************************************************************************

NOTE: Grubbing is typically not required at sites where contaminated soil is being excavated for treatment and/or disposal. Typically, vegetation that is cut off above a certain height is defined as clean and any stumps and brush below this height are defined as contaminated.

**************************************************************************

Clearing shall be performed to the limits shown on the drawings in accordance with Section 02231 CLEARING AND GRUBBING.

### 3.3 CONTAMINATED MATERIAL REMOVAL

**************************************************************************

NOTE: Excavations should be marked and secured in accordance with the requirements specified in Section 01351 SAFETY, HEALTH, AND EMERGENCY RESPONSE (HTRW/UST).

**************************************************************************
3.3.2 Excavation

NOTE: For large excavations, more than one excavation log may be required.

Areas of contamination shall be excavated to the depth and extent shown on the drawings and not more than [60] mm [0.2] feet beyond the depth and extent shown on the drawings unless directed by the Contracting Officer. Excavation shall be performed in a manner that will limit spills and the potential for contaminated material to be mixed with uncontaminated material. An excavation log describing visible signs of contamination encountered shall be maintained for each area of excavation. Excavation logs shall be prepared in accordance with ASTM D 5434.

3.3.3 Shoring

If workers must enter the excavation, it shall be evaluated, shored, sloped or braced as required by EM 385-1-1 and 29 CFR 1926 section 650.

3.3.4 Dewatering

NOTE: Dewatering can significantly increase the cost of a project involving the excavation of contaminated material and should be carefully considered during design. TM 5-818-5 Dewatering and Groundwater Control provides guidance on the design of dewatering systems.

If water from dewatering operations will be allowed to discharge on or into the ground, an NPDES permit for dewatering is required. Reference the permits paragraph of Section 01355 ENVIRONMENTAL PROTECTION for permit requirements.

Surface water shall be diverted to prevent entry into the excavation. [Dewatering shall be limited to that necessary to assure adequate access, a safe excavation, prevent the spread of contamination, and to ensure that compaction requirements can be met.] [No dewatering shall be performed without prior approval of the Contracting Officer.]

3.4 CONFIRMATION SAMPLING AND ANALYSIS

NOTE: Confirmation samples and analyses are used to verify cleanup criteria have been met. These test results should be of relatively high quality. For this reason, the designer should consider the regulatory requirements, the complexity of the monitoring needed, and quantitative Data Quality Objectives in determining the analytical methods specified.

The number of confirmation samples must be based on the size of the excavation and regulatory requirements. For small excavations, a minimum of
one sample should be taken from near the center of the excavation (or where there is the highest potential for contamination). Additional samples may be oriented symmetrically relative to the center sample and the limits of the excavation.

Many military facilities have base-wide sampling and analysis plans which have been approved by the applicable regulatory agencies. These plans may specify the number of confirmation samples which must be taken.

For larger excavations, EPA 230/02-89-042 Methods of Evaluation and Attainment of Cleanup Standards provides guidance on the design of statistically based sampling intervals.

With regulator approval, confirmation sampling and analysis may be accomplished using an averaging technique for comparison to cleanup criteria. This is based on the fact that most soil risk exposure scenarios do not model contamination as existing in discrete hot spots but as a more disperse phenomenon. Two ways to accomplish this averaging technique are to take discrete samples and average the data or by compositing sample material before analysis. A composite sample typically consists of 4 to 6 samples which are mixed together. One sample is then obtained from the composite sample for analysis. EM 200-1-3 provides guidance on compositing samples. Composite samples are not applicable to volatile organic contaminants because the compositing process will result in volatilization of contaminants. If composite samples are required, Section 01450 CHEMICAL DATA QUALITY CONTROL should be edited by a qualified chemist to describe procedures for compositing samples.

Confirmation sampling at a site with radioactive contamination in surface soils or on building surfaces will be performed in accordance with the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, EPA 402-R-97-016. This manual is a guide for confirmation survey design (planning) and for data evaluation. Its primary purpose is to acquire legally defensible data concerning the post excavation residual radioactivity at the site to demonstrate that the site meets release criteria.

The Contracting Officer shall be present to inspect the removal of contaminated material from each site. After all material suspected of being contaminated has been removed, the excavation shall be examined for evidence of contamination. If the excavation appears to be free of contamination, field analysis shall be used to determine the presence of [_____] contamination using [a real time vapor monitoring instrument] [immunoassay field kits] [_____]. Excavation of additional material shall
be as directed by the Contracting Officer. After all suspected contaminated material is removed, confirmation samples shall be collected and analyzed for the following contaminants:

<table>
<thead>
<tr>
<th>Chemical Parameter</th>
<th>Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>[____]</td>
<td>[____]</td>
</tr>
</tbody>
</table>

Samples shall be collected at a frequency of one per [____] square meters yards from the bottom [and each of the side walls] or as directed by the Contracting Officer. A minimum of one sample shall be collected from the bottom [and each side wall] of the excavation. Based on test results, the Contractor shall propose any additional excavation which may be required to remove material which is contaminated above action levels. Additional excavation shall be subject to approval by the Contracting Officer. Locations of samples shall be marked in the field and documented on the as-built drawings.

3.5 CONTAMINATED MATERIAL STORAGE

**************************************************************************
NOTE: For CERCLA sites, permits are not required to store hazardous waste in a stockpile. However, storage structures and conditions must be in compliance the Applicable, Relevant, and Appropriate Regulations (ARARs). For RCRA sites, permits are required to store hazardous waste in a stockpile. However, for RCRA sites, hazardous waste can be stored in a drum or roll-off unit for up to 90 days without a permit.

For temporary storage of more than 90 days, dual containment of hazardous liquid and some hazardous solids may be required. Containment system requirements are described in 40 CFR 264.175. For stock piles that meet the definition of a waste pile, see 40 CFR 264.250.

To provide secondary containment, tanks and roll-off units are sometimes stored on lined areas similar in design to what is described in paragraph Stockpiles.

**************************************************************************

Material shall be placed in temporary storage [immediately after excavation] [after treatment while awaiting test results]. The following paragraphs describe acceptable methods of material storage. Storage units shall be in good condition and constructed of materials that are compatible with the material or liquid to be stored. If multiple storage units are required, each unit shall be clearly labeled with an identification number and a written log shall be kept to track the source of contaminated material in each temporary storage unit.

3.5.1 Stockpiles

**************************************************************************

NOTE: Check state regulations to determine the minimum requirements for stockpiles and modify this paragraph accordingly. For contaminated material with high moisture content, the subgrade for the
stockpile must be sloped and a sump should be provided.

Scrim reinforced geomembranes are commonly specified for stockpile covers and liners. Due to their higher strength properties, scrim reinforced geomembranes can generally be thinner than non-reinforced geomembranes.

For post treatment stockpiles, chemical testing is usually required to determine if material is contaminated or clean. Maximum stockpile size should be based on the required frequency of chemical testing. For example, if chemical tests are required at a frequency of one per 1,000 cubic meters (cubic yards), then stockpiles should be no greater than 1,000 cubic meters (cubic yards) in size.

Stockpiles shall be constructed to isolate stored contaminated material from the environment. The maximum stockpile size shall be [_____] cubic meters. yards. Stockpiles shall be constructed to include:

a. [A chemically resistant geomembrane liner free of holes and other damage. Non-reinforced geomembrane liners shall have a minimum thickness of [0.5] [_____] mm. [20] [_____] mils. Scrim reinforced geomembrane liners shall have a minimum weight of 20 kg/100 square meters. 40 lbs. per 1000 square feet. The ground surface on which the geomembrane is to be placed shall be free of rocks greater than 12 mm 0.5 inches in diameter and any other object which could damage the membrane.] [Pavement shall be used as the liner system. Pavement shall be constructed in accordance with Section [______]].

b. Geomembrane cover free of holes or other damage to prevent precipitation from entering the stockpile. Non-reinforced geomembrane covers shall have a minimum thickness of 0.25 mm. 10 mils. Scrim reinforced geomembrane covers shall have a minimum weight of 13 kg/100 square meters 26 lbs. per 1000 square feet. The cover material shall be extended over the berms and anchored or ballasted to prevent it from being removed or damaged by wind.

c. Berms surrounding the stockpile, a minimum of 300 mm 12 inches in height. Vehicle access points shall also be bermed.

d. The liner system shall be sloped to allow collection of leachate. Storage and removal of liquid which collects in the stockpile, in accordance with paragraph Liquid Storage.

3.5.2 Roll-Off Units

Roll-off units used to temporarily store contaminated material shall be water tight. A cover shall be placed over the units to prevent precipitation from contacting the stored material. The units shall be located [as shown on the drawings] [______]. Liquid which collects inside the units shall be removed and stored in accordance with paragraph Liquid Storage.
3.5.3 Liquid Storage

Liquid collected from excavations and stockpiles shall be temporarily stored in [220 L barrels] [2000 L tanks]. [55 gallon barrels] [500 gallon tanks]. Liquid storage containers shall be water-tight and shall be located [as shown on the drawings].

3.6 SAMPLING

3.6.1 Sampling of Stored Material

--------------------------------------------------------------------------------
NOTE: Additional samples are sometimes collected from excavated material to determine the contaminants present prior to treatment or disposal.

Composite samples are often collected from stockpiled material. However, composite samples cannot be taken if the samples are being analyzed for volatile organic contaminants.

At sites with radioactive contamination, ex-situ sampling of excavated material is typically performed to ensure that the material meets disposal facility acceptance criteria and, in some cases, to assist with the preparation of shipping papers. The ex-situ sampling regime is site-specific. It is usually determined in consultation with the disposal facility and its regulatory agency.

--------------------------------------------------------------------------------

Samples of stored material shall be collected at a frequency of once per [_____] cubic meters. Samples shall be tested for the following:

<table>
<thead>
<tr>
<th>Chemical Parameter</th>
<th>Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>[_____]</td>
<td>[_____]</td>
</tr>
</tbody>
</table>

Stored material with contaminant levels that exceed the action levels shall be treated [offsite]. Analyses for contaminated material to be taken to an offsite treatment facility shall conform to local, state, and federal criteria as well as to the requirements of the treatment facility. Documentation of all analyses performed shall be furnished to the Contracting Officer. Additional sampling and analyses to the extent required by the approved offsite treatment, storage or disposal (TSD) facility shall be the responsibility of the Contractor and shall be performed at no additional cost to the Government [subject to approval by the Contracting Officer]. [onsite. Treatment shall be in accordance with Section [_____]].

3.6.2 Sampling Liquid

--------------------------------------------------------------------------------
NOTE: Liquid should generally be tested for the same contaminants as are found in the contaminated solid material being removed. The frequency of testing should be determined on a site specific basis. Offsite disposal will generally require additional testing and analysis prior to disposal.

SECTION 02111 Page 15
NPDES requirements must be considered for onsite disposal of liquids.

Liquid collected from [excavations] [storage areas] [decontamination facilities] shall be sampled at a frequency of once for every [2,000] [_____] L [500] [_____] gallons of liquid collected. Samples shall be tested for the following:

<table>
<thead>
<tr>
<th>Chemical Parameter</th>
<th>Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Liquid with contaminant levels that exceed action levels shall be treated [offsite]. Analyses for contaminated liquid to be taken to an offsite treatment facility shall conform to local, state, and federal criteria as well as to the requirements of the treatment facility. Documentation of all analyses performed shall be furnished to the Contracting Officer. Additional sampling and analysis to the extent required by the approved offsite treatment, storage or disposal (TSD) facility receiving the material shall be the responsibility of the Contractor and shall be [performed at no additional cost to the Government] [subject to approval by the Contracting Officer]. [onsite. Treatment shall be in accordance with Section [_____] .]

### 3.6.3 Sampling Beneath Storage Units

NOTE: At some sites, samples are collected to verify the soil on which a storage unit is placed has not become contaminated.

Sampling along any connecting pipelines that transport contaminated liquid may also be appropriate. A standard practice is to sample at 6 m (20 foot) intervals under piping and at connections such as bends, elbows, or tees.

Samples from beneath each storage unit shall be collected prior to construction of and after removal of the storage unit. Samples shall be collected at a frequency of one per each [_____] square meters yards from a depth interval of [0 to 0.15] [_____] m [0 to 0.5] [_____] feet and shall be tested for the following:

<table>
<thead>
<tr>
<th>Chemical Parameter</th>
<th>Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on test results, soil which has become contaminated above action levels shall be removed at no additional cost to the Government. Contaminated material which is removed from beneath the storage unit shall be handled in accordance with paragraph Sampling of Stored Material. As directed by the Contracting Officer and at no additional cost to the Government, additional sampling and testing shall be performed to verify areas of contamination found beneath stockpiles have been cleaned up to below action levels.

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3.7 SPILLS

NOTE: Regarding preestablished spill reporting procedures, the designer should consult CEMP-RT memorandum of 20 July 1995, Subject: Spill Reporting Procedures for USACE Personnel Involved in HTW Projects.

Evaluate whether a contingency plan is needed per 40 CFR 262.34. This regulation is a potential requirement for large quantity generators of hazardous waste. At military installations, a plan is typically already in place.

In the event of a spill or release of a hazardous substance (as designated in 40 CFR 302), pollutant, contaminant, or oil (as governed by the Oil Pollution Act (OPA), 33 U.S.C. 2701 et seq.), the Contractor shall notify the Contracting Officer immediately. If the spill exceeds the reporting threshold, the Contractor shall follow the pre-established procedures as described in the [RCRA Contingency Plan] [Base Wide Contingency Plan] [_____] for immediate reporting and containment. Immediate containment actions shall be taken to minimize the effect of any spill or leak. Cleanup shall be in accordance with applicable federal, state, and local regulations. As directed by the Contracting Officer, additional sampling and testing shall be performed to verify spills have been cleaned up. Spill cleanup and testing shall be done at no additional cost to the Government.

3.8 BACKFILLING

NOTE: If allowed by the regulatory authority, field analyses should be used to reduce laboratory turn-around time and minimize the duration an excavation must be left open.

After completion of backfilling, a 0.15 meter (6 inch) layer of top soil is typically placed in areas that are not paved. The topsoil is placed in a single lift to the lines and grades shown on the drawings. Top soil and seeding requirements should be described in a different section of the specification package.

3.8.1 Confirmation Test Results

Excavations shall be backfilled immediately after all contaminated materials have been removed and confirmation test results have been approved. Backfill shall be placed and compacted to the lines and grades shown on the drawings.

3.8.2 Compaction

NOTE: The following paragraph outlines density requirements for in-place backfill. If the density
of the backfill is not critical, modify this paragraph by replacing the density testing requirements with procedural requirements for compaction.

Approved backfill shall be placed in lifts with a maximum loose thickness of [200] [_____] mm. [8] [_____] inches. Soil shall be compacted to [90] [_____] percent of [ASTM D 698] [ASTM D 1557] maximum dry density. Density tests shall be performed at a frequency of once per [930] [_____] square meters [10,000] [_____] square feet per lift. A minimum of [one density test] [_____] density tests shall be performed on each lift of backfill placed. Field in-place dry density shall be determined in accordance with ASTM D 1556, ASTM D 2167, or ASTM D 2922. If ASTM D 2922 is used, a minimum of one in ten tests shall be checked using ASTM D 1556 or ASTM D 2167. Test results from ASTM D 1556 or ASTM D 2167 shall govern if there is a discrepancy with the ASTM D 2922 test results.

3.9 DISPOSAL REQUIREMENTS

Offsite disposal of contaminated material shall be in accordance with Section 02120A TRANSPORTATION AND DISPOSAL OF HAZARDOUS MATERIALS.

3.10 CLOSURE REPORT

NOTE: In addition to progress photos, video tapes have been used at some sites to record site activities.

[_____] copies of a Closure Report shall be prepared and submitted within [14] [_____] calendar days of completing work at the site. The report shall be labeled with the contract number, project name, location, date, name of general contractor, and the Corps of Engineers District contracting for the work. The Closure Report shall include the following information as a minimum:

a. A cover letter signed by a [responsible company official] [Professional Engineer registered in the State of [_____] who is a responsible company official] certifying that all services involved have been performed in accordance with the terms and conditions of the contract documents and regulatory requirements.

b. A narrative report including, but not limited to, the following:

(1) site conditions, ground water elevation, and cleanup criteria;
(2) excavation logs;
(3) field screening readings;
(4) quantity of materials removed from each area of contamination;
(5) quantity of water/product removed during dewatering;
(6) sampling locations and sampling methods;

(7) sample collection data such as time of collection and method of preservation;

(8) sample chain-of-custody forms; and

(9) source of backfill.

c. Copies of all chemical and physical test results.

d. Copies of all manifests and land disposal restriction notifications.

e. Copies of all certifications of final disposal signed by the responsible disposal facility official.

f. Waste profile sheets.

g. Scale drawings showing limits of each excavation, limits of contamination, known underground utilities within 15 m 50 feet of excavation, sample locations, and sample identification numbers. On-site stockpile, storage, treatment, loading, and disposal areas shall also be shown on the drawings.

h. Progress Photographs. Color photographs shall be used to document progress of the work. A minimum of four views of the site showing the location of the area of contamination, entrance/exit road, and any other notable site conditions shall be taken before work begins. After work has been started, activities at each work location shall be photographically recorded [daily] [weekly]. Photographs shall be a minimum of 76.2 x 127.0 mm 3 x 5 inches and shall include:

(1) Soil removal and sampling.

(2) Dewatering operations.

(3) Unanticipated events such as spills and the discovery of additional contaminated material.

(4) Contaminated material/water storage, handling, treatment, and transport.

(5) Site or task-specific employee respiratory and personal protection.

(6) Fill placement and grading.

(7) Post-construction photographs. After completion of work at each site, the Contractor shall take a minimum of four views of each excavation site.

A digital version of all photos shown in the report shall be included with the Closure Report. Photographs shall be a minimum of 76mm by 127 mm 3 inches by 5 inches and shall be mounted back-to-back in double face plastic sleeves punched to fit standard three ring binders. Each print shall have an information box attached. The box shall be typewritten and arranged as follows:
APPENDIX C

BASE CIVIL ENGINEER WORK REQUEST AIR FORCE
FORM 332
BASE 7 IL ENGINEER WORK REQUEST

Public reporting burden for this collection of information is estimated to average 3 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project 0704-0188, Washington DC 20503. Please DO NOT RETURN your form to either of these addresses. Send your completed form to HQ AFESC/DEMA.

SECTION I - TO BE COMPLETED BY REQUESTER

1. FROM (Organization): L.
2. OFFICE SYMBOL: $E.'
3. DATE OF REQUEST: 21 June 2005
4. WORK REQUEST NO. (For BCE Use): 22048

5. NAME AND PHONE NO. OF REQUESTER: Dan Holmquist
6. REQUIRED COMPLETION DATE: 2005

7. BUILDING, FACILITY OR STREET ADDRESS WHERE WORK IS TO BE ACCOMPLISHED: Sumu-123 "Foy Yard"

8. DESCRIPTION OF WORK TO BE ACCOMPLISHED (Include Sketch or Plan, when appropriate):

   "Excavate Contaminated Soil under wash rack."

   RECEIVED 25 June 05

9. BRIEF JUSTIFICATION FOR WORK TO BE ACCOMPLISHED (Not required for maintenance and repair):

10. DONATED RESOURCES "Coordination Only" Funded Through ERP

<table>
<thead>
<tr>
<th>FUNDS</th>
<th>LABOR</th>
<th>MATERIAL</th>
<th>CONTRACT BY REQUESTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>NONE</td>
<td>NONE</td>
<td>NONE</td>
</tr>
</tbody>
</table>

11. NAME OF REQUESTER: Daniel Holmquist
12. GRADE OF REQUESTER: GS-12
13. SIGNATURE OF REQUESTER: (See Reverse of Form)

14. COORDINATION

SECTION II - FOR BASE CIVIL ENGINEER USE

15. WORK ORDER (Place an "X" in the appropriate box.)

<table>
<thead>
<tr>
<th>IN-SERVICE</th>
<th>SELF-HELP</th>
<th>CONTRACT</th>
<th>SABER</th>
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16. DIRECT SCHEDULED WORK (Place an "X" in the appropriate box.)

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<tr>
<th>EMERGENCY</th>
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<th>ROUTINE</th>
<th>SELF-HELP</th>
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</table>

17. SELF-HELP (Place an "X" in the appropriate box.)

<table>
<thead>
<tr>
<th>BRIEFING REQUIRED</th>
<th>ADEQUATE COORDINATION</th>
<th>INSPECTION REQUIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

SECTION III - COMPLETE ONLY IF WORK IS TO BE ACCOMPLISHED BY WORK ORDER

18. WORK CLASS
19. PRIORITY
20. ESTIMATED HOURS
21. ESTIMATED FUNDED COST
22. ESTIMATED TOTAL COST

23. THERE IS NO NEED FOR AN ENVIRONMENTAL ASSESSMENT (APR 10-21)
24. A WRITTEN ASSESSMENT IS NEEDED HAS BEEN PROCESSED
25. APPROVED
26. DISAPPROVED

27. REMARKS

SECTION IV - APPROVING AUTHORITY

28. NAME AND GRADE (Please Type or Print)
29. SIGNATURE
30. DATE

AP IMT 332, 19910101, V4

PREVIOUS EDITION IS OBSOLETE.

MASTER FILE COPY
APPENDIX D

CES FOUNDATION PLAN DRAWINGS
APPENDIX E

UFGS SECTION 02315
EXCAVATION, FILLING AND BACKFILLING FOR BUILDINGS
JUNE 2004
SECTION 02315
EXCAVATION, FILLING AND BACKFILLING FOR BUILDINGS

PART 1 - GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 1556 (1990; R 1996) Density and Unit Weight of Soil in Place by the Sand-Cone Method

ASTM D 1557 (1991) Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/cu. ft. (2,700 kN-m/cu.m.))

ASTM D 2216 (1992) Laboratory Determination of Water (Moisture) Content of Soil, and Rock

ASTM D 2487 (1993) Classification of Soils for Engineering Purposes (Unified Soil Classification System)

ASTM D 2922 (1996) Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

ASTM D 3017 (1988; R 1993) Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)

ASTM D 4318 (1995a) Liquid Limit, Plastic Limit, and Plasticity Index of Soils

1.2 DEGREE OF COMPACTION

Degree of compaction is expressed as a percentage of the maximum density obtained by the test procedure presented in ASTM D 1557, abbreviated as percent laboratory maximum density.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section 01330 - SUBMITTAL PROCEDURES:

SD-06 Test Reports
Testing: G.

The Contractor shall furnish certified test reports and analysis certifying that the satisfactory materials, nonexpansive fill, proposed for use at the project site conform to the specified requirements, and for all tests conducted in accordance with the PART 3 paragraph TESTING.

PART 2 - PRODUCTS

2.1 MATERIALS

2.1.1 Satisfactory Materials

Satisfactory materials shall comprise any materials classified by ASTM D 2487 as GW, GP, GM, GC, SW, SP, SM, SC, and CL. ML shall be considered satisfactory for use as subgrade when in an undisturbed condition. Satisfactory materials shall be free of trash, debris, roots or other organic matter, or stones larger than 76 mm (3 inches) in any dimension.

2.1.2 Unsatisfactory Materials

Unsatisfactory materials include materials classified in ASTM D 2487 as Pt, OH, OL, ML, MH, CH and any other materials not defined as satisfactory. ML shall be considered unsatisfactory when disturbed and shall not be allowed for use as fill or backfill. Blending of unsatisfactory materials with other materials in order to produce a satisfactory material, shall not be allowed. Materials found to contain significant amounts of gypsum, as determined by the Contracting Officers Representative, shall also be considered unsatisfactory. Unstable material is that material that cannot be properly compacted or will not support construction equipment or fill material due to excess moisture. Potentially unstable materials are soils with natural moisture contents near or above the plastic limit as determined by ASTM D 4318 or greater than 2 percent above the optimum moisture content as determined by ASTM D 1557. Unstable material shall be considered unsatisfactory.

2.1.3 Cohesionless and Cohesive Materials

Cohesionless materials include materials classified in ASTM D 2487 as GW, GP, SW, and SP. Cohesive materials include materials classified as GC, SC, CL, MH, and CH. Materials classified as GM, GP-GM, GW-GM, SW-SM, SP-SM, and SM shall be identified as cohesionless only when the fines are nonplastic.

2.1.4 Nonexpansive Soils

Nonexpansive soils shall be satisfactory material having a plasticity index not less than 4 nor greater than 12 when tested in accordance with ASTM D 4318.

2.1.5 Capillary Water Barrier

Capillary water barrier shall consist of clean, crushed, nonporous rock or crushed gravel, well graded from course to fine. The maximum particle size
shall be 37.5 mm (1-1/2 inch) and no more than 2 percent, by weight, shall pass the 4.75 mm (No. 4) sieve size.

PART 3 - EXECUTION

3.1 CLEARING AND GRUBBING

Clearing and grubbing is specified in Section 02230 - CLEARING AND GRUBBING.

3.2 TOPSOIL

Topsoil shall be stripped to a depth of 50 millimeters (2 inches) below existing grade within the designated excavations and grading lines and deposited in storage piles for later use. Excess topsoil shall be disposed as specified for excess excavated material.

3.3 EXCAVATION

Excavation shall conform to the dimensions and elevations indicated for each building, structure, and footing except as specified, and shall include trenching for utility and foundation drainage systems to a point 1.5 m (5 feet) beyond the building line of each building and structure, and all work incidental thereof. Excavation shall extend a sufficient distance from walls and footings to allow for placing and removal of forms. Excavations below indicated depths will not be permitted except to remove unsatisfactory material. Unsatisfactory material encountered below the grades shown shall be removed as directed, replaced with satisfactory material; and payment will be made in conformance with the CHANGES clause of the CONTRACT CLAUSES. Satisfactory material removed below the depths indicated, without specific direction of the Contracting Officer, shall be replaced, at no additional cost to the Government, with satisfactory materials to the indicated excavation grade; except that concrete footings shall be increased in thickness to the bottom of the overdepth excavations and over-break in rock excavation. Satisfactory material shall be placed and compacted as specified in paragraph FILLING AND BACKFILLING. Determination of elevations and measurements of approved overdepth excavation of unsatisfactory material below grades indicated shall be done under the direction of the Contracting Officer.

3.4 DRAINAGE AND DEWATERING

3.4.1 Drainage

Surface water shall be directed away from excavation and construction sites to prevent erosion and undermining of foundations. Diversion ditches, dikes and grading shall be provided and maintained as necessary during construction. Excavated slopes and backfill surfaces shall be protected to prevent erosion and sloughing. Excavation shall be performed so that the site, the area immediately surrounding the site, and the area affecting operations at the site shall be continually and effectively drained.
3.4.2 Dewatering

Groundwater flowing toward or into excavations shall be controlled to prevent sloughing of excavation slopes and walls, boils, uplift and heave in the excavation and to eliminate interference with orderly progress of construction. French drains, sumps, ditches or trenches will not be permitted within 900 mm (3 feet) of the foundation of any structure, except with specific written approval, and after specific contractual provisions for restoration of the foundation area have been made. Control measures shall be taken by the time the excavation reaches the water level in order to maintain the integrity of the in situ material. While the excavation is open, the water level shall be maintained continuously, at least .5 meters (1.5 feet) below the working level.

3.5 SHORING

Shoring, including sheet piling, shall be furnished and installed as necessary to protect workmen, banks, adjacent paving, structures, and utilities. Shoring, bracing, and sheeting shall be removed as excavations are backfilled, in a manner to prevent caving.

3.6 CLASSIFICATION OF EXCAVATION

Excavation will be unclassified regardless of the nature of material encountered.

3.7 BLASTING

Blasting will not be permitted.

3.8 UTILITY AND DRAIN TRENCHES

Trenches for underground utilities systems and drain lines shall be excavated to the required alignments and depths. The bottoms of trenches shall be graded to secure the required slope and shall be tamped if necessary to provide a firm pipe bed. Recesses shall be excavated to accommodate bells and joints so that pipe will be uniformly supported for the entire length. Rock, where encountered, shall be excavated to a depth of at least 150 mm (6 inches) below the bottom of the pipe, and the overdepth shall be backfilled with satisfactory material placed and compacted in conformance with paragraph FILLING AND BACKFILLING.

3.9 BORROW

Where satisfactory materials are not available in sufficient quantity from required excavations, approved materials shall be obtained as specified in Section 02300 EARTHWORK.
3.10 EXCAVATED MATERIALS

Satisfactory excavated material required for fill or backfill shall be placed in the proper section of the permanent work required under this section or shall be separately stockpiled if it cannot be readily placed. Satisfactory material in excess of that required for the permanent work and all unsatisfactory material shall be disposed of as specified in Section 02300 - EARTHWORK.

3.11 FINAL GRADE OF SURFACES TO SUPPORT CONCRETE

Excavation to final grade shall not be made until just before concrete is to be placed.

3.12 SUBGRADE PREPARATION

Unsatisfactory material in surfaces to receive fill or in excavated areas shall be removed and replaced with satisfactory materials as directed by the Contracting Officer. The surface shall be scarified to a depth of 150 mm (6 inches) before the fill is started. If the in-situ material is classified as ML material, then the ground surface shall be rolled or compacted to at least 85 percent laboratory maximum density. If the ground surface exists in-situ at a minimum of 85 percent laboratory maximum density, then additional compaction shall not be required. Sloped surfaces steeper than 1 vertical to 4 horizontal shall be plowed, stepped, benched, or broken up so that the fill material will bond with the existing material. When subgrades are less than the specified density, the ground surface shall be broken up to a minimum depth of 150 mm (6 inches), pulverized, and compacted to the specified density. When the subgrade is part fill and part excavation or natural ground, the excavated or natural ground portion shall be scarified to a depth of 300 mm (12 inches) and compacted as specified for the adjacent fill. Material shall not be placed on surfaces that are muddy, frozen, or contain frost. Compaction shall be accomplished by sheepfoot rollers, pneumatic-tired rollers, steel-wheeled rollers, or other approved equipment well suited to the soil being compacted. Material shall be moistened or aerated as necessary to plus or minus 2 percent of optimum moisture. Minimum subgrade density shall be as specified in paragraph FILLING AND BACKFILLING.

3.13 FILLING AND BACKFILLING

Satisfactory materials shall be used in bringing fills and backfills to the lines and grades indicated and for replacing unsatisfactory materials. Nonexpansive soils shall be used in nonexpansive fill under building floor slabs and foundations. Removal and replacement of existing material with nonexpansive material shall be as specified in paragraph SUBGRADE PREPARATION. Where nonexpansive fill is indicated under floor slabs or foundations all fill under such slabs or foundations shall be nonexpansive fill. The subgrade below the nonexpansive fill shall be loosened to depth of 150 mm (6 inches), moistened, manipulated and recompacted as specified hereinafter. Satisfactory fill materials shall be placed in horizontal layers not exceeding 200 mm (8 inches) in loose thickness, or 150 mm (6 inches) when hand-operated compactors are used. After placing, each layer shall be plowed, disked, or otherwise
broken up, moistened or aerated as necessary, thoroughly mixed and compacted as specified. Backfilling shall not begin until construction below finish grade has been approved, underground utilities systems have been inspected, tested and approved, forms removed, and the excavation cleaned of trash and debris. Backfill shall be brought to indicated finish grade. Backfill shall not be placed in wet or frozen areas. Where pipe is coated or wrapped for protection against corrosion, the backfill material up to an elevation 600 mm (2 feet) above sewer lines and 300 mm (1 foot) above other utility lines shall be free from stones larger than 25 mm (1 inch) in any dimension. Heavy equipment for spreading and compacting backfill shall not be operated closer to foundation or retaining walls than a distance equal to the height of backfill above the top of footing; the area remaining shall be compacted in layers not more than 100 mm (4 inches) in compacted thickness with power-driven hand tampers suitable for the material being compacted. Backfill shall be placed carefully around pipes or tanks to avoid damage to coatings, wrappings, or tanks. Backfill shall not be placed against foundation walls prior to 7 days after completion of the walls. As far as practicable, backfill shall be brought up evenly on each side of the wall and sloped to drain away from the wall. Each layer of fill and backfill shall be compacted to not less than the percentage of maximum density specified below:

<table>
<thead>
<tr>
<th>Percent Laboratory maximum density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohesive material</td>
</tr>
<tr>
<td>Cohesionless material</td>
</tr>
</tbody>
</table>

**Fill, embankment, and backfill**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cohesive</th>
<th>Cohesionless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under structures, building slabs, steps, paved areas, around footings, and in trenches</td>
<td>90</td>
<td>95</td>
</tr>
<tr>
<td>Under sidewalks and grassed areas</td>
<td>85</td>
<td>90</td>
</tr>
<tr>
<td><strong>Nonexpansive materials</strong></td>
<td>Compact to not less than 92</td>
<td></td>
</tr>
</tbody>
</table>

**Subgrade**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cohesive</th>
<th>Cohesionless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under building slabs, steps, and paved areas, top 305 mm (12 inches)</td>
<td>90</td>
<td>95</td>
</tr>
<tr>
<td>Under sidewalks, top 150 mm (6 inches)</td>
<td>85</td>
<td>90</td>
</tr>
<tr>
<td><strong>Nonexpansive materials</strong></td>
<td>Compact to not less than 92</td>
<td></td>
</tr>
</tbody>
</table>

Approved compacted subgrades that are disturbed by the Contractor's operations or adverse weather shall be scarified and compacted as specified herein before to the required density prior to further construction thereon. Recompaction over underground utilities and heating lines shall be by hand tamping.
3.14 TESTING

Testing shall be the responsibility of the Contractor and shall be performed at no additional cost to the Government. Testing shall be performed by a Government approved commercial testing laboratory or may be performed by the Contractor subject to approval. Field in-place density shall be determined in accordance with ASTM D 1556, or ASTM D 2922 Direct Transmission Method. When ASTM D 2922 is used, the calibration curves shall be checked and adjusted if necessary by the procedure described in ASTM D 2922, paragraph ADJUSTING CALIBRATION CURVE. ASTM D 2922 results in a wet unit weight of soil and when using this method ASTM D 3017 shall be used to determine the moisture content of the soil. Note: Many of the soils at Holloman AFB contain gypsum. Due to the presence of hydrated water in gypsum, moisture content readings determined by ASTM D 3017 will be in excess of the true values. Accurate moisture content readings may be determined in gypsum containing soils using ASTM D 2216 and incorporating the special precautions described therein. The calibration curves furnished with the moisture gauges shall also be checked along with density calibration checks as described in ASTM D 3017. The calibration checks of both the density and moisture gauges shall be made at the beginning of a job on each different type of material encountered and at intervals as directed by the Contracting Officer. The following number of tests, if performed at the appropriate time, shall be the minimum acceptable for each type operation.

3.14.1 In-Place Densities

In-place density and moisture content test results shall be included with the Contractor’s daily construction quality control reports.

3.14.1.1 In-Place Density of Subgrades

One test per 93 square meters (1,000 square foot) or fraction thereof per shift of work.

3.14.1.2 In-Place Density of Fills and Backfills

One test per 93 square meters (1,000 square feet) or fraction thereof per shift of work of each lift for fill or backfill areas compacted by other than hand or hand-operated machines. The density for each lift of fill or backfill materials for trenches, pits, building perimeters or other structures or areas less than 152 meters (500 feet) in width, which are compacted with hand or hand-operated machines shall be tested as follows: One test per each area less than 46 square meters (500 square feet), or one test for each 30 linear meters (100 linear feet) of long narrow fills 91 meters (300 feet) or more in length. If ASTM D 2922 is used, in-place densities shall be checked by ASTM D 1556 as follows: One check per lift for each 91 linear meters (300 linear feet) of long narrow fills, and a minimum of 2 checks per lift for other fill and backfill areas.
3.14.2 Moisture Content

In the stockpile, excavation or borrow areas, a minimum of two tests per day per type of material or source of materials being placed is required during stable weather conditions. During unstable weather, tests shall be made as dictated by local conditions and approved moisture content shall be tested in accordance with ASTM D 2216.

3.14.3 Optimum Moisture and Laboratory Maximum Density

Tests shall be made for each type material or source of material, including borrow material to determine the optimum moisture and laboratory maximum density values. One representative test per 1,500 cubic meters (2,000 cubic yards) of fill and backfill, or when any change in material occurs which may affect the optimum moisture content or laboratory maximum density will be made.

3.15 CAPILLARY WATER BARRIER

Capillary water barrier under concrete floor and area-way slabs on grade shall be placed directly on the non-expansive fill and shall be compacted with a minimum of two passes of a hand-operated plate-type vibratory compactor.

3.16 GRADING

Areas within 1.5 m (5 feet) outside of each building and structure line shall be constructed true-to-grade, shaped to drain, and shall be maintained free of trash and debris until final inspection has been completed and the work has been accepted.

3.17 SPREADING TOPSOIL

Areas outside the building lines from which topsoil has been removed shall be topsoiled. The surface shall be free of materials that would hinder planting or maintenance operations. The subgrade shall be pulverized to a depth of 50 mm (2 inches) by diskng or plowing for the bonding of topsoil with the subsoil. Topsoil shall then be uniformly spread, graded, and compacted to the thickness, elevations, slopes shown, and left free of surface irregularities. Topsoil shall be compacted by one pass of a cultipacker, roller, or other approved equipment weighing 1.46 kN/m to 2.34 kN/m (100 to 160 pounds per linear foot) of roller. Topsoil shall not be placed when the subgrade is frozen, excessively wet, extremely dry, or in a condition otherwise detrimental to seeding, planting, or proper grading.

3.18 PROTECTION

Settlement or washing that occurs in graded, topsoiled, or backfilled areas prior to acceptance of the work, shall be repaired and grades reestablished to the required elevations and slopes.

- - o 0 o - -
APPENDIX F

USEPA INNOVATIVE TECHNOLOGY VERIFICATION REPORT: FIELD MEASUREMENT TECHNOLOGIES FOR TOTAL PETROLEUM HYDROCARBONS IN SOIL
Innovative Technology Verification Report

Field Measurement Technologies for Total Petroleum Hydrocarbons in Soil

siteLAB® Corporation
siteLAB® Analytical Test Kit UVF-3100A
Environmental Technology Verification Report, "Field Measurement Technologies for Total Petroleum Hydrocarbons in Soil" siteLAB Corporation siteLAB Analytical Test Kit UVF-3100A EPA/600/R-01/080, Las Vegas, NV: US Environmental Protection Agency

Abstract

siteLAB (& Analytical Test Kit UVF-3100A (UVF-3 IOOA) developed by siteLAB Corporation (siteLAB)) was demonstrated under the U.S. Environmental Protection Agency Superfund Innovative Technology Evaluation Program in June 2000 at the Navy Base Ventura County site in Port Hueneme, California. The purpose of the demonstration was to collect reliable performance and cost data for the UVF-3 IOOA and six other field measurement device for total petroleum hydrocarbons (TPH) in soil. In addition to assessing ease of device operation, the key objectives of the demonstration included determining the (1) method detection limit, (2) accuracy and precision, (3) effects of interferents and soil moisture content on TPH measurement, (4) sample throughput, and (5) TPH measurement costs for each device. The demonstration involved analysis of both performance evaluation samples and environmental samples collected in five areas contaminated with gasoline, diesel, lubricating oil, or other petroleum products. The performance and cost results for a given field measurement device were compared to those for an off-site laboratory reference method, "Test Methods for Evaluating Solid Waste" (SW-846) Method 8015B (modified). During the demonstration, siteLAB & required 37 hours, 20 minutes, for TPH measurement of 199 samples and 13 extract duplicates. The TPH measurement costs were estimated to be $7,090 for siteLAB's UVF-3 IOOA rental option; $7,720 for the UVF-3 IOOA on-site testing service option; and $17,670 for the UVF-3 IOOA purchase option compared to $4,300 for the reference method. The method detection limits were determined to be 3.4 and 6.32 milligrams per kilogram for the UVF-3 IOOA and reference method, respectively. During the demonstration, the UVF-3 IOOA exhibited good accuracy and precision, ease of use, and lack of sensitivity to interferents that are not petroleum hydrocarbons (neat materials, including tetrachloroethene; turpenes; and 1,2,4-trichlorobenzene and soil spiked with humic acid). However, the device showed less than 5 percent response to neat materials (methyl tert-butyl ether and Stoddard solvent) that are petroleum hydrocarbons. In addition, it exhibited minor sensitivity to soil moisture content during TPH measurement of weathered gasoline soil samples. Despite some of the limitations observed during the demonstration, the demonstration findings collectively indicated that the UVF-3 IOOA is a reliable field measurement device for TPH in soil.

Mention of trade names, corporate names or commercial products does not constitute endorsement or recommendation by EPA for use.

Key Words and Document Analysis

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Innovative Technology Verification Report

siteLAB® Corporation
siteLAB® Analytical Test Kit UVF-3100A

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Contract No. 68-CS-0037

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National Exposure Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency

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Abbreviations, Acronyms, and Symbols

> Greater than
≤ Less than or equal to
± Plus or minus
µg Microgram
µm Micrometer
AC Alternating current
AEHS Association for Environmental Health and Sciences
AFB Air Force Base
API American Petroleum Institute
ASTM American Society for Testing and Materials
bgs Below ground surface
BTEX Benzene, toluene, ethylbenzene, and xylene
BVC Base Ventura County
Calibration Kit UVF Calibration Kit
CCV Continuing calibration verification
CFC Chlorofluorocarbon
CFR Code of Federal Regulations
DC Direct current
DER Data evaluation report
DRO Diesel range organics
EDRO Extended diesel range organics
EDRO standard EDRO C_{10}-C_{40} Aromatics (Weathered Diesel) standard
EPA U.S. Environmental Protection Agency
EPH Extractable petroleum hydrocarbon
EPH standard EPH C_{11}-C_{22} Aromatic Hydrocarbons standard
ERA Environmental Resource Associates
Extraction Kit 20-Sample Extraction Kit
Extraction System UVF-3100A Extraction System
FFA Fuel Farm Area
FID Flame ionization detector
GC Gas chromatograph
GRO Gasoline range organics
HPLC High-performance liquid chromatography
ICV Initial calibration verification
IDW Investigation-derived waste
ITVR Innovative technology verification report
kg Kilogram
L Liter
LCS Laboratory control sample
LCSD Laboratory control sample duplicate
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<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<td>MCAWW</td>
<td>“Methods for Chemical Analysis of Water and Wastes”</td>
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<td>MDL</td>
<td>Method detection limit</td>
</tr>
<tr>
<td>Means</td>
<td>R.S. Means Company</td>
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<tr>
<td>mg</td>
<td>Milligram</td>
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<tr>
<td>min</td>
<td>Minute</td>
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<td>mL</td>
<td>Milliliter</td>
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<td>mm</td>
<td>Millimeter</td>
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<tr>
<td>MMT</td>
<td>Monitoring and Measurement Technology</td>
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<td>MS</td>
<td>Matrix spike</td>
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<td>MSD</td>
<td>Matrix spike duplicate</td>
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<td>MTBE</td>
<td>Methyl-tert-butyl ether</td>
</tr>
<tr>
<td>n-C_x</td>
<td>Alkane with “x” carbon atoms</td>
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<td>NERL</td>
<td>National Exposure Research Laboratory</td>
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<td>NEX</td>
<td>Naval Exchange</td>
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<tr>
<td>ng</td>
<td>Nanogram</td>
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<tr>
<td>nm</td>
<td>Nanometer</td>
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<tr>
<td>ORD</td>
<td>Office of Research and Development</td>
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<tr>
<td>ORO</td>
<td>Oil range organics</td>
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<td>OSWER</td>
<td>Office of Solid Waste and Emergency Response</td>
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<tr>
<td>PAH</td>
<td>Polynuclear aromatic hydrocarbon</td>
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<td>PC</td>
<td>Petroleum company</td>
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<td>PCB</td>
<td>Polychlorinated biphenyl</td>
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<td>PCE</td>
<td>Tetrachloroethene</td>
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<td>PE</td>
<td>Performance evaluation</td>
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<td>PHC</td>
<td>Petroleum hydrocarbon</td>
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<td>PPE</td>
<td>Personal protective equipment</td>
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<td>PRA</td>
<td>Phytoremediation Area</td>
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<td>PRO</td>
<td>Petroleum range organics</td>
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<td>QA</td>
<td>Quality assurance</td>
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<td>QC</td>
<td>Quality control</td>
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<td>R^2</td>
<td>Square of the correlation coefficient</td>
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<td>RPD</td>
<td>Relative percent difference</td>
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<td>RSD</td>
<td>Relative standard deviation</td>
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<td>SFT</td>
<td>Slop Fill Tank</td>
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<td>SITE</td>
<td>Superfund Innovative Technology Evaluation</td>
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<td>siteLAB®</td>
<td>siteLAB® Corporation</td>
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<td>Severn Trent Laboratories in Tampa, Florida</td>
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<td>Total petroleum hydrocarbons</td>
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<td>UST</td>
<td>Underground storage tank</td>
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<td>siteLAB® Analytical Test Kit UVF-3100A</td>
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<td>VPH</td>
<td>Volatile petroleum hydrocarbon</td>
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<tr>
<td>VPf standard</td>
<td>VPH C_7-C_{10} + BTEX Aromatic Hydrocarbons standard</td>
</tr>
</tbody>
</table>
Acknowledgments

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Chapter 1

Introduction

The U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD) National Exposure Research Laboratory (NERL) conducted a demonstration of seven innovative field measurement devices for total petroleum hydrocarbons (TPH) in soil. The demonstration was conducted as part of the EPA Superfund Innovative Technology Evaluation (SITE) Monitoring and Measurement Technology (MMT) Program using TPH-contaminated soil from five areas located in three regions of the United States. The demonstration was conducted at Port Hueneme, California, during the week of June 12, 2000. The purpose of the demonstration was to obtain reliable performance and cost data on field measurement devices in order to provide (1) potential users with a better understanding of the devices’ performance and operating costs under well-defined field conditions and (2) the developers with documented results that will assist them in promoting acceptance and use of their devices. The TPH results obtained using the seven field measurement devices were compared to the TPH results obtained from a reference laboratory chosen for the demonstration, which used a reference method modified for the demonstration.

This innovative technology verification report (ITVR) presents demonstration performance results and associated costs for the siteLAB® Analytical Test Kit UVF-3100A (UVF-3100A). The UVF-3100A was developed by the Oak Ridge National Laboratory in collaboration with siteLAB® Corporation (siteLAB®) under the sponsorship of the U.S. Department of Energy and the EPA. Specifically, this report describes the SITE Program, the scope of the demonstration, and the components and definition of TPH (Chapter 1); the innovative field measurement device and the technology upon which it is based (Chapter 2); the three demonstration sites (Chapter 3); the demonstration approach (Chapter 4); the selection of the reference method and laboratory (Chapter 5); the assessment of reference method data quality (Chapter 6); the performance of the field measurement device (Chapter 7); the economic analysis for the field measurement device and reference method (Chapter 8); the demonstration results in summary form (Chapter 9); and the references used to prepare the ITVR (Chapter 10). Supplemental information provided by siteLAB® is presented in the appendix.

1.1 Description of SITE Program

Performance verification of innovative environmental technologies is an integral part of the regulatory and research mission of the EPA. The SITE Program was established by the EPA Office of Solid Waste and Emergency Response (OSWER) and ORD under the Superfund Amendments and Reauthorization Act of 1986. The overall goal of the SITE Program is to conduct performance verification studies and to promote the acceptance of innovative technologies that may be used to achieve long-term protection of human health and the environment. The program is designed to meet three primary objectives: (1) identify and remove obstacles to the development and commercial use of innovative technologies, (2) demonstrate promising innovative technologies and gather reliable performance and cost information to support site characterization and cleanup activities, and (3) develop procedures and policies that encourage the use of innovative technologies at Superfund sites as well as at other waste sites or commercial facilities.

The intent of a SITE demonstration is to obtain representative, high-quality performance and cost data on one or more innovative technologies so that potential users can assess the suitability of a given technology for a specific application. The SITE Program includes the following elements:
• **MMT Program**—Evaluates innovative technologies that sample, detect, monitor, or measure hazardous and toxic substances. These technologies are expected to provide better, faster, or more cost-effective methods for producing real-time data during site characterization and remediation studies than do conventional technologies.

• **Remediation Technology Program**—Conducts demonstrations of innovative treatment technologies to provide reliable performance, cost, and applicability data for site cleanups.

• **Technology Transfer Program**—Provides and disseminates technical information in the form of updates, brochures, and other publications that promote the SITE Program and participating technologies. The Technology Transfer Program also offers technical assistance, training, and workshops to support the technologies. A significant number of these activities are performed by EPA's Technology Innovation Office.

The TPH field measurement device demonstration was conducted as part of the MMT Program, which provides developers of innovative hazardous waste sampling, detection, monitoring, and measurement devices with an opportunity to demonstrate the performance of their devices under actual field conditions. These devices may be used to sample, detect, monitor, or measure hazardous and toxic substances in water, soil gas, soil, and sediment. The technologies include chemical sensors for in situ (in place) measurements, soil and sediment samplers, soil gas samplers, groundwater samplers, field-portable analytical equipment, and other systems that support field sampling or data acquisition and analysis.

