February 13, 1995  
WCFS Project No. F93102

U.S. Army Corps of Engineers  
Tulsa District  
ATTN: Mr. Walter Kneib (CESWT-EC-DR)  
P.O. Box 61  
1645 South 101st East Avenue  
Tulsa, Oklahoma 74121-0061

Re: Transmittal of Final Project Planning Documents  
RCRA Facility Investigation  
Temperature Test Facility  
White Sands Missile Range, New Mexico

Dear Mr. Kneib:

Transmitted with this letter please find twelve (12) copies of the final project planning documents for the RCRA Facility Investigation at the Temperature Test Facility, White Sands Missile Range, New Mexico. Enclosed in Volume I is the final Project Work Plan (PWP), the final Field Sampling and Analysis Plan (FSAP), and the final Chemical Data Acquisition Plan (CDAP). Enclosed in Volume II is the final Health and Safety Program Plan (HSPP) and the final Community Relations Plan (CRP).

Our current schedule calls for WCFS and subcontractor personnel to mobilize to the field on March 6, 1995 and attend the site work briefing to be conducted by USACE on March 7, 1995.

We look forward to continuing on with this project. Please feel free to contact us if you have any questions.

Very truly yours,

David C. Convy  
Project Manager

enclosure

Douglas E. Fiscus  
Program Manager
WORK PLAN
FOR THE
RCRA FACILITY
INVESTIGATION
AT THE
TEMPERATURE TEST
FACILITY
WHITE SANDS
MISSILE RANGE;
NEW MEXICO

Prepared for
Department of the Army
U.S. Army Engineers District
Tulsa District Corps of Engineers
Tulsa, Oklahoma
February 1995

Woodward-Clyde Federal Services
10975 El Monte, Suite 100
Overland Park, Kansas 66211
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<td>Atomic Adsorption</td>
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<td>bgs</td>
<td>below ground surface</td>
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<td>gpm</td>
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<td>IDW</td>
<td>Investigation Derived Waste</td>
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<td>MAR</td>
<td>Multifunction Array Radar</td>
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<td>Definition</td>
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<td>MeCl</td>
<td>Methylene Chloride</td>
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<td>MCL</td>
<td>Maximum Contaminant Level; established under the Safe Drinking Water Act. An MCL is the maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system</td>
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<td>U.S. Army Corps of Engineers (see COE)</td>
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<td>VOA</td>
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<td>Volatile Organic Compound</td>
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1.1 INTRODUCTION

Woodward-Clyde Federal Services (WCFS) has been contracted by the Tulsa District, U. S. Army Corps of Engineers (USACE) on behalf of White Sands Missile Range (WSMR) to conduct a RCRA Facility Investigation (RFI) at the Temperature Test Facility (TTF) at the U. S. Army Installation in southeastern New Mexico. The TTF was designed to simulate extreme weather conditions by inducing a wide range of temperature and climatic variations. The WSMR is investigating past hazardous waste management practices and potential releases at the TTF and other solid waste management (SWMUs) at the facility. The TTF is being proposed as SWMU #101 in Appendix III of the Installations Hazardous Waste Permit which became effective October 24, 1989.

This document is the Work Plan for the RFI activities at the TTF and presents the objectives of the investigation and information on project management, data management, schedule and budget.

1.1.1 Objective and Scope of Investigation

WCFS will perform RFI activities at the TTF to delineate the vertical and horizontal extent of the previous MeCl spill, identify release sources, and provide sufficient data to perform a CMS.

In order to accomplish the stated objectives, WCFS will collect soil gas and soil samples in the areas of the TTF where previous investigations have not fully characterized the impact from a known release of methylene chloride (MeCl). These areas include the floor drain system which received the MeCl spill and transported it to the former evaporation pond. Testing of the floor drain system indicated the system does leak. While the drain lines do not represent a current source of contamination to the environment, potentially contaminated soil surrounding the lines may be a source. Therefore, up to 100 shallow soil gas samples and not to exceed 9 deep soil gas samples (at depths up to approximately 100 feet below
ground surface) will be collected and analyzed in the field for MeCl, trichloroethylene (TCE), tetrachloroethylene (PCE), 1,1,1-trichloroethane (TCA), 1,1-dichloroethene (DCE), 1,1-dichloroethane (DCA), chloroform, Freon 22, Freon 503, Freon 113, Freon 11. The TCE, PCE, and TCA are suspected to be contaminants in the MeCl originally used as refrigerant. The DCE, DCA, and chloroform were detected when the existing soil gas monitoring wells were sampled in June 1994. The various freons are either used at the facility or, in the case of Freon 11, have been identified in previous investigations as being present in the subsurface.

In addition, ten soil borings to an average of 100 feet will be installed and soil samples collected approximately every 10 feet for analysis of volatile organic compounds (VOC) by EPA Method 8240. WCFS will also sample the existing groundwater monitoring wells and the existing soil gas monitoring wells. Samples from the soil gas monitoring wells will be screened in the field for the compounds listed above and sent to an off-site analytical laboratory for VOC analysis. (Note: The existing soil gas monitoring wells were sampled in June 1994).

Upon completion of the field investigation and data collection activities, an RFI report will be prepared documenting the RFI activities and findings. The field data and analytical results of samples collected during the RFI will be used to characterize the nature and extent of contamination at the TTF. The data will be evaluated and analyzed to further define the contamination type, source or sources, extent, direction, rate of migration and distance the contamination has traveled at the facility. Inter-media transfer of contaminants will also be addressed as appropriate and the data will be interpreted to evaluate the characteristics of the release against established health and environmental criteria to evaluate the need for corrective measures.

1.1.2 Organization of Work Plan

This work plan and the supporting documents are intended to present the objectives and a means for documenting the RFI activities at the TTF. The work plan is based on guidance found in the Interim Final RCRA Facility Investigation (RFI) Guidance (EPA, 1989). Additional information was also obtained from RFI work plans developed by Sverdrup
Environmental, Inc. (SvE, 1993) for other solid waste management units located at the WSMR facility.

The work plan is presented in the following sections:

- Section 1.0 presents the introduction, objective and scope of investigation, site background including history of the TTF and a description of the regional geology and hydrogeology, a summary of previous investigations, and a pre-investigation evaluation of corrective measures technologies

- Section 2.0 presents an overview of the RFI activities to be conducted at the TTF and describes the tasks to be implemented in accordance with this work plan

- Section 3.0 presents the Project Management Plan (PMP) which identifies key personnel for WSMR, USACE, and WCFS, as well as identifying the proposed subcontractors, and highlighting the schedule

- Section 4.0 presents the Data Management Plan (DMP) which describes how data and documentation will be maintained, which software will be used, the types and content of reports to be prepared, and a proposed outline for the RFI Report

- Section 5.0 introduces the Field Sampling and Analysis Plan (FSAP) and briefly describes the elements contained therein

- Section 6.0 introduces the Chemical Data Acquisition Plan (CDAP) and briefly describes the elements contained therein

- Section 7.0 introduces the Health and Safety Program Plan (HSPP) and briefly describes the elements contained therein including the unexploded ordnance plan

- Section 8.0 introduces the Community Relations Plan (CRP) and briefly describes the elements contained therein

- Section 9.0 presents the references

- Appendix A is the FSAP

- Appendix B is the CDAP
1.2 SITE BACKGROUND

The following section presents a brief history of the WSMR and an overview of the physical characteristics of the area.

1.2.1 History

1.2.1.1 White Sands Missile Range

WSMR was established July 9, 1945, as White Sands Proving Ground. One week later, on July 16, 1945, the world’s first atomic device was detonated, on the northern portion of the range, at an area now known as Trinity Site. Missile testing began in September 1945. The name was officially changed to WSMR in 1958.

The New Mexico desert was selected for the nation’s first rocket center for several reasons: the land was already controlled or owned by the government, the area had almost year-round clear weather and unlimited visibility, the desert was sparsely populated, and it afforded relatively easy recovery of spent missiles.

WSMR represents the consolidation of six component parcels of land in the Tularosa Basin of central New Mexico. The parcels included are:

- The Fort Bliss Transfer Area (formerly part of the Fort Bliss Anti-Aircraft Range),
- The Alamogordo Bombing Range (used for bombing and training missions prior to 1945)
- The San Andres National Wildlife Refuge
- The Jornada Experimental Range
- The Ordnance/California Institute of Technology Area.
This land consolidation was known as the Department of Defense "Integrated Range." In May 1952, all public lands in the Integrated Range were placed under the responsibility of the Department of the Army. In 1963, the Air Force transferred all its leases to the Army, with the exception of the Holloman Supplemental Area and Holloman Air Force Base. In 1959, the Army established the Range Extension Area, approximately 25 square miles, as a co-use area for missile systems with a required trajectory over 100 miles.

Much of the WSMR lands are under exclusive use leases with Federal, State and private owners. Since 1969, efforts have been made to acquire the state and private lands and to extinguish the grazing and mining rights through condemnation proceedings. As of May 1978, some 54,980 acres of private land had been acquired through condemnation proceedings in Federal Court, leaving approximately 16,055 acres to be obtained. The Range Extension Area north of WSMR is co-used with residents who are evacuated during missile missions. Although no specific impact areas are present within the extension, its control is required for safety and security.

1.2.1.2 Temperature Test Facility (TTF)

The contract for construction of the TTF was awarded by the U.S. Army Corps of Engineers on September 25, 1981. The TTF was turned over to WSMR for beneficial occupancy on January 27, 1984. The TTF was designed to simulate extreme weather conditions by inducing a wide range of temperature and climatic variations including freezing rain. Materials and equipment are tested under these extreme conditions to determine their capabilities under climatic duress. However, the facility was initially unable to perform its mission due to a variety of problems, one of which was excessive leakage of refrigerant from the numerous gaskets in the secondary cooling system.

Refrigerants (halogenated hydrocarbons) are required for the operational demands of the facility. MeCl was used extensively for this purpose in early operations. MeCl was stored in underground tanks immediately east of the TTF building. These tanks were part of a "closed loop" system designed to permit the recirculation and reuse of the refrigerant. The secondary cooling system, which includes units both inside and outside the TTF building, is a closed pressurized loop including numerous expansion and storage tanks. Although originally designed to use MeCl as a heat transfer medium, in 1991 after major redesign of
the facility, MeCl was replaced with Syltherm. The original design also did not include a relief tank for refrigerant, and the relief tank was added to the system in July 1984.

Syltherm is used at the TTF as the heat transfer medium (brine). The brine flows directly through the heat exchangers in order to control the temperature of the two large test chambers. Within the three brine loops (hot, cold, ambient) is contained approximately 15,000 gallons of Syltherm.

Syltherm replaced methylene chloride, the original facility brine, for several reasons:

- Methylene chloride readily vaporizes as it escapes through shaft seals, flanges and other small leaks throughout the facility brine loops. The contractor who maintained and operated the facility had to purchase up to three 1500 gallon tankloads of methylene chloride per year.
- Since the methylene chloride escaped in large quantities, the TTF was a registered RCRA air pollutant facility.
- Methylene chloride poses a breathing air health hazard for workers since it readily vaporizes to contaminate the work environment.

The primary cooling system is located entirely within the TTF building. Refrigerants used in the primary cooling system include Freon 22 and Freon 503. Freon 113 has also been used at the TTF mainly as a cleaning agent.

All tanks are pressurized during facility operation except for the relief tank, which receives the flow from relief valves located along the pressurized system within the building and stores the refrigerant for reuse. The relief tank was pumped periodically, and the refrigerant from it returned to the system via a small process tank located inside the TTF building.

Water generated by freezing rain experiments and other processes, was piped by gravity flow from floor drains in the TTF building into a 1,050 gallon interceptor/storage tank about 150 feet southeast of the building. Initially the liquids were drained to a 10,000-square foot surface area, polyvinyl chloride (PVC) - lined evaporation pond. The pond was approximately 200 feet east of the TTF building and was used until about January 1985. Leakage of seals in the refrigeration loop permitted the refrigerants to enter water that was
discharged to the evaporation pond. Sewage and other non-process wastewater from the facility was piped to a drain field north of the evaporation pond.

The original PVC-lined wastewater evaporation pond was not engineered to receive or hold water containing significant quantities of solvents. However, a release of MeCl in July 1983 and loss of refrigerants within the TTF building led to their subsequent transfer via floor drains to the evaporation pond. Introduction of MeCl containing TCA, TCE, and PCE to the pond caused damage to the PVC liner and infiltration of water containing the halogenated hydrocarbons into the unsaturated zone. The date when infiltration of the wastewater began (the initial failure of the PVC liner) is not exactly known, but probably occurred about January 1984.

In January 1985, the personnel of the TTF at WSMR discovered that the evaporation pond at the facility had lost integrity, resulting in the release of the contaminants to the soil. WSMR has performed an assessment of the subsurface contamination, conducted extensive closure activities (WSMR 1992a), proceeded with post-closure activities (WSMR 1992b), and has taken steps to remediate the TTF site.

1.2.2 Location and Setting

WSMR is a U.S. Army Installation under the jurisdiction of the U.S. Army Test and Evaluation Command (TECOM). WSMR lies within the Mexican highland section of the basin and range province in Dona Ana, Socorro, Lincoln, Otero and Sierra counties, New Mexico. The major portion of WSMR lies within the Tularosa Basin and the northwest portion lies within the Jornada del Muerto Basin, the eastern limit of Tularosa Basin lies just outside WSMR proper, and is formed from north-to-south by the Jicarilla, Sierra Blanca and Sacramento mountains. The total land area for WSMR is approximately 6,700 square miles, making WSMR the largest land-area military installation in the U.S. The headquarters and all Installation support activities are located at the Main Post Area of WSMR, which is in the southwestern corner of the Installation near the San Augustine Pass which separates the Organ and San Augustine Mountains. U.S. Highway 70 crosses through this pass. The WSMR regional setting is shown in Figure 1-1.
WSMR is primarily located within an enclosed basin called the Tularosa Basin although a part of the Installation lies within the Jornada del Muerto Basin. Centrally located on the range is a 300-square-mile area which contains White Sands National Monument and the Alkalai Flats. The basin is bordered by the San Andres Mountains to the west and the Jicarilla, Sierra Blanca and Sacramento Mountains to the east of WSMR.

The terrain of WSMR varies from desert flats to rugged mountains. Most of the mountain area is a very steep, broken, strong rock land. Rock land dominates the area overshadowing any particular soil type. Most surface drainage is toward the center of the range in the vicinity of Lake Lucero and the Alkali Flats. A perennial surface water stream is created by sewage treatment plant effluent located five miles east of the main post sewage treatment plant.

The TTF is located in Dona Ana County, New Mexico, about 20 miles northeast of Las Cruces. It is within the boundaries of WSMR, and is about 2.5 miles east of the Main Post. The TTF lies at an elevation of approximately 4,010 feet in the southwestern part of the Tularosa Basin. The location of the TTF relative to Main Post is shown in Figure 1-1.

1.2.3 Regional Geology

WSMR lies within the Mexican Highland Section of the Basin and Range Province. This physiographic section is characterized by a series of tilted fault blocks forming longitudinal, asymmetric ridges or mountains, and broad intervening basins. As stated above, the major portion of WSMR lies within the Tularosa Basin which is a down faulted graben about 6,500 square miles in area in the eastern part of the province; the northwest portion lies within the Jornada del Muerto Basin. The basin is bounded on the west by the Organ and San Andres Mountains, which are separated by St. Augustine Pass. Approximately five miles further to the northeast are the Oscura Mountains which extend to the northern range boundary. The eastern limit of Tularosa Basin lies just outside WSMR proper, and is formed from north-to-south by the Jicarilla, Sierra Blanca and Sacramento Mountains.

The TTF is located in the southwestern part of the Tularosa Basin. The TTF lies near the mouth of a structural embayment which separates the Organ Mountains and the San Augustin Mountains on the southwestern margin of the basin.
The Precambrian granite and quartzite basement complex is overlain by Pennsylvanian age rocks in the northern third of the WSMR area and early Paleozoic rocks in the southern two-thirds of the WSMR. Rocks of Permian age overlie the Pennsylvanian rocks, possibly disconformably. Triassic strata lie, apparently conformably, on the Permian rocks. A thick sequence of Cretaceous rocks overlie Triassic rocks and generally is best exposed in the eastern and northwestern parts of the area.

Tertiary and Quaternary sediments were derived by weathering, principally from Paleozoic and Mesozoic age rocks. These deposits generally have a chemical and mineralogic character similar to those of the rocks from which they were derived.

Quaternary age sediments are widespread through the area and are thickest in the Tularosa Basin and the Jornada del Muerto Basins. These deposits consist mainly of silt, sand, and gravel weathered from the mountain masses surrounding the basins. Thus, these deposits contain materials derived from rocks ranging in age from Precambrian through Tertiary. The maximum thickness of Quaternary alluvium ranges from about 150 feet under the Rio Grande floodplain to 500 feet or more in some parts of the Tularosa and the Jornada del Muerto Basins.

The basin fill underlying the vicinity of the TTF consists of bolson deposits, probable playa deposits, aeolian and fluvial facies and distal alluvial - fan deposits emanating from the Organ Mountains 4 miles west of the site. These deposits are generally porous, and are composed of poorly consolidated clays, silts, sands and gravels. Nine alluvial fill units were defined in the upper part of the unsaturated zone at the TTF during previous investigations and are shown in Figure 1-3. Due to lateral shifting of drainages during deposition, the alluvium contains an irregularly stacked sequence of coarse (channel) and fine (overbank) deposits. Relatively thick lenses of clays and silts may have been deposited in closed basins containing dry lakes (playas), such as Lake Lucero, north of the TTF. Older soil horizons (paleosols) may be recognized locally as fine-grained caliche layers or oxidized zones, or by the presence of root molds.
1.2.4 Regional Hydrogeology

The primary aquifer in the Main Post area is a wedge-shaped unconfined aquifer in the bolson deposits of the Tularosa Basin. Recharge for the aquifer is supplied by drainage from the alluvial fans and infiltration of storm run-off in natural depressions on the bolson surface. Beneath and to the east of the freshwater wedge, the groundwater is saline. Dependent upon groundwater withdrawal rates, depth to groundwater in the Main Post area may be greater than 350 feet. The source of the groundwater at WSMR is from precipitation, of which only 25 percent reaches the saturated zone. Yearly precipitation ranges from less than 7 inches in the Tularosa Basin to 25 inches in the higher mountains. At present, the only groundwater use within 5 miles of the TTF is the WSMR Main Post well field, centered upgradient about 3 miles northwest of the TTF.

In many of the outlying areas, the quality of the groundwater is poor due to very high dissolved solids content. The natural groundwater flow direction in the Main Post Area is to the east, toward the center of the valley. In the Main Post area, groundwater flow is greatly affected by pumping from the Main Post well field, which provides potable water for the Main Post and adjacent facilities. The overall impact on groundwater elevation and flow direction varies with the rate of pumping from each well and with recharge from the vicinity of the mountains to the west. Under static, non-pumping conditions, groundwater elevation may be expected to vary from 200 to 300 feet below general ground level in the Post area.

Because of the enormous size of the Installation, each work area has its own potable water distribution system rather than one system for the entire Installation.

The central part of the Tularosa Basin, east of the Main Post, contains saline water. Of particular significance to the groundwater resources of the Main Post Area is the re-entrant or indentation of a large alluvial apron into the Organ Mountains. Seemingly, this re-entrant has entrapped a larger quantity of freshwater than commonly occurs along the mountain front, and is a major groundwater source for the Main Post Area.

Eleven water wells located throughout the Main Post Area have a combined capacity in excess of 14 million gallons per day. The average depth of the wells is approximately
768 feet which encounter a maximum thickness of 709 feet of saturated unconsolidated sand, gravel and clay. The water level depth in the 11 wells ranges from 305 to 400 feet below the surface. It is estimated that the water-bearing zone could be up to 1,722 feet thick near the western edge of the basin and pinches out just west of the Don Anna-Otero County boundary where saline water is encountered.

No central water treatment plant is utilized in the Main Post Area. There is, however, a central chlorine station where all well water, prior to entering the distribution network, is chlorinated and the potable water for the housing area is fluoridated. The distribution network consists of 6- to 12-inch-diameter asbestos cement, cast iron and galvanized lines, and three elevated and two ground storage tanks.

The Small Missile Range (SMR) is located some 6.8 miles north of the Main Post Area and overlies a potable water aquifer. Potable water for this site is supplied by one well with a capacity of 73 gallons per minute (gpm).

The High Energy Laser System Test Facility (HELSTF) area lies some 11 miles north of the SMR complex. Two wells located 8.1 miles from the site supply 120 to 140 gpm of potable water to a ground level storage tank at the HELSTF site.

The Stallion Range Center (SRC) is in the northwestern sector of the Installation. Two wells produce non-potable water to an electrodialysis plant. This plant was installed in 1969 and consists of two desalination units in one building; each unit is capable of producing 50 to 66 gallons of potable water per day. A ground storage tank, distribution lines, and pumps furnish potable water within the SRC.

Because there are no potable water sources at other range stations, water is hauled by tanker to these locations. Included are such areas as North Oscura Peak and Crew Shelter, Oscura Range Center, Salinas Peak Crew Shelter, Rhodes Canyon Range Center, and many instrumentation sites throughout the range. Each site is equipped with storage tanks and small water pressure systems as required.
1.2.5 Hydrology

The Tularosa Basin is a closed groundwater basin in which any precipitation which is not rapidly evaporated flows centripetally toward playas in the central part of the basin. Groundwater in the Tularosa Basin is contained in an unconfined, water-table aquifer whose upper surface approximately parallels the surface topography of the alluvial fill (GCL, 1987).

West of the TTF, the water table lies approximately 200 feet below the land surface and has a gradient of about 0.008 (42 feet per mile) to the east. The gradient decreases to less than 0.002 (10 feet per mile) in the vicinity of the TTF and lies approximately 220 feet below the land surface. The aquifer underlying the TTF is used as the source of domestic and process water for the WSMR Headquarters area and other facilities. A groundwater divide is located between the TTF and the WSMR supply wells, imposed as the result of flow reversal in the cone of depression produced by the well field. Pumpage by WSMR supply wells has produced a large cone of depression centered about 1.5 miles north of the Headquarters area. Continued pumpage can be expected to cause eastward and southeastward expansion of this cone of depression, reducing the elevation of the water table along the groundwater divide to the southeast of the cone of depression (GCL, 1987). Groundwater levels in the vicinity of the supply wells have declined as much as 75 feet since 1949 as a result of pumping.

In a study by Geoscience Consultants Ltd. (GCL, 1987), the maximum additional drawdown or decline in groundwater levels near the TTF over a period of 30 years from the present would reduce the groundwater elevation in the Main Post well field to an elevation of about 3,860 feet. Since the present groundwater elevation at the TTF is 3,812 feet, this appears insufficient to induce reversal of the flow from TTF, thus a groundwater divide will still exist between TTF and the Main Post well field.

Aquifer transmissivity estimates for wells in the vicinity of WSMR Headquarters range from 160 ft²/day to 79,000 ft²/day, with wells in close proximity to each other commonly showing a wide range of values (Orr and Myers, 1986). The wide variance in aquifer test results may be caused by a variety of factors, including, heterogeneity of the alluvial fill, particularly with regard to grain size, varying well completion methods and depths, and boundary effects imposed by bedrock in the subsurface within a short distance of many supply wells.
Groundwater in the vicinity of the WSMR Post Headquarters is moderately hard, but of good quality for domestic use. Eleven supply wells north and east of the Post Headquarters presently derive water from the alluvial aquifer. Dissolved solids in groundwater increase with distance eastward from the mountain front, reflecting the increased residence time of water moving from the mountain front toward the center of the Tularosa Basin. In 1985, well T-14, located at Hood Tank, 1.5 miles northeast of the TTF, yielded a water sample from a depth of 300 feet below the land surface which had a specific conductance of over 2,000 micromhos per centimeter, more than twice that of other wells in the WSMR Post Headquarters area. The dissolved solids concentration of groundwater is commonly about 0.65 times the specific conductance, indicating that this water sample from well T-14 had a total dissolved solids concentration of about 1,300 mg/l. Dissolved solids increase further with increasing distance east of the site and with increasing depth in the aquifer (Doty and Cooper, 1970 and McLean, 1975).

1.2.6 Meteorology and Climatology

The climate of the southern Tularosa Basin is arid to semi-arid with average annual precipitation of about 8 inches per year. Most of the rain is produced by local convective thunderstorms during the summer months. At the White Sands National Monument, 30 miles northeast of the TTF, average annual precipitation is 8.11 inches, 4.68 inches of which is recorded during the months of June through September; mean annual snowfall is 2.3 inches. At Las Cruces, 20 miles southwest of the TTF and southwest of the Organ Mountains, average annual precipitation is 8.49 inches, 5.12 inches of which falls during June through September; mean annual snowfall is 3.3 inches. Mean monthly temperatures at White Sands National Monument range from 39.7 degrees Fahrenheit (December) to 80.6 degrees Fahrenheit (July); those at Las Cruces range from 41.6 degrees Fahrenheit (January) to 79.5 degrees Fahrenheit (July).

WSMR Main Post is at an elevation of almost 4,000 feet. Snowfall is infrequent, although heavy snows have occurred. With an average rainfall of only 10.8 inches, mostly occurring during late summer as thunderstorms, often accompanied by hail, it is considered a dry area. Intense localized storms have caused flash flooding in the past. The average summer high temperature is 92 degrees Fahrenheit with lows of about 65 degrees Fahrenheit. During the
winter months (December through February), the average high is 57 degrees Fahrenheit, with an average low of 36 degrees Fahrenheit. Average annual humidity 37 percent.

Wind is the dominant climatic factor at WSMR, especially from February through May. The prevailing southerly winds blow unimpeded across the desert and at times reach gale proportions. Wind storms may last for days in the spring.

Very little surface water exists on WSMR due to the low precipitation and high evaporation rates. An exception is during intense localized storms during which flash flooding can occur. The TTF area is not within the 100-year flood plain. Surface drainage in the region originates in the mountains and flows across the alluvial fans. This drainage terminates in Lake Lucero, the lowest portion of the basin. Accumulations of storm run-off in natural depressions on the bolson surface provides recharge for the primary aquifer in the Main Post area. Although the local drainage courses are oriented toward the center of the basin, the overall drainage is to the south.

Salt Creek originates at the southern end of the Oscura Mountains and empties into the Alkali Flats. Three Rivers Creek originates in the Sacramento Mountains east of WSMR and also terminates in the Alkali Flats. These two creeks and several smaller creeks are dry except immediately following excessive rainfall or snow melt in the mountains. One large spring (Malpais Spring) on the southwest edge of the eastern lava flow discharges to the basin floor. Lake Lucero contains gypsum water and the Malpais Springs are saline. None of the surface water on the Installation is potable.

1.2.7 Demography and Land Use

Statistics for fiscal year 1989 (October 1, 1988 through September 30, 1989) indicate an Installation workforce of 9,527. Civilian (U.S. Government) personnel totaled 4,542, while military and contractor personnel totaled 1,078 and 3,907, respectively.

The 1989 statistics revealed that 15 percent of the employees lived at WSMR proper. The Las Cruces area housed 50 percent, the majority of WSMR employees. The El Paso area claimed 18 percent. Twelve percent of the employees lived in the Alamogordo area and the remaining 5 percent lived in other areas. There were 1,271 family members living on the
The "noon-time" Post population, including all family members living on WSMR and all employees, was 10,798.

The WSMR encompasses more area than the States of Delaware and Rhode Island, and the District of Columbia combined. WSMR principally uses the land for rocket and missile testing. There exist co-use areas that nearly double the size of the range. The areas are inhabited largely by ranching families.

1.2.8 Ecology

The WSMR is in a true desert and contains a large diversity of ecological habitat. The biota are specially adapted to a xeric existence. The white gypsum (calcium sulfate: CaSO₄) dunes are the habitat from which the Installation takes its name. Most of the dunes and surrounding flats are protected as White Sands National Monument, which is operated by the National Park Service, U.S. Department of the Interior. However, significant portions of the dunes, as well as the ultimate source of the gypsum, in the San Andres Mountains, occur on Army property.

The Tularosa Basin contains typical xerophilous species. Some grasses, native to the Chihuahuan Desert, are making a comeback on the Installation because valley lands have been protected from cattle grazing for the past few decades. The biota on WSMR sharply contrasts with that found in the Tularosa Valley. Large trees and alpine plants occupy highland areas near the mountain crests. The San Andres Mountains harbor the last known viable New Mexican population of desert bighorn sheep. The sheep are protected within the remote San Andres National Wildlife Refuge, an island within WSMR which is administered by the U.S. Fish and Wildlife Service, Department of the Interior.

WSMR and adjacent areas are home to the White Sands pupfish, (Cyprinodon tularosa). This species exists only in Malpais Spring (on the Installation) and nearby Salt Creek (also on the Installation); it is the only fish known to inhabit the floor of the Tularosa Valley. The pupfish is on the New Mexico Protected Species List, and has been recommended for Federal protection.
The northwestern boundary of WSMR lies very close to Bosque del Apache National Wildlife Refuge. The refuge serves as a major wintering ground for tens of thousands of sandhill cranes and snow geese. The refuge also has been designated as the wintering ground for the western population of whooping cranes; as a result, a few whooping cranes are overwintering at Bosque del Apache.

Since both snow geese and sandhill cranes have been observed on WSMR, it is likely that whooping cranes also fly onto WSMR.

1.3 SUMMARY OF PREVIOUS INVESTIGATIONS

This section presents discussions of previous investigations pertaining to the TTF. Included in chronological order are the summaries from previous investigations conducted by Southwest Engineering, Geoscience Consultants Ltd. (GCL, 1987), Bath & Associates, Inc. (1989), ERC Environmental and Energy Services (1990), and Cortez III Environmental Services (1992).

1.3.1 Southwest Engineering

In response to the release of potentially contaminated waters into the subsurface, soil borings were completed under the direction of WSMR personnel. Nine soil borings were completed by Southwest Engineering, Inc. of Las Cruces, New Mexico. Analytical results from these borings indicated the MeCl contamination of alluvial units underlying the site had occurred. The largest contamination seemed to be isolated in the silty and clayey strata between 50 and 75 feet below ground surface.

1.3.2 Geoscience Consultants Ltd. (1985, 1986)

Following the initial borings completed by Southwest Engineering, GCL commenced a phased field investigation program to perform an additional assessment. The purpose of the GCL assessment was to define the lateral and vertical extent of contamination and to estimate the mass of contaminant in the soil. GCL initiated their study in June 1985 and completed the Final Contamination Assessment Report in May 1987.
Their field work included a soil gas survey, a shallow and deep borehole sampling program, installation of vadose zone monitoring wells, and installation and sampling of groundwater monitoring wells.

1.3.2.1 Soil Gas Survey

During June and July 1985, a shallow soil gas survey was conducted in the vicinity of the evaporation pond. The primary objective of the survey was to define the concentrations of contaminants in the shallow soil gas and delineate their extent surrounding the evaporation pond. Soil gas samples were collected from a total of 50 locations from a depth of 5 to 6 feet in the vicinity of the TTF. The soil gas survey indicated that contamination existed beneath the site from at least four compounds; MeCl, TCE, TCA, and PCE. The highest concentrations of MeCl detected (270 and 750 µg/l) in the shallow soil gas were at sampling locations near the southwest corner of the evaporation pond. In the area northwest of the evaporation pond, between the pond and the TTF building, soil gas analysis for MeCl was inhibited by the presence of an unidentified component. The component is suspected to be a Freon compound, a component known to have been used in the TTF facility. Because of the interference by this component, the detection limit for MeCl was elevated to 20 µg/l for points near the southeast corner and east of the TTF building.

In addition to MeCl, three other chlorinated hydrocarbons (TCA, TCE, and PCE) were detected during the GCL investigation of the shallow soil gas. TCA was present at concentrations of up to 200 µg/l beneath the evaporation pond, and the detected TCA plume extent was determined to be greater than the MeCl plume. TCA was also detected at 90 µg/l near the relief valve approximately 100 feet east of the TTF building. Both TCE and PCE were found in the shallow soil gas at slightly lower concentrations than TCA. As with TCA, the highest concentrations of TCE and PCE detected were beneath the southern end of the evaporation pond and near the relief valve.

1.3.2.2 Soil Boring Program and Installation of Vadose Zone Monitoring Wells

From the information gained in the soil gas investigation, GCL located 19 boreholes to define the vertical extent of contamination as well as to more precisely define the site stratigraphy. The borings were also intended to confirm the lateral extent of contamination...
indicated by the soil gas investigation. During Phase I drilling, 12 boreholes were completed at depths of 100 feet. The results from these boreholes necessitated the second phase of drilling. Phase II of drilling consisted of 7 boreholes (2 wells to depths of 200 feet, 1 well to a depth of 150 feet, and 4 wells to a depth of 100 feet). Fourteen of the 19 soil boreholes drilled were completed as air monitor wells.

The results showed that MeCl was present at depths greater than 100 feet and estimated an affected area of approximately 60,000 square feet. The mass of MeCl present in the soil was estimated to be 2,900 kilograms.

1.3.2.3 Installation of Groundwater Wells

Four RCRA groundwater wells and one exploratory piezometer were installed by GCL. MeCL, TCE, TCA, and PCE were not detected in any of the RCRA groundwater wells.

1.3.3 Bath & Associates, Inc. (1989)

The Temperature Test Facility leak and cathodic protection test was conducted on December 27 and 28 of 1989 by Bath & Associates, Inc. for Dynaspan Services Company. The purpose of the drainage system leak test was to ensure that the drainage system was a completely closed system and that no MeCl could escape into the ground. Bath & Associates witnessed a leak test on the complete facility drainage system including the interceptor, underground storage tank and above-ground 90-foot diameter tank. They also witnessed a test of the cathodic protection system for the 90-foot diameter above-ground tank.

Pneumatic pressure tests conducted on the piping system revealed leaks. A standing water test on the interceptor tank indicated the presence of leaks. A pneumatic test of the holding tank did not reveal leaks, but was not conclusive. Visual inspection of the evaporation pond revealed no observable flaws.

Bath & Associates, Inc. concluded that at least some portions of the system were leaking and that more thorough testing was required to ascertain whether other portions of the system were free from leaks.
1.3.4 ERC Environmental and Energy Services (1990)

A vapor extraction (VES) pilot study designed to evaluate the vapor extraction of MeCl at the TTF was performed by ERC Environmental Services. The pilot study was conducted over a 5-day period, within which five different extraction/observation arrays were tested. Data pertaining to the chemical composition and flow characteristics of soil air were collected in order to recommend design criteria for a full-scale remediation system.

The ERC pilot study concluded that vapor extraction was the best method of remediation for the site and provided a plan using existing and addition air wells for remediation.

1.3.5 Cortez III Environmental Services (1992)

A study was conducted to determine the possible movement of the existing MeCl contamination towards groundwater or if the large clay layers had impeded the downward movement at the TTF. The study was conducted in September and October of 1992 by Cortez III Environmental Services, Engineers from New Mexico State University, and the WSMR MTD-AA Chemistry Laboratory.

Two air monitoring wells (9201 and 9202) were completed in the vicinity of the former evaporation pond. It was concluded by Cortez III that the 9201 borehole (located near the southwest corner of the evaporation pond) had a maximum concentration of MeCl of 583 ppm. The concentrations of MeCl observed were consistent with previous studies within the same lithologic unit.

It was not possible, with the information that was received from borehole 9202 (located west of the evaporation pond), to make any determination on the origin, areal extent, or amount of the MeCl near the TTF building. Cortez concluded that it was possible that there was contamination near the TTF building that was not detected during the GCL contamination assessment investigation.
1.4 PRE-INVESTIGATION EVALUATION OF CORRECTIVE MEASURES TECHNOLOGIES

A pre-investigation evaluation of corrective measures technologies was performed during preparation of this RFI Work Plan to identify potential corrective actions that could be reasonably implemented at the TTF for the containment, removal, treatment, or disposal of the identified contaminant(s). The technologies identified may be further developed into a CMS to be used to establish potential remedial alternatives for the contamination associated with the TTF.

Three media are of potential interest for the TTF: soil, soil vapor, and groundwater. Contamination in the vadose zone has been detected during previous investigations. MeCl, TCE, TCA, PCE, and an unidentified Freon compound (GCL, 1987) have been detected in soil gas and soil studies in the vicinity of the TTF. Although no groundwater contamination has been detected to date, technologies for treatment of groundwater contaminated with the chemicals detected in soil gas have been included pending additional investigation.

Potential corrective technologies were identified by first considering general response actions appropriate for the media and contaminants of interest. For example, containment is an appropriate response action for both soil vapor and groundwater contaminated with volatile organic compounds. Technologies which might be used to accomplish the goal of containing the contaminated media include capping, drainage control, and horizontal or vertical barriers. Descriptions of the technologies assist in understanding why the technology is a potential component of future corrective measures. The potential corrective technologies were assembled after extensive review of:

- EPA documents
- EPA's Alternative Treatment Technology Information Center (ATTIC) database
- Dialogue Information Services, Inc. database search (includes ATTIC, VISITT, NTIS, Enviroline, Inspec, Water Resources Abstracts, Federal Research in Progress, and PTS databases)
- Pertinent technical journals and seminar/conference proceedings
• Information provided by remediation contractors

• WCC's past experience in the hazardous waste remediation area

Some of the EPA documents used in this review are:

• Remedial Action at Waste Disposal Sites Handbook (EPA, 1985)

• Technology Screening Guide for Treatment of CERCLA Soils and Sludges (EPA, 1988)

• Compendium of Technologies Used in the Treatment of Hazardous Wastes (EPA, 1987)

• Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites (EPA, 1989)

Tables 1-1, 1-2, and 1-3 list the potential corrective measures technologies for soil, soil vapor, and groundwater, respectively. The technologies listed in these tables were selected based on the fate and transport characteristics of the VOCs identified during previous investigations and on the applicability of a given technology to a specific medium.

1.4.1 Potential Corrective Measures Technologies for Soil

The containment options considered for soil at the TTF include capping, drainage controls, horizontal barriers, and vertical barriers. A large area of the TTF is currently capped (i.e. the former evaporation pond) with a RCRA style cap and/or covered with concrete or asphalt. In addition, drainage at the facility is currently controlled by culverts which run along the northern and southern boundaries of the cap.

Horizontal barriers are constructed layers to prevent downward migration of contaminants. Grout can be injected horizontally beneath contaminated zones or contaminated material can be underlain with a synthetic liner. Grout injection is a potential corrective technology for soil.

Vertical barriers such as grout curtains, sheet piling, or slurry walls can be constructed surrounding contamination or in the direction of contaminant migration to prevent lateral
movement. The limiting factor in determining the applicability of vertical barriers to a site is often the depth of contamination. Based on data available to date, the depth of contamination at the TTF does not appear to prevent consideration of vertical barriers as a potential corrective technology.

The method for removal of contaminated soil is excavation. Depth of contamination can be a limiting factor in the use of excavation as a removal mechanism.

Two biological methods are potential corrective technologies for the treatment of volatile organic compounds in soil. The first is landfarming which involves the addition of oxygen and nutrients to soil to promote biological degradation of contaminants. The second method is bioslurry treatment. A slurry of soil and water is created and placed in batch reactors where mechanical aerators add oxygen, and nutrients are added directly to the slurry.

Several physical/chemical methods are potential corrective technologies for volatile organic compounds in soil. Heated air stripping involves the addition of heated air to the soil to volatilize contaminants. To accomplish soil washing, surfactants in solution or other solvents are added to the excavated soil in batch reactors. The contaminants are transferred from the soil to the solvent in a more concentrated form requiring additional treatment or controlled disposal. Stabilization/fixation is a process whereby flyash, kiln dust, cement, or other pozzolanic agent is added to the soil to limit the mobility of contaminants. The technique of stabilization/fixation can be applicable to soil with low concentrations (generally less than 1%) of organic compounds.

Thermal methods available for the treatment of soil contaminated with volatile organic compounds include incineration and low temperature thermal desorption. Various types of incinerators are available for the destruction of organic compounds using high temperatures. Low temperature thermal desorption is a similar thermal method using lower temperatures, particulate control, and an after-burner to destroy off-gases. Both thermal methods have several commercially available on- and off-site versions.

Treated or non-hazardous soil would be disposed in an on- or off-site landfill. An off-site landfill would need to be permitted under the Resource Conservation and Recovery Act.
(RCRA) of 1976 to accept the type of waste to be disposed. An on-site landfill could be constructed to receive treated or non-hazardous soil from the remediated areas of the TTF.

1.4.2 Potential Corrective Measures Technologies for Soil Vapor

The containment options considered for soil vapor at the TTF including capping, drainage controls, horizontal barriers, and vertical barriers are discussed in Section 1.4.1. Vacuum extraction is the removal method that is potentially applicable to contaminated soil vapor. The technology involves the application of a vacuum to vadose zone wells to affect removal of volatile organic compounds from the unsaturated zone. Once the contaminated vapor is removed, treatment involves adsorption of the contaminants on vapor phase granular activated carbon or thermal destruction using catalytic oxidation. Catalytic oxidation may not result in complete destruction of certain compounds, so additional consideration will need to be given to its applicability as a potential correction technology. Pilot studies of this type have been conducted at the TTF with varying levels of success depending upon the lithologic unit tested.

An in-situ method of treatment for soil vapor contaminated with volatile organic compounds is bioventing. The process involves installation of injection wells in the vadose zone and the introduction of oxygen and nutrients to promote the biodegradation of the contaminants.

1.4.3 Potential Corrective Measures Technologies for Groundwater

The containment options considered for groundwater contaminated with volatile organic compounds are the same as for soil and soil vapor. Refer to Section 1.4.1 for a discussion of the potential corrective containment technologies.

Three methods for removal of contaminated groundwater are potentially applicable should contamination be detected at the TTF. The first method of removal is extraction wells. Extraction wells are specially constructed wells located within or adjacent to zones of contaminated groundwater and used to extract or hydraulically contain contaminated groundwater. Extraction/injection wells are a similar option with the injection wells used to reintroduce treated or uncontaminated groundwater to the aquifer. The third option for removal of contaminated groundwater is an interceptor trench or drain. An interceptor
trench/drain is a vertical trench filled with permeable material to allow the entry of groundwater from the contaminated aquifer. The depth to groundwater at the site could potentially limit the use of interceptor trenches/drains.

Several biological treatment methods are potential corrective technologies. Aerobic or anaerobic treatment methods such as trickling filters, activated sludge, and fixed-film reactors, for example, are techniques adapted from wastewater treatment. Depending on the concentrations of contaminants in groundwater, if found, one of these methods may apply. A variation of the activated sludge method of wastewater treatment is powdered activated carbon treatment (PACT). This enhancement of a biological treatment method involves the addition of activated carbon to the wastewater treatment system to adsorb contaminants.

The physical/chemical treatment options available for groundwater contaminated with volatile organic compounds are air or steam stripping, granular activated carbon, and ultraviolet (UV) oxidation. Air or steam stripping serves to volatilize contaminants from groundwater by introducing air or steam. The resulting off-gases may require treatment prior to discharge. Granular activated carbon (GAC) involves the use of specially treated coal or bituminous material to adsorb contaminants from the waste stream or contaminated groundwater. Once the GAC capacity is exhausted, the carbon must be disposed or regenerated. UV oxidation is a process involving the treatment of contaminated water with ultraviolet light. The method results in the oxidation of organic compounds to non-hazardous constituents.

One thermal method is a potential corrective technology for volatile organic compounds in groundwater. Incineration involves the application of heat to a contaminated waste stream and results in the oxidation of organic compounds to non-hazardous constituents.

Two in-situ treatment methods may apply. Air sparging involves the introduction of air in-situ to volatilize contaminants from the groundwater. The contaminants are then removed from the vadose zone using vacuum extraction. The technique is somewhat new, but has been applied with success in situations involving vadose zone and groundwater contaminated with volatile organic compounds.

The second in-situ method for consideration is biodegradation. A similar concept for treatment of contaminants in the vadose zone (bioventing) was described in the previous
section. The application for groundwater would be similar: introduction of oxygen and nutrients to the zone of contamination to enhance naturally occurring biological degradation of contaminants.

Reinjection, recharge trench, deep well injection, discharge to an installation wastewater treatment plant, stream discharge, or agricultural or industrial reuse are potential corrective technologies for groundwater contaminated with volatile organic compounds. Reinjection involves the reintroduction of treated or uncontaminated groundwater to the aquifer from which it was removed. A recharge trench is similar to an interceptor trench/drain except that treated or uncontaminated water would be pumped into the trench installed within the saturated zone. Treated or untreated water could be discharged to a nearby on- or off-site treatment plant currently used for treatment of wastewater.

A nearby stream or other body of water could be used to discharge treated or uncontaminated groundwater. The water could also be released to the septic leach field associated with the TTF. Treated or uncontaminated water could also be used for livestock. Industrial reuse possibilities for treated or uncontaminated groundwater include process water or non-contact cooling water.
The following section presents an overview of the RFI activities scheduled to be completed at the TTF. Implementation of the identified tasks in a sequential and orderly manner will allow the RFI to be successfully completed.

2.1 TASK 1 - SITE VISIT AND REVIEW OF EXISTING DOCUMENTS

Prior to initiating the preparation of the RFI work plans, WCFS personnel performed a visual site inspection of the TTF and surrounding area. Results from previous investigations and other government furnished information provided by the Contracting Officer were also reviewed.

2.2 TASK 2 - RFI WORK PLAN

WCFS has prepared this RFI work plan (and supporting documents) as a guide to all RFI activities related to the TTF. The plan will be submitted for review and approval prior to initiating any field work. The work plan as a whole addresses the following activities and items:

- Physical characteristics of the facility
- Pre-investigation evaluation of corrective measures technologies
- Project management
- Health and safety
- Field sampling and analysis
- Evaluation, management, and disposal of investigation derived waste (IDW)
- Soil gas investigations (shallow (±20 feet) and deep (not to exceed 100 feet))
- Soil borings
- Groundwater monitoring well sampling and analysis
- Soil gas monitoring well sampling and analysis
- Chemical data acquisition/quality assurance/quality control
- Community relations
2.3 TASK 3 - RCRA FACILITY FIELD INVESTIGATION

2.3.1 Shallow Soil Gas Survey

WCFS will conduct a shallow soil gas survey (SGS) in accordance with this work plan. Soil gas samples will be collected and analyzed at up to 100 points in the vicinity of the TTF. Work activities include layout of the sampling grid, preparation for sampling, sample collection and analysis, and sample location surveying. Soil gas samples will be analyzed in the field for MeCl, TCE, PCE, TCA, 1,1-DCE, 1,1-DCA, chloroform, and Freon 22, Freon 503, Freon 113, and Freon 11.

2.3.2 Deep Soil Gas Survey

WCFS will conduct a deep soil gas survey in accordance with this work plan. Deep soil gas samples will be collected and analyzed at up to nine locations in the vicinity of the TTF at depths not to exceed 100 feet below ground surface. Deep soil gas samples will be collected with the aid of a hollow-stem auger drill rig. Pilot holes will be drilled to just above the desired sampling depth with hollow-stem augers and soil gas samples will then be collected and analyzed in the field for the compounds listed in Section 2.3.1 above.

2.3.3 Soil Borings

WCFS will drill a total of 10 soil borings to an average depth of 100 feet below ground surface (bgs). Four randomly selected soil samples will be collected for physical testing at the same time samples are collected for chemical analysis. The soil boring location will be chosen randomly at the start of field activities. Discrete soil samples will be collected for analysis of volatile organics by EPA Method 8240 approximately every 10 feet. Prior to drilling, a magnetometer survey of each boring location will be conducted to check for unexploded ordnance. All investigation derived waste (i.e. drill cuttings, decontamination water, and personal protective equipment) will be managed in accordance with the Investigation Derived Waste (IDW) Management Plan (see Section 6.0 of the FSAP).
2.3.4 Groundwater Monitoring Well Sampling

WCFS will sample the 4 existing RCRA groundwater monitoring wells. No new monitoring well installation is planned for this investigation.

2.3.5 Soil Gas Monitoring Well Sampling

WCFS will sample the existing soil gas monitoring wells at the TTF. The soil gas subcontractor will purge and sample the wells and collect a sample for field screening and laboratory analysis. All samples will be submitted for off-site laboratory analysis. The field GC will be calibrated for the compounds of concern listed in Section 2.3.1.

2.3.6 Samples

Samples of soil gas, soil and groundwater will be collected for analysis. Shallow and deep soil gas samples will be analyzed for volatile organics and freons by a mobile laboratory in the field (on-site). Soil, soil gas, and groundwater samples will be analyzed for volatile organics in an off-site laboratory. Samples analyzed off-site will be collected, shipped, stored and generally handled in accordance with the FSAP (Appendix A) and CDAP (Appendix B). In addition to the volatile organic analysis, a maximum of 9 soil samples will be submitted for physical testing. Test parameters include grain size analysis, atterberg limits, and moisture content using methods published by the American Society of Testing and Materials (ASTM).

Ten percent of the soil and groundwater samples collected for chemical analysis will be submitted for QC analysis to the same lab that will be analyzing the investigative samples. No QC samples are planned for physical test parameters. Ten percent of the soil and groundwater samples will be submitted for QA analysis to:

- U. S. Army Corps of Engineers
  Southwestern Division Laboratory
  4815 Cass Street
  Dallas, Texas  75235
2.3.7 Investigation Derived Waste

An Investigation Derived Waste Management Plan (IDWMP) was prepared for use during RFI field activities at the TTF.

During the performance of the field investigations, various waste materials will be generated. These include drill cuttings, excavated materials, decontamination fluids, purge fluids, and personal protection equipment (PPE). The IDWMP has been structured so that it can be used to manage the different wastes that will be generated during the performance of various field investigations planned to be conducted at the TTF.

The IDWMP (Section 6.0 of the FSAP) describes the measures to be implemented at the TTF for the management of wastes generated during field sampling and investigative activities.