The MMT Program promotes acceptance of technologies that can be used to (1) accurately assess the degree of contamination at a site, (2) provide data to evaluate potential effects on human health and the environment, (3) apply data to assist in selecting the most appropriate cleanup action, and (4) monitor the effectiveness of a remediation process. The program places a high priority on innovative technologies that provide more cost-effective, faster, and safer methods for producing real-time or near-real-time data than do conventional, laboratory-based technologies. These innovative technologies are demonstrated under field conditions, and the results are compiled, evaluated, published, and disseminated by the ORD. The primary objectives of the MMT Program are as follows:

• Test and verify the performance of innovative field sampling and analytical technologies that enhance sampling, monitoring, and site characterization capabilities

• Identify performance attributes of innovative technologies to address field sampling, monitoring, and characterization problems in a more cost-effective and efficient manner

• Prepare protocols, guidelines, methods, and other technical publications that enhance acceptance of these technologies for routine use

The MMT Program is administered by the Environmental Sciences Division of the NERL in Las Vegas, Nevada. The NERL is the EPA center for investigation of technical and management approaches for identifying and quantifying risks to human health and the environment. The NERL mission components include (1) developing and evaluating methods and technologies for sampling, monitoring, and characterizing water, air, soil, and sediment; (2) supporting regulatory and policy decisions; and (3) providing the technical support needed to ensure effective implementation of environmental regulations and strategies. By demonstrating innovative field measurement devices for TPH in soil, the MMT Program is supporting the development and evaluation of methods and technologies for field measurement of TPH concentrations in a variety of soil types. Information regarding the selection of field measurement devices for TPH is available in American Petroleum Institute (API) publications (API 1996, 1998).

The MMT Program’s technology verification process is designed to conduct demonstrations that will generate high-quality data so that potential users have reliable information regarding device performance and cost. Four steps are inherent in the process: (1) needs identification and technology selection, (2) demonstration planning and implementation, (3) report preparation, and (4) information distribution.

The first step of the verification process begins with identifying technology needs of the EPA and the regulated community. The EPA regional offices, the U.S. Department of Energy, the U.S. Department of Defense, industry, and state environmental regulatory agencies are...
asked to identify technology needs for sampling, monitoring, and measurement of environmental media. Once a need is identified, a search is conducted to identify suitable technologies that will address the need. The technology search and identification process consists of examining industry and trade publications, attending related conferences, exploring leads from technology developers and industry experts, and reviewing responses to Commerce Business Daily announcements. Selection of technologies for field testing includes evaluation of the candidate technologies based on several criteria. A suitable technology for field testing

- Is designed for use in the field
- Is applicable to a variety of environmentally contaminated sites
- Has potential for solving problems that current methods cannot satisfactorily address
- Has estimated costs that are lower than those of conventional methods
- Is likely to achieve better results than current methods in areas such as data quality and turnaround time
- Uses techniques that are easier or safer than current methods
- Is commercially available

Once candidate technologies are identified, their developers are asked to participate in a developer conference. This conference gives the developers an opportunity to describe their technologies’ performance and to learn about the MMT Program.

The second step of the verification process is to plan and implement a demonstration that will generate high-quality data to assist potential users in selecting a technology. Demonstration planning activities include a predemonstration sampling and analysis investigation that assesses existing conditions at the proposed demonstration site or sites. The objectives of the predemonstration investigation are to (1) confirm available information on applicable physical, chemical, and biological characteristics of contaminated media at the sites to justify selection of site areas for the demonstration; (2) provide the technology developers with an opportunity to evaluate the areas, analyze representative samples, and identify logistical requirements; (3) assess the overall logistical requirements for conducting the demonstration; and (4) provide the reference laboratory with an opportunity to identify any matrix-specific analytical problems associated with the contaminated media and to propose appropriate solutions. Information generated through the predemonstration investigation is used to develop the final demonstration design and sampling and analysis procedures.

Demonstration planning activities also include preparing a detailed demonstration plan that describes the procedures to be used to verify the performance and cost of each innovative technology. The demonstration plan incorporates information generated during the predemonstration investigation as well as input from technology developers, demonstration site representatives, and technical peer reviewers. The demonstration plan also incorporates the quality assurance (QA) and quality control (QC) elements needed to produce data of sufficient quality to document the performance and cost of each technology.

During the demonstration, each innovative technology is evaluated independently and, when possible and appropriate, is compared to a reference technology. The performance and cost of one innovative technology are not compared to those of another technology evaluated in the demonstration. Rather, demonstration data are used to evaluate the individual performance, cost, advantages, limitations, and field applicability of each technology.

As part of the third step of the verification process, the EPA publishes a verification statement and a detailed evaluation of each technology in an ITVR. To ensure its quality, the ITVR is published only after comments from the technology developer and external peer reviewers are satisfactorily addressed. In addition, all demonstration data used to evaluate each innovative technology are summarized in a data evaluation report (DER) that constitutes a complete record of the demonstration. The DER is not published as an EPA document, but an unpublished copy may be obtained from the EPA project manager.

The fourth step of the verification process is to distribute information regarding demonstration results. To benefit technology developers and potential technology users, the EPA distributes demonstration bulletins and ITVRs through direct mailings, at conferences, and on the Internet. The ITVRs and additional information on the
SITE Program are available on the EPA ORD web site (http://www.epa.gov/ORD/SITE).

1.2 Scope of Demonstration

The purpose of the demonstration was to evaluate field measurement devices for TPH in soil in order to provide (1) potential users with a better understanding of the devices' performance and costs under well-defined field conditions and (2) the developers with documented results that will assist them in promoting acceptance and use of their devices.

Chapter 2 of this ITVR describes both the technology upon which the UVF-3100A is based and the field measurement device itself. Because TPH is a "method-defined parameter," the performance results for the device are compared to the results obtained using an off-site laboratory measurement method—that is, a reference method. Details on the selection of the reference method and laboratory are provided in Chapter 5.

The demonstration had both primary and secondary objectives. Primary objectives were critical to the technology verification and required the use of quantitative results to draw conclusions regarding each field measurement device's performance as well as to estimate the cost of operating the device. Secondary objectives pertaining to information that was useful but did not necessarily require the use of quantitative results to draw conclusions regarding the performance of each device. Both the primary and secondary objectives are discussed in Chapter 4.

To meet the demonstration objectives, samples were collected from five individual areas at three sites. The first site is referred to as the Navy Base Ventura County (BVC) site; is located in Port Hueneme, California; and contained three sampling areas. The Navy BVC site lies in EPA Region 9. The second site is referred to as the Kelly Air Force Base (AFB) site; is located in San Antonio, Texas; and contained one sampling area. The Kelly AFB site lies in EPA Region 6. The third site is referred to as the petroleum company (PC) site, is located in north-central Indiana, and contained one sampling area. The PC site lies in EPA Region 5.

In preparation for the demonstration, a predemonstration sampling and analysis investigation was completed at the three sites in January 2000. The purpose of this investigation was to assess whether the sites and sampling areas were appropriate for evaluating the seven field measurement devices based on the demonstration objectives. Demonstration field activities were conducted between June 5 and 18, 2000. The procedures used to verify the performance and costs of the field measurement devices are documented in a demonstration plan completed in June 2000 (EPA 2000). The plan also incorporates the QA/QC elements that were needed to generate data of sufficient quality to document field measurement device and reference laboratory performance and costs. The plan is available through the EPA ORD web site (http://www.epa.gov/ORD/SITE) or from the EPA project manager.

1.3 Components and Definition of TPH

To understand the term "TPH," it is necessary to understand the composition of petroleum and its products. This section briefly describes the composition of petroleum and its products and defines TPH from a measurement standpoint. The organic compounds containing only hydrogen and carbon that are present in petroleum and its derivatives are collectively referred to as petroleum hydrocarbons (PHC). Therefore, in this ITVR, the term "PHC" is used to identify sample constituents, and the term "TPH" is used to identify analyses performed and the associated results (for example, TPH concentrations).

1.3.1 Composition of Petroleum and Its Products

Petroleum is essentially a mixture of gaseous, liquid, and solid hydrocarbons that occur in sedimentary rock deposits. On the molecular level, petroleum is a complex mixture of hydrocarbons; organic compounds of sulfur, nitrogen, and oxygen; and compounds containing metallic constituents, particularly vanadium, nickel, iron, and copper. Based on the limited data available, the elemental composition of petroleum appears to vary over a relatively narrow range: 83 to 87 percent carbon, 10 to 14 percent hydrogen, 0.05 to 6 percent sulfur, 0.1 to 2 percent nitrogen, and 0.05 to 1.5 percent oxygen. Metals are present in petroleum at concentrations of up to 0.1 percent (Speight 1991).

Petroleum in the crude state (crude oil) is a mineral resource, but when refined it provides liquid fuels, solvents, lubricants, and many other marketable products. The hydrocarbon components of crude oil include
paraffinic, naphthenic, and aromatic groups. Paraffins (alkanes) are saturated, aliphatic hydrocarbons with straight or branched chains but without any ring structure. Naphthenes are saturated, aliphatic hydrocarbons containing one or more rings, each of which may have one or more paraffinic side chains (alicyclic hydrocarbons). Aromatic hydrocarbons contain one or more aromatic nuclei, such as benzene, naphthalene, and phenanthrene ring systems, that may be linked with (substituted) naphthenic rings or paraffinic side chains. In crude oil, the relationship among the three primary groups of hydrocarbon components is a result of hydrogen gain or loss between any two groups. Another class of compounds that is present in petroleum products such as automobile gasoline but rarely in crude oil is known as olefins. Olefins (alkenes) are unsaturated, aliphatic hydrocarbons.

The distribution of paraffins, naphthenes, and aromatic hydrocarbons depends on the source of crude oil. For example, Pennsylvania crude oil contains high levels of paraffins (about 50 percent), whereas Borneo crude oil contains less than 1 percent paraffins. As shown in Figure 1-1, the proportion of straight or branched paraffins decreases with increasing molecular weight or boiling point fraction for a given crude oil; however, this is not true for naphthenes or aromatic hydrocarbons. The proportion of monocyclonaphthenes decreases with increasing molecular weight or boiling point fraction, whereas the opposite is true for polycyclonaphthenes (for example, tetralin and decalin) and polynuclear aromatic hydrocarbons (PAH); the proportion of mononuclear aromatic hydrocarbons appears to be independent of molecular weight or boiling point fraction.

Various petroleum products consisting of carbon and hydrogen are formed when crude oil is subjected to distillation and other processes in a refinery. Processing of crude oil results in petroleum products with trace quantities of metals and organic compounds that contain nitrogen, sulfur, and oxygen. These products include liquefied petroleum gas, gasoline, naphthas, kerosene, fuel oils, lubricating oils, coke, waxes, and asphalt. Of these products, gasoline, naphthas, kerosene, fuel oils, and lubricating oils are liquids and may be present at petroleum-contaminated sites. Except for gasoline and

![Diagram showing the distribution of various petroleum hydrocarbon types throughout boiling point range of crude oil.](source: Speight 1991)

Figure 1-1. Distribution of various petroleum hydrocarbon types throughout boiling point range of crude oil.
some naphthas, these products are made primarily by collecting particular boiling point fractions of crude oil from a distillation column. Because this classification of petroleum products is based on boiling point and not on chemical composition, the composition of these products, including the ratio of aliphatic to aromatic hydrocarbons, varies depending on the source of crude oil. In addition, specific information (such as boiling point and carbon ranges) for different petroleum products, varies slightly depending on the source of the information. Commonly encountered forms and blends of petroleum products are briefly described below. The descriptions are primarily based on information in books written by Speight (1991) and Gary and Handwerk (1993). Additional information is provided by Dryoff (1993).

1.3.1.1 Gasoline

Gasoline is a major exception to the boiling point classification described above because “straight-run gasoline” (gasoline directly recovered from a distillation column) is only a small fraction of the blended gasoline that is commercially available as fuel. Commercially available gasolines are complex mixtures of hydrocarbons that boil below 180 °C or at most 225 °C and that contain hydrocarbons with 4 to 12 carbon atoms per molecule. Of the commercially available gasolines, aviation gasoline has a narrower boiling range (38 to 170 °C) than automobile gasoline (-1 to 200 °C). In addition, aviation gasoline may contain high levels of paraffins (50 to 60 percent), moderate levels of naphthenes (20 to 30 percent), a low level of aromatic hydrocarbons (10 percent), and no olefins, whereas automobile gasoline may contain up to 30 percent olefins and up to 40 percent aromatic hydrocarbons.

Gasoline composition can vary widely depending on the source of crude oil. In addition, gasoline composition varies from region to region because of consumer needs for gasoline with a high octane rating to prevent engine “knocking.” Moreover, EPA regulations regarding the vapor pressure of gasoline, the chemicals used to produce a high octane rating, and cleaner-burning fuels have affected gasoline composition. For example, when use of tetraethyl lead to produce gasoline with a high octane rating was banned by the EPA, oxygenated fuels came into existence. Production of these fuels included addition of methyl-tert-butyl ether (MTBE), ethanol, and other oxygenates. Use of oxygenated fuels also results in reduction of air pollutant emissions (for example, carbon monoxide and nitrogen oxides).

1.3.1.2 Naphthas

“Naphtha” is a generic term applied to petroleum solvents. Under standardized distillation conditions, at least 10 percent of naphthas should distill below 175 °C, and at least 95 percent of naphthas should distill below 240 °C. Naphthas can be both aliphatic and aromatic and contain hydrocarbons with 6 to 14 carbon atoms per molecule. Depending on the intended use of a naphtha, it may be free of aromatic hydrocarbons (to make it odor-free) and sulfur (to make it less toxic and less corrosive). Many forms of naphthas are commercially available, including Varnish Makers’ and Painters’ naphthas (Types I and II), mineral spirits (Types I through IV), and aromatic naphthas (Types I and II). Stoddard solvent is an example of an aliphatic naphtha.

1.3.1.3 Kerosene

Kerosene is a straight-run petroleum fraction that has a boiling point range of 205 to 260 °C. Kerosene typically contains hydrocarbons with 12 or more carbon atoms per molecule. Because of its use as an indoor fuel, kerosene must be free of aromatic and unsaturated hydrocarbons as well as sulfur compounds.

1.3.1.4 Jet Fuels

Jet fuels, which are also known as aircraft turbine fuels, are manufactured by blending gasoline, naphtha, and kerosene in varying proportions. Therefore, jet fuels may contain a carbon range that covers gasoline through kerosene. Jet fuels are used in both military and commercial aircraft. Some examples of jet fuels include Type A, Type A-1, Type B, JP-4, JP-5, and JP-8. The aromatic hydrocarbon content of these fuels ranges from 20 to 25 percent. The military jet fuel JP-4 has a wide boiling point range (65 to 290 °C), whereas commercial jet fuels, including JP-5 and Types A and A-1, have a narrower boiling point range (175 to 290 °C) because of safety considerations. Increasing concerns over combat hazards associated with JP-4 jet fuel led to development of JP-8 jet fuel, which has a flash point of 38 °C and a boiling point range of 165 to 275 °C. JP-8 jet fuel contains hydrocarbons with 9 to 15 carbon atoms per molecule. Type B jet fuel has a boiling point range of 55 to 220 °C and a carbon range of 5 to 13 atoms per molecule. A new specification is currently being developed by the American Society for Testing and Materials (ASTM) for Type B jet fuel.
1.3.1.5 Fuel Oils

Fuel oils are divided into two classes: distillates and residuals. No. 1 and 2 fuel oils are distillates and include kerosene, diesel, and home heating oil. No. 4, 5, and 6 fuel oils are residuals or black oils, and they all contain crude distillation tower bottoms (tar) to which cutters (semirefined or refined distillates) have been added. No. 4 fuel oil contains the most cutter stock, and No. 6 fuel oil contains the least.

Commonly available fuel oils include No. 1, 2, 4, 5, and 6. The boiling points, viscosities, and densities of these fuel oils increase with increasing number designation. The boiling point ranges for No. 1, 2, and 4 fuel oils are about 180 to 320, 175 to 340, and 150 to 480 °C, respectively. No. 1 and 2 fuel oils contain hydrocarbons with 10 to 22 carbon atoms per molecule; the carbon range for No. 4 fuel oil is 22 to 40 atoms per molecule. No. 5 and 6 fuel oils have a boiling point range of 150 to 540 °C but differ in the amounts of residue they contain: No. 5 fuel oil contains a small amount of residue, whereas No. 6 fuel oil contains a large amount. No. 5 and 6 fuel oils contain hydrocarbons with 28 to 90 carbon atoms per molecule. Fuel oils typically contain about 60 percent aliphatic hydrocarbons and 40 percent aromatic hydrocarbons.

1.3.1.6 Diesel

Diesel is primarily used to operate motor vehicle and railroad diesel engines. Automobile diesel is available in two grades: No. 1 and 2. No. 1 diesel, which is sold in regions with cold climates, has a boiling point range of 180 to 320 °C and a cetane number above 50. The cetane number is similar to the octane number of gasoline; a higher number corresponds to less knocking. No. 2 diesel is very similar to No. 2 fuel oil. No. 2 diesel has a boiling point range of 175 to 340 °C and a minimum cetane number of 52. No. 1 diesel is used in high-speed engines such as truck and bus engines, whereas No. 2 diesel is used in other diesel engines. Railroad diesel is similar to No. 2 diesel but has a higher boiling point (up to 370 °C) and lower cetane number (40 to 45). The ratio of aliphatic to aromatic hydrocarbons in diesel is about 5. The carbon range for hydrocarbons present in diesel is 10 to 28 atoms per molecule.

1.3.1.7 Lubricating Oils

Lubricating oils can be distinguished from other crude oil fractions by their high boiling points (greater than 400 °C) and viscosities. Materials suitable for production of lubricating oils are composed principally of hydrocarbons containing 25 to 35 or even 40 carbon atoms per molecule, whereas residual stocks may contain hydrocarbons with 50 to 60 or more (up to 80 or so) carbon atoms per molecule. Because it is difficult to isolate hydrocarbons from the lubricant fraction of petroleum, aliphatic to aromatic hydrocarbon ratios are not well documented for lubricating oils. However, these ratios are expected to be comparable to those of the source crude oil.

1.3.2 Measurement of TPH

As described in Section 1.3.1, the composition of petroleum and its products is complex and variable, which complicates TPH measurement. The measurement of TPH in soil is further complicated by weathering effects. When a petroleum product is released to soil, the product's composition immediately begins to change. The components with lower boiling points are volatilized, the more water-soluble components migrate to groundwater, and biodegradation can affect many other components. Within a short period, the contamination remaining in soil may have only some characteristics in common with the parent product.

This section provides a historical perspective on TPH measurement, reviews current options for TPH measurement in soil, and discusses the definition of TPH that was used for the demonstration.

1.3.2.1 Historical Perspective

Most environmental measurements are focused on identifying and quantifying a particular trace element (such as lead) or organic compound (such as benzene). However, for some “method-defined” parameters, the particular substance being measured may yield different results depending on the measurement method used. Examples of such parameters include oil and grease and surfactants. Perhaps the most problematic of the method-defined parameters is TPH. TPH arose as a parameter for wastewater analyses in the 1960s because of petroleum industry concerns that the original "oil and grease" analytical method, which is gravimetric in nature, might inaccurately characterize petroleum industry wastewaters that contained naturally occurring vegetable oils and greases along with PHCs. These naturally occurring materials are typically long-chain fatty acids (for example, oleic acid, the major component of olive oil).
Originally, TPH was defined as any material extracted with a particular solvent that is not adsorbed by the silica gel used to remove fatty acids and that is not lost when the solvent is evaporated. Although this definition covers most of the components of petroleum products, it includes many other organic compounds as well, including chlorinated solvents, pesticides, and other synthetic organic chemicals. Furthermore, because of the evaporation step in the gravimetric analytical method, the definition excludes most of the petroleum-derived compounds in gasoline that are volatile in nature. For these reasons, an infrared analytical method was developed to measure TPH. In this method, a calibration standard consisting of three components is analyzed at a wavelength of 3.41 micrometers (μm), which corresponds to an aliphatic CH₂ hydrocarbon stretch. As shown in Table 1-1, the calibration standard is designed to mimic a petroleum product having a relative distribution of aliphatic and aromatic compounds as well as a certain percentage of aliphatic CH₂ hydrocarbons. The infrared analytical method indicates that any compound that is extracted by the solvent, is not adsorbed by silica gel, and contains a CH₂ bond is a PHC. Both the gravimetric and infrared analytical methods include an optional, silica gel fractionation step to remove polar, biogenic compounds such as fatty acids, but this cleanup step can also remove some petroleum degradation products that are polar in nature.

In the 1980s, because of the change in focus from wastewater analyses to characterization of hazardous waste sites that contained contaminated soil, many parties began to adopt the existing wastewater analytical methods for application to soil. Unfortunately, the term "TPH" was in common use, as many states had adopted this term (and the wastewater analytical methods) for cleanup activities at underground storage tank (UST) sites. Despite efforts by the API and others to establish new analyte names (for example, gasoline range organics [GRO] and diesel range organics [DRO]), "TPH" is still present in many state regulations as a somewhat ill-defined term, and most state programs still have cleanup criteria for TPH.

1.3.2.2 Current Options for TPH Measurement in Soil

Three widely used technologies measure some form of TPH in soil to some degree. These technologies were used as starting points in deciding how to define TPH for the demonstration. The three technologies and the analytes measured are summarized in Table 1-2.

Of the three technologies, gravimetry and infrared are discussed in Section 1.3.2.1. The third technology, the gas chromatograph/flame ionization detector (GC/FID), came into use because of the documented shortcomings of the other two technologies. The GC/FID had long been used in the petroleum refining industry as a product QC tool to determine the boiling point distribution of pure petroleum products. In the 1980s, environmental laboratories began to apply this technology along with sample preparation methods developed for soil samples to measure PHCs at environmental levels (Zilis, McDevitt, and Parr 1988). GC/FID methods measure all organic compounds that are extracted by the solvent and that can be chromatographed. However, because of method limitations, the very volatile portion of gasoline compounds containing four or five carbon atoms per molecule is not addressed by GC/FID methods; therefore, 100 percent recovery cannot be achieved for pure gasoline. This omission is not considered significant because these low-boiling-point aliphatic compounds (1) are not expected to be present in environmental samples (because of volatilization) and (2) pose less environmental risk than the aromatic hydrocarbons in gasoline.

The primary limitation of GC/FID methods relates to the extraction solvent used. The solvent should not interfere with the analysis, but to achieve environmental levels of

<p>| Table 1-1. Summary of Calibration Information for Infrared Analytical Method |
|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Standard Constituent</th>
<th>Constituent Type</th>
<th>Portion of Constituent in Standard (percent by volume)</th>
<th>Number of Carbon Atoms</th>
<th>Portion of Aliphatic CH₂ in Standard Constituent (percent by weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexadecane</td>
<td>Straight-chain aliphatic</td>
<td>37.5</td>
<td>2</td>
<td>CH₂</td>
</tr>
<tr>
<td>Isooctane</td>
<td>Branched-chain aliphatic</td>
<td>37.5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>Aromatic</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
Table 1-2. Current Technologies for TPH Measurement

<table>
<thead>
<tr>
<th>Technology</th>
<th>What is Measured</th>
<th>What is Not Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravimetry</td>
<td>All analytes removed from the sample by the extraction solvent that are not volatized</td>
<td>Volatiles; very polar organics</td>
</tr>
<tr>
<td>Infrared</td>
<td>All analytes removed from the sample by the extraction solvent that contain an aliphatic CHn stretch</td>
<td>Benzene, naphthalene, and other aromatic hydrocarbons with no aliphatic group attached; very polar organics</td>
</tr>
<tr>
<td>Gas chromatograph/flame ionization detector</td>
<td>All analytes removed from the sample by the extraction solvent that can be chromatographed and that respond to the detector</td>
<td>Very polar organics; compounds with high molecular weights or high boiling points</td>
</tr>
</tbody>
</table>

Detection (in the low milligram per kilogram [mg/kg] range) for soil, some concentration of the extract is needed because the sensitivity of the FID is in the nanogram (ng) range. This limitation has resulted in three basic approaches for GC/FID analyses for GRO, DRO, and PHCs.

For GRO analysis, a GC/FID method was developed as part of research sponsored by API and was the subject of an interlaboratory validation study (API 1994); the method was first published in 1990. In this method, GRO is defined as the sum of the organic compounds in the boiling point range of 60 to 170 °C, and the method uses a synthetic calibration standard as both a window-defining 2x and a quantitation standard. The GRO method was specifically incorporated into EPA "Test Methods for Evaluating Solid Waste" (SW-846) Method 8015B in 1996 (EPA 1996). The GRO method uses the purge-and-trap technique for sample preparation, effectively limiting the TPH components to the volatile compounds only.

For DRO analysis, a GC/FID method was developed under the sponsorship of API as a companion to the GRO method and was interlaboratory-validated in 1994. In the DRO method, DRO is defined as the sum of the organic compounds in the boiling point range of 170 to 430 °C. As in the GRO method, a synthetic calibration standard is used for quantitation. The DRO method was also incorporated into SW-846 Method 8015B in 1996. The technology used in the DRO method can measure hydrocarbons with boiling points up to 540 °C. However, the hydrocarbons with boiling points in the range of 430 to 540 °C are specifically excluded from SW-846 Method 8015B so as not to include the higher-boiling-point petroleum products. The DRO method uses a solvent extraction and concentration step, effectively limiting the method to nonvolatile hydrocarbons.

For PHC analysis, a GC/FID method was developed by Shell Oil Company (now Equilon Enterprises). This method was interlaboratory-validated along with the GRO and DRO methods in an API study in 1994. The PHC method originally defined PHC as the sum of the compounds in the boiling point range of about 70 to 400 °C, but it now defines PHC as the sum of the compounds in the boiling point range of 70 to 490 °C. The method provides options for instrument calibration, including use of synthetic standards, but it recommends use of products similar to the contaminants present at the site of concern. The PHC method has not been specifically incorporated into SW-846; however, the method has been used as the basis for the TPH methods in several states, including Massachusetts, Washington, and Texas. The PHC method uses solvent microextraction and thus has a higher detection limit than the GRO and DRO methods. The PHC method also begins peak integration after elution of the solvent peak for n-pentane. Thus, this method probably cannot measure some volatile compounds (for example, 2-methyl pentane and MTBE) that are measured using the GRO method.

1.3.2.3 Definition of TPH

It is not possible to establish a definition of TPH that would include crude oil and its refined products and exclude other organic compounds. Ideally, the TPH definition selected for the demonstration would have

- Included compounds that are PHCs, such as paraffins, naphthenes, and aromatic hydrocarbons
- Included, to the extent possible, the major liquid petroleum products (gasoline, naphtha, kerosene, jet fuels, fuel oils, diesel, and lubricating oils)
- Had little inherent bias based on the composition of an individual manufacturer's product
• Had little inherent bias based on the relative concentrations of aliphatic and aromatic hydrocarbons present

• Included much of the volatile portion of gasoline, including all weathered gasoline

• Included MTBE

• Excluded crude oil residuals beyond the extended diesel range organic (EDRO) range

• Excluded nonpetroleum organic compounds (for example, chlorinated solvents, pesticides, polychlorinated biphenyls [PCB], and naturally occurring oils and greases)

• Allowed TPH measurement using a widely accepted method

• Reflected accepted TPH measurement practice in many states

Several states, including Massachusetts, Alaska, Louisiana, and North Carolina, have implemented or are planning to implement a TPH contamination cleanup approach based on the aliphatic and aromatic hydrocarbon fractions of TPH. The action levels for the aromatic hydrocarbon fraction are more stringent than those for the aliphatic hydrocarbon fraction. The approach used in the above-mentioned states involves performing a sample fractionation procedure and two analyses to determine the aliphatic and aromatic hydrocarbon concentrations in a sample. However, in most applications of this approach, only a few samples are subjected to the dual aliphatic and aromatic hydrocarbon analyses because of the costs associated with performing sample fractionation and two analyses.

For the demonstration, TPH was not defined based on the aliphatic and aromatic hydrocarbon fractions because

• Such a definition is used in only a few states.

• Variations exist among the sample fractionation and analysis procedures used in different states.

• The repeatability and versatility of sample fractionation and analysis procedures are not well documented.

• In some states, TPH-based action levels are still used.

• The associated analytical costs are high.

As stated in Section 1.3.2.2, analytical methods currently available for measurement of TPH each exclude some portion of TPH and are unable to measure TPH alone while excluding all other organic compounds, thus making TPH a method-defined parameter. After consideration of all the information presented above, the GRO and DRO analytical methods were selected for TPH measurement for the demonstration. However, because of the general interest in higher-boiling-point petroleum products, the integration range of the DRO method was extended to include compounds with boiling points up to 540 °C. Thus, for the demonstration, the TPH concentration was the sum of all organic compounds that have boiling points between 60 and 540 °C and that can be chromatographed, or the sum of the results obtained using the GRO and DRO methods. This approach accounts for most gasoline, including MTBE, and virtually all other petroleum products and excludes a portion (25 to 50 percent) of the heavy lubricating oils. Thus, TPH measurement for the demonstration included PHCs as well as some organic compounds that are not PHCs. More specifically, TPH measurement did not exclude nonpetroleum organic compounds such as chlorinated solvents, other synthetic organic chemicals such as pesticides and PCBs, and naturally occurring oils and greases. A silica gel fractionation step used to remove polar, biogenic compounds such as fatty acids in some GC/FID methods was not included in the sample preparation step because, according to the State of California, this step can also remove some petroleum degradation products that are also polar in nature (California Environmental Protection Agency 1999). The step-by-step approach used to select the reference method for the demonstration and the project-specific procedures implemented for soil sample preparation and analysis using the reference method are detailed in Chapter 5.
Chapter 2
Description of Ultraviolet Fluorescence Spectroscopy and the UVF-3100A

Measurement of TPH in soil by field measurement devices generally involves extraction of PHCs from soil using an appropriate solvent followed by measurement of the TPH concentration in the extract using an optical method. An extraction solvent is selected that will not interfere with the optical measurement of TPH in the extract. Some field measurement devices use light in the visible wavelength range, and others use light outside the visible wavelength range (for example, ultraviolet light).

The optical measurements made by field measurement devices may involve absorbance, reflectance, or fluorescence. In general, the optical measurement for a soil extract is compared to a calibration curve in order to determine the TPH concentration. Calibration curves may be developed by (1) using a series of calibration standards selected based on the type of PHCs being measured at a site or (2) establishing a correlation between off-site laboratory measurements and field measurements for selected, site-specific soil samples.

Field measurement devices may be categorized as quantitative, semiquantitative, and qualitative. These categories are explained below.

• A quantitative measurement device measures TPH concentrations ranging from its reporting limit through its linear range. The measurement result is reported as a single, numerical value that has an established precision and accuracy.

• A semiquantitative measurement device measures TPH concentrations above its reporting limit. The measurement result may be reported as a concentration range with lower and upper limits.

• A qualitative measurement device indicates the presence or absence of PHCs above or below a specified value (for example, the reporting limit or an action level).

The UVF-3100A is a field measurement device capable of providing quantitative TPH measurement results. Optical measurements made using the UVF-3100A are based on ultraviolet fluorescence spectroscopy, which is described in Section 2.1. Calibration curves for the UVF-3100A are developed using calibration standards.

Section 2.1 describes the technology upon which the UVF-3100A is based, Section 2.2 describes the UVF-3100A itself, and Section 2.3 provides siteLAB contact information. The technology and device descriptions presented below are not intended to provide complete operating procedures for measuring TPH concentrations in soil using the UVF-3100A. Detailed operating procedures for the device, including soil extraction, TPH measurement, and TPH concentration calculation procedures, are available from siteLABs. Supplemental information provided by siteLABs is presented in the appendix.

2.1 Description of Ultraviolet Fluorescence Spectroscopy

This section describes the technology, ultraviolet fluorescence spectroscopy, upon which the UVF-3100A is based. This technology is suitable for measuring aromatic hydrocarbons independent of their carbon range. TPH measurement using ultraviolet fluorescence spectroscopy involves extraction of PHCs from soil using an organic solvent. Light in the ultraviolet range is used to irritate the extract and measure its TPH concentration.

Figure 2-1 shows a general schematic of ultraviolet fluorescence spectroscopy. The excitation and emission optics shown in the figure consist of optical lenses that are
used to focus light on a monochromator. A monochromator is a series of optical filters that reduce a broad-wavelength light beam to a single-wavelength beam.

In ultraviolet fluorescence spectroscopy, a multiple-wavelength lamp that emits light in the ultraviolet range is used as a light source. The ultraviolet light is directed through the excitation optics. When the resulting, focused ultraviolet light is used to irradiate the sample extract under analysis, some of the ultraviolet light is absorbed by the molecules in the extract, resulting in excitation of those molecules. The excited state of the molecules is transient, and in many cases, the excess energy is lost as heat when the molecules return to a stable state. However, some molecules return to a stable state by emitting the excess energy as light in the ultraviolet range. The light emitted has longer wavelengths than those of the ultraviolet light absorbed by the molecules and can be detected and measured. The phenomenon of releasing excess energy as light is described as fluorescence.

A large number of organic molecules and a small number of inorganic ions can fluoresce. In general, organic molecules with aromatic rings are the most likely to fluoresce. Some common classes of fluorescent organic molecules include aromatic hydrocarbons, alkyl-substituted aromatic hydrocarbons, aromatic amines, aromatic amino acids, some halo-substituted aromatic hydrocarbons, phenols, heterocyclic molecules, and a few aromatic acids (Fritz and Schenk 1987). Therefore, ultraviolet fluorescence spectroscopy may be used to identify the concentration of fluorescing PHCs—specifically, the aromatic hydrocarbon portion of TPH—in a sample extract.

In ultraviolet fluorescence spectroscopy, the emission optics are placed at a 90-degree angle to the excitation optics. The longer-wavelength light emitted by the excited molecules passes through the emission optics and is detected by a photomultiplier tube. The photomultiplier tube detects and amplifies the emitted light and converts

Figure 1-1. Schematic of ultraviolet fluorescence spectroscopy.
it into an electrical signal that is used to determine the intensity of the light emitted (fluorescence intensity). The emission optics and photomultiplier tube are placed at a 90-degree angle to the light source in order to minimize the light source interference detected by the photomultiplier tube.

A spectrum of fluorescence intensity versus emission wavelength is generated and evaluated to determine whether any of the peaks correspond to known groups of hydrocarbons. The fluorescence intensity of a sample extract depends on the amount of ultraviolet light absorbed by the extract at a specified wavelength. The amount of light absorbed can be calculated using Beer-Lambert's law, which may be expressed as shown in Equation 2-1.

\[ A = ebc \]  

(2-1)

where

\[ A = \text{Absorbance} \]
\[ e = \text{Molar absorptivity (centimeter per mole per liter [L])} \]
\[ b = \text{Light path length (centimeter)} \]
\[ c = \text{Concentration of absorbing species (mole per L)} \]

Thus, according to Beer-Lambert's law, the absorbance of aromatic hydrocarbons is directly proportional to the total concentration of the absorbing aromatic hydrocarbons and the path length of the ultraviolet light that is not absorbed by the sample extract and passes through the extract. In Equation 2-1, the molar absorptivity is a proportionality constant, which is a characteristic of the absorbing aromatic hydrocarbon and changes as the wavelength or the light irradiating the sample extract changes. Therefore, Beer-Lambert's law applies only to monochromatic light (light energy of one wavelength).

Because the fluorescence intensity of a sample extract depends on the amount of light energy absorbed by the extract, the fluorescence intensity of an extract is directly proportional to the concentrations of aromatic hydrocarbons in the extract. To determine the aromatic hydrocarbon concentration of a sample extract, a calibration curve can be generated based on the fluorescence intensity and the corresponding aromatic hydrocarbon concentrations using known standards that are selected based on the type of PHCs being measured at a site. Alternatively, a calibration curve can be generated based on the fluorescence intensity and the corresponding site-specific TPH, GRO, or EDRO results.

### 2.2 Description of UVF-3100A

The UVF-3100A was developed by siteLABs. The device is manufactured for siteLABs by Turner Designs and has been modified and distributed for environmental use by siteLABs. The UVF-3100A has been commercially available since October 1998. This section describes the device and summarizes its operating procedure.

#### 2.2.1 Device Description

The siteLABs portable fluorometer included in the UVF-3100A is fitted with excitation and emission filters that are appropriate for TPH analysis of soil samples. In addition, siteLABs has developed and provides software that can be used to manage and present data generated by the UVF-3100A.

The fluorometer uses a mercury vapor lamp with a predominant emission of 254-nanometer (nm) wavelength as its light source. Light from the lamp is directed through an excitation filter with a bandwidth of 254 nm before it irradiates a sample extract held in a quartz cuvette. Depending on the analysis being conducted, the fluorometer is fitted with an appropriate emission filter that corresponds to the wavelength at which the sample extract is expected to fluoresce. For GRO, an emission filter with a bandwidth between 275 and 285 nm is used, and for EDRO, an emission filter with a bandwidth between 300 and 400 nm is used. These filters are used because GRO and EDRO aromatic hydrocarbons fluoresce within these wavelength ranges. Both the excitation and emission filters are fitted into sleeves that fit into ports in the fluorometer. Methanol is used as the extraction solvent to analyze soil samples using the UVF-3100A.

The UVF-3100A can be used to measure petroleum products. Because aromatic hydrocarbons fluoresce when they are excited by ultraviolet light, the fluorometer can measure their concentrations in sample extracts. Aliphatic hydrocarbons do not fluoresce; therefore, the fluorometer cannot quantify aliphatic hydrocarbon concentrations. However, according to siteLABs, its software can estimate aliphatic hydrocarbon fractions and individual PAH or benzene, toluene, ethylbenzene, and xylene (BTEX) concentrations. The software produces such estimates by generating response factors based on aromatic and
aliphatic hydrocarbon ratios for two to five site-specific samples analyzed by an off-site laboratory using a GC method. In addition, if results are generated using a particular calibration curve (for example, a curve prepared using synthetic standards), the siteLAB software may be used to generate results based on an alternate calibration curve (for example, a curve prepared using petroleum products).

siteLAB has determined method detection limits (MDL) for the UVF-3100A by analyzing sand blanks; the MDLs claimed by siteLAB for petroleum products in soil range from 0.08 to 6.9 mg/kg and are listed in Table 2-1. An evaluation of the MDL accuracy, and precision achieved by the UVF-3100A during the demonstration is presented in Chapter 7.

Table 2-1. UVF-3100A Method Detection Limits

<table>
<thead>
<tr>
<th>Petroleum Product or Hydrocarbons</th>
<th>Method Detection Limit for Soil (milligram per kilogram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 2 fuel oil</td>
<td>0.50</td>
</tr>
<tr>
<td>No. 4 fuel oil</td>
<td>0.20</td>
</tr>
<tr>
<td>No. 8 fuel oil</td>
<td>0.08</td>
</tr>
<tr>
<td>Diesel</td>
<td>0.00</td>
</tr>
<tr>
<td>50 percent weathered diesel</td>
<td>0.34</td>
</tr>
<tr>
<td>Gasoline</td>
<td>6.9</td>
</tr>
<tr>
<td>50 percent weathered gasoline</td>
<td>3.9</td>
</tr>
<tr>
<td>Motor oil</td>
<td>1.0</td>
</tr>
<tr>
<td>Polynuclear aromatic hydrocarbons</td>
<td>0.04</td>
</tr>
<tr>
<td>Benzene, toluene, ethylbenzene, and xylene (GRO)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

The operating temperature range for the UVF-3100A is 0 to 38 °C. The lowest operating temperature is based on the possibility of the fluorometer's quartz crystal display freezing. According to siteLAB, the UVF-3100A does not have a storage temperature or operating humidity restriction.

The UVF-3100A contains three primary components: the (1) UVF-3100A Extraction System (Extraction System), (2) 20-Sample Extraction Kit (Extraction Kit), and (3) UVF Calibration Kit (Calibration Kit). Table 2-2 lists the items included in each of these components. The Extraction System, Extraction Kit, and Calibration Kit fit in a portable field case that is 36 inches long, 24 inches wide, and 12 inches high and weighs 55 pounds. The UVF-3100A may be operated using a direct current (DC) power source such as a 12-volt power outlet in an automobile; therefore, an alternating current (AC) power source is not required in the field. During the demonstration, siteLAB operated the UVF-3100A using AC power from the demonstration field trailer.

Table 2-2. UVF-3100A Components

<table>
<thead>
<tr>
<th>UVF-3100A Extraction System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorometer</td>
</tr>
<tr>
<td>Alternating current power adapter</td>
</tr>
<tr>
<td>Direct current power converter</td>
</tr>
<tr>
<td>RS-232 cable</td>
</tr>
<tr>
<td>Quartz cuvettes (2)</td>
</tr>
<tr>
<td>Timer (batteries included)</td>
</tr>
<tr>
<td>Certified clean sand (500 grams)</td>
</tr>
<tr>
<td>High-performance liquid chromatography-grade methanol (1 liter)</td>
</tr>
<tr>
<td>Solvent dispenser bottle</td>
</tr>
<tr>
<td>5-milliliter volumetric flask</td>
</tr>
<tr>
<td>10-milliliter volumetric flask</td>
</tr>
<tr>
<td>Tissue wipes</td>
</tr>
<tr>
<td>2 stainless-steel spatulas</td>
</tr>
<tr>
<td>Adjustable pipette</td>
</tr>
<tr>
<td>Test tube rack</td>
</tr>
<tr>
<td>Battery-powered balance (9-volt battery included)</td>
</tr>
<tr>
<td>Markers</td>
</tr>
<tr>
<td>Shaker/mixer can</td>
</tr>
<tr>
<td>siteLAB software</td>
</tr>
<tr>
<td>Portable field case</td>
</tr>
<tr>
<td>Instruction manual and quick reference guide</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>20-Sample Extraction Kit</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 extraction jars</td>
</tr>
<tr>
<td>20 weighing boats</td>
</tr>
<tr>
<td>20 pipette tips</td>
</tr>
<tr>
<td>20 syringes with detachable filters</td>
</tr>
<tr>
<td>40 10-milliliter test tubes</td>
</tr>
<tr>
<td>40 stainless-steel mixing vials</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UVF Calibration Kit</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 calibration standards</td>
</tr>
<tr>
<td>Reference method standard</td>
</tr>
</tbody>
</table>

Connecting the fluorometer to a computer allows downloading and manipulation of calibration and sample data using the siteLAB software, although a computer connection is not needed to collect or read data. An RS-232 cable is provided to connect the fluorometer to a computer. At a minimum, the computer used should support the Microsoft Windows 95 operating system and have Microsoft Excel software installed. If a computer that does not meet these requirements is used, a special computer program and technical support can be provided by siteLAB to assist the user in manipulating data.

According to siteLAB, 40 to 50 samples can be analyzed in an 8-hour period by one field technician using the UVF-3100A. Each sample takes 5 to 10 minutes to process and 5 to 10 seconds to analyze. siteLAB does not
provide the user with a training video. However, the sample analysis procedures for the UVF-3100A can be learned with a few practice attempts using the instruction manual provided with the Extraction System. siteLAB® provides technical support over the telephone during regular business hours at no additional cost. Although it is not required for operation of the UVF-3100A, siteLAB® also offers 0.5 to 1 day of training in device operation and data management. The cost of this training, excluding travel and per diem costs for a siteLAB® instructor, is included in the purchase cost of the UVF-3100A.

siteLAB® considers the UVF-3100A to be innovative because the device adapts a laboratory technology for field use. The device is able to separately report aromatic hydrocarbon concentrations for GRO and EDRO analyses.

2.2.2 Operating Procedure

Measuring TPH in soil using the UVF-3100A involves extraction and concentration measurement. The UVF-3100A can measure both GRO and EDRO components of sample extracts. Both analyses may be performed on one sample extract; however, the emission filter must be replaced and the device must be recalibrated between the GRO and EDRO analyses. During the demonstration, siteLAB® calibrated the UVF-3100A using an Extractable Petroleum Hydrocarbons (EPH) C_{11}-C_{22} Aromatic Hydrocarbons standard (EPH standard) and an EDRO C_{10}-C_{40} Aromatics (Weathered Diesel) standard (EDRO standard) for EDRO analyses and a Volatile Petroleum Hydrocarbons (VPH) C_{9}-C_{10} + BTEX Aromatic Hydrocarbons standard (VPH standard) for GRO analyses.

During the demonstration, extraction of a given soil sample was completed by adding 10 milliliters (mL) of methanol to 10 grams of the sample. The mixture was agitated manually using the shaker/mixer can. A syringe with a detachable filter was used to transfer the extract to a test tube. The extract was then decanted into a quartz cuvette that was placed in the chamber of the fluorometer. The extract was analyzed, and the device displayed the TPH concentration in parts per million, which is equivalent to a soil concentration in mg/kg. If the extract was diluted, or if a soil sample was extracted using a soil to solvent ratio other than 1:1, the dilution was entered in the siteLAB® software analysis report, and the software calculated the soil concentration. Calibration checks of the fluorometer were performed by analyzing a methanol blank after analysis of every 20 samples. In addition, QC checks of the fluorometer were also performed by analyzing a sand blank six times during the demonstration.

2.3 Developer Contact Information

Additional information about the UVF-3100A can be obtained from the following source:

siteLAB® Corporation
Mr. Steve Greason
27 Greensboro Road
Hanover, NH 03755
Telephone: (603) 643-7800
Fax: (603) 643-7900
E-mail: sgreason@site-lab.com
Internet: www.site-lab.com
APPENDIX G

NMED TPH SCREENING GUIDELINES
JUNE 24, 2003
NEW MEXICO ENVIRONMENT DEPARTMENT TPH SCREENING GUIDELINES
June 24, 2003

In some instances, it may be practical to assess areas of soil contamination that are the result of releases of petroleum products such as jet fuel and diesel, using total petroleum hydrocarbon (TPH) analyses. TPH results may be used to delineate the extent of petroleum-related contamination at these sites and ascertain if the residual level of petroleum products in soil represents an unacceptable risk to future users of the site. Petroleum hydrocarbons represent complex mixtures of compounds, some of which are regulated constituents and some compounds that are not regulated. In addition, the amount and types of the constituent compounds in a petroleum hydrocarbon release differ widely depending on what type of product was spilled and how the spill has weathered. This variability makes it difficult to determine the toxicity of weathered petroleum products in soil solely from TPH results; however, these results can be used to approximate risk in some cases, depending upon the nature of the petroleum product, the release scenario, how well the site has been characterized, and anticipated potential future land uses. In some cases, site clean up cannot be based solely on results of TPH sampling. NMED will make these determinations on a case by case basis, if NMED determines that additional data are necessary, then these TPH guidelines must be used in conjunction with the screening guidelines for individual petroleum-related contaminants in Table 3 and other contaminants, as applicable.

The screening levels for each petroleum carbon range from the Massachusetts Department of Environmental Protection (MADEP) Volatile Petroleum Hydrocarbons/Extractable Petroleum Hydrocarbons (VPH/EPH) approach and the percent composition table below were used to generate screening levels corresponding to total TPH. Except for waste oil, the information in the compositional assumptions table was obtained from Table 5-1 of the Massachusetts Department of Environmental Protection guidance document Implementation of the MADEP VPH/EPH Approach Final Draft June 2001. TPH toxicity was based only on the weighted sum of the toxicity of the hydrocarbon fractions listed in Table 1.

Table 1: TPH Compositional Assumptions in Soil

<table>
<thead>
<tr>
<th>Petroleum Product</th>
<th>C11-C22 Aromatics</th>
<th>C9-C18 Aliphatics</th>
<th>C19-C36 Aliphatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel #2/ new crankcase oil</td>
<td>60%</td>
<td>40%</td>
<td>0%</td>
</tr>
<tr>
<td>#3 and #6 Fuel Oil</td>
<td>70%</td>
<td>30%</td>
<td>0%</td>
</tr>
<tr>
<td>Kerosene and jet fuel</td>
<td>30%</td>
<td>70%</td>
<td>0%</td>
</tr>
<tr>
<td>Mineral oil dielectric fluid</td>
<td>20%</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>Unknown oila</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Waste Oilb</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

a Sites with oil from unknown sources must be tested for VOCs, SVOCs, metals, and PCBs to determine if other potentially toxic constituents are present. The TPH guidelines in Table 2 are not designed to be protective of exposure to these constituents therefore they must be tested for, and compared to, their individual NMED soil screening guidelines.

b Compositional assumption for waste oil developed by NMED is based on review of chromatographs of several types of waste oil. Sites with waste oil must be tested for VOCs, SVOCs, metals, and PCBs to determine if other potentially toxic constituents are present. The TPH guidelines in Table 2 are not designed to be protective of exposure to these constituents therefore they must be tested for, and compared to, their individual NMED soil screening guidelines.
A TPH screening guideline was calculated for each of the types of petroleum product based on the assumed composition from the above table for petroleum products and the direct soil standards incorporating ceiling concentrations given in the MADEP VPH/EPH Excel spreadsheet for each of the carbon fractions. Ground water concentrations are based on the weighted sum of the noncarcinogenic toxicity of the petroleum fractions assuming the water is drinking water.

Table 2: TPH Screening Guidelines

<table>
<thead>
<tr>
<th>Petroleum Product</th>
<th>TPH Residential Direct Exposure (mg/kg)</th>
<th>TPH Industrial Direct Exposure (mg/kg)</th>
<th>Concentration in Ground Water (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel #2/crankcase oil</td>
<td>880</td>
<td>2200</td>
<td>1.8</td>
</tr>
<tr>
<td>#3 and #6 Fuel Oil</td>
<td>860</td>
<td>2150</td>
<td>1.4</td>
</tr>
<tr>
<td>Kerosene and jet fuel</td>
<td>940</td>
<td>2350</td>
<td>3.0</td>
</tr>
<tr>
<td>Mineral oil dielectric fluid</td>
<td>1560</td>
<td>3400</td>
<td>3.7</td>
</tr>
<tr>
<td>Unknown oil</td>
<td>800</td>
<td>2000</td>
<td>2.3</td>
</tr>
<tr>
<td>Waste Oil</td>
<td>2500</td>
<td>5000</td>
<td>Petroleum-Related Contaminants</td>
</tr>
<tr>
<td>Gasoline</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Petroleum-Related Contaminants</td>
</tr>
</tbody>
</table>

Mineral oil based hydraulic fluids can be evaluated for petroleum fraction toxicity using the screening guidelines from Table 2 specified for waste oil, because this type of hydraulic fluid is composed of approximately the same range of carbon fractions as waste oil. However, these hydraulic fluids often contain proprietary additives that may be significantly more toxic than the oil itself; these additives must be considered on a site- and product-specific basis (see ATSDR hydraulic fluids profile reference). **Use of alternate screening guideline values requires prior written approval from the New Mexico Environment Department.** TPH screening guidelines in Table 2 must be used in conjunction with the screening levels for petroleum-related contaminants given in Table 3 because the TPH screening levels are NOT designed to be protective of exposure to these individual petroleum-related contaminants. Table 3 petroleum related contaminants screening levels are based on the New Mexico Environment Department soil screening levels (NMED SSLs) released in December of 2000.

The list of petroleum-related contaminants does not include PAHs with individual screening levels that would exceed the total TPH screening levels (acenaphthene, anthracene, fluoranthene, fluorene, and pyrene). In addition, these TPH screening guidelines are based solely on human health, not ecological risk considerations, protection of surface water, or potential indoor air impacts from soil vapors. Potential soil vapor impacts to structures or utilities are not addressed by these guidelines. Site-specific investigations for potential soil vapor impacts to structures or utilities must be done to assure that screenings are consistently protective of human health, welfare or use of the property. NMED believes that use of these screening guidelines will allow more efficient screenings of petroleum release sites at sites while protecting human health and the environment. Copies of the references cited below are available on the MADEP website at [http://www.state.ma.us/dep/bwsc/vph_eph.htm](http://www.state.ma.us/dep/bwsc/vph_eph.htm) and the NMED website at [http://www.nmenv.state.nm.us/HWB/guidance.html](http://www.nmenv.state.nm.us/HWB/guidance.html).
### Table 3. Petroleum-Related Contaminants Screening Guidelines

<table>
<thead>
<tr>
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* no NMED value available, value taken from MADEP paper
* for contaminated soil in contact with ground water

### References


APPENDIX H

KOMATSU HYDRAULIC PLATE COMPACTOR
SPECIFICATIONS
Hydraulic Plate Compactor

Hydraulic Excavator Attachment

Capable of handling even your toughest compaction tasks, these quality hydraulic compactors are designed for rapid mounting and simple operation.

- **MAXIMUM PRODUCTION**
  The compactor’s oversized eccentric, driven by its hydraulic motor, transmits powerful vibration waves through the baseplate to the soil.

- **MINIMUM MAINTENANCE**
  Bearings run in oil bath; no greasing is required. Baseplate and eccentric housing are integrally mounted; no bolts to tighten. Heavy rubber isolators prevent vibrations from reaching the boom of the excavator.

- **VIBRATORY PILE DRIVING**
  Where soils are suitably granular, the plate compactor can readily double as a pile driver. When placed atop a steel pile, a fencepost or similar object, the compactor’s powerful vibrating forces excite the soil particles; then, with only slight down pressure from the boom, the pile quickly slides into the earth.

PC95 - PC400
Applications
Operating system combines maximum eccentric weight with the exact proportions of amplitude and vibration frequency necessary to generate the most effective centrifugal force. Capable of producing a Mod Proctor Density of 95% or better, the hydraulic plate compactor is outstanding for compacting granular and moderately cohesive soils.
APPENDIX I

ASTM METHOD D 2922
STANDARD TEST METHODS FOR DENSITY OF SOIL AND SOIL-AGGREGATE IN PLACE BY NUCLEAR METHODS (SHALLOW DEPTH)
Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)\(^1\)

This standard is issued under the fixed designation D 2922; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reaffirmation. A superscript epsilon (\(\varepsilon\)) indicates an editorial change since the last revision or reaffirmation.

These test methods have been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

\(^{1}\) Note—Table 1 was corrected editorially in December 1997.

1. Scope

1.1 These test methods cover the determination of the total or wet density of soil and soil-rock mixtures by the attenuation of gamma radiation where the source and detector(s) remain on the surface (Backscatter Method) or the source or detector is placed at a known depth up to 300 mm (12 in.) while the detector(s) or source remains on the surface (Direct Transmission Method).

1.2 The density in mass per unit volume of the material under test is determined by comparing the detected rate of gamma radiation with previously established calibration data.

1.3 The values tested in SI units are to be regarded as the standard. The inch-pound equivalents may be approximate.

1.4 It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass \(\text{lbm}\) and a unit of force \(\text{lbf}\). This implicitly combines two separate systems of units: that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. This standard has been written using the gravitational system of units when dealing with the inch-pound system. In this system the pound \(\text{lbm}\) represents a unit of force \(\text{lbf}\) (weight). However, the use of balances or scales recording pounds of mass \(\text{lbm}\), or the recording of density in \(\text{lbm}/\text{ft}^3\) should not be regarded as a nonconformance with this standard.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific Hazard statements, see Section 6.

2. Referenced Documents

2.1 ASTM Standards:

- D 698 Test Method for Moisture-Density Relations of Soil and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop\(^2\)
- D 1557 Test Method for Moisture-Density Relations of Soil and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop\(^2\)
- D 32 16 Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures \(^3\)
- D 30 17 Test Method for Water Content of Soil and Rock In-Place by Nuclear Methods (Shallow Depth)\(^3\)
- D 4253 Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table \(^3\)
- D 4643 Test Method for Determination of Water Content by the Microwave Oven Method \(^3\)
- D 47 18 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles \(^3\)
- D 4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Method \(^3\)
- D 4959 Test Method for Determination of Water (Moisture) Content by Direct Heating Method \(^3\)

3. Significance and Use

3.1 The test methods described are useful as rapid, nondestructive techniques for the in-place determination of density of soil and rock.

3.2 The test methods are suitable for quality control and acceptance testing for construction and for research and development applications.

3.3 The nondestructive nature of the tests allow repetitive measurements to be made at a single test location.

4. Interferences

4.1 The chemical composition of the sample may affect the measurement, and adjustments may be necessary.

4.2 The test methods exhibit spatial bias in that the instrument is more sensitive to the density of the material in close proximity to the surface (Backscatter Method only).

\(^{2}\) Annual Book of ASTM Standards, Vol 04.08.

\(^{3}\) Annual Book of ASTM Standards, Vol 04.09.
been corrected out of the direct transmission method and any remaining bias is insignificant. The backscatter method is still more sensitive to the material within the first several inches from the surface.

4.3 Oversize rocks or large voids in the source-detector path may cause higher or lower density determination. Where lack of uniformity in the soil due to layering, rock or voids is suspected, the test volume site should be dug up and visually examined to determine if the test material is representative of the full material in general and if rock correction (see 9.6) is required.

4.4 The sample volume is approximately 0.0028 m³ (0.10 ft³) for the Backscatter Method and 0.0057 m³ (0.20 ft³) for the Direct Transmission Method when the test depth is 1.5 cm (6 in.). The actual sample volume is indeterminate and varies with the apparatus and the density of the material. In general, the higher the density the smaller the volume.

5. Apparatus

5.1 Nuclear Gage—An electronic counting instrument, capable of being seated on the surface of the material under test, and which contains:

5.1.1 A sealed source of high energy gamma radiation such as cesium or radium.

5.1.2 Gamma Detector—Any type of gamma detector such as a Geiger-Mueller tube(s).

5.2 Reference Standard—A block of material used for checking instrument operation and to establish conditions for a reproducible reference count rate.

5.3 Site Preparation Device—A plate, straightedge, or other suitable leveling tool which may be used for planning the test site to the required smoothness, and in the Direct Transmission Method, guiding the drive pin to prepare a perpendicular hole.

5.4 Drive Pin—A pin of slightly larger diameter than the rod in the Direct Transmission Instrument, used to prepare a hole in the material under test for inserting the rod.

5.5 Drive Pin Extractor—A tool that may be used to remove the drive pin in a vertical direction so that the pin will not distort the hole in the extraction process.

5.5.1 A slide hammer, with a drive pin attached, may also be used both to prepare a hole in the material to be tested and to extract the pin without distortion to the hole.

6. Hazards

6.1 This equipment utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of this equipment must become familiar with applicable safety procedures and government regulations.

6.2 Effective user instructions together with routine safety procedures, such as source leak tests, recording and evaluation of film badge data, etc., are a recommended part of the operation and storage of this instrument.

7. Calibration

7.1 Calibration of the instrument will be in accordance with Annex A.1.

8. Standardization and Reference Check

8.1 Nuclear gages are subject to long-term aging of the radioactive source, detectors, and electronic systems, which may change the relationship between count rate and material density. To offset this aging, the gage may be calibrated as the ratio of the measured count rate to a count rate made on a reference standard or to an air-gap count (for the backscatter air-gap technique, see 9.5.1.3). The reference count rate should be of the same order of magnitude as the measured count rate over the useful density range of the instrument.

8.2 Standardization of the gage shall be performed at the start of each day's work, and a permanent record of these data shall be retained. Perform the standardization with the gage located at least 8 m (25 ft) away from other sources of radioactive material, and clear of large masses or other items which may affect the reference count rate.

8.2.1 If recommended by the instrument manufacturer to provide more stable and consistent results: (1) turn on the gauge prior to use to allow it to stabilize, (2) leave the power on during the use of the gage for that day.

8.2.2 Using the reference standard, take at least four repetitive readings at the normal measurement period and determine the mean. If available on the gage, one measurement period of four or more times the normal period is acceptable. This constitutes one standardization check.

8.2.3 If the value obtained above is within the limits stated below, the gage is considered to be in satisfactory condition, and the value may be used to determine the count ratios for the day of use. If the value is outside these limits, allow additional time for the gage to stabilize, make sure the area is clear of sources of interference, and then conduct another standardization check. If the second standardization check is within the limits, the gage may be used, but if it also fails the test, the gage shall be adjusted or repaired as recommended by the manufacturer. The limits are as follows:

\[ \left| N_c - N_e \right| \leq 2.0 \sqrt{N_c F} \tag{1} \]

where:

- \( N_c \) = value of current standardization count,
- \( N_e \) = average of the past four values of \( N_c \) taken for prior usage, and
- \( F \) = value of prescale. [The prescale value \( (F) \) is a divisor which reduces the actual value for the purpose of display. The manufacturer will supply this value if other than 1.0.] Some instruments may have provisions to compute and display these values.

8.2.3.1 If the instrument standardization has not been checked within the previous three months, perform at least four new standardization checks, and use the mean as the value for \( N_e \).

8.3 Use the value of \( N_c \) to determine the count ratios for the current day's use of the instrument. If for any reason the measured density becomes suspect during the day's use, perform another standardization check.

9. Procedure for Field Use

9.1 Standardize the gage. (See Section 8.)

9.2 Select a test location. If the gage will be closer than 250 mm (10 in.) to any vertical mass that might influence the result, such as in a trench or alongside a pipe, follow the manufacturer's correction procedure.

9.3 Remove all loose and disturbed material. Remove
additional material as necessary to reach the material that represents a valid sample of the zone or stratum to be tested. Surface drying and spatial bias should be considered in determining the depth of material to be removed.

9.4 Plane or scrape a smooth horizontal surface so as to obtain maximum contact between the gage and the material being tested. The placement of the gage on the surface of the material to be tested is always important, but is especially critical to the successful determination of density when using the backscatter method. The optimum condition in all cases, is total contact between the bottom surface of the gauge and the surface of the material being tested. To correct for surface irregularities, use of native fines or fine sand as a filler may be necessary. The depth of the filler should not exceed approximately 3 mm (1/8 in.) and the total area filled should not exceed 10% of the bottom area of the instrument. The maximum depth of any void beneath the gage that can be tolerated without filling shall not exceed approximately 3 mm (1/8 in.). Several trial seatings may be required to achieve these conditions.

9.5 Proceed with the test in the following manner:

9.5.1 Backscatter Procedure:
9.5.1.1 Seat the gage firmly on the prepared test site.
9.5.1.3 Keep all other radioactive sources away from the gauge to avoid affecting the measurement so as not to affect the readings.
9.5.1.3 Secure and record one or more readings for the normal measurement period in the backscatter position.

NOTE 2—When using the backscatter air-gap procedure, follow the instrument manufacturers instructions regarding apparatus setup. Take the same number of readings for the normal measurement period in the air-gap position as in the standard backscatter position. Determine the air-gap ratio by dividing counts per minute obtained in the air-gap position by counts per minute obtained in standard backscatter position.

9.5.1.4 Determine the ratio of the reading to the standard count or to the air gap count. From this count ratio and the appropriate calibration and adjustment data, determine the in-place wet density.

9.5.2 Direct Transmission Procedure:
9.5.2.1 Make a hole perpendicular to the prepared surface using the guide and the hole-forming device 5.4, or by drilling if necessary. The hole shall be of such depth and alignment that insertion of the probe will not cause the gage to tilt from the plane of the prepared area. The depth of the hole must be deeper than the depth to which the probe will be placed. The guide shall be the same size as the base of the gage, with the hole in the same location on the guide as the probe on the gage. The corners of the guide are marked by scoring the surface of the soil. The guide plate is then removed and any necessary repairs are made to the prepared surface.

9.5.2.2 Proceed with testing in the following manner:
9.5.2.3 Set the gage on the soil surface, carefully aligning it with the marks on the soil so that the probe will be directly over the pre-formed hole.
9.5.2.4 Insert the probe in the hole.
9.5.2.5 Set the gage firmly by rotating it about the probe with a back and forth motion.
9.5.2.6 Pull gently on the gage in the direction that will bring the side of the probe against the side of the hole that is closest to the detector (or source) location in the gage housing.

9.5.2.7 Keep all other radioactive sources away from the gage to avoid affecting the measurement.

9.5.2.8 Secure and record one or more readings for the normal measurement period.

9.5.2.9 Determine the ratio of the reading to the standard count. From this count ratio and the appropriate calibration and adjustment data, determine the in-place wet density.

NOTE 3—Some instruments have built-in provisions to compute the ratio, wet density, and to enter an adjustment bias. Additionally some instruments may have provisions to measure and compute moisture content, and dry density.

9.6 If the volume tested is as defined in 4.4 has excess oversize material with respect to the limitations in the appropriate Test Methods D 698, D 1557 or D 4253, then a correction for wet density (unit weight) and water content must be applied. This correction will be done in accordance with Practice D 4718. This test method requires sampling from the actual test volume.

9.6.1 If samples of the measure material are to be taken for purposes of correlation with other test methods or rock correction, the volume measured can be approximated by a 200 mm (8 in.) diameter cylinder located directly under the center line of the radioactive source and detector(s). The height of the cylinder to be excavated will be the depth setting of the source and when using the Direct Transmission method or approximately 75 mm (3 in.) when using the Backscatter Method.

9.6.2 An alternative to the correction for oversize particles, that can be used with mass density methods or minimal oversize situations, involves multiple tests. Tests may be taken at adjacent locations and the results averaged to get a representative value. Comparisons need to be made to evaluate whether the presence of a single large rock or void in the soil is producing unrepresentative values of density. Whenever values obtained are questionable, the test volume site should be dug up and visually examined.

10 Calculation of Results

10.1 The in-place wet density is determined as outlined in 9.5. If dry density is required, the in-place water content shall be determined using either gravimetric samples and laboratory determination of water content (Test Methods D 2216, D 4643, D 4959, D 4944), or an instrument which determines water content by neutron thermalization (Test Method D 3017).

10.1.1 If the water content is determined by nuclear methods, Test Method D 3017, subtract the kg/m³ (lb/ft³) of moisture from the kg/m³ (lb/ft³) of wet density, and obtain dry density in kg/m³ (lb/ft³).

10.1.2 If the water content is determined by other methods, and is in the form of percent, proceed as follows:

\[
\rho_d = \frac{100\rho_w}{100 + W}
\]

where:
\[\rho_d = \text{dry density in kg/m}^3 (\text{lb/ft}^3)\]
\[\rho_w = \text{wet density in kg/m}^3 (\text{lb/ft}^3),\]
\[W = \text{water as a percent of the dry mass.}\]
11. Report
11.1 Report the following information:
11.1.1 Standardization and adjustment data for the date of the tests.
11.1.2 Make, model and serial number of the test instrument.
11.1.3 Name of the operator(s).
11.1.4 Test site identification.
11.1.5 Visual description of material tested.
11.1.6 Test mode (backscatter or direct transmission) and test depth (if applicable).
11.1.7 Wet and dry densities in kg/m³ or unit weights in lb/ft³.
11.1.8 Water content in percent of dry mass or dry unit weight.

12. Precision and Bias
12.1 Precision:
12.1.1 Precision-Criteria for judging the acceptability of wet density test results obtained by this test method are given in Table 1. The figure in column three represents the standard deviations that have been found to be appropriate for the materials tested in column one. The figures given in column four are the limits that should not be exceeded by the difference between the results of two properly conducted tests. The figures given are based upon an interlaboratory study in which five test sites containing soils, with wet densities as shown in column two were tested by eight different devices and operators. The wet density of each test site was determined three times by each device.

12.1.2 An instrument count precision of 8 kg/m³ (0.5 lb/ft³) for the Backscatter Method and 4 kg/m³ (0.25 lb/ft³) for the Direct Transmission Method are typical on a material of approximately 2000 kg/m³ (125 lb/ft³) density, with a measurement time of one minute.

* The data used to establish this precision statement is contained in a Research Report available from ASTM Headquarters. Request RR:D 18-1004.

12.1.2.1 Instrument count precision is defined as the change in density that occurs corresponding to a one standard deviation change in the count due to the random decay of the radioactive source. The density of the material and the time period of the count must be stated. It may be determined from a series of 20 or more counts taken without moving the instrument, or alternately from the calibration data using the assumption that \( \sigma \) is equal to \( \sqrt{\text{count}} \) at that density. The count must be the true instrument count corrected for any pre-scaling (see 8.2.3).

\[
P = \frac{\sigma}{S}
\]

where:
- \( P \) = instrument precision in density (kg/m³ or lb/ft³)
- \( \sigma \) = one standard deviation of the count
- \( S \) = the slope of the calibration curve at the defined density value.

12.2 Bias
12.2.1 There is no accepted reference value for this test method, therefore, bias cannot be determined.

13. Keywords
13.1 density; field density; nuclear methods

ANNEX

(Mandatory Information)

AI. CALIBRATION

The densities of materials used to establish or verify the calibration should extend through a range representative of the density of the materials to be tested. The density of these material standards shall be determined to an accuracy of ± 0.2 %.

AI.3 Sufficient data shall be taken on each density standard to ensure an instrument count precision of at least one-half the instrument count precision required for field use. The data may be presented in the form of a graph, table, equation coefficients, or stored in the gauge, to allow covering the count rate data to material density.

A1.4 The method and test procedures used in establishing
the calibration count rate data shall be the same as those used for obtaining the field count rate data.

Al. 5 The material type, actual density and assigned standard block density of each calibration standard used to establish or verify the instrument calibration shall be stated as part of the calibration data.

Al.6 The standards shall be of sufficient size to not change the count rate if enlarged in any dimension. Minimum surface dimensions of approximately 6 10 mm long by 430 mm wide (24 by 17 in.) have proven satisfactory. For the Backscatter Method a minimum depth of 230 mm (9 in.) is adequate; for the Direct Transmission Method the depth shall be at least 50 mm (2 in.) deeper than the deepest rod depth. A larger surface area may be required for the Backscatter Air-Gap technique. Minimum surface dimensions may be reduced slightly if the standards are adjacent to a dense material.

Al.7 The most successful standards that have been established for accurate calibration have been made of aluminum, magnesium, aluminum/magnesium, granite and limestone. These standards have been used in combination with each other and with historical curve information to produce accurate and reliable calibration.

Al.7.1 Standards of soil, rock, and concrete that have the characteristics of reproducible uniformity are difficult to prepare. These standards may be of use for some special calibration or field calibration where local site material chemistry or background situation require special adaptation.
APPENDIX J

UFGS SECTION 03307
CONCRETE FOR MINOR STRUCTURES
### PART 1  GENERAL

1.1  REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

**ACI INTERNATIONAL (ACI)**

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<td>Guide to Curing Concrete</td>
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<td>ACI 318/318R</td>
<td>2002</td>
<td>Building Code Requirements for Structural Concrete and Commentary</td>
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<td>Metric Building Code Requirements for Structural Concrete and Commentary</td>
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<td>Steel Welded Wire Reinforcement, Plain, for Concrete</td>
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<td>ASTM A 615/A 615M</td>
<td>2004b</td>
<td>Deformed and Plain Billet-Steel Bars for Concrete Reinforcement</td>
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<td>ASTM C 143/C 143M</td>
<td>2003</td>
<td>Slump of Hydraulic Cement Concrete</td>
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<td>Sampling Freshly Mixed Concrete</td>
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<td>Air Content of Freshly Mixed Concrete by the Pressure Method</td>
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<td>Air-Entraining Admixtures for Concrete</td>
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<td>ASTM C 309</td>
<td>2003</td>
<td>Liquid Membrane-Forming Compounds for Curing Concrete</td>
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<tr>
<td>ASTM C 31/C 31M</td>
<td>2003a</td>
<td>Making and Curing Concrete Test Specimens in the Field</td>
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<tr>
<td>ASTM C 33</td>
<td>2003</td>
<td>Concrete Aggregates</td>
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ASTM C 618 (2003) Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete
ASTM C 94/C 94M (2004a) Ready-Mixed Concrete
ASTM D 1752 (2004a) Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction
ASTM D 75 (2003) Sampling Aggregates
ASTM D 98 (1998) Calcium Chloride

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 400 (1963) Requirements for Water for Use in Mixing or Curing Concrete
COE CRD-C 572 (1974) Specifications for Polyvinylchloride Waterstops

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.] [for information only. When used, a designation following the "d" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-03 Product Data

Air-Entraining Admixture
[Accelerating Admixture]
Water-Reducing or Retarding Admixture
Curing Materials
[Reinforcing Steel]
[Expansion Joint Filler Strips, Premolded]
[Joint Sealants - Field Molded Sealants]
[Waterstops]
Manufacturer's literature is available from suppliers which demonstrates compliance with applicable specifications for the above materials.

Batching and Mixing Equipment

Batching and mixing equipment will be accepted on the basis of manufacturer's data which demonstrates compliance with the applicable specifications.

Conveying and Placing Concrete

The methods and equipment for transporting, handling, depositing, and consolidating the concrete shall be submitted prior to the first concrete placement.

[Formwork]

Formwork design shall be submitted prior to the first concrete placement.

SD-06 Test Reports

Aggregates

Aggregates will be accepted on the basis of certificates of compliance and test reports that show the material(s) meets the quality and grading requirements of the specifications under which it is furnished.

Concrete Mixture Proportions

Ten days prior to placement of concrete, the contractor shall submit the mixture proportions that will produce concrete of the quality required. Applicable test reports shall be submitted to verify that the concrete mixture proportions selected will produce concrete of the quality specified.

SD-07 Certificates

Cementitious Materials

Certificates of compliance attesting that the concrete materials meet the requirements of the specifications shall be submitted in accordance with the Special Clause "CERTIFICATES OF COMPLIANCE". Cementitious material will be accepted on the basis of a manufacturer's certificate of compliance, accompanied by mill test reports that the material(s) meet the requirements of the specification under which it is furnished.

Aggregates

Aggregates will be accepted on the basis of certificates of compliance and tests reports that show the material(s) meet the quality and grading requirements of the specifications under which it is furnished.
1.3 UNIT PRICES

1.3.1 Concrete

1.3.1.1 Payment

All costs associated with [manufacturing,] furnishing, delivering, placing, finishing, and curing of concrete for the various items of the schedule, which price shall include the cost of all formwork. Payment for concrete for which payment is made as a lump sum is [not] to be included in this unit price payment item. Payment for grout, preformed expansion joints, field-molded sealants, waterstops, reinforcing steel bars or wire reinforcement is [not] to be included in this unit price payment item.

1.3.1.2 Measurement

Concrete will be measured for payment on the basis of the actual volume of concrete within the pay lines of the structures as indicated. Measurement of concrete placed against the sides of any excavation without the use of intervening forms will be made only within the pay lines of the structure. No deductions will be made for rounded or beveled edge, for space occupied by meal work, for electrical conduits or timber, or for voids or embedded items that are either less than 0.14 cubic meter 5 cubic feet in volume or 0.1 square meter 1 square foot in cross section.

1.3.1.3 Unit of Measure

Unit of measure: cubic meter, yard.

1.4 DESIGN AND PERFORMANCE REQUIREMENTS

The Government will maintain the option to sample and test [joint sealer, joint filler material, waterstop,] aggregates and concrete to determine compliance with the specifications. The Contractor shall provide facilities and labor as may be necessary to assist the Government in procurement of representative test samples. Samples of aggregates will be obtained at the point of batching in accordance with ASTM D 75. Concrete will be sampled in accordance with ASTM C 172. Slump and air content will be determined in accordance with ASTM C 143/C 143M and ASTM C 231, respectively, when cylinders are molded. Compression test specimens will be made, cured, and transported in accordance with ASTM C 31/C 31M. Compression test specimens will be tested in accordance with ASTM C 39/C 39M. Samples for strength tests will be taken not less than once each shift in which concrete is produced [from each class of concrete required]. A minimum of three specimens will be made from each sample; two will be tested at 28 days (90 days if pozzolan is used) for acceptance, and one will be tested at 7 days for information.

1.4.1 Strength

Acceptance test results will be the average strengths of two specimens tested at 28 days (90 days if pozzolan is used). The strength of the concrete will be considered satisfactory so long as the average of three consecutive acceptance test results equal or exceed the specified compressive strength, f'c, and no individual acceptance test result falls below f'c by more than 3.4 MPa. 500 psi.
1.4.2 Construction Tolerances

A Class "C" finish shall apply to all surfaces except those specified to receive a Class "D" finish. A Class "D" finish shall apply to all surfaces which will be permanently concealed after construction. The surface requirements for the classes of finish required shall be as specified in ACI 347R.

1.4.3 Concrete Mixture Proportions

Concrete mixture proportions shall be the responsibility of the Contractor. Mixture proportions shall include the dry weights of cementitious material(s); the nominal maximum size of the coarse aggregate; the specific gravities, absorptions, and saturated surface-dry weights of fine and coarse aggregates; the quantities, types, and names of admixtures; and quantity of water per cubic yard of concrete. All materials included in the mixture proportions shall be of the same type and from the same source as will be used on the project. Specified compressive strength f'c shall be [20.7] [3000] psi at 28 days (90 days if pozzolan is used). The maximum nominal size coarse aggregate shall be [19 mm] [25 mm] [37.5 mm] [3/4 inch] [1 inch] [1-1/2 inches], in accordance with ACI 310M/310R, ACI 318/318R. The air content shall be between 4.5 and 7.5 percent. The slump shall be between 50 and 125 mm. 2 and 5 inches. The maximum water cement ratio shall be [0.50] [0.60].

1.5 REGULATORY REQUIREMENTS

The [state statutory and regulatory requirements] listed below form a part of this specification to the extent referenced.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Cementitious Materials

Cementitious materials shall conform to the appropriate specifications listed:

2.1.1.1 Portland Cement

ASTM C 150, Type [I, IA, II, IIA, III, IIIA or V], [low alkali] [I, except that the tricalcium aluminate of the Type III or IIIA cement shall be limited to [5] [8] percent].

2.1.1.2 [Blended Hydraulic Cement

ASTM C 595, Type IS[MS][MH][A], IP[MS][MH][A], P[MS][LH][-A], IP(MP)[MS][MH], I[SM][MS][MH][-A] or [_____] [with Table 2 mortar expansion limits].]

2.1.1.3 Pozzolan

Pozzolan shall conform to ASTM C 618, Class C or F, including requirements of Tables 1A and 2A.

2.1.2 Aggregates
Aggregates shall meet the quality and grading requirements of [ASTM C 33 Class Designations 4M or better] [or] [state highway department specification in accordance with paragraph REGULATORY REQUIREMENTS].

2.1.3 Admixtures

Admixtures to be used, when required or approved, shall comply with the appropriate specification listed. Chemical admixtures that have been in storage at the project site for longer than 6 months or that have been subjected to freezing shall be retested at the expense of the contractor at the request of the Contracting Officer and shall be rejected if test results are not satisfactory.

2.1.3.1 Air-Entraining Admixture

Air-entraining admixture shall meet the requirements of ASTM C 260.

2.1.3.2 [Accelerating Admixture

Calcium chloride shall meet the requirements of ASTM D 98. Other accelerators shall meet the requirements of ASTM C 494/C 494M, Type C or E.]

2.1.3.3 Water-Reducing or Retarding Admixture

Water-reducing or retarding admixture shall meet the requirements of ASTM C 494/C 494M, Type A, B, or D. [High-range water reducing admixture Type F [or G] may be used only when approved, approval being contingent upon particular placement requirements as described in the Contractor's Quality Control Plan.]

2.1.4 Water

Water for mixing and curing shall be fresh, clean, potable, and free from injurious amounts of oil, acid, salt, or alkali, except that unpotable water may be used if it meets the requirements of COE CRD-C 400.

2.1.5 [Reinforcing Steel

Reinforcing steel bar shall conform to the requirements of ASTM A 615/A 615M, Grade 60. Welded steel wire fabric shall conform to the requirements of ASTM A 185. Details of reinforcement not shown shall be in accordance with ACI 318M/318RM, ACI 318/318R, Chapters 7 and 12.]

2.1.6 [Expansion Joint Filler Strips, Premolded

Expansion joint filler strips, premolded shall be sponge rubber conforming to ASTM D 1752, Type I.]

2.1.7 [Joint Sealants - Field Molded Sealants

Joint sealants - field molded sealants shall conform to ASTM C 920, Type M, Grade NS, Class 25, use NT for vertical joints and Type M, Grade P, Class 25, use T for horizontal joints. Bond-breaker material shall be polyethylene tape, coated paper, metal foil, or similar type materials. The backup material shall be compressible, nonshrink, nonreactive with the sealant, and a nonabsorptive material such as extruded butyl or polychloroprene foam rubber. Immediately prior to installation of
field-molded sealants, the joint shall be cleaned of all debris and further cleaned using water, chemical solvents, or other means as recommended by the sealant manufacturer or directed.

2.1.8 [Waterstops]

[Waterstops shall conform to COE CRD-C 572.]

2.1.9 [Formwork]

The design and engineering of the formwork as well as its construction, shall be the responsibility of the Contractor.

2.1.10 [Form Coatings]

Forms for exposed surfaces shall be coated with a nonstaining form oil, which shall be applied shortly before concrete is placed.

2.1.11 [Vapor Barrier]

Vapor barrier shall be polyethylene sheeting with a minimum thickness of 0.15 mm 6 mils or other equivalent material having a vapor permeance rating not exceeding 30 nanograms per pascal second square meter 0.5 perms as determined in accordance with ASTM E 96.

2.1.12 [Curing Materials]

Curing materials shall conform to the following requirements.

2.1.12.1 Impervious Sheet Materials

Impervious sheet materials, ASTM C 171, type optional, except polyethylene film, if used, shall be white opaque.

2.1.12.2 Membrane-Forming Curing Compound

ASTM C 309, Type 1-D or 2, Class [A] [B].

PART 3 EXECUTION

3.1 PREPARATION

3.1.1 General

Construction joints shall be prepared to expose coarse aggregate, and the surface shall be clean, damp, and free of laitance. Ramps and walkways, as necessary, shall be constructed to allow safe and expeditious access for concrete and workmen. Snow, ice, standing or flowing water, loose particles, debris, and foreign matter shall have been removed. Earth foundations shall be satisfactorily compacted. Spare vibrators shall be available. The entire preparation shall be accepted by the Government prior to placing.

3.1.2 Embedded Items

Reinforcement shall be secured in place; joints, anchors, and other embedded items shall have been positioned. Internal ties shall be arranged.
so that when the forms are removed the metal part of the tie will be not less than 50 mm 2 inches from concrete surfaces permanently exposed to view or exposed to water on the finished structures. Embedded items shall be free of oil and other foreign matters such as loose coatings or rust, paint, and scale. The embedding of wood in concrete will be permitted only when specifically authorized or directed. All equipment needed to place, consolidate, protect, and cure the concrete shall be at the placement site and in good operating condition.

3.1.3 Formwork Installation

Forms shall be properly aligned, adequately supported, and mortar-tight. The form surfaces shall be smooth and free from irregularities, dents, sags, or holes when used for permanently exposed faces. All exposed joints and edges shall be chamfered, unless otherwise indicated.

3.1.4 [Vapor Barrier Installation

Vapor barriers shall be applied over gravel fill. Edges shall be lapped not less than 150 mm. 6 inches. All joints shall be sealed with pressure-sensitive adhesive not less than 50 mm 2 inches wide. The vapor barrier shall be protected at all times to prevent injury or displacement prior to and during concrete placement.]

3.1.5 Production of Concrete

3.1.5.1 Ready-Mixed Concrete

Ready-mixed concrete shall conform to ASTM C 94/C 94M except as otherwise specified.

3.1.5.2 Concrete Made by Volumetric Batching and Continuous Mixing

Concrete made by volumetric batching and continuous mixing shall conform to ASTM C 685/C 685M.

3.1.5.3 Batching and Mixing Equipment

The contractor shall have the option of using an on-site batching and mixing facility. The facility shall provide sufficient batching and mixing equipment capacity to prevent cold joints. The method of measuring materials, batching operation, and mixer shall be submitted for review. [On-site plant shall conform to the requirements of either ASTM C 94/C 94M or ASTM C 685/C 685M.]

3.1.6 Waterstops

Waterstops shall be installed and spliced as directed by the manufacturer.

3.2 CONVEYING AND PLACING CONCRETE

Conveying and placing concrete shall conform to the following requirements.

3.2.1 General

Concrete placement shall not be permitted when weather conditions prevent proper placement and consolidation without approval. When concrete is
mixed and/or transported by a truck mixer, the concrete shall be delivered
to the site of the work and discharge shall be completed within 1-1/2 hours
[or 45 minutes when the placing temperature is 30 degrees C 85 degrees F or
greater unless a retarding admixture is used]. Concrete shall be conveyed
from the mixer to the forms as rapidly as practicable by methods which
prevent segregation or loss of ingredients. Concrete shall be in place and
consolidated within 15 minutes after discharge from the mixer. Concrete
shall be deposited as close as possible to its final position in the forms
and be so regulated that it may be effectively consolidated in horizontal
layers 450 mm 18 inches or less in thickness with a minimum of lateral
movement. The placement shall be carried on at such a rate that the
formation of cold joints will be prevented.

3.2.2 Consolidation

Each layer of concrete shall be consolidated by [rodding, spading, or]
internal vibrating equipment. [External vibrating equipment may be used
when authorized.] Internal vibration shall be systematically accomplished
by inserting the vibrator through the fresh concrete in the layer below at
a uniform spacing over the entire area of placement. The distance between
insertions shall be approximately 1.5 times the radius of action of the
vibrator and overlay the adjacent, just-vibrated area by approximately 100
mm. a few inches. The vibrator shall penetrate rapidly to the bottom of
the layer and at least 150 mm 6 inches into the layer below, if such a
layer exists. It shall be held stationary until the concrete is
consolidated and then withdrawn slowly at the rate of about 75 mm 3 inches
per second.

3.2.3 Cold-Weather Requirements

No concrete placement shall be made when the ambient temperature is below 2
degrees C 35 degrees F or if the ambient temperature is below 5 degrees C
40 degrees F and falling. Suitable covering and other means as approved
shall be provided for maintaining the concrete at a temperature of at least
10 degrees C 50 degrees F for not less than 72 hours after placing and at a
temperature above freezing for the remainder of the curing period. Salt,
chemicals, or other foreign materials shall not be mixed with the concrete
to prevent freezing. Any concrete damaged by freezing shall be removed and
replaced at the expense of the contractor.

3.2.4 Hot-Weather Requirements

When the rate of evaporation of surface moisture, as determined by use of
Figure 1 of ACI 308R, is expected to exceed 1 kilogram per square meter 0.2
pound per square foot per hour, provisions for windbreaks, shading, fog
spraying, or covering with a light-colored material shall be made in
advance of placement, and such protective measures shall be taken as
quickly as finishing operations will allow.

3.3 [FORM REMOVAL

Forms shall not be removed before the expiration of 24 hours after concrete
placement except where otherwise specifically authorized. Supporting forms
and shoring shall not be removed until the concrete has cured for at least
5 days. When conditions on the work are such as to justify the
requirement, forms will be required to remain in place for longer periods.]

3.4 FINISHING
3.4.1 General

No finishing or repair will be done when either the concrete or the ambient temperature is below 10 degrees C. 50 degrees F.

3.4.2 Finishing Formed Surfaces

All fins and loose materials shall be removed, and surface defects including tie holes shall be filled. All honeycomb areas and other defects shall be repaired. All unsound concrete shall be removed from areas to be repaired. Surface defects greater than 13 mm 1/2 inch in diameter and holes left by removal of tie rods in all surfaces not to receive additional concrete shall be reamed or chipped and filled with dry-pack mortar. The prepared area shall be brush-coated with an approved epoxy resin or latex bonding compound or with a neat cement grout after dampening and filled with mortar or concrete. The cement used in mortar or concrete for repairs to all surfaces permanently exposed to view shall be a blend of portland cement and white cement so that the final color when cured will be the same as adjacent concrete.

3.4.3 Finishing Unformed Surfaces

All unformed surfaces that are not to be covered by additional concrete or backfill shall be float finished to elevations shown, unless otherwise specified. Surfaces to receive additional concrete or backfill shall be brought to the elevations shown and left as a true and regular surface. Exterior surfaces shall be sloped for drainage unless otherwise shown. Joints shall be carefully made with a jointing tool. Unformed surfaces shall be finished to a tolerance of 10 mm 3/8 inch for a float finish [and 8 mm 5/16 inch for a trowel finish] as determined by a 3 m 10 foot straightedge placed on surfaces shown on the plans to be level or having a constant slope. Finishing shall not be performed while there is excess moisture or bleeding water on the surface. No water or cement shall be added to the surface during finishing.

3.4.3.1 Float Finish

Surfaces to be float finished shall be screeded and darbied or bullfloated to eliminate the ridges and to fill in the voids left by the screed. In addition, the darby or bullfloat shall fill all surface voids and only slightly embed the coarse aggregate below the surface of the fresh concrete. When the water sheen disappears and the concrete will support a person's weight without deep imprint, floating should be completed. Floating should embed large aggregates just beneath the surface, remove slight imperfections, humps, and voids to produce a plane surface, compact the concrete, and consolidate mortar at the surface.

3.4.3.2 [Trowel Finish

A trowel finish shall be applied to [____]. Trowelling shall be done immediately following floating to provide a smooth, even, dense finish free from blemishes including trowel marks. Finished surfaces shall be protected from damage during the construction period.]

3.4.3.3 [Broom Finish

A broom finish shall be applied to [____]. The concrete shall be screeded
and floated to required finish plane with no coarse aggregate visible. After surface moisture disappears, the surface shall be broomed or brushed with a broom or fiber bristle brush in a direction transverse to that of the main traffic or as directed.

3.4.3.4 [Expansion and Contraction Joints]

Expansion and contraction joints shall be made in accordance with the details shown or as otherwise specified. Provide 13 mm 1/2 inch thick transverse expansion joints where new work abuts an existing concrete. Expansion joints shall be provided at a maximum spacing of 10 m 30 feet on center in sidewalks [and at a maximum spacing of [_____] meters [_____] feet in slabs], unless otherwise indicated. Contraction joints shall be provided at a maximum spacing of [2] [_____] linear meters [6] [_____] linear feet in sidewalks [and at a maximum spacing of [_____] meters [_____] feet in slabs], unless otherwise indicated. Contraction joints shall be cut at a minimum of [25] [_____] mm [1] [_____] inch(es) deep with a jointing tool after the surface has been finished.

3.5 CURING AND PROTECTION

Beginning immediately after placement and continuing for at least 7 days, [except for concrete made with Type III cement, at least 3 days,] all concrete shall be cured and protected from premature drying, extremes in temperature, rapid temperature change, freezing, mechanical damage, and exposure to rain or flowing water. All materials and equipment needed for adequate curing and protection shall be available and at the site of the placement prior to the start of concrete placement. Preservation of moisture for concrete surfaces not in contact with forms shall be accomplished by one of the following methods:

a. Continuous sprinkling or ponding.

b. Application of absorptive mats or fabrics kept continuously wet.

c. Application of sand kept continuously wet.

d. Application of impervious sheet material conforming to ASTM C 171.

e. Application of membrane-forming curing compound conforming to ASTM C 309, Type 1-D, on surfaces permanently exposed to view and Type 2 on other surfaces shall be accomplished in accordance with manufacturer's instructions.

The preservation of moisture for concrete surfaces placed against wooden forms shall be accomplished by keeping the forms continuously wet for 7 days [except for concrete made with Type III cement, 3 days]. If forms are removed prior to end of the required curing period, other curing methods shall be used for the balance of the curing period. During the period of protection removal, the temperature of the air in contact with the concrete shall not be allowed to drop more than 15 degrees C 25 degrees F within a 24 hour period.

3.6 TESTS AND INSPECTIONS

3.6.1 General
The individuals who sample and test concrete as required in this specification shall have demonstrated a knowledge and ability to perform the necessary test procedures equivalent to the ACI minimum guidelines for certification of Concrete Field Testing Technicians, Grade I.

3.6.2 Inspection Details and Frequency of Testing

3.6.2.1 Preparations for Placing

Foundation or construction joints, forms, and embedded items shall be inspected in sufficient time prior to each concrete placement by the Contractor to certify that it is ready to receive concrete.

3.6.2.2 Air Content

Air content shall be checked at least [once] [twice] during each shift that concrete is placed [for each class of concrete required]. Samples shall be obtained in accordance with ASTM C 172 and tested in accordance with ASTM C 231.

3.6.2.3 Slump

Slump shall be checked [once] [twice] during each shift that concrete is produced [for each class of concrete required]. Samples shall be obtained in accordance with ASTM C 172 and tested in accordance with ASTM C 143/C 143M.

3.6.2.4 Consolidation and Protection

The Contractor shall ensure that the concrete is properly consolidated, finished, protected, and cured.

3.6.3 Action Required

3.6.3.1 Placing

The placing foreman shall not permit placing to begin until he has verified that an adequate number of acceptable vibrators, which are in working order and have competent operators, are available. Placing shall not be continued if any pile is inadequately consolidated.

3.6.3.2 Air Content

Whenever a test result is outside the specification limits, the concrete shall not be delivered to the forms and an adjustment shall be made to the dosage of the air-entrainment admixture.

3.6.3.3 Slump

Whenever a test result is outside the specification limits, the concrete shall not be delivered to the forms and an adjustment should be made in the batch weights of water and fine aggregate. The adjustments are to be made so that the water-cement ratio does not exceed that specified in the submitted concrete mixture proportion.

3.6.4 Reports
The results of all tests and inspections conducted at the project site shall be reported informally at the end of each shift and in writing weekly and shall be delivered within 3 days after the end of each weekly reporting period. See Section 01451A CONTRACTOR QUALITY CONTROL.

-- End of Section --
APPENDIX K

TECHNICAL SPECIFICATION
ITEM 00434
FLOWABLE FILL
TECHNICAL SPECIFICATION

ITEM 00434
FLOWABLE FILL

434.1 Description. This item specifies flowable fill to be used as backfill for construction of underground utilities, as called for on the drawings, or in other parts of the specifications. This material may be used in lieu of cement stabilized sand, at the option of the Engineer. Because of the time required for "setting up", this material can only be used at locations where the trench can be left open for approximately twelve hours prior to backfilling. Shoring for excavations and trenches shall meet the requirements of the latest edition of OSHA Regulation 1926, Subpart P.

434.2 Materials. Cement shall be Type I Portland cement conforming to ASTM C150.

Fly ash shall meet the requirements of ASTM C618, Class C. Fly ash shall have a minimum CaO content of 20-percent.

Sand shall be clean, durable sand containing not more than the following:

A. Deleterious Materials

Clay lumps, when tested in accordance with ASTM C142, shall be less than 0.5 percent.

Lightweight pieces, when tested in accordance with ASTM C123, shall be less than 5.0 percent.

Organic impurities, when tested in accordance with ASTM C40, shall not show a color darker than the standard color.

B. The plasticity index shall be six (6) or less when tested in accordance with ASTM D4318.

B. Sand shall be free of organic matter and deleterious substances and shall meet the following gradation requirement:

<table>
<thead>
<tr>
<th>Square Sieve Size</th>
<th>Percent Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>100%</td>
</tr>
<tr>
<td>No. 200</td>
<td>0 - 10%</td>
</tr>
</tbody>
</table>

Note: It is intended that the sand be a fine sand that will stay in suspension, in the mixture, to the extent required to obtain a flowable consistency. The gradation shall be adjusted to achieve this consistency.

Water shall be clean and clear, free of oils, acids, alkalis, organic matter, or other deleterious substances and shall conform to the requirements of ASTM Designation C94.

Admixtures shall conform to ASTM Designations C1017 and/or C494.

434.3 Mix Design. The following are given as typical mix designs for trial mixes. Adjustments of the proportions may be made to achieve proper solid suspension and optimum flowability. Admixtures may be used, if desired, to improve the characteristics of the mix. The suggested quantities of dry material per cubic yard are as follows:

Trial Mix No. 1

00434-1
Cement 100 lbs.
Fly Ash 250 lbs.
Sand 2600 lbs.
Water (approx.) 50 gals.

Trial Mix No. 2
Cement 100 lbs.
Fly Ash 300 lbs.
Sand 2600 lbs.
Water (approx.) 70 gals.

The above quantities will give an approximate yield of one cubic yard. The flowability of the mixture shall be observed by the Engineer and flowability increased/decreased by adjusting the water content as well as increasing/decreasing the air entraining admixture content.

434.4 Consistency. The consistency of the mix shall be tested by filling an open-ended three-inch diameter cylinder six-inches high, to the top with flowable fill. The cylinder shall be immediately pulled straight up and the correct consistency of the flowable fill shall produce a minimum eight-inch diameter circular type spread, with no segregation. The flowable fill shall maintain its consistency when placed.

434.5 Batching, Mixing, and Transportation. Materials are to be measured by weight. The flowable fill may be mixed in a central concrete mixer, a ready mix truck, or other means acceptable to the Engineer. The flowable fill shall be transported to the point of placement in a revolving drum mixer or in an agitator unit.

434.6 Placement. The flowable fill shall be placed by direct discharge from the mixer truck, or other approved methods. If necessary to prevent segregation, boots shall be used.

The flowable fill shall be placed in accordance with the drawings attached to Item 00430, "Construction of Underground Utilities" and Item 00480, "Precast Reinforced Concrete Box Sewers". It will be necessary to use cement stabilized sand as bedding, as shown by drawings HC430-1-2-3 and HC480-1-2. At the option of the Engineer, the flowable fill may be used above the bedding to the uppermost elevation shown on the referenced drawings.

434.7 Measurement. No direct payment shall be made for flowable fill when used as backfill in accordance with Items 430 and 480, and the drawings attached thereto.

Where used as backfill at other locations, and where measured, flowable fill shall be measured by the cubic yard, computed from the dry weight of the material.

434.8 Where measured for payment in accordance with Section 434.7 of this specification, flowable fill shall be paid for at the contract unit price bid per cubic yard, for flowable fill, which price shall be full payment for all materials, equipment, labor, and transportation necessary to complete the work.
Flowable fill is suitable for all routine backfilling and is especially beneficial as structural backfill beneath foundations and as a backfill for abandoned pipelines, culverts, tanks and other below-grade structures, utility trenches, catch basins, and others.

Flowable fill can be placed from a ready-mix truck in a full depth layer without compaction of thin layers. The flowable fill hardens within a reasonable time and can carry traffic without future settlement. The hardened flowable fill can serve as a temporary riding surface until a matching roadway surface can be placed on it.

**Application:** This is an acceptable material to use in original construction or in maintenance situations. It can be used to reduce the size of the excavation and in all weather conditions, including rain.

**Availability:** Most of the major ready-mix plans can provide specification material. It is supplied as a finished product by means of ready-mix trucks and is handled similarly to concrete except that it is flowable and does not require labor for placement.

**Mix Designs (Maximum Density):** The mixes fall into the categories of "very flowable" and "less flowable," which is controlled by the amount of water that is added. Both mixes contain sand from an approved source with sufficient cement and fly ash to obtain maximum density at optimal moisture with load-bearing capacity and stability characteristics as good as or better than a well-compacted granular base material. In either category, the mix design is the same except for the water content. The added volume shown in the very flowable mix is comprised only of the extra water used to obtain extra flowability. That extra water will be displaced during the consolidation process and the resulting in-place volume (yield) will be approximately 27 cubic feet (one cubic yard).

The less flowable mix can be used when it is desirable to put traffic back on a roadway quickly (usually 8 to 10 hours) or when being used to backfill pipes which could "float" out of position due to the buoyant effect of the very flowable mix. This mix will still have the workability necessary to self-consolidate around pipes without any "honeycomb" areas. The very flowable mix is self-leveling and requires minimal effort to place but requires longer time to displace the extra water and develop load-bearing capacity (usually 10 to 20 hours). Adding water to flowable fill to obtain the desired plastic characteristics will not compromise the quality of the hardened flowable fill.