WCFS will supply the equipment, labor, containers and other materials as necessary to manage the waste generated as a result of implementing the activities outlined above until it is given to the government for storage and/or disposal. IDW will be handled in accordance with the approved plan which incorporates the requirements of WSMR Regulation No. 200-1 (U.S. Department of the Army, 1991). The government will provide final disposal of all materials collected during the RFI.

2.4 TASK 4 - DATA VALIDATION AND SUMMARY REPORT

Following completion of the field activities and receipt of the data WCFS will prepare a data validation and summary report. This report will include an executive summary, introduction, detailed discussion, and conclusions. The report will be submitted for review and approval prior to submitting the draft RFI Report.

2.5 TASK 5 - RCRA FACILITY INVESTIGATION REPORT

The RCRA Facility Investigation Report shall be prepared to fully document all work performed. The report will be prepared according to the requirements of the Interim Final RCRA Facility Investigation guidance document (USEPA, 1989c). The report will include
an evaluation of the need for interim corrective actions and recommend such if required. The RFI Report will address the TTF and verify and characterize releases that have occurred. The characterization will include type and concentration of the constituent released. Documented releases will be compared to the published action levels in Subpart S, Appendix A, (CFR 264.521(a)(2)(i-iv)) and the action levels will be used as a guideline in determining if the release is above the action level. The rate and direction of migration, and the distance over which the release has traveled will also be evaluated. Inter-media transfer of waste will be addressed where applicable.

The RFI Report will also include a Health and Environmental Assessment (HEA). The HEA will be prepared to support or refute the need for a CMS.
3.0 PROJECT MANAGEMENT PLAN

3.1 INTRODUCTION

This section presents the PMP and provides a discussion of the technical approach, schedules, and personnel that will be assigned to this project. Qualifications of key personnel are also presented, as well as the overall management approach to be implemented by WCFS. Figure 3-1 presents the proposed organizational chart for this project.

3.2 WSMR PERSONNEL

The WSMR point of contact (POC) for this contract is Mr. Hector Magallanes (505) 678-2073. Activities will also be coordinated with Mr. Rick Reynaud (505) 678-6300 at the TTF.

3.3 USACE PERSONNEL

The USACE contacts for this project are Mr. Walter Kneib (918) 669-7045 (Technical Manager, Tulsa District) and Mr. David Scotto (817) 334-2724 (Project Manager, Fort Worth District).

3.4 WCFS PERSONNEL AND QUALIFICATIONS

3.4.1 Program Manager

The WCFS Program Manager for the TTF RFJ is Mr. Doug Fiscus (913) 344-1156. Mr. Fiscus is responsible for the overall management of projects of this type with the Tulsa District. Mr. Fiscus will be available to WSMR and USACE personnel as needed throughout the duration of this project to maintain client satisfaction with the technical performance as well as compliance with schedules and budgets during the performance of the project activities. He will assist the Project Manager with the coordination of all
administrative, progress, and financial reporting, and will on an as needed basis review deliverables.

Mr. Fiscus received his B.S. degree in Agricultural Engineering in 1960 and is a registered professional Mechanical Engineer. He has over 20 years experience in toxic and hazardous waste management, project management and design. He has served as project director or manager on hazardous waste remedial investigations, remedial action programs, and facility closures.

3.4.2 Project Manager

The WCFS Project Manager for this RFI is Mr. David Convy (913) 344-1153. Mr. Convy will serve as the primary POC between WCFS and WSMR/USACE personnel for all technical and administrative functions related to this project. Specific responsibilities include:

- Selecting and managing project subcontractors
- Implementing quality control procedures
- Assuring that all project personnel are qualified and properly trained for their work assignments
- Conducting periodic reviews of problem areas and identifying potential trends
- Tracking work progress against planned budgets and schedules
- Ensuring that all project changes are documented and corrective actions are taken
- Assigning Peer Reviewers (with input from the Program Manager)

He will also be responsible for preparing monthly activity reports for the project. He will directly supervise the task leaders for the project and coordinate document review activities through the duration of the project.
Mr. Convy received his B.A. degree in Biology in 1981 and his M.S. degree in Civil and Environmental Engineering in 1985. He has over 8 years of experience in environmental and hazardous waste investigations and management. His experience includes groundwater and soil quality assessments, remediation, and RI/FS and RFI Work Plan preparation and implementation at numerous CERCLA and RCRA sites throughout the country.

3.4.3 Health and Safety Officer

The Health and Safety Officer (HSO) for this RFI will be Ms. Carla Dods. Ms. Dods will oversee the development and implementation of the HSPP. She will also assure that the Health and Safety Plan is in compliance with OSHA Standard 29 CFR 1910.120, 29 CFR 1926, 49 CFR Transportation requirements and USACE EM 385-1-1 Safety and Health requirements.

Ms. Dods received a M.S. degree in Environmental Science in 1983. She has over 7.5 years experience in implementing safety plans for hazardous waste sites, safety and health training, implementing engineering controls for chemical and physical hazards, health and safety plan development and implementation, and OSHA compliance.

3.4.4 Quality Assurance Officer

Mr. Less Osborne is the Quality Assurance Officer (QAO) for this investigation and will assist the Project Manager in ensuring that quality work is accomplished on schedule. He will be responsible for:

- Directing the overall quality assurance (QA) program
- Maintaining QA oversight
- Reviewing QA sections of reports
- Reviewing applicable quality assurance/quality control (QA/QC) procedures
- Conducting audits or surveillance of selected field activities
- Initiating, reviewing, and implementing corrective actions as necessary
• Conducting periodic reviews of problem reports, surveillance reports, and corrective actions to identify potential trends and problem areas

Mr. Osborne will be responsible for those personnel who survey, audit, and monitor adherence to project QA objectives. Mr. Osborne or his designee may also periodically audit the analytical laboratory.

Mr. Osborne received a B.S. degree in Geology in 1976 and an M.S in Geology in 1981. He has over 13 years experience in the development, implementation, evaluation and oversight of quality assurance protocols.

3.4.5 Quality Control Coordinator

The Quality Control Coordinator for this project is Dr. Dennis Takade. In this capacity, Dr. Takade will assure the quality control of sampling, sample handling, sample custody, and field testing. He will also coordinate the QA/QC of the analytical laboratory and assure the required submittals are on time and of acceptable quality. Dr. Takade will report directly to Mr. Wayne Smith, Vice President of WCFS.

Dr. Takade has over 20 years experience in the operation of various analytical laboratory equipment, as well as the review and validation of data generated from GC/MS, ICP, AA, GC, and other analyses involved in environmental testing.

3.4.6 Field Manager

The Field Manager for the project will be Mr. Dan Kennedy. As Field Manager, Mr. Kennedy will be present at the work site and will coordinate all investigative activities. His responsibilities will include briefing field personnel on procedures, tasks, and responsibilities, and ensuring that proper procedures are followed in accordance with the approved Work Plan. Any changes to the Work Plan necessitated by field conditions will be documented by the Field Manager and coordinated with the Project Manager and WSMR and USACE personnel.
Mr. Kennedy received a B.S. degree in Geology in 1979 and an M.S. in Geology in 1993. He has over 15 years experience in the performance of geological and hydrogeological investigations. Mr. Kennedy has supervised a variety of environmental field work including; aquifer testing, soil boring and monitoring well installations, and groundwater and soils sampling.

3.4.7 Site Health and Safety Officer

Prior to initiating field activities a qualified individual will be assigned to serve as Site Health and Safety Officer (SHSO). The SHSO’s duties will be to ensure that all on-site workers conduct their work in accordance with the approved HSPP. In addition, the SHSO will verify that all workers at the site satisfy requirements of 29 CFR 1910.120 and that appropriate Personal Protective Equipment (PPE) is available. He will periodically monitor the breathing zone in the work site and take action to upgrade the level of PPE as necessary. Any changes to the HSPP necessitated by field conditions will be documented by the SHSO and coordinated with the Project Manager, Project Health and Safety Officer, and WSMR and USACE personnel.

3.4.8 Project Team

The project team will consist of engineers, scientists, technicians, and clerical staff with experience in the preparation and implementation of RFI-related activities.

The team members will be on site during all soil gas sampling and analysis, drilling, soil sampling, and soil gas monitoring well installation to assure that the goals of the field operation are achieved. Each of the team members selected will be experienced at conducting field activities at hazardous and toxic waste sites.

3.4.9 Peer Reviewers

All technical documents containing conclusions and recommendations will be peer reviewed by senior professionals for accuracy, clarity, and completeness. The reviewers will operate independent of the technical teams preparing the technical deliverables and provide unbiased,
third party reviews of deliverables. The primary peer reviewers for this project will be assigned by the Project Manager with input from the Program Manager.

3.5 SUBCONTRACTORS

The following tasks associated with this project will be performed by WCFS subcontractors:

- Soil Gas Sampling and Analysis
- Soil Borings (Drilling) and Deep Soil Gas Sample Collection
- Surveying
- Chemical Laboratory Analysis

WCFS is proposing to use the following subcontractors for each of the above categories because of their extensive experience and qualifications in providing the required services.

- Soil Gas Sampling and Analysis
  - Plains Environmental Services, Inc.
    P.O. Box 6288
    Salina, Kansas 67401-0288

- Soil Borings (Drilling) and Deep Soil Gas Sample Collection
  - Stewart Brothers
    P.O. Box 2067
    306 Airport Road
    Milan, New Mexico 87021

- Surveying
  - Southwest Engineering Incorporated
    475 Archuleta Road
    Las Cruces, New Mexico 88005

- Chemical Laboratory Analysis
  - Quanterra Environmental Services (formerly Enseco, Inc.)
    4955 Yarrow
    Arvada, Colorado 80002
3.6 SCHEDULE

A proposed schedule for the implementation of this RFI is presented in Figure 3-2.

The schedule assumes a 30-day review period for the Data Validation and Summary Report, a 30-day review period for the draft RFI Report and a 45-day review period for the draft final RFI report. A 14-day period for comment resolution related to the deliverables (i.e., Data Validation and Summary Report, draft RFI Report, and draft final RFI Report) was also used as an assumption in generating the schedule. This schedule may be expanded or compressed depending on the actual number of days taken for review and comment resolution.
4.0
DATA MANAGEMENT PLAN

4.1 INTRODUCTION

This DMP contains procedures for documenting and tracking the field investigation data and results. This plan will identify and set up data documentation materials and procedures, project file requirements, and project-related progress reporting procedures and documents. The plan also provides the format to be used to present the raw data and conclusions of the investigation.

4.2 MANAGEMENT INFORMATION SYSTEM (MIS)

WCFS will format and present all analyzed data generated from the RFI. Reproducible floppy disks will contain text in Wordperfect 5.1®, data in ASCII format, and drawings and maps in AUTOCAD® and/or Intergraph® formats.

Data collected in the field and laboratory will be entered into the selected management software. Microsoft Excel® and Paradox® will be used to store, analyze, and report data gathered in the investigation. It is estimated that an 8-week period will be required to perform the field investigation and acquire the laboratory analytical results. After this 8-week period, WCFS will submit to USACE personnel, disks and reports containing validated data collected during the RFI. Data will be identified by a site code and location identification, date, and a summary of what data were collected.

The following information will be provided in the database files:

- **Location Definition Information** - contains information such as location identification number, coordinates, location classification, elevation, depth and diameter. The UTM coordinates at WSMR are based on North American Datum (NAD) 83, the horizontal units are meters, and the vertical units are feet.
• Lithologic Description Information - contains geologic information normally included in boring logs. Types, depths, and descriptions of strata encountered as well as any aquifers penetrated are included in this file.

• Groundwater Level Data - contains data such as well measurement date, depth to water, and the identification of the person collecting the data.

• Sample Event Database - contains information on each sampling event. This includes location, depth, date sampled, as well as field measurements such as pH and conductivity. The sampling medium is also identified.

• Analytical Results - contains laboratory results including laboratory name, sample number, method used, parameter tested, value obtained, detection limit, and units.

4.3 GRAPHICS PRESENTATION

WCFS will present data in a graphic display format. All graphics displays will be digitized and submitted in an Intergraph® or AUTOCAD® format.

4.4 REPORTS

WCFS will prepare the two different types of reports. The two different types of reports are a Data Validation and Summary Report and the RFI Report. Each report is discussed in the following sections. Reports will be subject to internal technical and QA/QC review, and will be checked for accuracy. Draft reports will be identified as such by having "DRAFT" stamped on them. The Final RFI Report will be submitted within 14 days after receipt of comments on the draft Final RFI report.

4.4.1 Data Validation and Summary Report

WCFS will submit a Data Validation and Summary Report briefly presenting the results of this investigation and updating previously existing information. This Summary Report will be formatted to include an executive summary, an introduction, a detailed discussion, and a conclusion.
The introduction will contain the number of field samples collected, the number of QA and QC samples collected, the number of equipment blank samples collected, and the number of trip blank samples collected by medium. It will also describe the testing laboratory, and provide a table arranged by sample batch showing the field and laboratory identification number(s), test parameters, and laboratory code(s).

Validation of analytical data will be conducted through a qualitative evaluation of the representativeness and comparability of the data. Validation of laboratory analytical data will be made by calculation of values for precision, accuracy, and completeness, and by qualitative evaluation of representativeness and comparability. Therefore, the detailed discussion section will be arranged by sample media and the parameter tested. The discussion will include the following topics for each of the subheadings:

- **Accuracy** (matrix spike recovery)
- **Precision** (matrix spike duplication and relative percent difference)
- **Representativeness** (equipment, trip, and instrument blank data, as well as chain-of-custody forms)
- **Actual analytical method used** (the effects of any variance from the method and holding times prescribed in the CDAP)

The conclusion section will summarize the data collection problems encountered, corrective actions taken, the suitability of the data for its intended use, and whether the data fulfills the data quality objectives specified in the CDAP. Data will be assembled in a logical and readable fashion, reduced into summary data tables, and combined with the validation report. This report will contain copies of the soil gas analysis data as well as soil and groundwater data. All reduced data will be in accordance with the data reduction guidelines.

### 4.4.2 RFI Report

**Draft RFI Report**

Within 14 days after approval of the Data Validation and Summary Report, a draft RFI Report will be submitted for review. The RFI Report will be prepared documenting the RFI
activities and evaluating and analyzing the data and results. The main components of the RFI Report consist of the environmental setting, source characterization, contamination characterization, potential receptors, and investigation analysis. The environmental setting portion of the RFI Report will supplement the existing data. The description of the physical setting will incorporate the geology, hydrogeology, and soil data collected. Surface water and air aspects will be addressed only as appropriate. The information will include regional information from supplemental studies conducted by others as well as specific information for the TTF.

The source characterization will describe the field and analytical data collected to characterize the TTF. The characterization will include the types, quantities, disposition, and facility features affecting release and dispersion of the waste materials.

The field data and analytical results of samples collected during the RFI will be used to characterize the contamination at the TTF. The data will be evaluated and analyzed to preliminarily define the origin, extent, direction, and rate of migration (as appropriate) at the facility.

The investigation analysis will summarize and conclude the data presented in the preceding sections of the report. The nature and extent of contamination will be compared to background levels and appropriate regulations or guidelines. Any remaining or additional data gaps identified will also be discussed. Based on the results of this investigation, WCFS will recommend a scope of work for a Phase II RFI, if required.

The RFI Report will be prepared in accordance with the following guidance:


As part of the RFI Report, WCFS will perform a HEA to support or refute the need to conduct a CMS. The HEA will provide information on potential human, animal, and floral receptors which have the potential to be adversely impacted by site conditions. This section of the report will discuss the contaminants of concern, their toxicity, concentration, and mobility. The purpose of the HEA will be to present a baseline site evaluation, exposure assessment, and analysis of risk.
The HEA will be prepared in general accordance with the following guidance:


**Data Presentation**

Where applicable, WCFS will present data in a tabular display format. The following data may be displayed in the reports in tabular form:

- Unsorted (raw data)
- Statistical analysis data
- Comparisons of analytical results with background data
- Water table elevations
- Sampling location coordinates
- List of monitoring parameters with associated analytical measurements
- Summary data

Where applicable, WCFS will present data in a graphic display format. All graphics displays will be digitized and submitted in an Intergraph® or AUTOCAD® format. The following data may be included in graphical displays:

- Layout and topography
- Sampling locations and sampling grids
- Boundaries of sampling areas
- Stratigraphy and water table elevations (profiles, transects, or fence diagrams)
- Potentiometric contour maps of groundwater
- Geographical extent of contamination
- Vertical distribution of contaminant(s)
- Contamination values, averages, or maxima at sampling locations
- Changes in concentration with distance from sources

**Final RFI Report**

The Draft RFI and Draft Final RFI reports will be submitted for review and comment. Comments will be annotated and incorporated into the Draft Final and the Final RFI Report.
as appropriate. The Final RFI Report will be submitted for review within 14 days after the receipt of comments on the Draft Final RFI Report. The Final RFI Report will have a separate volume which includes the laboratory analytical results.

4.5 PROJECT FILE REQUIREMENTS

WCFS will maintain the project files containing personnel training records, medical records, etc. These files will be maintained in accordance with the company’s administrative procedure for records management.

In addition, WCFS will maintain the TTF RFI project files in its Overland Park, Kansas office while the project is active. Individual project files will be maintained using the following format:

1. Project Management
2. Communications
3. Government Furnished Information
4. Project Plans
5. Comments
6. Data/Notes
7. Draft Reports
8. Final Report

The above file system may be modified as the project proceeds and will be available for review during normal business hours at the following address:

Woodward-Clyde Federal Services
10975 El Monte, Suite 100
Overland Park, Kansas 66211
(913) 344-1000
5.0

OVERVIEW OF FIELD SAMPLING AND ANALYSIS PLAN

The FSAP (Appendix A contained in Volume II) was prepared to provide technical guidance and support during the field portion of the TTF RFI. The FSAP is specific to the various technical evaluations to be conducted in the investigation of the TTF.

The purpose of the FSAP is to describe all objectives, methods, and procedures for the RFI field work at the TTF. The FSAP includes soil and groundwater sample collection methodologies, drilling methodologies, shallow and deep soil gas collection methodologies, field testing requirements, sample analytical methods and handling requirements, sample documentation requirements, equipment decontamination requirements, and investigation derived waste handling requirements. The procedures outlined in the FSAP will be followed during investigation activities at the TTF unless unexpected conditions are encountered. Written approval will be obtained from WSMR and/or USACE personnel to affect a change in the field.
OVERVIEW OF CHEMICAL DATA ACQUISITION PLAN

The CDAP (Appendix B, contained in Volume II) provides the information and guidance necessary for maintaining QA/QC during the RFI process. The QA/QC standards set forth in the CDAP will govern all RFI related activities conducted at the TTF. RFI activities will be conducted in compliance with all applicable federal, state and local laws and regulations. This will also include all appropriate and applicable WSMR regulations. All measurements and samples will be collected in accordance with USEPA protocols and guidance and in accordance with the approved project plans.

The CDAP contained in Appendix B was prepared in accordance with ER 1110-1-263.
OVERVIEW OF THE HEALTH AND SAFETY PROGRAM PLAN

The HSPP (Appendix C, contained in Volume III) presents the health and safety requirements and guidelines for implementation of the field investigation at the TTF. The HSPP identifies and evaluates the physical and chemical hazards associated with the site work activities; specifies levels of protection; identifies key project personnel and specifies their safety responsibilities; and specifies decontamination procedures for personnel and equipment. The HSPP also outlines procedures to follow with respect to unexploded ordnance while working at WSMR.

The HSPP was developed in compliance with OSHA standard 29 CFR 1910.120, 29 CFR 1926, 49 CFR Transportation requirements, USACE EM385-1-1 Safety and Health requirements, and Woodward-Clyde corporate policy.
The CRP (Appendix D, contained in Volume III) presents a means for communicating the TTF RFI findings to interested local parties. The CRP is intended to be a stand-alone document which describes, in layman's terms, how the RFI is to be implemented, how the RFI will be managed, and how information will be gathered, interpreted, and incorporated into the RFI Report.

In general, the plan contains a preview of the community relations process, CRP implementation responsibility, a site description, community background, activities and personnel, and information sources. The CRP is a dynamic document and will be modified as necessary to respond to community concerns and suggestions.
REFERENCES


TABLE 1-1

POTENTIAL CORRECTIVE MEASURES TECHNOLOGIES FOR SOIL TEMPERATURE TEST FACILITY
WHITE SANDS MISSILE RANGE, NEW MEXICO

<table>
<thead>
<tr>
<th>General Response Action</th>
<th>Potential Corrective Technology</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Containment</td>
<td>Capping</td>
<td>Placement of impermeable cover over contaminated area to control surface infiltration.</td>
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<tr>
<td></td>
<td>Drainage Control</td>
<td>Modification of surface drainage to control surface infiltration.</td>
</tr>
<tr>
<td></td>
<td>Horizontal Barriers</td>
<td>Construction of liner below contamination to prevent downward migration.</td>
</tr>
<tr>
<td></td>
<td>Vertical Barriers</td>
<td>Construction of vertical barrier surrounding or partially surrounding contamination to prevent lateral migration.</td>
</tr>
<tr>
<td>Removal Treatment</td>
<td>Excavation</td>
<td>Controlled aeration and nutrient addition to promote biodegradation of contaminants.</td>
</tr>
<tr>
<td>Biological</td>
<td>Landfarming or Composting</td>
<td>Biological treatment of a soil slurry in batch reactors.</td>
</tr>
<tr>
<td></td>
<td>Bioslurry</td>
<td>Hot air passed through soil to strip volatile compounds.</td>
</tr>
<tr>
<td></td>
<td>Heated Air Stripping</td>
<td>Soil washed with detergents, solvents, or other reagents to extract target compounds.</td>
</tr>
<tr>
<td></td>
<td>Soil Washing</td>
<td>Addition of flyash, cement, or other pozzolanic agents to limit mobility of contaminants.</td>
</tr>
<tr>
<td>Physical/Chemical</td>
<td>Stabilization/Fixation</td>
<td>Various methods using addition of heat to destroy contaminants.</td>
</tr>
<tr>
<td></td>
<td>Incineration</td>
<td>Application of heat using a thermal dryer volatilizes contaminants. A bag house controls particulates and an after-burner destroys off-gases.</td>
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### TABLE 1-1

**POTENTIAL CORRECTIVE MEASURES TECHNOLOGIES FOR SOIL TEMPERATURE TEST FACILITY**

**WHITE SANDS MISSILE RANGE, NEW MEXICO**

(Continued)

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<tr>
<td>Treatment (continued)</td>
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<tr>
<td>In-Situ</td>
<td>Bioremediation</td>
<td>Addition of oxygen as hydrogen peroxide or ozone and nutrients to contaminants.</td>
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<tr>
<td></td>
<td>Stabilization/Fixation</td>
<td>Addition of flyash, cement, or other pozzolanic agents to limit mobility of contaminants with out removal of soil.</td>
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<tr>
<td></td>
<td>Thermal Desorption</td>
<td>Release of contaminants from bond with soil occurs through steam injection or other heat addition method.</td>
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<tr>
<td></td>
<td>Soil Flushing</td>
<td>Surfactants, solvents, or other reagents are sprayed on the ground surface to drive contaminants to groundwater where they are extracted.</td>
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<tr>
<td>Disposal</td>
<td>Off-Site Landfill</td>
<td>Treated or non-hazardous soil placed in RCRA-permitted landfill.</td>
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<tr>
<td></td>
<td>On-Site Landfill</td>
<td>Landfill designed and constructed on-site to receive treated or non-hazardous soil.</td>
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### TABLE 1-2

POTENTIAL CORRECTIVE MEASURES TECHNOLOGIES FOR SOIL VAPOR TEMPERATURE TEST FACILITY
WHITE SANDS MISSILE RANGE, NEW MEXICO

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<td>Containment</td>
<td>Capping</td>
<td>Placement of impermeable cover over contaminated area to control surface infiltration.</td>
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<td>Drainage Control</td>
<td>Modification of surface drainage to control infiltration.</td>
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<tr>
<td></td>
<td>Horizontal Barriers</td>
<td>Construction of liner below contamination to prevent downward migration.</td>
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<tr>
<td></td>
<td>Vertical Barriers</td>
<td>Construction of vertical barrier surrounding or partially surrounding contamination to prevent lateral migration.</td>
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<tr>
<td>Removal</td>
<td>Vacuum Extraction</td>
<td>Application of vacuum to extraction wells in the vadose zone to remove volatile organic contaminants.</td>
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<tr>
<td>Treatment</td>
<td>Granular Activated Carbon</td>
<td>Adsorptive media for removal of volatile organic compound from air.</td>
</tr>
<tr>
<td></td>
<td>Catalytic Oxidation</td>
<td>Application of heat to oxidize volatile organic compounds to non-hazardous constituents.</td>
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<tr>
<td></td>
<td>Bioventing</td>
<td>Addition of oxygen and possibly nutrients to promote in-situ biodegradation of contaminants.</td>
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TABLE 1-3
POTENTIAL CORRECTIVE MEASURES TECHNOLOGIES FOR GROUNDWATER TEMPERATURE TEST FACILITY
WHITE SANDS MISSILE RANGE, NEW MEXICO

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<th>Potential Corrective Technology</th>
<th>Description</th>
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<td><strong>Containment</strong></td>
<td><strong>Horizontal Barriers</strong></td>
<td>Construction of liner below contamination to prevent downward migration. Construction of vertical barrier surrounding or partially surrounding contamination to prevent lateral migration.</td>
</tr>
<tr>
<td><strong>Vertical Barriers</strong></td>
<td></td>
<td>Wells installed to allow extraction or hydraulic containment of contaminated groundwater. Wells installed to allow extraction or hydraulic containment of contaminated groundwater followed by reinjection of treated or uncontaminated groundwater.</td>
</tr>
<tr>
<td><strong>Removal</strong></td>
<td><strong>Extraction Wells</strong></td>
<td>Biological method involving degradation of contaminants in the presence of oxygen. Biological method involving degradation of contaminants in the absence of oxygen. Use of powdered activated carbon in combination with activated sludge treatment, an aerobic method, to remove contaminants.</td>
</tr>
<tr>
<td><strong>Extraction/Injection Wells</strong></td>
<td></td>
<td>Use of air or steam to volatilize contaminants from groundwater. May require treatment of volatilized contaminants using granular activated carbon. Adsorptive method for removal of contaminants from groundwater.</td>
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<tr>
<td><strong>Biological</strong></td>
<td><strong>Aerobic</strong></td>
<td>Ultraviolet light oxidizes contaminants to non-hazardous constituents.</td>
</tr>
<tr>
<td><strong>Anaerobic</strong></td>
<td></td>
<td>Various methods involving use of heat to oxidize contaminants to non-hazardous constituents.</td>
</tr>
<tr>
<td><strong>PACT</strong></td>
<td></td>
<td>Addition of air to groundwater system to volatilize contaminants, then captured using vacuum extraction.</td>
</tr>
<tr>
<td><strong>Physical/Chemical</strong></td>
<td><strong>Air or Steam Stripping</strong></td>
<td>Biological method for removal of contaminants from groundwater.</td>
</tr>
<tr>
<td><strong>Granular Activated Carbon</strong></td>
<td></td>
<td>Adsorptive method for removal of contaminants from groundwater.</td>
</tr>
<tr>
<td><strong>Ultraviolet (UV) Oxidation</strong></td>
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<td>Ultraviolet light oxidizes contaminants to non-hazardous constituents.</td>
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<tr>
<td><strong>Thermal</strong></td>
<td><strong>Incineration</strong></td>
<td>Various methods involving use of heat to oxidize contaminants to non-hazardous constituents.</td>
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<td><strong>In-Situ</strong></td>
<td><strong>Air Sparging</strong></td>
<td>Addition of oxygen and possibly nutrients to promote in-situ biodegradation of contaminants.</td>
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<td><strong>Bioventing</strong></td>
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TABLE 1-3

POTENTIAL CORRECTIVE MEASURES TECHNOLOGIES FOR GROUNDWATER TEMPERATURE TEST FACILITY
WHITE SANDS MISSILE RANGE, NEW MEXICO
(Continued)

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<tr>
<td>Disposal</td>
<td>Reinjection</td>
<td>Injection of treated or uncontaminated groundwater to the aquifer from which it was removed.</td>
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<td>Recharge Trench</td>
<td>Injection of water to saturated zone to recharge groundwater.</td>
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<td>Deep Well Injection</td>
<td>Injection of contaminated groundwater to a confined, non-potable aquifer.</td>
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<tr>
<td></td>
<td>Wastewater Treatment Plant</td>
<td>Transport of treated or untreated water to an on- or off-site wastewater treatment facility.</td>
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<tr>
<td></td>
<td>Septic System/Leach Field</td>
<td>Discharge treated or uncontaminated water to the TTF septic system/leach field</td>
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<tr>
<td></td>
<td>Stream Discharge</td>
<td>Discharge of treated or uncontaminated water to a nearby water body.</td>
</tr>
<tr>
<td></td>
<td>Agricultural Reuse</td>
<td>Application of treated or uncontaminated groundwater to crops or for livestock.</td>
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<tr>
<td></td>
<td>Industrial Reuse</td>
<td>Use as process or cooling water by industry.</td>
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NOTE:
1. THE EVAPORATIVE POND CAP IS DEFINED BY THE NORTH AND SOUTH CULVERT, THE CAP PERIMETER FENCE TO THE EAST, AND THE ASPHALT TO THE EAST OF THE TTF BUILDING.

SOURCE: DYNASPAN SERVICES, 1989
FIGURE 1-3
Lithologic Units at the Temperature Test Facility

Sandy Gravel, pale yellowish brown (10 YR 6/2); to dark yellowish brown (10 YR 4/2) and moderate brown (5 YR 4/4); medium to coarse grained sand; fine to medium pebble gravel; sub angular to sub rounded; very poorly to poorly sorted; moderate to poorly indurated; thickness 6-17 feet.

Gravelly Sand, moderate yellowish brown (10 YR 5/4); fine to medium pebble gravel; medium to coarse grained sand; sub angular to sub rounded; very poorly to poorly sorted; poorly indurated; thickness 4-9 feet.

Sandy Silty Clay; moderate red brown (10 R 4/6), moderate red orange (10 R 6/6); to moderate brown (5 YR 4/4); clay with medium to coarse grained sand; abundant root molds; thickness 2-4 feet.

Calche Cemented Gravelly Sand; light brown (5 YR 5/6) to moderate yellowish brown (10 YR 5/4), gray orange (10 YR 7/4); fine to coarse grained sand and fine pebble gravel; root molds; localized clay and calche nodules, thickness 14-28 feet.

Gravelly Sand; pale yellowish brown (10 YR 8/2) to light brown (5 YR 5/6); fine to coarse grained sand and fine pebble gravel; localized sand lenses; sub angular to moderately rounded; poorly sorted; poorly indurated; thickness 3-18 feet.

Sandy Clay; moderate brown (5 YR 3/4) to pale yellowish brown (10 YR 8/4) to light olive gray (5 YR 5/2); contains minor root molds and calche nodules; thickness 2-8 feet.

Sandy Silty Clay; appears greenish when first observed, grayish yellow (5 YR 8/4) to light olive gray (5 Y 5/2); contains minor root molds and calche nodules; thickness 2-8 feet.

Sand; pale yellowish brown (10 YR 6/2) to light brown (5 YR 5/6); grayish orange (10 YR 7/4); very fine to medium grained, localized coarse grained lenses; sub angular to sub rounded; moderately sorted; poorly to moderately indurated; thickness 2-7 feet.

Silty Clay; pale red brown (10 YR 5/4) to moderate brown (5 YR 4/4); sticky plastic clay with silt and minor sand; moderately well sorted; poorly indurated; contains calcich nodules and root molds; thickness 14-26 feet.

Sand; moderate brown (5 YR 4/4), moderate yellow brown (10 YR 5/4) to orange (10 YR 7/4); very fine to fine grained; sub rounded; moderately well sorted; poorly indurated; thickness 1-8.5 feet.

Silty Clay; dark yellowish brown (10 YR 4/2) to moderate brown (5 YR 4/4); contains calciche and minor calche nodules; thickness 1-4 feet.
### Activity Description

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APPENDIX A
FIELD SAMPLING AND ANALYSIS PLAN

The Field Sampling and Analysis Plan is contained in Volume I.
The Chemical Data Acquisition Plan is contained in Volume I.
The Health and Safety Program Plan is contained in Volume II.
The Community Relations Plan is contained in Volume II.
FIELD SAMPLING AND ANALYSIS PLAN FOR THE RCRA FACILITY INVESTIGATION AT THE TEMPERATURE TEST FACILITY WHITE SANDS MISSILE RANGE, NEW MEXICO

Prepared for
Department of the Army
U.S. Army Engineers District
Tulsa District Corps of Engineers
Tulsa, Oklahoma

February 1995

Woodward-Clyde
Woodward-Clyde Federal Services
10975 El Monte, Suite 100
Overland Park, Kansas 66211
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Prepared for Department of the Army U.S. Army Engineers District Tulsa District Corps of Engineers Tulsa, Oklahoma

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Project Number F93102
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1.1 OBJECTIVE OF THE RCRA FACILITY INVESTIGATION

Woodward-Clyde Federal Services (WCFS) will perform RCRA Facility Investigation (RFI) activities at the Temperature Test Facility (TTF) to further study areas of concern around the TTF in order to characterize and identify release sources and contaminants, evaluate vertical and horizontal extent of contamination, and provide sufficient data to develop a Phase II investigation (if necessary) or conduct a Corrective Measures Study if required.

Upon completion of the field investigation and data collection activities, an RFI report will be prepared documenting the RFI activities and findings. The field data and analytical results of samples collected during the RFI will be used to characterize the nature and extent of contamination at the TTF. The data will be evaluated and analyzed to further define the contamination type, source or sources, extent, direction, rate of migration and distance the contamination has traveled at the facility. Inter-media transfer of contaminants will also be addressed as appropriate and the data will be interpreted to evaluate the characteristics of the release against established health and environmental criteria to evaluate the need for corrective measures.

1.2 PURPOSE OF THE FIELD SAMPLING AND ANALYSIS PLAN

The purpose of the Field Sampling and Analysis Plan (FSAP) is to present the sampling methods, locations, frequencies, and rationale for the samples and describe the field procedures that will be followed during the RFI field activities.

The FSAP includes detailed descriptions of all sampling activities including:

- Total number of samples to be collected
- Sampling objectives
1.3 OVERVIEW OF THE FIELD ACTIVITIES

The RFI field investigation will focus on the following issues:

- Potential contamination around the perimeter of the TTF Building from leaky floor drain pipelines
- Verification of the methylene chloride (MeCl) extent south of the former evaporative pond characterized during the Contamination Assessment (GCL, 1987)
- Potential migration of volatile organic compounds (VOCs) away from the evaporative pond cap

The field activities will include the collection and analysis of 100 shallow soil gas samples, collection and analysis of 9 deep soil gas samples, the drilling and sampling of ten deep soil borings, and the collection of soil gas samples from 19 existing soil gas monitor wells (this activity was completed in June 1994). Groundwater samples will be collected from four existing groundwater monitor wells.

It has been reported by current TTF personnel that a major release of MeCl to the floor of the facility occurred during July 1983 (Reynaud, 1993). The MeCl entered the floor drains of the facility which were connected to the former evaporation pond by a single pipeline. Subsequently, the synthetic pond lining failed and water containing MeCl entered the soil immediately beneath the pond. The extent of MeCl and other chemicals thought to be impurities in the MeCl (1,1,1 trichloroethane (TCA), trichloroethene (TCE), tetrachloroethene (PCE), and an unidentified freon compound (GCL, 1987)) in the area of and surrounding the pond were characterized during previous investigations conducted in 1985 and 1986 (GCL, 1987). After the pond was removed from service, a stainless-steel tank was constructed to receive water from the facility floor drains. Closure of the evaporative pond involved constructing a liner cap. The original ductile iron drain piping that extended from the building to the pond was removed and replaced with a jacketed drain...
line which extended from the building to the stainless-steel tank. A leak test of the floor drain system extending beneath the TTF Building conducted in 1989 indicated that the drain system leaks (Bath and Associates, 1989). The leak test was conducted subsequent to the release of the MeCl to the floor drains, and it is not known if the drain system leaked at the time of the release. The leaky drain lines represent a potential source of MeCl to the soil beneath the lines at the time of the release of the MeCl to the floor.

Previous investigations have focused on the evaporative pond as a potential source of release of MeCl and have not addressed the drain lines as a potential source of release. The current extent of the original (leaky) drain lines (Drawing 1-1) is limited to immediately beneath the TTF Building. While the drain lines do not represent a current source of MeCl to the environment, the potentially contaminated soil surrounding the drain lines may represent a source of continuing release. Similarly, the potentially contaminated soil which surrounded the drain line as it extended from the building to the evaporative pond and which was not covered by the cap may represent a source. Samples collected north and south of the TTF Building during the Contamination Assessment (GCL, 1987) showed the presence of MeCl, TCE, TCA, PCE, and an unidentified volatile compound in soil gas. It is not known if shallow soil gas contamination is present on the east and west sides of the TTF Building because soil gas samples were not collected within 75 feet of those sides of the building. The RFI will focus on characterizing potential sources of release of MeCl in the vicinity of the TTF Building. Space constrictions inside the TTF Building make it unfeasible to collect intrusive samples near the original drain lines beneath the building. Therefore, the sampling activities will be concentrated outside the building along the perimeter formed by the north, west, and south walls. The evaporative pond cap extends to the east side of the building precluding further intrusive activities on that side.

A sequential approach will be used during the investigation of the soils during the RFI. Shallow soil gas samples (100 total) will be collected from a depth of approximately 20 feet and analyzed for VOCs. The sample locations will be concentrated around the north, west, and south sides of the TTF Building with a lesser concentration of locations along the south side of the former evaporative pond cap. Samples will also be collected along the north and east sides of the cap to evaluate the potential migration of VOCs away from the cap. Details of the shallow soil gas investigation are presented in Section 2.0, Soil Gas Investigation Plan.
Deep soil gas samples (9) will be collected from a depth not-to-exceed 100 feet below ground surface and analyzed for VOCs. The sample locations will be concentrated around the west and south sides of the TTF building, along the south and east sides of the evaporative cap to evaluate the potential migration of VOCs away from the southwest corner of the evaporative cap, and to the north of the TTF building and cap to give additional data. Details of the deep soil gas investigation are presented in Section 2.0, Soil Gas Investigation Plan.

Ten soil borings will be drilled to an average depth of 100 feet adjacent to the 10 shallow soils gas sampling locations with the highest total VOCs concentration. Nine alluvial units were defined at the site as shown on Figure 1-1 in the Contamination Assessment Report (GCL, 1987). One soil sample will be collected from each of the nine alluvial units with the exception of Unit 7 where two samples will be collected. Details of the soil investigation are presented in Section 3.0, Soil Boring Plan.

Soil gas monitor well samples will be collected from the 19 existing soil gas monitor wells installed during the Contamination Assessment and analyzed for VOCs. Details of soil gas monitor well sampling are presented in Section 4.0, Soil Gas Monitor Well Plan.

Groundwater samples will be collected from the four monitor wells installed during the Contamination Assessment and analyzed for VOCs. Sampling details are presented in Section 5.0, Groundwater Sampling Plan.

Investigation derived waste will be managed according to Section 6.0, Investigation Derived Waste Plan.

Decontamination of field equipment and collection of decontamination (decon) fluids are discussed in Section 7.0, Equipment Decontamination.

All sampling locations will be surveyed according to Section 8.0, Surveying Procedures and Standards.

Project organization is discussed in Section 9.0 and the references cited in the FSAP are in Section 10.0.
2.0  
SOIL GAS INVESTIGATION PLAN

2.1 INVESTIGATION OBJECTIVE

The objective of the soil gas investigation is to characterize the horizontal extent of VOCs in the shallow and deep soil gas in the vicinity of the TTF and outside the perimeter of the evaporative pond cap. The extent of VOCs in the shallow soil gas will provide a basis for subsequent location of the soil borings.

2.2 SAMPLING METHODS, LOCATIONS, AND FREQUENCIES FOR SHALLOW SOIL GAS

2.2.1 Shallow Soil Gas Sampling Locations

Shallow soil gas sampling locations are shown in Drawing 2-1. The sampling locations are intended to address the following issues:

- Potential contamination around the perimeter of the TTF Building from leaky floor drain pipelines
- Verification of the extent of MeCl contamination south of the former evaporative pond characterized during the Contamination Assessment (GCL, 1987)
- Potential migration of VOCs away from the evaporative pond cap

An algorithm will be applied to the soil gas investigation so that enough data are collected to characterize the nature and extent of soil gas contamination but data beyond what is necessary for the characterization will not be collected. Sampling will begin with the locations surrounding the perimeter of the TTF and the evaporative pond cap (Locations 25-31, 36, 37, 42, 43, 46-48, 53, 65-71, 73, 75, 76, 82-85, and 96-100). If a soil gas analyte (Section 2.2.3) is detected at a location, the location in the next row, which are normal to diagonal from the first location, will be sampled. For example, if TCE is detected at location 27, soil gas samples will be taken from locations 17-19. The same algorithm will
be applied for locations in the second row. If a soil gas analyte is not detected at a location, no further action will be taken. Therefore, the minimum number of locations that will be sampled is equal to the number of perimeter locations listed above, 34. Each location will be sampled no more than one time. Therefore, the maximum number of locations that will be sampled is 100.

2.2.2 Estimated Depths and Designations

Prior to intrusive activities, the following actions are required:

- Underground utilities location will be coordinated by the WSMR Directorate of Engineering and Housing, and WCFS will receive written approval from the WSMR Facility Engineer to drill to avoid disturbing utilities
- Underground piping, tanks, and other equipment associated with the operation of the TTF will be located and marked by TTF staff

Shallow soil gas samples will be collected from an average depth of 20 feet below ground surface. This depth corresponds to the estimated depth of the bottom of alluvial Unit 1. Alluvial Unit 1 is defined as a poorly sorted sandy gravel and gravelly sand up to 20 feet thick (GCL, 1987). Unit 1 is overlain by topsoil and underlain by Unit 2 which is a relatively thin but stratigraphically continuous sandy and silty clay unit 2 to 4 feet thick. The bottom of Unit 1 was chosen as the shallow soil gas sampling depth for the following reasons:

- The sampling depth is below the estimated depth (5 to 10 feet) of the drain pipeline invert
- The sampling depth is near the interface between a relatively high conductivity alluvial unit and a relatively low conductivity underlying alluvial unit which would potentially slow the vertical migration of the liquid phase of the VOCs
- The relatively high hydraulic conductivity of Unit 1 will produce a relatively large radius of influence for sample collection of soil gas.
If the sampling device meets refusal above 20 feet, the sampling location will be offset by 3 to 4 feet. If refusal is met in the offset location, the sample will be collected at the depth of refusal.

A unique sample designation will reflect the medium sampled, the sample location, and the depth of sampling. For example, the sample designation WSTF-SSG1-5020 refers to the White Sands TTF shallow soil gas sample collected at location 1, soil gas (5) at a depth of 20 feet below ground surface. The preliminary sample locations are shown on Drawing 2-1.

2.2.3 Analytes and QA/QC Samples

Each soil gas sample will be analyzed in the field for the following list of VOCs.

<table>
<thead>
<tr>
<th>Soil Gas Analytes</th>
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<tbody>
<tr>
<td>MeCl</td>
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<tr>
<td>TCA</td>
</tr>
<tr>
<td>TCE</td>
</tr>
<tr>
<td>PCE</td>
</tr>
<tr>
<td>1,1-DCE</td>
</tr>
<tr>
<td>1,1-DCA</td>
</tr>
<tr>
<td>Chloroform</td>
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<tr>
<td>Freon 22</td>
</tr>
<tr>
<td>Freon 503</td>
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<td>Freon 113</td>
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<td>Freon 11</td>
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The following tabulation is a summary of Quality Assurance/Quality Control (QA/QC) samples associated with the shallow soil gas investigation. The Chemical Data Acquisition Plan (CDAP) contains complete QA/QC details.
### QA/QC Sample Frequency Designation

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<th>QA/QC Sample</th>
<th>Frequency</th>
<th>Designation</th>
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<tr>
<td>Field Blank</td>
<td>Once per day prior to collecting investigative samples</td>
<td>Sequentially beginning with WSTF-SSG-5020-FB</td>
</tr>
<tr>
<td>Initial Calibration</td>
<td>Once per day prior to collecting investigative samples</td>
<td>Sequentially beginning with WSTF-SSG1-5020-IC</td>
</tr>
<tr>
<td>Continuing Calibration</td>
<td>After every 10 investigative samples and after the last investigative sample collected for a day</td>
<td>Sequentially beginning with WSTF-SSG1-5020-CC</td>
</tr>
<tr>
<td>Field Duplicate</td>
<td>After every 20 investigative samples</td>
<td>WSTF-SSG1-5020-QA</td>
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### 2.3 SHALLOW SOIL GAS SAMPLING PROCEDURES

This section presents procedures for conducting shallow soil gas sampling and analysis. The rationale for shallow soil gas sampling and the proposed locations, depths, and a list of analytes are presented in Section 2.2.

#### 2.3.1 Apparatus

A van (mobile laboratory) mounted gas chromatograph/mass spectrometer (GC/MS) will be used for the detection of VOCs in the soil gas samples.

Other equipment required:

- Soil probe rods (3 feet by 1 inch outside diameter (o.d.)) with detachable drive point
- Disposable drive points
- Hydraulically driven percussion hammer
- 1-cc disposable syringes
- 10-cc evacuated vials
- Polyethylene tubing (1/4 inch o.d.)
- Silicone tubing
- Vacuum pump w/valves and gauges
2.3.2 Sample Collection Procedure

Shallow soil gas samples will be collected from undisturbed soil by probing directly into the soil with 1-inch diameter rods (Drawing 2-2). Where asphalt is present, the probe rods will be pushed or driven through the asphalt. Where concrete is present, a percussion hammer drill will be used to drill through the concrete before attaching the probe rods.

Once the sampling van is positioned over the sampling location and the surficial material has been penetrated, the rods will be hydraulically driven to the desired sampling depth. Upon reaching sampling depth, the rods will be retracted approximately 2 inches to remove the drive point and create an annular space for soil gas removal. A length of silicon tubing will then be connected from the vacuum system to the exposed end of the polyethylene tubing in the probe rod. The decline of vacuum pressure with time at a given location and depth will be used to determine whether the porosity of the soil is sufficient to withdraw a representative sample. If soil conditions restrict vapor flow at a selected depth, the rods will be raised to an interval above the sample depth until sufficient vapor flow has been achieved. The vacuum pump will be operated for sufficient time to purge 5 to 10 volumes of the post-run tubing and silicon rubber tubing of residual air/gas prior to sample collection. The required purge operating time will be determined from vacuum gage readings which are calibrated to volume of gas removed.

After purging is completed, approximately 1 cc of soil gas will be collected by inserting a new disposable syringe into the silicon rubber tubing shown on Drawing 2-2. The soil gas sample will be immediately injected into the field GC/MS for analysis.

Following sampling, the probe rods will be removed and the spent polyethylene tubing will be discarded. The spent rods will be set aside to await decontamination prior to reuse at another sampling location. Decontamination procedures are discussed in Section 7.0.

Upon completion of soil gas sampling at each location, the probe holes will be backfilled from the surface by pouring powdered bentonite into the open hole, and patching the asphalt or concrete where appropriate.
Each sample location will be marked with a wooden lath labeled with the sample designation for future references and surveying. All information pertinent to soil gas analysis will be recorded in a field logbook and field log sheet (Figure 2-1). At a minimum, the following information will be recorded:

- Project name and number
- Date/time of sample collection
- Personnel present
- Type of equipment
- Sample location
- Sample depth
- Soil type (if known)
- Vacuum reading
- Flow rate of gas
- Length of time/volume of purged gas
- Volume of gas collected
- Measured concentrations
- Interval above the bottom of the hole that rods are raised
- Other data as required

Decontamination of the probe rods will be in accordance with the procedures detailed in Section 5.7.1 of the CDAP.

2.4 SAMPLING METHODS, LOCATIONS, AND FREQUENCIES FOR DEEP SOIL GAS

2.4.1 Deep Soil Gas Sampling Locations

Deep soil gas sampling locations are shown on Drawing 2-3. The sampling locations are intended to address:

- Potential contamination around the perimeter of the TTF building from leaky floor drain pipelines, (DSG-1, DSG-2, DSG-3, DSG-4)
- Verification of the extent of MeCl contamination south of the former evaporative pond characterized during the contamination assessment (GCL, 1987) (DSG-5, DSG-6, DSG-7)
- Provide additional data to the north and east (DSG-8, DSG-9)
2.4.2 Estimated Depths and Designations

- Underground utilities location will be coordinated by the WSMR Directorate of Engineering and Housing, and WCFS will receive written approval from the WSMR Facility Engineer to drill to avoid disturbing utilities.

- Underground piping, tanks, and other equipment associated with the operation of the TTF will be located and marked by TTF staff.

Deep soil gas samples will be collected from Alluvial Unit 3. A pilot hole will be drilled with hollow stem augers and sampled continuously for visual identification and logging. Upon reaching Alluvial Unit 3, the augers will be withdrawn and the soil gas sampling tools inserted into the hole. Alluvial Unit 3 is defined as a thick unit consisting of gravelly sands. Generally, two distinct subunits are apparent in Unit 3. The upper one being cemented by calcium carbonate, and the lower one poorly cemented. The total thickness of Unit 3 is approximately 30 to 40 feet thick (GCL, 1987). Unit 3 is overlain by Unit 2 which is relatively thin but stratigraphically continuous sandy silt and underlain by Unit 4 which is a sandy clay.

The bottom of Unit 3 was chosen for the deep soil gas sampling depth for the following reasons:

- The vapor extraction system (VES) pilot study (ERC, 1990) stated that of the alluvial units at the site, Unit 6 has the highest permeability and largest radius of influence, and that Unit 3 also has high permeability and large radius of influence.

- It is estimated that the potential for vertical migration of VOCs in the unsaturated zone for areas outside the former evaporation pond is small because of the absence of a driving force (i.e., standing water). Therefore, it is more likely for VOCs to reach the more shallow unit, Unit 3.