<table>
<thead>
<tr>
<th>Mix 1 Less Flowable</th>
<th>Mix 2 Very Flowable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weights</strong></td>
<td><strong>Volume</strong></td>
</tr>
<tr>
<td><strong>Min.</strong></td>
<td><strong>Min.</strong></td>
</tr>
<tr>
<td>50 lbs Cement</td>
<td>.25</td>
</tr>
<tr>
<td>600 lbs Fly Ash</td>
<td>4.24</td>
</tr>
<tr>
<td>2500 lbs Sand</td>
<td>15.17</td>
</tr>
<tr>
<td>458 lbs Water</td>
<td>7.34</td>
</tr>
<tr>
<td>SSD 55 Gal</td>
<td></td>
</tr>
<tr>
<td>8.68</td>
<td></td>
</tr>
<tr>
<td><strong>Total Cubic Feet</strong></td>
<td><strong>Total Cubic Feet</strong></td>
</tr>
<tr>
<td>27.00</td>
<td>28.34</td>
</tr>
</tbody>
</table>

*One cubic yard of very flowable fill will be mixed to contain more than 27 cubic feet due to the additional water.*

Above values are based on specific gravities - cement, 3.15; fly ash, 2.27; sand, 2.64; and water, 1.00. Anticipated unconfined compressive strength is 60 psi at 28 days and 150 psi at 56 days.
SUPPLEMENTAL SPECIFICATIONS

If the situation demands greater flowability than Mix 2, the Engineer may increase the fly ash in increments of 50 pounds while decreasing the sand in increments 58 pounds. If higher unconfined strengths are needed and the ability to easily re-excavate is not necessary the Engineer may increase the cement in increments of 10 pounds while decreasing the sand in increments of 8 pounds.

Low Density Flowable Fill: Low-density flowable fill is an option. Low-density flowable fill depends on about 30% air entrained into the plastic material to obtain the flowability characteristics of standard maximum-density flowable fill. Low-density flowable fill also depends on the development of cementitious bonds to obtain the load-bearing characteristics associated with the standard maximum-density flowable fill.

Before using low-density flowable fill, the mix design and laboratory test data shall be submitted to the Research and Materials Engineer for approval at least 30 days in advance of starting the work. Test data should show set times, flowability characteristics, and compressive strength at 28 days.

Materials and Equipment: The materials and equipment used to produce flowable fill shall be in compliance with the requirements of the Department’s standard Specifications for Highway Construction Edition of 1986 Subsection 700 applicable Special Provisions. Sampling and testing of maximum density flowable fill and the materials used to produce it will not be required.

Construction: The trench shall be prepared and the pipe joints or other utility placed as normal. There should be at least 6 inches of flowable fill above any utility line.

The Resident Engineer will select the appropriate mix design for the application at the site. Typically, the less flowable mix will be used to cover a utility pipe. Once the pipe is covered, it will be sufficiently anchored and water may be added to the remaining flowable fill to ease placement without danger of floating the pipe. If it is important to quickly return traffic to the roadway, the less flowable mix would be preferred full depth.

The flowable fill shall be discharged directly from the truck into the space to be filled, or by other methods approved by the Engineer. The mix may be placed part depth or full depth as conditions at the site dictate. Formed walls or other bulkheads shall be constructed to withstand the hydrostatic pressure exerted by the flowable fill. Trench ends outside the roadway should be blocked with sandbags or mounded soil rather than wood or metal forms. When backfilling utility lines such as pipe culverts, flowable fill shall be distributed evenly to prevent any movement of the line.

The material is self-consolidating and there is no need to use vibrators, even when placed in a less-flowable state. No field testing is needed when using flowable fill. The less flowable mix can be placed in the rain or in standing water and the hardened flowable fill will obtain uniform (controlled) density.

Finishing can be accomplished with a square shovel if the fill surface is at the bottom of the pavement or with a wood float if the surface will be temporarily used as a finish surface.

Once the flowable fill is in the trench, the self-consolidating material displaces the extra water not needed for maximum density. Provision shall be made for this "bleed water" to run off and away from the surface of the hardening flowable fill (use of vapor barriers such as plastic sheet are not desired). The material will usually support foot traffic within an hour after the bleeding ends. Typically, full traffic can be allowed on the hardened flowable fill within 8 to 20 hours (depending on the mix used, site conditions, volume to be backfilled, etc.) without damage to the fill or any structure below. If it is necessary to return traffic in less than 8 hours or if there is concern that traffic flow will "nut" the hardening flowable fill, steel plates shall be used to bridge over the hardening flowable fill as directed by the Engineer. If the filled cavity is too wide to bridge, steel plates shall be placed on top of the hardening flowable fill as soon as it is able to support foot traffic (one hour after bleeding ends), and full traffic can be allowed without damage to the fill or the structure below.

As the extra water is displaced from the consolidating flowable fill, there will be an initial subsidence of about one-eighth of an inch per vertical foot. Once the flowable fill hardens there will be no future settlement. The hardened flowable fill can be shaped to grade the next day to allow the patch thickness required by the Engineer. The patch may be applied directly on top of the flowable fill.
SUPPLEMENTAL SPECIFICATIONS

It will be the responsibility of the contractor to furnish the necessary information to obtain approval of the suggested mix design and to use the necessary construction techniques to assure that the finished material will perform as intended.

Basis of Payment: No separate measurement or payment will be made for this item.

Flowable Fill Content Mixtures and Specifications

Guidance on Materials Quantities for Mixtures

A mix design for the use of foundry sand and coal fly ash in flowable fill was developed for Ford Motor Company. The following table provides the recommended trial mixture from this specification.

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity per Cubic Yard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>50 lbs.</td>
</tr>
<tr>
<td>Coal fly ash</td>
<td>250 lbs.</td>
</tr>
<tr>
<td>Foundry sand</td>
<td>2,850 lbs.</td>
</tr>
<tr>
<td>Water</td>
<td>500 lbs.</td>
</tr>
</tbody>
</table>

The American Concrete Institute (ACI) report ACI229R-94 provides guidance on the percentages of coal fly ash that can be used in flowable fill mixtures. Among other things, ACI229R-94 addresses materials, including coal fly ash and foundry sands, mix design, and mixing, transporting, and placing. It also provides examples of mixture designs containing coal fly ash used by the states of Iowa, Florida, Illinois, Indiana, Oklahoma, Michigan, Ohio, and South Carolina. "Fly Ash Facts for Highway Engineers" (FHWA-SA-94-081, August 1995) addresses materials, strength, flowability, time of set, bleeding and shrinkage. This document can be ordered through the American Coal Ash Association.

Specifications, Test Methods, and Practices

EPA recommends that procuring agencies use ACI229R-94 and the ASTM standards listed in the following table when purchasing flowable fill or contracting for construction that involves backfilling or other fill applications.

<table>
<thead>
<tr>
<th>ASTM Specification Number</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 4832-95el</td>
<td>Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders</td>
</tr>
<tr>
<td>D 5239-92</td>
<td>Standard Practice for Characterizing Fly Ash for Use in Soil Stabilization</td>
</tr>
<tr>
<td>Standard Practice for Sampling Freshly Mixed Controlled Low Strength Material, D 5971-96</td>
<td></td>
</tr>
<tr>
<td>Standard Test Method for Flow Consistency of Controlled Low Strength Material, D 6103-07</td>
<td></td>
</tr>
<tr>
<td>Standard Test Method for Unit Weight, Yield, Cement Content and Air Content (Gravimetric) of Controlled Low Strength Material (CLSM), D 6023-96</td>
<td></td>
</tr>
<tr>
<td>Standard Practice for Sampling Freshly Mixed Controlled Low Strength Material, D 5971-96</td>
<td></td>
</tr>
<tr>
<td>Standard Test Method for Ball Drop on Controlled Low Strength Material (CLSM) to Determine Suitability for Load Application, D 6024-96</td>
<td></td>
</tr>
</tbody>
</table>

More than 20 states have specifications for flowable fill containing coal fly ash. They include California, Colorado, Delaware, Florida, Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New Mexico, North Carolina, Ohio, Texas, Washington, West Virginia, and Wisconsin.
APPENDIX L

ACI 229R-99

CONTROLLED LOW-STRENGTH MATERIALS
Controlled low-strength material (CLSM) is a self-compacted, cementitious material used primarily as a backfill in place of compacted fill. Many terms are currently used to describe this material, including flowable fill, unshrinkable fill, controlled density fill, flowable mortar, fly ash slurry, plastic soil-cement, soil-cement slurry and other various names. This report contains information on applications, material properties, mix proportioning, construction, and quality-control procedures. The intent of this report is to provide basic information on CLSM technology, with emphasis on CLSM material characteristics and advantages over conventional compacted fill.

**Keywords:** aggregates; backfill; compacted fill; controlled density fill; controlled low-strength material; flowable fill; flowable mortar; fly ash; foundation stabilization; low-density material; pipe bedding; plastic soil-cement; preformed foam; soil-cement slurry; trench backfill; unshrinkable fill; void filling.
CHAPTER 1—INTRODUCTION

Controlled low-strength material (CLSM) is a self-compacted, cementitious material used primarily as a backfill as an alternative to compacted fill. Several terms are currently used to describe this material, including flowable fill, unshrinkable fill, controlled density fill, flowable mortar, plastic soil-cement, soil-cement slurry, and other various names.

Controlled low-strength materials are defined by ACI 116R as materials that result in a compressive strength of 8.3 MPa (1200 psi) or less. Most current CLSM applications require unconfined compressive strengths of 2.1 MPa (300 psi) or less. This lower-strength requirement is necessary to allow for future excavation of CLSM.

The term CLSM can be used to describe a family of mixtures for a variety of applications. For example, the upper limit of 8.3 MPa (1200 psi) allows use of this material for applications where future excavation is unlikely, such as structural fill under buildings. Chapter 8 of this report describes low-density (LD) CLSM produced using preformed foam as part of the mixture proportioning. The use of preformed foam in LD-CLSM mixtures allow these materials to be produced having unit weights lower than those of typical CLSM. The distinctive properties and mixing procedures for LD-CLSM are discussed in the chapter. Future CLSM mixtures can be developed as anticorrosion fills, thermal fills, and durable pavement bases.

CLSM should not be considered as a type of low-strength concrete, but rather a self-compacted backfill material that is used in place of compacted fill. Generally, CLSM mixtures are not designed to resist freezing and thawing, abrasive or erosive forces, or aggressive chemicals. Nonstandard materials can be used to produce CLSM as long as the materials have been tested and found to satisfy the intended application.

Also, CLSM should not be confused with compacted soil-cement, as reported in ACI 230.1R. CLSM typically requires no compaction (consolidation) or curing to achieve the desired strength. Long-term compressive strengths for compacted soil-cement often exceed the 8.3 MPa (1200 psi) maximum limit established for CLSM.

Long-term compressive strengths of 0.3 to 2.1 MPa (50 to 300 psi) are low when compared with concrete. In terms of allowable bearing pressure, however, which is a common criterion for measuring the capacity of a soil to support a load, 0.3 to 0.7 MPa (50 to 100 psi) strength is equivalent to a well-compacted fill.

Although CLSM generally costs more per yd³ than most soil or granular backfill materials, its many advantages often result in lower in-place costs. In fact, for some applications, CLSM is the only reasonable backfill method available. Table 1 lists a number of advantages to using CLSM.

CHAPTER 2—APPLICATIONS

2.1—General

As stated earlier, the primary application of CLSM is as a structural fill or backfill in lieu of compacted soil. Because CLSM needs no compaction and can be designed to be fluid, it is ideal for use in tight or restricted-access areas where placing and compacting fill is difficult. If future excavation is anticipated, the maximum long-term compressive strength should generally not exceed 2.1 MPa (300 psi). The following applications are intended to present a range of uses for CLSM.

2.2—Backfills

CLSM can be readily placed into a trench, hole or other cavity (Fig. 2.1 and 2.2). Compaction is not required; hence, the trench width or size of excavation can be reduced. Granular or site-excavated backfill, even if compacted properly in the required layer thickness, can not achieve the uniformity and density of CLSM.

When backfilling against retaining walls, consideration should be given to the lateral pressures exerted on the wall by flowable CLSM. Where the lateral fluid pressure is a concern, CLSM can be placed in layers, allowing each layer to harden prior to placing the next layer.

Following severe settlement problems of soil backfill in utility trenches, the city of Peoria, Ill., in 1988, tried CLSM as an alternative backfill material. The CLSM was placed in trenches up to 2.7 m (9 ft) deep. Although fluid at time of placement, the CLSM hardened to the extent that a person’s weight could be supported within 2 to 3 hr. Very few shrinkage cracks were observed. Further tests were conducted on patching the overlying pavement within 3 to 4 hr. In one test, a pavement patch was successfully placed over a sewer trench.
immediately after backfilling with CLSM. As a result of these initial tests, the city of Peoria has changed its backfilling procedure to require the use of CLSM on all street openings.4

Some agencies backfill with a CLSM that has a setting time of 20 to 35 min. (after which time a person can walk on it). After approximately 1 hr, the wearing surface consisting of either a rapid-setting concrete or asphalt pavement is placed, resulting in a total traffic-bearing repair in about 4 hr.6

2.3—Structural fills

Depending upon the strength requirements, CLSM can be used for foundation support. Compressive strengths can vary from 0.7 to 8.3 MPa (100 to 1200 psi) depending upon application. In the case of weak soils, it can distribute the structure’s load over a greater area. For uneven or nonuniform subgrades under foundation footings and slabs, CLSM can provide a uniform and level surface. Compressive strengths will vary depending upon project requirements. Because of its strength, CLSM may reduce the required thickness or strength requirements of the slab. Near Boone, Iowa, 2141 m³ (2800 yd³) of CLSM was used to provide proper bearing capacity for the footing of a grain elevator.7

2.4—Insulating and isolation fills

LD-CLSM material is generally used for these applications. Chapter 8 addresses LD-CLSM material using pre-formed foam.

2.5—Pavement bases

CLSM mixtures can be used for pavement bases, subbases, and subgrades. The mixture would be placed directly from the mixer onto the subgrade between existing curbs. For base course design under flexible pavements, structural coefficients differ depending upon the strength of the CLSM. Based on structural coefficient values for cement-treated bases derived from data obtained in several states, the structural coefficient of a CLSM layer can be estimated to range from 0.16 to 0.28 for compressive strengths from 2.8 to 8.3 MPa (400 to 1200 psi).4

Good drainage, including curb and gutter, storm sewers, and proper pavement grades, is required when using CLSM mixtures in pavement construction. Freezing and thawing damage could result in poor durability if the base material is frozen when saturated with water.

A wearing surface is required over CLSM because it has relatively poor wear resistance properties. Further information regarding pavement base materials is found in ACI 325.3R.
2.6—Conduit bedding

CLSM provides an excellent bedding material for pipe, electrical, telephone, and other types of conduits. The flowable characteristic of the material allows the CLSM to fill voids beneath the conduit and provide a uniform support.

The U.S. Bureau of Reclamation (USBR) began using CLSM in 1964 as a bedding material for 380 to 2400 mm (15 to 96 in.) diameter concrete pipe along the entire Canadian River Aqueduct Project, which stretches 518 km (322 miles) from Amarillo to Lubbock, Tex. Soil-cement slurry pipe bedding, as referred to by the USBR, was produced in central portable batching plants that were moved every 16 km (10 miles) along the route. Ready-mixed concrete trucks then delivered the soil-cement slurry to the placement site. The soil was obtained from local blow sand deposits. It was estimated that the soil-cement slurry reduced bedding costs 40%. Production increased from 120 to 300 m (400 to 1000 linear ft) of pipe placed per shift.9

CLSM can be designed to provide erosion resistance beneath the conduit. Since the mid-1970s, some county agencies in Iowa have been placing culverts on a CLSM bedding. This not only provides a solid, uniform pipe bedding, but prevents water from getting between the pipe and bedding, eroding the support.10

Encasing the entire conduit in CLSM also serves to protect the conduit from future damage. If the area around the conduit is being excavated at a later date, the obvious material change in CLSM versus the surrounding soil or conventional granular backfill would be recognized by the excavating crew, alerting them to the existence of the conduit. Coloring agents have also been used in mixtures to help identify the presence of CLSM.

2.7—Erosion control

Laboratory studies, as well as field performance, have shown that CLSM resists erosion better than many other fill materials. Tests comparing CLSM with various sand and clay fill materials showed that CLSM, when exposed to a water velocity of 0.52 m/sec (1.7 ft/sec), was superior to the other materials, both in the amount of material loss and suspended solids from the material.11

CLSM is often used in riprap for embankment protection and in spilling basins below dam spillways, to hold rock pieces in place and resist erosion. CLSM is used to fill flexible fabric mattresses placed along embankments for erosion protection, thereby increasing their strength and weight. In addition to providing an erosion resistance under culverts, CLSM is used to fill voids under pavements, sidewalks, bridges and other structures where natural soil or noncohesive granular fill has eroded away.

2.8—Void filling

2.8.1 Tunnel shafts and sewers—When filling abandoned tunnels and sewers, it is important to use a flowable mixture. A constant supply of CLSM will keep the material flowing and make it flow greater distances. CLSM was used to fill an abandoned tunnel that passed under the Menomonee River in downtown Milwaukee, Wis. The self-leveling material flowed over 71.6 m (235 ft). On another Milwaukee project, 635 m³ (831 yd³) were used to fill an abandoned sewer. The CLSM reportedly flowed up to 90 m (300 linear ft).12

Before constructing the Mount Baker Ridge Tunnel in Seattle, Wash., an exploratory shaft 37 m (120 ft) deep, 3.7 m (12 ft) in diameter with 9.1 m (30 ft) long branch tunnels was excavated. After exploration, the shaft had to be filled before
construction of the tunnel. Only 4 hr were needed to fill the shaft with 601 m\(^3\) (786 yd\(^3\)) of CLSM.\(^{13}\)

2.8.2 Basements and underground structures—Abandoned basements are often filled in with CLSM by pumping or conveying the mixture through an open window or doorway. An industrial renovation project in LaSalle, Ill., required the filling of an existing basement to accommodate expansion plans. Granular fill was considered, but access problems made CLSM a more attractive alternative. About 300 m\(^3\) (400 yd\(^3\)) of material were poured in one day. A 200 mm (8 in.) concrete floor was then placed directly on top of the CLSM mixture.\(^{14}\)

In Seattle, buses were to be routed off busy streets into a tunnel with pedestrian stations.\(^{13}\) The tunnel was built by a conventional method, but the stations had to be excavated from the surface to the station floor. After the station was built, there was a 19,000 m\(^3\) (25,000 yd\(^3\)) void over each station to the street. So as not to disrupt traffic with construction equipment and materials, the voids were filled with CLSM, which required no layered placement or compaction.

CLSM has been used to fill abandoned underground storage tanks (USTs). Federal and State regulations have been developed that address closure requirements for underground fuel and chemical tanks. USTs taken out of service permanently must either be removed from the ground or filled with an inert material. The Iowa Department of Natural Resources has developed a guidance document for storage tank closures, which specifically mentions flowable fill.

2.8.3 Mines—Abandoned mines have been filled with CLSM to eliminate access, prevent subsidence, bottle up hazardous gases, cut off the oxygen supply for fires, and reduce or eliminate acid drainage. It is important that a flowable mixture be placed with a constant supply to facilitate the spread and minimize the quantity of injection/placement points. The western U.S. alone contains approximately 250,000 abandoned mines with various hazards.\(^{15}\) CLSM can be used to fill mine voids completely, or in areas of particular concern, to prevent subsidence, block trespasser entry, and eliminate or reduce acid or other harmful drainage. Abandoned underground coal mines in the eastern U.S. have been filled using CLSM that was manufactured from various coal combustion products for this purpose.\(^{16,17}\)

2.9—Nuclear facilities

CLSM is used in nuclear facilities for conventional applications such as those described previously. It provides a significant advantage over conventional granular backfill in that remote placement decreases personnel exposure to radiation. CLSM can also be used in unique applications at nuclear facilities, such as waste stabilization, encapsulation of decommissioned pipelines and tanks, encapsulation of waste-disposal sites, and new landfill construction. CLSM can be used to address a wide range of chemical and radio-nuclide-stabilization requirements.\(^{18,19}\)

2.10—Bridge reclamation

CLSM has been used in several states as part of a cost-effective process for bridge rehabilitation. The process requires putting enough culverts under the bridge to handle the hydrology requirements. A dam is placed over both ends of the culvert(s) and the culvert(s) are covered with fabric to keep the CLSM from flowing into the joints. These culvert(s) are set on granular backfill. The CLSM is then placed until it is 150 mm (6 in.) from the lower surface of the deck. A period of at least 72 hr is required before the CLSM is brought up to the bottom of the deck through holes cored in the deck. Later, the railing is removed and the deck is widened. The same procedure is then completed on the opposite side of the bridge. The work is done under traffic conditions. The camber of the roadway over the culvert(s) is the only clue that a bridge had ever been present. Iowa DOT officials estimate that the cost of four reclamation is equivalent to one replacement when this technology can be employed.\(^{10,21,22}\)

CHAPTER 3—MATERIALS

3.1—General

Conventional CLSM mixtures usually consist of water, portland cement, fly ash or other similar products, and fine or coarse aggregates or both. Some mixtures consist of water, portland cement, and fly ash only. Special low-density CLSM (LD-CLSM) mixtures, as described in Chapter 8 of this report, consist of portland cement, water, and preformed foam. Although materials used in CLSM mixtures meet ASTM or other standard requirements, the use of standardized materials is not always necessary. Selection of materials should be based on availability, cost, specific application, and the necessary characteristics of the mixture, including flowability, strength, excavatability, and density.

3.2—Cement

Cement provides the cohesion and strength for CLSM mixtures. For most applications, Type I or Type II portland cement conforming to ASTM C 150 is normally used. Other types of cement, including blended cements conforming to ASTM C 595, can be used if prior testing indicates acceptable results.

3.3—Fly ash

Coal-combustion fly ash is sometimes used to improve flowability. Its use can also increase strength and reduce bleeding, shrinkage, and permeability. High fly ash-content mixtures result in lower-density CLSM when compared with mixtures with high aggregate contents. Fly ashes used in CLSM mixtures do not need to conform to either Class F or C as described in ASTM C 618. Trial mixtures should be prepared to determine whether the mixture will meet the specified requirements. Refer to ACI 232.2R for further information.\(^{23,24}\)

3.4—Admixtures

Air-entraining admixtures and foaming agents can be valuable constituents for the manufacture of CLSM. The inclusion of air in CLSM can help provide improved workability, reduced shrinkage, little or no bleeding, minimal segregation, lower unit weights, and control of ultimate strength development. Higher air contents can also help enhance CLSM’s thermal insulation and freeze-thaw properties. Water content can be
3.5—Other additives

In specialized applications such as waste stabilization, CLSM mixtures can be formulated to include chemical and/or mineral additives that serve purposes beyond that of simple backfilling. Some examples include the use of swelling clays such as bentonite to achieve CLSM with low permeability. The inclusion of zeolites, such as analcime or chabazite, can be used to absorb selected ions where water or sludge treatment is required. Magnetite or hematite fines can be added to CLSM to provide radiation shielding in applications at nuclear facilities.6,25,26

3.6—Water

Water that is acceptable for concrete mixtures is acceptable for CLSM mixtures. ASTM C 94 provides additional information on water-quality requirements.

3.7—Aggregates

Aggregates are often the major constituent of a CLSM mixture. The type, grading, and shape of aggregates can affect the physical properties, such as flowability and compressive strength. Aggregates complying with ASTM C 33 are generally used because concrete producers have these materials in stock.

Granular excavation materials with somewhat lower-quality properties than concrete aggregate are a potential source of CLSM materials, and should be considered. Variations of the physical properties of the mixture components, however, will have a significant effect on the mixture’s performance. Silty sands with up to 20% fines passing through a 75 μm (No. 200) sieve have proven satisfactory. Also, soils with wide variations in grading have shown to be effective. Soils with clay fines, however, have exhibited problems with incomplete mixing, stickiness of the mixtures, excess water demand, shrinkage, and variable strength. These types of soils are not usually considered for CLSM applications. Aggregates that have been used successfully include:27

- ASTM C 33 specification aggregates within specified gradations;
- Pea gravel with sand;
- 19 mm (3/4 in.) minus aggregate with sand;
- Native sandy soils, with more than 10% passing a 75 μm (No. 200) sieve;
- Quarry waste products, generally 10 mm (3/8 in.) minus aggregates.

3.8—Nonstandard materials

Nonstandard materials, which can be available and more economical, can also be used in CLSM mixtures, depending upon project requirements. These materials, however, should be tested prior to use to determine their acceptability in CLSM mixtures.

Examples of nonstandard materials that can be substituted as aggregates for CLSM include various coal combustion products, discarded foundry sand, glass cullet, and reclaimed crushed concrete.28–30

Aggregates or mixtures that might swell in service due to expansive reactions or other mechanisms should be avoided. Also, wood chips, wood ash, or other organic materials may not be suitable for CLSM. Fly ashes with carbon contents up to 22% have been successfully used for CLSM.31

In all cases, the characteristics of the nonstandard material should be determined, and the suitability of the material should be tested in a CLSM mixture to determine whether it meets specified requirements. In certain cases, environmental regulations could require prequalification of the raw material or CLSM mixture, or both, prior to use.

3.9—Ponded ash or basin ash

Ponded ash, typically a mixture of fly ash and bottom ash slurried into a storage/disposal basin, can also be used in CLSM. The proportioning of the ponded ash in the resulting mixtures depends on its particle size distribution. Typically, it can be substituted for all of the fly ash and a portion of the fine aggregate and water. Unless dried prior to mixing, ponded ash requires special mixing because it is usually wet. Basin ash is similar to ponded ash except it is not slurried and can be dispensed of in dry basins or stockpiles.18–20

CHAPTER 4—PROPERTIES

4.1—Introduction

The properties of CLSM cross the boundaries between soils and concrete. CLSM is manufactured from materials similar to those used to produce concrete, and is placed from equipment in a fashion similar to that of concrete. In-service CLSM, however, exhibits characteristic properties of soils. The properties of CLSM are affected by the constituents of the mixture and the proportions of the ingredients in the mixture. Because of the many factors that can affect CLSM, a wide range of values may exist for the various properties discussed in following sections.32

4.2—Plastic properties

4.2.1 Flowability—Flowability is the property that distinguishes CLSM from other fill materials. It enables the materials to be self-leveling; to flow into and readily fill a void; and be self-compacting without the need for conventional placing and compacting equipment. This property represents a major advantage of CLSM compared with conventional fill materials that must be mechanically placed and compacted. Because plastic CLSM is similar to plastic concrete and grout, its flowability is best viewed in terms of concrete and grout technology.

A major consideration in using highly flowable CLSM is the hydrostatic pressure it exerts. Where fluid pressure is a
CONTROLLED LOW-STRENGTH MATERIALS

concern, CLSM can be placed in lifts, with each lift being allowed to harden before placement of the next lift. Examples where multiple lifts can be used are in the case of limited-strength forms that are used to contain the material, or where buoyant items, such as pipes, are encapsulated in the CLSM.

Flowability can be varied from stiff to fluid, depending upon requirements. Methods of expressing flowability include the use of a 75 x 150 mm (3 x 6 in.) open-ended cylinder modified flow test (ASTM D 6103), the standard concrete slump cone (ASTM C 143), and flow cone (ASTM C 939).

Good flowability, using the ASTM D 6103 method, is achieved where there is no noticeable segregation and the CLSM material spread is at least 200 mm (8 in.) in diameter. Flowability ranges associated with the slump cone can be expressed as follows:33

- Low flowability: less than 150 mm (6 in.);
- Normal flowability: 150 to 200 mm (6 to 8 in.);
- High flowability: greater than 200 mm (8 in.)

ASTM C 939, for determining flow of grout, has been used successfully with fluid mixtures containing aggregates not greater than 6 mm (1/4 in.) The method is briefly described in Chapter 7 on Quality Control. The Florida and Indiana Departments of Transportation (DOT) require an efflux time of 30 ± 5 sec. as measured by this method.

4.2.2 Segregation—Separation of constituents in the mixture can occur at high levels of flowability when the flowability is primarily produced by the addition of water. This situation is similar to segregation experienced with some high-slung concrete mixtures. With proper mixture proportioning and materials, a high degree of flowability can be attained without segregation. For highly flowable CLSM without segregation, adequate fines are required to provide suitable cohesiveness. Fly ash generally accounts for these fines, although silty or other noncohesive fines up to 20% of total aggregate have been used. The use of plastic fines, such as clay, should be avoided because they can produce deleterious results, such as increased shrinkage. In flowable mixtures, satisfactory performance of CLSM has been obtained with Class F fly ash contents as high as 415 kg/m³ (700 lb/yd³) in combination with cement, sand, and water. Some CLSM mixtures have been designed without sand or gravel, using only fly ash as filler material. These mixtures require much higher water content, but produce no noticeable segregation.

4.2.3 Subsidence—Subsidence deals with the reduction in volume of CLSM as it releases its water and entrapped air through consolidation of the mixture. Water used for flowability in excess of that needed for hydration is generally absorbed by the surrounding soil or released to the surface as bleed water. Most of the subsidence occurs during placement and the degree of subsidence is dependent upon the quantity of free water released. Typically, subsidence of 3 to 6 mm (1/8 to 1/4 in.) per ft of depth has been reported.34 This amount is generally found with mixtures of high water content. Mixtures of lower water content undergo little or no subsidence, and cylinder specimens taken for strength evaluation exhibited no measurable change in height from the time of filling the cylinders to the time of testing.

4.2.4 Hardening time—Hardening time is the approximate period of time required for CLSM to go from the plastic state to a hardened state with sufficient strength to support the weight of a person. This time is greatly influenced by the amount and rate of bleed water released. When this excess water leaves the mixture, solid particles realign into intimate contact and the mixture becomes rigid. Hardening time is greatly dependent on the type and quantity of cementitious material in the CLSM.

Normal factors affecting the hardening time are:

- Type and quantity of cementitious material;
- Permeability and degree of saturation of surrounding soil that is in contact with CLSM;
- Moisture content of CLSM;
- Proportioning of CLSM;
- Mixture and ambient temperature;
- Humidity; and
- Depth of fill.

Hardening time can be as short as 1 hr, but generally takes 3 to 5 hr under normal conditions.35 Penetration-resistance test according to ASTM C 403 can be used to measure the hardening time or approximate bearing capacity of CLSM. Depending upon the application, penetration numbers of 500 to 1500 are normally required to assure adequate bearing capacity.35

4.2.5 Pumping—CLSM can be successfully delivered by conventional concrete pumping equipment. As with concrete, proportioning of the mixture is critical. Voids must be adequately filled with solid particles to provide adequate cohesiveness for transport through the pump line under pressure without segregation. Inadequate void filling results in mixtures that can segregate in the pump and cause line blockage. Also, it is important to maintain a continuous flow through the pump line. Interrupted flow can cause segregation, which also could restrict flow and could result in line blockage.

In one example, CLSM using unwashed aggregate with a high fines content was pumped through a 127 mm (5 in.) pump system at a rate of 46 m³/hr (60 yd³/hr).36 In another example, CLSM with a slump as low as 51 mm (2 in.) was successfully delivered by concrete pump without the need for added consolidation effort.37

CLSM with high entrained-air contents can be pumped, although care should be taken to keep pump pressures low. Increased pump pressures can cause a loss in air content and reduce pumpability.

Pumpability can be enhanced by careful proportioning to provide adequate void filling in the mixture. Fly ash can aid pumpability by acting as microaggregate for void filling. Cement can also be added for this purpose. Whenever cementitious materials are added, however, care must be taken to limit the maximum strength levels if later excavation is a consideration.

4.3—In-service properties

4.3.1 Strength (bearing capacity)—Unconfined compressive strength is a measure of the load-carrying ability of CLSM. A CLSM compressive strength of 0.3 to 0.7 MPa (50
to 100 psi) equates to an allowable bearing capacity of a well-compacted soil.

Maintaining strengths at a low level is a major objective for projects where later excavation is required. Some mixtures that are acceptable at early ages continue to gain strength with time, making future excavation difficult. Section 4.3.7 provides additional information on excavatability.

4.3.2 Density—Wet density of normal CLSM in place is in the range of 1840 to 2320 kg/m³ (115 to 145 lb/ft³), which is greater than most compacted materials. A CLSM mixture with only fly ash, cement, and water should have a density between 1440 to 1600 kg/m³ (90 to 100 lb/ft³). Ponded ash or basin ash CLSM mixture densities are typically in the range of 1360 to 1760 kg/m³ (85 to 110 lb/ft³). Dry density of CLSM can be expected to be substantially less than that of the wet density due to water loss. Lower unit weights can be achieved by using lightweight aggregates, high entrained-air contents, and foamed mixtures, which are discussed in detail in Chapter 8.

4.3.3 Settlement—Compacted fills can settle even when compaction requirements have been met. In contrast, CLSM does not settle after hardening. Measurements taken months after placement of a large CLSM fill showed no measurable shrinkage or settlement. For a project in Seattle, Wash., 601 m³ (786 yd³) were used to fill a 37 m (120 ft) deep shaft. The placement took 4 hr and the total settlement was reported to be about 3 mm (1/8 in.).

4.3.4 Thermal insulation/conductivity—Conventional CLSM mixtures are not considered good insulating materials. Air-entrained conventional mixtures reduce the density and increase the insulating value. Lightweight aggregates, including bottom ash, can be used to reduce density. Foamed or cellular mixtures as described in Chapter 8 have low densities and exhibit good insulating properties.

Where high thermal conductivity is desired, such as in backfill for underground power cables, high density and low porosity (maximum surface contact area between solid particles) are desirable. As the moisture content and dry density increase, so does the thermal conductivity. Other parameters to consider (but of lesser importance) include mineral composition, particle shape and size, gradation characteristics, organic content and specific gravity.

4.3.5 Permeability—Permeability of most excavatable CLSM is similar to compacted granular fills. Typical values are in the range of 10⁻⁴ to 10⁻³ cm/sec. Mixtures of CLSM with higher strength and higher fines-content can achieve permeabilities as low as 10⁻⁷ cm/sec. Permeability is increased as cementitious materials are reduced and aggregate contents are increased. However, materials normally used for reducing permeability, such as bentonite clay and diatomaceous soil, can affect other properties and should be tested prior to use.

4.3.6 Shrinkage (cracking)—Shrinkage and shrinkage cracks do not affect the performance of CLSM. Several reports have indicated that minute shrinkage occurs with CLSM. Ultimate linear shrinkage is in the range of 0.02 to 0.05%. The limits for excavatability are somewhat arbitrary, depending upon the CLSM mixture. Mixtures using high quantities of coarse aggregate can be difficult to remove by hand, even at low strengths. Mixtures using fine sand or only fly ash as the aggregate filler have been excavated with a backhoe up to strengths of 2.1 MPa (300 psi).

When the re-excavatability of the CLSM is of concern, the type and quantity of cementitious materials is important. Acceptable long-term performance has been achieved with cement contents from 24 to 59 kg/m³ (40 to 100 lb/yd³) and Class F fly ash contents up to 208 kg/m³ (350 lb/yd³). Lime (CaO) contents of fly ash that exceed 10% by weight can be a concern where long-term strength increases are not desired.

Because CLSM will typically continue to gain strength beyond the conventional 28-day testing period, it is suggested, especially for high cementitious-content CLSM, that long-term strength tests be conducted to estimate the potential for re-excavatability.

In addition to limiting the cementitious content, entrained air can be used to keep compressive strengths low.

4.3.8 Shear modulus—The shear modulus, which is the ratio of unit shear stress to unit shear strain, of normal density CLSM is typically in the range of 160 to 380 MPa (3400 to 7900 ksf). The shear modulus is used to evaluate the expected shear strength and deformation of CLSM material.

4.3.9 Potential for corrosion—The potential for corrosion on metals encased in CLSM has been quantified by a variety of methods specific to the material that is in contact with CLSM. Electrical resistivity tests can be performed on CLSM in the same manner that natural soils are compared for their corrosion potential on corrugated metal culvert pipes (California Test 643). The moisture content of the sample is an important parameter for the resistivity of a sample, and the samples should be tested at their expected long-term field moisture content.
The Ductile Iron Pipe Research Association has a method for evaluating the corrosion potential of backfill materials. The evaluation procedure is based upon information drawn from five tests and observations: soil resistivity; pH; oxidation-reduction (redox) potential; sulfides; and moisture. For a given sample, each parameter is evaluated and assigned points according to its contribution to corrosivity.41 - 43

These procedures are intended as guides in determining a soil’s potential corrosivity to ductile iron pipe and should be used only by qualified engineers and technicians experienced in soil analysis and evaluation.

One cause of galvanic corrosion is the differences in potential from backfill soils of varying composition. The uniformity of CLSM reduces the chance for corrosion caused by the use of dissimilar backfill materials and their varying moisture contents.

4.3.10 Compatibility with plastics—High-, medium-, and low-density polyethylene materials are commonly used as protection for underground utilities or as the conduits themselves. CLSM is compatible with these materials. As with any backfill, care must be exercised to avoid damaging the protective coating of buried utility lines. The fine gradation of many CLSMs can aid in minimizing scratching and nicking these polyethylene surfaces.31

CHAPTER 5—MIXTURE PROPORTIONING

Proportioning for CLSM has been done largely by trial and error until mixtures with suitable properties are achieved. Most specifications require proportioning of ingredients; some specifications call for performance features and leave proportioning up to the supplier. ACI 211 has been used; however, much work remains to be done in establishing consistent reliability when using this method.37

Where proportions are not specified, trial mixtures are evaluated to determine how well they meet certain goals for strength, flowability, and density. Adjustments are then made to achieve the desired properties.

Table 5.1 presents a number of mixture proportions that have been used by state DOTs and others; however, requirements and available materials can vary considerably from project to project. Therefore, the information in Table 5.1 is provided as a guide and should not be used for design purposes without first testing with locally available materials.

The following summary can be made regarding the materials used to manufacture CLSM:

Cement—Cement contents generally range from 30 to 120 kg/m³ (50 to 200 lb/yd³), depending upon strength and hardening-time requirements. Increasing cement content while maintaining all other factors equal (that is, water, fly ash, aggregate, and ambient temperature) will normally increase strength and reduce hardening time.

Fly ash—Class F fly ash contents range from none to as high as 1200 kg/m³ (2000 lb/yd³) where fly ash serves as the aggregate filler. Class C fly ash is used in quantities of up to 210 kg/m³ (350 lb/yd³). The quantity of fly ash used will be determined by availability and flowability needs of the project.

Ponded ash/basin ash—Ponded ash/basin ash contents range from 300 to 500 kg/m³ (500 to 950 lb/yd³), depending upon the fineness of ash.18-20

Aggregate—The majority of specifications call for the use of fine aggregate. The amount of fine aggregate varies with the quantity needed to fill the volume of the CLSM after considering cement, fly ash, water, and air contents. In general, the quantities range from 1500 to 1800 kg/m³ (2600 to 3100 lb/yd³). Coarse aggregate is generally not used in CLSM mixtures as often as fine aggregates. When used, however, the coarse aggregate content is approximately equal to the fine aggregate content.

Water—More water is used in CLSM than in concrete. Water provides high fluidity and promotes consolidation of the materials. Water contents typically range from 193 to 344 kg/m³ (325 to 580 lb/yd³) for most CLSM mixtures containing aggregate. Water content for Class F fly ash and cement-only mixtures can be as high as 590 kg/m³ (1000 lb/yd³) to achieve good flowability. This wide range is due primarily to the characteristics of the materials used in CLSM and the degree of flowability desired. Water contents will be higher with mixtures using finer aggregates.

Admixtures—High doses of air-entraining admixtures and specifically formulated or packaged air-entraining admixtures, or both, can be used to lower the density or unit weight of CLSM. Accelerating admixtures can be used to accelerate the hardening of CLSM. When these products are used, the manufacturer’s recommendations for use with CLSM should be followed.

Other additives—Additives such as zeolites, heavy minerals, and clays can be added to typical CLSM mixes in the range of 2 to 10% of the total mixture. Fly ash and cement can be adjusted accordingly while maintaining all other factors.18-20

CHAPTER 6—MIXING, TRANSPORTING, AND PLACING

6.1—General

The mixing, transporting, and placing of CLSM generally follows methods and procedures given in ACI 304. Other methods can be acceptable, however, if prior experience and performance data are available. Whatever methods and procedures are used, the main criteria is that the CLSM be homogeneous, consistent, and satisfy the requirements for the purpose intended.

6.2—Mixing

CLSM can be mixed by several methods, including central-mixed concrete plants, ready-mixed concrete truck, pugmills, and volumetric mobile concrete mixers. For high fly ash mixtures where fly ash is delivered to the mixer from existing silos, batching operations can be slow.

Truck mixers are commonly used by ready-mixed concrete producers to mix CLSM; however, in-plant central mixers can be used as well. In truck-mixing operations, the following is one procedure that can be used for charging truck mixers with batch materials.
Table 5.1—Examples of CLSM mixture proportions

<table>
<thead>
<tr>
<th>Source</th>
<th>SC DOT</th>
<th>DOE-SR10</th>
<th>Unshrinkable fill2</th>
<th>Pond ash/basin ash mix3</th>
<th>Coarse aggregate CLSM4</th>
<th>Flowable fly ash slurry52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement content, kg/m³</td>
<td>30 (50)</td>
<td>30 (50)</td>
<td>30 to 60 (50 to 100)</td>
<td>30 (50)</td>
<td>30 (50)</td>
<td>58 (98)</td>
</tr>
<tr>
<td>Fly ash, kg/m³ (lb/yd³)</td>
<td>356 (600)</td>
<td>356 (600)</td>
<td>Class F</td>
<td>481 (810)</td>
<td>326 (550)</td>
<td>610 (1066)</td>
</tr>
<tr>
<td>Coarse aggregate, kg/m³ (lb/yd³)</td>
<td>1483 (2500)</td>
<td>1492 (2515)</td>
<td>1173 (1977)</td>
<td>1300 (2190)</td>
<td>1492 (2515)</td>
<td>749 (1262)</td>
</tr>
<tr>
<td>Fine aggregate, kg/m³ (lb/yd³)</td>
<td>273 to 320 (460 to 540)</td>
<td>397 to 336 (500 to 550)</td>
<td>152 (257)</td>
<td>451 (790)</td>
<td>301 (507)</td>
<td>634 (1068)</td>
</tr>
<tr>
<td>Approximate water content, kg/m³ (lb/yd³)</td>
<td>0.6 (80)</td>
<td>0.2 to 1.0 (30 to 150)</td>
<td>0.1 (17) at 1 day</td>
<td>0.4 (65)</td>
<td>0.4 (65)</td>
<td>0.7 (100)</td>
</tr>
</tbody>
</table>

Load truck mixer at standard charging speed in the following sequence:

- Add 70 to 80% of water required.
- Add 50% of the aggregate filler.
- Add all cement and fly ash required.
- Add balance of aggregate filler.
- Add balance of water.

For CLSM mixtures consisting of fly ash, cement, water, and no aggregate filler, an effective mixing method consists of initially charging the truck mixer with cement then water. After thoroughly mixing these materials, the fly ash is added. Additional mixing for a minimum of 15 min was required in one case to produce a homogeneous slurry.13

Pugmill mixing works efficiently for both high and low fly ash mixtures and other high fines-content mixtures. For high fly ash mixtures, the fly ash is fed into a hopper with a front-end loader, which supplies a belt conveyor under the hopper. This method of feeding the mixer is much faster than silo methods.
feed. To prevent bridging within the fly ash, a mechanical agitator or vibrator is used in the hopper. Cement is usually added to the mixer by conveyor from silo storage. If bagged cement is used, it is added directly into the mixer. The measurement for placement of CLSM mixed through a pugmill is generally based on weight rather than volume, which is typically used for concrete.

6.3—Transporting
Most CLSM mixtures are transported in truck mixers. Agitation of CLSM is required during transportation and waiting time to keep the material in suspension. Under certain on-site circumstances, CLSM has been transported in nonagitating equipment such as dump trucks. Agitator trucks, although providing some mixing action, may not provide enough action to prevent the solid materials from settling out.

CLSM has been transported effectively by pumps and other types of conveying equipment. In pumping CLSM, the fly ash serves as a lubricant to reduce the friction in the pipeline. However, the fine texture of the fly ash requires that the pump be in excellent condition and properly cleaned and maintained.

CLSM has also been transported effectively by volumetric-measuring and continuous-mixing concrete equipment (VMCM) (ACI 304.6R), particularly if it is desired to reduce waiting time. The major advantage of this equipment is its ability to mix at the job site and vary the water content to attain desired flowability. This is particularly true for fast-setting CLSM mixtures. VMCMs are equipped with separate bins for water, cementitious materials, and selected aggregates. The materials are transported to the job site where continuous mixing of water and dry materials make a good, easily regulated CLSM.

6.4—Placing
CLSM can be placed by chutes, conveyors, buckets, or pumps, depending upon the application and its accessibility. Internal vibration or compaction is not required because the CLSM consolidates under its own weight. Although it can be placed year round, CLSM should be protected from freezing until it has hardened. Curing methods specified for concrete are not considered essential for CLSM.

For trench backfill, CLSM is usually placed continuously. To contain CLSM when filling long, open trenches in stages or open-ended structures such as tunnels, the end points can be bulkheaded with sandbags, earth dams, or stiffer mixtures of CLSM.

For pipe bedding, CLSM can be placed in lifts to prevent floating the pipe. Each lift should be allowed to harden before continued placement. Other methods of preventing flotation include sand bags placed over the pipe, straps around the pipe anchored into the soil, or use of faster-setting CLSM placed at strategic locations over the pipe.

In the plastic state, CLSM is not self-supporting and places a load on the pipe. For large, flexible wall pipes, CLSM should be placed in lifts so that lateral support can develop along the side of the pipe before fresh CLSM is placed over the pipe. Backfilling retaining walls can also require the CLSM be placed in lifts to prevent overstressing the wall.

CLSM has been effectively placed by tremie under water without significant segregation. In confined areas, the CLSM displaces the water to the surface where it can easily be removed. Because of its very fluid consistency, CLSM can flow long distances to fill voids and cavities located in hard-to-reach places. Voids need not be cleaned, as the slurry will fill in irregularities and encapsulate any loose materials.

6.5—Cautions
6.5.1 Hydrostatic pressure—CLSM is often placed in a practically liquid condition and thus will exert a hydrostatic pressure against basement walls and other structures until it hardens. On deep fills, it is often necessary to place the CLSM in multiple lifts.

6.5.2 Quick condition—Liquid CLSM in deep excavations is essentially a quick-sand hazard and therefore should be covered until hardening occurs.

6.5.3 Floating tanks, pipes, and cables—Underground utilities and tanks must be secured against floating during CLSM placement.

CHAPTER 7—QUALITY CONTROL
7.1—General
The extent of a quality-control (QC) program for CLSM can vary depending upon previous experience, application, raw materials used, and level of quality desired. A QC program can be as simple as a visual check of the completed work where standard, pretested mixtures are being used. Where the application is critical, the materials are nonstandard, or where product uniformity is questionable, regular tests for consistency and strength may be appropriate.

Both as-mixed and in-service properties can be measured to evaluate the mixture consistency and performance. For most projects, CLSM is pretested using the actual raw materials to develop a mixture having certain plastic (flowability, consistency, unit weight) and hardened (strength, durability, permeability) characteristics. Following the initial testing program, field testing can consist of simple visual checks, or can include consistency measurements or compressive strength tests.

As stated above, the QC program can be simple or detailed. It is the responsibility of the specifier to determine an appropriate QC program that will assure that the product will be adequate for its intended use. The following procedures and test methods have been used to evaluate CLSM mixtures.

7.2 Sampling
Sampling CLSM that has been delivered to the project site should be performed in accordance with ASTM D 5971.

7.3—Consistency and unit weight
Depending upon application and placement requirements, flow characteristics can be important. CLSM consistency can vary considerably from plastic to fluid; therefore, several methods of measurement are available. Most CLSM mixtures perform well with various flow and unit weight proper-
Table 7.1—Test procedures for determining consistency and unit weight of CLSM mixtures

<table>
<thead>
<tr>
<th>Consistency</th>
<th>Fluid mixtures</th>
<th>Plastic mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASTM D 6103 &quot;Standard Test Method for Flow Consistency of Controlled Low Strength Material.&quot; Procedure consists of placing 75 mm diameter x 150 mm long (3 in. diameter x 6 in. long) open-ended cylinder vertically on level surface and filling cylinder to top with CLSM. Cylinder is then lifted vertically to allow material to flow out onto level surface. Good flowability is achieved where there is no noticeable segregation and material spread is at least 200 mm (8 in.) in diameter.</td>
<td>ASTM C 143 &quot;Slump of Portland Cement Concrete.&quot;</td>
</tr>
<tr>
<td></td>
<td>ASTM C 939 &quot;Flow of Grout for Preplaced-Aggregate Concrete.&quot; Florida Department of Transportation and Indiana Department of Transportation specifications require efflux time of 30 sec ±5 sec. Procedure is not recommended for CLSM mixtures containing aggregates greater than 6 mm (1/4 in.).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM D 6023 &quot;Standard Test Method for Unit Weight, Yield and Air Content (Gravimetric) of Controlled Low Strength Material.&quot; Ohio Ready Mixed Concrete Association has similar test method (FP3(94)).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM C 1152 &quot;Acid Soluble Chloride in Mortar and Concrete.&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM C 4380 &quot;Density of Bentonitic Slurries.&quot; Not recommended for CLSM containing aggregate greater than 3/4 in.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM D 1556 &quot;Density of Soil In-Place by Sand-Cone Method.&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM D 2922 &quot;Density of Soil and Soil Aggregate In-Place by Nuclear Method (Shallow Depth).&quot;</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.2—Test procedures for determining in-place density and strength of CLSM mixtures

<table>
<thead>
<tr>
<th>Unit weight</th>
<th>Fluid mixtures</th>
<th>Plastic mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASTM D 6024 &quot;Standard Test Method for Ball Drop on Controlled Low Strength Material to Determine Suitability for Load Application.&quot; This specification covers determination of ability of CLSM to withstand loading by repeatedly dropping metal weight onto in-place material.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM C 403 &quot;Time of Setting of Concrete Mixtures by Penetration Resistance.&quot; This test measures degree of hardness of CLSM. California Department of Transportation requires penetration number of 650 before allowing pavement surface to be placed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM D 4832 &quot;Preparation and Testing of Soil-Cement Slurry Test Cylinders.&quot; This test is used for molding cylinders and determining compressive strength of hardened CLSM.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM D 1196 &quot;Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements.&quot; This test is used to determine modulus of subgrade reaction (K values).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM D 4429 &quot;Bearing Ratio of Soils in Place.&quot; This test is used to determine relative strength of CLSM in place.</td>
<td></td>
</tr>
</tbody>
</table>

7.4—Strength tests

CLSM is used in a variety of applications requiring different load-carrying characteristics. The maximum loads to be imposed on the CLSM should be identified to determine the minimum strength requirements. In many cases, however, CLSM needs to be limited in its maximum strength. This is especially true where removal of the material at a later date is anticipated.