A unique sample designation will reflect the medium sampled, the sample location, and the depth of sampling. For example, the sample designation WSTF-DSG1-5050 refers to the White Sands TTF deep soil gas sample collected at Location 1, and soil gas (5), at a depth of 50 feet below ground surface. The preliminary sample locations are shown on Drawing 2-3.
2.4.3 Analytes and QA/QC Samples

Each soil gas sample will be analyzed in the field for the following list of VOCs.

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</tbody>
</table>

The following tabulation is a summary of Quality Assurance/Quality Control (QA/QC) samples associated with the shallow soil gas investigation. The Chemical Data Acquisition Plan (CDAP) contains complete QA/QC details.

<table>
<thead>
<tr>
<th>QA/QC Sample</th>
<th>Frequency</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Blank</td>
<td>Once per day prior to collecting investigative samples</td>
<td>Sequentially beginning with WSTF-SSG-5020-FB</td>
</tr>
<tr>
<td>Initial Calibration</td>
<td>Once per day prior to collecting investigative samples</td>
<td>Sequentially beginning with WSTF-SSG1-5020-IC</td>
</tr>
<tr>
<td>Continuing Calibration</td>
<td>After every 10 investigative samples and after the last investigative sample collected for a day</td>
<td>Sequentially beginning with WSTF-SSG1-5020-CC</td>
</tr>
<tr>
<td>Field Duplicate</td>
<td>After every 20 investigative samples</td>
<td>WSTF-SSG1-5020-QA</td>
</tr>
</tbody>
</table>

2.5 DEEP SOIL GAS SAMPLING PROCEDURES

This section presents procedures for conducting deep soil gas sampling and analysis. The rationale for deep soil gas sampling and the proposed locations, depths, and a list of analytes are presented in Section 2.4.
2.5.1 Apparatus

A van (mobile laboratory) mounted GC/MS will be used for the detection of VOCs in the soil gas samples.

Other equipment required:

- Drill rig with adapter for soil gas sampling
- Soil probe rods (3 feet by 1 inch outside diameter (o.d.)) with detachable drive point
- Disposable drive points
- 1-cc disposable syringes
- 10-cc evacuated vials
- Polyethylene tubing (1/4 inch o.d.)
- Silicone tubing
- Vacuum pump w/valves and gauges

2.5.2 Sample Collection Procedure

Deep soil gas samples will be collected with the aid of a drill rig. Hollow-stem augers will be used to drill down to the desired sampling depth. Once the desired sampling depth is reached, a wire line will be sent down through the augers and the bit will be retrieved. An adapted apparatus to collect soil gas samples will be attached to the drill rods and sent down through the augers. The probe will be pushed into the soil and then retracted approximately 2 inches to remove the drive point and create an annular space for soil gas removal. The mobile sampling van will be positioned near the drill rig and a length of silicon tubing will then be connected from the vacuum system to the exposed end of the polyethylene tubing in the adapted sampling apparatus. The decline of vacuum pressure with time at a given location and depth will be used to determine whether the porosity of the soil is sufficient to withdraw a representative sample. If soil conditions restrict vapor flow at a selected depth,
the rods will be raised to an interval above the sample depth until sufficient vapor flow has been achieved. The vacuum pump will be operated for sufficient time to purge 5 to 10 volumes of the post-run tubing and silicon rubber tubing of residual air/gas prior to sample collection. The required purge operating time will be determined from vacuum gage readings which are calibrated to volume of gas removed.

After purging is completed, approximately 1 cc of soil gas will be collected by inserting a new disposable syringe into the silicon rubber tubing. The soil gas sample will be immediately injected into the field GC/MS for analysis.

Following sampling, the probe rods will be removed and the spent polyethylene tubing will be discarded. The spent rods will be set aside to await decontamination prior to reuse at another sampling location.

Upon completion of soil gas sampling at each location, boreholes will be grouted to the ground surface. The cement grout mixture will consist of Portland cement 3 percent by weight, bentonite powder and the appropriate proportion of water. Deep soil gas sampling locations advanced in asphalt will be patched. No borings will be advanced in areas where concrete is present.

Each sample location will be marked with a wooden lath labeled with the sample designation for future references and surveying. All information pertinent to soil gas analysis will be recorded in a field logbook and field log sheet (Figure 2-1). At a minimum, the following information will be recorded:

- Project name and number
- Date/time of sample collection
- Personnel present
- Type of equipment
- Sample location
- Sample depth
- Soil type (if known)
- Vacuum reading
- Flow rate of gas
- Length of time/volume of purged gas
- Volume of gas collected
- Measured concentrations
- Interval above the bottom of the hole that rods are raised
- Other data as required

Decontamination of the probe rods and drill rig will be in accordance with the procedures detailed in Sections 5.7.1 and 5.7.2 of the CDAP.
3.1 INVESTIGATION OBJECTIVE

The objective of the soil boring investigation is to characterize the vertical and horizontal extent of VOCs in unsaturated soil in the vicinity of the TTF and outside the perimeter of the evaporative pond cap.

3.2 SAMPLING METHODS, LOCATIONS, AND FREQUENCIES

3.2.1 Soil Boring Locations

The soil borings have been located to concentrate sampling efforts in areas where VOCs are suspected to be in the soil. Ten soil borings will be drilled to an average depth of 100 feet below ground surface adjacent to the 10 shallow soil gas locations with the highest total VOCs concentrations. These 10 locations are proposed and data collected in the field may warrant a change in these locations, any changes will be discussed with WSMR/USACE and the regulators. At no time will a boring be drilled through the concrete slabs which are contiguous with the TTF Building or the cap covering the former evaporation pond.

3.2.2 Depths and Designations

Prior to intrusive activities, the following actions are required:

- Underground utilities will be located by WSMR personnel, and WCFS will receive written approval from the WSMR Facility Engineer to drill to avoid disturbing utilities
- Underground piping, tanks, and other equipment associated with the operation of the TTF will be located by TTF staff

Each boring will be advanced using hollow-stem augers. Soil samples will be continuously collected and the boring will be visually logged by a WCFS geologist or engineer. Each
boring will be advanced until sufficient soil samples have been collected to allow conclusive identification of alluvial Unit 9. The average depth of the top of Unit 9 is estimated to be approximately 100 feet below ground surface but varies across the site. Ten soil samples for VOC analysis will be collected from each boring relative to the lithologic units (Figure 1-1) as summarized in the following table:

<table>
<thead>
<tr>
<th>VOC Sample</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bottom of Unit 1</td>
</tr>
<tr>
<td>2</td>
<td>Bottom of Unit 2</td>
</tr>
<tr>
<td>3</td>
<td>Bottom of Unit 3</td>
</tr>
<tr>
<td>4</td>
<td>Bottom of Unit 4</td>
</tr>
<tr>
<td>5</td>
<td>Bottom of Unit 5</td>
</tr>
<tr>
<td>6</td>
<td>Bottom of Unit 6</td>
</tr>
<tr>
<td>7</td>
<td>Top of Unit 7</td>
</tr>
<tr>
<td>8</td>
<td>Bottom of Unit 7</td>
</tr>
<tr>
<td>9</td>
<td>Bottom of Unit 8</td>
</tr>
<tr>
<td>10</td>
<td>Top of Unit 9</td>
</tr>
</tbody>
</table>

Additional focus was placed on Unit 7 because GCL, 1987 reported that VOC concentrations were generally detected in the upper part of Unit 7 but not detected in the lower part of Unit 7. This suggests that Unit 7 acts as a barrier for the vertical migration of VOCs.

Geotechnical samples will be collected when possible, in each unit at the same time samples are collected for chemical analysis. The samples will be analyzed for Grain Size Distribution ASTM-D 421/422, Atterberg Limits ASTM-D 423/424, and Moisture Content ASTM-D 2216. The hydrometer analysis will be used to relate grain size to permeability.

Soil samples collected for QA/QC chemical analysis will be collected from the same portion of the 5-foot split-barrel sampler as the investigative sample, so as to be representative of the investigative sample in soil classification, soil characteristics, and contamination.

Unique sample designations will reflect the medium sampled, the sample location, and the depth of sampling. For example, the sample designation WSTF-SB01-2045 refers to the White Sands TTF soil boring sample collected at soil boring location 1, soil (2), at a depth to the top of the sample of 45 feet. The sample designation format is discussed in Section
7.1 of the CDAP. The soil boring location algorithm is described in Section 3.2.1. Designation of QA/QC samples for chemical analysis are discussed in the next section.

### 3.2.3 Analytes and QA/QC Samples

Each soil sample will be analyzed for the following list of VOCs.

<table>
<thead>
<tr>
<th>Analyte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloromethane</td>
</tr>
<tr>
<td>Bromomethane</td>
</tr>
<tr>
<td>Vinyl Chloride</td>
</tr>
<tr>
<td>Chloroethane</td>
</tr>
<tr>
<td>Methylene Chloride</td>
</tr>
<tr>
<td>Acetone</td>
</tr>
<tr>
<td>Carbon Disulfide</td>
</tr>
<tr>
<td>1,1-Dichloroethene</td>
</tr>
<tr>
<td>1,2-Dichloroethene (total)</td>
</tr>
<tr>
<td>Chloroform</td>
</tr>
<tr>
<td>1,2-Dichloroethene</td>
</tr>
<tr>
<td>2-Butanone (MEK)</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
</tr>
<tr>
<td>Carbon Tetrachloride</td>
</tr>
<tr>
<td>Bromodichloromethane</td>
</tr>
<tr>
<td>1,2-Dichloropropane</td>
</tr>
<tr>
<td>cis-1,3-Dichloropropene</td>
</tr>
<tr>
<td>Trichloroethene</td>
</tr>
<tr>
<td>Dibromochloromethane</td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
</tr>
<tr>
<td>Benzene</td>
</tr>
<tr>
<td>trans-1,3-Dichloropropene</td>
</tr>
<tr>
<td>Bromoform</td>
</tr>
<tr>
<td>4-Methyl-2-Pentanone (MIBK)</td>
</tr>
<tr>
<td>2-Hexanone</td>
</tr>
<tr>
<td>Tetrachloroethene</td>
</tr>
<tr>
<td>Toluene</td>
</tr>
<tr>
<td>1,1,2,2-Tetrachloroethane</td>
</tr>
<tr>
<td>Chlorobenzene</td>
</tr>
<tr>
<td>Ethylbenzene</td>
</tr>
<tr>
<td>Styrene</td>
</tr>
<tr>
<td>Xylenes (Total)</td>
</tr>
<tr>
<td>Vinyl Acetone</td>
</tr>
<tr>
<td>1,1-Dichloroethane</td>
</tr>
<tr>
<td>Freon 22</td>
</tr>
<tr>
<td>Freon 503</td>
</tr>
<tr>
<td>Freon 113</td>
</tr>
<tr>
<td>Freon 11</td>
</tr>
</tbody>
</table>
The following tabulation is a summary of QA/QC samples. The Chemical Data Acquisition Plan (CDAP) contains complete QA/QC details.

<table>
<thead>
<tr>
<th>QA/QC Sample</th>
<th>Frequency</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC Field Replicate (Grab sample sometimes referred to as a duplicate)</td>
<td>Once every 10 investigative samples, collected with an investigative sample and a QA Field Replicate sample</td>
<td>WSTF-SB01-2045-QC</td>
</tr>
<tr>
<td>QA Field Replicate (Grab sample sometimes referred to as a duplicate)</td>
<td>Once every 10 investigative samples collected with an investigative sample and a QC Field Replicate sample</td>
<td>WSTF-SB01-2045-QA</td>
</tr>
<tr>
<td>Equipment Rinsate (To be analyzed by the contract laboratory)</td>
<td>Once per day</td>
<td>WSTF-SB01-2045-EB</td>
</tr>
</tbody>
</table>

3.3 SOIL BORING SAMPLING PROCEDURES

This section presents the procedures for collecting subsurface soil samples with a drill rig for purposes of evaluating soil contamination. The locations of proposed soil borings and sampling depths are discussed in Section 3.2.

Soil borings will be advanced using a drill rig with 4½-inch I.D., hollow-stem augers equipped with a continuous core sampling device. Samples will be collected continuously from the ground surface using a 3½-inch O.D., split-barrel, 5 feet in length. The samples will be retrieved by wire line with the drill pipe in place for chemical analysis. As drill cuttings are produced and travel up the auger, they will then be discharged onto visqueen around the borehole and then placed into the cuttings into the appropriate holding vessels for disposal according to the Investigation Derived Waste Management Plan (Section 6.0).

Each recovered sample will be split along its length. Material from inside the sample "core" will be collected for laboratory analysis. Any material appearing to be slough will be removed. The sample containers for VOC analysis (1.5-inch diameter 4 ounce glass jars) will be filled immediately with soil from a discrete interval of about 0.5 feet. Care will be taken to minimize the disturbance of the sample. The jar will be filled as full as possible to eliminate air space. The VOC sample will not be composited. Depending on the
consistency of the unconsolidated material, VOC samples will be collected with a sharp edged stainless-steel scoop or the sample jar itself. The sampler will be decontaminated with water and Alconox before every sampling trip.

After VOC samples are obtained, the recovered sample will be descriptively logged and recovery will be measured prior to collecting geotechnical samples.

Upon completion of the soil sampling, boreholes will be grouted to the ground surface. The cement grout will be in proportions of 94 pounds of Portland cement, 6 pounds of powdered bentonite, and a maximum of 10 gallons of water. The bentonite will be mixed with the water prior to adding the cement. Borings advanced in asphalt will be patched. No borings will be advanced in areas where concrete is present.

The following information (at a minimum) will be recorded on a sample collection field sheet (Figure 3-1) and in a field logbook.

- Project name and number
- Date/time of sampling
- Personnel present
- Type of equipment
- Sample location
- Sample number
- Sample depth
- HNu reading(s) (also recorded on boring log in remarks column)
- Visual classification

Sample bottle labels (Figure 3-2) will include the following information:

- Project name and number
- Soil sample number
- Date/Time of Sampling
- Sampler name
- Preservative
- Analysis
- Lab
- Container size
Details on sample containers and preservation are presented in Section 6.2, Table 6-1 of the CDAP.

All sampling equipment will be decontaminated according to the procedures in Section 7.0.

The soil boring sampling will be performed in accordance with the health and safety protocol specified in the Site-Specific Health and Safety Plan.

A list of standard equipment needed for soil sampling is presented in Table 3-1.

During drilling and sampling operations, the soil sampling and cuttings will be logged by an experienced geologist or engineer in general accordance with ASTM D2488-90, Description and Identification of Soils (Visual Manual Procedure). Descriptions will include color, consistency/density, plasticity or grain size, moisture, major components of admixtures, and other pertinent information. Boring logs (Figure 3-3) will be prepared by the field geologist or engineer. HNu readings will be recorded in the remarks column of the boring log for consolidation into the RFI Report.

3.4 GEOTECHNICAL SOIL SAMPLING PROCEDURES

This section presents the procedures for collecting subsurface soil samples with a drill rig for purposes of geotechnical testing. The locations of proposed soil borings and sampling depths are discussed in Section 3.2.

Whenever possible, soil samples for geotechnical or physical tests will be collected from the same 3½-inch O.D., 5-foot split-barrel sampler as the chemical samples. Soil samples will be placed in 8-oz. geotechnical jars for physical analysis. The appropriate jars will be drilled as full as possible to eliminate air space. Each sample will be tested in a geotechnical laboratory for the following parameters:

- Moisture Content (ASTM D2216-90)
- Grain size distribution (ASTM D421-85/D422-63)
- Atterberg limits (ASTM D4318-84)
Based on the geologist's field description, the grain size distribution analysis will consist of either a combined washed sieve and hydrometer analysis, or a washed sieve analysis or hydrometer alone. The Atterberg limits will not be performed on soils described in the field as noncohesive. The laboratory physical tests will be used to assist in classifying soils and evaluating remediation methods.

The following information (at a minimum) will be recorded on a sample collection field sheet (Figure 3-1), on the sample jar labels, and in a field logbook.

- Project name and number
- Soil boring number
- Depth of sample
- Sample date
- Sampler's name
- Collection method
4.1 SOIL GAS MONITOR WELL SAMPLING PROCEDURE

Soil gas samples for mobile (field) laboratory analysis of existing soil gas monitor wells will be collected. The monitor wells will be purged prior to sampling by inserting approximately 1 foot of 1/4 inch O.D. post-run teflon tubing into a drilled hole in the top of the PVC well cap. The tubing will be sealed with putty and a vacuum applied for sufficient time to purge the monitor well of approximately 3 well volumes of air. The well volume will initially be calculated by sounding the bottom of the well with a weighted tape and calculating a well volume where:

\[ V = \pi r^2 h \]

\[ V = \text{volume in ft}^3 \]
\[ \pi = 3.1416 \]
\[ r = \text{radius of the well in feet} \]
\[ h = \text{height of well in feet} \]

After purging is complete, approximately 1cc of soil gas will be collected by inserting a decontaminated glass syringe into the silicon rubber tubing (refer to Drawing 4-4). The soil gas sample will be immediately injected into a field gas chromatograph (GC) for analysis.

Each soil gas monitor well sample will be analyzed in the field for the following list of VOCs (unless otherwise directed by the USACE). All samples will also be submitted for laboratory analysis by EPA Method TO-14. (Note: This work was completed in June 1994).

SOIL GAS MONITOR WELL SAMPLE ANALYTES (OFF-SITE LAB)

EPA Method TO-14
Soil Gas Monitor Well Sample Analytes (Field Lab)

<table>
<thead>
<tr>
<th>Analyte</th>
</tr>
</thead>
<tbody>
<tr>
<td>MeCl</td>
</tr>
<tr>
<td>TCA</td>
</tr>
<tr>
<td>TCE</td>
</tr>
<tr>
<td>PCE</td>
</tr>
<tr>
<td>1,1-DCE</td>
</tr>
<tr>
<td>1,1-DCA</td>
</tr>
<tr>
<td>Chloroform</td>
</tr>
<tr>
<td>Freon 22</td>
</tr>
<tr>
<td>Freon 503</td>
</tr>
<tr>
<td>Freon 113</td>
</tr>
<tr>
<td>Freon 11</td>
</tr>
</tbody>
</table>

One field blank will be collected at the beginning of the day. Blanks will be collected by drawing ambient air through the connected tubing inside the monitor well casing while drawing air through the tubing. Blank samples will be obtained by inserting a syringe into the silicon rubber tubing the field blank will then be immediately injected into the GC for analysis.

Calibration standards will be analyzed at the beginning of the day for purposes of calibrating the GC. The standards will include compounds whose GC chromatogram peaks occur within the expected GC operating range of the compounds of interest.

Soil gas monitor well samples will be analyzed by a mobile laboratory GC in the field (on-site). The resulting chromatograms will be interpreted for concentrations of the designated compounds. All chromatograms will be saved for possible later use in reports.

The following information (at a minimum) will be recorded on a sample collection field sheet (Figure 3-1) and in a field logbook.

- Project name and number
- Date/time of sampling
- Personnel present
- Type of equipment
- Sample location
- Sample number
- Hnu reading(s)
- Vacuum reading
- Flow rate of gas
- Length of time/volume purged
- Volume of gas collected
- Measured concentration

The soil gas monitor wells will be sampled in accordance with health and safety protocol specified in the site-specific health and safety plan.
5.0 GROUNDWATER SAMPLING PLAN

5.1 INVESTIGATION OBJECTIVE

The objective of the groundwater investigation is to determine if VOCs are present above detection limits in groundwater collected from the four existing monitoring wells.

5.2 SAMPLING METHODS, LOCATIONS, AND FREQUENCIES

Groundwater samples will be collected from the four existing monitoring wells shown on Drawing 5-1. The analytes and number of QA/QC samples are summarized in the following table. Groundwater monitoring well E-3 (upgradient well) will be sampled first. The remaining wells (E-2, E-3, E-4) may be sampled in any order after the upgradient well has been sampled. Monitoring well E-1 was randomly selected for QA/QC/Rinsate sampling.

<table>
<thead>
<tr>
<th>Well</th>
<th>Analyte</th>
<th>QA/QC Field Parameters</th>
<th>QA/QC Sample</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-1</td>
<td>X</td>
<td>X</td>
<td>None</td>
<td>WSTF-00E1-1000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>where X is the last digit of the year and YY is numerical abbreviation for the month of sampling</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>QC</td>
<td>WSTF-00E1-1000-QC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>QA</td>
<td>WSTF-00E1-1000-QA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>Rinsate</td>
<td>WSTF-00E1-1000-EB</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(To be analyzed by the contract laboratory)</td>
<td></td>
</tr>
<tr>
<td>E-2</td>
<td>X</td>
<td>X</td>
<td>None</td>
<td>WSTF-00E2-1000</td>
</tr>
<tr>
<td>E-3</td>
<td>X</td>
<td>X</td>
<td>None</td>
<td>WSTF-00E3-1000</td>
</tr>
<tr>
<td>E-4</td>
<td>X</td>
<td>X</td>
<td>None</td>
<td>WSTF-00E4-1000</td>
</tr>
</tbody>
</table>
The list of VOC analytes for groundwater is the same as the list presented in Section 3.2.3. The field parameters are summarized below.

<table>
<thead>
<tr>
<th>Field Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity</td>
</tr>
<tr>
<td>Conductivity</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>pH</td>
</tr>
</tbody>
</table>

5.3 GROUNDWATER SAMPLING PROCEDURES

This section presents procedures for sampling of the existing TTF groundwater monitoring wells and collecting groundwater samples for chemical analysis.

5.3.1 Water Level Measurements

Water levels will be measured in the wells prior to purging, sampling and other activities. The water level will be measured from a mark or notch at the top of the well casing using a water level indicator. The measurements will be recorded to the nearest 0.01 foot. The water level, well designation and time and date of measurement will be recorded in the appropriate logbook and/or data collection sheet.

The water level indicator will be decontaminated prior to use according to procedures described in Section 5.6 of the CDAP.

5.3.2 Groundwater Sampling Procedure

All wells will be purged prior to sampling with the dedicated positive gas displacement bladder pumps which were previously installed in the TTF monitor wells. Purging of all wells will continue until a minimum of 5 casing volumes are removed from each well and the field parameters of pH, temperature, and conductivity are stable. In the case of slow recharge, wells will be pumped dry and sampled as soon as a significant recharge has occurred to fill all sample containers. All purge water will be containerized at the well location (see Section 6.0).
A water level measurement will be obtained and recorded prior to purging and again
following sampling. The sampling team will also measure and record on the sample
collection field sheet (prior to sampling) the depth to water from the top of the well casing;
the casing radius (4 inches) and the total depth of the well (feet). Additionally, the team
will calculate the height of the water column (feet) and standing volume (gallons) of water
in the well to determine the quantity to be purged. A Digisense pH meter (or equivalent),
a celsius thermometer and YSI scientific specific conductance meter (or equivalent)
calibrated and maintained specifically for groundwater testing at the TTF will be used to take
measurements of pH, temperature and conductance. Readings will be recorded every
one-half well volume during purging until three similar readings are obtained. The total
volume of fluids purged from the well will be recorded.

Following purging, the wells will be sampled using the dedicated bladder pump. Vials for
VOCs will be filled in a manner that prevents air bubbles from forming in the vial after
placement of the cap. A list of sample containers and preservation requirements for various
chemical analyses are given in Section 6.1, Table 6-2 of the CDAP. Preservatives will be
added to the sample containers prior to sample collection.

The following information (at a minimum) will be recorded on a sample collection field
sheet (Figure 5-1) and in a field logbook:

- Project name and number
- Date/time of sampling
- Personnel present
- Type of equipment
- Sample location
- Sample number
- Well depth and diameter
- Water level and minimum purge volume
- Purge and sampling method
- Instrument calibration check
- Measurements of conductivity, temperature, and pH
- Color or turbidity of sample (if applicable)
- Purge volume
- Duplicate, rinsate, and split sample numbers
- Sample preparation and preservation (HNO3, etc.)
- Remarks or any special problems or observations
Sample bottle labels (Figure 3-2) will include the following information:

- Project name and number
- Water sample number
- Date/time of sampling
- Sampler name
- Preservative
- Analysis
- Lab
- Container size

After sample collection, the exterior of the sample container will be rinsed with deionized water. The sample will be chilled to 4°C by placing the sample in an ice bath or refrigerator. Prior to shipping, the samples will be packed in a shipping shuttle (ice chest or other device) in a manner intended to minimize breakage. Ice will be added to shuttle to help keep the samples cool, the completed chain-of-custody will be taped inside a reclosable plastic bag and taped to the lid of the shuttle, and the shuttle will be sealed for shipping. Each shuttle will be shipped to the designated analytical laboratory as discussed in Section 7.3 of the CDAP.

Decontamination of personnel and equipment during groundwater sampling will be in accordance with the provisions in Section 5.7.3 of the CDAP.

Groundwater sampling of monitor wells will be performed in accordance with the health and safety protocols specified in the Site-Specific Health and Safety Plan.

A list of equipment needed for groundwater sampling is presented in (Table 5-1).
6.0
INVESTIGATION DERIVED WASTE MANAGEMENT PLAN

6.1 PLAN OBJECTIVE

This Investigation Derived Waste Management Plan (IDWMP) was prepared for use during RFI field activities at the TTF.

During the performance of the field investigations, various waste materials will be generated. These include drill cuttings, excavated materials, decontamination fluids, purge fluids, and personal protection equipment (PPE). This IDWMP has been structured so that it can be used to manage the different wastes that will be generated during the performance of various field investigations planned to be conducted at the TTF.

6.2 PURPOSE

This IDWMP describes the measures to be implemented at the TTF for the management of wastes generated during field sampling and investigative activities.

This section describes the various waste management control measures planned for each waste stream. The waste management measures include:

- Waste segregation

- Containerization of the following:
  - drilling fluids (if any)
  - groundwater sampling purge water
  - decontamination fluids
  - drill cuttings and other excavated soil
  - PPE and other waste materials

- Labeling of waste containers

- Transportation of waste containers to a WSMR designated storage area

The Government will provide final disposal of all materials collected during the RFI.
The various waste streams are:

- **Solids**
  - Personal protective equipment (PPE)
  - General rubbish
  - Plastic sheeting
  - Drill cuttings
  - Excess grout

- **Liquids**
  - Decon fluids
  - Well purge water

Waste materials will be segregated in separate containers (supplied by WCFS) on the basis of general appearance, odor and field monitoring equipment. This segregation will be performed to prevent the cross contamination of the material and the potential creation of a greater quantity of material that will require disposal. The descriptions of how the various wastes will be handled is discussed in the following sections.

The management of the cuttings and water wastes will conform to the conditions of the WSMR RCRA Part B Permit, the general and specific requirements of EPA Region VI, and New Mexico Health and Environment Department, Environmental Improvement Division.

Containerized materials will be collected in drums and placed by WCFS or its subcontractor, in a secure area designated by WSMR. WSMR is responsible for final disposal of all hazardous materials collected. The drum contents will be clearly and legibly labeled on the exterior of the drum body and on the lids with a non-oxidizing, non-fading paint stick. In addition, each drum will be assigned a numeric code which will be stamped into the side of the drum. The code number will then be associated with a particular bore hole, monitoring well, etc. and recorded in a dedicated logbook.

### 6.3 WASTE MINIMIZATION

Central to any waste management plan is the minimization of the volume of waste generated and stored, and the amount of material which must be removed from the site for disposal. To minimize waste generation, the following general rules will be followed:
1. Do not contaminate materials unnecessarily:
   - Plan work ahead, based on the work procedure to be utilized
   - Avoid going through areas of known contamination so personal or vehicle decontamination is reduced
   - Use containers to minimize the spread of contamination
   - Do not place contaminated materials with clean materials

2. Decontaminate and reuse material and equipment when practical:
   - Use equipment which is easily cleaned in the field, i.e., stainless-steel sampling equipment

3. Use volume reduction techniques when practicable:
   - Minimize the use of disposable PPE when appropriate
   - Verify that waste containers are solidly packed to minimize the number of containers (not to exceed 90 percent of the rated capacity of the container)
   - Utilize only the size of container to meet your needs, i.e., do not use a garbage can size bag when a small polyethylene bag will do
   - Less hazardous substances should be used whenever possible; e.g., Isopropyl alcohol will be substituted for Hexane for decontamination procedures
   - Remove as much soil and contamination from sampling equipment as possible before washing with water to minimize the quantity of wastewater generated
   - Do not excessively purge monitoring wells

6.4 DRILL CUTTINGS AND OTHER SOIL MANAGEMENT

A significant quantity of drill cuttings will be generated at each boring location. All borings will be backfilled with grout. Cuttings from borings at the TTF will be placed in a DOT 17H open top 55-gallon drum before leaving the location. A paint stick will be used to label the drum with the following information:
A numeric code which will be stamped into the side of each drum.

All wastes expected to be generated during the drilling process will be containerized by W-C. Characterization and disposal will be performed by the Government or its contractor.

The quantity of cuttings expected to be generated during the drilling of borings is calculated as follows:

\[ V = (d \times 0.5)^2 \times 3.1416 \times h \]

Where:  
- \( d \) = diameter of boring in feet  
- \( h \) = depth of boring in feet  
- \( V \) = volume of boring in cubic feet

When determining the amount of waste to be generated during a boring activity an expansion factor of 25 percent will be used when estimating the number of drums required.

Assuming a borehole diameter of 12-1/4 inches (1.02 feet) an approximate depth of 100 feet deep, and ten (10) boreholes, the calculated waste solids volume is:

\[(1.02 \times 0.5)^2 \times 3.1416 \times 100 \times 10 \times 1.25 = 1,021 \text{ cubic feet} = 38 \text{ cubic yards}\]

6.5 DRILLING FLUIDS, PURGE WATER, DECONTAMINATION WATER, AND OTHER FLUID MANAGEMENT

The cleaning of drill rigs, drilling equipment and sampling equipment and the purging and sampling of groundwater wells will generate significant quantities of decontamination water and purge water. Washing of boots at personnel decontamination stations may also generate additional water. All wastewater will be containerized in DOT 17E closed-top 55-gallon...
drums. A paint stick will be used to label the drums with the information as given in Section 6.4.

The volume of water from monitor well purging can be calculated as follows:

\[ V = 0.041 \, d^2 h \]

Where:  
- \( h \) = depth of water in feet  
- \( d \) = diameter of well in inches  
- \( V \) = volume of water in gallons  
- 0.041 = conversion factor for inches/feet to gallons

This volume will be multiplied by the number of well volumes to be removed from the well to be purged.

Volumes of water generated by well purging is variable depending upon several criteria. However, for estimation purposes, assume 5 well volumes will be produced during well purging.

Assumptions: 4-inch well  
50 feet of water

\[ V = 0.041 \times 4^2 \times 50 \times 5 = 164 \text{ gallons per well} \]
\[ 4 \text{ wells} \times 164 \text{ gallons} = 656 \text{ gallons} \]

6.6 PERSONAL PROTECTIVE EQUIPMENT WASTE MANAGEMENT

PPE generated waste will include Tyvek coveralls, disposable nitrile and vinyl gloves, outer heavy duty vinyl and cotton work gloves, disposable latex boots, disposable HEPA/organic vapor respirator cartridges, and duct tape used to seal the wrists and ankles of the coveralls. All of these items will be placed in double plastic bags during the workday and transferred to DOT 17H open-top 55-gallon drums at the end of the day. This will serve to reduce the
amount of PPE that may require special disposal. The drum contents will be labeled on the exterior with a paint stick along with the accumulation start date and SWMU No 101 (Temperature Test Facility).

6.7 CHARACTERIZATION AND DISPOSITION

The estimated number of drums is listed by waste type in Table 6-1.

Waste characterization and disposition of the drummed waste will be the responsibility of the Government.

6.8 SPILL CONTROL PLAN

The emergency spill procedures will be enforced by Woodward-Clyde's Site Safety and Health Officer (SSHO) to first take immediate action to contain the spill through either stopping it at the source and/or by use of absorbent booms. Then the SSHO will contact the USACE who will notify the WSMR. In the event the USACE cannot be reached, the SSHO will contact WSMR directly. The notification will include:

- Name of person reporting
- Name of contractor reporting
- Location of the spill
- Estimated quantity
- Material spilled
- Potential hazards (fire, health, environment, etc.)
- Action taken to contain spills

The SSHO, in accord with USACE, will take appropriate action to clean up the spill.

The materials used to pick up and clean up the spill will be disposed of as a solid hazardous waste and will be properly packaged and labeled.

A "spill kit" will be kept at each site and will consist of:

- Four sets of personal protective clothing (disposable)
- Four pair Nitrile latex gloves with 10-inch gauntlet
• Barricade tape and post
• One 10-foot by 40-foot sheet of 10-mil-thick plastic
• Two shovels
• Two absorbent booms
• Fifty pounds of adsorbent material
• Four organic/acid gas respirators
All drill rigs and all their associated equipment and soil gas sampling equipment will be inspected by the site manager for cleanliness prior to any field activities. The site manager will document the inspection and any corrective actions in the field logbook and daily field report.

Drill rigs and all their associated equipment used to drill soil borings, collect soil samples, and drill deep soil gas sampling locations will be decontaminated at a location generally near the TTF Building as approved by WSMR point of contact (POC), Hector Magallanes.

The decontamination pad will be constructed of heavy sheet plastic placed on the sloping TTF asphalt parking lot. Upon completion of all decontamination of equipment, the ponded decon water will be pumped from the pad and containerized according to the IDWMP (Section 6.0).

Decontamination of shallow soil gas sampling equipment will take place in large (approximately 5-gallon) plastic buckets placed inside children’s plastic swimming pools for secondary containment. Any fluid splashed or spilled from the buckets to the swimming pool will be carefully bailed or poured into the containers specified in the IDWMP (Section 6.0). The fluids remaining in the buckets will be containerized in a similar manner. The swimming pool will be replaced if it becomes cracked or punctured. Action will be taken to prevent puncturing or repair any punctures when decontamination fluids are in the swimming pool.
8.0
SURVEYING PROCEDURES AND STANDARDS

Upon completion of all field activities, a location and elevation survey will be conducted on 10 soil boring locations, 100 shallow soil gas sampling locations and 9 deep soil gas sampling locations. Measurements will be made at the ground surface at shallow and deep soil gas locations and soil boring locations.

All shallow and deep soil gas sampling locations and soil borings will be plotted onto topographic maps of the TTF site. The maps and all coordinates will be referenced to the state plane coordinate system. All elevations will be referenced to the National Geodetic Vertical Datum (NGVD) 1929.

All soil borings and soil gas sampling locations will be plotted at the appropriate coordinate point on the map and identified by designation, coordinate (to the closest 1.0 foot) and natural ground surface elevation (to the closest 0.1 foot).

All surveying notes shall be recorded in a standard field notebook. There will be no erasures made in these books.
9.0
PROJECT ORGANIZATION

Project organization is discussed in Section 3.0 of the Work Plan.
REFERENCES


<table>
<thead>
<tr>
<th><strong>Sampling Equipment</strong></th>
<th><strong>Shipping Supplies</strong></th>
<th><strong>Preservation</strong></th>
<th><strong>Decontamination Equipment</strong></th>
<th><strong>Miscellaneous</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling instrument (drill rig)</td>
<td>Coolers/sample shuttles</td>
<td>Ice</td>
<td>Plastic buckets - 5-gallon</td>
<td>Sample collection field sheets</td>
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<tr>
<td>Tape - 200 feet</td>
<td>Trash bags</td>
<td>Reusable cold packs</td>
<td>Laboratory surfactant (Alconox)</td>
<td>Chain-of-custody forms</td>
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<tr>
<td>Sledge hammer</td>
<td>Foam packaging material</td>
<td></td>
<td>Distilled/deionized water</td>
<td>Custody seals</td>
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<td>Stakes</td>
<td>Zip-lock bags</td>
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<td>Scrub brushes</td>
<td>Shipping labels</td>
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<td>Surveyor's flags</td>
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<td>Spray bottles</td>
<td>Boring log forms</td>
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<td>Field book</td>
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<td></td>
<td>Small Plastic Swimming Pool</td>
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<td>Plastic bags</td>
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<td></td>
<td>Decontamination tubs</td>
<td></td>
</tr>
<tr>
<td>Paper towels/Handi-wipes</td>
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<td></td>
<td>Visquene</td>
<td></td>
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<tr>
<td>Laboratory-cleaned sample containers</td>
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<td></td>
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<tr>
<td>Sample labels</td>
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<tr>
<td>Label tape (clear)</td>
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<tr>
<td>Indelible pens</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>6-foot folding ruler</td>
<td></td>
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<tr>
<td><strong>Health and Safety Equipment</strong></td>
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<tr>
<td>HNu with 10.2 eV lamp (with cal. gas)</td>
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<td></td>
<td></td>
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<tr>
<td>PVC steel-toed boots</td>
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<tr>
<td>Tyvek suits</td>
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<tr>
<td>Inner/outer gloves</td>
<td></td>
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</tr>
<tr>
<td>Goggles</td>
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</tr>
<tr>
<td>Hard hats</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>First-aid kit</td>
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<td></td>
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</tr>
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<td><strong>Shipping Supplies</strong></td>
<td></td>
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<td><strong>Decontamination Equipment</strong></td>
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<td><strong>Miscellaneous</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Shipping Supplies</strong></td>
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<tr>
<td><strong>Preservation</strong></td>
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<td><strong>Decontamination Equipment</strong></td>
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<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
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TABLE 5-1  
FIELD SAMPLING EQUIPMENT FOR GROUNDWATER SAMPLING

<table>
<thead>
<tr>
<th>Sampling Equipment</th>
<th>Shipping Supplies</th>
<th>Decontamination Equipment</th>
<th>Miscellaneous</th>
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</thead>
<tbody>
<tr>
<td>Well keys</td>
<td>Coolers/sample shuttles</td>
<td>High pressure sprayer (steam cleaner) optional</td>
<td>Sample collection field sheets</td>
</tr>
<tr>
<td>Measuring tape - 200 feet</td>
<td>Trash bags</td>
<td>Small Plastic Swimming Pool</td>
<td>Chain-of-custody forms</td>
</tr>
<tr>
<td>Electronic water level indicator</td>
<td>Foam packaging material</td>
<td>Plastic buckets - 5-gallon</td>
<td>Custody seals</td>
</tr>
<tr>
<td>Field book</td>
<td>Packaging tape</td>
<td>Laboratory surfactant cleanser (Alconox)</td>
<td>Shipping seals</td>
</tr>
<tr>
<td>Laboratory cleaned sample bottles</td>
<td>Zip-lock bags</td>
<td>Distilled/deionized water</td>
<td>Shipping labels</td>
</tr>
<tr>
<td>In-line or portable SCT meter with calibration solutions (includes pH, specific conductivity meter and thermometer)</td>
<td><strong>Preservatives</strong></td>
<td>Scrub brushes</td>
<td></td>
</tr>
<tr>
<td>Sample labels</td>
<td>Reusable cold packs</td>
<td>Decontamination tubs</td>
<td></td>
</tr>
<tr>
<td>Label tape (clear)</td>
<td>Ice</td>
<td>Visquene</td>
<td></td>
</tr>
<tr>
<td>Indelible pens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper towels</td>
<td></td>
<td></td>
<td></td>
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</table>

**Health and Safety Equipment**
- HNu with 10.2 eV lamp (with cal. gas)
- PVC steel-toed boots
- Tyvek suits
- Inner/outer gloves
- Goggles
- Respirators and approved cartridges
- Hard hats
- Respirator cleaning packs
- First-aid kit
TABLE 6-1
NUMBER OF DRUMS REQUIRED FOR INVESTIGATIVE WASTES

<table>
<thead>
<tr>
<th>Activity</th>
<th>Waste Type</th>
<th>Estimated Quantity Cubic Yards</th>
<th>Estimated Quantity Gallons</th>
<th>Estimated Number of Drums (at 202.2 Gallons/Cubic Yard and 55 Gallons/Drum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Borings</td>
<td>Solids</td>
<td>(1)</td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Personal Protective Equipment (PPE)</td>
<td>Solids</td>
<td>(1)</td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Plastic Sheeting and Excess Grout</td>
<td>Solids</td>
<td>(1)</td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>General Rubbish</td>
<td>Solids</td>
<td>(1)</td>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>Groundwater Monitor Well Purging</td>
<td>Liquids</td>
<td></td>
<td>(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>Decon Fluids</td>
<td>Liquids</td>
<td></td>
<td>(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>TOTAL NUMBER OF DRUMS</td>
<td></td>
<td></td>
<td></td>
<td>(1)</td>
</tr>
</tbody>
</table>

(1) To be completed for each field activity.
FIGURE 1-1
Lithologic Units at the Temperature Test Facility

Sandy Gravel, pale yellowish brown (10 YR 6/2); to dark yellowish brown (10 YR 4/2) and moderate brown (5 YR 4/4); medium to coarse grained sand; fine to medium pebble gravel; sub angular to sub rounded; very poorly to poorly sorted; moderate to poorly indurated; thickness 6-17 feet.

Gravelly Sand, moderate yellowish brown (10 YR 5/4); fine to medium pebble gravel; medium to coarse grained sand; sub angular to sub rounded; very poorly to poorly sorted; poorly indurated; thickness 4-9 feet.

Sandy Silty Clay; moderate red brown (10 R 4/6), moderate red orange (10 R 6/6); to moderate brown (5 YR 4/4); clay with medium to coarse grained sand; abundant root molds; thickness 2-4 feet.

Calche Cemented Gravelly Sand; light brown (5 YR 5/6) to moderate yellowish brown (10 YR 5/4), gray orange (10 YR 7/4); fine to coarse grained sand and fine pebble gravel; root molds; localized clay and calcite nodules, thickness 14-28 feet.

Gravelly Sand; pale yellowish brown (10 YR 8/2) to light brown (5 YR 5/6); fine to coarse grained sand and fine pebble gravel; localized sand lenses; sub angular to moderately rounded; poorly sorted; poorly indurated; thickness 3-18 feet.

Sandy Clay; moderate brown (5 YR 3/4) to pale yellowish brown (10 YR 8/4) to light olive gray (5 YR 5/2); contains minor root molds and calcite nodules; thickness 2-8 feet.

Sandy Silty Clay; appears greenish when first observed, grayish yellow (5 YR 8/4) to light olive gray (5 Y 5/2); contains minor root molds and calcite nodules; thickness 2-8 feet.

Sand; pale yellowish brown (10 YR 6/2) to light brown (5 YR 5/6); grayish orange (10 YR 7/4); very fine to medium grained, localized coarse grained lenses; sub angular to sub rounded; moderately sorted; poorly to moderately indurated; thickness 2-7 feet.

Silty Clay; pale brown (10 YR 5/4) to moderate brown (5 YR 4/4); sticky plastic clay with silt and minor sand; moderately well sorted; poorly indurated; contains calcite nodules and root molds; thickness 14-26 feet.

Sand; moderate brown (5 YR 4/4), moderate yellow brown (10 YR 5/4) to orange (10 YR 7/4); very fine to fine grained; sub rounded; moderately well sorted; poorly indurated; thickness 1-8.5 feet.

Silty Clay; dark yellowish brown (10 YR 4/2) to moderate brown (5 YR 4/4); contains calcite and minor calcite nodules; thickness 1-4 feet.

SOURCE (GCL, 1987)
SOIL GAS SAMPLE COLLECTION FIELD SHEET

SITE NAME: ______________________________ PROJECT NUMBER: ______________

SAMPLE NUMBER: __________________________ PERSONNEL: __________________________

LOCATION DESCRIPTION: _____________________________________________________________

SAMPLE SPLIT (circle one): YES NO : SPLIT SAMPLE NUMBER: ______________________

SAMPLE DEPTH: ____________________________________________________________________

COLLECTION: YR: ______ MO: ______ DAY: ______ TIME: ______

SAMPLING METHOD/EQUIPMENT USED: __________________________________________________

SOIL DESCRIPTION:

DEPTH: ________________________________________________________________________

DESCRIPTION: __________________________________________________________________

SAMPLE CONTAINER: ________________ VACUUM READING: ________________

PRESERVATIVE: __________________________________________________________________

FLOW RATE OF GAS: __________________________________________________________________

ANALYSIS REQUESTED: __________________________________________________________________

VOLUME OF GAS COLLECTED: __________________________________________________________________

LENGTH OF TIME/VOLUME OF PURGED GAS: __________________________________________________________________

MEASURED CONCENTRATIONS: _____________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

NOTES/SKETCH MAP: _____________________________________________________________

ACAD FILE: F93102K
D.R.T. SC: 1-7
**GROUNDWATER SAMPLE COLLECTION FIELD SHEET**

**PROJECT NAME:** WHITE SANDS MISSILE RANGE  
**SAMPLE NUMBER:** ___________  
**LOCATION DESCRIPTION:** ___________  
**SAMPLE MEDIA:** GROUNDWATER  
**SAMPLE SPLIT:** ___________  
**WATER LEVEL MEASUREMENT FROM TOP OF RISER PIPE (ft):** ___________  
**COLLECTION:** YR: 93  MO: _____  DAY: _____  TIME: ___________  METHOD: DEDICATED SAMPLING PUMP

<table>
<thead>
<tr>
<th>SAMPLE CONTAINER</th>
<th>PRESERVATION</th>
<th>ANALYSIS REQUESTED (LAB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 X 40 ml vial</td>
<td>HCl (pH&lt;2), cool</td>
<td>VOC (CCL)</td>
</tr>
</tbody>
</table>

**FIELD ANALYSIS**

**TEMPERATURE, °C:** ___________  
**SAMPLE pH:** ___________  
**CONDUCTIVITY umhos/cm:** ___________  
**pH BUFFER BEFORE:** ___________  
**pH BUFFER AFTER:** ___________  
**APPEARANCE (circle one):** Clear  Sl. Cloudy  Cloudy  
**ODOR (circle one):** None  Weak  Strong

**DATE:** ___________  
**TIME:** ___________  
**METHOD:** DEDICATED SAMPLING PUMP

**DEVELOPMENT/PURGING**

**DATE:** ___________  
**CASING DIAMETER:** __ 4 in  
**WATER LEVEL BEFORE (ft):** ___________  
**WELL DEPTH (SOUNDED) (ft):** ___________  
**WATER LEVEL AFTER (ft):** ___________  
**TIME STARTED:** ___________  
**TIME COMPLETED:** ___________  
**METHOD:** Dedicated Sampling Pump

**HNU/OVA, BACKGROUND:** ___________  
**HNU/OVA, WELL HEAD:** ___________  
**METHOD:** Dedicated Sampling Pump

**COMMENTS:** _______________________________________________________________________________

**MIN. PURGE VOLUME = ( (Well Depth, TOR - Water level, TOR) x gal/ft + gal) x 3/3 = gal**
FINDINGS:

TEST PART I:
1. AIR LEAKAGE BETWEEN FLOOR DRAIN WALLS AND CONCRETE SLAB (LARGE TEST CHAMBER)
2. AIR LEAKAGE BETWEEN VALVE STEM AND VALVE BODY V-1 AND V-2
3. AIR LEAKAGE BETWEEN PIPE WALL AND CONCRETE CURB
4. AIR LEAKAGE BETWEEN CLEANOUT AND CONCRETE SLAB OUTSIDE EAST OF TTF BUILDING

TEST PART II (LARGE TEST CHAMBER ONLY):
1. AIR LEAKAGE BETWEEN 2 FLOOR DRAIN WALLS AND CONCRETE SLAB (IN LARGE TEST CHAMBER)
2. AIR LEAKAGE BETWEEN VALVE STEM AND VALVE BODY ON V-1

TEST PART III (SMALL TEST CHAMBER ONLY):
1. NO AIR LEAKAGE VISIBLE THEREFORE SUSPECT VALVE V-2 LEAKING

TEST PART IV:
1. MINOR AIR LEAKAGE AROUND 2 SCREWED PIPE CONNECTIONS (SUSPECT TANK VENT PIPE)

TEST PART V:
7 INCHES WATER LOSS FROM INTERCEPTOR TANK (AMOUNTS TO 175 GALLONS)

LEGEND:

- CONFIRMED SHALLOW SOIL GAS SAMPLING LOCATIONS
- PROPOSED SHALLOW SOIL GAS SAMPLING LOCATION

NOTE:
1. THE EVAPORATIVE POND CAP IS DEFINED BY THE NORTH AND SOUTH CULVERT, THE CAP PERIMETER FENCE TO THE EAST, AND THE ASPHALT TO THE EAST OF THE TTF BUILDING.

SOURCE: DYNASPAN SERVICES, 1989
1.8 CC DISPOSABLE SYRINGE
SYRINGE NEEDLE
SILICONE RUBBER TUBE
1/4 IN. TEFLOM TUBING

SILICONE RUBBER TUBE CONNECTION TO VACUUM PUMP
ADAPTOR FOR SAMPLING SOIL-GAS PROBE
CLEAR TUBING SLEEVE CONNECTOR (DISPOSABLE)
SOIL GAS FLOW DURING SAMPLING
3/4 IN. PIPE
COUPLING
1/4 IN. O.D. POST-RUN TEFLOM TUBING
THREADED TUBING CONNECTOR
COUPLING
SAMPLING PORT
SOIL GAS
DETACHABLE DRIVE POINT

TOTAL LENGTH AS NECESSARY TO REACH SAMPLING POINT
18 F.

WOODWARD-CLYDE
OVERLAND PARK, KANSAS

U.S. ARMY ENGINEER DISTRICT:
CORPS OF ENGINEERS
TULSA, OKLAHOMA

WHITE SANDS MISSILE RANGE, NEW MEXICO

DESIGNED BY:
G.W.W.

CHECKED BY:
L.A.T.

RCRA FACILITY INVESTIGATION
TEMPERATURE TEST FACILITY
WHITE SANDS MISSILE RANGE, NEW MEXICO

TYPICAL SHALLOW SOIL GAS SAMPLING PROBE

SCALE: NOT TO SCALE
DATE: JULY, 1994

WOODWARD-CLYDE
OVERLAND PARK, KANSAS

U.S. ARMY ENGINEER DISTRICT:
CORPS OF ENGINEERS
TULSA, OKLAHOMA

WHITE SANDS MISSILE RANGE, NEW MEXICO

DESIGNED BY:
G.W.W.

CHECKED BY:
L.A.T.

RCRA FACILITY INVESTIGATION
TEMPERATURE TEST FACILITY
WHITE SANDS MISSILE RANGE, NEW MEXICO

TYPICAL SHALLOW SOIL GAS SAMPLING PROBE

SCALE: NOT TO SCALE
DATE: JULY, 1994
NOTE:
1. REFER TO SECTION 2.4 AND 2.5 FOR DISCUSSION OF DEEP SOIL GAS SAMPLING LOCATIONS AND PROCEDURES.
2. THE EVAPORATIVE POND CAP IS DEFINED BY THE NORTH AND SOUTH CULVERT, THE CAP PERIMETER FENCE TO THE EAST, AND THE ASPHALT TO THE EAST OF THE TTF BUILDING.

LEGEND:
- PROPOSED DEEP SOIL GAS SAMPLING LOCATION

NOTES:
1. REFER TO SECTION 2.4 AND 2.5 FOR DISCUSSION OF DEEP SOIL GAS SAMPLING LOCATIONS AND PROCEDURES.
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1. THE EVAPORATIVE POND CAP IS DEFINED BY THE NORTH AND SOUTH CULVERT, THE CAP PERIMETER FENCE TO THE EAST, AND THE ASPHALT TO THE EAST OF THE TIF BUILDING.
2. WELL COMPLETION DATA FOR SOIL GAS MONITOR WELLS 10, 12, 13, 17 AND 20 WAS NOT AVAILABLE AT THE TIME THIS DRAWING WAS PRODUCED.
LEGEND:

E-4 APPROXIMATE LOCATION OF RCRA GROUNDWATER MONITORING WELL

NOTE:
1. THE EVAPORATIVE POND CAP IS DEFINED BY THE NORTH AND SOUTH CULVERT, THE CAP PERIMETER FENCE TO THE EAST, AND THE ASPHALT TO THE EAST OF THE TTF BUILDING.
CHEMICAL DATA ACQUISITION PLAN FOR THE RCRA FACILITY INVESTIGATION AT THE TEMPERATURE TEST FACILITY WHITE SANDS MISSILE RANGE, NEW MEXICO

Prepared for Department of the Army U.S. Army Engineers District Tulsa District Corps of Engineers Tulsa, Oklahoma

February 1995

Woodward-Clyde Federal Services 10975 El Monte, Suite 100 Overland Park, Kansas 66211
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Prepared for Department of the Army U.S. Army Engineers District Tulsa District Corps of Engineers Tulsa, Oklahoma

February 1995

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<td>Bung Top, White Steel Drum</td>
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<tr>
<td>mg/kg</td>
<td>Milligrams per Kilogram</td>
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<tr>
<td>mg/L</td>
<td>Milligrams per Liter</td>
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<td>MRD</td>
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<td>Matrix Spike</td>
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<td>MSD</td>
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<tr>
<td>OVM</td>
<td>Organic Vapor Monitor</td>
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<tr>
<td>PCE</td>
<td>Tetrachloroethylene (also perchloroethene)</td>
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<td>PID</td>
<td>Photoionization Detector</td>
</tr>
<tr>
<td>ppb</td>
<td>Parts Per Billion</td>
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<td>Personnel Protection Equipment</td>
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<td>ppm</td>
<td>Parts Per Million</td>
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<td>TCE</td>
<td>Trichloroethene</td>
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<td>Woodward-Clyde</td>
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<tr>
<td>WSMR</td>
<td>White Sands Missile Range</td>
</tr>
<tr>
<td>(\mu g/L)</td>
<td>Micrograms per Liter</td>
</tr>
<tr>
<td>(\mu g/kg)</td>
<td>Microgram per Kilogram</td>
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1.0 INTRODUCTION

This document is the Chemical Data Acquisition Plan (CDAP) for the RCRA Facility Investigation (RFI) at the Temperature Test Facility (TTF) White Sands Missile Range (WSMR), New Mexico. The CDAP is Appendix B to the RFI Work Plan and supplements the other project planning documents. All documents are necessary to understand the background, purpose, methods and procedures of the planned field investigation.

The purpose of this CDAP is to present the procedures required to document that the data obtained from the investigative activities at a site are of acceptable quality. Quality assurance (QA) is a plan which specifies measures used to obtain desired and verifiable levels of quality in all aspects of the investigation. Quality control (QC) is the functional mechanism to achieve quality data. The QA program will ensure that the QC procedures will result in high quality data. This document describes the QA/QC for each aspect of the planned investigation which will meet the data quality objectives (DQO) of this project.

1.1 ORGANIZATION OF THE CDAP

This document describes the data quality procedures and techniques to be implemented during the RFI at the TTF. The study will be accomplished through a deep and shallow soil gas survey (SGS), soil borings, sampling and analysis of subsurface soil, sampling and analysis of groundwater from existing groundwater monitoring wells and sampling and analysis of soils gas from existing soil gas monitor wells. The field investigation is targeted for early 1994.

The CDAP is based on guidance contained in Chemical Data Quality Management for Hazardous Waste Remedial Activities (USACE, 1990), and the USACE Scope of Work (SOW) (USACE, 1993). Additional information was also obtained from the existing RFI work plans developed for WSMR by Sverdrup Environmental, Inc. (SVE, 1993).
Section 2.0 discusses site location, description and history, and project objectives; Section 3.0 presents the project organization; and Section 4.0 contains the DQO for the project. Section 5.0 discusses the procedures to be used in sampling and Section 6.0 discusses laboratory testing and QC procedures. Sections 7.0 through 10.0 discuss sample control, data reduction and validation, audits, and corrective action. Section 11.0 lists References. Appendix A presents the forms to be used during the field activities, Appendix B contains the Analytical Laboratory Quality Assurance Plan, Appendix C the Soil Gas Survey Quality Assurance Plan and Appendix D the Soil Physical Testing American Society for Testing and Materials (ASTM) Standard Test Methods.

Section 2.3.5 of the USACE Scope of Work (SOW) specifies 15 items to be addressed in the CDAP. These items and the cross reference to the applicable sections of this CDAP are as follows:

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2.0 PROJECT DESCRIPTION

2.1 SITE LOCATION

The WSMR is a U.S. Army facility under the jurisdiction of the U.S. Army Test and Evaluation Command (TECOM). It is located in the Tularosa Basin of south-central New Mexico in the counties of Dona Ana, Socorro, Lincoln, Otero, and Sierra. The WSMR is comprised of nearly 4,000 square miles of land, approximately 99 miles long and 25 to 40 miles wide. The headquarters and all installation support activities are located in the Main Post Area which is 45 miles north of El Paso, Texas and 27 miles east-northeast of Las Cruces, New Mexico as shown in Figure 2-1.

The WSMR Main Post is at an elevation of almost 4,000 feet. The climate of the area is arid to semi-arid. Average annual precipitation is approximately 8 inches. Snowfall is infrequent, although heavy snows have occurred.

Rainfall usually occurs during late summer as thunderstorms often accompanied by hail. Flash floods usually follow heavy rainfalls. The average summer high temperature is 92°F with lows of about 65°F. During the winter months (December, January, and February), the average high temperature is 57°F, with an average low temperature of 36°F. Average annual humidity measurements are approximately 37 percent.

Wind is the dominant climatic factor at WSMR, especially during the months of February through May. The prevailing southerly winds blow unimpeded across the desert and at times reach gale proportions. Storms may last for days in the spring.

The TTF (Figure 2-2) is located approximately 4 miles east of the WSMR Main Post area. Soil in the vicinity of the TTF includes basin fill which consists of fine sands, silts, and clays emanating from the Organ Mountains located about 5 miles west of the site. West of the TTF, the water table lies approximately 200 feet below the land surface and has a gradient to the east. The aquifer is the source for domestic and process water supplying the WSMR Main Post.
2.2 SITE DESCRIPTION

The WSMR was established on July 9, 1945. It is an outdoor laboratory consisting of a large complex of test ranges, launch sites, impact areas, and instrumentation sites, along with the support facilities required to develop and test missiles and rockets. In parallel with off-range facilities, WSMR is used as a national range designated for the support of missile development and test programs for the Army, Navy, Air Force, NASA, and other governmental agencies.

The TTF was designed to simulate extreme weather conditions by inducing a wide range of temperature and climatic variations. Construction of the TTF was completed in 1984. The TTF as originally constructed consisted of the testing building, several underground storage tanks (USTs) with ancillary piping, and a surface evaporation pond. The original refrigerant was methylene chloride (MeCl) which was recycled using the USTs. The surface evaporation pond was used to evaporate process wastewater generated as a by-product of freezing rain tests performed in the test building.

Sometime after 1986, the USTs were relocated to water tight subterranean vaults and the evaporation pond was relocated to a stainless-steel tank at a different location (see Figure 2-2). The former evaporation pond and surrounding area were recently capped. The cap extends 320 feet east of the TTF building and consists of a 2-foot layer of compacted clay. Topping the clay are 2 inches of sand, a flexible synthetic membrane barrier, 2 more inches of sand, a 1-foot thick stabilized aggregate drainage layer, and a 2-inch thick surface layer of crushed rock. In 1991, MeCl was replaced in the system with a heat transfer liquid, named Syltherm®.

2.3 ENVIRONMENTAL HISTORY AND SUMMARY OF PREVIOUS ENVIRONMENTAL INVESTIGATIONS

A release of MeCl onto the ground occurred in July 1983. In January 1985, it was discovered that the liner of the surface evaporation pond had leaked the pond’s contents to the underlying soil. MeCl was believed to have been present in the process water leaked to the soil because of faulty seals in the piping system connecting the USTs to the refrigerating apparatus in the test facility. A soil gas survey and soil borings investigations
conducted in 1985 and 1986 defined a contaminant plume centered beneath the southern end of the evaporation pond (GCL, 1987). Sixteen (16) of the borings were completed as soil gas wells screened at different depths. A soil gas extraction well has also been installed (ERC, 1990). Four groundwater monitoring wells exist at the site.

### 2.4 PROJECT OBJECTIVES

The objective of this investigation is to obtain information in order to characterize and identify release sources and contaminants, evaluate vertical and horizontal extent of contamination, and provide sufficient data to develop a Phase II investigation (if necessary) or conduct a CMS if required. The contaminants of concern for this investigation are volatiles, especially the following eleven volatiles:

- Methylene Chloride (MeCl)
- 1,1,1-Trichloroethane (TCA)
- Trichloroethene (TCE)
- Tetrachloroethene (perchloroethene) (PCE)
- 1,1-Dichloroethene (DCE)
- 1,1-Dichloroethane (DCA)
- Chloroform
- Freon 22
- Freon 503
- Freon 113
- Freon 11

Field sampling activities are:

- 100-point shallow soil gas survey with analysis for MeCl, TCA, TCE, PCE, 1,1-DCE, 1,1-DCA, Chloroform, Freon 22, Freon 503, Freon 113, and Freon 11.

- 9-point deep soil gas survey with analysis for MeCl, TCA, TCE, PCE, 1,1-DCE, 1,1-DCA, Chloroform, Freon 22, Freon 503, Freon 113, and Freon 11.
• 10 soil borings to average 100-feet below ground surface (bgs) depth. 10 samples per boring for total of 100 samples. Analysis for volatiles by USEPA SW-846, Method 8240

• Soil gas sampling of 19 existing soil gas monitor wells

• Groundwater sampling of the four existing groundwater monitoring wells. Analysis for volatiles by USEPA SW-846, Method 8240

In addition to the above activities, QA/QC sampling and analysis will include:

• Quality assurance samples - @ 10 percent
• Quality control samples - @ 10 percent
• Matrix spike/matrix spike duplicate (MS/MSD) - @ 10 percent
• Equipment blank samples - approximately 8
• Trip blank samples - 1 per shipment for groundwater

All analytical chemistry data will be validated.

Project deliverables are:

• RFI Work Plan
• Field Sampling and Analysis Plan (FSAP)
• Chemical Data Acquisition Plan (CDAP)
• Health and Safety Program Plan (HSPP)
• Community Relations Plan (CRP)
• Data Validation and Summary Report
• RFI Report

The RFI Report will include a Health and Environmental Assessment to evaluate the characteristics of releases and recommend if corrective measures are necessary.

An overview of the RFI activities is provided in Section 2.0 of the Work Plan.

2.5 PROJECT SCHEDULE

Details of the project schedule are addressed in Section 3.0 of the Work Plan. Field investigations are anticipated to occur in the spring of 1995. The proposed Project Schedule is shown in Figure 2-3.
3.0
PROJECT ORGANIZATION

3.1 PROJECT PERSONNEL

The project organizational chart is presented in Figure 3-1.

The Program Manager provides technical and management oversight for the project. The Project Manager is responsible for the day-to-day conduct of the project. The Project Manager reports directly to the Program Manager.

The QA/QC functions will report directly to the Project Manager. They will oversee the field QA/QC activities and interact directly with the Field Document Control and Quality Control Officer. Both the QC Coordinator and the Field QC Officer will provide QA/QC oversight of the field subcontractors. The Field Document Control and QC Officer will be responsible for correct logging and labeling of all samples, chain of custody, packaging and shipment of samples. This person will also be responsible for control of all field forms including all drilling logs, monitoring well logs, and field activity reports.

Resumes of W-C personnel involved in this project are located in the Resume section of this CDAP.

3.1.1 Contract Field Crews

Woodward-Clyde (WC) will subcontract the following specialized services:

**Soil Gas Survey:**

Plains Environmental Services  
P.O. Box 6288  
Salina, Kansas  67401
Drilling and Soil Gas Monitoring Well Installation:

Stewart Brothers Drilling Company
306 Airport Road
Milan, New Mexico 87021

Land Surveyor:

Southwest Engineering, Inc.
475 Archuleta Road
Las Cruces, New Mexico 88005

3.1.2 Contract Laboratories

Physical and chemical testing services will be provided by the following laboratories:

Chemical Analyses:

Quanterra Environmental Services (formerly Enesco, Inc.)
4955 Yarrow Street
Arvada, Colorado 80002

Quanterra is validated through the USACE-MRD.

Soil Physical Testing:

Woodward-Clyde Geotesting Services, Inc.
45 H Commerce Way
Totowa, New Jersey 07512

3.2 QUALITY ASSURANCE/QUALITY CONTROL PERSONNEL

Mr. Less Osborne will serve as the Quality Assurance Officer. Dr. Dennis Takade will serve as Quality Control Coordinator. Dr. Takade (or his designee) will also conduct QA/QC field audits (refer CDAP, Section 9.0).
DATA QUALITY OBJECTIVES

DQOs are qualitative and quantitative statements which specify the quality of data required to meet the goals of the site characterization, health and environmental assessment, and design. Data developed during the study will be used to determine the presence and vertical and horizontal extent of contamination in the soil and groundwater. The evaluation of this data will be used to complete the RCRA Facility Investigation (RFI) report.

The level of analytical support that will meet these goals is Level III as described in Data Quality Objectives for Remedial Response Activities: Development Process, (EPA, 1987). As part of the analytical reporting requirements, the following minimum information is required from all reporting laboratories:

- Sample identification numbers cross-referenced with laboratory identification numbers and QC sample numbers
- Problems with arriving samples noted on chain-of-custody
- Each analyte reported as an actual value or less than a specified detection limit (i.e., below detection limit [BDL])
- Dilution factors, extraction dates, and analysis date
- QC samples results for laboratory blanks, surrogate spikes, matrix spikes, laboratory duplicates, field duplicates, and field blanks

The data developed from TTF Investigation will meet specific quality assurance objectives with respect to accuracy, precision, completeness, sensitivity, representativeness, and comparability. WCFS will ensure that the DQO's described below are met prior to proceeding with the RFI Report or initiate corrective action measures as described in Section 10.0. USACE is responsible for providing WCFS the information on comparability prior to WCFS completing the RFI Report.
4.1 ACCURACY

Accuracy is the degree to which a measurement agrees with the actual value; i.e., the amount of measurement bias. Accuracy is expressed as a percent recovery of a known concentration of reference material. The accuracy of an analytical procedure is determined by the addition of a known amount of material to a field sample matrix or a standard matrix as the field sample. The field sample matrix is described as all components of the sample mixture except the analyte (the compound being analyzed). The lab will be required to perform matrix spiking on 10 percent of field samples. Field sample matrix and standard matrix sample spiking show how the sample matrix--analyte chemical interactions affect the analytical results. The matrix behavior of the spiked field sample will be comparable to that of the matrix of the original sample. The matrix spike consists of a known amount of an analyte which is added to the matrix before analysis. After analysis for the spike is completed, the accuracy of the procedure is expressed as a percent recovery as shown by the following equation:

\[
\text{\% recovery} = \left( \frac{C_2 \text{ minus } C_1}{C_0} \right) \times 100\%
\]

where:

- \(C_0\) = amount of analyte added to the sample matrix,
- \(C_1\) = amount of analyte present in the unspiked sample matrix, and
- \(C_2\) = amount of spiked material recovered in the analysis.

Typically, the amount of a reference analyte spiked into a field sample matrix is specified by the laboratory quality control program, or 3 to 5 times the background concentration of the analyte in the sample matrix. Samples cannot be spiked for all organic compounds which could possibly exist in the field sample matrix. However, a set of surrogate compounds, each of whose physical and chemical properties is similar, is used as surrogate matrix spikes, or surrogates. Acceptable recovery ranges for each class of organic compounds are discussed in the analytical methods for each parameter.
4.2 PRECISION

Precision is a measure of the degree of reproducibility of an analytical value and is used as a check on the quality of the sampling and analytical procedures. Precision is determined by analyzing replicate samples. The significance of a precision measurement depends on whether the sample is a field replicate, lab replicate, or a matrix spike replicate. Field replicates are taken at the rate of 10 percent or one per batch (each daily shipment of samples from a site), whichever is greater. Precision of the analytical method, at each stage, is determined by calculation of a relative percent difference (RPD) between duplicate analytical recoveries of a sample component, relative to the average of those recoveries:

\[
RPD = \frac{|C_2 \text{ minus } C_1|}{(C_2 \text{ plus } C_1) \div 2} \times 100\%
\]

where:
- \(C_1\) = analyte concentration in the sample,
- \(C_2\) = analyte concentration in the sample replicate,
- \(|\cdot|\) = an absolute value (It is customary to express RPD as a positive number).

These calculations are usually performed on matrix spikes and matrix spike duplicates.

The RPD values for each class of organic compounds should not exceed the analytical methods requirements for each parameter (Table 6-5).

4.3 COMPLETENESS

Field completeness will be assessed by comparing the number of samples collected to the number of samples planned. Analytical completeness will be assessed by comparing the total number of samples with valid analytical results to the number of samples collected. The overall project completeness is, therefore, a comparison between the total number of valid samples to the number of samples planned. The results will be calculated following data validation and reduction. Completeness (C) is determined by:
\[
C = \frac{P_1}{P_0} \times 100\%
\]

where

\[P_0 = \text{total number of samples planned, and}
\]

\[P_1 = \text{number of valid data points.}
\]

A value of 90 percent or higher is the goal. For values less than 90 percent, problems in the sampling or analytical procedures should be examined and possible solutions explored.

4.4 SENSITIVITY

Sensitivity is a general term which refers to the calibration sensitivity and the analytical sensitivity of a piece of equipment. The calibration sensitivity is the slope of the calibration curve evaluated in the concentration range of interest. The analytical sensitivity is the ratio of the calibration sensitivity to the standard deviation of the analytical signal at a given analyte concentration. The detection limit, which is based on the sensitivity of the analysis, is the smallest reported concentration in a sample within a specified level of confidence. Practical quantitation limits represent the sum of all of the uncertainties in the analytical procedure plus a safety factor. The detection limit is a part of the quantitation limit. The reporting limits presented in Table 6-3 will be used for practical quantitation limits in achieving the sensitivity data quality objective.

4.5 REPRESENTATIVENESS

Representativeness expresses the degree to which sample data accurately and precisely represent actual site conditions. The determination of the representativeness of the data will be performed by:

- Comparing actual sampling procedures and chain-of-custody (COC) forms to those described in the work plan

- Identifying and eliminating nonrepresentative data in site characterization activities

- Evaluating holding times and condition of samples on arrival at the laboratory
• Examining blanks for cross contamination

Representativeness is a qualitative determination. The representativeness objective of this work plan is to eliminate all non-representative data.

4.6 COMPARABILITY

Comparability cannot be done by W-C because sufficient information to accomplish this task will not be available to the A-E contractor. Comparability will be done by USACE through use of data from previous studies and the QA sample analysis data from the Southwest Division (SWD) laboratories. Following is a definition of comparability.

Comparability is a qualitative measure of the confidence with which one data set can be compared to another. These data sets include data generated by different laboratories performed under this work plan, data generated by laboratories in previous investigative phases, data generated by the same laboratory over a period of several years, or data obtained using differing sampling techniques or analytical protocols. The comparability objectives of this work plan are (1) to generate consistent data using standard test methods; and (2) to salvage as much previously generated data as possible.
5.0
FIELD OPERATIONS

The field investigation at the TTF will include a soil gas survey, soil sampling, and sampling of existing groundwater monitoring wells and soil gas monitor wells. All new sample points will be surveyed for coordinate and elevations. Field QA/QC procedures will be implemented to achieve the DQO discussed in Section 4.0.

5.1 SOIL GAS SURVEY

Soil gas sampling methods, location, frequencies, equipment, and procedures are described in detail in Section 2.0 of the FSAP. Shallow soil gas sampling procedures are summarized as follows:

- The probe rod will be assembled and hydraulically driven to the desired sample depth
- A vacuum pump will be used to purge the soil gas sampling tubing
- A soil gas sample will be collected from the sampling tubing after the purging is completed
- The soil gas sample will be analyzed with a field gas chromatograph/mass spectrometer (GC/MS)
- The probe rod will be removed and the probe hole will be backfilled with powdered bentonite
- Field logbook and/or field log sheet will be completed

Deep soil gas sampling procedures are summarized as follows:

- Drill with hollow-stem auger to desired sampling depth
- Run wire line down through augers to retrieve drill bit
• Attach drive hammer to drilling rods, then attach sampling probe to rods and drive into bottom of boring
• A vacuum pump will be used to purge the soil gas sampling tubing
• Soil gas sample will be collected from the sampling tubing after the purging is complete
• The soil gas sample will be analyzed with a field GC/MS
• The probe rode will be removed, then the augers, and the sampling hole will be backfilled with grout (Type II Portland cement and 3 percent bentonite mixture) when the sampling is complete
• Field logbook and/or field log sheet will be completed.

5.2 SOIL BORING AND SAMPLING

Soil boring and sampling methods, locations, frequencies, equipment and procedures are described in detail in Section 3.0 of the FSAP. Soil boring and sampling procedures are summarized in this section.

Soil borings will be advanced with hollow-stem augers and continuously sampled with a split barrel sampler. VOC samples will be collected without compositing immediately after the recovered sample is split. Soil samples and cuttings will be logged during the drilling and sampling operations. The borehole will be backfilled with grout (Type II Portland cement and 3 percent bentonite mixture) when the sampling is completed.

Soil samples for physical tests will be collected from the same recovered sample as the chemical samples. The soil samples will be described in the field by a geologist or geotechnical engineer and classified according to the Unified Soil Classification System (USCS).

5.3 GROUNDWATER SAMPLING

Groundwater sampling procedures are described in detail in Section 5.3 of the FSAP and are summarized as follows:
• The groundwater level will be measured before purging

• The monitoring well will be purged and field parameters (pH, temperature, and conductivity) will be measured during purging. Purging will continue until a minimum of five casing volumes are removed and the field parameters stabilize

• Groundwater samples will be collected after purging is completed and shipped off-site for analysis

• The groundwater level will be measured after purging

• Field logbook and sample collection sheets will be completed

5.4 SOIL GAS MONITOR WELL SAMPLING

Soil gas monitor well sampling procedures are described in detail in Section 4.0 of the FSAP and are summarized below:

• Teflon tubing will be inserted into a drilling hole in the cap of the soil gas well and sealed

• A vacuum pump will be used to purge the soil gas sampling tubing

• A soil gas sample will be collected from the sampling tubing after the purging is completed

• The soil gas sample will be screened with a field gas chromatograph and analyzed in an off-site laboratory

• Field logbook and/or field log sheet will be completed

5.5 FIELD MEASUREMENTS

Field measurements include soil gas analysis for MeCl, TCA, TCE, PCE, 1,1-DCE, 1,1-DCA, Chloroform and Freon 22, Freon 503, Freon 113, and Freon 11. Groundwater level, pH, temperature, and conductivity measurements will be obtained during groundwater sampling. Organic vapors will also be monitored for health and safety purposes during sampling.
All monitoring equipment will be properly calibrated and used according to manufacturer's instructions. Copies of the owner's manual will be kept on-site for reference on the proper calibration, operation, and troubleshooting of equipment.

5.5.1 Soil Gas Analysis

Soil gas analysis will be performed on site with a field GS/MS as described in Section 2.0 of the FSAP, and Sections 5.1 and 5.4 in this report.

5.5.2 Groundwater Sampling Field Measurements

Groundwater level measurements will be taken with water level indicators that have tapes or cables marked in increments of 0.01 feet.

The field parameters (pH, temperature, and conductivity) will be measured with in-line portable SCT meter during purging. The SCT meter will be calibrated according to the manufacturer's instructions. The calibration will be checked frequently during the day and adjusted if necessary. Fresh buffer and standard solutions will be used for calibration. All calibrations and checks will be recorded in the field logbook.

5.5.3 Organic Vapor Monitoring

Photoionization detectors (PID), organic vapor monitors (OVM), and triple gas monitoring will be used for gas and organic vapor monitoring. All calibrations will be performed according to the manufacturer's instructions. The triple gas meters are capable of simultaneously measuring the lower explosive limit (LEL), carbon monoxide, and percent oxygen of the atmosphere.

5.5.3.1 Photoionization Detector

Calibration of all PIDs will be performed daily by attaching the calibration gas to the detector probe and adjusting the span setting to get the desired concentration value on the display. In general, 100 ppm isobutylene is used for calibration. PIDs can be set to read
ppm as isobutylene or ppm as another gas depending on the response factor for the gas of interest in relation to that of isobutylene.

All calibrations of the PIDs will be recorded in the field logbook. At a minimum, the following information will be recorded.

- Data and time of calibration
- Type and concentration of calibration gas
- Calibration and span settings (including the gas that the display reading is referenced to, for example, ppm as benzene or as isobutylene)

PID readings will be taken by placing the probe near the sample or in the atmosphere of interest and allowing sufficient time for the air to be drawn through and readings to stabilize (usually 5 to 10 seconds).

5.5.3.2 Organic Vapor Monitor

Calibration of OVM includes gain and range balancing, and primary calibration for the organic vapor compound of interest. Gain and range balancing sets the electronic amplifier gain for each of the three calibrate ranges. The OVM will be initially calibrated at the x10 range with a known concentration methane sample (near 100 ppm). This will be followed by balancing the OVM between the three calibrate ranges.

Primary calibration of OVM sets the "Gas Select Control" for the organic vapor of interest. This is accomplished by calibrating with a known mixture of the organic vapor compound of interest after the OVM is zeroed for normal background readings. Alternatively, the OVM can be calibrated to methane, and the concentration of organic vapor of interest will be estimated from relative response data.
5.6 LOCATION SURVEY

All soil gas survey points and soil borings will be surveyed for coordinate and elevations. Location survey procedures are discussed in detail in Section 8.0 of FSAP and are summarized in this section.

All coordinates will be referenced to the State Plane Coordinate System, NAD-83, or the WSMR coordinate system. All elevations will be referenced to the National Geodetic Vertical Datum of 1929.

Coordinates will be surveyed to the closest one foot. Ground elevations will be surveyed to the closest one-tenth of a foot. For each new monitoring well, the elevation of the concrete pad or survey marker and the top of the casing will be surveyed to the closest one-hundredth of a foot.

5.7 DECONTAMINATION

Decontamination of equipment will be performed to minimize potential cross-contamination of samples collected at the site.

5.7.1 Soil Gas Survey Equipment Decontamination

All non-disposable equipment for collecting soil gas samples will be decontaminated between sample points. Decontamination procedures for soil gas survey equipment are discussed in Appendix C.

5.7.2 Soil Boring Sampling Equipment Decontamination

All reusable soil boring sampling equipment, and any other tools used for intrusive work (deep soil gas sampling) will be decontaminated between borings. A single decontamination pad will be constructed at a central location at the site as described in Section 7.0 of FSAP. All drilling equipments will be cleaned with high-pressure hot water/steam-cleaning unit. All other tools and equipments will be decontaminated according to the following procedures:
• Scrape or brush off excess soil or contamination
• Scrub in a Alconox detergent and potable water wash using a brush
• Rinse thoroughly with potable water to remove detergent
• Rinse thoroughly with distilled water
• Place item on plastic sheeting or store in clean plastic bag until use

5.7.3 Groundwater Sampling Equipment Decontamination

Water level indicator will be decontaminated prior to each use during groundwater sampling. Decontamination procedures include rinsing with ASTM Type II or equivalent water and wiping the tape with a ASTM Type II water-moistened paper towel.

5.8 MANAGEMENT OF INVESTIGATION DERIVED WASTE

The field investigation includes the following operations.

• Operation of field trailer
• Shallow and deep soil gas survey
• Soil borings and soil sampling
• Sampling existing groundwater monitoring wells
• Sampling existing soil gas monitor wells

Specific details regarding investigation wastes are contained in the Investigation Derived Waste Management Plan (IDWMP) (Section 6.0 of FSAP). The IDWMP addresses:

• Waste sources
• Waste categories
• Waste minimization
• Waste volumes anticipated
• Spill Control Plan
• Waste management control
  - waste segregation/screening
  - contamination containment
  - containerization of wastes
  - waste inventory
  - waste storage, characterization and disposal
The waste streams generated during this investigation are:

- **Solids**
  - Personal protective equipment (PPE)
  - General rubbish and trash (waste paper, absorbent towels, drop cloths, plastic bags, etc.)
  - Plastic sheeting and other materials used for secondary containment
  - Drill cuttings
  - Excess grout

- **Liquids**
  - Decon fluids
  - Well purge water

The only activity involving a mobile (field) laboratory is the soil gas survey. The only wastes anticipated from this activity is decontamination wastes from decontamination of the soil probe rods used in obtaining samples of soil gas, PPE and general rubbish. Any excess analytical calibration gas or sample carrier gas will remain with the soil gas survey equipment van.

All wastes will be segregated where possible and placed in 55-gallon drums and labelled as to the contents of each drum. Each drum will be coded with a numeric code permanently fixed to the side of the drum. All drums will be recorded in a field log book listing the bore hole(s), monitoring well(s), etc. location served by the individual drum and the contents of the drum. All drums will be moved by W-C (or its subcontractor) to a containerized waste staging or assembly area designated by the WSMR facility personnel. Characterization of the wastes including any sampling and analysis, and disposal of the wastes is the responsibility of the Government.

A critical element of the IDWMP is waste minimization. A detailed discussion of the waste minimization steps to be used is contained in section 6.3 of the IDWMP. The major categories of waste minimization are:

- Do not contaminate materials unnecessarily
- Decontaminate and reuse material and equipment when practical
- Utilize volume reduction techniques when practical
The volume of waste generated is estimated as follows.

**Solids**
- drill cuttings from soil borings - 38 cubic yards
  @ 202.2 gallons/cubic yard & 55 gallons/drum = 139 drums
- PPE = 2 drums
- Plastic sheeting and excess grout = 4 drums
- General rubbish = 4 drums
  TOTAL 149 drums of solids

**Liquids**
- Groundwater monitoring well purging - 656 gallons
  @ 55 gallons/drum = 12 drums
- Decon fluids = 8 drums
  TOTAL 20 drums liquids

A second critical element of the IDWMP is the Spill Control Plan which is discussed in Section 6.8 of the IDWMP. In the event of a spill, emergency spill procedures will be enforced by Woodward Clyde's Site Safety and Health Officer (SSHO). Immediate action will be taken to contain a spill by stopping it at the source and/or use of absorbent materials. Spill notification procedures are specified in IDWMP section 6.8. All materials used to clean up a spill that cannot be reused through decontamination procedures will be containerized in 55-gallon drums using the same procedures used for the other categories of investigation derived wastes. A spill kit will be kept at each work site for immediate use in the event of a spill. IDWMP Section 6.8 lists the composition of each spill kit.

To provide protection of human health and the environment, all wastes will be considered as potential hazardous wastes and managed accordingly until characterization of the wastes proves otherwise.

**5.9 FIELD QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES**

Field QA/QC procedures are used to assess the quality of the sampling activities and analytical data. Field QA/QC samples include replicate samples, rinsate blanks, and trip blanks for soil and groundwater sampling, and blank and duplicate samples for soil gas survey.
QC samples are sent to W-C's subcontracted analytical laboratory along with the other field samples. The identity of these samples are held blind to the analysts and laboratory personnel until data are in deliverable form. QA samples are sent to the USACE-SWD analytical laboratory to evaluate the performance of W-C's subcontracted analytical laboratory.

5.9.1 Soil Gas Quality Control Samples

Soil gas quality control samples include duplicate samples, field blanks, and instrument calibration samples. The frequencies for analyzing soil gas QC samples are discussed in Section 2.2 of FSAP and Appendix C.

5.9.2 Replicate Samples

Replicate samples are multiple grab samples, collected separately, that equally represent a medium at a particular time and location.

Replicate samples will be collected in triplicate. Two of the three samples will be sent to W-C's subcontracted analytical laboratory as a regular field sample and as a replicate for QC purposes. The third sample will be sent to USACE-SWD analytical laboratory as a QA sample. The frequency of collecting replicate samples are discussed in Sections 3.2 and 5.2 of FSAP for soil and groundwater sampling, respectively.

5.9.3 Rinsate Blank

Rinsate blanks (also referred to as equipment blank) are used to evaluate the effectiveness of equipment decontamination procedures.

Rinsate blanks are prepared from a final rinse of sampling equipment with organic-free reagent water after the decontamination procedures are completed. The organic-free reagent water used will meet the ASTM Type II or equivalent reagent water requirements. The frequencies of collecting rinsate blank are discussed in Section 3.2 and 5.2 of the FSAP for soil and groundwater sampling, respectively.
5.9.4 Trip Blank

Trip blanks are used to measure the potential contamination of volatile organics samples during storage and shipment.

Trip blanks are prepared from organic-free reagent water meeting the ASTM Type II reagent water requirements, and will not contain any headspace. They are prepared by the analytical laboratories, and are sent to the field with the VOC vials. They will be returned to the laboratory for volatile organic analyses, along with the other volatile organics samples. One trip blank will be prepared for each cooler containing water samples to be analyzed for volatile organics.

5.9.5 Daily Quality Control Report

Daily QC report will be maintained to document all field QC measures taken, any departure from the approved plan, and corrective action.
6.0 LABORATORY TESTING AND QUALITY CONTROL PROCEDURES

6.1 LABORATORY TESTING

Soil gas samples will be analyzed by a field GC/MS. The quantitation limits for soil gas analysis are presented in Table 6-1.

Laboratory test methods, and sample containers and preservation requirements for chemical analyses are summarized in Table 6-2. The target compound list and the respective reporting limits for volatile organic analyses (VOA) are presented in Table 6-3.

Test methods for the physical (geotechnical) soil samples are summarized in Table 6-4.

6.2 LABORATORY QUALITY CONTROL PROCEDURES

To control and monitor the quality of data generated from chemical analyses, laboratory quality control procedures will be implemented, and are included in Appendixes B, C, and D. This section provides a summary of the laboratory quality control procedures and presents the project-specific quality control requirements for chemical analyses.

Instrument calibration and tuning will be performed to ensure that the analytical system is operating correctly and functioning at the proper sensitivity. This includes initial and continuing calibration of instruments.

Laboratory control check samples and calculation of surrogate recovery will be used to control, monitor, and assess data quality. Laboratory quality control check samples include duplicate, matrix spike (MS), matrix spike duplicate (MSD), and method blanks.
Project-specific quality control requirements include:

- Minimizing methylene chloride contamination within the laboratory, as methylene chloride is a contaminant of interest and is recognized as a common laboratory contaminant.

- MS/MSD and surrogate recoveries data will be used as control to chemical analyses. Matrix spike recovery and surrogate limits are presented in Table 6-5.

- A single laboratory control sample may take the place of the laboratory duplicate control sample (DCS) upon request.

The following procedures will be implemented in the laboratory to minimize methylene chloride contamination:

- Volatile blank water will be replaced daily.
- New volatile water will be purged with helium for 24 hours.

Corrective action will be performed in accordance with Section 10.0 when quality control data fall outside the acceptable criteria.
Sample control and documentation is required to maintain sample integrity. Precleaned sample containers and preservation will be used in accordance with the test methods. Samples will be properly sealed, labeled, and stored in the field once they are collected. Each sample will be assigned a unique field identification number. Samples will be properly packed and cooled for shipment, and the chain of custody will be recorded.

### 7.1 SAMPLE IDENTIFICATION DESIGNATION

A nine-digit sample identification designation consisting of three three-character fields will be used and is explained in this section.

All sample identification designation will have the following format:

**WSTF - hhhh - xaaa - bb**

where:

- **WS** = White Sands
- **TF** = Temperature Test Facility
- **hhhh** = boring number or soil gas point number
- **x** = indicates the sample medium where:
  - 1 = Groundwater
  - 2 = Soil
  - 3 = Sediment
  - 4 = Surface Water
  - 5 = Soil Gas
- **aaa** = depth below ground surface
- **bb** = QA/QC modifier when needed where:
  - QA = A QA sample replicate (goes to COEs SWD lab)
  - QC = A QC sample replicate (goes to contractor’s lab)
  - EB = Equipment blank
  - TB = Trip blank (QA or QC)
The sample identification designation for different types of sampling activities is explained in Table 7-1.

7.2 SAMPLE DOCUMENTATION AND LABELING

All information pertinent to a field activity will be recorded in a logbook and/or sample collection field sheets. In the case of the soil borings, boring logs will also be prepared. Sample identification labels will be used to label sample containers. Specific information to be included and examples of logbook, sample collection field sheets, and boring logs are included in the FSAP.

All entries in sample collection field sheets will be completed. Waterproof indelible ink will be used. In the case where no data is available, "NA" will be entered for "Not Applicable" or "UNK" will be entered for "unknown." To change an incorrect entry, a line will be drawn through the mistake and the change will be written, dated, and initialed above the line.

7.3 SAMPLE HANDLING, PACKAGING, AND SHIPMENT

7.3.1 Sample Handling and Packaging in the Field

All samples collected will remain in the possession of the sampling crew until shipment. Locked vehicles or trailers will be used for interim storage as necessary. If coolers (used for sample storage) must be left unattended for extended periods of time, signed custody seals will be placed on the coolers.

To minimize bottle breakage and provide adequate sample temperature during shipment, sample bottles will be prepared and packaged according to the following procedures:

- Waterproof metal or rigid plastic ice chests or coolers will be used as vehicle of sample shipment.
- Vermiculite, foam, or other inert packing material will be placed on the floor of the cooler.
• Bottles will be placed upright in the cooler and ice will be placed around, among, and on top of the sample bottles.

• Packing material will be placed in appropriate locations to minimize potential bottle breakage during shipment. Care will be taken so that the packing material does not thermally insulate the bottles from the ice placed in the shipping container.

• The completed chain-of-custody form will be placed into a Ziploc bag, sealed, and taped to the inside cover of the corresponding cooler.

• The drain of the cooler will be taped shut.

• The cooler lid will be secured by wrapping the cooler with strapping tape at a minimum of two different locations.

• The completed shipping label will be attached to the top of the cooler.

• The signed custody seal will be affixed upon the front right and back left of each cooler/lid interface and covered with clear packing tape.

7.3.2 Sample Shipment

Samples will be sent to all laboratories by overnight courier. Prior to sample shipment, arrangements will be made with each laboratory, including the USACE-SWD laboratory to receive and handle the samples. This is to ensure that sample temperatures and holding times are not exceeded.

7.3.3 Laboratory Sample Receiving

Upon receipt of the sample coolers at the appropriate laboratory, the laboratory will check the following items:

• The cooler will be checked for damage or leakage and the custody seals will be verified to be intact

• Contents of cooler will be compared with the chain-of-custody to verify that all sample ID and requested analyses match and that no samples are missing
• Bottles will be inspected for breakage or leakage and the field personnel will be notified immediately if this occurs

• The temperature of the sample will be measured and recorded on the chain-of-custody form

• The pH of liquid VOC samples will be measured (to verify pH is less than 2) and recorded

• Any discrepancies between cooler contents and chain-of-custody forms will be noted and/or comments provided regarding damaged samples or problems in the "Remarks" section of the chain-of-custody form

• The date, time, and signature should be recorded on the chain-of-custody form acknowledging the condition and receipt of samples

By signing the chain-of-custody forms, the laboratories will assume responsibility for proper storage, analysis, and disposal of the samples. The laboratories will store the samples in a secure area which is accessible only to authorized personnel.

7.4 SAMPLE CUSTODY

7.4.1 Chain-of-Custody Forms

COC forms are used to record the possession and handling of samples from the time of collection through analysis. For each transfer of the sample custody, the sample custodian will sign, and record the date and time on the chain-of-custody form. The field sample custodian will retain a copy (either carbon or photocopy) of the COC form. For sample packages sent by common carrier to the laboratory, the bill of lading will be retained as a part of the permanent chain-of-custody documentation.

The COC form will include the following information:

• Project description (e.g., project name, project number, project location, etc.)

• Laboratory name
- Sample identification number
- Sample type (i.e., soil, groundwater, etc.)
- Sample collection date
- Analysis requested
- Type and number of sample containers
- Preservation method
- Signature of sample custodian, date, and time for each transfer of sample custody

An example of chain-of-custody form is presented in Appendix A.

7.4.2 Custody Seals

Custody seals are used to ensure sample packages are not tampered with during shipment. The following information will be included on the custody seal:

- Signature of the sample custodian
- Date when the sample package is sealed
8.0
DATA REDUCTION, VALIDATION, AND REPORTING

8.1 ANALYTICAL DATA

8.1.1 Soil Gas Data

Soil gas data will be reduced on-site and all results will be recorded in a soil gas field log sheet. Subcontractor data packages for soil gas survey will include the following items:

- General Discussion: description of equipment and sampling method, analytical system and method, and quality control procedures
- Analytical Data: soil gas sample data and other pertinent information, such as sample/analyzed date and reporting limits
- Quality Control Information: includes QC sample data and instrument calibration information
- Soil gas field log sheets
- Laboratory supporting data, including laboratory notebook, and instrument printout

8.1.2 Volatile Organic Analysis Data

Data reduction procedures for VOC analysis are specified in SW-846 Method 8240 (USEPA, 1992). Laboratory data validation procedures are discussed in the laboratory Quality Assurance Plan (Appendix B). Laboratory data packages for VOC analysis will include the following items:

- Case Narrative: description of sample types, test performed, any problems encountered and corrective actions taken
- Analytical Data: VOC data and other pertinent information, including reporting units, sample, date, received date, and extraction date
• Quality Control Information: includes QC sample data and instrument calibration information

• Chain-of-Custody forms

• Laboratory supporting data, including laboratory notebook, and instrument printout

8.1.3 Soil Physical (Geotechnical) Test Data

Data reduction and reporting requirements for soil physical (geotechnical) testing are identified in the ASTM standard test methods (Appendix D).

8.2 DATA VALIDATION AND SUMMARY REPORT

W-C will perform a data validation on all analytical data generated. Data packages will be checked for completeness and the following items will be reviewed:

• Sample Quality Control: holding times, target analyte identification, quantitation, surrogates, and internal standards

• Method Quality Control: GC/MS tuning, initial calibration, continuing calibration, method blanks, spike/duplicates, and laboratory control samples

• Other Quality Control: field replicates, rinsate blanks, trip blanks, detection limits, precision, and accuracy

Data validation and summary report will be prepared and will include the following sections:

• Executive summary
• Introduction
• Detailed discussion
• Conclusion
• Data summary tables

The introduction section will include a discussion of number of field samples and each type of QA/QC samples (by medium) collected and the testing laboratories. A table showing
the field and laboratory sample identification numbers and test parameters (arranged by sample batch) will also be included.

The detailed discussion section will be arranged by sample media and the parameter tested, and the following topics will be discussed under each subsection:

- Accuracy
- Precision
- Representativeness
- Actual analytical method used (the effect of any variance from the method and holding times specified in Section 6.0)

The conclusion section will summarize the data collection problems, corrective actions, the suitability of data for its intended use, and whether data quality objectives discussed in Section 4.0 are met.

Data summary tables will include all analytical data from soil gas survey, soil boring sampling, geotechnical soil sampling, and groundwater sampling.

The method of reporting includes data files organized as ERMA files directly loadable into District GIS system using the ERMA file formats provided.
Audits are an important component of QA procedures and are used to help ensure that data quality objectives are met. Two types of audits, systems audits and performance audits, will be used during the performance of this project. QA audit procedures are contained in Section 19, Compendium of Superfund Field Operations Methods (USEPA, 1987).

9.1 SYSTEMS AUDIT

9.1.1 Analytical Chemistry Laboratory

The analytical chemistry laboratory periodically conducts in-house audits as part of their QA Plan (refer Appendix B). The laboratory QA officer conducts detailed reviews of the system components to ensure that each element of the system is functioning properly and within QA guidelines. These reviews include such items as:

- Sample chain-of-custody and log in
- Frequency of spikes, blanks, and duplicates
- Evaluation of precision and accuracy
- Spot check of calculations and control charts

In addition to the laboratory internal audit, the analytical chemistry laboratory used for this project has also been audited by Woodward-Clyde personnel. Laboratory used for chemical analysis will meet Woodward-Clyde's audit standards and are validated by USACE-MRD.

9.1.2 Soil Gas Survey Field Laboratory

The SGS QA Plan in Appendix C lists the QA procedures to be following in conducting the field SGS. A field audit will be performed by Woodward-Clyde personnel (see Section 9.2.2) to ensure that the various QA procedures are being followed. Specifically these will include:
• Instrumentation calibration to both known standards and ambient air background conditions
• Proper recordkeeping (sample identification and logging)
• Correct interpretation of chromatograph

9.1.3 Soil Physical Testing Laboratory

The laboratory used for soil physical (geotechnical) analyses is part of the Woodward-Clyde organization. ASTM procedures are followed for geotechnical analyses where such standards apply. The ASTM standards of the analysis required for this project are contained in Appendix D.

Internal audits are periodically conducted to ensure that the appropriate ASTM standards are being followed correctly.

9.1.4 Project Files

A surveillance of the project files will be conducted to ensure compliance with QA/QC requirements. The surveillance will check on adherence to requirements specified in this CDAP as well as completeness of the files.

9.2 PERFORMANCE AUDITS

Performance audits will be conducted of the components of the project. These will include two categories of audits, QA replicate samples and a field audit.

9.2.1 QA Replicate Samples

Replicate QA samples of soil and groundwater will be collected and sent to the USACE Southwest Division (SWD) Laboratory for chemical analysis. Comparison of the analysis results from the SWD laboratory and the contractor laboratory provides a direct performance measure. The number of QA and QC samples for this project is listed in Table 9-1.
9.2.2 Field Audits

A field audit will be conducted by an independent Woodward-Clyde auditor. This audit will focus on field procedures including:

- Recordkeeping
- Borehole logging
- Sample handling, packaging, storage, identification, and shipping
- Sample chain-of-custody
- Sample analytical requests

The field audit will also be conducted when the SGS is in progress and will include an audit of the SGS procedures.
10.0
CORRECTIVE ACTIONS

When nonconformance with QA procedures is discovered, corrective action will be taken. Procedures for corrective action are described in the Compendium of Superfund Field Operations Methods (USEPA, 1987).

10.1 FIELD ACTIVITIES

Field activities that are in error will be corrected as quickly as possible. The Field Manager will be responsible to see that corrective action is initiated and documented whenever the error has the potential to compromise the quality of the data being generated or whenever there is a possibility that the error might be repeated.

10.2 FIELD DATA

Corrective action for poor field data quality (as determined by replicate measurements or prior expectations) consists of remeasurement until successive readings agree within reasonable limits. Examples of replicate measurements and limits to which they should agree include the following:

- Temperature - Measurements should agree within 0.2°C
- pH - Measurements should agree within 0.1 pH unit
- Conductivity - Measurements should agree within 1 percent
- Depth and water level measurements - Readings should agree within 0.01 foot

If remeasurement is not successful, then instrument calibration, operation, and the user’s technique will be evaluated.
10.3 LABORATORY

Laboratory corrective action is described in the analytical method for that analysis and the laboratory quality assurance plan (Appendixes B, C, and D).

10.4 IMPLEMENTATION AND REPORTING

Following problem identification, the responsible individual, as assigned by the Project Manager or Site Coordinator, will identify the root cause(s) of the problem and analyze the problems, (root cause analysis). The responsible individual will develop a corrective action from the root cause analysis. For each problem, a corrective action report will be prepared to document that action was taken. The report will describe the problem, potential ramifications, the corrective action, implementation, results of implementation, and effectiveness of the correction action.