The strength of CLSM can be measured by several methods (Table 7.2). Unconfined compressive strength tests are the most common; however, other methods, such as penetrometer devices or plate load tests, can also be used. Compressive-strength specimens can vary in size from 50 x 50 mm (2 x 2 in.) cubes to 150 x 300 mm (6 x 12 in.) cylinders. Special care may be needed removing very low-strength CLSM mixtures from test molds. Additional care in the handling, transporting, capping, and testing procedures shall be taken because the specimens are often very fragile. Mold stripping techniques have included: placement of a hole on the center of the bottom of standard watertight cylinder molds by drilling or use of a hot probe, and addition of a dry polyester fleece pad on the inside bottom of the cylinder; for easy release of the specimen with or without air compression, splitting of the molds with a hot knife, and presplitting the molds and reattachment with duct tape for easy removal later. The use of grout molds has also been employed for testing CLSM. In this method, four 150 x 150 x 200 mm (6 x 6 x 8 in.) high concrete masonry units are arranged to provide a nominal 100 mm (4 in.) square space in the center. The four sides and bottom of the inside of the molds are lined with blotting paper to serve as a bond breacher for easy removal.

CHAPTER 8—LOW-DENSITY CLSM USING PREFORMED FOAM

8.1—General

This chapter is limited to low-density CLSM mixtures (LD-CLSM) produced using preformed foam as part of the mixture proportioning. Preformed foam is made up of air cells generated from foam concentrates or gas-forming
The use of preformed foam in LD-CLSM mixtures allows mixture proportionings to be developed having lower unit weights than those typical of standard CLSM mixtures. Preformed foam is used in LD-CLSM proportions to attain stable air void or cell structures within the paste of the mix. LD-CLSM mixtures can be batched at ready-mix plants or in specially designed job site batch plants. The preformed foam can be added to LD-CLSM mixtures during batching at the ready-mix plant, into the mixers of transit-mix trucks at the job site, or directly into the mixer during the batching operations of specially designed job site batch plants.

8.2—Applications

LD-CLSM mixtures can be alternatively considered in situations where standard CLSM mixtures have been determined applicable. LD-CLSMs are typically designed by unit weight. The ability to proportion mixtures having low unit weights is especially advantageous where weak soil conditions are encountered and the weight of the fill must be minimized. LD-CLSM is also effective as an insulating and isolation fill. The air void or cell structure inherent in LD-CLSM mixtures provides thermal insulation and can add some shock mitigation properties to the fill material.

8.3—Materials

Portland cement is a typical binder component used to produce most LD-CLSM mixtures. Neat cement paste LD-CLSMs can be produced by adding preformed foam to the paste during mixing. The encapsulated air within the preformed foam is often the primary volume-producing component in the LD-CLSM mixtures. LD-CLSMs can also be designed to include mineral fillers such as fly ash or sand. When considering the use of nonstandard binders or mineral filler materials in LD-CLSM mixture proportioning, pretesting is recommended.

Generally all preformed foams are pregenerated by the use of devices known as foam generators. These foam-generating devices, however, can be configured specifically to be used with a particular foaming agent. The manufacturer of the foaming agent to be used should be consulted to obtain specific foaming recommendations. Foaming agents used to produce the preformed foam must have a chemical composition capable of producing stable air cells that resist the physical and chemical forces imposed during the mixing, placing, and setting of the LD-CLSM mixture. If the air void or cellular structure within the mixture is not stable, a nonuniform increase in density will result. Procedures for the evaluation of foaming agents are specified in ASTM C 796 and ASTM C 869. Additional information can be found in ACI 523.1R.

8.4—Properties

The properties of LD-CLSM are primarily density-related. When batched using standard component materials, LD-CLSM can be produced having properties that fall within ranges described by the manufacturer of the foaming agent. When nonstandard component materials are used, trial batches should be produced and tested to confirm theoretical predictions.

The most significant property of LD-CLSM is the in-service density. Table 8.1 divides the in-service density into convenient ranges relating density with typical minimum compressive-strength values. Classes VI and VII may be subdivided into smaller ranges for specific applications.

8.5—Proportioning

Mixture proportioning of LD-CLSM typically begins with the designation of the desired in-place dry density and minimum compressive strength. Within these parameters, the mixture constituents are designed on a rational basis. Basic LD-CLSM mixtures consist of portland cement as a binder, water, and preformed foam. In addition to this base proportioning, fly ash can be included as a pozzolan or a densifying mineral filler. Sand aggregate is also often used to achieve density in mixture proportionings having unit weights more than 800 kg/m³ (30 lb/ft³). The manufacturer of the foam concentrate is generally responsible for the mixture proportioning, which is based on desired physical properties (density, compressive strength, etc.) of the in-place material.

8.6—Construction

8.6.1 Batchin—The batching sequence used to produce most LD-CLSM mixtures begins by metering the required water into a mechanical mixer. The portland cement binder, fly ash, or aggregates (if used) are individually weighed before entering the mixer. After the components are mixed to a uniform consistency, the required amount of preformed foam is added. The preformed foam is measured into the mixture through calibrated nozzle or by filling and weighing a mixing vessel of known volume. The accuracy of the foam-generating device and the batching apparatus is critical to the final mixture’s density and its subsequent reproducibility.

8.6.2 Mixing—All LD-CLSM component materials should be mechanically mixed to a uniform consistency prior to the addition of the preformed foam. To properly combine the mixture ingredients (including the foam) sufficient mixing action and speeds are required. When producing neat cement or cement/fly ash pastes for LD-CLSM mixtures, mixers that provide vigorous mixing action, such as high-speed paddle mixers, are preferred. Truck mixers readily blend LD-CLSM mixtures to the consistency required for the addition of preformed foam. When truck mixers are used to produce neat

<table>
<thead>
<tr>
<th>Class</th>
<th>In-service density, kg/m³ (lb/ft³)</th>
<th>Minimum compressive strength, MPa (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>290 to 380 (18 to 24)</td>
<td>0.1 (19)</td>
</tr>
<tr>
<td>II</td>
<td>380 to 480 (24 to 30)</td>
<td>0.3 (40)</td>
</tr>
<tr>
<td>III</td>
<td>480 to 580 (30 to 36)</td>
<td>0.6 (80)</td>
</tr>
<tr>
<td>IV</td>
<td>580 to 670 (36 to 42)</td>
<td>0.8 (120)</td>
</tr>
<tr>
<td>V</td>
<td>670 to 800 (42 to 50)</td>
<td>1.1 (160)</td>
</tr>
<tr>
<td>VI</td>
<td>800 to 1300 (50 to 80)</td>
<td>2.2 (320)</td>
</tr>
<tr>
<td>VII</td>
<td>1300 to 1900 (80 to 120)</td>
<td>3.4 (500)</td>
</tr>
</tbody>
</table>

CONTROLLED LOW-STRENGTH MATERIALS
cement or cement/fly ash paste mixtures, slightly longer mixing times are required. Other mixing processes, such as volumetric mixing, that produce uniformly consistent mixtures are also acceptable. The manufacturer of the foaming agent to be used should be consulted for specific recommendations on mixing procedures and approved mixing equipment.

5.6.3 Placing—LD-CLSM can be placed by chutes, buckets, or pumps. The method of placement must not cause a change in density by loss of air content beyond predictable ranges. Often, site-produced LD-CLSMs are delivered to the point of placement through pumplines. Progressing cavity pumps can be used, which provide nonpulsating and constant flow, minimizing air volume losses between the mixer and the point of deposit. By this method, LD-CLSMs can be pumped over 300 m (1000 ft).

CONVERSION FACTORS

<table>
<thead>
<tr>
<th>1 ft = 0.305 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in = 25.4 mm</td>
</tr>
<tr>
<td>1 lb = 0.454 kg</td>
</tr>
<tr>
<td>1 yd³ = 0.7646 m³</td>
</tr>
<tr>
<td>1 psi = 6.895 kPa</td>
</tr>
<tr>
<td>1 lb/ft³ = 16.02 kg/m³</td>
</tr>
<tr>
<td>1 lb/yd³ = 0.5933 kg/m³</td>
</tr>
<tr>
<td>1 ft/sec = 0.305 m/sec</td>
</tr>
</tbody>
</table>

CHAPTER 9—REFERENCES

9.1—Specified references

The documents of the various standard-producing organizations referred to in this document are listed below with their serial designation.

American Concrete Institute
116R Cement and Concrete Terminology
211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete
230.1R State-of-the-Art Report on Soil Cement
232.2R Use of Fly Ash in Concrete
304.6R Guide for Measuring, Mixing, Transporting and Placing Concrete
325.3R Guide for Design of Foundations and Shoulders for Concrete Pavements
523.1R Guide for Cast-in-Place Low Density Concrete

American Society for Testing and Materials (ASTM)
C 33 Specification for Concrete Aggregates
C 94 Specifications for Ready-Mixed Concrete
C 138 Test Method for Unit Weight, Yield and Air Content (Gradimetric) of Concrete
C 143 Test Method for Slump of Hydraulic Cement Concrete
C 150 Specification for Portland Cement
C 403 Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C 595 Specification for Blended Hydraulic Cements
C 618 Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
C 796 Test Method of Testing Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam

C 869 Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete
C 939 Test Method for Flow of GROUT for Preplaced-Aggregate Concrete
C 1152 Acid-Soluble Chloride in Mortar and Concrete
C 1556 Density of Soil in-place by Sand-cone Method
C 2922 Density of Soil and Soil Aggregate in-place by Nuclear Method (Shallow Depth)

D 1196 Test Methods for Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements
D 4380 Test Method for Density of Bentonite Slurries
D 4429 Test Method for Bearing Ratio of Soils in Place
D 4832 Test Method for Preparation and Testing of Soil-Cement Slurry Test Cylinders
D 5971 Practice for Sampling Freshly Mixed Controlled Low Strength Material
D 6023 Test Method for Unit Weight, Yield and Air Content (Gravimetric) of Controlled Low Strength Material
D 6024 Test Method of Ball Drop on Controlled Low Strength Material to Determine Suitability for Load Application
D 6103 Test Method for Flow Consistency of Controlled Low Strength Material

The above publications may be obtained from the following organizations:

American Concrete Institute
P.O. Box 9094
Farmington Hills, MI 48333-9094

American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

9.2—Cited references

APPENDIX M

UFGS SECTION 03300
CAST-IN-PLACE STRUCTURAL CONCRETE

&

UFGS SECTION 01610
AGGREGATE FOR PORTLAND CEMENT CONCRETE
PART 1 - GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO M 182 (1991; R 1996) Burlap Cloth Made From Jute or Kenaf, 19th Ed.

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 117/Al17R (1990; Errata) Standard Tolerances for Concrete Construction and Materials


ACI 214.3R (1988) Simplified Version of the Recommended Practice for Evaluation of Strength Test Results of Concrete

ACI 301 (1999) Structural Concrete for Buildings

ACI 302.1R (1996) Guide for Concrete Floor and Slab Construction

ACI 303R (1991) Guide to Cast-In-Place Architectural Concrete Practice

ACI 305R (1991) Hot Weather Concreting


AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM C 31 (1998) Making and Curing Concrete Test Specimens in the Field

ASTM C 33 REV A (1999) Concrete Aggregates
ASTM C 39  (1999) Compressive Strength of Cylindrical Concrete Specimens
ASTM C 42/C 42M  (1999) Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C 136  (1996a) Sieve Analysis of Fine and Coarse Aggregates
ASTM C 143/C 143M  (1998) Slump of Hydraulic Cement Concrete
ASTM C 171 REV A  (1997) Sheet Materials for Curing Concrete
ASTM C 172  (1999) Sampling Freshly Mixed Concrete
ASTM C 173  (1994a) Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C 231  (1997) Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C 309 REV A  (1998a) Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C 494  (1999) Chemical Admixtures for Concrete
ASTM C 496  (1996) Splitting Tensile Strength of Cylindrical Concrete Specimens
01300-2

ASTM C 618  (1999) Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete


ASTM C 940 REV A  (1989) Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in Laboratory

ASTM C 1017/C 1017M  (1998) Chemical Admixtures for Use in Producing Flowing Concrete

ASTM C 1059  (1999) Latex Agents for Bonding Fresh to Hardened Concrete


ASTM C 1116  (2000) Fiber-Reinforced Concrete and Shotcrete


ASTM D 75  (1997) Sampling Aggregates

ASTM D 1751  (1993) Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)


03300-3
1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. The office designations are as follows: "RE" for Resident Engineer approval, "ED" for Engineering approval, and "AE" for Architect-Engineer. The following shall be submitted in accordance with Section 01330 - SUBMITTAL PROCEDURES:

03300-4
The results of trial mixture design studies along with a statement giving the maximum nominal coarse aggregate size and the proportions of ingredients that will be used in the manufacture of each strength or class of concrete, at least 60 days prior to commencing concrete placing operations. Aggregate weights shall be based on the saturated surface dry condition. The statement shall be accompanied by test results from an approved independent commercial testing laboratory, showing that mixture design studies have been made with materials proposed for the project and that the proportions selected will produce concrete of the qualities indicated. No substitutions shall be made in the materials used in the mixture design studies without additional tests to show that the quality of the concrete is satisfactory.

A plan outlining concrete testing procedures and sampling intervals.

Hot Weather Placing Procedures; G, RE.

Contractor Quality Control Charts; G, RE.

Certified copies of laboratory test reports, including mill tests and all other test data, for portland cement, blended cement, pozzolan, aggregate, admixtures, and curing compound proposed for use on this project. These tests shall be made by an approved commercial testing laboratory or by a testing laboratory maintained by the manufacturers of the materials.

Written documentation for Contractor Quality Control personnel, Concrete Field Testing Technician and ACI Concrete Flatwork Technician/Finisher and Concrete Lab Testing Technician.

The Contractor will be responsible for testing all ingredients that are utilized in the concrete. No ingredient shall be used or concrete placed until all tests have been completed utilizing the applicable test methods and the Contracting Officer notifies the Contractor that the test results are satisfactory. The Contractor shall notify the Contracting Officer of the
manufacturer's brand name and type of each ingredient to be used in the concrete.

1.3.2 Aggregates

Aggregate sources shall be tested to determine if the source is capable of producing materials of a quality acceptable for this project. Proposed materials produced from similar strata, or of similar quality, must be approved.

1.3.2.1 Prequalified Cement Sources

Cement shall be delivered and used directly from a mill of a producer designated as a qualified source. A list of prequalified cement sources is available from the Commander and Director, U.S. Army Engineer Waterways Experiment Station (CEWES-SC-MP), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199. If the Contractor proposes to use cement from a source that is not prequalified, the Contractor shall notify CEWES-SC-MP within 7 days after notice to proceed and request instructions on how to have the cement source qualified.

1.3.2.2 Prequalified Pozzolan Sources

Pozzolan shall be delivered and used directly from a producer designated as a qualified source. A list of prequalified pozzolan sources is available from the Commander and Director, U.S. Army Engineer Waterways Experiment Station (CEWES-SC-MP), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199. If the Contractor proposes to use pozzolan that is not from a prequalified source, the Contractor shall notify CEWES-SC-MP within 7 days after notice to proceed and request instructions on how to have the source qualified.

1.4 QUALIFICATIONS

Contractor Quality Control personnel assigned to concrete construction shall be American Concrete Institute (ACI) Certified Workmen in one of the following grades or shall have written evidence of having completed similar qualification programs:

Concrete Field Testing Technician, Grade I
Concrete Laboratory Testing Technician, Grade I or II

The foreman or lead journeyman of the flatwork finishing crew shall have similar qualification for ACI Concrete Flatwork Technician/Finisher or equal, with written documentation.

1.5 FIELD TEST PANELS

Field test panels shall be constructed prior to beginning of work using the materials and procedures proposed for use on the job, to demonstrate the results to be attained. The quality and appearance of each panel shall be subject to the approval of the Contracting Officer, and, if not judged satisfactory, additional panels shall be constructed until approval is
attained. Formed or finished surfaces in the completed structure shall match the quality and appearance of the approved field example. The approved sample panel shall be protected from weather and construction operations and shall not be removed until the concrete work it represents is complete.

1.5.1 Sample Wall Panels

One sample panel at least 1220 mm (4 feet) by 1525 mm (5 feet) and minimum 150 mm (6 inches) thick shall be constructed to demonstrate Class A formed finish and a similar one for Class B formed finish. Panels shall be located where directed by the Contracting Officer. Each panel shall include a full length and full width joint line and shall have at least two voids, irregular in shape, each at least 300 mm (12 inches) by 300 mm (12 inches) by 75 mm (3 inches) deep either impressed in the concrete as placed or chipped in the hardened concrete. After the concrete is 7 days old, the voids shall be patched to demonstrate the effectiveness and the appearance of the Contractor's repair procedures.

1.5.2 Slab Panels

A slab panel at least 1220 mm (4 feet) by 1525 mm (5 feet) and 100 mm (4 inches) thick shall be constructed to demonstrate exposed aggregate slab finish and a similar panel for extra high class slab finish. Panels shall be located where directed by the Contracting Officer. Each panel shall have a full length joint line.

1.6 SPECIAL REQUIREMENTS

A pre-installation meeting with the Contracting Officer will be required at least 10 days prior to start of construction. The Contractor shall be responsible for calling the meeting; the Project Superintendent and active installation personnel shall be present.

1.7 GENERAL REQUIREMENTS

1.7.1 Tolerances

Except as otherwise specified herein, tolerances for concrete batching, mixture properties, and construction as well as definition of terms and application practices shall be in accordance with ACI 117/A117R. Level and grade tolerance measurements of slabs shall be made as soon as possible after finishing; when forms or shoring are used, the measurements shall be made prior to removal.

1.7.1.1 Floors

Floor slab finish tolerances shall be measured by the F-Number system in accordance with ASTM E 1155. For the purpose of this Section the following terminology correlation between ACI 117/A117R and this Section shall apply:
Floor Profile Quality
Classification From ACI 117/A117R

<table>
<thead>
<tr>
<th>Conventional Bullfloated</th>
<th>Same</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Straightedged</td>
<td>Same</td>
</tr>
<tr>
<td>Flat</td>
<td>Float Finish or Trowel Finish</td>
</tr>
</tbody>
</table>

Levelness tolerance shall not apply where design requires floors to be sloped to drains or sloped for other reasons. Tolerances of the following areas shall meet the requirements for the listed surfaces as specified in paragraphs 4.5.6 and 4.5.6.1 of ACI 117/117R:

Bullfloated - All areas as pretreatment to the final finish.

Float Finish - All areas as pretreatment to the final trowel finish or for depressed areas for bedding grout.

Trowel Finish - All areas, unless noted otherwise

1.7.1.2 Floors by the F-Number System

The flatness and levelness of floors shall be carefully controlled and the tolerances shall be measured by the F-Number system of Paragraph 4.5.6 and 4.5.6.1 of ACI 117/117R. The Contractor shall furnish an approved floor profilograph or other equipment capable of measuring the floor flatness (FF) number and the floor levelness (FL) number in accordance with ASTM E 1155. The Contractor shall perform the tolerance measurements within 72 hours after floor slab construction while being observed by the Contracting Officer. The tolerances of surfaces beyond the limits of ASTM E 1155 (the areas within 600 mm (24 inches) of embedments and construction joints) shall be acceptable to the Contracting Officer.

The minimum F-number values shall be as follows:

<table>
<thead>
<tr>
<th>SLABS ON GROUND</th>
<th>FF</th>
<th>FL</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE OF USE</td>
<td>Fr Overall</td>
<td>Fr Local</td>
</tr>
<tr>
<td>Noncritical: mechanical rooms, nonpublic areas, surfaces to have raised computer flooring, surfaces to have thick-set tile, and parking structure slabs</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Carpeted areas of commercial office buildings or lightly-trafficked office/industrial buildings</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Thin-set flooring or warehouse floor with moderate or heavy traffic</td>
<td>35</td>
<td>23</td>
</tr>
<tr>
<td>Warehouse with air pallet use, ice, or roller rinks</td>
<td>45</td>
<td>30</td>
</tr>
</tbody>
</table>

1.7.2 Special Properties. Holloman AFB Special Concrete Requirements (and in the Tularosa Basin of New Mexico)
The following requirements apply to all concrete used at Holloman AFB:

a. Coarse and fine aggregates shall be washed.

b. Calcium chloride or admixtures containing chloride salts shall not be used.

c. All concrete except interior floor slabs and areas to receive special toppings whose performance would be adversely affected by air in the concrete, shall have air entrainment. A waiver shall be obtained from the Contracting Officer prior to deleting air entrainment.

In addition, all building concrete shall:

(a) contain Type V cement, low alkali cement.

(b) have a compressive strength of 27.5 Mpa (4,000 PSI) at 28 days.

(c) have a maximum water to cementitious materials ratio, by weight, of 0.45.

(d) have an air content by volume of 5.0 to 7.0 percent for nominal maximum aggregate size of 19 mm (3/4-inch) or less, or 4.0 to 6.0 percent for nominal maximum aggregate size greater than 19 mm (3/4-inch).

(e) have a minimum percent of pozzolan required to be determined per specification Section 01610 - AGGREGATE FOR PORTLAND CEMENT CONCRETE.

(f) not exceed a slump of 75 mm (3 inches).

(g) be moist cured for 10 days.

(h) not use recycled concrete.

1.7.3 Strength Requirements and w/c Ratio

1.7.3.1 Strength Requirements

Specified compressive strength (f'c) and flexural strength of concrete shall be as specified in the drawings.

a. Compressive strength specimens (152 by 305 mm (6 by 12 inch) cylinders) shall be fabricated by an approved independent commercial testing laboratory and cured in accordance with ASTM C 31 and tested in accordance with ASTM C 39. The strength of the concrete will be considered satisfactory so long as the average of all sets of three consecutive test results equals or exceeds the specified compressive strength f'c and no individual test result falls below the specified strength f'c by more than 3.5 MPa (500 psi). See paragraph "Concrete Mixture", subparagraph "Strength Specimens", in PART 3 for specimen requirements. A "test" is defined as the average of two companion cylinders, or if only one cylinder is tested, the results of the
single cylinder test. Additional analysis or testing, including taking cores and/or load tests may be required at the Contractor's expense when the strength of the concrete in the structure is considered potentially deficient.

b. Investigation of Low-Strength Compressive Test Results. When any strength test of standard-cured test cylinders falls below the specified strength requirement by more than 3.5 MPa (500 psi) or if tests of field-cured cylinders indicate deficiencies in protection and curing, steps shall be taken to assure that the load-carrying capacity of the structure is not jeopardized. When the strength of concrete in place is considered potentially deficient, cores shall be obtained and tested in accordance with ASTM C 42. At least three representative cores shall be taken from each member or area of concrete in place that is considered potentially deficient. The location of cores will be determined by the Contracting Officer to least impair the strength of the structure. Concrete in the area represented by the core testing will be considered adequate if the average strength of the cores is equal to at least 85 percent of the specified strength requirement and if no single core is less than 75 percent of the specified strength requirement. Non-destructive tests (tests other than test cylinders or cores) shall not be used as a basis for acceptance or rejection. The Contractor shall perform the coring and repair the holes. Cores will be tested by the Government.

c. Load Tests. If the core tests are inconclusive or impractical to obtain or if structural analysis does not confirm the safety of the structure, load tests may be directed by the Contracting Officer in accordance with the requirements of ACI 318/318R. Concrete work evaluated by structural analysis or by results of a load test as being understrength shall be corrected in a manner satisfactory to the Contracting Officer. All investigations, testing, load tests, and correction of deficiencies shall be performed by and at the expense of the Contractor and must be approved by the Contracting Officer, except that if all concrete is found to be in compliance with the drawings and specifications, the cost of investigations, testing, and load tests will be at the expense of the Government.

1.7.3.1 Water-Cement Ratio

Maximum water-cement ratio (w/c) for normal weight concrete shall be 0.45.

This w/c may cause higher strengths than that required above for compressive. The maximum w/c required will be the equivalent w/c as determined by conversion from the weight ratio of water to cement plus pozzolan if used, by the weight equivalency method as described in ACI 211.1.

1.7.4 Air Entrainment

Concrete meeting the criteria in paragraph "Holloman AFB Special Concrete Requirements" shall conform to the requirements of that paragraph. Specified air content shall be attained at point of placement into the forms. Air content for normal weight concrete shall be determined in accordance with ASTM C 231.
1.7.5 Slump

Slump for concrete meeting the criteria in paragraph "Holloman AFB Special Concrete Requirements" shall conform to the requirements of that paragraph. Slump for concrete, as delivered to the point of placement into the forms, shall be within the following limits. Slump shall be determined in accordance with ASTM C 143.

<table>
<thead>
<tr>
<th>Structural Element</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls, columns and beams</td>
<td>51 mm (2 in.)</td>
<td>102 mm (4 in.)</td>
</tr>
<tr>
<td>Foundation walls, substructure</td>
<td>25 mm (1 in.)</td>
<td>75 mm (3 in.)</td>
</tr>
<tr>
<td>walls, footings, slabs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any structural concrete approved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>for placement by pumping:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At pump</td>
<td>51 mm (2 in.)</td>
<td>152 mm (6 in.)</td>
</tr>
<tr>
<td>At discharge of line</td>
<td>25 mm (1 in.)</td>
<td>102 mm (4 in.)</td>
</tr>
</tbody>
</table>

When use of a plasticizing admixture conforming to ASTM C 1017 or when a Type F or G high range water reducing admixture conforming to ASTM C 494 is permitted to increase the slump of concrete, concrete shall have a slump of 50 to 100 mm (2 to 4 inches) before the admixture is added and a maximum slump of 200 mm (8 inches) at the point of delivery after the admixture is added.

1.7.6 Concrete Temperature

During hot weather, the temperature of the concrete as delivered shall be as specified in paragraph "Hot Weather Requirements". When the ambient temperature during placing is 5 degrees C (40 degrees F) or less, or is expected to be at any time within 6 hours after placing, the temperature of the concrete as delivered shall be between 12 and 25 degrees C (55 and 75 degrees F).

1.7.7 Size of Coarse Aggregate

The largest feasible nominal maximum size aggregate (NMSA) specified in paragraph AGGREGATES shall be used in each placement. However, nominal maximum size of aggregate shall not exceed any of the following: three-fourths of the minimum cover for reinforcing bars, three-fourths of the minimum clear spacing between reinforcing bars, one-fifth of the narrowest dimension between sides of forms, or one-third of the thickness of slabs or toppings.
1.7.8 Special Properties and Products

Concrete may contain admixtures other than air entraining agents, such as water reducers, superplasticizers, or set retarding agents to provide special properties to the concrete, if specified or approved. Any of these materials to be used on the project shall be used in the mix design studies.

1.8 MIXTURE PROPORTIONS

Concrete shall be composed of portland cement, other cementitious and pozzolanic materials as specified, aggregates, water and admixtures as specified.

1.8.1 Proportioning Studies for Normal Weight Concrete

Trial design batches, mixture proportioning studies, and testing requirements for various classes and types of concrete specified shall be the responsibility of the Contractor. Mixture proportions shall be based on compressive strength as determined by test specimens fabricated in accordance with ASTM C 192 and tested in accordance with ASTM C 39. Samples of all materials used in mixture proportioning studies shall be representative of those proposed for use in the project and shall be accompanied by the manufacturer's or producer's test reports indicating compliance with these specifications. Trial mixtures having proportions, consistencies, and air content suitable for the work shall be made based on methodology described in ACI 211.1, using at least three different water-cement ratios for each type of mixture, which will produce a range of strength encompassing those required for each class and type of concrete required on the project. The maximum water-cement ratios required in the paragraph Maximum Allowable w/c Ratio will be the equivalent water-cement ratio as determined by conversion from the weight ratio of water to cement plus pozzolan by the weight equivalency method as described in ACI 211.1. The minimum percent of pozzolan required shall be determined per specification Section 01610 - AGGREGATE FOR PORTLAND CEMENT CONCRETE. Laboratory trial mixtures shall be designed for maximum permitted slump and air content. Separate sets of trial mixture studies shall be made for each combination of cementitious materials and each combination of admixtures proposed for use. Separate trial mixture studies shall also be made for concrete for any conveying or placing method proposed which requires special properties and for concrete to be placed in unusually difficult placing locations. The temperature of concrete in each trial batch shall be reported. For each water-cement ratio, at least two test cylinders for each test age shall be made and cured in accordance with ASTM C 192. They shall be tested at 14 and 48 days in accordance with ASTM C 39. From these test results, a curve shall be plotted showing the relationship between water-cement ratio and strength for each set of trial mix studies. In addition, a curve shall be plotted showing the relationship between 14 day and 48 day strengths. Each mixture shall be designed to promote easy and suitable concrete placement, consolidation and finishing, and to prevent segregation and excessive bleeding.
1.8.2 Average Compressive Strength Required for Mixtures

The mixture proportions selected during mixture design studies shall produce a required average compressive strength (f'cr) exceeding the specified compressive strength (f'c) by the amount indicated below. This required average compressive strength, f'cr, will not be a required acceptance criteria during concrete production. However, whenever the daily average compressive strength at 48 days drops below f'cr during concrete production, or daily average 14-day strength drops below a strength correlated with the 48-day f'cr, the mixture shall be adjusted, as approved, to bring the daily average back up to f'cr. During production, the required f'cr shall be adjusted, as appropriate, based on the standard deviation being attained on the job. Standard deviation shall be established in accordance with ACI 214. Test data shall be maintained and updated on a daily basis.

1.8.2.1 Computations from Test Records

Where a concrete production facility has test records, a standard deviation shall be established in accordance with the applicable provisions of ACI 214.3R. Test records from which a standard deviation is calculated shall represent materials, quality control procedures, and conditions similar to those expected; shall represent concrete produced to meet a specified strength or strengths (f'c) within 7 MPa (1,000 psi) of that specified for proposed work; shall consist of at least 30 consecutive tests and shall be current to within the last 12 months. A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 48 days. Required average compressive strength f'cr used as the basis for selection of concrete proportions shall be the larger of the equations that follow using the standard deviation as determined above:

\[ f'cr = f'c + 1.34S \text{ where units are in MPa} \]
\[ (f'cr = f'c + 1.34S \text{ where units are in psi}) \]

\[ f'cr = f'c + 2.33S - 3.45 \text{ where units are in MPa} \]
\[ (f'cr = f'c + 2.33S - 500 \text{ where units are in psi}) \]

Where \( S \) = standard deviation

Where a concrete production facility does not have test records meeting the requirements above but does have a record based on 15 to 29 consecutive tests, a standard deviation shall be established as the product of the calculated standard deviation and a modification factor from the following table:

<table>
<thead>
<tr>
<th>NUMBER OF TESTS</th>
<th>MODIFICATION FACTOR FOR STANDARD DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.16</td>
</tr>
<tr>
<td>20</td>
<td>1.08</td>
</tr>
<tr>
<td>25</td>
<td>1.03</td>
</tr>
<tr>
<td>30 or more</td>
<td>1.00</td>
</tr>
</tbody>
</table>

03300-13
1.8.2.2 Computations Without Previous Test Records

When a concrete production facility does not have sufficient field strength test records for calculation of the standard deviation, the required average strength f'cr shall be determined as follows:

a. If the specified compressive strength f'c is less than 20 MPa (3,000 psi) f'cr = f'c + 1000 psi.

b. If the specified compressive strength f'c is 20 to 35 MPa (3,000 to 5,000 psi) f'cr = f'c + 1,200 psi.

c. If the specified compressive strength f'c is over 35 MPa (5,000 psi) f'cr = f'c + 1,400 psi.

1.8.3 Average Flexural Strength Required for Mixtures

The mixture proportions selected during mixture design studies for flexural strength mixtures and the mixture used during concrete production shall be designed and adjusted during concrete production as approved, except that the overdesign for average flexural strength shall be 15 percent greater than the specified flexural strength at all times.

1.9 STORAGE OF MATERIALS

Cement and other cementitious materials shall be stored in weathertight buildings, bins, or silos which will exclude moisture and contaminants and keep each material completely separated. Aggregate stockpiles shall be arranged and used in a manner to avoid excessive segregation and to prevent contamination with other materials or with other sizes of aggregates. Aggregate shall not be stored directly on ground unless a sacrificial layer is left undisturbed. Reinforcing bars and accessories shall be stored above the ground on platforms, skids or other supports in such a manner as to avoid contamination and deterioration. Admixtures which have been in storage at the project site for longer than 6 months or which have been subjected to freezing shall not be used unless retested and proven to meet the specified requirements. Materials shall be capable of being accurately identified after bundles or containers are opened.

1.10 GOVERNMENT ASSURANCE INSPECTION AND TESTING

Day-to-day inspection and testing shall be the responsibility of the Contractor Quality Control (CQC) staff. However, representatives of the Contracting Officer can and will inspect construction as considered appropriate and will monitor operations of the Contractor's CQC staff. Government inspection or testing will not relieve the Contractor of any of his CQC responsibilities.
1.10.1 Materials

The Government will sample and test aggregates, cementitious materials, other materials, and concrete to determine compliance with the specifications as considered appropriate. The Contractor shall provide facilities and labor as may be necessary for procurement of representative test samples. Samples of aggregates will be obtained at the point of batching in accordance with ASTM D 75. Other materials will be sampled from storage at the jobsite or from other locations as considered appropriate. Samples may be placed in storage for later testing when appropriate.

1.10.2 Fresh Concrete

Fresh concrete will be sampled as delivered in accordance with ASTM C 172 and tested in accordance with these specifications, as considered necessary.

1.10.3 Hardened Concrete

Tests on hardened concrete will be required by the Government when such tests are considered necessary. All investigations and testing shall be performed by and at the expense of the Contractor and must be approved by the Contracting Officer, except that if all concrete is found to be in compliance with the drawings and specifications, the cost of investigations and testing will be at the expense of the Government.

1.10.4 Inspection

Concrete operations will be tested and inspected by the Government as the project progresses. Failure to detect defective work or material will not prevent rejection later when a defect is discovered nor will it obligate the Government for final acceptance.

PART 2 - PRODUCTS

2.1 CEMENTITIOUS MATERIALS

Cementitious materials shall be portland cement in combination with a pozzolan admixture and shall conform to appropriate specifications listed below. Use of cementitious materials in concrete which will have surfaces exposed in the completed structure shall be restricted so there is no change in color, source, or type of cementitious material. Only one brand of any one type of cement shall be used for exposed concrete surfaces of any individual structure. The alkali content of all cement shall not exceed 0.6 percent.

2.1.1 Portland Cement

ASTM C 150, Type V.
2.1.2 Pozzolan (Fly Ash)

Pozzolan shall conform to ASTM C 618, Class F. Requirement for maximum alkalis from Table 1A of ASTM C 618 shall apply. Maximum loss on ignition shall not be over 4 percent. Samples shall be obtained, prepared, and tested in accordance with ASTM C 311. Pozzolan (fly ash) will be accepted on the basis of certified test results showing that the pozzolan meets all requirements specified herein. The Contractor shall report certified test results for each mill lot of fly ash furnished. When, in the opinion of the Contracting Officer, the fly ash becomes damaged in transit or deteriorated because of age or improper storage, the fly ash proposed for use shall be sampled at the mixing site by the Contractor in the presence of a representative of the Contracting Officer and shall be tested by an independent testing laboratory for conformance with specification requirements. Fly ash being check tested shall not be used in the work prior to completion of the series of tests specified in ASTM C 311, paragraph 6.1. Fly ash failing to meet the test requirements shall be promptly removed from the site or in the case of ready mix concrete, shall be segregated at the batching plant as directed.

2.2 AGGREGATES

All aggregates shall conform to the following.

2.2.1 Fine Aggregate

Fine aggregate shall conform to the quality and gradation requirements of ASTM C 33.

2.2.2 Coarse Aggregate

Coarse aggregate shall conform to ASTM C 33, Class 5M, size designation 67.

2.3 CHEMICAL ADMIXTURES

Chemical admixtures, when required or permitted, shall conform to the appropriate specification listed. Admixtures shall be furnished in liquid form and of suitable concentration for easy, accurate control of dispensing.

2.3.1 Air-Entraining Admixtures

ASTM C 260 and shall consistently entrain the air content in the specified ranges under field conditions.

2.3.2 Accelerating Admixture

ASTM C 494, Type C or E, except that calcium chloride or admixtures containing calcium chloride shall not be used.

2.3.3 Water-Reducing or Retarding Admixture

ASTM C 494, Type A, B, or D.
2.3.4 High-Range Water-Reducer

ASTM C 494, Type F or G. The admixture shall be used only when approved in writing, such approval being contingent upon particular mixture control as described in the Contractor's Quality Control Plan and upon performance of separate mixture design studies.

2.3.5 Surface Retarder

COE CRD-C 94.

2.3.6 Other Chemical Admixtures

Chemical admixtures for use in producing flowing concrete shall comply with ASTM C 1017, Type I or II. These admixtures shall be used only when approved in writing, such approval being contingent upon particular mixture control as described in the Contractor's Quality Control Plan and upon performance of separate mixture design studies.

2.4 CURING MATERIALS

2.4.1 Impervious-Sheet

Impervious-sheet materials shall conform to ASTM C 171, type optional, except, that polyethylene sheeting shall not be used.

2.4.2 Membrane-Forming Compound

Membrane-Forming curing compound shall conform to ASTM C 309, Type 1-D or 2, except that only a styrene acrylate or chlorinated rubber compound meeting Class B requirements shall be used for surfaces that are to be painted or are to receive bituminous roofing, or waterproofing, or floors that are to receive adhesive applications of resilient flooring. The curing compound selected shall be compatible with any subsequent paint, roofing, waterproofing, or flooring specified. Nonpigmented compound shall contain a fugitive dye, and shall have the reflective requirements in ASTM C 309 waived.

2.4.3 Burlap and Cotton Mat

Burlap and cotton mat used for curing shall conform to AASHTO M 182.

2.5 WATER

Water for mixing and curing shall be fresh, clean, potable, and free of injurious amounts of oil, acid, salt, or alkali, except that non-potable water may be used if it meets the requirements of COE CRD-C 400. Water containing chloride salts shall not be used.
2.6 NON-METALLIC HIGH-STRENGTH NONSCHRINK GROUT

Non-metallic high-strength non-shrink grout shall conform to ASTM C 1107, Grade A, B or C, and shall be a commercial formulation suitable for the proposed application.

2.7 NONSLIP SURFACING MATERIAL

Nonslip surfacing material shall consist of 55 percent, minimum, aluminum oxide or silicon-dioxide abrasive ceramically bonded together to form a homogeneous material sufficiently porous to provide a good bond with portland cement paste; or factory-graded emery aggregate consisting of not less than 45 percent aluminum oxide and 25 percent ferric oxide. The aggregate shall be well graded from particles retained on the 0.600 mm (No. 30) sieve to particles passing the 2.36 mm (No. 8) sieve.

2.8 LATEX BONDING AGENT

Latex agents for bonding fresh to hardened concrete shall conform to ASTM C 1059.

2.9 EPOXY RESIN

Epoxy resins for use in repairs shall conform to ASTM C 881, Type V, Grade 2. Class as appropriate to the existing ambient and surface temperatures.

2.10 EMBEDDED ITEMS

Embedded items shall be of the size and type indicated or as needed for the application. Dovetail slots shall be galvanized steel. Hangers for suspended ceilings shall be as specified in Section 09510 - ACOUSTICAL CEILINGS. Inserts for shelf angles and bolt hangers shall be of malleable iron or cast or wrought steel.

2.11 PERIMETER INSULATION

Perimeter insulation shall be polystyrene conforming to ASTM C 578, Type II; polyurethane conforming to ASTM C 591, Type II; or cellular glass conforming to ASTM C 552, Type I or IV.

PART 3 - EXECUTION

3.1 PREPARATION FOR PLACING

Before commencing concrete placement, the following shall be performed. Surfaces to receive concrete shall be clean and free from frost, ice, mud, and water. Forms shall be in place, cleaned, coated, and adequately supported, in accordance with Section 03100 - STRUCTURAL CONCRETE FORMWORK. Reinforcing steel shall be in place, cleaned, tied, and adequately supported, in accordance with Section 03200 - CONCRETE REINFORCEMENT. Transporting and conveying equipment shall be in-place, ready for use, clean, and free of hardened concrete and foreign material. Equipment for
consolidating concrete shall be at the placing site and in proper working order. Equipment and material for curing and for protecting concrete from weather or mechanical damage shall be at the placing site, in proper working condition and in sufficient amount for the entire placement. When hot, windy conditions during concreting appear probable, equipment and material shall be at the placing site to provide windbreaks, shading, fogging, or other action to prevent plastic shrinkage cracking or other damaging drying of the concrete. All embedded items shall be in place and clean of any deleterious substance.

3.1.1 Foundations

3.1.1.1 Concrete on Earth Foundations

Earth (subgrade, base, capillary water barrier or subbase courses) surfaces upon which concrete is to be placed shall be clean, damp, and free from debris, frost, ice, and standing or running water. Prior to placement of concrete, the foundation shall be well drained and shall be satisfactorily graded and uniformly compacted.

3.1.1.2 Excavated Surfaces in Lieu of Forms

Concrete for footings may be placed directly against the soil provided the earth or rock has been carefully trimmed, is uniform and stable, and meets the compaction requirements of Section 02315 - EXCAVATION, FILLING, AND BACKFILLING FOR BUILDINGS. The concrete shall be placed without becoming contaminated by loose material, and the outline of the concrete shall be within the specified tolerances.

3.1.1.3 Preparation of Previously Placed Concrete

Concrete surfaces to which other concrete is to be bonded shall be abraded in an approved manner that will expose sound aggregate uniformly without damaging the concrete. Laitance and loose particles shall be removed. Surfaces shall be thoroughly washed and shall be moist but without free water when concrete is placed.

3.1.2 Perimeter Insulation

Perimeter insulation shall be installed at locations indicated. Adhesive shall be used where insulation is applied to the interior surface of foundation walls and may be used for exterior application.

3.1.3 Embedded Items

Before placement of concrete, care shall be taken to determine that all embedded items are firmly and securely fastened in place as indicated. Conduit and other embedded items shall be clean and free of oil and other foreign matter such as loose coatings or rust, paint, and scale. The embedding of wood in concrete will be permitted only when specifically authorized or directed. Voids in sleeves, inserts, and anchor slots shall be filled temporarily with readily removable materials to prevent the entry of
concrete into voids. Welding shall not be performed on embedded metals within 600 mm (2 feet) of the surface of the concrete.

3.2 CONCRETE PRODUCTION

3.2.1 Batching, Mixing, and Transporting Concrete

Concrete shall be furnished from a ready-mixed concrete plant. Ready-mixed concrete shall be batched, mixed, and transported in accordance with ASTM C 94, except as otherwise specified. Truck mixers, agitators, and nonagitating transporting units shall comply with NRMCA TMMB-01. Ready-mix plant equipment and facilities shall be certified in accordance with NRMCA QC 3. Approved batch tickets shall be furnished for each load of ready-mixed concrete. Information on the batch ticket shall be in accordance with ASTM C 94. Concrete shall be batched and mixed to conform to the following subparagraphs. Site-mixed concrete will not be allowed.

3.2.1.1 General

The batching plant shall be located off site close to the project. The batching, mixing and placing system shall have a capacity of at least 150 cubic meters (200 cubic yards) per hour. The batching plant shall conform to the requirements of NRMCA CPMB 100 and as specified; however, rating plates attached to batch plant equipment are not required.

3.2.1.2 Batching Equipment

The batching controls shall be semiautomatic or automatic, as defined in NRMCA CPMB 100. A semiautomatic batching system shall be provided with interlocks such that the discharge device cannot be actuated until the indicated material is within the applicable tolerance. The batching system shall be equipped with accurate recorder or recorders that meet the requirements of NRMCA CPMB 100. The weight of water and admixtures shall be recorded if batched by weight. Separate bins or compartments shall be provided for each size group of aggregate and type of cementitious material, to prevent intermingling at any time. Aggregates shall be weighed either in separate weigh batchers with individual scales or, provided the smallest size is batched first, cumulatively in one weigh batcher on one scale. Aggregate shall not be weighed in the same batcher with cementitious material. If both portland cement and other cementitious material are used, they may be batched cumulatively, provided that the portland cement is batched first. Water may be measured by weight or volume. Water shall not be weighed or measured cumulatively with another ingredient. Filling and discharging valves for the water metering or batching system shall be so interlocked that the discharge valve cannot be opened before the filling valve is fully closed. Piping for water and for admixtures shall be free from leaks and shall be properly valved to prevent backflow or siphoning. Admixtures shall be furnished as a liquid of suitable concentration for easy control of dispensing. An adjustable, accurate, mechanical device for measuring and dispensing each admixture shall be provided. Each admixture dispenser shall be interlocked with the batching and discharging operation of the water so that each admixture is separately batched and individually discharged automatically in
a manner to obtain uniform distribution throughout the water as it is added to the batch in the specified mixing period. When use of truck mixers makes this requirement impractical, the admixture dispensers shall be interlocked with the sand batchers. Different admixtures shall not be combined prior to introduction in water and shall not be allowed to intermingle until in contact with the cement. Admixture dispensers shall have suitable devices to detect and indicate flow during dispensing or have a means for visual observation. The plant shall be arranged so as to facilitate the inspection of all operations at all times. Suitable facilities shall be provided for obtaining representative samples of aggregates from each bin or compartment, and for sampling and calibrating the dispensing of cementitious material, water, and admixtures. Filling ports for cementitious materials bins or silos shall be clearly marked with a permanent sign stating the contents.

3.2.1.3 Scales

The weighing equipment shall conform to the applicable requirements of CPMB Concrete Plant Standard, and of NIST HB 44, except that the accuracy shall be plus or minus 0.2 percent of scale capacity. The Contractor shall provide standard test weights and any other auxiliary equipment required for checking the operating performance of each scale or other measuring devices. The tests shall be made at the specified frequency in the presence of a Government inspector. The weighing equipment shall be arranged so that the plant operator can conveniently observe all dials or indicators.

3.2.1.4 Batching Tolerances

Tolerances with Weighing Equipment:

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PERCENT OF REQUIRED WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementitious materials</td>
<td>0 to plus 1</td>
</tr>
<tr>
<td>Aggregate</td>
<td>plus or minus 2</td>
</tr>
<tr>
<td>Water</td>
<td>plus or minus 1</td>
</tr>
<tr>
<td>Chemical admixture</td>
<td>plus or minus 3</td>
</tr>
</tbody>
</table>

3.2.1.5 Moisture Control

The plant shall be capable of ready adjustment to compensate for the varying moisture content of the aggregates and to change the weights of the materials being batched.

3.2.1.6 Concrete Mixers

Mixers shall be stationary mixers or truck mixers. Mixers shall be capable of combining the materials into a uniform mixture and of discharging this mixture without segregation. The mixers shall not be charged in excess of the capacity recommended by the manufacturer. The mixers shall be operated at the drum or mixing blade speed designated by the manufacturer. The mixers shall be maintained in satisfactory operating condition, and the mixer drums shall be kept free of hardened concrete. Should any mixer at any time...
produce unsatisfactory results, its use shall be promptly discontinued until it is repaired.

3.2.1.7 Stationary Mixers

Concrete plant mixers shall be drum-type mixers of tilting, nontilting, horizontal-shaft, or vertical-shaft type, or shall be pug mill type and shall be provided with an acceptable device to lock the discharge mechanism until the required mixing time has elapsed. The mixing time and uniformity shall conform to all the requirements in ASTM C 94 applicable to central-mixed concrete.

3.2.1.8 Truck Mixers

Truck mixers, the mixing of concrete therein, and concrete uniformity shall conform to the requirements of ASTM C 94. A truck mixer may be used either for complete mixing (transit-mixed) or to finish the partial mixing done in a stationary mixer (shrink-mixed). Each truck shall be equipped with two counters from which it is possible to determine the number of revolutions at mixing speed and the number of revolutions at agitating speed. Or, if approved in lieu of this, the number of revolutions shall be marked on the batch tickets. Water shall not be added at the placing site unless specifically approved; and in no case shall it exceed the specified w/c. Any such water shall be injected at the base of the mixer, not at the discharge end.

3.3 TRANSPORTING CONCRETE TO PROJECT SITE

Concrete shall be transported to the placing site in truck mixers, or by approved pumping equipment. Nonagitating equipment, other than pumps, shall not be used for transporting lightweight aggregate concrete.

3.4 CONVEYING CONCRETE ON SITE

Concrete shall be conveyed from mixer or transporting unit to forms as rapidly as possible and within the time interval specified by methods which will prevent segregation or loss of ingredients using following equipment. Conveying equipment shall be cleaned before each placement.