Corrective action reporting to USACE will be the responsibility of the Project Manager. The Site QC Manager will also report corrective actions to Woodward-Clyde's QA Manager.
11.0 REFERENCES


### TABLE 6-1

**QUANTITATION LIMITS FOR SOIL GAS ANALYSIS**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Quantitation Limit (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene Chloride</td>
<td>1</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>1</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>1</td>
</tr>
<tr>
<td>Tetrachloroethene</td>
<td>1</td>
</tr>
<tr>
<td>1,1-Dichloroethene</td>
<td>1</td>
</tr>
<tr>
<td>1,1-Dichloroethane</td>
<td>1</td>
</tr>
<tr>
<td>Chloroform</td>
<td>1</td>
</tr>
<tr>
<td>Freon 22</td>
<td>1</td>
</tr>
<tr>
<td>Freon 503</td>
<td>1</td>
</tr>
<tr>
<td>Freon 113</td>
<td>1</td>
</tr>
<tr>
<td>Freon 11</td>
<td>1</td>
</tr>
</tbody>
</table>
## TABLE 6-2

**TEST METHOD, SAMPLE CONTAINER, PRESERVATION AND HOLDING TIME FOR CHEMICAL ANALYSES**

<table>
<thead>
<tr>
<th>Analyses</th>
<th>Matrix</th>
<th>Test Method</th>
<th>Container$^{1,2}$</th>
<th>Preservation</th>
<th>Maximum Holding Time$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatiles Organic Analyses</td>
<td>Soil</td>
<td>EPA SW-846 Method 8240</td>
<td>4-oz. (120-ml) wide mouth glass with Teflon liner</td>
<td>Cool to 4°C</td>
<td>14 days</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td>EPA SW-846 Method 8240</td>
<td>3, 40-ml vials with Teflon-lined septum caps</td>
<td>Cool to 4°C 4 drops concentrated HCl to pH &lt;2</td>
<td>14 days</td>
</tr>
</tbody>
</table>

**Notes:**

1. All containers must have Teflon-lined seals (Teflon-lined septa for VOA vials).
2. Sample containers will be precleaned according to standard EPA cleaning protocols and packaged in custody-sealed boxes before shipment to the site.
3. Holding time implies total holding time from sampling until analysis.
<table>
<thead>
<tr>
<th>Compound</th>
<th>Reporting Limits¹</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil (µg/kg)</td>
<td>Water (µg/L)</td>
<td></td>
</tr>
<tr>
<td>Acetone</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Bromodichloromethane</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Bromoform</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Bromomethane</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2-Butanone (MEK)</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Chloroethane</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Chloroform</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Chloromethane</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Dibromochloromethane</td>
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<td>5.0</td>
<td></td>
</tr>
<tr>
<td>1,1-Dichloroethane</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>1,2-Dichloroethane</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
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<tr>
<td>1,1-Dichloroethene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>1,2-Dichloroethene (total)</td>
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<td>5.0</td>
<td></td>
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<tr>
<td>1,2-Dichloropropane</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>cis-1,3-Dichloropropene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>trans-1,2-Dichloropropene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>2-Hexanone</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>4-Methyl-2-pentanone (MIBK)</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Styrene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>1,1,2,2-Tetrachloroethane</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Tetrachloroethene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Toluene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Vinyl acetate</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Xylenes</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
</tbody>
</table>

Note:

¹ Reporting limits may be adjusted if dilution is necessary.
TABLE 6-4

METHODS FOR SOIL PHYSICAL (GEOTECHNICAL) TESTS¹

<table>
<thead>
<tr>
<th>Test</th>
<th>Method Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain size</td>
<td>ASTM D421-85/D422-63</td>
</tr>
<tr>
<td>Atterberg limits</td>
<td>ASTM D4318-84</td>
</tr>
<tr>
<td>Moisture content</td>
<td>ASTM D2216-90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laboratory QC Check</th>
<th>Analyte</th>
<th>Percent Recovery</th>
<th>Precision (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Waters</td>
<td>Soils</td>
</tr>
<tr>
<td>MS/MSD</td>
<td>Benzene</td>
<td>76-127</td>
<td>66-142</td>
</tr>
<tr>
<td></td>
<td>Chlorobenzene</td>
<td>75-130</td>
<td>60-133</td>
</tr>
<tr>
<td></td>
<td>1,1-Dichloroethene</td>
<td>61-145</td>
<td>59-172</td>
</tr>
<tr>
<td></td>
<td>Toluene</td>
<td>75-125</td>
<td>59-139</td>
</tr>
<tr>
<td></td>
<td>Trichloroethene</td>
<td>71-120</td>
<td>64-137</td>
</tr>
<tr>
<td>Surrogate</td>
<td>d₄-1,2-Dichloroethane</td>
<td>76-114</td>
<td>70-121</td>
</tr>
<tr>
<td></td>
<td>d₅-Toluene</td>
<td>88-110</td>
<td>81-117</td>
</tr>
<tr>
<td></td>
<td>4-Bromofluorobenzene</td>
<td>86-115</td>
<td>74-121</td>
</tr>
<tr>
<td>Sampling Activity</td>
<td>Sample QA/QC Type</td>
<td>Designation¹</td>
<td>Remark</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------------------------------</td>
<td>--------------</td>
<td>--------</td>
</tr>
<tr>
<td>Shallow Soil Gas Sampling</td>
<td>Investigative Sample</td>
<td>WSTF-hhhh</td>
<td></td>
</tr>
<tr>
<td>Field Duplicate</td>
<td></td>
<td>WSTF-hhhh-5aaa-QA</td>
<td></td>
</tr>
<tr>
<td>Field Blank</td>
<td></td>
<td>WSTF-hhhh-5aaa-FB</td>
<td></td>
</tr>
<tr>
<td>Initial Calibration</td>
<td></td>
<td>WSTF-hhhh-5aaa-IC</td>
<td></td>
</tr>
<tr>
<td>Continuing Calibration</td>
<td></td>
<td>WSTF-hhhh-5aaa-CC</td>
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<tr>
<td>Unsaturated Soil Boring Sampling</td>
<td>Investigative Sample</td>
<td>WSTF-SB01-2aaa</td>
<td></td>
</tr>
<tr>
<td>QC Field Replicate</td>
<td></td>
<td>WSTF-SB01-2aaa-QC</td>
<td></td>
</tr>
<tr>
<td>QA Field Replicate</td>
<td></td>
<td>WSTF-SB01-2aaa-QA</td>
<td></td>
</tr>
<tr>
<td>Rinsate Blank</td>
<td></td>
<td>WSTF-SB01-2aaa-EB</td>
<td></td>
</tr>
<tr>
<td>Groundwater Sampling</td>
<td>Investigative Sample</td>
<td>WSTF-00E1-1000</td>
<td></td>
</tr>
<tr>
<td>QC Field Replicate</td>
<td></td>
<td>WSTF-00E1-1000-QC</td>
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TABLE 7-1
SAMPLE IDENTIFICATION DESIGNATION

E:\F93102\CDAP.DEF 02/09/95 4:10pm
Sheet 1 of 2


<table>
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<tr>
<th>Sampling Activity</th>
<th>Sample QA/QC Type</th>
<th>Designation¹</th>
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**Note:** ¹WSTF - hhh - xaaa - bb

where:

- **WS** = White Sands
- **TF** = Temperature Test Facility
- **hhh** = boring number or soil gas point number
- **x** = indicates the sample medium where:
  - 1 = Groundwater
  - 2 = Soil
  - 3 = Sediment
  - 4 = Surface Water
  - 5 = Soil Gas
- **aaa** = depth below ground surface
- **bb** = QA/QC modifier when needed where:
  - QA = A QA sample replicate (goes to COEs SWD lab)
  - QC = A QC sample replicate (goes to contractor's lab)
  - EB = Equipment blank
  - TB = Trip blank (QA or QC)
## TABLE 9-1

**QA/QC SAMPLES**

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<tr>
<th>Analyte</th>
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<td>Number of QA/QC Samples</td>
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<td>Total QA/QC Samples</td>
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<sup>1</sup> One (1) trip blank with each separate sample shipment.

<sup>2</sup> Matrix spike/matrix duplicate. This sample is in addition to the QC field duplicate and must be of sufficient volume to provide two (2) sample analyses of spiked and spiked duplicate.
NOTE:

1. The evaporative pond cap is defined by the North and South culvert, the cap perimeter fence to the East, and the asphalt to the East of the TTF building.

SOURCE: Dynaspan Services, 1989
Project Schedule
RCRA Facility Investigation
Temperature Test Facility
White Sands Missile Range, New Mexico

Activity Description

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FIGURE 3-1
PROJECT ORGANIZATION

White Sands Missile Range
Temperature Test Facility
RCRA Facility Investigation

WSMR/USACE

Project Audits & Field Audits
Dennis Takade

Program Manager
Doug Fiscus

Peer Review
To Be Assigned

Contract Admin.
Nancy Schroder

Engineer-In-Charge
Robert Junkrowski

Health & Safety
Carla Dods

Project Manager
David Convy

QC Coordinator
Dennis Takade

QA Officer
Less Osborne

Home Office
Project Team
To Be Assigned

Field Manager
Dan Kennedy

Field Subcontractors
- Plains Environmental Services
- Stewart Brothers Drilling
- Southwest Engineering Inc.

Field Team Members
To Be Assigned

Analytical Laboratories
QA/QC Directors
- Quanterra Environmental
- WC Geotesting Services

Document Control and QC Officer and
Waste Management Officer

Community Relations Assistance

RFI Report

Laboratory Data and Validation Report

Field Logs Report

Field Geologist(s)

Field Technician(s)

Site Health & Safety Officer
ROBERT S. JUNKROWSKI

Waste management
Geotechnical engineering
Project management

EDUCATION
University of Illinois, M.S., Civil Engineering, 1969
University of Illinois, B.S., Civil Engineering, 1967

REGISTRATION
Professional Engineer: Texas, Louisiana, Wyoming, Florida, Mississippi, Georgia, Colorado, Arkansas, New Mexico, Alabama, Oklahoma, Illinois, New Jersey, Montana, and Missouri

PROFESSIONAL HISTORY
Woodward-Clyde Consultants, Associate, 1979 to date
NFS/National Soil Services, Inc., Geotechnical Engineer, 1973-1975;
Project Engineer, 1975-1977; Senior Project Engineer and Assistant Chief Engineer, 1977-1978
Bureau of Reclamation, McCook, Nebraska and Denver, Colorado, Hydraulic Engineer, 1970-1972; Civil Engineer, 1972-1973
Shell Oil Company, Mechanical Engineer, 1969-1970

REPRESENTATIVE EXPERIENCE
Mr. Junkrowski's experience includes responsibility for the civil and geotechnical aspects of investigation, analysis, design, and construction of municipal and hazardous waste landfills, remedial action containment measures, and interim and final closures of hazardous and nonhazardous waste sites. He has been responsible for all phases of the projects, including problem definition, design of containment measures, permitting, preparation of plans and specifications, construction quality control, and design of post-construction monitoring systems. Some of his specific experience in the field of waste management includes:

- Senior Technical Reviewer for the design and construction of the City of Alliance Municipal Landfill Expansion in Alliance, Nebraska.

- Senior Technical Reviewer for the design of the closure of the Flying Cloud Sanitary Landfill in Eden Prairie, Minnesota.

- Senior Technical Reviewer for the design of the closure of the Glenwillow Sanitary Landfill located near Cleveland, Ohio.

- Project Manager for the design, construction, and post-construction monitoring of the closure of a hazardous waste landfill at a chemical plant in Houston, Texas. The closure included a soil-bentonite slurry wall, low permeability cover, and a groundwater extraction system.
• Project Manager for the problem definition, design and construction of the closure of two hazardous waste neutralization ponds at a chemical plant in Houston, Texas. The closure included a soil-bentonite slurry wall, waste excavation and stabilization, and low permeability cover.

• Project Manager for the design and construction of the closure of a hazardous waste landfill at a closed petrochemical plant near Cleveland, Ohio. The closure included a soil-bentonite slurry wall, construction of clay and synthetic liner landfill covers, and installation of a groundwater recovery system.

• Project Manager for the design of the first double-lined hazardous waste landfill cell constructed under RCRA guidance for the Chemical Waste Management Facility in Lake Charles, Louisiana.

• Project Manager for the design and permitting of a double-lined hazardous waste containment facility located at the Diamond Shamrock Chemical Company Battleground Plant.

• Design Manager for the design of a new RCRA landfill, constructed as part of a plant closure in west Texas.

• Project Manager for the design of a new Class II waste containment facility at the Amoco Chemical Company, Chocolate Bayou Facility.

• Project Manager for remedial activities including slurry wall construction, plant demolition, groundwater extraction system installation, and RCRA cover construction at a Superfund site in Newark, New Jersey.

• Project Manager for design of remedial measures required for the closure of four hazardous waste treatment lagoons in East St. Louis, Illinois. The remedial activities will include a cement-bentonite slurry wall and a RCRA cover.

• Remedial Design Manager for the closure of the Bio-Ecology Superfund site in Grand Prairie, Texas. The work included the design of a RCRA cell to contain contaminated soils and waste removed from other portions of the site.

• Project Manager for the design of the first hazardous waste landfill to be built to RCRA standards in Argentina.

• Design Manager for the design of closure activities for two municipal landfills located in northern Arkansas.
• Design Manager for the evaluation of cover alternatives for the Midway Landfill Superfund site located near Seattle, Washington.

• Design Manager for the design of incinerator ash disposal facilities in Florida, Oklahoma, and Missouri.

• Design Manager for the design of a soil-bentonite slurry wall constructed around brine storage ponds at the Big Hill Strategic Petroleum Reserve located in Jefferson County, Texas. He was also responsible for geotechnical design of other facilities located at the site.

• Project Manager for the Part B permitting aspects of two proposed hazardous waste containment facilities for hazardous waste located near Port Arthur, Texas.

AFFILIATIONS
American Society of Civil Engineers

PUBLICATIONS
A list of selected publications is available upon request.
PUBLICATIONS, REPORTS AND PRESENTATIONS


DAVID C. CONVY

EDUCATION

University of Iowa: M.S., Civil and Environmental Engineering, 1985
University of Northern Iowa: B.A., Biology, 1981

PROFESSIONAL HISTORY

Woodward-Clyde Federal Services, Project Engineer, 1993-Present
Woodward-Clyde Consultants, Project Engineer, 1985-1993
University of Iowa, Graduate Research Assistant, 1983-1985

REPRESENTATIVE EXPERIENCE

Mr. Convy has a wide range of environmental and waste management experience on small, mid-size and large environmental engineering and waste management projects. Mr. Convy’s experience includes work in both the private and public sector. His responsibilities include project management, project planning, project implementation, field and laboratory coordination, and reporting. His field experience includes soil, surface water and groundwater sampling, well installation and development, and air sampling. Representative project experience is summarized below:

- Project Manager for a remedial investigation/feasibility study at a former paint waste disposal site in Iowa. Contaminants of concern include heavy metals and high levels of volatile organics. The project utilized innovative field analyses techniques including X-ray fluorescence (XRF) and the use of a mobile laboratory for VOC analyses. These innovative techniques provided cost-effective real time data which allow the project to meet a tight regulatory schedule. Subsequent to the RI/FS, Mr. Convy provided ROD and negotiation support assistance prior to the RD/RA. Mr. Convy also managed the fast-track RD/RA which was completed in less than 9 months and employed value engineering saving substantial cost on the remedial action. The remedial action is currently nearing completion.

- Project Manager for an investigation of a pesticide formulating facility in eastern Missouri. Mr. Convy directed and participated in the preparation of the project documents detailing the proposed investigation (Work Plan, Sampling and Analysis Plan, and Quality Assurance Project Plan) and coordinated and managed all field activities associated with the project. Mr. Convy also directed the preparation of the Site Characterization Report and Endangerment Assessment. Groundwater investigations associated with the project are ongoing.
• Project Manager for a Phase I/Phase II environmental site assessment and subsequent remediation activities. Mr. Convy managed all aspects of the initial investigation and cleanup and acted as liaison between the seller (WCC client), buyer, and the Kansas Department of Health and Environment (KDHE).

• Project Manager for a project assignment from a major oil company that involved a pipeline rupture and the loss of approximately 1,600 barrels of unleaded gasoline. Duties include all aspects of project management and implementation as well as client interactions and negotiations. The projects included site characterization, innovative field technique implementation, feasibility study analysis, and product recovery.

• Project Manager for three REM II Region VII Superfund sites. The sites contained a variety of contaminated media and contaminants including a PCB contaminated site, a pesticide contaminated site, and a volatile organic and heavy metal contaminated site. Duties included day-to-day support of Region VII USEPA Regional Project Managers on issues relating to remedial investigation design and implementation, screening of remedial technologies, endangerment assessment, and PRP negotiations.

• Project Manager for an Underground Storage Tank (UST) assessment for a utility in Iowa. The project involved reviewing the clients current tank inventory and management program and recommendation for an updated management program in line with Federal regulations.

• Field Team Manager for a variety of field investigations at Superfund sites. Specific duties included field team scheduling and coordination, overall supervision of the sampling team activities, enforcement of QA/QC and health and safety program, and sample documentation.

• Task Leader for the preparation of a Quality Assurance Project Plan (QAPP) for a major field investigation in central Illinois. The QAPP was prepared in an expedited manner while maintaining outstanding technical quality so the work could be completed during the 1988 construction season.

• Member of the project team that developed the first Engineering Evaluation and Cost Analysis (EECA) document for USEPA under the Region VII REM II Superfund contract.

• Prepared the Waste Analysis Plan (WAP) and Groundwater Monitoring Plan as a part of a RCRA Part B permit application for a hazardous waste landfill.

• Mr. Convy has also been actively involved with the environmental site assessment and auditing program in the Overland Park office.
LESS W. OSBORNE

Total Quality Management
QA/QC
construction oversight
project management

EDUCATION

M.S., Geology, Colorado State University, 1981
B.S.(Honors), Geology, Fort Lewis College, 1976

REGISTRATION

ASME-NQA-1 Certified Lead Auditor
DOE "Q" Clearance, Active

PROFESSIONAL HISTORY

Woodward-Clyde, Quality Manager, 1993-Present
IT Corporation, TQM and QA Manager, 1988-1993
Unocal-Molycorp, Staff Geologist, 1981-1986

REPRESENTATIVE EXPERIENCE

Mr. Osborne has over thirteen years diversified experience in the development, implementation, evaluation and oversight of quality management protocols. He presently is the central region quality manager for Woodward-Clyde. He is responsible for quality program issues related to the service provided to clients in the federal and commercial sector. In addition, Mr. Osborne is responsible for development and implementation of the Woodward-Clyde Total Quality Management program. He develops, coordinates, and guides a corporate quality improvement process based on the precept that client satisfaction is the driving force for delivery of services. Mr. Osborne brings a broad and practical base of experience in science and engineering to the implementation of quality systems.

He has implemented quality management and improvement programs that consist of the following elements:

- Quality improvement
- Information management
- Staff management
- Training on TQM, QA, QC, and project quality issues
- Quality planning
- Qualifications
- Procurement control
- Design and analyses
- Verification

WCFS
• DQO development, laboratory interface, and validation
• Standard procedures
• Records management
• Document control and configuration management
• Change control
• Nonconformance and corrective action
• Equipment control and calibration
• Audits, reviews, surveillances, and inspections
• Quality document preparation

He has provided both technical and project management of tasks performed at the Rocky Flats Nuclear Weapons Plant in Colorado. In this role he coordinated proposal scoping meetings to determine the best technical approach in the most cost effective manner. EG&G contract technical representatives were often included in meetings to provide requirements and clarify scope. This proactive approach resulted in time and cost savings while increasing quality. Personnel were evaluated for technical ability to accomplish the scope of the task. Routine status meetings were held to check on progress and compliance with the task scope. QA audits were scheduled and performed to verify compliance with the QA Program and other requirements. Peer reviews of task work products were also scheduled and conducted to help ensure the best product. He provided the technical and quality management oversight to tasks involved in RFI/RI Work Plans for several operable units, remedial investigation implementation, Past Remedy Report, Treatability Study Work Plans for different types of processes, operation and maintenance of the ion-exchange, oxidation/reduction treatment plant, RCRA permitting, Final IM/IRA Decision Document, large scale groundwater sampling, well abandonment and replacement, Groundwater Assessment Plan, environmental database development, air emission surveys and modeling, and Part B permit modifications.

Mr. Osborne designed, managed, and implemented the Quality Assurance Program for a basic ordering agreement with EG&G. The program consisted of a hierarchical structure based on a Quality Assurance Program Plan (QAPP) that is compliant with DOE Order 5600-6B (including ASME-NQA-1, and the subsequent DOE Order 5600-6C) and EPA QAMS-005. This extensive document provided programmatic guidance for the performance of activities and the basis for compliance with EG&G’s QA requirements. Supplemental Quality Assurance Project Plans (QAPP)s were prepared to supplement, supplant, and amend the QAPP as appropriate.

He has also established Data Quality Objectives (DQO)s and developed programmatic and detailed Quality Assurance Project Plans (QAPP)s for the following projects:

• Closure development and implementation of 23 RCRA units at the Martin Marietta site in Waterton, Colorado
• The Denver Toluene CERCLA site
• The Murtaugh Expanded Site Investigation (ESI) at a pesticide landfill in Idaho.
• The US Army Corp of Engineers, Rocky Mountain Arsenal Hydrazine decommissioning project
• The Remedy Design at the Hardage Criner Superfund site in Oklahoma
• The Remedy Construction at the Hardage Criner Superfund site in Oklahoma

Mr. Osborne has performed audits of the activities at the WIPP site and provided consultation and guidance to the DOE at Hanford, Washington on the integration and implementation of ASME-NQA-1 with EPA QAMS-005.

Mr. Osborne has performed detailed stratigraphic interpretation of critical sedimentary units at the Hardage-Criner Superfund Site. He also prepared numerous cross-sections and contour maps to support interpretations for remedy design.

He has supervised magnetometer surveys, groundwater sampling, and soil gas surveys for a confidential client. He has also performed field oversight, supervision, and monitoring of well installation, sampling, waste management, and groundwater recovery and treatment.

Mr. Osborne has been the project engineer at construction sites. He was responsible for the field coordination of building trades, design professionals, and the owner/client. His responsibilities included the following:

• Interpretation of architectural and structural drawings
• Resolution of design and constructability conflicts
• Documentation of construction progress
• Tracking of labor and materials costs against budget
• Evaluation and management of subcontractor change orders
• Preparation of cost estimates for contractor change orders
• Contract negotiations with subcontractors and owner/client
• Verification of work completion against contracts, and plans and specifications
• Review and evaluation of construction submittals
• Configuration management of site drawings and specifications
• Maintenance and tracking of construction records
• Scheduling and coordination of independent testing laboratories

PROFESSIONAL ORGANIZATIONS
American Society for Quality Control, Project Management, and Energy Divisions
Society for Mining, Metallurgy, and Exploration, Inc.
DENNIS Y. TAKADE, Ph. D.

pesticide chemistry
hazardous waste management
environmental health and toxicology
risk assessment
expert witness

EDUCATION

University of California at Riverside, Rockefeller Foundation Post-Doctoral Research Scholar. Biological and Environmental Fate of Selective Organophosphorus and Carbamic Acid Insecticides 1973-1975
University of California at Riverside, Ph.D., Insecticide Chemistry and Metabolism, 1973
Long Beach State University, B.S., Zoology, 1966

PROFESSIONAL HISTORY

Woodward-Clyde Consultants, Senior Project Scientist, Senior Associate, 1985-Present
Private Consultant, Toxicology and Environmental Health, 1985
MRI, Head - QA Section and Toxicology, 1980-1985
Velsicol Chemical Corp., Director - Scientific Services/Environmental Sciences, Manager - Technical Liaison, 1977-1980
Northrop Services, Inc., Supervisor - Pesticide and Toxic Chemicals Analysis Laboratory, 1976-1977

REPRESENTATIVE EXPERIENCE

Dr. Takade provides expertise in environmental chemistry, chemical fate, environmental health and toxicology, risk assessment, health and safety planning, quality assurance, laboratory audits, and data validation. In addition, Dr. Takade is or has been the Project Manager for numerous risk assessment projects in support of RI/FS projects or for establishing cleanup goals. He has also been the Project Manager for RI/FS, CERCLA site characterization and remediation projects among others. In addition, Dr. Takade is the Risk Assessment Practice Leader for the Overland Park office and spends 50% of his time in a key leadership role on national Risk Assessment Practice issues and projects. Some of the major projects include:

- Project Director for several multi-million dollar IRM removal actions and RI/FS projects involving pesticide formulation facilities contaminated with DDT, arsenical pesticides, toxaphene, cyclodiene insecticides (aldrin, dieldrin, chlordane, heptachlor and endrin), and organophosphorus insecticides. These projects included a requirement for treatability feasibility studies, and fate and transport analysis along with risk assessments.
DENNIS Y. TAKADE, Ph. D.

- Supervised data validation efforts on more than 15 projects - both Superfund and RCRA - in Regions II, IV, V and VII. Included analytical data from Woodward-Clyde Consultants and non Woodward-Clyde Consultants projects. Data included CLP and SW 846 methods for organics, metals and explosives (SW 846).

- Project Advisor for the evaluation of the potential of an inplant activated sludge system to degrade chlorinated pesticide wastewater effluent. Included an analysis of the impact on human and environmental effects.

- Project Manager for a dioxin contaminated site in St. Louis, Missouri. Designed and implemented a unique sampling plan for obtaining samples in the Mill Creek storm sewer. Qualitative evaluation of risk also included in project.

- Senior scientist responsible for coordinating the defense of company products in regards to regulatory, environmental and product liability issues by acting as a technical expert and expert witness in pesticide chemistry, environmental fate, environmental toxicology and chemical analyses. These products were chlorinated insecticides and various herbicides.

- Provided consultation and expert testimony to a technical committee of potentially responsible parties regarding potential health risks posed by a site contaminated with PCBs. Peer reviewed a risk assessment and feasibility study prepared by consultants to the city of Toledo. Prepared response document outlining technical and regulatory deficiencies. Assisted client in developing, proposing, and defending alternate site remedies.

- Supervised the preparation of a risk assessment to establish baseline risks by airborne pesticides and arsenic posed by soils contaminated with those compounds at a pesticide formulating facility in Missouri. Supervised preparation of cleanup goals for site remediation. Successfully negotiated cleanup goals with USEPA.

- Project Manager for technical oversight of RI/FS activities at DOE's Weldon Spring site, one of the first mixed hazardous waste/radiological waste sites utilizing the CERCLA RI/FS approach. Provides key input regarding approach to RI/FS approach. Peer reviewed risk assessment and RI/FS work plans. Provided input as to alternate approaches and methods for risk analysis.

- Formed, with Dr. William S. Eaton, WCC Corporate laboratory audit committee to establish guidelines for the use of laboratories for analyzing samples. The committee also designed and established training procedures for auditing laboratories.

- Supervised preparation of a risk assessment to evaluate the health hazards posed by lead contaminated soil on a site formerly occupied by a lead and zinc smelter. The
DENNIS Y. TAKADE, Ph. D.

project was on a very fast track basis and was completed within four weeks. Cleanup levels were successfully negotiated with USEPA.

- Supervised preparation of a health risk assessment, including the development of health-based cleanup goals, for a facility in southern California. The primary chemical compounds of concern were halogenated solvents.

- Supervised preparation of a health risk assessment of soil contamination for an active pesticide formulation facility in New Jersey.

- Peer reviewer for a health risk assessment which evaluated the human health impact of potential groundwater contamination from past oil refinery operation.

- Supervised and acted as expert witness for preparation of cleanup goals and provided oversight on the remediation of lead contamination at a former vehicle maintenance facility in preparation of the site for residential development.

- Supervised the preparation of a health risk assessment for an RFI at an active chemical production facility. Project included development of critical toxicity values (i.e., references doses) for synthetic organic intermediates comprising the groundwater contamination.

- Program Manager for inhalation toxicology program evaluating the long-term health effects of potential environmental pollutants. Implemented systems to meet and exceed QA requirements and met client expectations. Project completed within budget and two weeks before deadline.

- Peer reviewed risk assessment prepared for an active herbicide manufacturing facility in Louisiana.

- Developed a model environmental fate and degradation system for radio labeled organophosphorus insecticides.

- Developed a position paper describing the environmental of organochlorine pesticides in aquatic environments.

- Guest lecturer at a "Practical Approaches to Solving PCB Problems" Seminar in Arlington, Virginia to address PCB Health Effects and Industrial Hygiene.

- Project Manager for a project assessing the impact of regulatory decisions on a wood treatment plant. Planned and conducted a sampling and analysis task in response to an accidental spill. Provided recommendations on clean-up and designed spill prevention program.
• Designed and implemented the Good Laboratory Practices and Quality Assurance system for Midwest Research Institute covering a wide range of projects in excess of $15 million per year.

• Managed and supervised a group of 35 scientists involved in analytical method development, environmental fate transport, exposure assessment and analytical chemistry for an pesticide manufacturer.

• Managed and supervised a group of 50 scientists and technicians under contract to EPA. Provided hands-on supervision to the pesticides and toxic substances laboratory which analyzed environmental samples such as dioxin at the 5 parts per trillion level.

AFFILIATIONS

American Chemical Society
Sigma Xi (Scientific Research Society of North America)
SELECTED PUBLICATIONS AND REPORTS


DAN J. KENNEDY

EDUCATION

Oklahoma State University: Master of Science, Geology, 1993
University of Kansas: Bachelor of Science, Geology, 1977

PROFESSIONAL HISTORY

Woodward-Clyde Federal Services, Assistant Project Geologist, 1993 - Present
Consulting Geologist, 1983 - 1993
Sun Oil Company, Production Geologist, 1979 - 1981

PROFESSIONAL REGISTRATIONS

Registered Geologist, Arkansas
Certified Professional Geological Scientist - AIPG #7004

REPRESENTATIVE EXPERIENCE

Mr. Kennedy has over 15 years of experience in geology and hydrogeology. He is currently an Assistant Project Geologist in the Oklahoma City office. Mr. Kennedy has been involved in the preparation of several RFI Workplans and their subsequent implementation. His field experience includes monitoring well installation, soil gas surveys, surface and borehole geophysical surveys, surface mapping, and water, sediment, and soil sampling. Examples of projects in which Mr. Kennedy has been involved include:

- Site Manager for a RCRA Facility Investigation at a federal facility in Oklahoma City, Oklahoma. Project included subsurface soil sampling, borehole geophysical surveys, installation of deep monitoring wells, slug tests, and groundwater sampling.

- Team member for a Remedial Feasibility Investigation at the Department of Energy’s Pantex Plant, Amarillo, Texas. Project included subsurface soil sampling and soil gas surveys.

- Team member for quarterly groundwater sampling events at former Nebraska Ordinance Plants located at both Mead and Hastings, Nebraska.
• Research the identification of source of higher chlorides concentrations in fresh water aquifers using various numerous geochemical relationships.

• Coordinated numerous types of surface geochemical studies (radiometric, helium, iodine, soil gas, and microbial).

• Coordinated surface geophysical studies using seismic and magnetic methods.

• Conducted field studies for exploration oil and gas companies.

• Supervised and coordinated geological well-site operations on numerous deep subsurface tests.

AFFILIATIONS

National Water Well Association
American Association of Petroleum Geologists
American Institute of Professional Geologists
The following examples of field sample documentation are included in the FSAP:

- Shallow and Deep Soil Gas Sample Collection Field Sheet (Figure 2-1, FSAP)
- Soil Sample Collection Field Sheet (Figure 3-1, FSAP)
- Soil and Groundwater Sample Container Labels (Figure 3-2, FSAP)
- Drilling Logs (Figure 3-3, FSAP)
- Groundwater Sample Collection Field Sheet (Figure 5-1, FSAP)

Appendix A-1 presents the chain-of-custody form to be used in this project.
Appendix A-1 Chain-of-Custody Form

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<td>WHITE - CLIENT Pink - LAB</td>
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Enseco
A Corning Company

Rocky Mountain Analytical Laboratory
4955 Yarrow Street
Arvada, CO 80002
303/441-6611
FAX: 303/431-7171

Enseco Houston
1420 East North Belt Drive
Suite 120
Houston, TX 77032
713/987-9767
FAX: 713/987-9769
QUALITY ASSURANCE
PROGRAM PLAN
FOR
ENVIRONMENTAL CHEMICAL ANALYSIS

Prepared By:
Enseco Incorporated

Revision: 3.5
May, 1992

© Enseco Incorporated, 1988

Approval:

Mark J. Bollinger
Vice President/General Manager
Central Region

John E. Farrell
Vice President/General Manager
Eastern Region

Jack L. Custer
Vice President/General Manager
Wadsworth/ALERT Region

R. James Bentley
Vice President/General Manager
Western Region
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**Appendix I**
Enseco Recommended Maximum Holding Times and Sample Collection/Preservation Information

**Appendix II**
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1. INTRODUCTION

Enseco Incorporated (Enseco) of Corning Lab Services Incorporated (CLSI) comprises the largest and most experienced network of environmental testing laboratories in the United States. The Enseco facilities are organized into four geographic regions:

Eastern Region:
- Enseco-East in Somerset, New Jersey
- Enseco-Erco Laboratory in Cambridge, Massachusetts

Central Region:
- Enseco-Rocky Mountain Analytical Laboratory in Arvada, Colorado
- Enseco-Mixed Waste Laboratory in Arvada, Colorado
- Enseco-Houston Technical Service Center in Houston, Texas

Western Region:
- Enseco-California Analytical Laboratory in Sacramento, California
- Enseco-CRL in Garden Grove, California
- Enseco-Air Toxics Laboratory in City of Industry, California
- Enseco-Mobile Laboratories in Garden Grove, California

Wadsworth/ALERT Region:
- Wadsworth/ALERT Laboratories in North Canton, Ohio
- Wadsworth/ALERT Laboratories in Pittsburgh, Pennsylvania
- Wadsworth/ALERT Laboratories in Tampa, Florida

Addresses and telephone numbers for these facilities are listed in Table 1-1.

This document describes the Enseco Quality Assurance policies and procedures related to chemical analysis for environmental pollutants in water, soil, and waste.
TABLE 1-1
ENSECO FACILITIES

Eastern Region

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Address</th>
<th>Phone</th>
<th>Facsimile</th>
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<tr>
<td>Enseco-East</td>
<td>2200 Cottontail Lane</td>
<td>(908) 469-5800</td>
<td>(908) 469-7516</td>
</tr>
<tr>
<td>Enseco-East Laboratory</td>
<td>205 Alewife Brook Parkway</td>
<td>(617) 661-3111</td>
<td>(617) 354-5258</td>
</tr>
<tr>
<td>Enseco-Rocky Mountain Analytical</td>
<td>4955 Yarrow Street</td>
<td>(303) 421-6611</td>
<td>(303) 467-9136</td>
</tr>
<tr>
<td>Enseco-Houston Technical Service Center</td>
<td>1420 East North Belt, Ste. 120</td>
<td>(713) 987-9767</td>
<td>(713) 987-9769</td>
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Central Region

<table>
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<tr>
<td>Enseco-CRL</td>
<td>7440 Lincoln Way</td>
<td>(714) 898-6370</td>
<td>(714) 891-5917</td>
</tr>
<tr>
<td>Enseco-Mobile Laboratories</td>
<td>7440 Lincoln Way</td>
<td>(714) 898-6370</td>
<td>(714) 891-5917</td>
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Western Region

<table>
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<th>Facility Name</th>
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<td>Enseco-Mobile Laboratories</td>
<td>7440 Lincoln Way</td>
<td>(714) 898-6370</td>
<td>(714) 891-5917</td>
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TABLE 1-1
ENSECO FACILITIES

(Continued)

<table>
<thead>
<tr>
<th>Wadsworth/ ALERT Region</th>
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| Wadsworth/ALERT Laboratories  
4101 Shuffel Drive, NW  
North Canton, OH  44720  
(216) 497-9396  
Facsimile (216) 497-0772  | Wadsworth/ALERT Laboratories  
450 William Pitt Way, Bldg. 6  
Pittsburgh, PA  15238  
(412) 826-5477  
Facsimile (412) 826-5571  |

Wadsworth/ALERT Laboratories  
5910 Breckenridge Parkway  
Breckenridge II, Suite H  
Tampa, FL  33610  
(813) 621-0784  
Facsimile (813) 623-6021  |
2. QUALITY ASSURANCE POLICY

Enseco’s commitment is to meet the client's requirements by providing quality environmental analytical services to both the public and private sectors. The quality management system at Enseco stresses process improvement and error prevention through training and planning. It provides for detection of errors that occur through quality control and auditing. The goal of each laboratory is to generate error-free work through the support of personal standards of performance, the attitude that errors can be prevented, and to devise permanent solutions for problems which are detected. A comprehensive system of measurement and display of key characteristics of the laboratory provides opportunity for continuous improvement. The extensive Quality Assurance program, as part of the quality management system, ensures the production of scientifically sound, legally defensible data of known, documentable and verifiable quality. This program relies on clearly defined objectives, well-documented procedures, a comprehensive audit system, and management support, both Corporate and Regional for its effectiveness.

All work at Enseco is conducted under this QAPP unless another approved program plan, project plan or contract is in place which describes a quality management system appropriate to the client's requirements to generate scientifically sound, legally defensible data of known, documentable and verifiable quality.
3. PURPOSE AND SCOPE OF DOCUMENT

Purpose

This QA Program Plan presents an overview of the essential elements of the Enseco QA program. This plan is modeled along EPA guidelines as outlined in "Interim Guidelines and Specifications for Preparing Quality Assurance Program Plans," QAMS-004/80, December 29, 1980 and "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," QAMS-005/80, February, 1983. Both of these documents have been issued by the Office of Monitoring Systems and Quality Assurance, Office of Research and Development, U.S. Environmental Protection Agency (U.S. EPA). Elements above and beyond those specified in these two documents have been included in this QA Program Plan in order to completely describe the Enseco QA/QC system.

Scope

The Enseco QA program is designed to control and monitor the quality of data generated in Enseco laboratories. The program has four key elements.

- Demonstrating laboratory capability by providing information which documents the overall qualifications of the laboratory to perform environmental analyses;
- Establishing procedures for controlling laboratory operations which measure laboratory and instrument performance on a daily basis;
- Measuring matrix effects to determine the effect of a specific matrix on method performance, and
- Reporting appropriate QC information with the analytical results to enable the end-user to assess the quality of the data.
The specific procedures involved in implementing each aspect of the program are described in this document. An overview of these QC procedures, along with the section number in which each is discussed, is given in Table 3-1.

The QA/QC policies and procedures described herein are designed to eliminate systematic errors and minimize the occurrence of other errors. The QA program forms the framework for minimizing errors, identifying those errors which do occasionally occur, and correcting them at their source. These QA/QC policies and procedures must be coupled with the professional judgment of the technical staff in interpreting the events surrounding the generation of the final result to ensure that quality data is consistently produced, and decisions and corrective actions are fully documented.

In many instances, Enseco participates with its clients in the preparation and evaluation of project-specific Quality Assurance Project Plans (QAPjP). Typically the elements of the Enseco QAPP are incorporated into these documents. In some instances other requirements may be specified. Each QAPjP must be reviewed and signed by the QA Director or his/her designee of the Enseco facility entering into the client agreement to assure that minimum standards of quality exist by which the work can be evaluated as to its scientific and legal integrity. The QA Director must assure that both the analytical testing objectives and regulatory requirements of the project are described in the project plan. In the presence of an approved QAPjP, Enseco laboratories must follow the specific requirements of that project plan which supersedes the Enseco QAPP for any work explicitly associated with that QAPjP.
Table 3-1

ELEMENTS OF QA PROGRAM PLAN

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Operational Elements</th>
<th>Section of QA Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABORATORY QUALIFICATIONS</td>
<td>Facilities/equipment/staff..................................................................................</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Written SOPs for all laboratory procedures, including:.........................................</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Sample custody........................................................................................................</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Calibration procedures............................................................................................</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Analytical procedures............................................................................................</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Data validation.......................................................................................................</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Documented QA program...........................................................................................</td>
<td>1-15</td>
</tr>
<tr>
<td></td>
<td>Laboratory certifications.......................................................................................</td>
<td>12</td>
</tr>
<tr>
<td>LABORATORY PERFORMANCE</td>
<td>Check samples........................................................................................................</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Laboratory Control Samples....................................................................................</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Calibration data/calibration verification................................................................</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Method detection limits..........................................................................................</td>
<td>14</td>
</tr>
<tr>
<td>MATRIX EFFECTS</td>
<td>Matrix spike/matrix duplicate/matrix spike duplicate analyses................................</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Sample surrogate recoveries..................................................................................</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Standard additions.................................................................................................</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Field blanks............................................................................................................</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Method detection limits (determined with specific sample matrix)...........................</td>
<td>11</td>
</tr>
<tr>
<td>DATA REPORTING</td>
<td>Data reduction and validation...............................................................................</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Data reporting........................................................................................................</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Reporting Limits.................................................................................................</td>
<td>14</td>
</tr>
</tbody>
</table>

* Described in a separate document available from each facility.
4. DEFINITION OF TERMS

Quality Assurance (QA): the total integrated program for assuring the reliability of data generated in the laboratory.

Quality Control (QC): the routine application of specific, well-documented procedures to ensure the generation of data of known and accepted quality, thus fulfilling the objectives of the QA program.

Quality Assurance Program Plan (QAPP): an assemblage of management policies, objectives, principles, and general procedures outlining the techniques by which the laboratory produces data of known and accepted quality.

Quality Assurance Project Plan (QAPjP): an assemblage of detailed procedures describing how the laboratory will generate data that meet the Data Quality Objective (DQOs) of a specific project.

Standard Operating Procedure (SOP): a detailed, written description of a procedure designed to systematize and standardize the performance of the procedure.

Legally Defensible Data: data which are supported by a QAPP and documentation adequate to reconstruct the analytical process. Legal defensibility is not dependent on the level of deliverables.

Holding Time: the period of time during which a sample can be stored after collection and preservation according to method or client requirements.
Initiate Preparation: the point in time at which the separation of organic extractable compounds or metals from the sample matrix by solvent extraction, acid digestion, or leachate generation is begun.

Initiate Analysis: the point in time at which the sample, extract or digestate is introduced into an instrument or process which complies with the SOP for analysis of the parameter of interest.

Standard Additions (SA): the practice of adding a series of known amounts of an analyte to an environmental sample. The fortified samples are then analyzed and the recovery of the analytes calculated. The practice of SA's is generally used with metal analyses to compensate for the effect of the sample matrix on the accuracy of the analyses.
5. RESPONSIBILITIES AND AUTHORITIES

Executing an effective QA program in a large and complex multi-laboratory system demands the commitment and attention of both management and staff. The QA effort is administered by the Director of Technology/Quality Assurance who manages the Corporate Quality Assurance Office. The Director of Technology/Quality Assurance reports directly to the President and Chief Executive Officer (CEO) and has the responsibility for overseeing and regulating all laboratory functions (see Figure 5-1). The Corporate QA Director reports to the Director of Technology/Quality Assurance and has the responsibility of the day-to-day functions of the QA office. The QA Office operates independently of all areas generating analytical data to ensure complete objectivity in the evaluation of laboratory operations.

The implementation of the QA program within each region is administered by the Regional QA Director. The Regional QA Director reports to both the Corporate QA Director and to the Vice President/General Manager or the Assistant General Manager who manages the region. Each facility has a QA Director who monitors the day to day QA activities at that facility. The QA Director participates in the facility Quality Improvement Team (QIT) and management team meetings as a full partner of the management team to ensure the policies of the organization with respect to client service and quality are met. In addition, all scientists within the organization play a vital role in assuring the quality of their work. We believe that the success of Enseco is dependent upon the continued commitment of all within the organization to a strong and viable QA Program. The responsibilities and levels of authority within the organization are described below. The descriptions which follow are intended to address the functions required of these positions. Actual position titles may vary among the facilities.
FIGURE 5-1

QA ORGANIZATIONAL CHART

President of CLSI

President, CEO of Enseco

Vice President/General Manager

Laboratory Management

Regional QA Director

Director of Technology/QA

Corporate QA Director
Corporate Quality Assurance Office

Members

The QA effort within Enseco is directed by the Corporate QA Director under the management of the Director of Technology/Quality Assurance to carry out the responsibilities of the department.

Responsibilities

The Corporate QA Director is responsible for:

- Developing and implementing a Corporate QA program that ensures that all data generated in Enseco laboratories are scientifically sound, legally defensible, and of known precision and accuracy;

- Monitoring the QA Plan to ensure compliance with QA objectives in all Enseco laboratories;

- Developing and implementing new QA procedures within the corporation to improve data quality;

- Conducting audits and inspections of all Enseco laboratories on a regular basis, reporting the results of those audits to Regional and Corporate management, and recommending corrective actions as needed to ensure compliance with the Enseco QA Program Plan and/or applicable QA Project Plan;

- Establishing databases that accurately reflect the performance of each of the Enseco laboratories;
- Assisting facility QA Directors in the implementation of the Enseco QA Plan;
- Chairing the Enseco QA Committee, a working committee which includes all of the Regional and facility QA Directors and deals with QA issues on an ongoing basis;
- Monitoring the status of facility certifications;
- Conducting seminars on QA issues for both clients and staff; and
- Promoting sound QA practices within the environmental regulatory and analytical communities.

Authority

Both the Director of Technology/Quality Assurance and the Corporate QA Director have the authority on issues dealing with data quality and have the authority to require that procedures be amended or discontinued, or analyses suspended or repeated. The Director of Technology/Quality Assurance and the Corporate QA Director have the authority to recommend appropriate disciplinary action up to or including suspension or termination of employees on the grounds of dishonesty, incompetence, or repeated non-compliance with QA procedures. In addition, these Corporate Directors have the authority to overrule decisions and actions of the Regional and facility QA Directors and must approve the termination or transfer of any Regional or facility QA Director. The authority of the Corporate QA Director and the Director of Technology/Quality Assurance comes directly from the President of CLSI.
Regional Quality Assurance Departments

Members

Each Region has a Regional Quality Assurance Director who reports directly to the Vice President/General Manager and indirectly to the Corporate QA Director.

Responsibilities

The Regional QA Director is responsible for:

- Overseeing the implementation of the QA Plan within the Region to ensure compliance with the QA objectives;
- Assisting staff in maintaining regulatory analytical compliance;
- Overseeing and assisting the facility QA staff in meeting the responsibilities of the facility Quality Assurance Departments at each facility in the Region as described below;
- Reporting the status of the facility QA programs within the Region to the Corporate QA Director with formal and informal communications;
- Providing training opportunities relating to QA for both QA and laboratory staff;
- Conducting seminars on QA issues for clients;
- Assisting facility QA Directors and managers in resolution of data quality inquiries;
- Assisting the Corporate QA office in the writing of QA policies and procedures;
Serving as a member of the QA Committee;

- Serving as a channel of communications between the Vice President/General Manager and the facility QA groups; and

- Meeting client requirements.

Authority

The Regional QA Director is the final authority within each region on all issues dealing with data quality. He/she has the authority to require that procedures be amended or discontinued or analyses suspended or repeated. In addition, the Regional QA Director has the authority to overrule decisions and actions of the facility QA Directors and must approve the termination or transfer of any facility QA Director. He/she can make recommendations to the Vice President/General Manager and the Corporate Director of QA regarding suspension or termination of employees for incompetence or non-compliance with QA procedures. The Regional QA Director reports to the Vice President/General Manager. The authority of the Regional QA Director comes directly from the Corporate QA Director.

Facility Quality Assurance Departments

Members

Each facility QA Department is managed by a QA Director. The QA Director reports directly to the laboratory management and the Regional QA Director. The QA Director is supported by a QA staff within the facility.
Responsibilities

The facility QA Director or his/her designee is responsible for:

- Implementing QA policies;
- Actively supporting the implementation of the QA Plan within the laboratory to ensure compliance with QA objectives;
- Assisting in maintaining regulatory analytical compliance;
- Conducting in-house audits to identify potential problems and ensure compliance with written SOPs;
- Establishing databases that reflect the performance of the laboratory and review data;
- Prescribing and monitoring corrective actions;
- Serving as the in-house client representative on all project inquiries involving data quality issues;
- Monitoring the preparation and verification of analytical standards;
- Assisting analysts in the writing of SOPs;
- Approving SOPs in concurrence with management;
- Reporting the status of the laboratory QA program to management and the Regional and Corporate QA Director with formal and informal communications;
- Maintaining records and archives of all QC data, PE results, audit comments, and customer inquiries concerning data quality;
- Assuring that the laboratory staff has access to current SOPs;
- Monitoring laboratory performance including holding times, PE performance, and meeting program and project specific requirements.
- Conducting seminars on QA issues for clients;
- Training laboratory staff on QA principles and requirements;
- Approving QA Project Plans;
- Assisting the Corporate QA office in the writing of QA policies and procedures;
- Serving as a member of the QA Committee;
- Auditing subcontractors; and
- Meeting client requirements.

Authority

The facility QA Director is the final authority within each facility on all issues dealing with data quality. He/she has the authority to require that procedures be amended or discontinued or analyses suspended or repeated. He/she can make recommendations to the Vice President/General Manager and the Regional QA Director regarding suspension or termination of employees for incompetence or non-compliance with QA procedures. The authority of the facility QA Director comes directly from the Corporate Director of QA through the Regional QA Director.

Facility Management

Members

The managers and supervisors who direct the analytical work at each facility are directly responsible for ensuring that all employees reporting to them are complying with the Enseco QA Plan.
Responsibilities

Facility management is responsible for:

- Actively implementing the Enseco QA Plan within the facility;
- Responding to and implementing corrective actions;
- Following the Corporate ethics statement;
- Maintaining accurate SOPs and enforcing their use in the laboratory;
- Providing training for laboratory staff;
- Maintaining a work environment that emphasizes the importance of data quality;
- Providing management support to the Corporate, Regional, and facility QA departments; and
- Meeting client requirements.

Authority

The managers and supervisors of the facility have the authority to accept or reject data based on compliance with well-defined QC criteria. In addition, managers and supervisors, with the approval of the QA department, can accept or reject data that fall outside of established QC guidelines if, in their judgment, there are technical reasons which warrant the acceptance or rejection of the data. These circumstances must be well documented and any need for corrective action identified by the incident must be defined and initiated. The authority of the facility management comes directly from the Vice President/General Manager.
Laboratory Personnel

Members

All facility personnel involved in the generation and reporting of data have a responsibility to understand and follow the Enseco QA Plan.