3.4.1 Buckets

The interior hopper slope shall be not less than 58 degrees from the horizontal, the minimum dimension of the clear gate opening shall be at least 5 times the nominal maximum-size aggregate, and the area of the gate opening shall not be less than 0.2 square meters (2 square feet). The maximum dimension of the gate opening shall not be greater than twice the minimum dimension. The bucket gates shall be essentially grout tight when closed and may be manually, pneumatically, or hydraulically operated except that buckets larger than 1.5 cubic meters (2 cubic yards) shall not be manually operated. The design of the bucket shall provide means for positive regulation of the amount and rate of deposit of concrete in each dumping position.
3.4.2 Transfer Hoppers

Concrete may be charged into nonagitating hoppers for transfer to other conveying devices. Transfer hoppers shall be capable of receiving concrete directly from delivery vehicles and shall have conical-shaped discharge features. The transfer hopper shall be equipped with a hydraulically operated gate and with a means of external vibration to effect complete discharge. Concrete shall not be held in nonagitating transfer hoppers more than 30 minutes.

3.4.3 Trucks

Truck mixers operating at agitating speed or truck agitators used for transporting plant-mixed concrete shall conform to the requirements of ASTM C 94. Nonagitating equipment shall be used only for transporting plant-mixed concrete over a smooth road and when the hauling time is less than 15 minutes. Bodies of nonagitating equipment shall be smooth, watertight, metal containers specifically designed to transport concrete, shaped with rounded corners to minimize segregation, and equipped with gates that will permit positive control of the discharge of the concrete.

3.4.4 Chutes

When concrete can be placed directly from a truck mixer, agitator, or nonagitating equipment, the chutes normally attached to this equipment by the manufacturer may be used. A discharge deflector shall be used when required by the Contracting Officer. Separate chutes and other similar equipment will not be permitted for conveying concrete.

3.4.5 Belt Conveyors

Belt conveyors shall be designed and operated to assure a uniform flow of concrete from mixer to final place of deposit without segregation of ingredients or loss of mortar and shall be provided with positive means, such as discharge baffle or hopper, for preventing segregation of the concrete at the transfer points and the point of placing. Belt conveyors shall be constructed such that the idler spacing shall not exceed 900 mm (36 inches). The belt speed shall be a minimum of 90 meters (300 feet) per minute and a maximum of 225 meters (750 feet) per minute. If concrete is to be placed through installed horizontal or sloping reinforcing bars, the conveyor shall discharge concrete into a pipe or elephant truck that is long enough to extend through the reinforcing bars.

3.4.6 Concrete Pumps

Concrete may be conveyed by positive displacement pump when approved. The pumping equipment shall be piston or squeeze pressure type; pneumatic placing equipment shall not be used. The pipeline shall be rigid steel pipe or heavy-duty flexible hose. The inside diameter of the pipe shall be at least 3 times the nominal maximum-size coarse aggregate in the concrete mixture to be pumped but not less than 100 mm (4 inches). Aluminum pipe shall not be used.
3.5 PLACING CONCRETE

Mixed concrete shall be discharged within 1-1/2 hours or before the mixer drum has revolved 300 revolutions, whichever comes first after the introduction of the mixing water to the cement and aggregates. When the concrete temperature exceeds 30 degrees C (85 degrees F), the time shall be reduced to 45 minutes. Concrete shall be placed within 15 minutes after it has been discharged from the transporting unit. Concrete shall be handled from mixer or transporting unit to forms in a continuous manner until the approved unit of operation is completed. Adequate scaffolding, ramps and walkways shall be provided so that personnel and equipment are not supported by in-place reinforcement. Placing will not be permitted when the sun, heat, wind, or limitations of facilities furnished by the Contractor prevent proper consolidation, finishing and curing. Sufficient placing capacity shall be provided so that concrete can be kept free of cold joints.

3.5.1 Depositing Concrete

Concrete shall be deposited as close as possible to its final position in the forms, and there shall be no vertical drop greater than 1.5 meters (5 feet) except where suitable equipment is provided to prevent segregation and where specifically authorized. Depositing of the concrete shall be so regulated that it will be effectively consolidated in horizontal layers not more than 300 mm (12 inches) thick, except that all slabs shall be placed in a single layer. Concrete to receive other construction shall be screeded to the proper level. Concrete shall be deposited continuously so that fresh concrete is deposited on in-place concrete that is still plastic. Fresh concrete shall not be deposited on concrete that has hardened sufficiently to cause formation of seams or planes of weakness within the section. Concrete that has surface dried, partially hardened, or contains foreign material shall not be used. When temporary spreaders are used in the forms, the spreaders shall be removed as their service becomes unnecessary. Concrete shall not be placed in slabs over columns and walls until concrete in columns and walls has been in-place at least two hours or until the concrete begins to lose its plasticity. Concrete for beams, girders, brackets, column capitals, haunches, and drop panels shall be placed at the same time as concrete for adjoining slabs.

3.5.2 Consolidation

Immediately after placing, each layer of concrete shall be consolidated by internal vibrators, except for slabs 100 mm (4 inches) thick or less. The vibrators shall at all times be adequate in effectiveness and number to properly consolidate the concrete; a spare vibrator shall be kept at the jobsite during all concrete placing operations. The vibrators shall have a frequency of not less than 10,000 vibrations per minute, an amplitude of at least 0.6 mm (0.025 inch). The head diameter shall be appropriate for the structural member and the concrete mixture being placed. Vibrators shall be inserted vertically at uniform spacing over the area of placement. The distance between insertions shall be approximately 1-1/2 times the radius of action of the vibrator so that the area being vibrated will overlap the
adjacent just-vibrated area by a reasonable amount. The vibrator shall penetrate rapidly to the bottom of the layer and at least 150 mm (6 inches) into the preceding layer if there is such. Vibrator shall be held stationary until the concrete is consolidated and then vertically withdrawn slowly while operating. Form vibrators shall not be used unless specifically approved and unless forms are constructed to withstand their use. Vibrators shall not be used to move concrete within the forms. Slabs 100 mm (4 inches) and less in thickness shall be consolidated by properly designed vibrating screeds or other approved technique. Frequency and amplitude of vibrators shall be determined in accordance with COE CRD-C 521. Grate tampers ("jitterbugs") shall not be used.

3.5.3 Cold Weather Requirements

Special protection measures, conforming to ACI 306R and approved by the Contracting Officer, shall be used if freezing temperatures are anticipated before the expiration of the specified curing period. The ambient temperature of the air where concrete is to be placed and the temperature of surfaces to receive concrete shall be not less than 5 degrees C (40 degrees F). The temperature of the concrete when placed shall be not less than 10 degrees C (50 degrees F) nor more than 25 degrees C (75 degrees F). Heating of the mixing water or aggregates will be required to regulate the concrete placing temperature. Materials entering the mixer shall be free from ice, snow, or frozen lumps. Salt, chemicals or other materials shall not be incorporated in the concrete to prevent freezing. Upon written approval, an accelerating admixture conforming to ASTM C 494, Type C or E may be used, provided it contains no calcium chloride. Calcium chloride shall not be used.

3.5.4 Hot Weather Requirements

When the ambient temperature during concrete placing is expected to exceed 30 degrees C (85 degrees F), the concrete shall be placed in accordance with ACI 305R and finished with procedures previously submitted and as specified herein. The concrete temperature at time of delivery to the forms shall not exceed the temperature shown in the table below when measured in accordance with ASTM C 1064. Cooling of the mixing water or aggregates or placing concrete in the cooler part of the day may be required by the Contracting Officer, to obtain an adequate placing temperature. A retarder may be used, as approved by the Contracting Officer, to facilitate placing and finishing. Steel forms and reinforcements shall be cooled as approved prior to concrete placement when steel temperatures are greater than 49 degrees C (120 degrees F). Conveying and placing equipment shall be cooled if necessary to maintain proper concrete-placing temperature. During periods of hot weather, the following precautions shall be taken to prevent the formation of plastic-shrinkage cracks resulting from excessive loss of moisture from the concrete:

a. The metal forms and/or underlying base or subgrade materials that will not be covered by vapor barrier or similar material shall be cooled by sprinkling or fogging with water immediately before the placement of concrete.
b. All concrete shall be delivered to the forms at a temperature below 30 degrees C (85 degrees F), except that concrete with retarding admixtures may have temperatures of 30 to 33 degrees C (85 to 90 degrees F) as deposited in the forms.

c. Placement may be allowed only at night or in early morning hours if necessary to maintain the concrete temperature and keep forms cool.

d. The concrete shall be placed and finished as rapidly as practicable and curing will start immediately after final finishing has been completed on any section of a floor or placement.

e. The finished surface of the concrete shall be kept damp by applying a water fog or mist with approved spraying equipment until mats can be applied as required by the moist curing method.

f. Curing for the first 24 hours after placement shall be by the moist curing method. After this initial curing period any of the specified methods may be used for the remaining period of curing.

### Maximum Allowable Concrete Placing Temperature

<table>
<thead>
<tr>
<th>Relative Humidity, Percent, During Time of Concrete Placement</th>
<th>Maximum Allowable Concrete Temperature Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than or equal to 60</td>
<td>33 C (90 F)</td>
</tr>
<tr>
<td>Less than 60</td>
<td>30 C (85 F)</td>
</tr>
</tbody>
</table>

#### 3.5.5 Prevention of Plastic Shrinkage Cracking

During hot weather with low humidity, and particularly with appreciable wind, as well as interior placements when space heaters produce low humidity, the Contractor shall be alert to the tendency for plastic shrinkage cracks to develop and shall institute measures to prevent this. Particular care shall be taken if plastic shrinkage cracking is potentially imminent and especially if it has developed during a previous placement. Periods of high potential for plastic shrinkage cracking can be anticipated by use of Fig. 2.1.5 of ACI 305R. In addition the concrete placement shall be further protected by erecting shades and windbreaks and by applying fog sprays of water, sprinkling, ponding or wet covering. Plastic shrinkage cracks that occur shall be filled by injection of epoxy resin as directed, after the concrete hardens. Plastic shrinkage cracks shall never be troweled over or filled with slurry.

#### 3.5.6 Placing Concrete in Congested Areas

Special care shall be used to ensure complete filling of the forms, elimination of all voids, and complete consolidation of the concrete when placing concrete in areas congested with reinforcing bars, embedded items, waterstops and other tight spacing. An appropriate concrete mixture shall be
used, and the nominal maximum size of aggregate (NMSA) shall meet the specified criteria when evaluated for the congested area. Vibrators with heads of a size appropriate for the clearances available shall be used, and the consolidation operation shall be closely supervised to ensure complete and thorough consolidation at all points. Where necessary, splices of reinforcing bars shall be alternated to reduce congestion. Where two mats of closely spaced reinforcing are required, the bars in each mat shall be placed in matching alignment to reduce congestion. Reinforcing bars may be temporarily crowded to one side during concrete placement provided they are returned to exact required location before concrete placement and consolidation are completed.

3.6 JOINTS

Joints shall be located and constructed as indicated. Joints not indicated on the drawings shall be located and constructed to minimize the impact on the strength of the structure. In general, such joints shall be located near the middle of the spans of supported slabs, beams, and girders unless a beam intersects a girder at this point, in which case the joint in the girder shall be offset a distance equal to twice the width of the beam. Joints in walls and columns shall be at the underside of floors, slabs, beams, or girders and at the tops of footings or floor slabs, unless otherwise approved. Joints shall be perpendicular to the main reinforcement. All reinforcement shall be continued across joints; except that reinforcement or other fixed metal items shall not be continuous through expansion joints, or through construction or contraction joints in slabs on ground. Reinforcement shall be 50 mm (2 inches) clear from each joint. Except where otherwise indicated, construction joints between interior slabs on ground and vertical surfaces shall be at least 3/8 inch expansion joint material (a bond breaker material will not be allowed), extending for the full depth of the slab. The perimeters of the slabs shall be free of fins, rough edges, spalling, or other unsightly appearance. Reservoir for sealant for construction and contraction joints in slabs shall be formed to the dimensions shown on the drawings by removing snap-out joint-forming inserts or by sawing sawable inserts. Joints to be sealed shall be cleaned and sealed as indicated and in accordance with Section 07900 - JOINT SEALING.

3.6.1 Construction Joints

For concrete walls, construction joints shall be located so that the unit of operation does not exceed 12.2 meters (40 feet). Concrete shall be placed continuously so that each unit is monolithic in construction. Fresh concrete shall not be placed against adjacent hardened concrete until it is at least 24 hours old. Where concrete work is interrupted by weather, end of work shift or other similar type of delay, location and type of construction joint shall be subject to approval of the Contracting Officer. Unless otherwise indicated and except for slabs on ground, reinforcing steel shall extend through construction joints. Construction joints in slabs on ground shall be as indicated on the drawings. Concrete columns, walls, or piers shall be in place at least 2 hours, or until the concrete begins to lose its plasticity, before placing concrete for beams, girders, or slabs thereon. Prior to
placing additional concrete, horizontal construction joints shall be prepared as specified in paragraph Preparation of Previously Placed Concrete.

3.6.2 Contraction Joints in Slabs on Ground

See section 03150 - EXPANSION JOINTS, CONTRACTION JOINTS, AND WATERSTOPS.

3.6.3 Expansion Joints

Installation of expansion joints and sealing of these joints shall conform to the requirements of Section 03150 - EXPANSION JOINTS, CONTRACTION JOINTS, AND WATERSTOPS and Section 07900 - JOINT SEALING.

3.6.4 Waterstops

Waterstops shall be installed in conformance with the locations and details shown on the drawings using materials and procedures specified in Section 03150 - EXPANSION JOINTS, CONTRACTION JOINTS, AND WATERSTOPS.

3.6.5 Dowels and Tie Bars

Dowels and tie bars shall be installed at the locations shown on the drawings and to the details shown, using materials and procedures specified in Section 03200 - CONCRETE REINFORCEMENT and herein. Conventional smooth "paving" dowels shall be installed in slabs using approved methods to hold the dowel in place during concreting within a maximum alignment tolerance of 1 mm in 100 mm (1/8 inch in 12 inches). "Structural" type deformed bar dowels, or tie bars, shall be installed to meet the specified tolerances. Care shall be taken during placing adjacent to and around dowels and tie bars to ensure there is no displacement of the dowel or tie bar and that the concrete completely embeds the dowel or tie bar and is thoroughly consolidated.

3.7 FINISHING FORMED SURFACES

Forms, form materials, and form construction are specified in Section 03100 - STRUCTURAL CONCRETE FORMWORK. Finishing of formed surfaces shall be as specified herein. Unless another type of architectural or special finish is specified, surfaces shall be left with the texture imparted by the forms except that defective surfaces shall be repaired. Except for major defects, as defined hereinafter, surface defects shall be repaired as specified herein within 24 hours after forms are removed. Repairs of the so-called "plaster-type" (a thin finish coat of cementitious material and aggregate applied to the formed surface) will not be permitted in any location. Tolerances of formed surfaces shall conform to the requirements of ACI 117/A117R. These tolerances apply to the finished concrete surface, not to the forms themselves; forms shall be set true to line and grade. Form tie holes requiring repair and other defects whose depth is at least as great as their surface diameter shall be repaired as specified in paragraph Damp-Pack Mortar Repair. Defects whose surface diameter is greater than their depth shall be repaired as specified in paragraph Repair of Major Defects. Repairs shall be finished flush with adjacent surfaces and with the same surface texture. The cement used for all repairs shall be a blend of job cement with
white cement proportioned so that the final color after curing and aging will be the same as the adjacent concrete. Concrete with excessive honeycomb, or other defects which affect the strength of the member, will be rejected. Repairs shall be demonstrated to be acceptable and free from cracks or loose or drummy areas at the completion of the contract. Repairs not meeting these requirements will be rejected and shall be replaced.

3.7.1 Class C and Class D Finish

Class C finish is required at surfaces not exposed to public view. Class D finish is required at surfaces below grade. Fins, ravelings, and loose material shall be removed, and, except as otherwise indicated or as specified in Section 03100 - STRUCTURAL CONCRETE FORMWORK, holes left by removal of form ties shall be reamed and filled. Honeycomb and other defects more than 12 mm (1/2 inch) deep or more than 50 mm (2 inches) in diameter shall be repaired. Defects more than 50 mm (2 inches) in diameter shall be cut back to sound concrete, but in all cases at least 25 mm (1 inch) deep.

3.8 REPAIRS

3.8.1 Damp-Pack Mortar Repair

Form tie holes requiring repair and other defects whose depth is at least as great as their surface diameter but not over 100 mm (4 inches) shall be repaired by the damp-pack mortar method. Form tie holes shall be reamed and other similar defects shall be cut out to sound concrete. The void shall then be thoroughly cleaned, thoroughly wetted, brush-coated with a thin coat of neat cement grout and filled with mortar. Mortar shall be a stiff mix of 1 part portland cement to 2 parts fine aggregate passing the 1.18 mm (No. 16 mesh) sieve, and minimum amount of water. Only sufficient water shall be used to produce a mortar which, when used, will stick together on being molded into a ball by a slight pressure of the hands and will not exude water but will leave the hands damp. Mortar shall be mixed and allowed to stand for 30 to 45 minutes before use with remixing performed immediately prior to use. Mortar shall be thoroughly tamped in place in thin layers using a hammer and hardwood block. Holes passing entirely through walls shall be completely filled from the inside face by forcing mortar through to the outside face. All holes shall be packed full. Damp-pack repairs shall be moist cured for at least 48 hours.

3.8.2 Repair of Major Defects

Major defects will be considered to be those more than 12 mm (1/2 inch) deep or, for Class A and B finishes, more than 12 mm (1/2 inch) in diameter and, for Class C and D finishes, more than 50 mm (2 inches) in diameter. Also included are any defects of any kind whose depth is over 100 mm (4 inches) or whose surface diameter is greater than their depth. Major defects shall be repaired as specified below.
3.8.2.1 Surface Application of Mortar Repair

Defective concrete shall be removed, and removal shall extend into completely sound concrete. Approved equipment and procedures which will not cause cracking or microcracking of the sound concrete shall be used. If reinforcement is encountered, concrete shall be removed so as to expose the reinforcement for at least 50 mm (2 inches) on all sides. All such defective areas greater than 7800 square mm (12 square inches) shall be outlined by saw cuts at least 25 mm (1 inch) deep. Defective areas less than 7800 square mm (12 square inches) shall be outlined by a 25 mm (1 inch) deep cut with a core drill in lieu of sawing. All saw cuts shall be straight lines in a rectangular pattern in line with the formwork panels. After concrete removal, the surface shall be thoroughly cleaned by high pressure washing to remove all loose material. Surfaces shall be kept continually saturated for the first 12 of the 24 hours immediately before placing mortar and shall be damp but not wet at the time of commencing mortar placement. The Contractor, at his option, may use either hand-placed mortar or mortar placed with a mortar gun. If hand-placed mortar is used, the edges of the cut shall be perpendicular to the surface of the concrete. The prepared area shall be brush-coated with a thin coat of neat cement grout. The repair shall then be made using a stiff mortar, preshrunk by allowing the mixed mortar to stand for 30 to 45 minutes and then remixed, thoroughly tamped into place in thin layers. If hand-placed mortar is used, the Contractor shall test each repair area for drumminess by firm tapping with a hammer and shall inspect for cracks, both in the presence of the Contracting Officer's representative, immediately before completion of the contract, and shall replace any showing drumminess or cracking. If mortar placed with a mortar gun is used, the gun shall be a small compressed air-operated gun to which the mortar is slowly hand fed and which applies the mortar to the surface as a high-pressure stream, as approved. Repairs made using shotcrete equipment will not be accepted. The mortar used shall be the same mortar as specified for damp-pack mortar repair. If gun-placed mortar is used, the edges of the cut shall be beveled toward the center at a slope of 1:1. All surface applied mortar repairs shall be continuously moist cured for at least 7 days. Moist curing shall consist of several layers of saturated burlap applied to the surface immediately after placement is complete and covered with polyethylene sheeting, all held closely in place by a sheet of plywood or similar material rigidly braced against it. Burlap shall be kept continually wet.

3.8.2.2 Repair of Deep and Large Defects

Deep and large defects will be those that are more than 150 mm (6 inches) deep and also have an average diameter at the surface more than 450 mm (18 inches) or that are otherwise so identified by the Project Office. Such defects shall be repaired as specified herein or directed, except that defects which affect the strength of the structure shall not be repaired and that portion of the structure shall be completely removed and replaced. Deep and large defects shall be repaired by procedures approved in advance including forming and placing special concrete using applied pressure during hardening. Preparation of the repair area shall be as specified for surface application of mortar. In addition, the top edge (surface) of the repair area shall be sloped at approximately 20 degrees from the horizontal, upward.
toward the side from which concrete will be placed. The special concrete shall be a concrete mixture with low water content and low slump, and shall be allowed to age 30 to 60 minutes before use. Concrete containing a specified expanding admixture may be used in lieu of the above mixture; the paste portion of such concrete mixture shall be designed to have an expansion between 2.0 and 4.0 percent when tested in accordance with ASTM C 940. A full width "chimney" shall be provided at the top of the form on the placing side to ensure filling to the top of the opening. A pressure cap shall be used on the concrete in the chimney with simultaneous tightening and revibrating the form during hardening to ensure a tight fit for the repair. The form shall be removed after 24 hours and immediately the chimney shall be carefully chipped away to avoid breaking concrete out of the repair; the surface of the repair concrete shall be dressed as required.

3.8.3 Resinous and Latex Material Repair

In lieu of the portland cement bonding coats specified above, an epoxy resin or a latex bonding agent may be used only if approved by the Contracting Officer.

3.9 FINISHING UNFORMED SURFACES

The finish of all unformed surfaces shall meet the requirements of paragraph Tolerances in PART 1, when tested as specified herein.

3.9.1 General

The ambient temperature of spaces adjacent to unformed surfaces being finished and of the base on which concrete will be placed shall be not less than 10 degrees C (50 degrees F). In hot weather all requirements of paragraphs Hot Weather Requirements and Prevention of Plastic Shrinkage Cracking shall be met. Unformed surfaces that are not to be covered by additional concrete or backfill shall have a float finish, with additional finishing as specified below, and shall be true to the elevation shown on the drawings. Surfaces to receive additional concrete or backfill shall be brought to the elevation shown on the drawings, properly consolidated, and left true and regular. Unless otherwise shown on the drawings, exterior surfaces shall be sloped for drainage, as directed. Where drains are provided, interior floors shall be evenly sloped to the drains. Joints shall be carefully made with a jointing or edging tool. The finished surfaces shall be protected from stains or abrasions. Grate tampers or "jitterbugs" shall not be used for any surfaces. The dusting of surfaces with dry cement or other materials or the addition of any water during finishing shall not be permitted. If bleedwater is present prior to finishing, the excess water shall be carefully dragged off or removed by absorption with porous materials such as burlap. During finishing operations, extreme care shall be taken to prevent over finishing or working water into the surface; this can cause "crazing" (surface shrinkage cracks which appear after hardening) of the surface. Any slabs with surfaces which exhibit significant crazing shall be removed and replaced. During finishing operations, surfaces shall be checked with a 10 foot straightedge, applied in both directions at regular intervals while the concrete is still plastic, to detect high or low areas.
3.9.2 Rough Slab Finish

As a first finishing operation for unformed surfaces and as final finish for slabs to receive mortar setting beds, the surface shall receive a rough slab finish prepared as follows. The concrete shall be uniformly placed across the slab area, consolidated as previously specified, and then screeded with straightedge strike-offs immediately after consolidation to bring the surface to the required finish level with no coarse aggregate visible. Side forms and screed rails shall be provided, rigidly supported, and set to exact line and grade. Allowable tolerances for finished surfaces apply only to the hardened concrete, not to forms or screed rails. Forms and screed rails shall be set true to line and grade. "Wet screeds" shall not be used.

3.9.3 Floated Finish

Slabs to receive more than a rough slab finish shall next be given a wood float finish. The screeding shall be followed immediately by darbying or bull floating before bleeding water is present, to bring the surface to a true, even plane. Then, after the concrete has stiffened so that it will withstand a man's weight without imprint of more than 6 mm (1/4 inch) and the water sheen has disappeared, it shall be floated to a true and even plane free of ridges. Floating shall be performed by use of suitable hand floats or power driven equipment. Sufficient pressure shall be used on the floats to bring a film of moisture to the surface. Hand floats shall be made of wood, magnesium, or aluminum. Concrete that exhibits stickiness shall be floated with a magnesium float. Care shall be taken to prevent over-finishing or incorporating water into the surface.

3.9.4 Troweled Finish

After floating is complete and the surface moisture has disappeared, unformed surfaces shall be steel-troweled to a smooth, even, dense finish, free from blemishes including trowel marks. In lieu of hand finishing, an approved power finishing machine may be used in accordance with the directions of the machine manufacturer. Additional trowelings shall be performed, either by hand or machine until the surface has been troweled 3 times, with waiting period between each. Care shall be taken to prevent blistering and if such occurs, troweling shall immediately be stopped and operations and surfaces corrected. A final hard steel troweling shall be done by hand, with the trowel tipped, and using hard pressure, when the surface is at a point that the trowel will produce a ringing sound. The finished surface shall be thoroughly consolidated and shall be essentially free of trowel marks and be uniform in texture and appearance. The concrete mixture used for troweled finished areas shall be adjusted, if necessary, in order to provide sufficient fines (cementitious material and fine sand) to finish properly.

3.9.5 Non-Slip Finish

Non-slip floors shall be constructed in accordance with the following subparagraphs.
3.9.5.1 Broomed

After floating, the surface shall be lightly steel troweled, and then carefully scored by pulling a hair or coarse fiber push-type broom across the surface. Brooming shall be transverse to traffic or at right angles to the slope of the slab. After the end of the curing period, the surface shall be vigorously broomed with a coarse fiber broom to remove all loose or semi-detached particles.

3.10 EXTERIOR SLAB AND RELATED ITEMS

See specification SECTION 02770 - CONCRETE SIDEWALKS AND CURBS AND GUTTERS for pavement and sidewalk requirements.

3.11 CURLING OF INTERIOR BUILDING SLABS.

3.11.1 General

The edges of slabs-on-ground and slabs-on-metal-deck shall be designed, detailed and constructed to minimize the effects of curling at free edges of the slabs and at construction and contraction joints. Curling has become an increasing problem with slabs on CESPA projects in New Mexico and Arizona.

3.11.2 Definition of "Curling" per ACI 302.1R.

Curling is the distortion (rising up) of a slab's corners and edges due to differences in moisture content or temperature between the top and bottom of a slab. The top dries out or cools, and contracts more than the wetter or warmer bottom.

3.11.3 Conditions Relevant to Slab Curling that Affect the Contractor.

a. When concrete is placed on an impermeable subbase, all moisture must move through the slab to the surface. The bottom of the slab stays wet for an extended period of time while the top dries and shrinks.

    Possible Solution: Use a permeable (porous) dry - almost dry - sub-base.

b. Water vapor retarders further limit the ability of moisture to leave through the bottom of a slab, intensifying the problem.

    Possible Solution: If a vapor retarder is necessary, use a minimum 76 mm (3-inch) layer of compacted granular fill material (not sand) between the vapor barrier and concrete slab. If this fill is dry - or almost dry - this will permit some moisture loss from the slab bottom.

c. In high-slump (high water/cement ratio) concrete, excessive water results in increased evaporation and, in turn, higher drying shrinkage of the top of a slab which results in curling of a slab.
Possible Solutions:
1. Maintain the proper slump.
2. Avoid delays in placement that requires large quantities of retempering water.
3. Use a high-range water-reducing admixture (superplasticizer) with good shrinkage-reduction history and tests.

d. Porous aggregates in a concrete mix retain water that is also available for evaporation and, depending on the aggregate quality, can lead to shrinkage in the aggregate portion of the mix.

Possible Solutions:
1. Avoid aggregates known to have high-shrinkage potential, such as sandstone, slate, hornblende, and some types of basalt. Hard, rigid aggregates that are difficult to compress provide more restraint to shrinkage of cement paste in concrete than softer aggregates.
2. Select hard aggregates that are well-graded for good workability at minimum water contents, and contain a minimum of fines. Aggregates should be generally round or cubical in shape, with a minimum of flat or elongated particles. Minimize aggregate gap-grading. Quartz, granite, feldspar, limestone, dolomite, and some basalt aggregates generally produce concretes with low drying shrinkage.
3. Increase the maximum size of coarse aggregate and use coarse sand. Maximizing aggregate content reduces the total paste content and thereby reduces curling. If possible, include 1 ¾-inch top-size aggregate in the mix.
4. Reduce the sand content to the lowest level consistent with adequate workability and mixing water requirements.
5. Reduce excessive fines in the aggregate due to insufficient washing or contamination during handling.

e. Poor curing methods cause the top of the slab to start drying sooner than it should thus leading to drying shrinkage and curling.

Possible Solution: Cure the slab well, particularly during early ages. Use of a continuous moist cure or a high-solids curing compound — especially during the first few days — can greatly reduce the rate of water lost from the concrete and help reduce moisture differentials. After proper curing, further reduce moisture loss from the top of slabs by using coatings, sealers, and waxes which will be compatible with the adhesives of any floor finishes.

f. "Wet curing" methods can allow water to seep through the slab joints, thus saturating the subgrade and keeping the bottom of the slab wet as the areas where curling occurs — at the edges of the slab and at the joints.

Possible Solution: May consider not using "wet curing" curing methods.

g. Excessive bleeding and rapid slab surface setting or crusting can cause shrinkage and curling.
Possible Solution: Dewatering techniques (ACI 302.1R, Section 8.3.6) of fresh concrete slab surfaces can significantly reduce water content, and thus help reduce slab curling.

h. Temperature exceeding 80 degrees F when concrete is being placed accelerates surface drying and can result in substantial temperature contraction if ambient temperatures drop significantly during the first few nights after concrete placement.

Possible Solution: Minimize the as-mixed temperature of the concrete.

i. Cement.

Possible Solution: Consider using shrinkage-compensating cement.

j. Preventive Measures in Design. CESPA has taken preventive measures during design to minimize curling of slabs. The preventive measures are as follows.

(1) The slab reinforcing has been located a distance of 1 1/2-inches from the top surface of the slab.

Result: This places the slab reinforcing as close to the top of the slab as possible thus providing compressive steel to counter the shrinkage of the top of the slab.

(2) The edges of the slabs have been tied to the foundation in order to resist the curling (rising up) of the slab edge.

Result: The slab cannot curl or raise up because it is tied down to the foundation.

(3) Load-transfer devices at construction and control joints have been specified provided in the form of either dowels through the joints or a formed shear keys in the joints.

Results: The load-transfer devices do not let differential movement take place between the slabs either side of the joint.

3.12 CURING AND PROTECTION

3.12.1 General

Concrete shall be cured by an approved method for the period of time given below:

Concrete with Type V cement 10 days

Immediately after placement, concrete shall be protected from premature drying, extremes in temperatures, rapid temperature change, mechanical injury and damage from rain and flowing water for the duration of the curing period.
Air and forms in contact with concrete shall be maintained at a temperature above 10 degrees C (50 degrees F) for the first 3 days and at a temperature above 0 degrees C (32 degrees F) for the remainder of the specified curing period. Exhaust fumes from combustion heating units shall be vented to the outside of the enclosure, and heaters and ducts shall be placed and directed so as not to cause areas of overheating and drying of concrete surfaces or to create fire hazards. Materials and equipment needed for adequate curing and protection shall be available and at the site prior to placing concrete. No fire or excessive heat, including welding, shall be permitted near or in direct contact with the concrete at any time. Except as otherwise permitted by paragraph Membrane Forming Curing Compounds, moist curing shall be provided for any areas to receive any paint or other applied coating, or to which other concrete is to be bonded. Except for plastic coated burlap, impervious sheeting alone shall not be used for curing.

3.12.2 Moist Curing

Concrete to be moist-cured shall be maintained continuously wet for the entire curing period, commencing immediately after finishing. If water or curing materials used stain or discolor concrete surfaces which are to be permanently exposed, the concrete surfaces shall be cleaned as approved. When wooden forms are left in place during curing, they shall be kept wet at all times. If steel forms are used in hot weather, nonsupporting vertical forms shall be broken loose from the concrete soon after the concrete hardens and curing water continually applied in this void. If the forms are removed before the end of the curing period, curing shall be carried out as on unformed surfaces, using suitable materials. Surfaces shall be cured by ponding, by continuous sprinkling, by continuously saturated burlap or cotton mats, or by continuously saturated plastic coated burlap. Burlap and mats shall be clean and free from any contamination and shall be completely saturated before being placed on the concrete. The Contractor shall have an approved work system to ensure that moist curing is continuous 24 hours per day.

3.12.3 Membrane Forming Curing Compounds

Membrane curing shall not be used on surfaces that are to receive any subsequent treatment depending on adhesion or bonding to the concrete, including surfaces to which a smooth finish is to be applied or other concrete to be bonded. However, a styrene acrylate or chlorinated rubber compound meeting ASTM C 309, Class B requirements, may be used for surfaces which are to be painted or are to receive bituminous roofing or waterproofing, or floors that are to receive adhesive applications of resilient flooring. The curing compound selected shall be compatible with any subsequent paint, roofing, waterproofing or flooring specified. Membrane curing compound shall not be used on surfaces that are maintained at curing temperatures with free steam. Curing compound shall be applied to formed surfaces immediately after the forms are removed and prior to any patching or other surface treatment except the cleaning of loose sand, mortar, and debris from the surface. All surfaces shall be thoroughly moistened with water. Curing compound shall be applied to slab surfaces as soon as the bleeding water has disappeared, with the tops of joints being temporarily sealed to
prevent entry of the compound and to prevent moisture loss during the curing period. The curing compound shall be applied in a two-coat continuous operation by approved motorized power-spraying equipment operating at a minimum pressure of 500 kPa (75 psi), at a uniform coverage of not more than 10 cubic meters per L (400 square feet per gallon) for each coat, and the second coat shall be applied perpendicular to the first coat. Concrete surfaces which have been subjected to rainfall within 3 hours after curing compound has been applied shall be resprayed by the method and at the coverage specified. Surfaces on which clear compound is used shall be shaded from direct rays of the sun for the first 3 days. Surfaces coated with curing compound shall be kept free of foot and vehicular traffic, and from other sources of abrasion and contamination during the curing period.

3.12.4 Impervious Sheetinmg

Except for plastic coated burlap, impervious sheeting alone shall not be used for curing. Impervious-sheet curing shall only be used on horizontal or nearly horizontal surfaces. Surfaces shall be thoroughly wetted and be completely covered with the sheeting. Sheetinmg shall be at least 450 mm (18 inches) wider than the concrete surface to be covered. Covering shall be laid with light-colored side up. Covering shall be lapped not less than 300 mm (12 inches) and securely weighted down or shall be lapped not less than 100 mm (4 inches) and taped to form a continuous cover with completely closed joints. The sheet shall be weighted to prevent displacement so that it remains in contact with the concrete during the specified length of curing. Coverings shall be folded down over exposed edges of slabs and secured by approved means. Sheets shall be immediately repaired or replaced if tears or holes appear during the curing period.

3.12.5 Ponding or Immersion

Concrete shall be continually immersed throughout the curing period. Water shall not be more than 10 degrees C (20 degrees F) less than the temperature of the concrete.

3.12.6 Cold Weather Curing and Protection

When the daily ambient low temperature is less than 0 degrees C (32 degrees F) the temperature of the concrete shall be maintained above 5 degrees C (40 degrees F) for the first seven days after placing. During the period of protection removal, the air temperature adjacent to the concrete surfaces shall be controlled so that concrete near the surface will not be subjected to a temperature differential of more than 13 degrees C (25 degrees F) as determined by suitable temperature measuring devices furnished by the Government, as required, and installed adjacent to the concrete surface and 50 mm (2 inches) inside the surface of the concrete. The installation of the thermometers shall be made by the Contractor as directed.

3.13 SETTING BASE PLATES AND BEARING PLATES

After being properly positioned with steel shims or anchor bolts leveling nuts, column base plates, bearing plates for beams and similar structural
members, and machinery and equipment base plates shall be set with non-metallic high-strength non-shrink grout under the base plate(s). The thickness of the grout shall be as indicated on the drawings. Concrete and metal surfaces in contact with grout shall be clean and free of oil and grease, and concrete surfaces in contact with grout shall be damp and free of laittance when grout is placed.

3.13.1 Mixing and Placing of Non-metallic High-strength Non-shrink Grout

Mixing and placing shall be in conformance with the material manufacturer's instructions and as specified therein. Ingredients shall be thoroughly dry-mixed before adding water. After adding water, the batch shall be mixed for 3 minutes. Batches shall be of size to allow continuous placement of freshly mixed grout. Grout not used within 30 minutes after mixing shall be discarded. The space between the top of the concrete or machinery-bearing surface and the plate shall be filled solid with the grout. Forms shall be of wood or other equally suitable material for completely retaining the grout on all sides and on top and shall be removed after the grout has set. The placed grout shall be carefully worked by rodding or other means to eliminate voids; however, overworking and breakdown of the initial set shall be avoided. Grout shall not be retempered or subjected to vibration from any source. Where clearances are unusually small, placement shall be under pressure with a grout pump. Temperature of the grout, and of surfaces receiving the grout, shall be maintained at 18 to 30 degrees C (65 to 85 degrees F) until after setting.

3.13.2 Treatment of Exposed Surfaces

Exposed surfaces shall have a smooth-dense finish and be left untreated. Curing shall comply with paragraph CURING AND PROTECTION.

3.14 TESTING AND INSPECTION FOR CONTRACTOR QUALITY CONTROL

The Contractor shall perform the inspection and tests described below and, based upon the results of these inspections and tests, shall take the action required and shall submit specified reports. When, in the opinion of the Contracting Officer, the concreting operation is out of control, concrete placement shall cease and the operation shall be corrected. The laboratory performing the tests shall conform with ASTM C 1077. Materials may be subjected to check testing by the Government from samples obtained at the manufacturer, at transfer points, or at the project site. The Government will inspect the laboratory, equipment, and test procedures prior to start of concreting operations and at least once per 6 months thereafter for conformance with ASTM C 1077.

3.14.1 Grading and Corrective Action

3.14.1.1 Fine Aggregate

At least twice per week in which concrete is being delivered, there shall be one sieve analysis and fineness modulus determination in accordance with ASTM C 136 and COE CRD-C 104 for the fine aggregate or for each fine aggregate if
it is batched in more than one size or classification. The location at which samples are taken may be selected by the Contractor as the most advantageous for control. However, the Contractor is responsible for delivering fine aggregate to the mixer within specification limits. When the amount passing on any sieve is outside the specification limits, the fine aggregate shall be immediately resampled and retested. If there is another failure on any sieve, the fact shall immediately reported to the Contracting Officer, concreting shall be stopped, and immediate steps taken to correct the grading.

3.14.1.2 Coarse Aggregate

At least twice per week in which concrete is being delivered, there shall be a sieve analysis in accordance with ASTM C 136 for each size of coarse aggregate. The location at which samples are taken may be selected by the Contractor as the most advantageous for production control. However, the Contractor shall be responsible for delivering the aggregate to the mixer within specification limits. A test record of samples of aggregate taken at the same locations shall show the results of the current test as well as the average results of the five most recent tests including the current test. The Contractor may adopt limits for control coarser than the specification limits for samples taken other than as delivered to the mixer to allow for degradation during handling. When the amount passing any sieve is outside the specification limits, the coarse aggregate shall be immediately resampled and retested. If the second sample fails on any sieve, that fact shall be reported to the Contracting Officer. Where two consecutive averages of 5 tests are outside specification limits, the operation shall be considered out of control and shall be reported to the Contracting Officer. Concreting shall be stopped and immediate steps shall be taken to correct the grading.

3.14.2 Quality of Aggregates

Thirty days prior to the start of concrete placement, the Contractor shall perform all tests for aggregate quality required by ASTM C 33. In addition, after the start of concrete placement, the Contractor shall perform tests for aggregate quality at least every three months, and when the source of aggregate or aggregate quality changes. Samples tested after the start of concrete placement shall be taken immediately prior to entering the concrete mixer.

3.14.3 Scales, Batching and Recording

The accuracy of the scales shall be checked by test weights prior to start of concrete operations and at least once every three months. Such tests shall also be made as directed whenever there are variations in properties of the fresh concrete that could result from batching errors. Once a week the accuracy of each batching and recording device shall be checked during a weighing operation by noting and recording the required weight, recorded weight, and the actual weight batched. At the same time, the Contractor shall test and ensure that the devices for dispensing admixtures are operating properly and accurately. When either the weighing accuracy or batching accuracy does not comply with specification requirements, the plant
shall not be operated until necessary adjustments or repairs have been made. Discrepancies in recording accuracies shall be corrected immediately.

3.14.4 Batch-Plant Control

The measurement of concrete materials including cementitious materials, each size of aggregate, water, and admixtures shall be continuously controlled. The aggregate weights and amount of added water shall be adjusted as necessary to compensate for free moisture in the aggregates. The amount of air-entraining agent shall be adjusted to control air content within specified limits. A report shall be prepared indicating type and source of cement used, type and source of pozzolan used, amount and source of admixtures used, aggregate source, the required aggregate and water weights per cubic meter (cubic yard), amount of water as free moisture in each size of aggregate, and the batch aggregate and water weights per cubic meter (cubic yard) for each class of concrete batched during each day's plant operation.

3.14.5 Concrete Mixture

3.14.5.1 Air Content Testing

Air content tests shall be made when test specimens are fabricated. At least one test for air content for each 38 cubic meters (50 c.y.), or fraction thereof, of concrete shall be made on each class of concrete during concrete production. Additional tests shall be made when excessive variation in workability is reported by the placing foreman or Government inspector. Tests shall be made in accordance with ASTM C 231 for normal weight concrete. Test results shall be plotted on control charts which shall at all times be readily available to the Government and shall be submitted weekly. Copies of the current control charts shall be kept in the field by testing crews and results plotted as tests are made. When a single test result reaches either the upper or lower action limit, a second test shall immediately be made. The results of the two tests shall be averaged and this average used as the air content of the batch to plot on both the air content and the control chart for range, and for determining need for any remedial action. The result of each test, or average as noted in the previous sentence, shall be plotted on a separate control chart for each mixture on which an "average line" is set at the midpoint of the specified air content range from paragraph Air Entrainment. An upper warning limit and a lower warning limit line shall be set 1.0 percentage point above and below the average line, respectively. An upper action limit and a lower action limit line shall be set 1.5 percentage points above and below the average line, respectively. The range between each two consecutive tests shall be plotted on a secondary control chart for range where an upper warning limit is set at 2.0 percentage points and an upper action limit is set at 3.0 percentage points. Samples for air content may be taken at the mixer, however, the Contractor is responsible for delivering the concrete to the placement site at the stipulated air content. If the Contractor's materials or transportation methods cause air content loss between the mixer and the placement, correlation samples shall
be taken at the placement site as required by the Contracting Officer, and the air content at the mixer controlled as directed.

3.14.5.2 Air Content Corrective Action

Whenever points on the control chart for percent air reach either warning limit, an adjustment shall immediately be made in the amount of air-entraining admixture batched. As soon as practical after each adjustment, another test shall be made to verify the result of the adjustment. Whenever a point on the secondary control chart for range reaches the warning limit, the admixture dispenser shall be recalibrated to ensure that it is operating accurately and with good reproducibility. Whenever a point on either control chart reaches an action limit line, the air content shall be considered out of control and the concreting operation shall immediately be halted until the air content is under control. Additional air content tests shall be made when concreting is restarted.

3.14.5.3 Slump Testing

As a minimum, at least one slump test for every 38 cubic meters (50 c.y.), or fraction thereof, of concrete shall be made of each mixture of concrete during each day's concrete production, in accordance with ASTM C 143. See paragraph, "Strength Specimens". Also, additional tests shall be made when excessive variation in workability is reported by the placing foreman or Government inspector. Test results shall be plotted on control charts which shall at all times be readily available to the Government and shall be submitted weekly. Copies of the current control charts shall be kept in the field by testing crews and results plotted as tests are made. When a single slump test reaches or goes beyond either the upper or lower action limit, a second test shall immediately be made. The results of the two tests shall be averaged and this average used as the slump of the batch to plot on both the control charts for slump and the chart for range, and for determining need for any remedial action. Limits shall be set on separate control charts for slump for each type of mixture. The upper warning limit shall be set at 12.5 mm (1/2 inch) below the maximum allowable slump specified in paragraph Slump in PART I for each type of concrete and an upper action limit line and lower action limit line shall be set at the maximum and minimum allowable slumps, respectively, as specified in the same paragraph. The range between each consecutive slump test for each type of mixture shall be plotted on a single control chart for range on which an upper action limit is set at 50 mm (2 inches). Samples for slump shall be taken at the mixer. However, the Contractor is responsible for delivering the concrete to the placement site at the stipulated slump. If the Contractor's materials or transportation methods cause slump loss between the mixer and the placement, correlation samples shall be taken at the placement site as required by the Contracting Officer, and the slump at the mixer controlled as directed.

3.14.5.4 Slump Corrective Action

Whenever points on the control charts for slump reach the upper warning limit, an adjustment shall immediately be made in the batch weights of water and fine aggregate. The adjustments are to be made so that the total

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water content does not exceed that amount allowed by the maximum w/c ratio specified, based on aggregates which are in a saturated surface dry condition. When a single slump reaches the upper or lower action limit, no further concrete shall be delivered to the placing site until proper adjustments have been made. Immediately after each adjustment, another test shall be made to verify the correctness of the adjustment. Whenever two consecutive individual slump tests, made during a period when there was no adjustment of batch weights, produce a point on the control chart for range at or above the upper action limit, the concreting operation shall immediately be halted, and the Contractor shall take appropriate steps to bring the slump under control. Additional slump tests shall be made as directed.

3.14.5.5 Temperature

The temperature of the concrete shall be measured when compressive strength specimens are fabricated. Measurement shall be in accordance with ASTM C 1064. The temperature shall be reported along with the compressive strength data.

3.14.5.6 Strength Specimens

The Contractor shall make test specimens for compressive strength, as appropriate. Concrete specimens shall be made immediately after discharge from the mixer and all test specimens shall be made from the same sample of concrete. At least one set of test specimens shall be made for each different concrete mixture placed per shift of Contractor or subcontractor concrete production operations, and it shall not be less than one for the first 38 cubic meters (50 c.y.) of concrete placed, or fraction thereof. The Contractor shall cast extra specimens for strength determination when required for form removal approval. A set of test specimens for concrete with a 48-day specified strength per paragraph "Strength Requirements" in PART 1 shall consist of four specimens, one to be tested at 14 days, two at 48 days and one held in reserve for future testing, if necessary. If extra specimens were cast for verifying strength for form removal approval, they may be tested as required. Test specimens shall be molded and cured in accordance with ASTM C 31 and tested in accordance with ASTM C 39 for test cylinders. Each strength specimen set shall also be tested for slump and air content. Additional sets of test specimens shall be made, as directed by the Contracting Officer, when inconsistencies, variations or loss of control of mixtures occur, or when low strengths have been detected, at no additional cost to the Government. A truly random (not haphazard) sampling plan shall be developed by the Contractor and approved by the Contracting Officer prior to the start of construction. The plan shall assure that sampling is done in a completely random and unbiased manner. Results of all strength tests shall be reported immediately to the Contracting Officer. Quality control charts shall be kept for individual strength "tests", ("test" as defined in paragraph Strength Requirements in PART 1) moving average of last 3 "tests" for strength, and moving average for range for the last 3 "tests" for each mixture. The charts shall be similar to those found in ACI 214.3R. Charts shall be submitted weekly and shall be readily available to the Government at all times.
3.14.6 Inspection Before Placing

Foundations, construction joints, forms, and embedded items shall be inspected by the Contractor in sufficient time prior to each concrete placement in order to certify to the Contracting Officer that they are ready to receive concrete. The results of each inspection shall be reported in writing.

3.14.7 Placing

The placing foreman shall supervise placing operations, shall determine that the correct quality of concrete or grout is placed in each location as specified and as directed by the Contracting Officer, and shall be responsible for measuring and recording concrete temperatures and ambient temperature hourly during placing operations, weather conditions, time of placement, volume placed, and method of placement. The placing foreman shall not permit batching and placing to begin until it has been verified that an adequate number of vibrators in working order and with competent operators are available. Placing shall not be continued if any pile of concrete is inadequately consolidated. If any batch of concrete fails to meet the temperature requirements, immediate steps shall be taken to improve temperature controls.

3.14.8 Vibrators

The frequency and amplitude of each vibrator shall be determined in accordance with COE CRD-C 521 prior to initial use and at least once a month when concrete is being placed. Additional tests shall be made as directed when a vibrator does not appear to be adequately consolidating the concrete. The frequency shall be determined while the vibrator is operating in concrete with the tachometer being held against the upper end of the vibrator head while almost submerged and just before the vibrator is withdrawn from the concrete. The amplitude shall be determined with the head vibrating in air. Two measurements shall be taken, one near the tip and another near the upper end of the vibrator head, and these results averaged. The make, model, type, and size of the vibrator and frequency and amplitude results shall be reported in writing. Any vibrator not meeting the requirements of paragraph Consolidation, shall be immediately removed from service and repaired or replaced.

3.14.9 Curing Inspection

3.14.9.1 Moist Curing Inspections

At least once each shift, and not less than twice per day on both work and non-work days, an inspection shall be made of all areas subject to moist curing. The surface moisture condition shall be noted and recorded.
3.14.9.2 Moist Curing Corrective Action

When a daily inspection report lists an area of inadequate curing, immediate corrective action shall be taken, and the required curing period for those areas shall be extended by 1 day.

3.14.9.3 Membrane Curing Inspection

No curing compound shall be applied until the Contractor has verified that the compound is properly mixed and ready for spraying. At the end of each operation, the Contractor shall estimate the quantity of compound used by measurement of the container and the area of concrete surface covered, shall compute the rate of coverage in square meters per Liter (square feet per gallon), and shall note whether or not coverage is uniform.

3.14.9.4 Membrane Curing Corrective Action

When the coverage rate of the curing compound is less than that specified or when the coverage is not uniform, the entire surface shall be sprayed again.

3.14.9.5 Sheet Curing Inspection

At least once each shift and once per day on non-work days, an inspection shall be made of all areas being cured using impervious sheets. The condition of the covering and the tightness of the laps and tapes shall be noted and recorded.

3.14.9.6 Sheet Curing Corrective Action

When a daily inspection report lists any tears, holes, or laps or joints that are not completely closed, the tears and holes shall promptly be repaired or the sheets replaced, the joints closed, and the required curing period for those areas shall be extended by 1 day.

3.14.10 Cold-Weather Protection

At least once each shift and once per day on non-work days, an inspection shall be made of all areas subject to cold-weather protection. Any deficiencies shall be noted, corrected, and reported.

3.14.11 Mixer Uniformity

3.14.11.1 Stationary Mixers

Prior to the start of concrete placing and once every 6 months when concrete is being placed, uniformity of concrete mixing shall be determined in accordance with ASTM C 94.

3.14.11.2 Truck Mixers

Prior to the start of concrete placing and at least once every 6 months when concrete is being placed, uniformity of concrete mixing shall be determined
in accordance with ASTM C 94. The truck mixers shall be selected randomly for testing. When satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of the blades may be regarded as satisfactory.

3.14.11.3 Mixer Uniformity Corrective Action

When a mixer fails to meet mixer uniformity requirements, either the mixing time shall be increased, batching sequence changed, batch size reduced, or adjustments shall be made to the mixer until compliance is achieved.

3.14.12 Reports

All results of tests or inspections conducted shall be reported informally as they are completed and in writing daily. A weekly report shall be prepared for the updating of control charts covering the entire period from the start of the construction season through the current week. During periods of cold-weather protection, reports of pertinent temperatures shall be made daily. These requirements do not relieve the Contractor of the obligation to report certain failures immediately as required in preceding paragraphs. Such reports of failures and the action taken shall be confirmed in writing in the routine reports. The Contracting Officer has the right to examine all contractor quality control records.
1. CONCRETE AGGREGATE SOURCES

Fine and coarse aggregates to be used in all concrete shall be evaluated and tested by the Contractor for alkali-aggregate reactivity in accordance with ASTM C 1260 Modified, as hereinafter specified. Aggregate used for testing shall be the Contractor's proposed aggregates. All proposed size groups of coarse and fine aggregates shall be represented. The aggregates shall be evaluated in combination and shall match the Contractor's proposed mix design proportioning. Test results of the proposed aggregates in combination with the cementitious materials, as specified below, shall have a measured expansion of less than 0.08 percent at 16 days. Should the test data indicate an expansion of greater than 0.08 percent, additional testing, by the Contractor utilizing the modified version of ASTM C 1260 shall be performed.

ASTM C 1260 shall be modified as follows:

   a. Utilize the project Type V, low alkali cement and the project Class "F" fly ash (pozzolan) in combination as the cementitious material for the test proportioning.

   b. Project Class "F" fly ash shall be used at a minimum rate of 30 percent, by mass, of the total cementitious material.

   c. A decreased quantity of fly ash will be allowed, to a minimum of 20 percent, by mass, of the total cementitious material, if laboratory test results indicate that the maximum allowable expansion of 0.08 percent, at 16 days age, is not exceeded. A Corps of Engineers validated, independent laboratory, qualified to perform ASTM C 1260 testing, shall perform the tests.

   d. If the above testing does not lower the expansion to less than 0.08 percent, at 16 days, the aggregate(s) shall be rejected and the Contractor shall submit new aggregate sources for retesting.

The results of all testing and investigation shall be submitted to the Contracting Officer for evaluation and acceptance.
APPENDIX N

UFGS SECTION 02741N
BITUMINOUS CONCRETE PAVEMENT
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DIVISION 02 - SITE CONSTRUCTION

SECTION 02741N

BITUMINOUS CONCRETE PAVEMENT

09/99

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-- End of Section Table of Contents --
NOTE: This guide specification covers the requirements for asphaltic concrete paving for vehicular traffic and should not be used for airfield paving.

Comments and suggestion on this specification are welcome and should be directed to the technical proponent of the specification. A listing of the technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

NOTE: The designer shall verify that the application of the state specification is indeed appropriate for the facility being designed or constructed. The following information shall be shown on the project drawings:

1. Plan with dimensions of the various types of paving.

2. Typical cross sections indicating dimensions of components of various types of paving, shoulders, and ditches, if any.

3. Joints between new and existing paving and between different types of paving.

4. A longitudinal profile of paving. Transverse
profile will be shown in typical cross section.

************************************************************************

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO T 230 (1968; R 2000) Determining Degree of Pavement Compaction of Bituminous Aggregate Mixtures

AASHTO T 30 (1993; R 1998) Mechanical Analysis of Extracted Aggregate

ASTM INTERNATIONAL (ASTM)


ASTM D 2172 (2001e1) Quantitative Extraction of Bitumen from Bituminous Paving Mixtures

ASTM D 2950 (1991; R 1997) Density of Bituminous Concrete in Place by Nuclear Methods

U.S. DEPARTMENT OF TRANSPORTATION (DOT)


U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS TT-P-115 (Rev. F) Paint, Traffic (Highway, White and Yellow)

1.2 SUBMITTALS

************************************************************************

NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some...
submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

**************************************************************************
Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only or as otherwise designated. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-03 Product Data
   Precast car stops

SD-04 Samples
   Uncompacted mix
   Pavement cores

SD-06 Test Reports
   Trial batch reports
   Mix design
   Asphalt concrete
   Density
   Thickness

SECTION 02741N  Page 5
Straightedge test
Submit reports for testing specified under paragraph entitled "Field Quality Control."

SD-07 Certificates
Asphalt mix delivery record
Asphalt concrete and material sources

Obtain approval of the Contracting Officer for materials and material sources 2 days prior to the use of such material in the work.

Asphalt concrete
Curbs
Guard (Guide) rails
Median barriers
Traffic signs

Submit certificates, signed by the producer, that paving materials and incidental construction items conform to specification requirements.

1.3 QUALITY ASSURANCE

**************************************************************************
NOTE: Insert abbreviation for the state highway department document (SHS) appropriately throughout this specification.
**************************************************************************

**************************************************************************
NOTE: Use words in brackets or fill in blanks with correct terminology from the referenced state highway department document to identify specific portions of the referenced state highway department document.
**************************************************************************

1.3.1 Regulatory Requirements

Provide work and materials in accordance with applicable requirements of SHS [____]. [Divisions and Sections] [Sections and Paragraphs] [[____] and [____]] mentioned herein refer to those specifications. Paragraphs in SHS [____] entitled "Quantity and Payment" ["Method of Measurement" and "Basis of Payment"] ["____"] shall not apply.
1.3.2 Modification of References

Where term "Engineer" is used in SHS [__] it shall be construed to mean [Contracting Officer] [Contractor's Quality Control representative].
[Where term "state" is used, it shall mean "Federal Government"].

1.3.3 Mix Delivery Record Data

Record and submit the following information to each load of mix delivered to the job site. Submit within one day after delivery on Government-furnished forms:

a. Truck No:

b. Time In:

c. Time Out:

d. Tonnage and Discharge Temperature:

e. Mix Type:

f. Location:

g. Stations Placed:

1.3.4 Trial Batch

Submit current bituminous design reports for all mix types proposed for use on the project.

1.3.5 Mix Design

Submit results of laboratory tests performed on each mix design. Testing shall have been accomplished not more than one year prior to date of material placement.

PART 2 PRODUCTS

2.1 ASPHALT CONCRETE

**************************************************************************
NOTE: Insert abbreviation for the state highway department document referenced above.
**************************************************************************

Provide asphalt concrete in accordance with the applicable requirements of the SHS [__], except where specified otherwise. [Recycled asphalt pavement material may be used as permitted by SHS [__].]

2.2 SUBBASE

**************************************************************************
NOTE: Use words in brackets or fill in blanks with
**************************************************************************
correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.

*******************

SHS [___], materials for construction of the subbase shall be in accordance with [Division [___], Section [___]] [Section [___], paragraph [___]] [[___], [___]].

2.3 BASE COURSE

*******************

NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.

*******************

SHS [___], materials for construction of the base course shall be in accordance with [Division [___], Section [___]] [Section [___], paragraph [___]] [[___], [___]], [Type [___]] [Class [___]].

2.4 SURFACE COURSE

*******************

NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.

*******************

SHS [___], materials for construction of the surface course shall be in accordance with [Division [___], Section [___]] [Section [___], paragraph [___]] [Type [___]] [Class [___]].

2.5 STRIPING

*******************

NOTE: Select the first option when the referenced state highway department document includes paint and striping. Select the second option when the referenced state highway department document does not include paint and striping.

*******************

NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.
2.6 CURBS [AND GUTTERS]

NOTE: Select the first option when the referenced state highway department document includes materials for curbs and gutters. Select the second option when the referenced state highway department document does not include concrete materials for curbs and gutters and include Section 03300, "Cast-In-Place Concrete" in the project specification, as appropriate.

SHS [____], materials for construction of curbs [and gutters] shall be in accordance with [Division [____], Section [____]] [Section [____]], paragraph [____], [[____], [____]].

[Concrete is specified in Section N CAST-IN-P ACE C NCRETE.]

2.8 MEDIAN BARRIERS

NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.
from referenced state highway department document. 
Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.

**************************************************************************

SHS [_____], materials for construction of the median barriers shall be in accordance with [Division [_____], Section [_____]] [Section [_____], paragraph [_____]] [____], [____].

2.9 TRAFFIC SIGNS

**************************************************************************

NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.

**************************************************************************

SHS [_____], provide traffic signs in accordance with [Division [_____], Section [_____]] [Section [_____], paragraph [_____]] [____], [____].

2.10 PRECAST CAR STOPS

Provide car stops to the profile and size indicated. [Manufacture with air entrained concrete having a minimum compressive strength of 25 MPa 3,000 psi at 28 days, with two No. 4 reinforcing rods located at mid-point of its cross section and with two galvanized sleeves for anchoring.] [Manufacture with 100 percent recycled content level of plastic or rubber in accordance with DOT D-6.1].

2.11 COMPOSITION OF MIXTURE REQUIREMENTS

2.11.1 Mixture Properties

Gradation of mineral aggregate shall be as specified. Percentage of bituminous material provided in the bituminous mixtures shall be within the limits specified. Mixtures shall have the following physical properties:

<table>
<thead>
<tr>
<th>Test Property</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability (50 Blows)</td>
<td>Not less than 454 kg</td>
</tr>
<tr>
<td>Flow (0.25 mm)</td>
<td>Not more than 20 nor less than 8</td>
</tr>
<tr>
<td>Percent Air Voids</td>
<td>Not less than 3 nor more than 8 for binder course; not less than 3 nor more than 5 for wearing course</td>
</tr>
<tr>
<td>Percent Voids in Mineral Aggregates</td>
<td>See Table I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Property</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability (50 Blows)</td>
<td>Not less than 1000 pounds</td>
</tr>
<tr>
<td>Flow (0.01 inch)</td>
<td>Not more than 20 nor less than 8</td>
</tr>
<tr>
<td>Percent Air Voids</td>
<td>Not less than 3 nor more than 8 for binder</td>
</tr>
</tbody>
</table>

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Test Property

Values

Percent Voids in
Mineral Aggregates

<table>
<thead>
<tr>
<th>Test Property</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Voids in Mineral Aggregates</td>
<td>course; not less than 3 nor more than 5 for wearing course</td>
</tr>
<tr>
<td></td>
<td>See Table I</td>
</tr>
</tbody>
</table>

TABLE I

MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE (VMA)

<table>
<thead>
<tr>
<th>U.S.A. Standard Sieve Designation</th>
<th>Nominal Maximum Particle Size, mm</th>
<th>Minimum VMA Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75 mm</td>
<td>4.75</td>
<td>18</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>9.5</td>
<td>16</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>12.5</td>
<td>15</td>
</tr>
<tr>
<td>19.0 mm</td>
<td>19.0</td>
<td>14</td>
</tr>
<tr>
<td>25.0 mm</td>
<td>25.0</td>
<td>13</td>
</tr>
</tbody>
</table>

TABLE I

MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE (VMA)

<table>
<thead>
<tr>
<th>U.S.A. Standard Sieve Designation</th>
<th>Nominal Maximum Particle Size, Inch</th>
<th>Minimum VMA Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>0.187</td>
<td>18</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>0.375</td>
<td>16</td>
</tr>
<tr>
<td>1/2 inch</td>
<td>0.500</td>
<td>15</td>
</tr>
<tr>
<td>3/4 inch</td>
<td>0.750</td>
<td>14</td>
</tr>
<tr>
<td>1 inch</td>
<td>1.000</td>
<td>13</td>
</tr>
</tbody>
</table>

2.11.2 Quantity of Bituminous Material

**************************************************************************

NOTE: If slag or any unusually porous aggregate is anticipated for possible use in the mix, the maximum asphalt cement percentages indicated may need to be increased. Check requirements of local materials and modify percentages as necessary.

**************************************************************************

Mix asphalt cement with aggregates of corresponding mixes in the following proportions:

ASPHALT CEMENT PERCENT BY WEIGHT OF TOTAL MIX

<table>
<thead>
<tr>
<th>Binder Course</th>
<th>Wearing Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 8</td>
<td>5 to 9</td>
</tr>
</tbody>
</table>

SECTION 02741N Page 11
PART 3 EXECUTION

3.1 PREPARATION

3.1.1 Excavation and Filling

Excavation and filling to establish elevation of subgrade is specified in Section 02300 EXCAVATION.

3.2 CONSTRUCTION

**************************************************************************
NOTE: Insert abbreviation for the state highway department document referenced above.
**************************************************************************

Provide construction in accordance with the applicable requirements of the SHS [____], except where indicated or specified otherwise.

3.2.1 Subgrade

**************************************************************************
NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.
**************************************************************************

SHS [____], preparation of subgrade shall be in accordance with [Division [____], Section [____]], [Section [____], paragraph [____]] [____], [____] [Section 02300 EXCAVATION.]

3.2.2 Subbase

**************************************************************************
NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.
**************************************************************************

SHS [____], methods of construction of the subbase shall be in accordance with [Division [____], Section [____]] [Section [____], paragraph [____]] [____], [____].

3.2.3 Base Course

**************************************************************************
NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs

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is identical to that used on drawings for same item.

SHS [____], methods of construction of the base course shall be in accordance with [Division [____], Section [____]] [Section [____], paragraph [____]] [[____], [____]].

3.2.4 Surface Course

NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.

SHS [____], methods of construction of the surface course shall be in accordance with [Division [____], Section [____]] [Section [____], paragraph [____]] [[____], [____]]. Placement will not be permitted unless the Contractor has a working asphalt thermometer on site.

3.2.5 Striping

NOTE: Include the bracketed portion (first sentence) when the referenced state highway department document includes paint and striping.

NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.

SHS [____], provide paint striping in accordance with [Division [____], Section [____]] [Section [____], paragraph [____]] [[____], [____]]. Allow bituminous pavement to cure for at least 21 days before paint is applied. Pavement shall be thoroughly clean and entirely free of loose sand, stones, dust, oil, grease, water, and other substances that will be deleterious to the paint or will adversely affect the adhesion of the paint. Do not apply paint during high wind (over 24 km/h) (over 15 miles per hour) or high humidity (over 70 percent). Apply paint only when ambient temperature is 5 degrees C 40 degrees F or above and rising but not more than 35 degrees C 95 degrees F. Dimensions and arrangement of striping shall be as indicated. Apply paint to a wet film thickness of 0.38 mm 0.015 inch by means of conventional traffic line striping equipment. Traffic shall not be permitted to use the painted areas for a minimum of 30 minutes after painting of lines has been completed.
3.2.6 Curbs [and Gutters]

**************************************************************************
NOTE: Select the first option when the referenced state highway department document includes materials for curbs and gutters. Select the second option when the referenced state highway department document does not include concrete materials for curbs and gutters and include Section 03300, "Cast-In-Place Concrete" in the project specification, as appropriate.
**************************************************************************

**************************************************************************
NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.
**************************************************************************

SHS [____], methods of construction of curbs [and gutters] shall be in accordance with [Division [____], Section [____]] [Section [____], paragraph [____]] [[____], [____]].

[Provide curbs [and gutters] as indicated. Provide concrete construction as specified in Section 03300N CAST-IN-PLACE CONCRETE.]

3.2.7 Guard (Guide) Rails

**************************************************************************
NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.
**************************************************************************

SHS [____], methods of construction of the guard (guide) rails shall be in accordance with [Division [____], Section [____]] [Section [____], paragraph [____]] [[____], [____]].

3.2.8 Median Barrier

**************************************************************************
NOTE: Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.
**************************************************************************

SHS [____], methods of construction of the median barriers shall be in accordance with [Division [____], Section [____]] [Section [____],
3.2.9 Traffic Signs

**************************************************************************
**NOTE:** Use words in brackets or fill in blanks with correct terminology and insert appropriate numbers from referenced state highway department document. Be certain that terminology used in these paragraphs is identical to that used on drawings for same item.
**************************************************************************

SHS [__], install traffic signs in accordance with [Division [__], Section [__]] [Section [__], paragraph [__]] [[__], [__]].

3.2.10 Precast Car Stops

Provide car stops where indicated. Install with an anchor rod driven through each sleeve.

3.3 FIELD QUALITY CONTROL

Sample shall be taken by Contractor as specified herein. Contractor shall replace pavement where sample cores have been removed. Submit [2] [__] pavement cores when using the in-place nuclear density method.

3.3.1 Sample and Core Identification

place each sample and core in a container and securely seal to prevent loss of material. Tag each sample for identification. Tag shall contain the following information:

a. Contract No.
b. Sample No.
c. Quantity
d. Date of Sample
e. Sample Description
f. Source/Location/Stations Placed/depth below the finish grade
g. Intended Use
h. Thicknesses of various lifts placed

3.3.2 Testing

3.3.2.1 Bituminous Mix Testing

Take two samples per day per mix type at plant or from truck. Test uncompacted mix for extraction in accordance with ASTM D 2172 and sieve
analysis in accordance with AASHTO T 30. Test samples for stability and flow in accordance with ASTM D 1559. When two consecutive tests fail to meet requirements of specifications, cease placement operations and test a new trial batch prior to resumption of placement operations. Submit [2] [____] per day of each mix type. When two tests on uncompacted mix fail submit new trial batch for approval.

3.3.2.2 Testing of Pavement Course

a. Density: Determine density of pavement by testing cores obtained from the binder and wearing course in accordance with AASHTO T 230. Take three cores at location designated by Contracting Officer for each [18 metric tons] [200 tons][____], or fraction thereof, of asphalt placed. Deliver cores undisturbed and undamaged to laboratory and provide test results within [48] [____] hours of each day placement of paving materials.

b. Thickness: Determine thickness of the binder and wearing course from cores taken for density test.

c. Straightedge Test: Test compacted surface of binder course and wearing course with a straightedge as work progresses. Apply straightedge parallel with and at right angles to center line after final rolling. Variations in the binder course surface shall not be more than 6 [13] [3] mm 1/4 [1/2] [1/8] inches from the lower edge of the 3.0 m 10 foot straightedge; variations in wearing course surface shall not be more than 6 [13] [3] mm 1/4 [1/2] [1/8] from the lower edge of the 3.0 m 10 foot straightedge. Pavement showing irregularities greater than that specified shall be corrected as directed by Contracting Officer.

3.3.2.3 Alternate Testing Method for Pavement Courses

At Contractor's option the following in-place testing method may be used to determine density and thickness in lieu of testing specified above. Frequency of testing shall be the same. When in-place nuclear method to determine density is used, take two pavement cores at locations designated by Contracting Officer and turn over to Government to verify pavement thickness.

a. Density: Determine density of pavement by in-place testing using Nuclear Method in accordance with ASTM D 2950.

b. Thickness: Determine thickness of finished pavement by use of following equation:

\[ t = \frac{W(1000)}{d} \]

Where \( t \) = pavement thickness, in mm.
\( W \) = average weight per square weight by kg per square meter of mixture actually used in work.
\( d \) = compacted density as measured by nuclear density device, (psf) (kg/3...
\[ t = \frac{W}{0.75d} \]

Where \( t \) = pavement thickness, in inches.

\( W \) = average weight per square yard of mixture actually used in work.

\( d \) = compacted density as measured by nuclear density device.

-- End of Section --
APPENDIX O

STATE OF NEW MEXICO DEPARTMENT OF TRANSPORTATION SPECIFICATIONS
SECTION 416 MINOR PAVING
SECTION 416—MINOR PAVING

416.1 DESCRIPTION

416.11 General. Minor Paving shall consist of hot-mix asphalt paving that is placed in areas that receive significant traffic loading, but which are of small quantity or require unusual placement or nature of production (short days, many small placement areas, etc.), making square-meter (square-yard) measurement more appropriate. Examples of minor pavement include bridge approaches, intersection improvements, auxiliary lanes, etc. Turnouts that provide access to commercial establishments or to more than one residence will also be considered minor paving.

416.12 Description of Work. This work shall consist of constructing one or more courses of hot-mix asphalt (HMA) on a prepared base. HMA shall be composed of a mixture of bituminous material, aggregate, blending sand, mineral filler, hydrated lime, or liquid anti-strip if required.

416.2 MATERIALS.

416.21 General. HMA for minor paving shall be of the type and gradation shown in the Contract. Materials used for minor bituminous paving shall comply with requirements of subsection 420.2 or 422.2, as applicable.

416.3 CONSTRUCTION REQUIREMENTS.

416.31. The Contractor shall comply with all requirements of subsection 420.3.

416.4 CONTRACTOR PROCESS CONTROL.

416.41 The Contractor shall demonstrate the ability to produce acceptable material prior to placement. The Contractor shall control construction processes in such a manner that material produced is in compliance with all applicable specifications. The Contractor shall provide all materials, equipment, and personnel necessary for process control. Process control will be considered incidental to the product being produced and no direct payment will be made therefor.

The Contractor shall provide the Project Manager with a proposed Process Control Plan at least 10 working days before beginning all relevant work. The plan at a minimum shall describe or list materials, methods, and equipment to be used in producing the product; methods, equipment, personnel, facilities, and testing program to be used for process control testing; procedures for identifying and correcting problems which could result in nonconforming material; and a list of personnel with chain-of-command and level of authority to modify processes.

The Contractor shall make available to the Department all process control test results, process control charts, or other documentation of the Contractor's process control efforts. Deviations from the approved process control plan shall be submitted to the Project Manager before performing related work. The Contractor shall make a good-faith effort to control construction processes. Failure to submit a process control plan or failure to follow the approved process control plan will constitute grounds for suspending the Contractor's operations.
416.5 ACCEPTANCE.

416.51 General. Acceptance will be based on inspection of the constructed product for obvious nonconformance with the Specifications, and on laboratory testing. Testing will be performed on specimens of fresh hot-mix asphalt taken from the roadbed prior to compaction and on cut pavement samples (cores). Acceptance criteria will consist of air voids as determined from laboratory-compacted specimens, asphalt content as determined by binder ignition AASHTO T 308, final thickness of the compacted mat as measured from cores in accordance with ASTM D3549, and density of the compacted roadbed as determined from cores.

Acceptance testing will be performed by Department representatives who have been certified in the relevant test procedures by the State Materials Bureau through the Technician Training and Certification Program (TTCP). Testing will be performed in accordance to the latest AASHTO or Agency methods, as modified by the State Materials Bureau. Test methods and modifications can be found in the current TTCP Manual.

416.52 Acceptance Lots and Pay Factor Determination. Density acceptance will be based on the average of three cores per acceptance lot. Air voids and asphalt content acceptance will be based on one test per acceptance lot. Acceptance lot size will be 1350 m$^2$ (1500 yd$^2$) or less, as determined by the Project Manager.

Pay factors will be determined from Tables 416-A through 416-D. The target values for asphalt content and air voids will be obtained from the approved job mix formula. The payment for each acceptance lot will be determined by multiplying the unit bid price by each pay factor, and multiplying the result by the total lot area.

<table>
<thead>
<tr>
<th>Percent Density</th>
<th>Pay Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 97.99</td>
<td>Reject*</td>
</tr>
<tr>
<td>97.0–97.99</td>
<td>90%</td>
</tr>
<tr>
<td>96.0–96.99</td>
<td>95%</td>
</tr>
<tr>
<td>95.0–95.99</td>
<td>100%</td>
</tr>
<tr>
<td>94.0–94.99</td>
<td>102%</td>
</tr>
<tr>
<td>93.0–93.99</td>
<td>100%</td>
</tr>
<tr>
<td>92.0–92.99</td>
<td>95%</td>
</tr>
<tr>
<td>91.0–91.99</td>
<td>90%</td>
</tr>
<tr>
<td>90.0–90.99</td>
<td>80%</td>
</tr>
<tr>
<td>Less than 90.00</td>
<td>Reject*</td>
</tr>
</tbody>
</table>

Table 416-A
PRICE ADJUSTMENTS FOR DENSITY

<table>
<thead>
<tr>
<th>Deviation from Target Value</th>
<th>Pay Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 0.5%</td>
<td>102%</td>
</tr>
<tr>
<td>0.5% to 1.3%</td>
<td>100%</td>
</tr>
<tr>
<td>1.31% to 1.69%</td>
<td>90%</td>
</tr>
<tr>
<td>1.7% to 1.99%</td>
<td>75%</td>
</tr>
<tr>
<td>2.0% or more</td>
<td>Reject*</td>
</tr>
</tbody>
</table>

Table 416-B
PRICE ADJUSTMENT FOR AIR VOIDS
Table 416-C
PRICE ADJUSTMENT FOR ASPHALT CONTENT

<table>
<thead>
<tr>
<th>Deviation from Target Value</th>
<th>Pay Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 0.1%</td>
<td>102%</td>
</tr>
<tr>
<td>0.1% to 0.29%</td>
<td>100%</td>
</tr>
<tr>
<td>0.30% to 0.49%</td>
<td>90%</td>
</tr>
<tr>
<td>0.5% or Greater</td>
<td>Reject*</td>
</tr>
</tbody>
</table>

Table 416-D
PRICE ADJUSTMENT FOR THICKNESS

<table>
<thead>
<tr>
<th>Deficiency from Plan Minimum Thickness</th>
<th>Pay Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>None (Plan Minimum or Thicker)</td>
<td>102%</td>
</tr>
<tr>
<td>&lt; 6 mm (1/4 in.)</td>
<td>100%</td>
</tr>
<tr>
<td>6 mm &lt; 12.0 mm (1/4 in. &lt; 1/2 in.)</td>
<td>90%</td>
</tr>
<tr>
<td>12.0 mm &lt; 19 mm (1/2 in. &lt; 3/4 in.)</td>
<td>75%</td>
</tr>
<tr>
<td>19 mm &lt; 25 mm (3/4 in. &lt; 1 in.)</td>
<td>50%</td>
</tr>
<tr>
<td>25 mm (1 in.)</td>
<td>Corrective Action Required*</td>
</tr>
</tbody>
</table>

* Rejected material is to be removed and replaced at no additional cost to the Department. In lieu of removing material, the Engineer may allow material to remain in place at 50% of contract price, if this is determined to be in the best interest of the Department.

** Corrective action shall consist of removal and replacement of the nonconforming material, or overlay or other surface corrective measures approved by the Project Manager. Thin or feathered edge surface patching will not be acceptable. Overlay lift thicknesses must meet State Materials Bureau minimum requirements for gradation being used.

416.6 METHOD OF MEASUREMENT.

416.61 Minor pavement will be measured by the square meter (square yard).

416.7 BASIS OF PAYMENT.

416.71 Minor pavement will be paid for at the contract unit price per square meter (square yard), adjusted as specified in subsection 416.52. The unit price will include all materials including aggregate, bituminous material, and hydrated lime or liquid antistrip, as well as all mixing, hauling, placement, and compaction required to construct the pavement to the line and grades shown on the plans.

Payment will be made under:

<table>
<thead>
<tr>
<th>Pay Item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor Pavement</td>
<td>Square Meter (Square Yard)</td>
</tr>
</tbody>
</table>
APPENDIX P

ACCUTEST LABORATORIES
USACE LABORATORY VALIDATION APPROVAL
US DEPARTMENT OF ARMY
JULY 9, 2004
Hazardous, Toxic and Radioactive Waste
Center of Expertise

Svetlana Izosimova
Accutest Laboratories Southeast, Inc.
4405 Vineland Road, Suite C-15
Orlando, FL 32811

Dear Ms Izosimova:

This correspondence addresses the recent evaluation of Accutest Laboratories Southeast, Inc. of Orlando, FL by the U.S. Army Corps of Engineers (USACE) for chemical analysis in support of the USACE Hazardous, Toxic and Radioactive Waste Program.

Your laboratory is now validated for the parameters listed below:

<table>
<thead>
<tr>
<th>METHOD</th>
<th>PARAMETERS</th>
<th>MATRIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>300.0/9056</td>
<td>Anions&lt;sup&gt;(5)&lt;/sup&gt;</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>5030B/8021B</td>
<td>Aromatic Volatile Organics</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>5030B/8021b</td>
<td>Aromatic Volatile Organics</td>
<td>Solids&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>9010B/9014</td>
<td>Cyanide</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>9010B/9014</td>
<td>Cyanide</td>
<td>Solids&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>8330A</td>
<td>Explosives&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Water</td>
</tr>
<tr>
<td>8330A</td>
<td>Explosives&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Solids</td>
</tr>
<tr>
<td>7196A</td>
<td>Hexavalent Chromium</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>1664</td>
<td>Oil and Grease</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>1664</td>
<td>Oil and Grease</td>
<td>Solids&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3510C/8081A</td>
<td>Organochlorine Pesticides</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3550B/8081A</td>
<td>Organochlorine Pesticides</td>
<td>Solids&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3510C/8082</td>
<td>Polychlorinated Biphenyls</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3550B/8082</td>
<td>Polychlorinated Biphenyls</td>
<td>Solids&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3510C/8270C</td>
<td>Semivolatile Organics</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3550B/8270C</td>
<td>Semivolatile Organics</td>
<td>Solids&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3010A/6010B/7470A</td>
<td>TAL Metals&lt;sup&gt;(4)&lt;/sup&gt;</td>
<td>Water&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>3050B/6010B/7471A</td>
<td>TAL Metals&lt;sup&gt;(4)&lt;/sup&gt;</td>
<td>Solids&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Enclosed for your information is a copy of the Laboratory Inspection and Evaluation Report. Your laboratory has responded to the deficiencies as noted in the report. No further responses are necessary.

Based on the successful analysis of the National Environmental Laboratory Accreditation Conference Proficiency Testing samples for the appropriate fields of testing, the results of the laboratory inspection, and your Corrective Action Report, your laboratory will be validated for sample analysis by the methods listed above. The evaluation, which was conducted for your facility, is based substantially on ISO Guide 25 (General Requirements for the Competence of Testing Laboratories) and USACE Engineering Manual (EM) 200-1-3, Appendix I (Shell for Analytical Chemistry Requirements). The period of validation is 24 months and expires on July 9, 2006.

The USACE reserves the right to conduct additional laboratory inspections or to suspend validation status for any or all of the listed parameters if deemed necessary. It should be noted that your laboratory may not subcontract USACE analytical work to any other laboratory location without the approval of this office. This laboratory validation does not guarantee the delivery of any analytical samples from a USACE Contracting Officer Representative.
Any questions or comments can be directed to Richard Kissinger at (402) 697-2569. General questions regarding laboratory validation may be directed to the Laboratory Validation Coordinator at (402) 697-2574.

Sincerely,

Marcia C. Davies, Ph.D.
Director, USACE Hazardous, Toxic and Radioactive Waste Center of Expertise

Enclosure
APPENDIX Q

NMED SOIL SCREENING LEVELS REVISION 2.0,
FEBRUARY 2004
Appendix A

State of New Mexico Soil Screening Levels

Table A-1 provides State of New Mexico Soil Screening Levels (SSLs), as developed by the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) and the Ground Water Quality Bureau Voluntary Remediation Program for 206 chemicals most commonly associated with environmental releases within the state. These NMED SSLs are derived using default exposure parameter values (as presented in Table A-2) and chemical- and State of New Mexico-specific physical parameters (as presented in Table B-1 of Appendix B). These default values are assumed to be appropriately conservative in the face of uncertainty and are likely to be protective for the majority of site conditions relevant to soil exposures within New Mexico.

However, the NMED SSLs are not necessarily protective of all known human exposure pathways, reasonable land uses or ecological threats. Thus, before applying NMED SSLs at a site, it is extremely important to compare the conceptual site model (CSM) with the assumptions upon which the NMED SSLs are predicated to ensure that the site conditions and exposure pathways match those used to develop the NMED SSLs. If this comparison indicates that the site at issue is more complex than the corresponding SSL scenarios, or that there are significant exposure pathways not accounted for by the NMED SSLs, then the NMED SSLs are insufficient for use in a defensible assessment of the site. A more detailed site-specific approach will be necessary to evaluate the additional pathways or site conditions.

Table A-1

Column 1: The first column in Table A-1 presents the names of the 206 chemicals for which NMED has developed SSLs.

Column 2: The second column presents NMED SSLs predicated on residential soil exposures.

Column 3: The third column presents indicator categories for the NMED SSL residential basis, whether predicated on carcinogenic effects (ca), noncarcinogenic effects (nc), soil saturation limits (sat) or a non-risk based “max” determination. NMED SSLs predicated on a carcinogenic endpoint reflect age-adjusted child-to-adult exposures. NMED SSLs predicated on a noncarcinogenic endpoint reflect child-only exposures. Detected concentrations above the “sat” value may indicate the presence of nonaqueous phase liquid (NAPL). For certain inorganic and semivolatile organic compounds (SVOCs) that exhibit relatively low toxicity, a non risk-based maximum concentration of $10^5$ mg/kg is given when the risk-based SSL exceeds that level. These are noted as “max” in the tables.

Columns 4 and 6: The fourth and sixth columns present NMED SSLs analogous to Column 1, with the exception that these values correspond to Industrial/Occupational and Construction worker (adult-only) exposures, respectively.

Columns 5 and 7: The fifth and seventh columns present endpoint bases analogous to Column 3.
for the Industrial/Occupational and Construction worker receptor populations, respectively. Unlike the Residential population, noncarcinogenic endpoint notes for these receptor populations are predicated on adult-only exposures.

Column 8: The eighth column notes which chemicals are considered VOCs (for inhalation considerations). Those chemicals not considered VOCs are evaluated within the SSLs relative to inhalation of particulate emissions.

Columns 9 and 10: The ninth column presents NMED SSLs for the migration to groundwater pathway developed using a default dilution attenuation factor (DAF) of 1, which assumes no effective dilution or attenuation. These values can be considered at sites where little or no dilution or attenuation of soil leachate concentrations is expected (e.g., shallow water tables, karst topography). Column 10 presents NMED SSLs for the migration to groundwater pathway developed using a DAF of 20 to account for natural processes that reduce contaminant concentrations in the subsurface.

As noted above, separate NMED SSLs are presented for use in evaluating three discrete potential receptor populations: Residential, Industrial/Occupational, and Construction. Each NMED SSL considers incidental ingestion of soil, inhalation of volatiles (limited to those chemicals noted as volatile organic compounds [VOCs] within Table A-1) or particulate emissions from impacted soil, and dermal contact with soil.

Generally, if a contaminant is detected at a level in soil exceeding the most relevant NMED SSL, and the site-specific CSM is in general agreement with the underlying assumptions upon which the NMED SSLs are predicated, this result indicates the potential for adverse human health effects to occur. Conversely, if no contaminants are detected above the most relevant NMED SSL, this tends to indicate to the user that environmental conditions may not necessitate remedial action of the surface soil or the vadose zone.

A detection above an NMED SSL does not indicate that unacceptable exposures are, in fact, occurring. The NMED SSLs are predicated on relatively conservative exposure assumptions and an exceedance only tends to indicate the potential for adverse effects. The NMED SSLs do not account for additive exposures, whether for carcinogenic or noncarcinogenic endpoints. Section 5 of Part A addresses a methodology by which an environmental manager may determine whether further site-evaluation is warranted, however, this methodology does not replace the need for defensible risk assessment where indicated.

The NMED SSLs address a basic subset of exposures fundamental to the widest array of environmentally-impacted sites within the State of New Mexico. The NMED SSLs cannot address all relevant exposure pathways associated with all sites. The utility of the NMED SSLs depends heavily upon the understanding of site conditions as accurately reflected in the CSM and nature and extent of contamination determinations. Consideration of the NMED SSLs does not preclude the need for site-specific risk assessment in all instances.
# Table A-1

## NMED Soil Screening Levels

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Residential Soil (mg/kg)</th>
<th>Endpoint</th>
<th>Industrial/ Occupational Soil (mg/kg)</th>
<th>Endpoint</th>
<th>Construction Worker Soil (mg/kg)</th>
<th>Endpoint</th>
<th>VOC</th>
<th>DAF 1 (mg/kg)</th>
<th>DAF 20 (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acenaphthene</td>
<td>4.69E+03</td>
<td>nc</td>
<td>3.48E+04</td>
<td>nc</td>
<td>1.44E+04</td>
<td>nc</td>
<td>X</td>
<td>3.99E+00</td>
<td>7.98E+01</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>9.43E+01</td>
<td>nc</td>
<td>3.42E+02</td>
<td>nc</td>
<td>3.68E+02</td>
<td>nc</td>
<td>X</td>
<td>3.32E+04</td>
<td>6.63E-03</td>
</tr>
<tr>
<td>Acetone</td>
<td>7.64E+04</td>
<td>nc</td>
<td>1.00E+05</td>
<td>sat</td>
<td>1.00E+06</td>
<td>sat</td>
<td>X</td>
<td>1.03E-01</td>
<td>2.06E+00</td>
</tr>
<tr>
<td>Acrylonitrile</td>
<td>3.86E+00</td>
<td>ca</td>
<td>1.15E+01</td>
<td>ca</td>
<td>5.22E+01</td>
<td>nc</td>
<td>X</td>
<td>6.61E-06</td>
<td>1.32E-04</td>
</tr>
<tr>
<td>Acetophenone</td>
<td>1.31E+03</td>
<td>sat</td>
<td>1.31E+03</td>
<td>sat</td>
<td>1.31E+03</td>
<td>sat</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acrolein</td>
<td>1.84E+01</td>
<td>nc</td>
<td>6.70E+01</td>
<td>nc</td>
<td>6.01E-01</td>
<td>nc</td>
<td>X</td>
<td>8.39E-06</td>
<td>1.68E-04</td>
</tr>
<tr>
<td>Aldrin</td>
<td>2.84E-01</td>
<td>ca</td>
<td>1.12E+00</td>
<td>ca</td>
<td>6.99E+00</td>
<td>nc</td>
<td>X</td>
<td>1.47E-02</td>
<td>2.94E-01</td>
</tr>
<tr>
<td>Aluminum</td>
<td>7.78E+04</td>
<td>nc</td>
<td>1.00E+05</td>
<td>max</td>
<td>1.44E+04</td>
<td>nc</td>
<td>X</td>
<td>7.50E+03</td>
<td>1.50E+05</td>
</tr>
<tr>
<td>Anthracene</td>
<td>2.35E+04</td>
<td>nc</td>
<td>2.64E+05</td>
<td>nc</td>
<td>8.53E+04</td>
<td>nc</td>
<td>X</td>
<td>8.00E+01</td>
<td>1.60E+03</td>
</tr>
<tr>
<td>Antimony</td>
<td>3.13E+01</td>
<td>nc</td>
<td>4.54E+02</td>
<td>nc</td>
<td>1.24E+02</td>
<td>nc</td>
<td>X</td>
<td>2.71E-01</td>
<td>5.42E+00</td>
</tr>
<tr>
<td>Arsenic</td>
<td>3.90E+00</td>
<td>ca</td>
<td>1.77E+01</td>
<td>ca</td>
<td>8.52E+01</td>
<td>nc</td>
<td>X</td>
<td>2.92E+00</td>
<td>5.83E-01</td>
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<tr>
<td>Barium</td>
<td>5.45E+03</td>
<td>nc</td>
<td>7.35E+04</td>
<td>nc</td>
<td>1.44E+03</td>
<td>nc</td>
<td>X</td>
<td>4.12E+01</td>
<td>8.23E+02</td>
</tr>
<tr>
<td>Benzene</td>
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<td>Diethyl phthalate</td>
<td>4.80E+04</td>
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<td>1.66E+02</td>
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<td>3.01E+01</td>
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<td>7.04E+04</td>
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<td>1.00E+05</td>
<td>sat</td>
<td>2.06E+04</td>
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<td>X</td>
<td>1.41E+00</td>
<td>2.83E+01</td>
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<td>6.62E+02</td>
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<td>1.20E+01</td>
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<td>1.02E+02</td>
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<td>Iron</td>
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<td>Residential Soil (mg/kg)</td>
<td>Industrial/ Occupational Soil (mg/kg)</td>
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<td>VOC (mg/kg)</td>
<td>DAF 1 (mg/kg)</td>
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<td>Lead</td>
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<td>1.80E+01</td>
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<td>Residential Soil (mg/kg)</td>
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<td>Industrial/Occupational Soil (mg/kg)</td>
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<td>DAF 1 (mg/kg)</td>
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<td>9.29E+04</td>
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<td></td>
<td>6.22E+02</td>
<td>1.24E+04</td>
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Notes: * - An oral absorption efficiency of 5% was assumed for the dermal route.
ca = carcinogenic effect basis
nc = noncarcinogenic effect basis
sat = soil saturation limit basis
max = low toxicity maximum, health based SSL exceeds $10^5$ mg/kg
Compounds solid at ambient temperature will present a risk-based level over the soil saturation level (USEPA 2001a).
APPENDIX R

SITE-SPECIFIC ADDENDUM TO THE BASEWIDE QUALITY ASSURANCE PROJECT PLAN
QUALITY ASSURANCE PROJECT PLAN ADDENDUM

VOLUNTARY CORRECTIVE MEASURES
SOLID WASTE MANAGEMENT UNIT 123

HOLLOMAN AIR FORCE BASE
NEW MEXICO

Prepared for:
49 CES/CEV
Holloman Air Force Base
New Mexico

Under Contract To:
U.S. Army Corps of Engineers
Omaha, Nebraska

Contract No. DACA45-03-D-0023
Delivery/Task Order No. 0013
Bhate Project No. 9050197

Prepared by:

bhate associates
1608 13th Avenue South, Suite 300
Birmingham, Alabama 35205
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August 2005

Bhate Project No.: 9050197
August 2005
QUALITY ASSURANCE PROJECT PLAN ADDENDUM
VOLUNTARY CORRECTIVE MEASURES
SOLID WASTE MANAGEMENT UNIT 123
HOLLOMAN AIR FORCE BASE
NEW MEXICO

REVIEW SHEET

COMMITMENT TO IMPLEMENT THIS QUALITY ASSURANCE PROJECT PLAN ADDENDUM

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<td>[Signature]</td>
<td>August 12, 2005</td>
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<tr>
<td>Project Chemist</td>
<td>[Signature]</td>
<td>Date: August 12, 2005</td>
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<tr>
<td>Frank Gardner</td>
<td>[Signature]</td>
<td>Date: August 8, 2005</td>
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<td>Project Manager</td>
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<td>Date: August 8, 2005</td>
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<td>John Hymer</td>
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Bhate Project No.: 9050197

August 2005
QUALITY ASSURANCE PROJECT PLAN ADDENDUM

VOLUNTARY CORRECTIVE MEASURES

SOLID WASTE MANAGEMENT UNIT 123

HOLLOMAN AIR FORCE BASE

NEW MEXICO

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<tr>
<th>Abbreviation</th>
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<tr>
<td>Bhate</td>
<td>Bhate Environmental Associates, Inc.</td>
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<tr>
<td>BTEX</td>
<td>Benzene, Ethylbenzene, Toluene, and Xylenes</td>
</tr>
<tr>
<td>DRO</td>
<td>Diesel Range Organics</td>
</tr>
<tr>
<td>EDD</td>
<td>Electronic data deliverable</td>
</tr>
<tr>
<td>ERPIMS</td>
<td>Environmental Resources Program Information Management System</td>
</tr>
<tr>
<td>GRO</td>
<td>Gasoline Range Organics</td>
</tr>
<tr>
<td>HAFB</td>
<td>Holloman Air Force Base</td>
</tr>
<tr>
<td>LCL</td>
<td>Lower Control Limit</td>
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<td>LCS</td>
<td>Laboratory Control Sample</td>
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<td>MDL</td>
<td>Method Detection Limit</td>
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<td>MS/MSD</td>
<td>Matrix Spike/Matrix Spike Duplicate</td>
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<tr>
<td>NELAC</td>
<td>National Environmental Laboratory Accreditation Conference</td>
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<tr>
<td>ORO</td>
<td>Oil Range Organics</td>
</tr>
<tr>
<td>OVA</td>
<td>Organic Vapor Analyzer</td>
</tr>
<tr>
<td>PAHs</td>
<td>Polynuclear Aromatic Hydrocarbons</td>
</tr>
<tr>
<td>QA</td>
<td>Quality assurance</td>
</tr>
<tr>
<td>QAM</td>
<td>Quality Assurance Manual</td>
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<td>QC</td>
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<td>RPD</td>
<td>Relative Percent Difference</td>
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<tr>
<td>SOPs</td>
<td>Standard Operating Procedures</td>
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<td>Solid Waste Management Unit</td>
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<td>TPH</td>
<td>Total petroleum hydrocarbons</td>
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</tr>
<tr>
<td>µg/kg</td>
<td>Micrograms per kilogram</td>
</tr>
<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>VCM</td>
<td>Voluntary Corrective Measures</td>
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<td>VOC</td>
<td>Volatile organic compound</td>
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QUALITY ASSURANCE PROJECT PLAN ADDENDUM

This Quality Assurance Project Plan Addendum (QAPP Addendum) has been developed to assure that sample collection, analyses, and evaluations are legally and scientifically defensible for Voluntary Corrective Measures (VCM) at Solid Waste Management Unit 123 (SWMU 123) on Holloman Air Force Base (HAFB). This document is an addendum to the Basewide Quality Assurance Project Plan, Holloman Air Force Base, New Mexico (Bhate Environmental Associates, Inc. [Bhate], November 2003) (Basewide QAPP) and must be used in conjunction with that document. This document contains the site specific information for the work at SWMU 123 outlined in the Voluntary Corrective Measures Work Plan, Solid Waste Management Unit (SWMU) 123, Holloman Air Force Base, New Mexico (Bhate, August 2005) (SWMU 123 Work Plan).
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1 INTRODUCTION

Bhate Environmental Associates, Inc., (Bhate) has been retained by the U.S. Army Corps of Engineers (USACE), under contract DACA45-03-D-0023, Task Order No. 0013, to conduct VCMs at SWMU 123 at Holloman Air Force Base (HAFB), New Mexico. The VCMs include multiple tasks as outlined in the USACE Scope of Services dated May 5, 2005. This document is to provide site specific quality assurance/quality control (QA/QC) that will serve as the primary QAPP document for the excavation activities at SWMU 123.

See the Basewide QAPP and SWMU 123 Work Plan for additional information on HAFB and SWMU 123.
This page intentionally left blank.
2 PROJECT LABORATORY

The analytical work for this project will be performed by Accutest Laboratories, 4405 Vineland Road, Suite C-15, Orlando, Florida 32811. The key laboratory personnel who will be involved with this project include:

Harry Behzadi, Accutest Laboratory Director, (407) 425-6700
Sue Bell, Accutest Project Manager, (813) 741-3338
Doris Curry, Accutest Quality Assurance Manager, (407) 425-6700

Accutest is certified by both the National Environmental Laboratory Accreditation Conference (NELAC) and the USACE and has extensive previous experience in working on USACE projects. The Accutest Laboratory Quality Assurance Manual (QAM) and Standard Operating Procedures (SOPs) have been reviewed by Bhate and found to meet all the requirements for this project. The QAM and SOPs are available for further review if required.
3 DATA CATEGORIES

The data use determines the required levels of data quality. The two levels of data quality established by the USACE are screening and definitive. Under this QAPP Addendum, the data to be generated under each level in this project are presented in Table 3-1 (Screening) and Table 3-2 (Definitive). The screening data collected for this project will include volatile organic compound (VOC) headspace screening of soil samples and field testing for total petroleum hydrocarbons (TPH) for guidance in sample selection for analysis. A percentage of the soil samples will be subjected to laboratory confirmation. The definitive data generated by the laboratory will be presented as preliminary data within 24 hours and with limited data deliverables (i.e. Level II data packages) using a 14 day turn-around-time. All definitive data produced by the laboratory will also be presented in an Environmental Resources Program Information Management System (ERPIMS) format electronic data deliverable (EDD).
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4 DATA QUALITY ASSURANCE AND QUALITY CONTROL

The general data QA and QC requirements for HAFB are presented in the Basewide QAPP. The field QC requirements for this project are presented in Table 4-1. The project specific laboratory QC limits are listed in Table 4-2.