Responsibilities

Laboratory personnel are responsible for:

- Having a working knowledge of the Enseco QA Plan;
- Ensuring that all work is generated in compliance with the Enseco QA Plan;
- Following the Corporate ethics statement;
- Performing all work according to written SOPs and client-specific QAPjPs;
- Ensuring that all documentation related to their work is complete and accurate;
- Providing management and QA with immediate notification of quality problems; and
- Meeting client requirements.

Authority

Laboratory personnel have the authority to accept or reject data based on compliance with well-defined QC criteria. The acceptance of data that fall outside of established QC guidelines or rejection of data for technical reasons that meet established QC guidelines
must be approved by laboratory management and the QA department. Laboratory personnel have the authority to recommend a stop-work order due to quality problems. This recommendation can be made either to their supervisor or to the QA Department. The authority of the laboratory personnel flows from the Vice President/General Manager.
6. SAMPLING PROCEDURES

The generation of quality data begins with the collection of the sample, and therefore the integrity of the sample collection process is of concern to the laboratory. Samples must be collected in such a way that no foreign material is introduced into the sample and no material of interest escapes from the sample prior to analysis. To ensure sample integrity, the following must be considered:

- Samples must be collected in appropriate containers. In general, glass containers are used for organic parameters and polyethylene containers for inorganic/metal parameters (see Appendix I);
- The sample containers must be properly cleaned to ensure that the sample is not contaminated during the collection process;
- Samples must be preserved appropriately to minimize the loss of materials of interest due to adsorption, chemical or biological degradation, or volatilization (see Appendix I);
- Appropriate volumes of sample must be collected to ensure that the required detection limits can be met and quality control samples can be analyzed (see Appendix I); and
- Samples must be properly shipped to the laboratory, in the appropriate time frame, to ensure that holding times for the analyses can be met (see Appendix I).

Sample Containers and Preservatives

Enseco can make available to the client sample containers that are properly cleaned and preserved for use in sample collection. Appropriate containers and preservatives, and minimum sample volumes required for analyzing routine organic, metal, and wet chemistry parameters are listed in Appendix I.
Holding Times

EPA has established holding time requirements for some analyses. These holding time requirements are listed in Appendix I, along with container and preservative requirements. As indicated in Appendix I, holding time requirements differ depending on the regulatory program. Enseco follows the holding times given in SW-846, Update I of SW-846, 40 CFR Part 136, or Methods of Chemical Analysis of Water & Waste, based on the method source, unless otherwise instructed by the client. CLP holding times are followed when CLP protocols are requested by the client.

Sample Disposition

Sample disposition procedures, including disposition of empty sample containers, meet Federal and State regulations.
7. SAMPLE CUSTODY

Upon receipt by the laboratory, samples proceed through an orderly processing sequence specifically designed to ensure continuous integrity of both the sample and its documentation.

All samples are received by the facility's sample control group and are carefully checked for label identification, and completed, accurate chain-of-custody records. Each sample is then assigned a unique laboratory identification number through a computerized Laboratory Information Management System (LIMS) that stores all identifications and essential information. This process is summarized in Figure 7-1. Access to all Enseco laboratories is restricted to prevent any unauthorized contact with samples, extracts, or documentation.

Samples must be transmitted under chain-of-custody both between the field and laboratory and between the laboratory and any subcontractor laboratory as documentation of sample possession. Samples are not transferred to subcontractor laboratories without prior approval of the client.

An example of a Chain-Of-Custody Record used to transmit samples from the client to the laboratory is given in Figure 7-2. An example of a Chain-Of-Custody Record (Interlaboratory Analysis Form) used to transmit samples to subcontractor laboratories is given in Figure 7-3.

Sample bottles provided to the client by Enseco are transmitted under custody.
FIGURE 7-1

ENSECO SAMPLE PROCESSING FLOW CHART

Sample Control

* Check and document physical condition of sample
* Log into LIMS
* Verify documentation and parameter assignment

Proper Storage

* Store sample according to preservation guidelines
* Transfer sample to lab with proper documentation

Laboratories

* Document analytical work
* Return unused samples to Sample Control

Sample Control

* Return sample to client or arrange for sample disposal
# QA Program Plan

**Figure 7-2**

**Chain of Custody**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Sample ID/Description</th>
<th>Sample Type</th>
<th># Containers</th>
<th>Analysis Parameters</th>
<th>Remarks</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Sample ID/Description</th>
<th>Sample Type</th>
<th># Containers</th>
<th>Analysis Parameters</th>
<th>Remarks</th>
</tr>
</thead>
</table>

**Custody Transfers Prior to Shipping**

<table>
<thead>
<tr>
<th>Released By (SIGNED)</th>
<th>Received By (SIGNED)</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
</table>

**Shipping Details**

<table>
<thead>
<tr>
<th>Method of Shipment</th>
<th>Shipping Number</th>
</tr>
</thead>
</table>

**Eneco**

A Corning Company

Rocky Mountain Analytical Laboratory
4935 Yarmouth Street
Aurora, CO 80011

303/431-7171 FAX 303/431-7171

QA Program Plan

Section No. 7
Revision No. 3.5
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# QA Program Plan

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**FIGURE 7-3**

## INTERLABORATORY CHAIN OF CUSTODY

<table>
<thead>
<tr>
<th>SHEET TO</th>
<th>ANALYTICAL REQUESTS</th>
<th>SHIP RESULTS TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATTENTION</td>
<td></td>
<td>ATTENTION</td>
</tr>
<tr>
<td>EXPORT ID</td>
<td></td>
<td>COMMENTS</td>
</tr>
</tbody>
</table>

**TEST PRICE**

<table>
<thead>
<tr>
<th>SUBTOTAL</th>
<th>DISCOUNT / SURCHARGE</th>
<th>TOTAL</th>
</tr>
</thead>
</table>

**SPECIAL INSTRUCTIONS**

- HOLDING TIMES: Enseco, EPA-CLP, NRP,OTHER...
- RAW DATA COPIES NEEDED: Yes, No
- CUSTODY SEALS INTACT: Yes, No
- RECEIVED: DATE/TIME

**IMPORT COPY**
8. CALIBRATION PROCEDURES AND FREQUENCY

Standard and Reagent Preparation

A critical element in the generation of quality data is the purity or quality and traceability of the standard solutions and reagents used in the analytical operations. Enseco continually monitors the quality of reagents and standard solutions through a series of well-documented procedures.

Primary reference standards and standard solutions used by the laboratories are obtained from an EPA Cooperator Supplier, the National Institute of Standards and Technology, or other reliable commercial sources to ensure the highest purity possible. All standards and standard solutions are tracked to identify the supplier, lot number, purity/concentration, receipt/preparation date, preparer's name, method of preparation, expiration date, and all other pertinent information.

Standard solutions are validated prior to use. Validation procedures can range from a check for chromatographic purity to verification of the concentration of the standard using a standard prepared at a different time or obtained from a different source. Stock and working standards are checked regularly for signs of deterioration, such as discoloration, formation of precipitates, or change in concentration. Care is exercised in the proper storage and handling of standard solutions, and all containers are labeled as to compound, concentration, solvent, expiration date, and preparation data (initials of preparer and date of preparation). Standards are stored separately from samples.
Reagents are examined for purity by subjecting an aliquot or subsample to the analytical method in which it will be used. In addition, bulk solvents are analyzed for undesirable contaminants prior to use in the laboratory. These analyses are documented.

**Instrument Calibration and Tuning**

Calibration of instrumentation is required to ensure that the analytical system is operating correctly and functioning at the proper sensitivity to meet established reporting limits. Each instrument is calibrated with standard solutions appropriate to the type of instrument and the working range established for the analytical method. The frequency of calibration and calibration verification and the concentration of calibration standards are determined by the manufacturer’s guidelines, the analytical method, or the requirements of special contracts.

**Gas Chromatography/Mass Spectrometry (GC/MS)**

Prior to analysis of samples, the instrument is tuned with bromofluorobenzene (BFB) for volatile compounds and decafluorotriphenylphosphine (DFTPP) for semivolatile compounds or other tune criteria as specified by the method used. No samples are analyzed until the instrument has met the tuning criteria of the method.

In general, the instrument is then calibrated for all target compounds. An initial calibration curve is produced to define the working range. This initial calibration is evaluated on a daily
basis (when samples are analyzed) to ensure that the system is within calibration. If the continuing calibration standard does not meet the established criteria, corrective action is taken, which may include recalibration.

Chromatography

The field of chromatography involves a variety of instrumentation and detection systems. While calibration standards and acceptance criteria vary depending on the type of system and analytical methodology required for a specific analysis, the general principles of calibration apply uniformly. Each chromatographic system is calibrated prior to performance of analyses. Initial calibration consists of analyzing standards across the working range. The calibration is checked on a daily basis (when samples are analyzed) to ensure that the system remains within specifications. In addition, continuing calibration checks are performed at frequencies required by the method used. If the calibration checks do not meet established criteria, corrective action is taken which may include recalibration and reanalysis of samples. The corrective action procedures include examination of instrument performance and analysis information, consultation with the Supervisor and a decision path to determine if recalibration and reanalysis of samples back to the previous acceptable calibration check is warranted.

Metals

Metals analysis basically involves two types of analytical instrumentation: inductively coupled argon plasma emission spectroscopy (ICP), and atomic absorption spectroscopy (AA).
ICP

Each ICP is calibrated prior to any analyses being performed using criteria prescribed in the analytical method employed. The calibration is then verified using standards from an independent source. The working range of the instrument is established once every quarter using a linear range verification check standard. No values are reported out of the linear range without dilution.

A calibration curve is established daily by analyzing a minimum of two standards, one of which is a calibration blank. The calibration is monitored throughout the day by analyzing a Continuing Calibration Blank (CCB) and a Continuing Calibration Verification standard (CCV). If the verification standard and blank do not meet established criteria, corrective action must be performed. The corrective action procedures include examination of instrument performance and analysis information, consultation with the Supervisor and a decision path to determine if recalibration and reanalysis of samples back to the previously acceptable calibration check is warranted.

An interelement check standard is analyzed at the beginning and end of each analytical run on the ICP to verify that interelement and background correction factors have remained constant. Results outside of the established criteria trigger reanalysis of samples.

AA

Each AA unit is calibrated prior to any analyses being conducted. A calibration curve is prepared with a minimum of a calibration blank and three standards and then verified with a standard that has been
prepared from an independent source at a concentration near the middle of the calibration range. The calibration is then verified on an ongoing basis with a calibration blank (CCB) and a CCV. If the ongoing calibration standard and blank do not meet established acceptance criteria, corrective action must be performed. The corrective action procedures include examination of instrument performance and analysis information, consultation with the Supervisor and a decision path to determine if recalibration and reanalysis of samples back to the previously acceptable calibration check is warranted. For GFAA, all samples are spiked at the instrument to verify the absence of matrix effects or interferences. The method of standard additions or sample dilution is used when matrix interferences are present as determined by the results of the analytical spike.

Wet Chemistry

The field of conventional, non-metals analysis (wet chemistry) involves a variety of instrumental and wet chemical techniques. While calibration and standardization procedures vary depending on the type of system and analytical methodology required for a specific analysis, the general principles of calibration apply universally. Each system is calibrated prior to analyses being conducted. Calibration consists of defining the working range by use of a series of standard solutions and identifying potential interferences. The calibration is checked on an ongoing basis to ensure that the system remains within specifications. If the ongoing calibration check does not meet established criteria, corrective action must be performed. The corrective action procedures include examination of instrument performance and analysis information, consultation with the
Supervisor and a decision path to determine if recalibration and reanalysis of samples back to the previous acceptable calibration check is warranted. Continuing calibrations are not performed for non-instrumental methods such as Total Dissolved Solids.
9. ANALYTICAL PROCEDURES

Most analyses performed by Enseco are driven by regulatory concerns. Therefore, methods used at Enseco predominantly originate from regulatory agencies. Generally the methods used are those specified by the U.S. EPA and other federal agencies, state agencies, and professional organizations, as provided in the following references:

- Current EPA (CLP) protocols for the analysis of organic and inorganic hazardous substances including chlorinated dioxins and furans.
- "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," EPA-600/4-82-057 (July, 1982).
The choice of method is dependent on the objectives of the study in terms of qualitative certainty, quantitative sensitivity, precision and accuracy, the type of matrix to be analyzed, and the regulatory program. Each method used routinely is documented in the form of an SOP. The SOP contains detailed instructions concerning both the use and the expected performance of the method. Enseco may deviate from standard methodologies if necessary or appropriate due to the nature or composition of the sample, based on the reasonable judgment of Enseco.

10. DATA REDUCTION, VALIDATION, AND REPORTING

Data Reduction and Validation

All analytical data generated within Enseco laboratories are extensively reviewed prior to report generation to assure the validity of the reported data. The data validation process consists of data generation, reduction, and three documented reviews (see Figure 10-1). The first review is performed by the person generating the data. This review assures that the work is done correctly the first time. The second review is an independent technical review of the data to ensure the work is error-free and to provide a mechanism to correct errors that are missed during the first review. The third review serves to ensure that the completed project meets the client's specifications. In each stage, the review process is documented by the signature of the reviewer and the date reviewed. In addition to the three reviews, a periodic random data audit is performed by the QA Department. This is described in Section 12. This review process is described below.

The analyst who generates the analytical data has the prime responsibility for the correctness and completeness of the data. All data are generated and reduced following protocols specified in laboratory SOPs. Each analyst reviews the quality of his or her work based on an established set of guidelines. The analyst reviews the data package to ensure that:

- Sample preparation information is correct and complete;
- Analysis information is correct and complete;
FIGURE 10-1
DATA VALIDATION SCHEME

1. Initiate Sample Analysis
   - Chemist Reviews Data
     - Results Acceptable
       - Yes: Perform Corrective Action
     - No: Data Reviewer
       - Results Acceptable
         - Yes: Perform Corrective Action
         - No: Perform Corrective Action
       - QA Audits
       - Hardcopy Report to Client
     - Quality Assurance Office
- The appropriate SOPs have been followed;
- Analytical results are correct and complete;
- QC samples are within established control limits;
- Blanks are within appropriate QC limits;
- Analytical and/or preparation holding times are met;
- Special sample preparation and analytical requirements have been met; and
- Documentation is complete (e.g., all anomalies in the preparation and analysis have been documented, holding times are documented, etc.).

The data reduction and validation steps are documented, signed and dated by the analyst. The analyst then passes the data package to an independent reviewer, who performs a second review.

The second review is performed by a supervisor or data reviewer whose function is to provide an independent review of the data package. This review is also conducted according to an established set of guidelines and is structured to ensure that:

- Calibration data are appropriate to the method and completely documented;
- QC samples are within established guidelines;
- Qualitative identification of sample components is correct;
- Quantitative results are correct;
- Documentation is complete and correct (e.g., anomalies in the preparation and analysis have been documented; holding times are documented, etc.).
- The data are ready for incorporation into the final report; and
- The data package is complete and ready for data archive.

The second review is structured so that all calibration data and QC sample results are reviewed and all of the analytical results from 10% of the samples are checked back to the bench sheet. If no problems are found with the data package, the review is complete. If any problems are found with the data package, an additional 10% of the samples are checked to the bench sheet. The process continues until no errors are found or until the data package has been reviewed in its entirety.

An important element of the second review is the documentation of any errors that have been identified and corrected during the review process. Enseco believes that the data package submitted by the analyst should be error-free. Errors that are found are documented. The cause of the errors is then addressed by the supervisor with additional training or clarification of procedures to ensure that quality data will be generated at the bench.

The second data review is also documented and the signature of the reviewer and the date of review recorded. The reviewed data are then approved for release and a final report is prepared.

Before the report is released to the client, the project is reviewed for completeness and to ensure that the data meet the overall objectives of the project. This review is labeled the third review.
Each step of this review process involves evaluation of data quality based on both the results of the QC data and the professional judgment of those conducting the review. This application of technical knowledge and experience to the evaluation of the data is essential in ensuring that data of high quality are generated consistently.

Data Reporting

A variety of reporting formats, from computerized data tables, to complex reports discussing regulatory issues, to a CLP-deliverables package, are available. In general, Enseco reports contain:

General Discussion: Description of sample types, tests performed, any problems encountered and general comments are given.

Analytical Data: Data are reported by sample or by test with the appropriate significant figures and reporting limits, adjusted for dilution. Pertinent information including dates sampled, received, prepared, and extracted are provided.

Laboratory Performance QC Information: The results (Percent Recovery and Relative Percent Difference) of the Laboratory Control Samples analyzed with the project are listed, together with the control limits. Also, the analytical results for method blanks generated during analysis of organic, metals, and pertinent wet chemistry parameters are given.

Matrix-Specific QC Information: Results of any sample duplicates, matrix spikes, matrix spike duplicates or other project-specific QC requested by the client are also reported. The results include
supporting information such as amount spiked, percent recovery or percent difference.

**Methodology:** Reference for analytical methodology used is cited.

**Other Deliverables:** Other deliverables available include disk deliverables, sample raw data packages, complete deliverable packages, and custom report formats.
11. INTERNAL QC CHECKS

The Enseco QA/QC program controls, monitors, and assesses data quality with internal QC checks. Internal QC checks are used to answer three questions:

1) Are laboratory operations "in control," (i.e., operating within acceptable QC guidelines), during data generation?

2) What effect does the sample matrix have on the data being generated?

3) What effect do field conditions have on the analytical results?

The first question is answered by Laboratory Performance QC. Laboratory performance QC is based on the use of a standard, control matrix to generate precision and accuracy data that are compared, on a daily basis, to control limits. This information, in conjunction with method blank data, is used to assess daily laboratory performance.

The second question is addressed with Matrix-Specific QC. Matrix-Specific QC is based on the use of an actual environmental sample for precision and accuracy determinations and commonly relies on the analysis of matrix spikes, matrix duplicates, and matrix spike duplicates. This information is used to assess the effect of the matrix on analytical data.

The third question is addressed with Field QC samples. These samples, including field blanks, trip blanks, equipment blanks, field duplicates, and field splits monitor the collection, transport and storage of environmental samples.
Laboratory Performance QC is provided as a standard part of every routine Enseco analysis. Matrix-Specific QC is available as an option to the client and should be specified based on the types of matrices to be analyzed and the Data Quality Objectives (DQOs) and regulatory requirements of the project. A complete discussion of these programs follows.

Laboratory Performance QC Program

Laboratory Performance QC is performed for every routine Enseco analysis to demonstrate that laboratory operations are "in control". The main elements of Laboratory Performance QC are:

- The analysis of Laboratory Control Samples, which include Duplicate Control Samples (DCS), Single Control Samples (SCS), and method blanks, and
- The use of calibration standards to assure that both qualitative identification and quantitative measurements are within control limits.

The Laboratory Control Sample program is discussed below. Please refer to Section 8 of this manual for a discussion of calibration procedures.

Laboratory Control Samples (LCS)

Laboratory Control Samples (LCS) are well-characterized, laboratory generated samples used to monitor the laboratory's day-to-day performance of routine analytical methods. Three types of LCS are routinely analyzed: Duplicate Control Samples (DCS), Single Control Samples (SCS), and method blanks. Certain LCS (DCS, SCS) are used to monitor the precision and accuracy of the analytical process, independent of matrix
effects. Other LCS (method blanks) are used to identify any background interference or contamination of the analytical system which may lead to the reporting of elevated concentration levels or false positive data. Each of these LCS are described below.

The results of the LCS are compared to well-defined laboratory acceptance criteria to determine whether the laboratory system is "in control." Controlling lab operations with LCS (as opposed to matrix spike/matrix spike duplicate samples), offers the advantage of being able to differentiate quality problems due to laboratory procedural errors from those due to matrix effects. As a result, procedural errors can be identified and corrected by the analyst at the bench, without waiting for extensive senior level review or costly and time-consuming reanalysis of the sample.

Duplicate Control Samples (DCS)

Duplicate Control Samples (DCS) are used to monitor the precision and accuracy of the analytical system on an on-going basis. Each DCS set consists of a standard, control matrix that is spiked with a group of target compounds representative of the method analytes. A DCS pair is analyzed for every 20 samples processed by the method. DCS are analyzed with environmental samples to provide evidence that the laboratory is performing the method within accepted QC guidelines for accuracy and precision.

Accuracy data (average recovery of each analyte in the DCS pair) and precision data (Relative Percent Difference [RPD] between each analyte in the DCS pair) are compared to control limits that have been established for each of the analytes contained in the DCS. Initially, control limits
for analytes spiked into the DCS are taken directly from the CLP program or published methods. If published limits are not available, either Enseco historical data are used to set the control limits or limits are estimated from method validation data. The control limits are recalculated periodically, as sufficient laboratory data become available. Control limits for accuracy for each analyte are based on the historical average recovery (mean of the average recoveries of the DCS pairs) plus or minus three standard deviation units. Control limits for precision for each analyte are based on the historical RPD. Acceptable RPDs range from zero (no difference between DCS results) to the average RPD plus three standard deviation units. Analytical data that are generated with a DCS pair which falls within the established control limits are judged to be in control. Data generated with a DCS pair which falls outside of the control limits are considered suspect and corrective action must be performed. The procedure used to evaluate data from control samples is given in Figure 11-1. The corrective action procedures include examination of instrument performance and preparation and analysis information, consultation with the supervisor, and finally a decision path for determining whether reanalysis is warranted.

DCS have been established for each routine analytical method. Reagent water is used as the control matrix for the analysis of aqueous samples and deionized water leachates of solids for wet chemistry parameters. The DCS compounds are spiked into reagent water and carried through the appropriate steps of the analysis. The control matrix for solids samples for organic analyses is typically standard Ottawa sand, an ASTM approved material for use in highway construction, due to its homogeneity. The DCS compounds are spiked into the Ottawa sand and carried through the appropriate steps of the analysis. For metal analyses, a spiked solid matrix from a commercial source is used. The DCS for some wet chemistry
FIGURE 11-1
LABORATORY CONTROL
SAMPLE EVALUATION

Laboratory Control Sample Generated

LCS Analyzed

Data Acceptable

Yes

Report data with all associated samples

No

Validate Proper Instrument Performance

Problem Identified

Yes

Correct & reanalyze

Data Acceptable

Yes

Report data with all associated samples

No

Refer problem to Supervisor

Is problem related only to LCS

Yes

Confer with Sample Prep Group

Report data with all associated samples (with explanation)

No

Reprepare & Reanalyze

Can samples be reextracted

No

Document on LCS Form

Yes

Report data with all associated samples (with explanation)
parameters are obtained from a commercial source and used without dilution.

DCS precision and accuracy data are archived in the LIMS. In addition, the associated DCS data are reported with each set of sample results to enable the client to make a quality assessment of the data.

**Single Control Samples (SCS)**

As stated above, a DCS pair is analyzed with every 20 samples to measure the precision and accuracy of an analysis on an ongoing basis. However, samples are often analyzed in lots of less than 20, due to holding time or turn-around time requirements. Since it is necessary to have a measure of laboratory performance with each batch of samples processed, Enseco has instituted the SCS program.

An SCS consists of a control sample that is spiked with surrogate compounds appropriate to the method being used. In cases where no surrogate is available, (e.g., metals or wet chemistry) the analytes used for the DCS are spiked into the control sample. For some wet chemistry parameters, the SCS is obtained from a commercial source and used without dilution. An SCS is prepared for each sample lot for which the DCS pair are not analyzed. Recovery data generated from the SCS are compared to control limits that have been established for each of the compounds being monitored. Initially, CLP control limits or Enseco historical data are used to set the control limits. Control limits are recalculated periodically as sufficient SCS data are available. Control limits for SCS components are based on the historical average recovery in the SCS plus or minus three standard deviation units.
Analytical data that are generated with an SCS which falls within the control limits are judged to be in control. Data that are generated with an SCS which falls outside of acceptance criteria are considered suspect and corrective action must be performed. The protocols for evaluating SCS are identical to those established for DCS (see Figure 11-1). SCS recovery (accuracy) data are archived in the LIMS. In addition, the associated SCS data are reported with each set of sample results to enable the client to make a quality assessment of the data.

Method Blanks

Method blanks, also known as analytical, process or preparation blanks, are analyzed to assess the level of background interference or contamination which exists in the analytical system and which might lead to the reporting of elevated concentration levels or false positive data.

As part of the standard Enseco QC program, a method blank is analyzed with every batch of samples processed. A method blank consists of reagents specific to the method which are carried through every aspect of the procedure, including preparation, clean-up and analysis. The results of the method blank analysis are evaluated, in conjunction with other QC information, to determine the acceptability of the data generated for that batch of samples.

Ideally, the concentration of target analytes in the blank should be below the Reporting limit for that analyte. In practice, however, some common laboratory solvents and metals are difficult to eliminate to the levels commonly reported in environmental analyses. Therefore, criteria for determining blank acceptability must be based on consideration of the analytical techniques used, analytes reported, and Reporting Limits required.
For organic analyses, the concentration of target analytes in the blank must be below the Reporting Limit for that analyte in order for the blank to be considered acceptable. An exception is made for common laboratory contaminants (methylene chloride, acetone, 2-butanone, and phthalate esters) which may be present in the blank at up to 5 times the Reporting Limit and still be considered acceptable. This policy has been established in recognition of the fact that these compounds are frequently found at low levels in method blanks due to the materials used in the collection, preparation, and analysis of samples for organic parameters.

For non-routine organic analyses, other components may be established as common contaminants for that particular analysis. For example, naphthalene is frequently found in PAH-SIM analyses. If, upon thorough review of the method during validation it is deemed impossible to eliminate trace amounts of analytes from the process, these analytes are likewise allowed at up to 5 times the reporting limit.

For metals and Wet Chemistry analyses, where the Reporting Limits are typically near the Instrument Detection Limit (IDL), the policy is that the concentration of the target analytes in the blank must be below two times the Reporting Limit. If the blank value for a target analyte lies below the Reporting Limit, the analyte is reported with no flag on the associated sample data. If the blank value lies between the Reporting Limit and two times the Reporting Limit, the analyte in the associated samples is flagged to indicate contamination was present in the blank. A blank containing an analyte(s) above two times the Reporting Limit is considered unacceptable unless the lowest concentration of the analyte in the associated samples is at least ten times the blank concentration or the concentration of the analyte in all samples associated with the blank is below the reporting limit.
In addition, for Wet Chemistry tests, the method SOP directs how the blank is treated. Generally, a reagent blank is used both to zero the equipment and as one of the calibration standards. If a preparation step is required for the analysis, then a preparation blank is also analyzed to determine the extent of contamination or background interference. Some methods require that the concentration of analyte found in this preparation blank be subtracted from the concentration of the analyte found in any associated sample prior to calculating the final result.

Blanks have no application or significance for some Wet Chemistry parameters (e.g. pH).

If the blank for any test does not meet acceptance criteria, the source of contamination must be investigated and appropriate corrective action must be taken and documented. Investigation includes an evaluation of the data to determine the extent and effect of the contamination on the sample results. Corrective actions may include reanalysis of the blank, and/or repreparation and reanalysis of the blank and all associated samples. If a blank meets the criteria, but has analytes above the reporting limit, investigation should occur to determine whether any corrective action could eliminate an ongoing source of target analytes. Additional actions or explicit corrective action procedures detailed in protocols, methods or project-specific project plans must be followed when applicable.

For organic and metals analyses, and selected Wet Chemistry tests, method blank results are reported with each set of sample results. Sample results are not corrected for blank contamination unless required by the analytical method or requested by the client. Occasionally, due to limited sample volume or other constraints, the laboratory reports data associated with an unacceptable blank. In these cases, the actual
observed value (if any) is reported in the method blank. Sample results for any analyte(s) observed in the blank are flagged to indicate contamination was present in the associated method blank.

Matrix-Specific QC

Matrix-Specific QC is used to assess the effects of a sample matrix on the analytical data. The main elements of Matrix-Specific QC are:

- The analysis of matrix spikes, matrix duplicates, and matrix spike duplicates;
- Monitoring the recovery of surrogate compounds from environmental samples;
- Monitoring the results of standard additions in environmental samples; and
- The determination of method detection limits in a specific matrix.

Different regulatory programs have different requirements in terms of Matrix-Specific QC. At a minimum, the laboratories analyze matrix spikes, matrix spike duplicates or matrix duplicates at the frequency specified by the method, in order to meet the regulatory requirements of the method. These data are only reported when requested. These data are not used to control the laboratory. In order to ensure that the data generated meet all Data Quality Objectives, Enseco recommends that its clients request and include Matrix-Specific QC for their samples that fulfills the Data Quality Objectives and regulatory requirements of the project. A discussion of the different elements of Matrix-Specific QC follows.
Matrix Spikes, Matrix Duplicates, and Matrix Spike Duplicates

A Matrix Spike (MS) is an environmental sample to which known concentrations of representative target analytes have been added. The MS, in addition to an unspiked aliquot, is taken through the entire analytical procedure and the recovery of the analytes is calculated. Results are expressed as percent recovery. The MS is used to evaluate the effect of the sample matrix on the accuracy of the analysis.

A Matrix Duplicate (MD) is an environmental sample that is divided into two separate aliquots. The aliquots are processed separately and the results compared to determine the effects of the matrix on the precision of the analysis. Results are expressed as RPD.

A Matrix Spike Duplicate (MSD) is an environmental sample that is divided into two separate aliquots, each of which is spiked with known concentrations of analytes. The two spiked aliquots, in addition to an unspiked sample aliquot, are processed separately and the results compared to determine the effects of the matrix on the precision and accuracy of the analysis. Results are expressed as RPD and percent recovery.

Surrogate Recoveries

Surrogates are organic compounds which are similar to the analytes of interest in chemical behavior, but which are not normally found in environmental samples. Surrogates are added to samples to monitor the effect of the matrix on the accuracy of the analysis. Results are reported in terms of percent recovery.
Enseco routinely adds surrogates to samples requiring GC or GC/MS analysis and reports these surrogate recoveries to the client. The laboratory does not control its operations based on surrogate recoveries in environmental samples, however individual methods may dictate sample reanalyses based on surrogate criteria. When required by regulations, these method requirements supersede Enseco practices. As discussed earlier in this section, Enseco controls its analytical systems based on the results of Laboratory Control Samples. The surrogate recoveries are primarily used by the laboratory to assess matrix effects. However, obvious problems with sample preparation and analysis (e.g. evaporation to dryness, leaking septum, etc.) which can lead to poor surrogate spike recoveries must be ruled out prior to attributing low surrogate recoveries to matrix effects.

Field QC

Field QC are check samples that monitor contamination originating from the collection, transport or storage of environmental samples. These include trip blanks, equipment blanks and field blanks. A trip blank is a laboratory control matrix (typically water) which is sent to the field in an appropriate sample container, remains unopened in the field, and then is sent back to the laboratory. The purpose of the trip blank is to assess the impact of field and shipping conditions on the samples. An equipment blank is blank water that is poured through the sample collection device to check the adequacy of the cleaning procedures for the sampling equipment. The blank water used to generate the equipment blank may be provided by the laboratory. The results from field QC samples are reported to the client as samples in the same concentration units as the samples. Field blanks are samples of the same or similar matrix exposed to the sampling environment at the time of sampling. No
correction of the analytical data is done in the laboratory based on the analysis of field QC samples.

Matrix-Specific Detection Limits

Method Detection Limits (MDL's) determined on a specific sample matrix are called Matrix-Specific Detection Limits. See Section 14 for a discussion of detection and reporting limits.
12. PERFORMANCE AND SYSTEM AUDITS

Enseco laboratories participate in a variety of federal and state programs that subject each of the laboratories to stringent system and performance audits on a regular basis. A system audit is a review of laboratory operations conducted to verify that the laboratory has the necessary facilities, equipment, staff and procedures in place to generate acceptable data. A performance audit verifies the ability of the laboratory to correctly identify and quantitate compounds in blind check samples submitted by the auditing agency. The purpose of these audits is to identify those laboratories that are capable of generating scientifically sound data. The laboratories are approved or certified to perform environmental analyses under various programs (e.g., those administered by the U.S. Department of Energy, U.S. Air Force, U.S. Navy, and over 20 states). The most current list of certifications held by each laboratory is available upon request.

In addition to external audits conducted by certifying agencies or clients, Enseco regularly conducts the following internal audits:

- Data audits of randomly selected projects are reported. The frequency is determined by the error rate found. This is referred to as the QA data audit (see Figure 10-1). This audit includes verifying that holding times have been met, calibration checks are adequate, qualitative and quantitative results are correct, documentation is complete, and QC results are complete and accurate. Any problems identified require corrective actions.

- The facility QA Director conducts a system audit periodically. These audits may be coordinated at the regional level. Individual laboratory groups conduct semiannual self-audits of their systems. These system audits monitor the conformance of the laboratory to the QA program and include assessment of facilities, staff, SOPs, sample management, and general documentation procedures.
The facility QA Director is responsible for conducting compliance audits of each laboratory group to assess compliance with specific contracts, SOPs, and other requirements. Each laboratory group shall be audited at least once per year.

- Periodic (at least yearly) audits conducted by the Corporate QA Office. These audits provide an independent review of the system for compliance with the QA program and assess resolution of previously identified problems.

- Special audits by the facility or Regional QA Director or Corporate QA Office when a problem is suspected.

Enseco laboratories also routinely analyze check samples as described below:

- Laboratory Control Samples (DCS, SCS, and method blanks) are analyzed at a frequency equal to at least 5% of the total number of samples analyzed (see Section 11).

- Enseco laboratories participate in the analyses of EPA check samples provided under the Water Supply (WS) and Water Pollution (WP) Performance Evaluation Studies. The results of these PE samples are tabulated by the Corporate QA Office to identify performance trends within the Enseco laboratories.

- The laboratories participate in multiple state certification programs which require that PE samples be analyzed periodically.

- Blind check samples from an independent commercial firm are sent to the laboratories periodically by the Corporate QA Office.

The results of these check samples are used to identify areas where additional training is needed or clarification of procedures is required. Corrective action reports are prepared to document the investigation of these results and corrective actions implemented to correct any deficiencies revealed by these programs.
In both the system and performance audit processes, the proper implementation of corrective actions must be assured to effect permanent solutions to problems detected.
13. PREVENTIVE MAINTENANCE

To minimize downtime and interruption of analytical work, preventive maintenance is routinely performed on each analytical instrument. Laboratory personnel are trained in routine maintenance procedures for most instrumentation. When repairs are necessary, they are performed by either trained staff or trained service engineers employed by the instrument manufacturer.

Each laboratory has SOPs on file that describe preventive maintenance procedures and schedules. The laboratories also maintain detailed logbooks documenting the preventive maintenance and repairs performed on each analytical instrument.
14. SPECIFIC ROUTINE PROCEDURES USED TO ASSESS DATA QUALITY AND DETERMINE REPORTING LIMITS

Data Quality Assessment

The effectiveness of a QA program is measured by the quality of data generated by the laboratory. Data quality is judged in terms of its precision, accuracy, representativeness, completeness and comparability. These terms are described as follows:

Precision is the degree to which the measurement is reproducible. Precision can be assessed by replicate measurements of DCS, reference materials, or environmental samples. Enseco routinely monitors precision by comparing the RPD between DCS measurements with the upper control limit established at plus three standard deviations from the mean RPD of historical DCS data.

Precision is frequently determined by comparison of replicates. The standard deviation(s) of "n" measurements of "x" is commonly used to estimate precision and is calculated as follows:

\[ s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2} \]

where a quantity "x" (e.g., a concentration) is measured "n" times.
The relative standard deviation, which expresses standard deviation as a percentage of the mean, is generally useful in the comparison of three or more replicates (although it may be applied in the case of \( n = 2 \)).

\[
RSD = 100 \left( \frac{s}{\bar{x}} \right)
\]

where:  
- \( RSD \) = relative standard deviation  
- \( s \) = standard deviation  
- \( \bar{x} \) = mean

In the case of duplicates, the RPD between the two samples may be used to estimate precision.

\[
RPD = \left( \frac{|D_1 - D_2|}{(D_1 + D_2)/2} \right) \times 100
\]

where:  
- \( RPD \) = relative percent difference  
- \( D_1 \) = first sample value  
- \( D_2 \) = second sample value (duplicate)

**Accuracy** is a determination of how close the measurement is to the true value. Accuracy can be assessed using LCS, standard reference materials, or spiked environmental samples. Unless specified otherwise in special contracts, Enseco monitors accuracy by comparing LCS results with control limits established at plus or minus three standard deviation units from the mean of historical LCS results.
The determination of the accuracy of a measurement requires a knowledge of the true or accepted value for the signal being measured. Accuracy may be calculated in terms of percent recovery as follows:

\[
\text{Percent Recovery} = \frac{x}{T} \times 100
\]

where: \( x \) = the observed value of measurement
\( T \) = "true" value

Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. Analytical data should represent the sample analyzed. Enseco strives to accommodate all sample matrices. Some samples may require analysis of multiple phases to obtain representative results.

Completeness is a measure of the amount of valid data obtained from a measurement system compared with the amount that was expected to be obtained under normal conditions.

To be considered complete, the data set must contain all analytical results and data specified for the project. In addition, all data are compared to project requirements to ensure that specifications were met. Any deviations are reported in the report narrative.

The percent completeness for each set of samples can be calculated as follows:

\[
\text{Completeness} = \frac{\text{valid data obtained}}{\text{total data planned}} \times 100\%
\]

where valid data are determined by the data acceptance criteria defined in the project plan.
Comparability expresses the confidence with which one data set can be compared to another data set measuring the same property. Comparability is ensured through the use of established and approved analytical methods, consistency in the basis of analysis (wet weight, volume, etc.), consistency in reporting units (ppm, ppb, etc.), and analysis of standard reference materials.

**Reporting Limits**

Assuring the validity of quantitative measurements at low concentrations is an extremely difficult technical problem. With regulatory action levels being pushed lower and lower, the validity of any given measurement becomes even more important. The consequences of false positive or false negative data can be significant.

A number of terms have been used, by the EPA and other technical groups, to express the lowest concentration of an analyte which can be measured. Some of these terms, their definitions, and sources are listed in Table 14-1. A graphical representation of these terms is given in Figure 14-1.

Enseco has established a Reporting Limit (RL) for each analyte in each method. These Reporting Limits were established by collecting Method Detection Limit (MDL) data for organic and wet chemistry analyses and Instrument Detection Limit (IDL) data for metals analyses from each Enseco laboratory. The MDL data were collected using the procedures described in 40 CFR 136 Appendix B. IDL data were calculated using the procedures outlined in the EPA Contract Laboratory Program (CLP) Statement of Work dated 7/88. The MDL/IDL data were then compared to various limits published in EPA methods and in the regulations. For example for Volatile Organics, the MDL data generated in Enseco
laboratories were compared to the Practical Quantitation Limits (PQLs) published in SW-846 method 8240; the PQLs contained in the July 9, 1987, Federal Register Final Rulemaking on Appendix IX; the Contract Required Quantitation Limits (CRQLs) in the CLP Method for Volatile Organics; and the MDLs in Method 624. Then a Reporting Limit for each analyte was established which considered all of this information. The Reporting Limit was set at a level above which we were confident that our laboratories could detect and quantify the analyte consistently. Using this procedure, the Reporting Limits established are generally between 2 to 5 times the laboratory MDL or IDL. This range is consistent with the American Chemical Society definition for the Limit of Quantitation (LOQ). (See Table 14-1)

Enseco routinely reports results below the reporting limit as Not Detected (ND) because, by definition, the reliability of the data at that level is questionable. As an option, Enseco can report data below the reporting limit and flag the data as estimated. Reporting limits are adjusted for sample dilution.
### TABLE 14-1

**DEFINITION OF DETECTION LIMIT TERMS**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Determination</th>
<th>Calculation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection Limit (DL)</td>
<td>The concentration which is distinctly detectable above, but close to a blank</td>
<td>Analysis of replicate standards</td>
<td>Two times the standard deviation</td>
<td>Methods for Chemical Analysis of Water and Wastes</td>
</tr>
<tr>
<td>Limit of Detection (LOD)</td>
<td>The lowest concentration that can be determined to be statistically different from a blank</td>
<td>Analysis of replicate samples</td>
<td>Three times the standard deviation</td>
<td>ACS Definition</td>
</tr>
<tr>
<td>Method Detection Limit (MDL)</td>
<td>The minimum concentration of a substance that can be identified, measured and reported with 99% confidence that the analyte concentration is greater than zero.</td>
<td>Analysis of a minimum of seven replicates spiked at 1 to 5 times the expected detection limit.</td>
<td>The standard deviation times the Student t-value at the desired confidence level. (For seven replicates, the value is 3.14)</td>
<td>40 CFR 136 Definition for EPA Water Programs</td>
</tr>
<tr>
<td>Instrument Detection Limit (IDL)</td>
<td>The smallest signal above background noise that an instrument can detect reliably.</td>
<td>Analysis of seven replicate standards on three non-consecutive days.</td>
<td>Three times the standard deviation</td>
<td>Contract Laboratory Program</td>
</tr>
<tr>
<td>Method Quantitation Limit (MQL)</td>
<td>The minimum concentration of a substance that can be measured and reported</td>
<td>Analysis of replicate samples</td>
<td>Five times the standard deviation</td>
<td>SW-846</td>
</tr>
<tr>
<td>Limit of Quantitation (LOQ)</td>
<td>The level above which quantitative results may be obtained with a specified degree of confidence</td>
<td>Analysis of replicate samples</td>
<td>Ten times the standard deviation</td>
<td>ACS Definition</td>
</tr>
<tr>
<td>Practical Quantitation Limit (PQL)</td>
<td>The lowest level that can be reliably determined within specified limits of precision and accuracy during routine laboratory operating conditions</td>
<td>Interlaboratory analysis of check samples</td>
<td>1) Ten times the MDL</td>
<td>RCRA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2) Value where 80% of laboratories are within 20% of the true value</td>
<td>SDWA Program</td>
</tr>
<tr>
<td>Contract Required Detection Limit (CRDL)</td>
<td>Reporting limit specified for laboratories under contract to the EPA for Superfund activities</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Contract Laboratory Program</td>
</tr>
</tbody>
</table>
FIGURE 14-1

Graphical Representation of Detection Limit Terms
(See Table 14-1 for Definitions)

NOTE: The values along the horizontal "Standard Deviation (SD)" axis are approximate values and are meant to show the relative, not absolute, relationship between the terms.
15. CORRECTIVE ACTION

When errors, deficiencies, or out-of-control situations exist, the QA program provides systematic procedures, called "corrective actions," to resolve problems and restore proper functioning to the analytical system.

Laboratory personnel are alerted that corrective actions may be necessary if:

- QC data are outside the acceptable limits for precision and accuracy;
- Blanks contain contaminants above acceptable levels;
- Undesirable trends are detected in DCS and SCS recoveries or RPD between duplicates;
- There are unusual changes in detection limits;
- Deficiencies are detected during internal or external audits or from the results of performance evaluation samples; or
- Inquiries concerning data quality are received from clients.

Corrective action procedures are often handled at the bench level by the analyst, who reviews the preparation or extraction procedure for possible errors, checks the instrument calibration, spike and calibration mixes, instrument sensitivity, and so on. If the problem persists or cannot be identified, the matter is referred to the laboratory supervisor, manager and/or QA department for further investigation. Every effort must be made to determine the cause of the problem so that a permanent solution can be implemented. Once resolved, full documentation of the corrective action procedure is filed with the project records.
Investigations made by laboratory or QA personnel that result in corrective actions affecting more than one project must be documented and reported in the monthly QA report to management. Documentation of investigations of negative performance on PE samples and corrective actions taken is forwarded to the appropriate certifying agencies when required. These reports are always included in the monthly reports to management.
16. QA REPORTS TO MANAGEMENT

The reporting system is a valuable tool for measuring the overall effectiveness of the QA program. It serves as an instrument for evaluating the program design, identifying problems and trends, and planning for future needs. Facility QA Directors submit extensive monthly reports to the Regional QA Director who is responsible for submitting the regional report to the Vice President/General Manager and the Corporate QA office. These reports include:

- Results of site visits and audits by regulatory agencies and clients including the laboratory's response to deficiencies or action items required by the auditors;
- Results of internal audits including facility audits, contract compliance audits and periodic data audits;
- Performance evaluation sample results and corrective action reports;
- Summary of certification activity including new certifications applied for, certifications renewed and any actions taken by certifying agencies (suspensions, decertifications, probation or reinstatements);
- Discussion of specific client inquiries including summary of the issue, resolution, and correspondence between the client and the laboratory;
- Holding Time Violations, by facility and by department including narrative discussion of problem areas and corrective actions implemented;
- Performance on major contracts;
- Narrative including comments and recommendations on any pertinent issues.

The Corporate QA Director regularly reports on the status of the QA Program to each Vice President/General Manager, to the Director of Technology/Quality Assurance, and to the President and CEO. These reports summarize the information gathered through the laboratory reporting system and contain a thorough review and evaluation of laboratory operations throughout Enseco.
17. LABORATORY DOCUMENTATION

Complete and accurate documentation of analytical and procedural information is an important part of the QA program. The following describes different types of documentation used in the Enseco laboratories.

Standard Operating Procedures

Details of analytical and QC protocols are contained in Standard Operating Procedures (SOPs). SOPs are documents that contain detailed proprietary information on how to perform a laboratory procedure. Enseco has laboratory SOPs that describe:

- Performance of an Analytical Method;
- Preparation of Standards and Reagents;
- Equipment Operation, Calibration, and Maintenance; and
- General Laboratory Procedures.

Examples of the elements contained in these SOPs are given in Appendix II.

All SOPs are approved by the QA Department in concurrence with management, as documented by their signatures, before being implemented. The distribution of current SOPs and archiving of outdated ones is controlled through the QA Department.

Because of the detailed nature of SOPs, Enseco considers them to be proprietary documents. SOPs are available for review at each location.
LIMS

Enseco laboratories rely on a customized Laboratory Information Management System (LIMS) as the primary database. Client information, sample results, and QC results are all stored in the LIMS. Reports are generated directly from the database to eliminate transcription errors.

Laboratory Bench Sheets/Notebooks

Laboratory bench sheets or notebooks are used to document information from routine laboratory operations, including sample preparation and analysis. The information is recorded in a complete and organized manner such that the analysis can be reconstructed, if necessary. Portions of information from the bench sheet or notebook are also stored in the LIMS. Laboratory notebooks are also used to document information such as methods development information. Each bench sheet or notebook page is initialed and dated as information is entered.
Control Charts

Enseco laboratories use control charts to visually track precision and accuracy data. These control charts are used to identify trends in the analyses which may indicate a problem with the analytical procedure. When an adverse trend is detected, corrective action is performed.

Anomalies

Any situation which is outside of the normal scope of operations, as described in the laboratory SOPs, is documented. Examples of anomalous situations include: formation of a precipitate in an extract; formation of an emulsion during an extraction step; or missed holding times. These situations are documented to enable a thorough review of the data to occur. This documentation is maintained as part of the project record.

Out-of-Control situations are also documented. An Out-of-Control situation occurs when QC data fall outside of established control limits. At a minimum, the documentation associated with an Out-of-Control situation is reviewed by the supervisor. Out-of-Control situations trigger Corrective Action. Corrective Actions taken are also documented. The QA department must be notified when corrective actions affect more than an isolated occurrence of an event.

Project Files

The project file consists of a project summary file and a raw data file. The project summary file includes correspondence from the client,
(letters, phone logs, contracts, project plans) copies of preliminary and final reports, chain of custody, air bills, level 3 review checklists, QA review checklist when applicable and the summary file inventory. The raw data file includes sample data, QC data, benchsheets, level 1 and level 2 review checklists, instrument logbook pages pertinent to the project and the raw data file inventory. Contracts, project plans, calibration data and QC data may be stored separately from the project record. All project records must contain cross-references to any information stored separately from the project record. When a project is complete, all records are passed to the Document Custodian who inventories the file, checks for completeness, and puts the file into document archive.