All final definitive data will be reviewed and validated by the Bhate Senior Chemist, Michael J. D’Auben, based on the guidelines of the U.S. Environmental Protection Agency (USEPA) National Functional Guidelines for Data Validation and the site specific laboratory QC limits.
5 REFERENCES


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Table 3-1
Summary of Screening Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Matrix</th>
<th>Testing Method</th>
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<tr>
<td>Volatile Organic Compounds (VOCs)</td>
<td>Soil</td>
<td>Organic Vapor Analyzer (OVA)</td>
</tr>
<tr>
<td>Total Petroleum Hydrocarbons (TPHs)</td>
<td>Soil</td>
<td>SiteLAB® Analytical Test Kit Ultraviolet Fluorometer (UVF) 3100A</td>
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</table>
Table 3-2  
Summary of Definitive Data

<table>
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<th>Parameter</th>
<th>Matrix</th>
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<td>Benzene, Ethylbenzene, Toluene, and Xylenes (BTEX)</td>
<td>Soil</td>
<td>U.S. Environmental Protection Agency (USEPA) SW-846 Method 8260B</td>
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<tr>
<td>Polynuclear Aromatic Hydrocarbons (PAHs)</td>
<td>Soil</td>
<td>USEPA SW-846 Method 8270C</td>
</tr>
<tr>
<td>Total Petroleum Hydrocarbons (TPHs)</td>
<td>Soil</td>
<td>USEPA SW-846 Method 8015M</td>
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Summary of Field QC Samples

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<th>Equipment Blanks</th>
<th>Trip Blanks**</th>
<th>Field Duplicates</th>
<th>Field Splits</th>
<th>MS/MSD</th>
<th>Total</th>
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<tr>
<td>Soil</td>
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<td>1</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>11</td>
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* Estimated. Total number of samples will be determined in the field.
** Estimated. One trip blank will be included in each cooler containing volatile samples.

BTEX = Benzene, toluene, ethylbenzene, and xylenes
PAHs = Polynuclear aromatic hydrocarbons
TPHs = Total petroleum hydrocarbons
MS/MSD = Matrix spike/matrix spike duplicate
EPA = Environmental Protection Agency
<table>
<thead>
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<th>Parameter</th>
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<th>LCS Soil</th>
<th>Recovery</th>
<th>Matrix Spike Soil</th>
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<td>Dibromofluoromethane (surr)</td>
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<td>1,2-Dichloroethane-d4 (surr)</td>
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<td><strong>PAHs by EPA Method 8270C</strong></td>
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<td>Acenaphthene</td>
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<td>Benzo(b)fluoranthene</td>
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<td>50</td>
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<td>Benzo(g,h,i)pyrene</td>
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<td>Fluorene</td>
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<td>59</td>
<td>115</td>
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<td>Pyrene</td>
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<td>2,4,6-Tribromophenol (surr)</td>
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### Table 4-2
Summary of Laboratory QC Limits
Accutest Laboratories, Orlando, FL

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<th>LCS</th>
<th>Matrix Spike Soil</th>
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<td>2-Fluorobiphenyl (surr)</td>
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<td>--</td>
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<td>Terphenyl-d14 (surr)</td>
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<td>45</td>
<td>135</td>
<td>--</td>
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<tr>
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<td>µg/kg</td>
<td>%</td>
<td>%</td>
<td>%</td>
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<td>C6-C10 (GRO)</td>
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<td>4-Bromofluorobenzene (surr)</td>
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<td>50</td>
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<td>C22-C36 (ORO)</td>
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<td>50</td>
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<td>Ortho-terphenyl (surr)</td>
<td>--</td>
<td>57</td>
<td>115</td>
<td>--</td>
</tr>
</tbody>
</table>

**Notes:**
- **MDL** = Method detection limit
- **LCS** = Laboratory control sample
- **LCL** = Lower control limit
- **UCL** = Upper control limit
- **MSD** = Matrix spike duplicate
- **RPD** = Relative percent difference
- **µg/kg** = Micrograms per kilogram
- **BTEX** = Benzene, toluene, ethylbenzene, and xylenes
- **PAHs** = Polynuclear aromatic hydrocarbons
- **EPA** = Environmental Protection Agency
- **GRO** = Gasoline Range Organics
- **ORO** = Oil Range Organics
- **DRO** = Diesel Range Organics
APPENDIX S

SITE-SPECIFIC ADDENDUM TO THE BASEWIDE HEALTH AND SAFETY PLAN
SITE-SPECIFIC ADDENDUM
TO THE BASEWIDE HEALTH AND SAFETY PLAN
SOLID WASTE MANAGEMENT UNIT (SWMU) 123
HOLLOMAN AIR FORCE BASE
NEW MEXICO

Prepared for:
49 CES/CEV
Holloman Air Force Base
New Mexico

Under Contract To:
U.S. Army Corps of Engineers
Omaha District
Omaha, Nebraska

Contract No.: DACA45-03-D0023
Delivery/Task Order No. 0013

August 2005

Prepared by:
Bhate Environmental Associates, Inc.
1608 13th Avenue South, Suite 300
Birmingham, Alabama 35205

Bhate Project No. 9050197
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# Health and Safety Plan

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<th>Title</th>
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<td>Communications</td>
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<td>Medical Surveillance and Training</td>
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<td>8.1 Training Requirements</td>
<td>8-1</td>
</tr>
<tr>
<td>9</td>
<td>Hazardous Chemicals</td>
<td>9-1</td>
</tr>
<tr>
<td>10</td>
<td>Emergency Action and Response</td>
<td>10-1</td>
</tr>
<tr>
<td>11</td>
<td>Emergency Contacts</td>
<td>11-1</td>
</tr>
<tr>
<td>12</td>
<td>Hospital Directions</td>
<td>12-1</td>
</tr>
</tbody>
</table>

## Figures

- Figure 12-1 Hospital Route Map

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## Attachments

- A - Activity Hazards Analyses
- B - General Work and Safety Rules
ACRONYMS AND ABBREVIATIONS

ACGIH  American Conference of Governmental Industrial Hygienists
AHA    Activity Hazard Analysis
ANSI   American National Standards Institute
Bhate  Bhate Environmental Associates, Inc.
CFR    Code of Federal Regulations
CGI    Combustible gas indicator
CIH    Certified Industrial Hygienist
CPR    Cardiopulmonary Resuscitation
dBA    Decibels acoustic
EM     Engineering Manual
FID    Flame ionization detector
HAFB   Holloman Air Force Base
HASP   Health and Safety Plan
HSM    Health and Safety Manager
MSDS   Material Safety Data Sheet
mg/M³  Milligrams per cubic meter of air
NFPA   National Fire Protection Agency
OSHA   Occupational Safety and Health Administration
PCS    Petroleum contaminated soils
PEL    Permissible Exposure Limit
PG     Professional Geologist
PID    Photoionization detector
POL    Petroleum, Oil, and Lubricant
PPE    Personal protective equipment
ppm    Parts per million
SLM    Sound level meter
SPF    Sun protection factor
SSHO   Site Safety and Health Officer
<table>
<thead>
<tr>
<th>ACRONYMS AND ABBREVIATIONS (CONTINUED)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSHP</td>
</tr>
<tr>
<td>SWMU</td>
</tr>
<tr>
<td>TLV</td>
</tr>
<tr>
<td>USACE</td>
</tr>
<tr>
<td>VOC</td>
</tr>
</tbody>
</table>
1 PROJECT SAFETY COORDINATION

The Bhate personnel who are responsible for safety and health issues at the Solid Waste Management Unit (SWMU) 123 project site are identified in Table 1-1. A signature below indicates that the respective personnel have reviewed and approved this Site-Specific Addendum to the Basewide Health and Safety Plan (HASP) submitted by Bhate Environmental Associates, Inc. (Bhate), for implementation on this scope of work. The requirements of this site-specific addendum are applicable to Bhate employees, their subcontractors, and site visitors.

Table 1-1. Project Personnel and Health and Safety Responsibilities

<table>
<thead>
<tr>
<th>Title</th>
<th>Name:</th>
<th>Office Telephone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Manager/SSHO</td>
<td>John Hymer</td>
<td>(505) 679-2100</td>
</tr>
<tr>
<td>Senior Project Manager</td>
<td>Frank Gardner, PG</td>
<td>(970) 216-7819</td>
</tr>
<tr>
<td>Health and Safety Manager</td>
<td>Judy McBride, CIH</td>
<td>(205) 918-4000</td>
</tr>
</tbody>
</table>

SSHO = Site Safety and Health Officer  
PG = Professional Geologist  
CIH = Certified Industrial Hygienist
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2 PROJECT BACKGROUND AND SCOPE

The objective of this remedial excavation is to remove, through excavating, and properly remediate or dispose of petroleum contaminated soils (PCS) at the SWMU 123 site. Over a period of years, various fuels have been released through deteriorating fuel lines or spills and migrated contaminating the soils beneath the wash rack within the Petroleum, Oil, and Lubricant (POL) Yard. The anticipated activities for the project include:

- Mobilization and demobilization of equipment;
- Soil excavation and loading; and,
- Excavated soils placement and land-farm maintenance, as applicable.
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3 HAZARD ASSESSMENT AND CONTROLS

3.1 Task Hazard(s) Summary

The potential health and safety hazards of this task are summarized below in Table 3-1. The potential for encountering these hazards is ranked (high, moderate, or low) based on the work to be performed and the hazard control measures to be used.

Table 3-1. Task Hazards Summary

<table>
<thead>
<tr>
<th>Summary</th>
<th>Hazard potential [High, Moderate, or Low]</th>
<th>Description of potential hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Moderate</td>
<td>• Walking and surfaces</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Heavy equipment and vehicular traffic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Materials handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Slips, trips, and falls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Excavating</td>
</tr>
<tr>
<td>Utilities</td>
<td>Moderate</td>
<td>• Buried</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Over head</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Building</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Although these hazards should not be associated with this</td>
</tr>
<tr>
<td></td>
<td></td>
<td>particular scope of work, it is necessary to verify that the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hazards can be controlled</td>
</tr>
<tr>
<td>Chemical</td>
<td>Moderate</td>
<td>• Potential for exposure to neat products should be limited to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>equipment fluids (fuel, lubricants, coolant, etc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Petroleum Hydrocarbons</td>
</tr>
<tr>
<td>Physical</td>
<td>Moderate</td>
<td>• Thermal stressors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Equipment noise</td>
</tr>
<tr>
<td>Biological</td>
<td>Low</td>
<td>• Potential for contact should be minimal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(i.e. Plants, animals, insects, spiders, infectious waste)</td>
</tr>
</tbody>
</table>

3.2 Hazard Control Measures

General safe work practices and control measures are identified and summarized in the Basewide HASP. Additional task-specific hazards and control measures are identified for non-routine tasks as part of the Activity Hazard Analysis (AHA) process. AHAs have been developed for each of the following activities listed in Table 3-2 and are included in Attachment A.
Table 3-2. Task-Specific Hazard Control Measures by AHA

<table>
<thead>
<tr>
<th>Activities with an AHA:</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Site Activities/Mobilization and Demobilization</td>
</tr>
<tr>
<td>Soil Excavation and Loading</td>
</tr>
</tbody>
</table>

3.3 Written Safety Procedures and Programs

Table 3-3 provides a summary of the existing safety procedures and programs which will be used for this task or site. Copies of applicable procedures and programs are included in Basewide HASP, as indicated.

Table 3-3. Written Safety Procedures and Programs

<table>
<thead>
<tr>
<th>Reference Procedure or Program</th>
<th>Applicable Section(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhate Hazard Communication Program</td>
<td>All (Refer to Basewide HASP)</td>
</tr>
<tr>
<td>Bhate Respiratory Protection Program</td>
<td>All (Refer to Basewide HASP)</td>
</tr>
<tr>
<td>Bhate Hearing Conservation Program</td>
<td>All (Refer to Basewide HASP)</td>
</tr>
</tbody>
</table>

3.4 Permits

Table 3-4 summarizes the required work permits that must be completed prior to the start of field work. No Bhate work permits are anticipated for this project.

Table 3-4. Required Work Permits

<table>
<thead>
<tr>
<th>Permit</th>
<th>Notes and comments (reference activities, procedures, and coordination with appropriate organizations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holloman Air Force Base (HAFB) Excavation Permit</td>
<td></td>
</tr>
<tr>
<td>Site Manager will arrange for Air Force Form 332 to be completed and obtain a dig permit/utility clearance through the HAFB Infrastructure Organization.</td>
<td></td>
</tr>
<tr>
<td>HAFB Hotwork Permit</td>
<td>Site Manager will arrange for all hotwork to be coordinated through the HAFB Fire Department before work commences.</td>
</tr>
</tbody>
</table>
4 PERSONAL PROTECTIVE EQUIPMENT

4.1 Purpose

The purpose of this program is to ensure that personal protective equipment (PPE) is selected in accordance with 29 Code of Federal Regulations (CFR) §1910.132, properly used and maintained, and that Bhate personnel are properly trained in the inspection, use, and maintenance of PPE.

4.2 Scope

This program applies to all Bhate operations including the activities of contractors on Bhate-managed projects.

4.3 Definition

4.3.1 Personal Protective Equipment

Items which are worn and are designed to protect the health and safety of an employee. This includes, but it is not limited to, chemical resistant shoes, boots, gloves, chemical protective clothing, hard hats, safety glasses, hearing protection, cooling/heating vests, life-lines and harnesses, and respirators. Additional program requirements for respirators are provided in the Respiratory Protection Program.

4.3.2 Responsibilities

4.3.2.1 All Bhate Personnel

All personnel required to use PPE are responsible for wearing the appropriate PPE when required, inspecting the PPE prior to use, properly wearing the PPE, and as necessary, properly maintaining the PPE.

4.3.2.2 Project Management Personnel

The Site Manager is responsible for understanding the specific PPE requirements for each project task and ensuring that PPE is provided and worn when required and in the intended manner.

4.3.2.3 Site Safety and Health Officer

The SSHO is responsible for:
- Monitoring PPE usage;
• Recommending modifications to PPE requirements to project management and the Health and Safety Manager (HSM), as necessary;
• Ensuring that project personnel have the proper training on the PPE which they are required to use, and performing training and retraining, as necessary.

The following PPE as presented in Table 4-1 will be used for the identified activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Head/Face</th>
<th>Foot</th>
<th>Hands</th>
<th>Respiratory</th>
<th>Clothing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilization / Demobilization</td>
<td>Hard Hat (for Steel toed Leather None 3' 4 Minimum of long overhead hazards), boots gloves as pants and shirts Safety Glasses with needed rigid side shields.</td>
<td>Steel toed boots</td>
<td>Leather gloves as needed</td>
<td>None³,⁴</td>
<td>Minimum of long pants and shirts with a minimum 4-inch sleeve, reflective vest</td>
</tr>
<tr>
<td>General Site Labor</td>
<td>Hard Hat (for Steel toed Leather None 3' 4 Minimum of long overhead hazards), boots gloves as pants and shirts Safety Glasses with needed rigid side shields.</td>
<td>Steel toed boots</td>
<td>Leather gloves as needed</td>
<td>None³,⁴</td>
<td>Minimum of long pants and shirts with a minimum 4-inch sleeve, reflective vest</td>
</tr>
<tr>
<td>Equipment Operation</td>
<td>Hard Hat² (for Steel toed Leather None 3' 4 Minimum of long overhead hazards), boots gloves as pants and shirts Safety Glasses with needed rigid side shields.</td>
<td>Steel toed boots. Boot covers for entering and exiting equipment.</td>
<td>Leather gloves as needed</td>
<td>As required³,⁴ N95 Air Purifying Respirator with Organic vapor cartridges based on monitoring</td>
<td>Minimum of long pants and shirts with a minimum 4-inch sleeve, reflective vest</td>
</tr>
<tr>
<td>Equipment Decontamination</td>
<td>Hard Hat² (for Steel toed Leather None 3' 4 Minimum of long overhead hazards), boots gloves as pants and shirts Safety Glasses with needed rigid side shields.</td>
<td>Steel toed boots. Boot covers.</td>
<td>Chemical resistant gloves</td>
<td>None³,⁴ N95 Air Purifying Respirator with Organic vapor cartridges based on monitoring</td>
<td>Minimum of long pants and shirts with a minimum 4-inch sleeve, reflective vest, Tyvek coveralls may be worn as recommended by the SSHO</td>
</tr>
<tr>
<td>Soil Sampling</td>
<td>Hard Hat² (for Steel toed Leather None 3' 4 Minimum of long overhead hazards), boots gloves as pants and shirts Safety Glasses with needed rigid side shields.</td>
<td>Steel toed boots</td>
<td>Chemical resistant gloves</td>
<td>As required³,⁴ N95 Air Purifying Respirator with Organic vapor cartridges based on monitoring</td>
<td>Minimum of long pants and shirts with a minimum 4-inch sleeve, Tyvek coveralls may be worn as recommended by the SSHO</td>
</tr>
<tr>
<td>Supervision of work</td>
<td>Hard Hat (for Steel toed Leather None 3' 4 Minimum of long overhead hazards), boots gloves as pants and shirts Safety Glasses with needed rigid side shields.</td>
<td>Steel toed boots</td>
<td>Leather gloves as needed</td>
<td>As required³,⁴</td>
<td>Minimum of long pants and shirts with a minimum 4-inch sleeve, reflective vest</td>
</tr>
</tbody>
</table>
Note:
1. Safety Glasses with rigid side shields approved by American National Standards Institute (ANSI) Z-87 required at all times.
2. Hard hats are not required inside fully enclosed equipment cabs.
3. Voluntary use of respirators is authorized for comfort from nuisance dusts and odors, provided they are issued and used in accordance with established respiratory protection program procedures.
4. Cartridge change out will occur at the following conditions:
   - Damage to cartridge
   - Cartridge is wet, restriction in breathing, unusual odors
   - Cartridge is visibly clogged with dust, restriction in breathing
   - After 8 hours of use
   - Changes that may be otherwise identified in 29 CFR §1910.120.

The following qualified person certifies that the selection of PPE is based on best available information about the work requirements and anticipated hazards.

<table>
<thead>
<tr>
<th>Printed name:</th>
<th>Signature:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Judy McBride, CIH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bhate Health and Safety Manager</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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5 SITE MONITORING

5.1 General

Site monitoring shall be performed as necessary for site remediation and clean construction work. This section covers general site monitoring for employee exposure to physical and chemical hazards including air contaminants (dust, metals, volatile organic compounds (VOCs), and other specific compounds).

Minimum site monitoring requirements are determined during the project design stage, and are specified in the Site Safety and Health Plan (SSHP). Site monitoring shall be performed by, or under the direction of a SSHO.

5.2 Required Site Monitoring

Site monitoring is required under the following conditions:

- When required by the contract, or SSHP
- When required by specific Occupational Safety and Health Administration (OSHA) standards (e.g., 29 CFR §1910.120, hearing conservation, asbestos, benzene, cadmium, inorganic arsenic, lead, formaldehyde, vinyl chloride, etc.)
- When worker exposure is reasonably anticipated to be greater than 50% of the OSHA Permissible Exposure Limit (PEL), American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV), or other recognized occupational exposure limit
- When necessary to verify the adequacy of hazard control measures and/or PPE, including respiratory protection
- When necessary to assess and evaluate worker exposure, or to resolve worker complaints or concerns

With the concurrence of the HSM, site monitoring may be discontinued after representative initial monitoring is conducted and worker exposures are shown to be adequately controlled through the use of engineering, work practice, or PPE control measures. If work activities change so that the initial monitoring is no longer representative of worker exposure, monitoring must be reinitiated.

5.3 Monitoring Strategy

The site monitoring program considers the factors that may affect worker exposure and the following elements:

- Monitoring requirements, contaminants, and monitoring equipment limitations
• Specific work locations (SWMU 123), work activities, work practices, personnel, and equipment to be used onsite

• Health and safety program requirements for site monitoring

5.4 Direct Reading Exposure Monitoring

Direct reading instruments for exposure monitoring are extremely useful on construction and hazardous waste sites. The primary advantages include ease of use, ability to monitor constantly changing conditions, and the rapid detection of flammable atmospheres, oxygen deficiency, certain gases and vapors, and physical hazards including noise and radiation.

The following are some of the instruments that may be used for exposure monitoring:

• Photoionization detector (PID)
• Flame ionization detector (FID)
• Combustible gas indicator (CGI)
• Specific gas monitors (e.g., oxygen, carbon monoxide, hydrogen sulfide)
• Colorimetric indicating tubes (e.g., Draeger tubes)
• Specialized air monitors
• Noise dosimeter
• Sound level meter (SLM)

Routine direct reading monitoring results (date/time, calibration information, results, and activities monitored) shall be recorded on the Air Monitoring Data Sheet (Real-Time Air Monitoring) or an equivalent form if approved by the Health and Safety Manager. Monitoring results shall be recorded initially and periodically throughout the monitoring period (e.g., every 15 minutes, when results are above background levels, when site operations or locations change, or when unexpected site conditions arise). When direct reading air monitoring results at the work location equal or exceed the action levels specified in the SSHP, the SSHO shall conduct exclusion zone perimeter air monitoring. If the air concentrations at the perimeter of the exclusion zone equal or exceed the action level(s), the boundaries of the exclusion zone shall be expanded as necessary to maintain exclusion zone air contaminant concentrations below the action level(s).

Site monitoring will be conducted using direct-reading instruments primarily in the workers' breathing zone. To the extent feasible, site operations will be conducted and modified as needed to ensure that personnel are situated upwind of the excavation activities. Initial upwind background and work-zone readings will be obtained before the initiation of activities. Readings of breathing zones (unless location is otherwise specified) will be taken periodically during all activities. The SSHO has the authority to modify the level of protection required for work at this site as well as halt operations as deemed necessary to control personal exposures. Monitoring results will be recorded on an Atmospheric Monitoring Log Field Health and Safety form.
maintained by the SSHO. Monitoring, calibrating, and maintaining instruments are the responsibility of the SSHO. Table 5-1 summarizes the site monitoring parameters and action levels applicable for direct reading exposure monitoring.

<table>
<thead>
<tr>
<th>Activity(s)</th>
<th>Instrument</th>
<th>Action Level(s) and Frequency</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>TVA 1000B OVA PID/FID</td>
<td>0 - 9 parts per million (ppm)</td>
<td>Continue work in required PPE and continue monitoring.</td>
</tr>
<tr>
<td></td>
<td>ToxiRae Personal PID</td>
<td>Every 15 minutes during intrusive activities</td>
<td></td>
</tr>
<tr>
<td>Soil Placement at and Maintenance of Land-farm</td>
<td></td>
<td></td>
<td><strong>Monitor for benzene.</strong> Ensure personnel are upwind, notify the Site Manager. SSHO may upgrade PPE to Level C respiratory protection with organic vapor cartridge, as necessary. If benzene is detected follow response actions outlined for benzene.</td>
</tr>
<tr>
<td>Soil Sampling</td>
<td>Draeger Air Monitor with Benzene chips (By colorimetric tube or similar) Where indicted by PID readings</td>
<td>No detection up to 0.2 ppm</td>
<td>Continue work activities in required protective equipment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 0.2 ppm</td>
<td>Cease work, exit the area to upwind location and notify the Site Manager.</td>
</tr>
<tr>
<td></td>
<td>Personal DataRam or similar particulate monitor.</td>
<td>=1.5 mg/M³ particulates (average) not to exceed 5.0 mg/M³ 5 minute monitoring periods every minutes as necessary if visible dust is not controlled</td>
<td>Stop work, increase dust suppression</td>
</tr>
</tbody>
</table>

mg/M³ = Milligrams per cubic meter of air
This page intentionally left blank.
6 SITE CONTROL

Site-specific site control measures will be used to control access to the work area. Tables 6-1 and 6-2 summarize the site control requirements applicable for both general work areas and work areas with potentially contaminated soils, respectively.

Table 6-1. Site Control for General Work Area(s)

<table>
<thead>
<tr>
<th>Location</th>
<th>Site Control Procedure (discuss important elements such as signs, barricades, fencing, briefings, sign-in/out logs, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Work Area</td>
<td>The work area will be clearly demarcated with signage and/or caution tape, as needed, or where necessary to restrict foot or vehicle traffic, temporary construction fencing will be erected. Entry into the work area will require authorization by the Site Manager.</td>
</tr>
</tbody>
</table>

Table 6-2. Site Control for Potentially Contaminated Area(s)

<table>
<thead>
<tr>
<th>Location</th>
<th>Site Control Procedure (discuss important elements such as signs, barricades, briefings, qualifications, required supplies and equipment, sign-in/out logs, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support Zone</td>
<td>Located outside of contaminated areas, access will be from clean areas or from the Exclusion Zone through the Contamination Reduction Zone.</td>
</tr>
<tr>
<td>Contamination Reduction Zone</td>
<td>The Contamination Reduction Zone will be demarcated with caution tape or temporary construction fencing. Decontamination stations will be located here.</td>
</tr>
<tr>
<td>Exclusion Zone</td>
<td>Exclusion Zone work areas will be clearly demarcated with caution tape or temporary construction fencing. All access to this area will require the use of a sign-in/out log.</td>
</tr>
</tbody>
</table>

6.1 Decontamination

Required decontamination procedures are described below in Table 6-3.

Table 6-3. Decontamination Procedures by Location

<table>
<thead>
<tr>
<th>Type of decontamination</th>
<th>Decontamination Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel decontamination</td>
<td>Personnel will be required to thoroughly wash hands and face prior to eating, drinking, or smoking. Disposable PPE (from potential sampling events) will be collected for proper disposal. Additional decontamination procedures will be developed by the SSHO as needed.</td>
</tr>
<tr>
<td>Equipment decontamination</td>
<td>Prior to leaving the work area equipment (tires, excavator/loader buckets, hand tools) will be dry decontaminated. Soils from the dry decontamination process will be disposed with the excavated materials. Decontamination tools may include brooms and shovels.</td>
</tr>
</tbody>
</table>
7 COMMUNICATIONS

Cellular telephones will be available to contact emergency services as required. Refer to Sections 10, 11, and 12 of this HASP Addendum for site specific guidance on emergency situations and appropriate actions. Site communication amongst employees shall be a combination of audio, equipment/air horns, and/or line of sight hand communications. **Cellular telephone use is not permitted while operating equipment.**
8 MEDICAL SURVEILLANCE AND TRAINING

The medical surveillance and training requirements for Bhate's on-site employees working at SWMU 123 will follow the requirements outlined in the Basewide HASP Sections 5 and 7.4.

8.1 Training Requirements

All personnel performing on-site work activities, wherein they may be exposed to hazards resulting from field activities, will have completed applicable training in compliance with 29 CFR Part 1910/29 CFR Part 1926 and Engineering Manual (EM) 385-1-1. Table 8-1 provides a summary of the minimum training requirements for site project personnel.

<table>
<thead>
<tr>
<th>Required worker training</th>
<th>Site-specific training requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>V 40-hour General Site Worker</td>
<td>All personnel working on site shall attend site-specific orientation/training prior to starting on site project work. This training will be facilitated by the SSHO.</td>
</tr>
<tr>
<td>V 8-hour Supervisor (as applicable)</td>
<td></td>
</tr>
<tr>
<td>V 8-hour Refresher (as applicable)</td>
<td></td>
</tr>
</tbody>
</table>

No retraining requirements are anticipated during the project.

Additionally, at a minimum, the SSHO or the designated representative will be certified in First Aid and Cardiopulmonary Resuscitation (CPR), and will be continuously present during site operations.
9 HAZARDOUS CHEMICALS

Hazardous chemicals (as defined in 29 CFR § 1910.1200) to be brought or used on-site are identified below. This chemical inventory and Material Safety Data Sheet (MSDSs) will be maintained by the SSHO.

Table 9-1. Sample Chemical Identification

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Amount</th>
<th>Location</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assorted fuels, lubricants, coolants, etc. necessary for equipment operation</td>
<td>No storage planned. Quantities limited to immediate use requirements of on-site equipment.</td>
<td>No storage planned. Materials to be brought on-site by vendor’s maintenance vehicle.</td>
<td>Equipment Servicing and Operation</td>
</tr>
</tbody>
</table>
This page intentionally left blank.
10 EMERGENCY ACTION AND RESPONSE

Personnel responsible for coordinating emergency response actions during the SWMU 123 site remediation activities are identified below in Table 10-1. A map showing directions to the authorized medical facility is attached in Figure 12-1.

Table 10-1. Emergency Coordinator

<table>
<thead>
<tr>
<th>Responsibility</th>
<th>Name</th>
<th>Phone Number(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Emergency Coordinator</td>
<td>Mr. John Hymer</td>
<td>Office (505) 679-2100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cell (505) 491-9171</td>
</tr>
</tbody>
</table>

If an emergency situation develops which requires evacuation of the work area, the evacuation procedures in Table 10-2 shall be followed.

Table 10-2. Evacuation Procedures

<table>
<thead>
<tr>
<th>Evacuation Step</th>
<th>Methods and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notify affected workers</td>
<td>Use of site communication methods as applicable</td>
</tr>
<tr>
<td>Evacuate to safe location</td>
<td>Assemble at the primary evacuation site (support area outside of the exclusion zone)</td>
</tr>
<tr>
<td>Assemble and account for workers</td>
<td>Emergency Coordinator shall account for personnel using site Sign in/Sign out sheet</td>
</tr>
<tr>
<td>Notify Fire and Emergency Services</td>
<td>Notification as needed</td>
</tr>
<tr>
<td>Complete incident report</td>
<td>Follow the Incident Reporting and Investigation Procedure</td>
</tr>
</tbody>
</table>
Table 10-3 summarizes potential emergency situations and response actions that are applicable for the SWMU 123 project site.

### Table 10-3. Potential Emergency Situations

<table>
<thead>
<tr>
<th>In case of</th>
<th>Response Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury or illness</td>
<td>Treat injury with applicable First Aid. All work related injuries beyond first aid will result in notification of Emergency Services and notification of the employee supervisor. Any employee requiring advanced medical treatment will be accompanied by a knowledgeable company employee that can answer potential questions on job duties and hazards. Make notifications in accordance with the Incident Reporting and Investigation Procedure.</td>
</tr>
<tr>
<td>Chemical exposure</td>
<td>First Aid shall be provided such as but not limited to: move victim to fresh air, remove contaminated clothing, flush affected skin with water, and seek medical attention.</td>
</tr>
<tr>
<td>Fire or explosion</td>
<td>Notify emergency services immediately. All personnel shall evacuate the immediate area of the fire and move to an upwind location. Personnel shall not engage in fire fighting activities (except for use of fire extinguisher) unless trained to do so and only in the incipient stages of fire.</td>
</tr>
<tr>
<td>Adverse weather</td>
<td>Tornados, lightning, or other threatening weather conditions will result in an immediate shut down of operations and evacuation of personnel. Lightning proximity will be determined by measuring the time interval between the visually observed lightning flash and the subsequent sound of thunder. An interval less than 30 seconds will prompt the shut down. Operations will be shut down for the period of the storm passing plus an additional 20 minutes.</td>
</tr>
<tr>
<td>Material spill or release</td>
<td>Vehicles and equipment will be maintained and inspected so as to prevent fluid leaks. Should any vehicle fluid leaks occur the equipment will be taken out of service to make necessary repairs and any contaminated material will be clean-up and disposed of properly. Spill kits will be available to facilitate prompt containment and clean-up of spills. Notification will be made in accordance with the Incident Reporting and Investigation Procedure. Storage areas will be designed to have secondary containment as required, work plans executed to accommodate stormwater runoff and minimize the potential for contamination spread.</td>
</tr>
</tbody>
</table>
11 EMERGENCY CONTACTS

In the event of an emergency, the following contacts should be made, as appropriate:

HAFB Emergency Number (using HAFB phone system) .......................................... 9-911
Operators will assist with Medical, Fire, and Police emergencies

HAFB Security Force ......................................................................... (505) 572-5037

HAFB Fire Protection ........................................................................ (505) 572-1117

HAFB Hospital – 49th Medical Group (Main switchboard) ....................... (505) 572-2778

Civilian Hospital (Alamogordo) Gerald Champion Regional Medical Center......(505) 439-6100

After initial contacts have been made and the situation has stabilized, notify the Site Manager/SSHO, Senior Project Manager, and/or HSM, as appropriate.
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12 HOSPITAL DIRECTIONS

In the event of a true medical emergency ("life or limb"), HAFB Emergency Services should be used. Notification of any injury must be made to HAFB Emergency Services. Bhate personnel and subcontractors should not transport injured personnel to the HAFB Hospital without prior authorization from HAFB Emergency Services.

Other injuries should be treated as necessary at Gerald Champion Regional Medical Center at 2669 Scenic Drive, Alamogordo, NM 88330. From HAFB, exit the Main Gate and proceed east on US-70 onto US-54, continue north on US-54 to Indian Wells Road, turn right heading east to Scenic Drive, and turn left on Scenic proceed to the medical center. A map to this hospital is presented in Figure 12-1.
FIGURES
Figure 12-1. Hospital Route Map

Source: Microsoft Expedia Street Maps

HOSPITAL ROUTE MAP
Gerald Champion Regional Hospital
Not to Scale
### ATTACHMENT A

**ACTIVITY HAZARD ANALYSES (AHAS)**

<table>
<thead>
<tr>
<th>AHA No.</th>
<th>AHA Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHA - 1</td>
<td>General Site Activities, Mobilization, and Demobilization</td>
</tr>
<tr>
<td>AHA - 2</td>
<td>Soil Excavation and Loading</td>
</tr>
<tr>
<td>AHA - 3</td>
<td>Soils Placement and Land-farm Maintenance</td>
</tr>
</tbody>
</table>
## ATTACHMENT A

### ACTIVITY HAZARD ANALYSES (AHAS)

<table>
<thead>
<tr>
<th>AHA No.</th>
<th>AHA Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHA - 1</td>
<td>General Site Activities, Mobilization, and Demobilization</td>
</tr>
<tr>
<td>AHA - 2</td>
<td>Soil Excavation and Loading</td>
</tr>
<tr>
<td>AHA - 3</td>
<td>Soils Placement and Land-farm Maintenance</td>
</tr>
</tbody>
</table>
This page intentionally left blank.
## Activity Hazard Analysis (AHA) – 1

**Task:** General Site Activities; Site Mobilization, and Demobilization  
**Project:** SWMU 123

**Minimum Personal Protective Equipment (PPE):** Level D PPE  
**Location:** Holloman Air Force Base, New Mexico

<table>
<thead>
<tr>
<th>Activity</th>
<th>Potential Hazard(s)</th>
<th>Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>General site activities</td>
<td>Slips, trips, or falls on walking and working surfaces</td>
<td>• Maintain clean work areas by following good housekeeping procedures</td>
</tr>
<tr>
<td>Mobilization and Demobilization</td>
<td></td>
<td>• Be alert for uneven terrain and steep slopes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Wear slip resistant footwear when walking/working on slippery surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Keep work area free of dirt, grease, slippery materials, debris, and tools</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provide adequate lighting in all work areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Flag or cover work areas to protect against falls</td>
</tr>
<tr>
<td>Exposure to high noise from heavy</td>
<td></td>
<td>• Hearing protection will be worn with a noise reduction rating capable of</td>
</tr>
<tr>
<td>equipment and power tools</td>
<td></td>
<td>maintaining personal exposure below 85 decibels acoustic (dBA) (ear muffs or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>plugs); SSHO will determine the need for hearing protection; all equipment will</td>
</tr>
<tr>
<td></td>
<td></td>
<td>be equipped with manufacturer's required mufflers</td>
</tr>
<tr>
<td>Eye injury</td>
<td></td>
<td>• Use approved safety glasses with rigid side shields</td>
</tr>
<tr>
<td>Overhead hazards</td>
<td></td>
<td>• Personnel will be required to wear hard hats that meet ANSI Standard Z89.1 in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>all construction areas, and areas with overhead hazards</td>
</tr>
<tr>
<td>Dropped objects</td>
<td></td>
<td>• Steel toe boots meeting ANSI Standard Z41 will be worn in all construction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>areas</td>
</tr>
<tr>
<td>Back injury from lifting heavy</td>
<td></td>
<td>• Site personnel will be instructed on proper lifting techniques</td>
</tr>
<tr>
<td>loads</td>
<td></td>
<td>• Mechanical devices should be used to reduce manual handling of materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Team lifting should be utilized if mechanical devices are not available</td>
</tr>
<tr>
<td>Thermal Stressors (i.e. heat</td>
<td></td>
<td>• Employees will have appropriate clothing for variable weather</td>
</tr>
<tr>
<td>stress, cold stress)</td>
<td></td>
<td>• Wear long sleeves and long pants, sunscreen with a high sun protection factor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(SPF) on exposed skin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Employees will take breaks and drink plenty of fluids, as necessary, to prevent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>heat stress</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Refer to the Basewide HASP for detailed information on heat and cold stress</td>
</tr>
</tbody>
</table>

**Revision Date:** August 2005  
**Revision No. 00**  
**AHA – 1 - 1**
## AHA – 1 (continued)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Potential Hazard(s)</th>
<th>Control Measures</th>
</tr>
</thead>
</table>
| General site activities | Spills/Fire | • Fuel cans will be National Fire Protection Agency (NFPA) approved and used with pouring spout or funnel  
• Equipment shall be conducted in approved locations  
• Spill and absorbent materials will be readily available  
• Smoking and open flames are not permitted in fueling/greasing areas  
• All heavy equipment will be equipped with ABC type fire extinguishers which will be inspected monthly and documented |
| Mobilization and Demobilization (continued) | | |
| Vehicular traffic in work area and heavy equipment operation | | • Maintain awareness of vehicle movement in work area  
• Exercise caution when approaching heavy equipment  
• Equipment will be equipped with functioning back-up alarms, signal lamps and alerting horns. Operators are required to use seat belts. |
| Inclement weather | | • Halt activities immediately and take cover during thunderstorm or tornado warnings, shelter in a building if possible, stay away from windows  
• If outdoors, crouch close to ground and limit body surface in contact with ground by staying on feet  
• Listen to radio or TV announcements for pending weather information  
• Do not try to outrun a tornado on foot or in a vehicle |
| (Thunderstorms and tornadoes) | | |
| Extension cords | | • Extension cords shall be inspected daily  
• Extension cords that have faulty plugs, damaged insulation, or are unsafe in any way shall be removed from service  
• Cords shall be protected from damage from sharp edges, projection, pinch points (doorways) and vehicular traffic  
• Cords shall be designed for heavy duty use |

### Equipment Used

<table>
<thead>
<tr>
<th>Inspection Requirements</th>
<th>Training Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level D PPE</strong></td>
<td>Personnel have read and understand the work plan and AHA Site specific briefing</td>
</tr>
<tr>
<td>First Aid Kits</td>
<td>At least two individuals on-site will have current CPR and First aid training</td>
</tr>
<tr>
<td>Portable Eyewash</td>
<td></td>
</tr>
<tr>
<td>Fire Extinguishers</td>
<td></td>
</tr>
<tr>
<td>Mobilization Equipment</td>
<td></td>
</tr>
</tbody>
</table>
## Activity Hazard Analysis (AHA) – 2

**Task:** Excavation and Soil Loading  
**Project:** SWMU 123  
**Minimum Personal Protective Equipment (PPE):** Level D PPE  
**Location:** Holloman Air Force Base, New Mexico

<table>
<thead>
<tr>
<th>Activity</th>
<th>Potential Hazard(s)</th>
<th>Control Measures</th>
</tr>
</thead>
</table>
| Excavation                    | Overhead/buried utilities               | • Completion of a HAFB Excavation Permit is required prior to the start of construction activities  
                                 |                                         | • Overhead utilities should be considered live until determined otherwise. Maintain a minimum distance of 15 feet from overhead utilities  
                                 |                                         | • All underground utilities must be clearly marked before beginning work  
                                 | Heavy equipment operation              | • Construction equipment operators shall have the experience, skills, and knowledge to safely operate the equipment to be used  
                                 |                                         | • Personnel in areas in which heavy equipment is being operated shall wear high visibility traffic safety vests and make eye contact with the operator before approaching  
                                 |                                         | • Access to the work area shall be coordinated with the Site Manager  
                                 |                                         | • Equipment (including trucks) shall be inspected and documented at the beginning of each shift  
                                 |                                         | • Maintain awareness of vehicle movement in work area  
                                 |                                         | • Exercise caution when approaching heavy equipment  
                                 |                                         | • Equipment will be equipped with functioning back-up alarms, signal lamps and alerting horns. Operators are required to use seat belts  
                                 |                                         | • Signs, barricades, flagmen, and/or other traffic control devices will be used to control traffic in the work area  
                                 |                                         | • Buckets and attachments shall be placed on the ground if operator not at controls or if ground personal approach  
                                 | Excavation Safety                      | • Ensure equipment is placed so as to not contribute to a cave-in situation  
                                 |                                         | • No personnel will be allowed to enter the excavation unless the excavation has been properly inspected, shoring and means of egress installed as necessary, all heavy equipment has been moved away from the affected edges, and any spoils have been removed from the edge  
                                 |                                         | • Do not place spoil piles closer than 2 feet from the edge of the excavation  

---

Bhate Project No.: 9050197  
August 2005  
AHA – 2 - 1
## Health and Safety Plan
### Site-Specific Addendum

#### Hazards and Controls

<table>
<thead>
<tr>
<th>Equipment Used</th>
<th>Inspection Requirements</th>
<th>Training Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level D PPE</td>
<td>Inspect PPE before and after each use. First aid kits will be inspected weekly.</td>
<td>Training in PPE inspection, use, and maintenance is conducted as part of the initial hazardous waste 40-hour training. This training provides personnel with an understanding of the inspection, use (including donning, doffing, adjusting, and wearing), limitations, care, and maintenance of PPE. Personnel have read and understand the work plan and AHA Site-specific briefing.</td>
</tr>
<tr>
<td>First Aid Kits</td>
<td>First aid kits will be inspected weekly.</td>
<td></td>
</tr>
<tr>
<td>Portable Eyewash</td>
<td>Portable eye wash will be inspected weekly. Fire extinguishers will be inspected, maintained monthly and equipped with inspection tags. Daily inspections will be performed. Weekly inspections will be documented.</td>
<td></td>
</tr>
<tr>
<td>Fire Extinguishers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Equipment (Loader, Excavator, Haul Trucks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to soil contaminants</td>
<td>• Utilize appropriate PPE and decontamination procedures</td>
<td></td>
</tr>
<tr>
<td>Soils Loading</td>
<td>• Conduct work activities in a manner that minimizes potential contact with excavated materials</td>
<td></td>
</tr>
<tr>
<td>Soils Loading</td>
<td>Falling materials and flying debris striking personnel</td>
<td></td>
</tr>
<tr>
<td>Soils Loading</td>
<td>Loading equipment must have cab protection, functioning back-up alarms, signal lamps and alerting horns. Operators are required to use seat belts. Ground personnel are not permitted to approach equipment in motion or while materials being handled. Maintain clear radius of machine. Operator must minimize the amount of materials spilled on the exterior of trucks during loading operations.</td>
<td></td>
</tr>
<tr>
<td>Dust</td>
<td>Adequate dust suppression with water should be utilized to minimize visible dust emissions. If visible dust is prevalent, utilize personal dust monitor to evaluate.</td>
<td></td>
</tr>
<tr>
<td>Striking heavy equipment and operators</td>
<td>Construction equipment operators shall have the experience, skills, and knowledge to safely operate the equipment to be used</td>
<td></td>
</tr>
<tr>
<td>Overloading capacity</td>
<td>Equipment will be operated with cab doors and windows closed</td>
<td></td>
</tr>
<tr>
<td>Overloading capacity</td>
<td>Load charts of all equipment will be reviewed and followed</td>
<td></td>
</tr>
</tbody>
</table>
## Task: Soils Placement and Land-farm Maintenance

### Minimum Personal Protective Equipment (PPE): Level D PPE

### Location: Holloman Air Force Base, New Mexico

<table>
<thead>
<tr>
<th>Activity</th>
<th>Potential Hazard(s)</th>
<th>Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Placement and Land-farm Maintenance</td>
<td>Exposure to soil contaminants</td>
<td>• Utilize appropriate PPE and decontamination procedures.</td>
</tr>
<tr>
<td>Hazards and recommended controls from AHA-1</td>
<td></td>
<td>• Conduct work activities in a manner that minimizes potential contact with excavated materials.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Utilize placement method that minimizes haul truck traffic through contaminated material.</td>
</tr>
<tr>
<td>Heavy equipment operation</td>
<td></td>
<td>• Construction equipment operators shall have the experience, skills, and knowledge to safely operate the equipment to be used.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Personnel in areas in which heavy equipment is being operated shall wear high visibility traffic safety vests and make eye contact with the operator before approaching.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Access to the work area shall be coordinated with the Site Manager.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Equipment (including trucks) shall be inspected and documented at the beginning of each shift.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Maintain awareness of vehicle movement in work area.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Exercise caution when approaching heavy equipment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Equipment will be equipped with functioning back-up alarms, signal lamps and alerting horns. Operators are required to use seat belts.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Signs, barricades, flagmen, and/or other traffic control devices will be used to control traffic in the work area.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Buckets and attachments shall be placed on the ground if operator not at controls or if ground personnel approach.</td>
</tr>
</tbody>
</table>

Revision Date: August 2005
### Activity Hazard Analysis (AHA) – 3 (continued)

<table>
<thead>
<tr>
<th>Equipment Used</th>
<th>Inspection Requirements</th>
<th>Training Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level D PPE</td>
<td>Inspect PPE before and after each use.</td>
<td>Training in PPE inspection, use, and maintenance is conducted as part of the initial</td>
</tr>
<tr>
<td></td>
<td>First aid kits will be inspected weekly.</td>
<td>hazardous waste 40-hour training. This training provides personnel with an understanding</td>
</tr>
<tr>
<td>First Aid Kits</td>
<td>Portable eye wash will be inspected weekly.</td>
<td>of the inspection, use (including donning, doffing, adjusting, and wearing), limitations,</td>
</tr>
<tr>
<td>Portable Eyewash</td>
<td>Fire extinguishers will be inspected, maintained monthly and equipped with inspection tags.</td>
<td>care, and maintenance of PPE.</td>
</tr>
<tr>
<td>Fire Extinguishers</td>
<td>Daily inspections will be performed. Weekly inspections will be documented.</td>
<td>Personnel have read and understand the work plan and AHA</td>
</tr>
<tr>
<td>Heavy Equipment (Loader,</td>
<td></td>
<td>Site specific briefing</td>
</tr>
<tr>
<td>Excavator, Haul Trucks)</td>
<td></td>
<td>At least two individuals on-site will have current CPR and First aid training</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ATTACHMENT B

GENERAL WORK AND SAFETY RULES
ATTACHMENT B

GENERAL WORK AND SAFETY RULES

All site personnel will adhere to the following general safety rules. These precautionary measures are designed to reduce the risks of inadvertent or accidental injury or chemical exposure during onsite operations.

1. All site personnel must attend each day's Daily Safety Briefing.
2. Be familiar with standard operating procedures and adhere to all instructions and requirements in the Corporate Health and Safety Plan or SSHP.
3. Any individual taking prescribed drugs shall inform the SSHO of the type of medication. The SSHO will review the matter with the HSM, as necessary, who will decide if the employee can safely work onsite while taking the medication.
4. Medicine and alcohol can exacerbate the effects from exposure to toxic chemicals. While field operations are in effect, alcoholic beverage intake should be minimized or avoided during off-work hours. Personnel performing onsite operations should not take prescribed drugs where the potential for absorption, inhalation, or ingestion of toxic substances exists unless specifically approved by a qualified physician. Do not work when ill.
5. The personal protective equipment specified by the Corporate Health and Safety Plan or SSHP shall be worn by all site personnel. This includes hard hats and safety glasses which must be worn at all times in active work areas.
6. Facial hair (beards, long sideburns, or mustaches) which may interfere with a satisfactory fit of a respirator mask is not allowed on any person who may be required to wear a respirator.
7. Eating, drinking, chewing tobacco or gum, smoking, and any other practice that may increase the possibility of hand-to-mouth contact is prohibited in the work area. (Exceptions may be permitted by the SSHO to allow fluid intake during heat stress conditions.)
8. All lighters, matches, cigarettes, and other forms of tobacco are prohibited in the work area.
9. All signs and demarcations shall be followed. Such signs and demarcations shall not be removed except as authorized by the SSHO.
10. No one shall enter a permit-required confined space without a permit. Confined space entry permits shall be implemented as issued.
11. All personnel must follow Hot Work Permits as issued.
12. All personnel must follow the work-rest regimens and other practices required by the heat stress program.
13. Rest breaks shall be taken in approved locations.
14. All personnel must follow lockout/tagout procedures when working on equipment involving moving parts or hazardous energy sources.
15. No person shall operate equipment unless trained and authorized.
16. No one may enter an excavation greater than 4 feet deep unless authorized by the Competent Person. Excavations must be sloped or shored properly. Safe means of access and egress from excavations must be maintained.

17. Ladders and scaffolds shall be solidly constructed, in good working condition, and inspected prior to use. No one may use defective ladders or scaffolds.

18. Fall protection or fall arrest systems must be in place when working at elevations greater than 6 feet for temporary working surfaces and 4 feet for fixed platforms.

19. Safety belts, harnesses, and lanyards must be selected by the Site Manager. The user must inspect the equipment prior to use. No defective personal fall protection equipment shall be used. Personal fall protection that has been shock loaded must be discarded.

20. Hand and portable power tools must be inspected prior to use. Defective tools and equipment shall not be used.

21. Ground fault interrupters shall be used for cord and plug equipment used outdoors or in damp locations. Electrical cords shall be kept out of walkways and puddles unless protected and rated for the service.

22. Improper use, mishandling, or tampering with health and safety equipment and samples is prohibited.

23. Horseplay of any kind is prohibited.

24. Possession or use of alcoholic beverages, controlled substances or firearms on any site is forbidden.

25. All incidents, no matter how minor must be reported immediately to the Site Manager.

26. All personnel shall be familiar with the Site Emergency Response Plan.

The above health and safety rules are not all inclusive and it is your responsibility to comply with all regulations set forth by OSHA, the Bhate Corporate Health and Safety Plan, SSHPs, or our Clients.