Training Records

Employees participate in structured training which includes learning job skills; Environmental Health and Safety, First Aid and Hazard Communication training; quality training and other support skills (e.g. LIMS). Employee participation in and completion of company-sponsored or company-directed training programs must be documented.
APPENDIX I

MAXIMUM HOLDING TIMES AND
SAMPLE COLLECTION/PRESERVATION INFORMATION

Sources:
Tables A-E
40 CFR Part 136
Methods for Chemical Analysis of Water and Wastes
SW-846, 3rd Edition, Update I

Table F:
Contract Laboratory Program Statement of
Work for Organic Analysis dated 3/90 (as amended)
Contract Laboratory Program Statement of
Work for Inorganic Analysis dated 7/88

Table G:
Federal Register, June 29, 1990

(QA Program Plan, Revision: 3.5)
## A. VOLATILE ORGANICS

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Holding Time (From Date Sampled)</th>
<th>Container</th>
<th>Preservative</th>
<th>Minimum Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WATER SAMPLES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Residual Chlorine Present</td>
<td>14 days</td>
<td>3 40 mL vials with Teflon lined septum caps</td>
<td>HCl to pH&lt;2, 40°C</td>
<td>40 mL</td>
</tr>
<tr>
<td>Residual Chlorine Present</td>
<td>14 days</td>
<td>3 40 mL vials with Teflon lined septum caps</td>
<td>4 drops of 10% sodium thiosulfate, HCl to pH&lt;2, 40°C</td>
<td>40 mL</td>
</tr>
<tr>
<td>Acrolein and Acrylonitrile</td>
<td>14 days</td>
<td>3 40 mL vials with Teflon lined septum caps</td>
<td>Adjust to pH 4-5, 40°C</td>
<td>40 mL</td>
</tr>
<tr>
<td><strong>SOIL/SEDIMENTS AND SLUDGES</strong></td>
<td>14 days</td>
<td>Glass jar with Teflon liner or core tube</td>
<td>40°C</td>
<td>10 g</td>
</tr>
<tr>
<td><strong>CONCENTRATED WASTE SAMPLES</strong></td>
<td>14 days</td>
<td>Glass jar with Teflon liner or core tube</td>
<td>None</td>
<td>10 g</td>
</tr>
</tbody>
</table>

The above information applies to the following parameters and methods:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatile Halocarbons</td>
<td>601/8010 (GC)</td>
</tr>
<tr>
<td>Volatile Aromatics</td>
<td>602/8020 (GC)</td>
</tr>
<tr>
<td>Volatile Organics</td>
<td>624/8240/8260 (GC/MS), 8015 (GC)</td>
</tr>
<tr>
<td>Acrolein/Acrylonitrile</td>
<td>603/8030 (GC)</td>
</tr>
</tbody>
</table>

AI-1 (QA Program Plan, Revision: 3.5)
### B. SEMIVOLATILE ORGANICS

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Holding Time (From Date Sampled)</th>
<th>Container</th>
<th>Preservative</th>
<th>Minimum Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WATER SAMPLES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Residual Chlorine Present</td>
<td>Samples must be extracted within 7 days and analyzed within 40 days of extraction.</td>
<td>1 liter glass with Teflon liner</td>
<td>40°C</td>
<td>1 liter</td>
</tr>
<tr>
<td>Residual Chlorine Present</td>
<td>Samples must be extracted within 7 days and analyzed within 40 days of extraction.</td>
<td>1 liter glass with Teflon liner</td>
<td>Add 3 mL 10% sodium thiosulfate per gallon, 40°C</td>
<td>1 liter</td>
</tr>
<tr>
<td><strong>SOIL/SEDIMENTS AND SLUDGES</strong></td>
<td>Samples must be extracted within 14 days and analyzed within 40 days of extraction.</td>
<td>Glass jar with Teflon liner or core tube</td>
<td>40°C</td>
<td>50 g</td>
</tr>
<tr>
<td><strong>CONCENTRATED WASTE SAMPLES</strong></td>
<td>Samples must be extracted within 14 days and analyzed within 40 days of extraction.</td>
<td>Glass jar with Teflon liner or core tube</td>
<td>None</td>
<td>50 g</td>
</tr>
</tbody>
</table>

The above information applies to the following parameters and methods:

**Parameter** | **Method**
---|---
Phenols | 604/8040 (GC)
Phthalate Esters | 606/8060 (GC)
Organochlorine Pesticides/PCBs | 608/8080 (GC)
Polyaromatic Hydrocarbons | 610/8310 (HPLC)
Organophosphate Pesticides | 614/8140 (GC)
Phenoxy Acid Herbicides | 615/8150 (GC)
Semivolatile Organics | 625/8270 (GC/MS)
Carbamate & Urea Pesticides | 632 (HPLC)
C. OTHER ORGANICS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method No.</th>
<th>Matrix</th>
<th>Holding Time(a) (from Date Sampled)</th>
<th>Container</th>
<th>Preservative</th>
<th>Min. Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dioxins/Furans</td>
<td>8280</td>
<td>Water</td>
<td>30 days extn. 45 days anal.(b)</td>
<td>One liter glass</td>
<td>4°C</td>
<td>1000 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>30 days extn. 45 days anal.(b)</td>
<td>core tube or glass jar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroleum Hydrocarbons as Gasoline</td>
<td>TPH-Gasoline Purge &amp; Trap (LUFT manual)</td>
<td>Water</td>
<td>14 days</td>
<td>40 mL vials with Teflon liners</td>
<td>4°C, HCl to pH &lt; 2</td>
<td>50 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>14 days</td>
<td>Core tube or glass jar</td>
<td>4°C</td>
<td>50 g</td>
</tr>
<tr>
<td>Petroleum Hydrocarbons as Diesel</td>
<td>TPH-Diesel Extractable (LUFT manual)</td>
<td>Water</td>
<td>14 days extn. 40 days anal.</td>
<td>One liter glass</td>
<td>4°C, HCl to pH &lt; 2</td>
<td>500 mL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>14 days extn. 40 days anal.</td>
<td>Core tube or glass jar</td>
<td>4°C</td>
<td>50 g</td>
</tr>
<tr>
<td>Petroleum Hydrocarbons (TPH)</td>
<td>TPH-IR (418.1)</td>
<td>Water</td>
<td>28 days</td>
<td>One liter glass</td>
<td>4°C, H₂SO₄ to pH &lt; 2</td>
<td>1000 mL</td>
</tr>
</tbody>
</table>

(a) extn: extraction  anal: analysis
(b) from date of collection

AI-3 (QA Program Plan, Revision: 3.5)
## D. METALS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method No.</th>
<th>Matrix</th>
<th>Holding Time (from Date Sampled to Analysis)</th>
<th>Container</th>
<th>Preservative(a)</th>
<th>Min. Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals (ICP)</td>
<td>200.7/6010</td>
<td>Water</td>
<td>6 months</td>
<td>Poly</td>
<td>$\text{HNO}_3$ to $\text{pH} &lt; 2.0$ at $40^\circ \text{C}$</td>
<td>100 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>6 months</td>
<td>core tube/glass jar</td>
<td></td>
<td>10 g</td>
</tr>
<tr>
<td>Arsenic (GF-AA)</td>
<td>206.2/7060</td>
<td>Water</td>
<td>6 months</td>
<td>Poly</td>
<td>$\text{HNO}_3$ to $\text{pH} &lt; 2.0$ at $40^\circ \text{C}$</td>
<td>100 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>6 months</td>
<td>core tube/glass jar</td>
<td></td>
<td>10 g</td>
</tr>
<tr>
<td>Mercury (CV-AA)</td>
<td>245.1/7470</td>
<td>Water</td>
<td>28 days</td>
<td>Poly</td>
<td>$\text{HNO}_3$ to $\text{pH} &lt; 2.0$ at $40^\circ \text{C}$</td>
<td>100 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>28 days</td>
<td>core tube/glass jar</td>
<td></td>
<td>10 g</td>
</tr>
<tr>
<td>Selenium (GF-AA)</td>
<td>270.2/7740</td>
<td>Water</td>
<td>6 months</td>
<td>Poly</td>
<td>$\text{HNO}_3$ to $\text{pH} &lt; 2.0$ at $40^\circ \text{C}$</td>
<td>100 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>6 months</td>
<td>core tube/glass jar</td>
<td></td>
<td>10 g</td>
</tr>
<tr>
<td>Thallium (GF-AA)</td>
<td>279.2/7841</td>
<td>Water</td>
<td>6 months</td>
<td>Poly</td>
<td>$\text{HNO}_3$ to $\text{pH} &lt; 2.0$ at $40^\circ \text{C}$</td>
<td>100 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>6 months</td>
<td>core tube/glass jar</td>
<td></td>
<td>10 g</td>
</tr>
<tr>
<td>Lead (GF-AA)</td>
<td>239.2/7421</td>
<td>Water</td>
<td>6 months</td>
<td>Poly</td>
<td>$\text{HNO}_3$ to $\text{pH} &lt; 2.0$ at $40^\circ \text{C}$</td>
<td>100 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>6 months</td>
<td>core tube/glass jar</td>
<td></td>
<td>10 g</td>
</tr>
<tr>
<td>Chromium (III/VI)</td>
<td>220.7/218.4/312B/7196</td>
<td>Water</td>
<td>24 hours</td>
<td>Poly</td>
<td>$40^\circ \text{C}$</td>
<td>100 ml</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil/Waste</td>
<td>24 hours extn. (b)</td>
<td>core tube/glass jar</td>
<td></td>
<td>10 g</td>
</tr>
</tbody>
</table>

(a) Listed preservative is for total metals. Dissolved or suspended metals require filtration prior to pH adjustment.

(b) Holding time applies to extract obtained from leached sample.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method No.</th>
<th>Matrix</th>
<th>Holding Time (from Date Sampled to Analysis)</th>
<th>Container</th>
<th>Preservative</th>
<th>Min. Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidity</td>
<td>305.1</td>
<td>Water</td>
<td>14 days</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>310.1</td>
<td>Water</td>
<td>14 days</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
<tr>
<td>Ammonia</td>
<td>350.1</td>
<td>Water</td>
<td>28 days</td>
<td>Glass</td>
<td>4°C, H2SO4 to pH &lt; 2</td>
<td>50 ml</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand</td>
<td>405.1</td>
<td>Water</td>
<td>48 hours</td>
<td>Poly</td>
<td>4°C</td>
<td>200 ml</td>
</tr>
<tr>
<td>Bromide</td>
<td>300.0</td>
<td>Water</td>
<td>28 days</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
<tr>
<td>Chemical Oxygen Demand</td>
<td>410.4</td>
<td>Water</td>
<td>28 days</td>
<td>Glass</td>
<td>4°C, H2SO4 to pH &lt; 2</td>
<td>100 ml</td>
</tr>
<tr>
<td>Chloride</td>
<td>300.0</td>
<td>Water</td>
<td>28 days</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
<tr>
<td>Chlorine, residual</td>
<td>330.1</td>
<td>Water</td>
<td>ASAP</td>
<td>Poly</td>
<td>4°C</td>
<td>100 ml</td>
</tr>
<tr>
<td>Coliform, Total &amp; Fecal</td>
<td>909A/909C</td>
<td>Water</td>
<td>6 hours</td>
<td>Sterile poly</td>
<td>4°C, Na2S2O3</td>
<td>100 ml</td>
</tr>
<tr>
<td>Parameter</td>
<td>Method No.</td>
<td>Matrix</td>
<td>Holding Time (from Date Sampled)</td>
<td>Container</td>
<td>Preservative</td>
<td>Min. Sample Size</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------</td>
<td>------------</td>
<td>----------------------------------</td>
<td>-----------</td>
<td>--------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Cyanide</td>
<td>335.1/335.2/335.3</td>
<td>Water</td>
<td>14 days</td>
<td>Poly</td>
<td>4°C, NaOH to pH &gt; 12 (a)</td>
<td>250 ml</td>
</tr>
<tr>
<td>Fluoride</td>
<td>340.2</td>
<td>Water</td>
<td>28 days</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
<tr>
<td>Gross Alpha, Beta and Radium</td>
<td>9310/9315</td>
<td>Water</td>
<td>6 months</td>
<td>Poly</td>
<td>HNO₃ to pH &lt; 2</td>
<td>2000 ml</td>
</tr>
<tr>
<td>Hardness</td>
<td>200.7/314A/314B</td>
<td>Water</td>
<td>6 months</td>
<td>Poly</td>
<td>HNO₃ to pH &lt; 2</td>
<td>50 ml</td>
</tr>
<tr>
<td>Iodide</td>
<td>Dionex</td>
<td>Water</td>
<td>28 days</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
<tr>
<td>Nitrate</td>
<td>353.2/300.0</td>
<td>Water</td>
<td>48 hours</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
<tr>
<td>Nitrite</td>
<td>354.1</td>
<td>Water</td>
<td>48 hours</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
<tr>
<td>Nitrite plus Nitrate</td>
<td>353.2</td>
<td>Water</td>
<td>28 days</td>
<td>Glass</td>
<td>4°C, H₂SO₄ to pH &lt; 2</td>
<td>50 ml</td>
</tr>
<tr>
<td>Parameter</td>
<td>Method No.</td>
<td>Matrix</td>
<td>Holding Time (from Date Sampled)</td>
<td>Container</td>
<td>Preservative</td>
<td>Min. Sample Size</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------</td>
<td>--------</td>
<td>----------------------------------</td>
<td>-----------</td>
<td>-------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Odor</td>
<td>140.1</td>
<td>Water</td>
<td>ASAP</td>
<td>Glass</td>
<td></td>
<td>4°C 1000 mL</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>413.1/413.2</td>
<td>Water</td>
<td>28 days</td>
<td>Glass</td>
<td>4°C, H2SO4</td>
<td>1000 mL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>to pH &lt; 2</td>
<td></td>
</tr>
<tr>
<td>Orthophosphate</td>
<td>365.3</td>
<td>Water</td>
<td>48 hours</td>
<td>Poly</td>
<td>4°C</td>
<td>100 mL</td>
</tr>
<tr>
<td>pH</td>
<td>150.1</td>
<td>Water</td>
<td>ASAP</td>
<td>Poly</td>
<td>4°C</td>
<td>50 mL</td>
</tr>
<tr>
<td>Phenolics</td>
<td>420.1/420.2</td>
<td>Water</td>
<td>28 days (b)</td>
<td>Glass</td>
<td>4°C, H2SO4</td>
<td>100 mL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>to pH &lt; 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(c)</td>
<td></td>
</tr>
<tr>
<td>Specific Conductance</td>
<td>120.1</td>
<td>Water</td>
<td>28 days</td>
<td>Poly</td>
<td>4°C</td>
<td>50 mL</td>
</tr>
<tr>
<td>Sulfate</td>
<td>300.0</td>
<td>Water</td>
<td>28 days</td>
<td>Poly</td>
<td>4°C</td>
<td>50 mL</td>
</tr>
<tr>
<td>Sulfide</td>
<td>376.2</td>
<td>Water</td>
<td>7 days</td>
<td>Poly</td>
<td>4°C, NaOH</td>
<td>100 mL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>to pH &gt; 9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Zn(C2H3O3)2</td>
<td></td>
</tr>
<tr>
<td>Sulfite</td>
<td>377.1</td>
<td>Water</td>
<td>ASAP</td>
<td>Poly</td>
<td>4°C</td>
<td>100 mL</td>
</tr>
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(E. WET CHEMISTRY (Cont.))

(Enesco)

AI-7

(QA Program Plan, Revision: 3.5)
### E. WET CHEMISTRY (Cont.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method No.</th>
<th>Matrix</th>
<th>Holding Time (from Date Sampled)</th>
<th>Container</th>
<th>Preservative</th>
<th>Min. Sample Size</th>
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</thead>
<tbody>
<tr>
<td>Surfactants (MBAS)</td>
<td>425.1</td>
<td>Water</td>
<td>48 hours</td>
<td>Poly</td>
<td>4°C</td>
<td>100 ml</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>160.1</td>
<td>Water</td>
<td>7 days</td>
<td>Poly</td>
<td>4°C</td>
<td>100 ml</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen</td>
<td>351.2</td>
<td>Water</td>
<td>28 days</td>
<td>Glass</td>
<td>4°C, H₂SO₄ to pH &lt; 2</td>
<td>100 ml</td>
</tr>
<tr>
<td>Total Organic Carbon (TOC)</td>
<td>415.1</td>
<td>Water</td>
<td>28 days</td>
<td>Glass</td>
<td>4°C, H₂SO₄ to pH &lt; 2</td>
<td>100 ml</td>
</tr>
<tr>
<td>Total Organic Halogen (TOX)</td>
<td>9020</td>
<td>Water</td>
<td>28 days (d)</td>
<td>Glass</td>
<td>4°C, H₂SO₄ to pH &lt; 2</td>
<td>200 ml</td>
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<tr>
<td>Total Phosphorus</td>
<td>365.3</td>
<td>Water</td>
<td>28 days</td>
<td>Glass</td>
<td>H₂SO₄ to pH &lt; 2</td>
<td>100 ml</td>
</tr>
<tr>
<td>Total Solids</td>
<td>160.3</td>
<td>Water</td>
<td>7 days</td>
<td>Poly</td>
<td>4°C</td>
<td>100 ml</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>160.2</td>
<td>Water</td>
<td>7 days</td>
<td>Poly</td>
<td>4°C</td>
<td>100 ml</td>
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### E. WET CHEMISTRY (Cont.)

<table>
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<th>Container</th>
<th>Preservative</th>
<th>Min. Sample Size</th>
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<tr>
<td>Total Volatile Solids</td>
<td>160.4</td>
<td>Water</td>
<td>7 days</td>
<td>Poly</td>
<td>4°C</td>
<td>100 ml</td>
</tr>
<tr>
<td>Turbidity</td>
<td>180.1</td>
<td>Water</td>
<td>48 hours</td>
<td>Poly</td>
<td>4°C</td>
<td>50 ml</td>
</tr>
</tbody>
</table>

a) Samples to be analyzed for cyanide should be field-tested for residual chlorine. If residual chlorine is detected, ascorbic acid should be added.

b) The 28 day holding time is specified in Table 1 of Methods for Chemical Analysis of Water and Wastes, issued March 1983. This information supercedes that contained in Method 420.1/420.2 published in 1979.

c) Samples to be analyzed for phenolics should be field-tested for residual chlorine. If residual chlorine is detected, ferrous ammonium sulfate should be added.

d) The 28 day holding time is specified in Table 2-20 of SW-846 3rd edition, Update I, 1987.
### F. CLP HOLDING TIMES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Matrix</th>
<th>Holding Time(a) (from Date Received)</th>
<th>Container</th>
<th>Preservative</th>
<th>Min. Sample Size</th>
</tr>
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<tr>
<td>Volatile Organics</td>
<td>Water</td>
<td>10 days</td>
<td>3 40 mL vials with Teflon lined caps</td>
<td>4°C</td>
<td>40 mL</td>
</tr>
<tr>
<td></td>
<td>Soil</td>
<td>10 days</td>
<td>Glass jar with Teflon liner or core tube</td>
<td>4°C</td>
<td>10 g</td>
</tr>
<tr>
<td>Extractable Organics</td>
<td>Water</td>
<td>5 days extn. 40 days anal.</td>
<td>1 liter glass with Teflon liner</td>
<td>4°C</td>
<td>1000 mL</td>
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<tr>
<td></td>
<td>Soil</td>
<td>10 days extn. 40 days anal.</td>
<td>Glass jar with Teflon liner or core tube</td>
<td>4°C</td>
<td>50 g</td>
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<tr>
<td>Metals (other than Mercury)</td>
<td>Water</td>
<td>180 days</td>
<td>P,G (b)</td>
<td>HNO₃ to pH &lt; 2 4°C</td>
<td>100 mL 10 g</td>
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<tr>
<td></td>
<td>Soil</td>
<td>180 days</td>
<td>P,G</td>
<td>HNO₃ to pH &lt; 2 4°C</td>
<td>100 mL 10 g</td>
</tr>
<tr>
<td>Mercury</td>
<td>Water</td>
<td>26 days</td>
<td>P,G</td>
<td>HNO₃ to pH &lt; 2 4°C</td>
<td>100 mL 10 g</td>
</tr>
<tr>
<td></td>
<td>Soil</td>
<td>26 days</td>
<td>P,G</td>
<td>HNO₃ to pH &lt; 2 4°C</td>
<td>100 mL 10 g</td>
</tr>
<tr>
<td>Cyanide</td>
<td>Water</td>
<td>12 days</td>
<td>P,G</td>
<td>0.6 g ascorbic acid,(c) NaOH to pH &gt;12, 4°C</td>
<td>100 mL 10 g</td>
</tr>
<tr>
<td></td>
<td>Soil</td>
<td>12 days</td>
<td>P,G</td>
<td>0.6 g ascorbic acid,(c) NaOH to pH &gt;12, 4°C</td>
<td>100 mL 10 g</td>
</tr>
</tbody>
</table>

(a) Holding times calculated from verified time of sample receipt (VTSR) at laboratory  
(b) Polyethylene (P) or glass (G)  
(c) Only used in the presence of residual chlorine
## G. TCLP HOLDING TIMES

<table>
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<th>Parameter</th>
<th>Matrix</th>
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<th>From: TCLP Extraction</th>
<th>To: Analysis</th>
<th>Container</th>
<th>Preservative (1)</th>
<th>Min. Sample Size</th>
</tr>
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<tr>
<td>Volatiles</td>
<td>Waste</td>
<td>14</td>
<td>14</td>
<td>Glass</td>
<td>4 degrees C</td>
<td>4 oz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semivolatiles</td>
<td>Waste</td>
<td>14</td>
<td>(2)</td>
<td>Glass</td>
<td>4 degrees C</td>
<td>32 oz (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>Waste</td>
<td>28</td>
<td>28</td>
<td>Glass</td>
<td>4 degrees C</td>
<td>32 oz (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metals (Except Mercury)</td>
<td>Waste</td>
<td>180</td>
<td>180</td>
<td>Glass</td>
<td>4 degrees C</td>
<td>32 oz (3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Preservative of incoming sample from field, unless refrigeration results in irreversible physical change to the sample. Refrigeration required for volatiles fraction.

2. Two-tiered holding time: Must be prepared within 7 days of TCLP Extraction and must be analyzed within 40 days of analytical prep extraction.

3. Smaller sample size is adequate for solid samples or individual fractions. A combined volume of 32 oz is recommended for semivolatiles and metals. A separate 4 oz container should always be used for the volatile fraction. Volatile fractions should be stored with minimal headspace.
APPENDIX II

STANDARD OPERATING PROCEDURES (SOP) ELEMENTS
Title (includes method number)

1. Scope and Application
   1.1 Analytes
   1.2 Detection limit (instrument and method)
   1.3 Applicable matrices
   1.4 Dynamic range
   1.5 Approximate analytical time (i.e., 5 minutes, 2 days)

2. Method Summary
   2.1 Generic description of method and chemistry behind it (i.e., extract with solvent, convert to methyl ester, analyze by electron-capture gas chromatography)

3. Comments
   3.1 Interferences
   3.2 Helpful hints

4. Safety Issues

5. Sample Collection, Preservation, Containers, and Holding Times

6. Apparatus

7. Reagents and Standards

   8.1 Sample preparation
   8.2 Calibration
   8.3 Analysis

AI1-1
9. QA/QC Requirements
   9.1 QC samples
   9.2 Acceptance criteria (precision and accuracy, % of multi-component QC analytes which must be within windows)
   9.3 Corrective action required (reference current QC manual)

10. Calculations

11. Reporting
   11.1 Reporting units
   11.2 Reporting limits
   11.3 Significant figures and reporting values below detection limit
   11.4 LIMS data entry

12. References
   12.1 Method source
   12.2 Deviations from source method and rationale

13. Appendices (optional)

   Additional information may be placed in appendices. This may include supporting data (e.g. method validation information), tables, flow charts, etc.
ELEMENTS FOR SOP
LABORATORY, STANDARDS AND REAGENTS

Title

1. Reagent/Standard Name

2. Type (reagent, calibration standard, DCS, SCS, stock solution, etc.)

3. Constituents/concentration/solvent

4. Safety Issues

5. Shelf Life

6. Procedure
   6.1 Preparation
   6.2 Documentation (purchase date, open date, labeling, etc.)
   6.3 Verification

7. Responsibilities

8. Appendices (optional) Any additional information.
ELEMENTS FOR SOP
LABORATORY, EQUIPMENT OPERATION, CALIBRATION, AND MAINTENANCE

Title

1. Purpose

2. Safety Issues (applicable to the specific equipment)

3. Procedure
   3.1 Initial start-up
   3.2 Calibration and performance documentation
   3.3 Example output
   3.4 Shut-down sequence
   3.5 Maintenance and maintenance records

4. Responsibilities

5. Comments

6. Definitions

7. Appendices (optional) Any additional information.

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(QA Program Plan, Revision: 3.5)
Title

1. Purpose

2. Policies

3. Safety Issues

4. Procedure

5. Responsibilities

6. Comments

7. Definitions

8. Appendices (optional) Any additional information.
APPENDIX C
PLAINS ENVIRONMENTAL SERVICES STANDARD
OPERATING AND QUALITY ASSURANCE PROCEDURES
MOBILE LABORATORY SERVICES

STANDARD OPERATING AND QUALITY ASSURANCE PROCEDURES
FOR
SOIL VAPOR INVESTIGATIONS
SHALLOW GROUNDWATER SAMPLING AND ANALYSIS
AND SOIL SAMPLING AND ANALYSIS

PLAINS ENVIRONMENTAL SERVICES
SALINA, KANSAS
APRIL 1994
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</table>
SECTION I. INTRODUCTION

Plains Environmental Services (PES) is an independent, small business offering cost effective mobile laboratory services. The sampling equipment and mobile laboratory instrumentation permits real-time data acquisition for soil vapor surveys, shallow groundwater and soil investigations for the detection of volatile organic compounds (VOCs). All equipment and instrumentation is state-of-the-art including laboratory quality gas chromatography and computerized data integration for archiving, retrieval, and review.

PES has extensive experience in the use of headspace analysis of groundwater and soil samples combined with soil gas analytical techniques for effectively delineating contamination sources and for tracking groundwater plumes for VOC contaminants. Our experience includes investigations at several hundred sites throughout a 16 state area using these sampling and mobile laboratory techniques.

The hydraulically driven sampling equipment has successfully been used to penetrate subsurface materials to depths greater than 75 feet. Consolidated materials such as concrete can be penetrated through thicknesses up to 12 inches. The analytical system provides high quality, high resolution results with the capability of parts per billion (ppb) sensitivity for a wide range of volatile organic compounds.

All field personnel have been professionally trained in the operation of the mobile equipment and are current under OSHA 1910.120 for the 40-Hour Health and Safety Training requirements.
SECTION II. EQUIPMENT AND SAMPLING METHODS

EQUIPMENT. All sampling and analytical equipment are installed in Ford E-250 or E-350 Super-Vans for ease of mobility and efficient sample handling from sample collection to sample analysis. A floor plan of the sampling equipment and laboratory area is presented in Plate 1.

PROBE UNIT. The probe unit consists of a Geoprobe Model 8-M which includes a hydraulically driven percussion hammer used for probe penetration. Steel probe rods are three feet in length and one inch o.d. Rod ends are threaded for easy connection and tight seals to provide a continuous probe and to prevent air leakage. The rods are hydraulically driven to depths of sampling interest. The steel rods with disposable driving points can withstand forces required to penetrate subsurface materials to depths of 75 feet. In addition to soil gas sampling, Plains Environmental Services is equipped to perform groundwater and soil sampling with the probe unit.

SOIL GAS SAMPLING. Probe rods are hydraulically driven to the sampling depth with the Geoprobe system. The probe unit is equipped with a retraction device which allows removal of the rods from the soil. Soil gas samples are collected by retracting the rods 1-2 inches to remove the driving point and to create a space for soil gas removal. A 1/4 inch o.d. polyethylene tube is inserted through the probe rods and threaded into the point holder forming a continuous gas sampling line. This sampling system assures a contamination free, leak-proof sampling train. Vacuum is applied to the head of the sampling tube for soil gas extraction. The sampling train is purged with 5 - 10 volumes of air to remove extraneous air before sampling. Soil gas samples are collected by use of 1-cc syringes and transferred to the gas chromatograph for analysis.

GROUNDWATER SAMPLING. Shallow groundwater samples are collected by probing to groundwater depths with the probe rods and then removing the probe rods. One-half inch PVC pipe is screened by cutting slots in the pipe and inserted into the one inch hole. After the "well" has charged with groundwater, polyethylene (3/8" o.d.) tubing is inserted through the opening of the PVC well casing for water sampling. A peristaltic pump is connected to the top of the polyethylene tubing for sample collection. Forty milliliter vials are filled with 20 mL of sample, capped, and heated to approximately 60 C. This effectively removes volatile organic compounds from the aqueous phase to the headspace which is then sampled and injected into the gas chromatograph.

Alternately, a small bailer can be used to sample water at depths of greater than 30 feet or when the concern for volatility may preclude the use of a peristaltic pump.

SOIL SAMPLING. Soil samples can be collected at discrete levels by the use of a special sampling tube attached to the end of the probe rod. Soil samples can be added to a 40-mL vial for headspace analysis or collected and sent to an off-site laboratory for analysis.
Plan View
Geoprobe Model 8-A and Mobil Laboratory Unit
in Ford E-150 Super-Van

Plains Environmental Services
Probe Unit

Plate 1 Date: 3/1992
Scale: 1/16"=1" Drawn by: DWG
VACUUM/VOLUME SYSTEM. A vacuum/volume system consisting of a vacuum pump (capable of applying 24 inches of mercury), a storage tank, two vacuum gauges, and a line valve allows for a controlled purge and sampling rate which minimizes soil gas disturbance. The line gauge and valve provide an accurate measurement of purge volumes which reduces the disruption of soil gas equilibrium. Silicon tubing is used to connect the vacuum system to the probe head. Silicon has been shown to be inert to organics and does not readily adsorb organic compounds within a short contact time. The vacuum/volume system is depicted in Plate 2. After rod purging the rods are permitted to return to atmospheric pressure (line gauge reading of zero), an indication that the rods have been filled with soil gas. The volume of soil gas purged and the purge time are recorded on the Field Log Sheet (Figure 3). The vacuum/volume system provides information on soil permeability which is useful in determining the appropriateness of soil gas sampling.

SAMPLE COLLECTION AND TRANSFER. Soil gas samples are collected by inserting a 1-cc syringe through the silicon tubing at the rod head (see Plate 3). The syringe is immediately taken to the gas chromatograph for direct injection of the sample. Alternately, 10-cc evacuated vials are used with double ended transfer needles to collect samples when duplicates are required, when samples are needed for off-site analysis, or when the gas chromatograph can not process samples fast enough to keep up with the sampling equipment. Stored samples have been shown to be stable for several days.

DECONTAMINATION. Probe point holders and post-run tubing (PRT) adapters are decontaminated by washing with an alconox solution and rinsing with deionized water. They are air dried and randomly checked for contamination before reuse. If contamination persists, vacuum stripping or a propane torch is used to apply heat to the point holders and PRT adapters which effectively removes volatile organics for reuse. Clean or new tubing is used for each sample point and a clean or new disposable syringe is used for each sample which minimizes the potential for cross contamination.

ANALYTICAL SYSTEM. The analytical system includes a laboratory grade gas chromatograph (GC) and computerized data processing station for data acquisition, storage, and retrieval. A Shimadzu GC Model GC-14 equipped with flame ionization detector (FID), photoionization detector (PID), and an electron capture detector (ECD) provides a wide range of sensitivity for detecting petroleum hydrocarbons (especially aliphatics), aromatic compounds, and chlorinated organic solvents. The GS system uses a J&W Scientific, DB-624 megabore capillary column which effectively separates a wide range of volatile organic compounds. PID/FID and PID/ECD detectors can be connected in series for additional verification of analytes. The data station consists of a Shimadzu Data Processor Model C-R4A dual channel, dual disk processor which acquires, stores, calculates, and prints chromatogram results. Up to 10 chromatograms can be
VACUUM GAUGE, ALSO CALIBRATED WITH TANK STIP VOLUME. A 1/2" GAUGE FACE.

VACUUM PUMP. 12 V D.C.

VACUUM TANK. 11.35L

VACUUM PUMP ELECTRICAL CONTROL SWITCH.

PERMANENT TUBING.

VALVE.

MOULDING BRACKET.

BARBED FITTING.

SILICONE TUBING.

EXHAUST THROUGH BULKHEAD FITTING.

VEHICLE FLOOR.

BARBED FITTING.

SAMPLE CAP.
recalled on the CRT screen for fingerprinting which is extremely useful in determining sources of site contamination involving multiple component contaminants. Overlaying chromatograms is particularly useful in distinguishing between gasoline, diesel, and fuel oil fuels. All data are stored on 3.5 inch disks and hard copied from the printer.

A detector configuration of the PID/ECD will provide results in the parts per billion by volume range. The FID configuration provides results in the parts per million by volume range. Copies of chromatograms for some of the compounds of interest are presented in Figures 1 and 2.

ANALYTICAL SYSTEM (GC/MSD). The analytical system includes a laboratory grade gas chromatograph (GC) and computerized data processing station for data acquisition, storage, and retrieval. An HP5890A GC equipped with an HP5971A MSD (mass selective detector) provides ppmv sensitivity for identifying a wide range of volatile organic compounds (VOCs). A J&W Scientific DB-624 megabore capillary column (0.53mm x 30m) is used to effectively separate a wide range of VOCs. All data is captured, processed, and stored with the HP5971A MSD/DOS ChemStation System. The Wiley database of 130,000 MS spectra can be used to identify unknown compounds. The instrument is tuned daily using the auto tune function with PFTBA (perfluorotributylamine). Instrument resolution is approximately 1 amu.

Semi-volatile compounds, i.e., PNAs, diesel fuel, engine oil, creosotes, PCBs, asphalt, and pesticides can be analyzed on-site using thin layer chromatography (TLC). TLC methods have been used effectively to determine "hot spots" and to track plumes in soil and groundwater. Detection limits of ppm levels restrict the use of this technique for determining gross contamination. Colorimetric field analytical techniques developed by 3-M have been used effectively to track groundwater plumes for herbicides at ppb levels.

Ion selective electrodes are used to determine inorganic contaminants (e.g. nitrates, chlorides) in groundwater samples.
Figure 1. PID

<table>
<thead>
<tr>
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<td>30</td>
<td>1.167</td>
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<tr>
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<td>1022</td>
<td>2</td>
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<tr>
<td></td>
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<td></td>
</tr>
<tr>
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<td></td>
<td>4.799</td>
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Figure 2. ECD

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<td>12</td>
<td>0.001</td>
<td>CCL1</td>
</tr>
<tr>
<td>2</td>
<td>0.541</td>
<td>1298</td>
<td>64</td>
<td>0.001</td>
<td>CCL1</td>
</tr>
<tr>
<td>1</td>
<td>2.001</td>
<td>1633</td>
<td>16</td>
<td>0.001</td>
<td>CCL1</td>
</tr>
<tr>
<td>4</td>
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<td>10895</td>
<td>56</td>
<td>0.001</td>
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<tr>
<td>5</td>
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<td>1984695</td>
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<td>total</td>
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<td>114381</td>
<td></td>
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</table>

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SECTION III. QUALITY ASSURANCE/QUALITY CONTROL

QA/QC. Quality assurance procedures included in this proposal are intended to assure the quality and integrity of sample collection and sample analysis. Strict adherence to QC procedures and qualified field personnel who understand potential sources of sample contamination and analytical systems are crucial to successful on-site, turn-key operations. Laboratory quality data can be generated in the field providing that experienced personnel and state-of-the-art analytical equipment are available. PES conducts all field analysis under the direction of an experienced senior chemist using state-of-the-art equipment and technology. All sampling equipment and analytical equipment represents vendor top-of-the-line instrumentation. Operators have been factory trained in the operation of the equipment.

FIELD LOG SHEET. A field log will be maintained to assist in sample tracking and identification. An example of the Field Log Sheet is included in Figure 3.

SAMPLE INTEGRITY. Sample integrity is maintained by the prevention of equipment contamination and by using disposable supplies when practical. All reused sampling equipment is decontaminated before sampling. Materials such as tubing and sample transfer or storage containers are disposable and not reused. Under normal operating conditions, samples are injected into the gas chromatograph within 30 seconds of sample collection which minimizes sample loss and potential for degradation or contamination. New syringes and new tubing are used at the rod head where samples are withdrawn. Plate 3 illustrates the sample collection technique.

FIELD BLANKS. The sample system is checked by analyzing field blanks on the complete system at the beginning and end of the day and after every 20 samples. Rods, tubing, syringes and vials are assured of being contaminant free by performing the field blanks. A syringe blank is analyzed daily to provide background information of ambient air conditions for possible sample contamination and also for health and safety purposes. When ambient air contamination exists, the Project Manager and Safety Officer are notified. If worker safety or data quality is endangered by continuing, work is suspended and appropriate corrective action taken to remedy the problem.

INSTRUMENT CALIBRATION. The GC is calibrated with standards for each analyte of interest. Commercially available gas standards such as carbon tetrachloride for the electron capture detector (ECD) or benzene, toluene, and xylene for the flame ionization (FID) and photoionization detectors (PID) are also analyzed daily; at the beginning of each run, after every 10 field samples, and at the end of each day. PES prepares and analyzes gas standards for each compound of interest within several days of project startup. Commercially available standards are used to monitor retention time and response factor variability.
Figure 3. Field Log Sheet

<table>
<thead>
<tr>
<th>Site ID:</th>
<th>Sampler:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>Analyst:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Time</th>
<th>Depth (ft)</th>
<th>PES No.</th>
<th>Purge Vol. (L)</th>
<th>Comments</th>
</tr>
</thead>
</table>

- 12 -
Due to the expense and difficulty of purchasing gas standards, it is not always possible to use commercially prepared gas standards for the analytes being investigated. The use of a commercially available standard for monitoring detector sensitivity and response factor stability has shown to be satisfactory in monitoring the GC's performance.

In case gross contamination is detected and samples cannot be diluted sufficiently for field analysis, a greater than result is reported.

DUPLICATES. One sample duplicate will be analyzed for every 20 field samples analyzed. Duplicate peak areas greater than 500 counts should have a relative percent difference (RPD) of not greater than 25% where:

\[
\text{RPD} = \left( \frac{X_1 - X_2}{(X_1 + X_2)/2} \right) \times 100\%
\]

\( X_1 = \text{sample result} \)
\( X_2 = \text{duplicate sample result} \)

CONTINGENCIES. The analytical equipment is protected from the sampling equipment area by an insulated enclosure between the laboratory mid-section of the van and the back Geoprobe area. Contingencies in the case of analytical equipment failure include the use of evacuated vials which have been shown to retain vapor samples for several days without significant sample deterioration.

---

1 This is an expected range. The actual range is determined from data generated from each project site.
SECTION IV. PERSONNEL QUALIFICATIONS/EXPERIENCE

PES is committed to providing high quality, technical expertise in soil gas applications. The commitment to responsive, accurate, and efficient surveys is exemplified by the professional staff assigned to all projects. The mobile laboratory is always staffed by at least one experienced chemist with experience in soil gas sampling and in operating the gas chromatograph system. All PES field personnel participate in an annual medical monitoring program and are current in the 40-Hour Basic Health and Safety Training as required under OSHA 1910.120. Resumes of key professional staff are included in the Appendix.

PES offers the following references for projects involving soil gas investigations.


10. Mr. Michael G. Felix, Nebraska Department of Environmental Control, 301 Centennial Mall South, Lincoln, Nebraska 68509. Project: Soil gas sampling in several cities in Nebraska. Scope of Work: Determination of potential sources for contamination of municipal water systems. (402) 471-4217.


12. Mr. Tracy Cooley, Burns & McDonnell, 4800 E. 63rd Street, Kansas City, MO 64141. Projects: Soil gas investigations at the various service stations in the Kansas City area. (816) 333-4375.
APPENDIX

RESUMES

A - 1
RESUME

Lynn R. Newcomer
President

EDUCATION
- Goshen College - B.A. in Biology - 1968
- University of Iowa - M.S. in Chemistry - 1979
- Dallas, Texas - Characterizing and Identifying Hazardous Wastes - 1985
- Cincinnati, Ohio - Environmental Protection Agency Symposium on Municipal Sludges and Dredging - 1986, 1987
- OSHA 40-Hour Training CFR Part 1910.120

PROFESSIONAL AFFILIATIONS
- American Chemical Society
- Kansas Oil Marketers Association
- Petroleum Marketers Association of America

TECHNICAL PAPERS
- Author of "The Determination of Volatile Organic Compounds by Gas Chromatography Using an Automated Heated Headspace Technique. Submitted to the U.S. EPA Region IV, Atlanta, Georgia, December 1988
- Author of "Soil Gas Exploration" presented at the 41st Annual Geotechnical Engineering Conference sponsored by The University of Kansas, Lawrence, Kansas, February 1992 and at the Dallas Geological Society in Dallas, Texas, May 1992
EXPERIENCE

Mr. Newcomer started Plains Environmental Services in May 1988 after spending seven years as Technical Director at Wilson Laboratories, Salina, Kansas. His experience also includes 13 years as a high school and college chemistry instructor. He was presented the Outstanding Young Educator Award in 1974, and was awarded a National Science Foundation grant in 1978.

As Technical Director, Mr. Newcomer provided expertise in all areas of analytical chemistry including method development and validation, technical writing, sampling and analysis plans, data review, and quality control procedures. His regulatory expertise includes RCRA, CERCLA, SARA, and SDWA requirements. Mr. Newcomer has served as an expert witness for litigations involving claims of negligence and interpretation of laboratory results.

Most recently, Mr. Newcomer has been involved in developing, training, and operating mobile laboratory equipment for the sampling and analysis of volatile organic compounds by gas chromatography. He has trained several engineering firms in the operation of mobile laboratory equipment similar to the equipment owned and operated by Plains Environmental Services. Both soil gas and automated heated headspace methods using multiple detectors have been used to delineate contamination boundaries of subsurface materials. His work has been directly related to meeting USEPA consent order and state regulatory requirements. During the past four years he has been actively involved in providing mobile laboratory services at several hundred sites within a 24 state area. His work has included several large Superfund sites in Nebraska, Texas, Massachusetts, and Idaho. He was part of a project team which designed an innovative technique for deep soil gas sampling (depths of greater than 100 feet below ground surface) at a Superfund site in the Fall of 1991.
RESUME
Sandee J. Stainbrook
Chemist

EDUCATION
- Kansas Wesleyan University - B.S. in Chemistry - 1988
- OSHA 40-Hour Training CFR Part 1910.120

EXPERIENCE
Ms. Stainbrook taught high school general science and chemistry for two years with the Peace Corps. She has also worked one year as a chemist for a major food processing company and one year as a chemist for the USDA.

Ms. Stainbrook has been trained in the operation of our field analytical equipment and has several years experience in operating gas chromatograph instruments. She has been involved in numerous soil gas and groundwater investigations at Superfund sites. Project sites include Hastings and Mead, Nebraska; Mountain Home AFB; Dyess AFB; and Offutt AFB.

Her experience has included working at several hundred sites in more than 20 states. She has been instrumental in providing recommendations for source identification and in delineating groundwater contamination plumes during field operations.

Her experience also includes data evaluation and review. She is also a key person in preparing analytical reports for PES's mobile laboratory operations.

RESUME
Jesse V. Kalvig
Technician

EDUCATION
- Kansas State University-Salina- Associate of Technology Degree in Industrial Engineering - 1992
- OSHA 40-Hour Training CFR Part 1910.120

EXPERIENCE
Mr. Kalvig has had extensive experience in field services including soil vapor, soil, and groundwater sampling. He has more than one year's experience with the field sampling equipment used by PES. He has worked at many Superfund and industrial sites within a 18 state area.
RESUME

Darren L. Jantzi
Chemist

EDUCATION
- Goshen College - B.A. in Chemistry - 1993
- OSHA 40-Hour Training CFR Part 1910.120

EXPERIENCE
Mr. Jantzi has had experience in operating the field equipment, gas chromatographs, and gas chromatograph mass spectrometers used by PES. He has worked at many sites within a 12 state area including Superfund sites at Hastings, Nebraska; Holloman AFB; Mountain Home AFB; White Sands Missile Range; Massachusetts Military Reservation; and Homestead AFB.

He has been involved with numerous soil vapor and groundwater investigations. These investigations have been used to identify source areas and to delineate contamination plumes.

His experience also includes the evaluation and review of both gas chromatography and mass spectral data.

RESUME

Douglas E. Mick
Geologist

EDUCATION
- Fort Hays State University - B.S. in Geology - 1992
- OSHA 40-Hour Training CFR Part 1910.120

EXPERIENCE
Mr. Mick has had experience in operating the field equipment used by PES. He has been involved in various field investigations in the Midwest identifying source areas of subsurface contamination. He has had experience in writing work plans and reports for the Kansas Department of Health and Environment (KDHE), in performing site investigations for the KDHE, in mapping contamination plumes and groundwater elevations, and in sampling monitor wells.

He has been involved with Superfund projects at Mead, Nebraska; Mountain Home AFB; Massachusetts Military Reservation; and Homestead AFB. He has also been involved with a highly sensitive project in Hastings, Nebraska for the U.S. EPA Region VII.
RESUME
Cristina L. Renne
Chemist

EDUCATION
- Certified Environmental Management - Internship - 1993
- Kansas Wesleyan University - B.S. in Chemistry - 1993
- OSHA 40-Hour Training CFR Part 1910.120

EXPERIENCE
Ms. Renne worked as a laboratory assistant for an industrial hygiene firm during the school year of 1993. Her responsibilities included sample preparation and analysis by gas chromatography.

Ms. Renne has been trained and has experience in the operation of our field equipment and analytical instruments. She has been involved in several sites within a 10 state area including Superfund sites at Hastings and Mead, Nebraska; Dyess AFB; and Offutt AFB.

She has been involved with numerous soil vapor, groundwater and soil investigations. These investigations have been used to identify source areas and to delineate contamination plumes.

Ms. Renne's experience also includes the evaluation and review of data as well as preparing analytical reports.
APPENDIX D
ASTM SOIL PHYSICAL TESTINGS
STANDARD TEST METHODS
APPENDIX D

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APPENDIX D-2 STANDARD TEST METHOD FOR PARTICLE-SIZE ANALYSIS OF SOIL, ASTM D422-63

APPENDIX D-3 STANDARD TEST METHOD FOR LABORATORY DETERMINATION OF WATER (MOISTURE) CONTENT OF SOIL AND ROCK, ASTM D2216-92

APPENDIX D-4 STANDARD TEST METHOD FOR LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX OF SOILS, ASTM D4318-84
APPENDIX D-1

STANDARD PRACTICE FOR DRY PREPARATION OF SOIL SAMPLES FOR PARTICLE-SIZE ANALYSIS AND DETERMINATION OF SOIL CONSTANT, ASTM D421-85
Standard Practice for
Dry Preparation of Soil Samples for Particle-Size Analysis and
Determination of Soil Constants

This standard is issued under the fixed designation D 421; 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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the dry preparation of soil samples as received from the field for particle-size analysis and the determination of the soil constants.

1.2 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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.

2. Referenced Documents

2.1 ASTM Standards:
D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
E 11 Specification for Wire-Cloth Sieves for Testing Purposes

3. Significance and Use

3.1 This practice can be used to prepare samples for particle-size and plasticity tests where it is desired to determine test values on air-dried samples, or where it is known that air drying does not have an effect on test results relative to samples prepared in accordance with Practice D 2217.

4. Apparatus

4.1 Balance, sensitive to 0.1 g.
4.2 Mortar and Rubber-Covered Pestle, suitable for breaking up the aggregations of soil particles.
4.3 Sieves—A series of sieves, of square mesh woven wire cloth, conforming to Specification E 11. The sieves required are as follows:
- No. 4 (4.75-mm)
- No. 10 (2.00-mm)
- No. 40 (425-μm)

4.4 Sampler—A riffle sampler or sample splitter, for quartering the samples.

5. Sampling

5.1 Expose the soil sample as received from the field to the air at room temperature until dried thoroughly. Break up the aggregations thoroughly in the mortar with a rubber-covered pestle. Select a representative sample of the amount required to perform the desired tests by the method of quartering or by the use of a sampler. The amounts of material required to perform the individual tests are as follows:

5.1.1 Particle-Size Analysis—For the particle-size analysis, material passing a No. 10 (2.00-mm) sieve is required in amounts equal to 115 g of sandy soils and 65 g of either silt or clay soils.

5.1.2 Tests for Soil Constants—For the tests for soil constants, material passing the No. 40 (425-μm) sieve is required in total amount of 220 g, allocated as follows:

<table>
<thead>
<tr>
<th>Test</th>
<th>Grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid limit</td>
<td>100</td>
</tr>
<tr>
<td>Plastic limit</td>
<td>15</td>
</tr>
<tr>
<td>Centrifuge moisture equivalent</td>
<td>10</td>
</tr>
<tr>
<td>Volumetric shrinkage</td>
<td>30</td>
</tr>
<tr>
<td>Check tests</td>
<td>65</td>
</tr>
</tbody>
</table>

6. Preparation of Test Sample

6.1 Select that portion of the air-dried sample selected for purpose of tests and record the mass as the mass of the total test sample uncorrected for hygroscopic moisture. Separate the test sample by sieving with a No. 10 (2.00-mm) sieve. Grind that fraction retained on the No. 10 sieve in a mortar with a rubber-covered pestle until the aggregations of soil particles are broken up into the separate grains. Then separate the ground soil into two fractions by sieving with a No. 10 sieve.

6.2 Wash that fraction retained after the second sieving free of all fine material, dry, and weigh. Record this mass as the mass of coarse material. Sieve the coarse material, after being washed and dried, on the No. 4 (4.75-mm) sieve and record the mass retained on the No. 4 sieve.

7. Test Sample for Particle-Size Analysis

7.1 Thoroughly mix together the fractions passing the No. 10 (2.00-mm) sieve in both sieving operations, and by the method of quartering or the use of a sampler, select a portion weighing approximately 115 g for sandy soils and approximately 65 g for silt and clay soil for particle-size analysis.

8. Test Sample for Soil Constants

8.1 Separate the remaining portion of the material passing the No. 10 (2.00-mm) sieve into two parts by means of a No. 40 (425-μm) sieve. Discard the fraction retained on the No. 40 sieve. Use the fraction passing the No. 40 sieve for the determination of the soil constants.
The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.
Standard Test Method for Particle-Size Analysis of Soils

This standard is issued under the fixed designation D 422; 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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 μm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 μm is determined by a sedimentation process, using a hydrometer to secure the necessary data (Notes 1 and 2).

NOTE 1—Separation may be made on the No. 4 (4.75-mm), No. 10 (2.00-mm), or No. 200 (75-μm) sieve instead of the No. 10. For whatever sieve used, the size shall be indicated in the report.

NOTE 2—Two types of dispersion devices are provided: (1) a high-speed mechanical stirrer, and (2) air dispersion. Extensive investigations indicate that air-dispersion devices produce a more positive dispersion of plastic soils below the 20-μm size and appreciably less degradation on all sizes when used with sandy soils. Because of the definite advantages favoring air dispersion, its use is recommended. The results from the two types of devices differ in magnitude, depending upon soil type, leading to marked differences in particle size distribution for sizes finer than 20 μm.

2. Referenced Documents

2.1 ASTM Standards:
D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
E 11 Specification for Wire-Cloth Sieves for Testing Purposes
E 100 Specification for ASTM Hydrometers

3. Apparatus

3.1 Balances—A balance sensitive to 0.01 g for weighing the material passing a No. 10 (2.00-mm) sieve, and a balance sensitive to 0.1 % of the mass of the sample to be weighed for weighing the material retained on a No. 10 sieve.

3.2 Stirring Apparatus—Either apparatus A or B may be used.

3.2.1 Apparatus A shall consist of a mechanically operated stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 10,000 rpm without load. The shaft shall be equipped with a replaceable stirring paddle made of metal, plastic, or hard rubber, as shown in Fig. 1. The shaft shall be of such length that the stirring paddle will operate not less than ½ in. (19.0 mm) nor more than 1½ in. (38.1 mm) above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 2 shall be provided to hold the sample while it is being dispersed.

3.2.2 Apparatus B shall consist of an air-jet dispersion cup (Note 3) conforming to the general details shown in Fig. 3 (Notes 4 and 5).

NOTE 3—The amount of air required by an air-jet dispersion cup is of the order of 2 ft³/min; some small air compressors are not capable of supplying sufficient air to operate a cup.

NOTE 4—Another air-type dispersion device, known as a dispersion tube, developed by Chu and Davidson at Iowa State College, has been shown to give results equivalent to those secured by the air-jet dispersion cups. When it is used, soaking of the sample can be done in the sedimentation cylinder, thus eliminating the need for transferring the slurry. When the air-dispersion tube is used, it shall be so indicated in the report.

NOTE 5—Water may condense in air lines when not in use. This water must be removed, either by using a water trap on the air line, or by blowing the water out of the line before using any of the air for dispersion purposes.

3.3 Hydrometer—An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per litre of suspension, and conforming to the requirements for hydrometers 151H or 152H in Specifications E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

3.4 Sedimentation Cylinder—A glass cylinder essentially 18 in. (457 mm) in height and 2½ in. (63.5 mm) in diameter, and marked for a volume of 1000 mL. The inside diameter shall be such that the 1000-mL mark is 36 ± 2 cm from the bottom on the inside.

3.5 Thermometer—A thermometer accurate to 1°F (0.5°C).

3.6 Sieves—A series of sieves, of square-mesh woven-wire cloth, conforming to the requirements of Specification E 11. A full set of sieves includes the following (Note 6):

---

1 This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.63 on Texture, Plasticity, and Density Characteristics of Soils.

2 Annual Book of ASTM Standards, Vol 04.08.
4 Annual Book of ASTM Standards, Vol 14.03.

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5 Detailed working drawings for this cup are available at nominal cost from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103. Order Adjunct No. 12-404220-00.
Metric Equivalents

<table>
<thead>
<tr>
<th>in.</th>
<th>0.001</th>
<th>0.049</th>
<th>0.203</th>
<th>(\frac{1}{2})</th>
<th>(\frac{3}{4})</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>0.03</td>
<td>1.24</td>
<td>5.16</td>
<td>12.7</td>
<td>19.0</td>
</tr>
</tbody>
</table>

**FIG. 1** Detail of Stirring Paddles

3.7 Water Bath or Constant-Temperature Room—A water bath or constant-temperature room for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature at or near 68°F (20°C). Such a device is illustrated in Fig. 4. In cases where the work is performed in a room at an automatically controlled constant temperature, the water bath is not necessary.

3.8 Beaker—A beaker of 250-mL capacity.

3.9 Timing Device—A watch or clock with a second hand.

4. Dispersing Agent

4.1 A solution of sodium hexametaphosphate (sometimes called sodium metaphosphate) shall be used in distilled or demineralized water, at the rate of 40 g of sodium hexametaphosphate/litre of solution (Note 7).

**Note 7**—Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersive action. Solutions should be prepared frequently (at least once a month) or adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions should have the date of preparation marked on them.

4.2 All water used shall be either distilled or demineralized water. The water for a hydrometer test shall be brought to the temperature that is expected to prevail during the hydrometer test. For example, if the sedimentation cylinder is to be placed in the water bath, the distilled or demineralized water to be used shall be brought to the temperature of the controlled water bath; or, if the sedimentation cylinder is used in a room with controlled temperature, the water for the test shall be at the temperature of the room. The basic temperature for the hydrometer test is 68°F (20°C). Small variations of temperature do not introduce differences that are of practical significance and do not prevent the use of corrections derived as prescribed.
5. Test Sample

5.1 Prepare the test sample for mechanical analysis as outlined in Practice D 421. During the preparation procedure the sample is divided into two portions. One portion contains only particles retained on the No. 10 (2.00-mm) sieve while the other portion contains only particles passing the No. 10 sieve. The mass of air-dried soil selected for purpose of tests, as prescribed in Practice D 421, shall be sufficient to yield quantities for mechanical analysis as follows:

5.1.1 The size of the portion retained on the No. 10 sieve shall depend on the maximum size of particle, according to the following schedule:

<table>
<thead>
<tr>
<th>Nominal Diameter of Largest Particles, in. (mm)</th>
<th>Approximate Minimum Mass of Portion, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>⅜ (9.5)</td>
<td>500</td>
</tr>
<tr>
<td>⅜ (19.0)</td>
<td>1000</td>
</tr>
<tr>
<td>1 (25.4)</td>
<td>2000</td>
</tr>
<tr>
<td>1⅜ (38.1)</td>
<td>3000</td>
</tr>
<tr>
<td>2 (50.8)</td>
<td>4000</td>
</tr>
<tr>
<td>3 (76.2)</td>
<td>5000</td>
</tr>
</tbody>
</table>

5.1.2 The size of the portion passing the No. 10 sieve shall be approximately 115 g for sandy soils and approximately 65 g for silt and clay soils.

5.2 Provision is made in Section 5 of Practice D 421 for weighing of the air-dry soil selected for purpose of tests, the separation of the soil on the No. 10 sieve by dry-sieving and washing, and the weighing of the washed and dried fraction retained on the No. 10 sieve. From these two masses the percentages retained and passing the No. 10 sieve can be calculated in accordance with 12.1.

NOTE 8—A check on the mass values and the thoroughness of pulverization of the clods may be secured by weighing the portion passing the No. 10 sieve and adding this value to the mass of the washed and oven-dried portion retained on the No. 10 sieve.

SIEVE ANALYSIS OF PORTION RETAINED ON NO. 10 (2.00-mm) SIEVE

6. Procedure

6.1 Separate the portion retained on the No. 10 (2.00-mm) sieve into a series of fractions using the 3-in. (75-mm), 2-in. (50-mm), 1⅜-in. (37.5-mm), 1-in. (25.0-mm), ⅜-in. (19.0-mm), ⅜-in. (9.5-mm), No. 4 (4.75-mm), and No. 10 sieves, or as many as may be needed depending on the sample, or upon the specifications for the material under test.

6.2 Conduct the sieving operation by means of a lateral and vertical motion of the sieve, accompanied by a jarring action in order to keep the sample moving continuously over the surface of the sieve. In no case turn or manipulate fragments in the sample through the sieve by hand. Continue sieving until not more than 1 mass % of the residue on a sieve passes that sieve during 1 min of sieving. When mechanical sieving is used, test the thoroughness of sieving by using the hand method of sieving as described above.

6.3 Determine the mass of each fraction on a balance conforming to the requirements of 3.1. At the end of weighing, the sum of the masses retained on all the sieves used should equal closely the original mass of the quantity sieved.
HYDROMETER AND SIEVE ANALYSIS OF PORTION PASSING THE NO. 10 (2.00-mm) SIEVE

7. Determination of Composite Correction for Hydrometer Reading

7.1 Equations for percentages of soil remaining in suspension, as given in 14.3, are based on the use of distilled or demineralized water. A dispersing agent is used in the water, however, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

7.1.1 Both soil hydrometers are calibrated at 68°F (20°C), and variations in temperature from this standard temperature produce inaccuracies in the actual hydrometer readings. The amount of the inaccuracy increases as the variation from the standard temperature increases.

7.1.2 Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

7.1.3 The net amount of the corrections for the three items enumerated is designated as the composite correction, and may be determined experimentally.

7.2 For convenience, a graph or table of composite corrections for a series of 1°F temperature differences for the range of expected test temperatures may be prepared and used as needed. Measurement of the composite corrections may be made at two temperatures spanning the range of expected test temperatures, and corrections for the intermediate temperatures calculated assuming a straight-line relationship between the two observed values.

7.3 Prepare 1000 mL of liquid composed of distilled or demineralized water and dispersing agent in the same proportion as will prevail in the sedimentation (hydrometer) test. Place the liquid in a sedimentation cylinder and the cylinder in the constant-temperature water bath, set for one of the two temperatures to be used. When the temperature of the liquid becomes constant, insert the hydrometer, and, after a short interval to permit the hydrometer to come to the temperature of the liquid, read the hydrometer at the top of the meniscus formed on the stem. For hydrometer 151H the composite correction is the difference between this reading and one; for hydrometer 152H it is the difference between the reading and zero. Bring the liquid and the hydrometer to the other temperature to be used, and secure the composite correction as before.

8. Hygroscopic Moisture

8.1 When the sample is weighed for the hydrometer test, weigh out an auxiliary portion of from 10 to 15 g in a small metal or glass container, dry the sample to a constant mass in an oven at 230 ± 9°F (110 ± 5°C), and weigh again. Record the masses.

9. Dispersion of Soil Sample

9.1 When the soil is mostly of the clay and silt sizes, weigh out a sample of air-dry soil of approximately 50 g. When the soil is mostly sand the sample should be approximately 100 g.

9.2 Place the sample in the 250-mL beaker and cover with 125 mL of sodium hexametaphosphate solution (40 g/L). Stir until the soil is thoroughly wetted. Allow to soak for at least 16 h.

9.3 At the end of the soaking period, disperse the sample further, using either stirring apparatus A or B. If stirring apparatus A is used, transfer the soil - water slurry from the beaker into the special dispersion cup shown in Fig. 2, washing any residue from the beaker into the cup with distilled or demineralized water (Note 9). Add distilled or demineralized water, if necessary, so that the cup is more than half full. Stir for a period of 1 min.

Note 9—A large size syringe is a convenient device for handling the water in the washing operation. Other devices include the wash-water bottle and a hose with nozzle connected to a pressurized distilled water tank.

9.4 If stirring apparatus B (Fig. 3) is used, remove the cover cap and connect the cup to a compressed air supply by means of a rubber hose. A air gage must be on the line between the cup and the control valve. Open the control valve so that the gage indicates 1 psi (7 kPa) pressure (Note 10). Transfer the soil - water slurry from the beaker to the air-jet dispersion cup by washing with distilled or demineralized water. Add distilled or demineralized water, if necessary, so that the total volume in the cup is 250 mL, but no more.

Note 10—The initial air pressure of 1 psi is required to prevent the soil - water mixture from entering the air-jet chamber when the mixture is transferred to the dispersion cup.

9.5 Place the cover cap on the cup and open the air control valve until the gage pressure is 20 psi (140 kPa). Disperse the soil according to the following schedule:

<table>
<thead>
<tr>
<th>Plasticity Index</th>
<th>Dispersion Period, min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 5</td>
<td>5</td>
</tr>
<tr>
<td>5 to 20</td>
<td>10</td>
</tr>
<tr>
<td>Over 20</td>
<td>15</td>
</tr>
</tbody>
</table>

Soils containing large percentages of mica need be dispersed for only 1 min. After the dispersion period, reduce the gage pressure to 1 psi preparatory to transfer of soil - water slurry to the sedimentation cylinder.

10. Hydrometer Test

10.1 Immediately after dispersion, transfer the soil - water slurry to the glass sedimentation cylinder, and add distilled or demineralized water until the total volume is 1000 mL.

10.2 Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min to complete the agitation of the slurry (Note 11). At the end of 1 min set the cylinder in a convenient location and take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

Note 11—The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns.
Any soil remaining in the bottom of the cylinder during the first few
turns should be loosened by vigorous shaking of the cylinder while it is
in the inverted position.

10.3 When it is desired to take a hydrometer reading, carefully insert the hydrometer about 20 to 25 s before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning motion in a graduate of clean distilled or demineralized water.

NOTE 12—It is important to remove the hydrometer immediately after each reading. Readings shall be taken at the top of the meniscus formed by the suspension around the stem, since it is not possible to secure readings at the bottom of the meniscus.

10.4 After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

11. Sieve Analysis

11.1 After taking the final hydrometer reading, transfer the suspension to a No. 200 (75-μm) sieve and wash with tap water until the wash water is clear. Transfer the material on the No. 200 sieve to a suitable container, dry in an oven at 230 ± 9°F (110 ± 5°C) and make a sieve analysis of the portion retained, using as many sieves as desired, or required for the material, or upon the specification of the material under test.

CALCULATIONS AND REPORT

12. Sieve Analysis Values for the Portion Coarser than the No. 10 (2.00-mm) Sieve

12.1 Calculate the percentage passing the No. 10 sieve by dividing the mass passing the No. 10 sieve by the mass of soil originally split on the No. 10 sieve, and multiplying the result by 100. To obtain the mass passing the No. 10 sieve, subtract the mass retained on the No. 10 sieve from the original mass.

12.2 To secure the total mass of soil passing the No. 4 (4.75-mm) sieve, add to the mass of the material passing the No. 10 sieve the mass of the fraction passing the No. 4 sieve and retained on the No. 10 sieve. To secure the total mass of soil passing the 3/4-in. (9.5-mm) sieve, add to the total mass of soil passing the No. 4 sieve, the mass of the fraction passing the 3/4-in. sieve and retained on the No. 4 sieve. For the remaining sieves, continue the calculations in the same manner.

12.3 To determine the total percentage passing for each sieve, divide the total mass passing (see 12.2) by the total mass of sample and multiply the result by 100.

13. Hygroscopic Moisture Correction Factor

13.1 The hygroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

14. Percentages of Soil in Suspension

14.1 Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

14.2 Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the No. 10 (2.00-mm) sieve, and multiplying the result by 100. This value is the weight \( W \) in the equation for percentage remaining in suspension.

14.3 The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows (Note 13): For hydrometer 151H:

\[
P = \left( \frac{100000}{W} \right) \times \frac{C}{(G - G_1)} \times \frac{1}{R - G_1}
\]

(Note 13.—The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

\[
P = \left( \frac{R a}{W} \right) \times 100
\]

where:

- \( a \) = correction factor to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1).
- \( P \) = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension.
- \( R \) = hydrometer reading with composite correction applied (Section 7),
- \( W \) = oven-dry mass of soil in a total test sample represented by mass of soil dispersed (see 14.2), g,
- \( G \) = specific gravity of the soil particles, and
- \( G_1 \) = specific gravity of the liquid in which soil particles are suspended. Use numerical value of one in both instances in the equation. In the first instance any possible variation produces no significant effect, and in the second instance, the composite correction for \( R \) is based on a value of one for \( G_1 \).)

15. Diameter of Soil Particles

15.1 The diameter of a particle corresponding to the percentage indicated by a given hydrometer reading shall be calculated according to Stokes' law (Note 14), on the basis that a particle of this diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer is measuring the density of the suspension. According to Stokes' law:

\[
D = \sqrt{\frac{30n/980(G - G_1)}{L/T}}
\]

where:

- \( D \) = diameter of particle, mm.
\[ n = \text{coefficient of viscosity of the suspending medium (in this case water) in poises (varies with changes in temperature of the suspending medium),} \]

\[ L = \text{distance from the surface of the suspension to the level at which the density of the suspension is being measured, cm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth (Table 2))}, \]

\[ T = \text{interval of time from beginning of sedimentation to the taking of the reading, min,} \]

\[ G = \text{specific gravity of soil particles, and} \]

\[ G_r = \text{specific gravity (relative density) of suspending medium (value may be used as 1.000 for all practical purposes).} \]

Note 14—Since Stokes’ law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

15.2 For convenience in calculations the above equation may be written as follows:

\[ D = K\sqrt{L/T} \]

where:

\[ K = \text{constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of} \]

\[ K \text{ for a range of temperatures and specific gravities are given in Table 3. The value of} \]

\[ K \text{ does not change for a series of readings constituting a test, while values of} \]

\[ L \text{ and} \]

\[ T \text{ do vary.} \]

15.3 Values of \( D \) may be computed with sufficient accuracy, using an ordinary 10-in. slide rule.

Note 15—The value of \( L \) is divided by \( T \) using the \( A \)- and \( B \)-scales, the square root being indicated on the \( D \)-scale. Without ascertaining the value of the square root it may be multiplied by \( K \), using either the \( C \)-or \( C' \)-scale.

16. Sieve Analysis Values for Portion Finer than No. 10 (2.00-mm) Sieve

16.1 Calculation of percentages passing the various sieves, used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the No. 10 sieve had it not been removed. This mass is equal to the total percentage retained on the No. 10 sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in 14.2), and the result divided by 100.

16.2 Calculate next the total mass passing the No. 200 sieve. Add together the fractional masses retained on all the sieves, including the No. 10 sieve, and subtract this sum from the mass of the total sample (as calculated in 14.2), and multiply the result by 100.
arithmetic scale as the ordinate. When the hydrometer analysis is not made on a portion of the soil, the preparation of the graph is optional, since values may be secured directly from tabulated data.

18. Report

18.1 The report shall include the following:

18.1.1 Maximum size of particles,

18.1.2 Percentage passing (or retained on) each sieve, which may be tabulated or presented by plotting on a graph (Note 16),

18.1.3 Description of sand and gravel particles:

18.1.3.1 Shape—rounded or angular,

18.1.3.2 Hardness—hard and durable, soft, or weathered and friable,

18.1.4 Specific gravity, if unusually high or low,

18.1.5 Any difficulty in dispersing the fraction passing the No. 10 (2.00-mm) sieve, indicating any change in type and amount of dispersing agent, and

18.1.6 The dispersion device used and the length of the dispersion period.

Note 16—This tabulation of graph represents the gradation of the sample tested. If particles larger than those contained in the sample were removed before testing, the report shall so state giving the amount and maximum size.

18.2 For materials tested for compliance with definite specifications, the fractions called for in such specifications shall be reported. The fractions smaller than the No. 10 sieve shall be read from the graph.

18.3 For materials for which compliance with definite specifications is not indicated and when the soil is composed almost entirely of particles passing the No. 4 (4.75-mm) sieve, the results read from the graph may be reported as follows:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percentage Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-in.</td>
<td></td>
</tr>
<tr>
<td>2-in.</td>
<td></td>
</tr>
<tr>
<td>1½-in.</td>
<td></td>
</tr>
<tr>
<td>1-in.</td>
<td></td>
</tr>
<tr>
<td>½-in.</td>
<td></td>
</tr>
<tr>
<td>No. 4 (4.75-mm)</td>
<td></td>
</tr>
<tr>
<td>No. 10 (2.00-mm)</td>
<td></td>
</tr>
<tr>
<td>No. 40 (425-μm)</td>
<td></td>
</tr>
<tr>
<td>No. 200 (75-μm)</td>
<td></td>
</tr>
<tr>
<td>0.074 mm</td>
<td></td>
</tr>
<tr>
<td>0.005 mm</td>
<td></td>
</tr>
<tr>
<td>0.001 mm</td>
<td></td>
</tr>
</tbody>
</table>

18.4 For materials for which compliance with definite specifications is not indicated and when the soil contains material retained on the No. 4 sieve sufficient to require a sieve analysis on that portion, the results may be reported as follows (Note 17):

SIEVE ANALYSIS

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percentage Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-in.</td>
<td></td>
</tr>
<tr>
<td>2-in.</td>
<td></td>
</tr>
<tr>
<td>1½-in.</td>
<td></td>
</tr>
<tr>
<td>1-in.</td>
<td></td>
</tr>
<tr>
<td>½-in.</td>
<td></td>
</tr>
<tr>
<td>No. 4 (4.75-mm)</td>
<td></td>
</tr>
<tr>
<td>No. 10 (2.00-mm)</td>
<td></td>
</tr>
<tr>
<td>No. 40 (425-μm)</td>
<td></td>
</tr>
<tr>
<td>No. 200 (75-μm)</td>
<td></td>
</tr>
<tr>
<td>0.074 mm</td>
<td></td>
</tr>
<tr>
<td>0.005 mm</td>
<td></td>
</tr>
<tr>
<td>0.001 mm</td>
<td></td>
</tr>
</tbody>
</table>

Note 17—No. 8 (2.36-mm) and No. 50 (300-μm) sieves may be substituted for No. 10 and No. 40 sieves.

19. Keywords

19.1 grain-size; hydrometer analysis; hygroscopic moisture; particle-size; sieve analysis
APPENDIX D-3
STANDARD TEST METHOD FOR LABORATORY DETERMINATION OF WATER (MOISTURE) CONTENT OF SOIL AND ROCK, ASTM D2216-92
Standard Test Method for
Laboratory Determination of Water (Moisture) Content of Soil and Rock

This standard is issued under the fixed designation D 2216; 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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the laboratory determination of the water (moisture) content of soil, rock, and similar materials by mass. For simplicity, the word “material” hereinafter also refers to either soil or rock, whichever is most applicable.

1.2 The water content of a material is defined by this standard as the ratio, expressed as a percentage, of the mass of “pore” or “free” water in a given mass of material to the mass of the solid material.

1.3 The term “solid particles” as used in geotechnical engineering is typically assumed to mean naturally occurring mineral particles of soil and rock that are not readily soluble in water. Therefore, the water content of materials containing extraneous matter (such as cement, and the like) may require special treatment or a qualified definition of water content. In addition, some organic materials may be decomposed by oven drying at the standard drying temperature for this method (110°C). Materials containing gypsum (calcium sulfate dihydrate or other compounds having significant amounts of hydrated water) may present a special problem as this material slowly dehydrates at the standard drying temperature (110°C) and at very low relative humidities, forming a compound (calcium sulfate hemihydrate) which is not normally present in natural materials except in some desert soils. In order to reduce the degree of dehydration of gypsum in those materials containing gypsum, or to reduce decomposition in highly organic soils, it may be desirable to dry these materials at 60°C or in a desiccator at room temperature. Thus, when a drying temperature is used which is different from the standard drying temperature as defined by this test method, the resulting water content may be different from standard water content determined at the standard drying temperature.

Note 1—Test Methods D 2974 provides an alternate procedure for determining water content of peat materials.

1.4 Materials containing water with substantial amounts of soluble solids (such as salt in the case of marine sediments) when tested by this method will give a mass of solids which includes the previously soluble solids. These materials require special treatment to remove or account for the presence of precipitated solids in the dry mass of the specimen, or a qualified definition of water content must be used.

1.5 This test method requires several hours for proper drying of the water content specimen. Test Method D 4643 provides for drying of the test specimen in a microwave oven which is a shorter process.

1.6 This standard requires the drying of material in an oven at high temperatures. If the material being dried is contaminated with certain chemicals, health and safety hazards can exist. Therefore, this standard should not be used in determining the water content of contaminated soils unless adequate health and safety precautions are taken.

1.7 This standard does not purport to address all of the safety problems, 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.

2. Referenced Documents

2.1 ASTM Standards:
D 653 Terminology Relating to Soil, Rock, and Contained Fluids
D 2974 Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
D 4220 Practice for Preserving and Transporting Soil Samples
D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D 4643 Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method
D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing
E 145 Specification for Gravity-Convection And Forced-Ventilation Ovens

3. Terminology

3.1 Refer to Terminology D 653 for standard definitions of terms.

3.2 Description of Term Specific to This Standard:
3.2.1 water content (of a material)—the ratio of the mass of water contained in the pore spaces of soil or rock material, to the solid mass of particles in that material, expressed as a percentage.

---

1 This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

2 Annual Book of ASTM Standards, Vol 04.08.
4. Summary of Test Method

4.1 A test specimen is dried in an oven to a constant mass. The loss of mass due to drying is considered to be water. The water content is calculated using the mass of water and the mass of the dry specimen.

5. Significance and Use

5.1 For many materials, the water content is one of the most significant index properties used in establishing a correlation between soil behavior and its properties.

5.2 The water content of a material is used in expressing the phase relationships of air, water, and solids in a given volume of material.

5.3 In fine-grained (cohesive) soils, the consistency of a given soil type depends on its water content. The water content of a soil, along with its liquid and plastic limits as determined by Test Method D 4318, is used to express its relative consistency or liquidity index.

6. Apparatus

6.1 Drying Oven, thermostatically-controlled, preferably of the forced-draft type, meeting the requirements of Specification E 145 and capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber.

6.2 Balances—All balances must meet the requirements of Specification D 4753 and this Section. A Class GP balance of 0.01 g readability is required for specimens having a mass of up to 200 g (excluding mass of specimen container) and a Class GP2 balance of 0.1 g readability is required for specimens having a mass over 200 g.

6.3 Specimen Containers—Suitable containers made of material resistant to corrosion and change in mass upon repeated heating, cooling, exposure to materials of varying pH, and cleaning. Containers with close-fitting lids shall be used for testing specimens having a mass of less than about 200 g; while for specimens having a mass greater than about 200 g, containers without lids may be used. One container is needed for each water content determination.

Note 2—The purpose of close-fitting lids is to prevent loss of moisture from specimens before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination.

6.4 Desiccator—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium phosphate. It is preferable to use a desiccant which changes color to indicate it needs reconstitution. See Section 10.5.

Note 3—Anhydrous calcium sulfate is sold under the trade name Driente.

6.5 Container Handling Apparatus, gloves, tongs, or suitable holder for moving and handling hot containers after drying.

6.6 Miscellaneous, knives, spatulas, scoops, quartering cloth, sample splitters, etc., as required.

7. Samples

7.1 Samples shall be preserved and transported in accordance with Practice 4220 Groups B, C, or D soils. Keep the samples that are stored prior to testing in noncorrodible airtight containers at a temperature between approximately 3 and 30°C and in an area that prevents direct contact with sunlight. Disturbed samples in jars or other containers shall be stored in such a way as to prevent or minimize moisture condensation on the insides of the containers.

7.2 The water content determination should be done as soon as practicable after sampling, especially if potentially corroding containers (such as thin-walled steel tubes, paint cans, etc.) or plastic sample bags are used.

8. Test Specimen

8.1 For water contents being determined in conjunction with another ASTM method, the specimen mass requirement stated in that method shall be used if one is provided. If no minimum specimen mass is provided in that method then the values given before shall apply.

8.2 The minimum mass of moist material selected to be representative of the total sample, if the total sample is not tested by this method, shall be in accordance with the following:

<table>
<thead>
<tr>
<th>Maximum particle size (100 % passing)</th>
<th>Standard Sieve Size to±1%</th>
<th>Recommended minimum mass of moist test specimen for water content reported</th>
<th>Recommended minimum mass of moist test specimen for water content reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mm or less</td>
<td>No. 10</td>
<td>20 g</td>
<td>20 g</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>No. 4</td>
<td>100 g</td>
<td>20 g*</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>3/4-in.</td>
<td>500 g</td>
<td>50 g</td>
</tr>
<tr>
<td>19.0 mm</td>
<td>5/8-in.</td>
<td>2.5 kg</td>
<td>250 g</td>
</tr>
<tr>
<td>37.5 mm</td>
<td>1 1/2-in.</td>
<td>10 kg</td>
<td>1 kg</td>
</tr>
<tr>
<td>75.0 mm</td>
<td>3-in.</td>
<td>50 kg</td>
<td>5 kg</td>
</tr>
</tbody>
</table>

Note—*To be representative not less than 20 g shall be used.

8.2.1 If the total sample is used it does not have to meet the minimum mass requirements provided in the table above. The report shall indicate that the entire sample was used.

8.3 Using a test specimen smaller than the minimum indicated in 8.2 requires discretion, though it may be adequate for the purposes of the test. Any specimen used not meeting these requirements shall be noted in the report of results.

8.4 When working with a small (less than 200 g) specimen containing a relatively large gravel particle, it is appropriate not to include this particle in the test specimen. However, any discarded material shall be described and noted in the report of the results.

8.5 For those samples consisting entirely of intact rock, the minimum specimen mass shall be 500 g. Representative portions of the sample may be broken into smaller particles, depending on the sample's size, the container and balance being used and to facilitate drying to constant mass, see Section 10.4.

9. Test Specimen Selection

9.1 When the test specimen is a portion of a larger amount of material, the specimen must be selected to be representative of the water condition of the entire amount of material. The manner in which the test specimen is selected depends on the purpose and application of the test, type of material being tested, the water condition, and the type of sample (from another test, bag, block, and the likes.)

9.2 For disturbed samples such as trimmings, bag samples, and the like, obtain the test specimen by one of the
following methods (listed in order of preference):

9.2.1 If the material is such that it can be manipulated and handled without significant moisture loss, the material should be mixed and then reduced to the required size by quartering or splitting.

9.2.2 If the material is such that it cannot be thoroughly mixed and/or split, form a stockpile of the material, mixing as much as possible. Take at least five portions of material at random locations using a sampling tube, shovel, scoop, trowel, or similar device appropriate to the maximum particle size present in the material. Combine all the portions for the test specimen.

9.2.3 If the material or conditions are such that a stockpile cannot be formed, take as many portions of the material as possible at random locations that will best represent the moisture condition. Combine all the portions for the test specimen.

9.3 Intact samples such as block, tube, split barrel, and the like, obtain the test specimen by one of the following methods depending on the purpose and potential use of the sample.

9.3.1 Carefully trim at least 3 mm of material from the outer surface of the sample to see if material is layered and to remove material that is drier or wetter than the main portion of the sample. Then carefully trim at least 5 mm, or a thickness equal to the maximum particle size present, from the entire exposed surface or from the interval being tested.

9.3.2 Slice the sample in half. If material is layered see Section 9.3.3. Then carefully trim at least 5 mm, or a thickness equal to the maximum particle size present, from the exposed surface of one half, or from the interval being tested. Avoid any material on the edges that may be wetter or drier than the main portion of the sample.

9.3.3 If a layered material (or more than one material type is encountered), select an average specimen, or individual specimens, or both. Specimens must be properly identified as to location, or what they represent, and appropriate remarks entered on data sheets.

10. Procedure

10.1 Determine and record the mass of the clean and dry specimen container (and its lid, if used).

10.2 Select representative test specimens in accordance with Section 9.

10.3 Place the moist test specimen in the container and, if used, set the lid securely in position. Determine the mass of the container and moist material using a balance (See 6.2) selected on the basis of the specimen mass. Record this value.

12. Report

12.1 The report (data sheet) shall include the following:

12.1.1 Identification of the sample (material) being tested, such as boring number, sample number, test number, container number etc.

12.1.2 Water content of the specimen to the nearest 1 % or 0.1 %, as appropriate based on the minimum sample used. If this method is used in concert with another method, the water content of the specimen should be reported to the value required by the test method for which the water content is being determined.

12.1.3 Indicate if test specimen had a mass less than the minimum indicated in 8.2.
12.1.4 Indicate if test specimen contained more than one material type (layered, etc.).
12.1.5 Indicate the method of drying if different from oven-drying at 110 ± 5°C.
12.1.6 Indicate if any material (size and amount) was excluded from the test specimen.

13. Precision and Bias
13.1 Statement on Bias—There is no accepted reference value for this test method; therefore, bias cannot be determined.
13.2 Statements on Precision:
13.2.1 Single-Operator Precision—The single-operator coefficient of variation has been found to be 2.7 percent. Therefore, results of two properly conducted tests by the same operator with the same equipment should not be considered suspect unless they differ by more than 7.8 percent of their mean.
13.2.2 Multilaboratory Precision—The multilaboratory coefficient of variation has been found to be 5.0 percent. Therefore, results of two properly conducted tests by different operators using different equipment should not be considered suspect unless they differ by more than 14.0 percent of their mean.

14. Keywords
14.1 consistency; index property; laboratory; moisture analysis; moisture content; soil aggregate; water content

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.
Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

This test method covers the determination of the liquid limit, plastic limit, and the plasticity index of soils as defined in Section 3.

Two procedures for preparing test specimens and two procedures for performing the liquid limit are provided:

A Multipoint test using a wet preparation procedure, described in Sections 10.1, 11, and 12.
B Multipoint test using a dry preparation procedure, described in Sections 10.2, 11, and 12.
C One-point test using a wet preparation procedure, described in Sections 13, 14, and 15.
D One-point test using a dry preparation procedure, described in Sections 13, 14, and 15.

The procedure to be used shall be specified by the requesting authority. If no procedure is specified, Procedure A shall be used.

NOTE 1—Prior to the adoption of this test method, a curved grooving tool was specified as part of the apparatus for performing the liquid limit test. The curved tool is not considered to be as accurate as the flat tool described in 6.2 since it does not control the depth of the soil in the liquid limit cup. However, there are some data which indicate that typically the liquid limit is slightly increased when the flat tool is used instead of the curved tool.

The plastic limit test procedure is described in Sections 16, 17, and 18. The plastic limit test is performed on material prepared for the liquid limit test. In effect, there are two procedures for preparing test specimens for the plastic limit test.

The procedure for calculating the plasticity index is given in Section 19.

The liquid limit and plastic limit of soils (along with the shrinkage limit) are often collectively referred to as the Atterberg limits in recognition of their formation by Swedish soil scientist, A. Atterberg. These limits distinguish the boundaries of the several consistency states of plastic soils.

As used in this test method, soil is any natural aggregation of mineral or organic materials, mixtures of such materials, or artificial mixtures of aggregates and natural mineral and organic particles.

The correlations on which the calculations of the one-point procedure are based may not be valid for certain soils, such as organic soils or soils from a marine environment. The liquid limit of these soils should therefore be determined by the multipoint procedure (Procedure A).

The liquid and plastic limits of many soils that have been allowed to dry before testing may be considerably different from values obtained on undried samples. If the liquid and plastic limits of soils are used to correlate or estimate the engineering behavior of soils in their natural moist state, samples should not be permitted to dry before testing unless data on dried samples are specifically desired.

The composition and concentration of soluble salts in a soil affect the values of the liquid and plastic limits as well as the water content values of soils (see Method D 2216). Special consideration should therefore be given to soils from a marine environment or other sources where high soluble salt concentrations may be present. The degree to which the salts present in these soils are diluted or concentrated must be given consideration if meaningful results are to be obtained.

Since the tests described herein are performed only on that portion of a soil which passes the 425-μm (No. 40) sieve, the relative contribution of this portion of the soil to the properties of the sample as a whole must be considered when using these tests to evaluate the properties of a soil.

The values stated in acceptable metric units are to be regarded as the standard. The values given in parentheses are for information only.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
2. Referenced Documents

2.1 *ASTM Standards*:
C 702 Methods for Reducing Field Samples of Aggregate to Testing Size²
D 75 Practice for Sampling Aggregates⁴
D 420 Practice for Investigating and Sampling Soil and Rock for Engineering Purposes⁴
D 653 Terminology Relating to Soil, Rock, and Contained Fluids⁴
D 1241 Specification for Materials for Soil-Aggregate Subbase, Base, and Surface Courses⁴
D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures⁴
D 2240 Test Method for Rubber Property—Durometer Hardness⁵
D 2487 Test Method for Classification of Soils for Engineering Purposes⁴
D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)⁶
D 3282 Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes⁶
E 11 Specification for Wire-Cloth Sieves for Testing Purposes⁶
E 319 Methods of Testing Single-Arm Balances⁶
E 898 Method of Testing Top-Loading, Direct-Reading Laboratory Scales and Balances⁶

3. Definitions

3.1 *Atterberg limits*—originally, seven “limits of consistency” of fine-grained soils were defined by Albert Atterberg. In current engineering usage, the term usually refers only to the liquid limit, plastic limit, and in some references, the shrinkage limit.

3.2 *consistency*—the relative ease with which a soil can be deformed.

3.3 *liquid limit (LL)*—the water content, in percent, of a soil at the arbitrarily defined boundary between the liquid and plastic states. This water content is defined as the water content at which a pat of soil placed in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (½ in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of 2 shocks per second.

Note 2—The undrained shear strength of soil at the liquid limit is considered to be 2 ± 0.2 kPa (0.28 psi).

3.4 *plastic limit (PL)*—the water content, in percent, of a soil at the boundary between the plastic and brittle states. The water content at this boundary is the water content at which a soil can no longer be deformed by rolling into 3.2 mm (¼ in.) in diameter threads without crumbling.

3.5 *plastic soil*—a soil which has a range of water content over which it exhibits plasticity and which will retain its shape on drying.

3.6 *plasticity index (PI)*—the range of water content over which a soil behaves plastically. Numerically, it is the difference between the liquid limit and the plastic limit.

3.7 *liquidity index*—the ratio, expressed as a percentage, of (1) the natural water content of a soil minus its plastic limit, to (2) its plasticity index.

3.8 *activity number (A)*—the ratio of (1) the plasticity index of a soil to (2) the percent by weight of particles having an equivalent diameter smaller than 0.002 mm.

4. Summary of Method

4.1 The sample is processed to remove any material retained on a 425-µm (No. 40) sieve. The liquid limit is determined by performing trials in which a portion of the sample is spread in a brass cup, divided in two by a grooving tool, and then allowed to flow together from the shocks caused by repeatedly dropping the cup in a standard mechanical device. The multipoint liquid limit, Procedures A and B, requires three or more trials over a range of water contents to be performed and the data from the trials plotted or calculated to make a relationship from which the liquid limit is determined. The one-point liquid limit, Procedures C and D, uses the data from two trials at one water content multiplied by a correction factor to determine the liquid limit.

4.2 The plastic limit is determined by alternately pressing together and rolling into a 3.2 mm (¼ in.) diameter thread a small portion of plastic soil until its water content is reduced to a point at which the thread crumbles and is no longer able to be pressed together and rolled. The water content of the soil at this stage is reported as the plastic limit.

4.3 The plasticity index is calculated as the difference between the liquid limit and the plastic limit.

5. Significance and Use

5.1 This test method is used as an integral part of several engineering classification systems to characterize the fine-grained fractions of soils (see Test Method D 2487 and Practice D 3282) and to specify the fine-grained fraction of construction materials (see Specification D 1241). The liquid limit, plastic limit, and plasticity index of soils are also used extensively, either individually or together with other soil properties to correlate with engineering behavior such as compressibility, permeability, compactibility, shrink-swell, and shear strength.

5.2 The liquid and plastic limits of a soil can be used with the natural water content of the soil to express its relative consistency or liquidity index and can be used with the percentage finer than 2-µm size to determine its activity number.

5.3 The one-point liquid limit procedure is frequently used for routine classification purposes. When greater precision is required, as when used for the acceptance of a material or for correlation with other test data, the multipoint procedure should be used.

5.4 These methods are sometimes used to evaluate the weathering characteristics of clay-shale materials. When subjected to repeated wetting and drying cycles, the liquid limits of these materials tend to increase. The amount of increase is considered to be a measure of a shale’s susceptibility to weathering.
5.5 The liquid limit of a soil containing substantial amounts of organic matter decreases dramatically when the soil is oven-dried before testing. Comparison of the liquid limit of a sample before and after oven-drying can therefore be used as a qualitative measure of organic matter content of a soil.

6. Apparatus

6.1 Liquid Limit Device—A mechanical device consisting of a brass cup suspended from a carriage designed to control its drop onto a hard rubber base. A drawing showing the essential features of the device and the critical dimensions is given in Fig. 1. The design of the device may vary provided that the essential functions are preserved. The device may be operated either by a hand crank or by an electric motor.

6.1.1 Base—The base shall be hard rubber having a D Durometer hardness of 80 to 90, and a resilience such that an 8-mm (1/32-in.) diameter polished steel ball, when dropped from a height of 25 cm (9.84 in.) will have an average rebound of at least 80% but no more than 90%. The tests shall be conducted on the finished base with feet attached.

6.1.2 Feet—The base shall be supported by rubber feet designed to provide isolation of the base from the work surface and having an A Durometer hardness no greater than 60 as measured on the finished feet attached to the base.

6.1.3 Cup—The cup shall be brass and have a weight, including cup hanger, of 185 to 215 g.

6.1.4 Cam—The cam shall raise the cup smoothly and continuously to its maximum height, over a distance of at least 180° of cam rotation. The preferred cam motion is a uniformly accelerated (parabolic) motion after contact and assures that the cup has no velocity at drop off. Other cam designs also provide this feature and may be used. However, if the cam-follower lift pattern is not known, zero velocity at drop off can be assured by carefully filing or machining the cam and follower so that the cup height remains constant over the last 20 to 45° of cam rotation.

Note 3—The cam and follower design in Fig. 1 is for uniformly accelerated (parabolic) motion after contact and assures that the cup has no velocity at drop off. Other cam designs also provide this feature and may be used. However, if the cam-follower lift pattern is not known, zero velocity at drop off can be assured by carefully filing or machining the cam and follower so that the cup height remains constant over the last 20 to 45° of cam rotation.

6.1.5 Carriage—The cup carriage shall be constructed in a way that allows convenient but secure adjustment of the height of drop of the cup to 10 mm (0.394 in.). The cup hanger shall be attached to the carriage by means of a pin which allows removal of the cup and cup hanger for cleaning and inspection.

6.1.6 Optional Motor Drive—As an alternative to the hand crank shown in Fig. 1, the device may be equipped with a motor to turn the cam. Such a motor must turn the cam at 2 ± 0.1 revolutions per second and must be isolated from the rest of the device by rubber mounts or in some other way that prevents vibration from the motor being transmitted to the rest of the apparatus. It must be equipped with an ON-OFF switch and a means of conveniently positioning the cam for height of drop adjustments. The results obtained using a motor-driven device must not differ from those obtained using a manually operated device.
DIMENSIONS

<table>
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<tr>
<th>LETTER</th>
<th>A</th>
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<th>C</th>
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**ESSENTIAL DIMENSIONS**

**BACK AT LEAST 15 MM FROM TIP**

**NOTE**: DIMENSION A SHOULD BE 1.9-2.0 AND DIMENSION D SHOULD BE 6.0-6.1 WHEN NEW TO ALLOW FOR ADEQUATE SERVICE LIFE

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6.2 **Flat Grooving Tool**—A grooving tool having dimensions shown in Fig. 2. The tool shall be made of plastic or noncorroding metal. The design of the tool may vary as long as the essential dimensions are maintained. The tool may, but need not, incorporate the gage for adjusting the height of drop of the liquid limit device.

6.3 **Gage**—A metal gage block for adjusting the height of drop of the cup, having the dimensions shown in Fig. 3. The design of the tool may vary provided the gage will rest securely on the base without being susceptible to rocking, and the edge which contacts the cup during adjustment is straight, at least 10 mm (3/8 in.) wide, and without bevel or radius.

6.4 **Containers**—Small corrosion-resistant containers with snug-fitting lids for water content specimens. Aluminum or stainless steel cans 2.5 cm (1 in.) high by 5 cm (2 in.) in diameter are appropriate.

6.5 **Balance**—A balance readable to at least 0.01 g and having an accuracy of 0.03 g within three standard deviations within the range of use. Within any 15-g range, a difference between readings shall be accurate within 0.01 g (Notes 4 and 5).

**NOTE 4**—See Methods E 898 and E 319 for an explanation of terms relating to balance performance.

**NOTE 5**—For frequent use, a top-loading type balance with automatic load indication, readable to 0.01 g, and having an index of precision (standard deviation) of 0.003 or better is most suitable for this method. However, nonautomatic indicating equal-arm analytical balances and some small equal arm top pan balances having readabilities and sensitivities of 0.002 g or better provide the required accuracy when used with a weight set of ASTM Class 4 (National Bureau of Standards Class P) or better. Ordinary commercial and classroom type balances such as beam balances are not suitable for this method.

6.6 **Storage Container**—A container in which to store the prepared soil specimen that will not contaminate the specimen in any way, and which prevents moisture loss. A porcelain, glass, or plastic dish about 11.4 cm (4½ in.) in diameter and a plastic bag large enough to enclose the dish and be folded over is adequate.
8. Sampling

8.1 Samples may be taken from any location that satisfies testing needs. However, Methods C 702, Practice D 75, and Recommended Practice D 420 should be used as guides for selecting and preserving samples from various types of sampling operations. Samples which will be prepared using the wet preparation procedure, I

6.7 Ground Glass Plate—A ground glass plate at least 30 cm (12 in.) square by 1 cm (1/8 in.) thick for mixing soil and rolling plastic limit threads.

6.8 Spatula—A spatula or pill knife having a blade about 2 cm (1/4 in.) wide by about 10 cm (4 in.) long. In addition, a spatula having a blade about 2.5 cm (1 in.) wide and 15 cm (6 in.) long has been found useful for initial mixing of samples.

6.9 Sieve—A 20.3 cm (8 in.) diameter, 425-μm (No. 40) sieve conforming to the requirements of Specification E 11 and having a rim at least 5 cm (2 in.) above the mesh. A 2-mm (No. 10) sieve meeting the same requirements may also be needed.

6.10 Wash Bottle, or similar container for adding controlled amounts of water to soil and washing fines from coarse particles.

6.11 Drying Oven—A thermostatically controlled oven, preferably of the forced-draft type, capable of continuously maintaining a temperature of 110 ± 5°C throughout the drying chamber. The oven shall be equipped with a thermometer of suitable range and accuracy for monitoring oven temperature.

6.12 Washing Pan—A round, flat-bottomed pan at least 7.6 cm (3 in.) deep, slightly larger at the bottom than a 20.3-cm (8-in.) diameter sieve.

6.13 Rod (optional)—A metal or plastic rod or tube 3.2 mm (1/8 in.) in diameter and about 10 cm (4 in.) long for judging the size of plastic limit threads.

7. Materials

7.1 A supply of distilled or demineralized water.

8. Sampling

8.1 Samples may be taken from any location that satisfies testing needs. However, Methods C 702, Practice D 75, and Recommended Practice D 420 should be used as guides for selecting and preserving samples from various types of sampling operations. Samples which will be prepared using the wet preparation procedure, I

8.2 Where sampling operations have preserved the natural stratification of a sample, the various strata must be kept separated and tests performed on the particular stratum of interest with as little contamination as possible from other strata. Where a mixture of materials will be used in construc-

9. Calibration of Apparatus

9.1 Inspection of Wear:

9.1.1 Liquid Limit Device—Determine that the liquid limit device is clean and in good working order. The following specific points should be checked:

9.1.1.1 Wear of Base—The spot on the base where the cup makes contact should be worn no greater than 10 mm (3/8 in.) in diameter. If the wear spot is greater than this, the base can be machined to remove the worn spot provided the resurfacing does not make the base thinner than specified in 6.1 and the other dimensional relationships are maintained.

9.1.1.2 Wear of Cup—The cup must be replaced when the grooving tool has worn a depression in the cup 0.1 mm (0.004 in.) deep or when the edge of the cup has been reduced to half its original thickness. Verify that the cup is firmly attached to the cup hanger.

9.1.1.3 Wear of Cup Hanger—Verify that the cup hanger pivot does not bind and is not worn to an extent that allows more than 3-mm (1/8-in.) side-to-side movement of the lowest point on the rim.

9.1.1.4 Wear of Cam—The cam shall not be worn to an extent that the cup drops before the cup hanger (cam follower) loses contact with the cam.

9.1.2 Grooving Tools—Inspect grooving tools for wear on a frequent and regular basis. The rapidity of wear depends on the material from which the tool is made and the types of soils being tested. Sandy soils cause rapid wear of grooving tools; therefore, when testing these materials, tools should be inspected more frequently than for other soils. Any tool with a tip width greater than 2.1 mm must not be used. The depth
of the tip of the grooving tool must be 7.9 to 8.1 mm.

Note 6—The width of the tip of grooving tools is conveniently checked using a pocket-sized measuring magnifier equipped with a millimetre scale. Magnifiers of this type are available from most laboratory supply companies. The depth of the tip of grooving tools can be checked using the depth measuring feature of vernier calipers.

9.2 Adjustment of Height of Drop—Adjust the height of drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10 ± 0.2 mm. See Fig. 4 for proper location of the gage relative to the cup during adjustment.

Note 7—A convenient procedure for adjusting the height of drop is as follows: place a piece of masking tape across the outside bottom of the cup parallel with the axis of the cup hanger pivot. The edge of the tape away from the cup hanger should becot the spot on the cup that contacts the base. For new cups, placing a piece of carbon paper on the base and allowing the cup to drop several times will mark the contact spot. Attach the cup to the device and turn the crank until the cup is raised to its maximum height. Slide the height gage under the cup from the front, and observe whether the gage contacts the cup or the tape. See Fig. 4. If the tape and cup are both contacted, the height of drop is approximately correct. If not, adjust the cup until simultaneous contact is made. Check adjustment by turning the crank at 2 revolutions per second while holding the gage in position against the tape and cup. If a ringing or clicking sound is heard without the cup rising from the gage, the adjustment is correct. If no ringing is heard or if the cup rises from the gage, readjust the height of drop. If the cup rocks on the gage during this checking operation, the cam follower pivot is excessively worn and the worn parts should be replaced. Always remove tape after completion of adjustment operation.

MULTIPOINT LIQUID LIMIT—PROCEDURES A AND B

10. Preparation of Test Specimens

10.1 Wet Preparation—Except where the dry method of specimen preparation is specified (10.2), prepare specimens for test as described in the following sections.

10.1.1 Samples Passing the 425-μm (No. 40) Sieve—When by visual and manual procedures it is determined that the sample has little or no material retained on a 425-μm (No. 40) sieve, prepare a specimen of 150 to 200 g by mixing thoroughly with distilled or demineralized water on the glass plate using the spatula. If desired, soak soil in a storage dish with small amount of water to soften the soil before the start of mixing. Adjust the water content of the soil to bring it to a consistency that would require 25 to 35 blows of the liquid limit device to close the groove (Note 8). If, during mixing, a small percentage of material is encountered that would be retained on a 425-μm (No. 40) sieve, remove these particles by hand, if possible. If it is impractical to remove the coarser material by hand, remove small percentages (less than about 15 %) of coarser material by working the specimen through a 425-μm (No. 40) sieve using a piece of rubber sheeting, rubber stopper, or other convenient device provided the operation does not distort the sieve or degrade material that would be retained if the washing method described in 10.1.2 were used. If larger percentages of coarse material are encountered during mixing, or it is considered impractical to remove the coarser material by the methods just described, wash the sample as described in 10.1.2. When the coarse particles found during mixing are concretions, shells, or other fragile particles, do not crush these particles to make them pass a 425-μm (No. 40) sieve, but remove by hand or by washing. Place the mixed soil in the storage dish, cover to prevent loss of moisture, and allow to stand for at least 16 h (overnight). After the standing period and immediately before starting the test, thoroughly remix the soil.

Note 8—The time taken to adequately mix a soil will vary greatly, depending on the plasticity and initial water content. Initial mixing times of more than 30 min may be needed for stiff, fat clays.

10.1.2 Samples Containing Material Retained on a 425-μm (No. 40) Sieve:

10.1.2.1 Select a sufficient quantity of soil at natural water content to provide 150 to 200 g of material passing the 425-μm (No. 40) sieve. Place in a pan or dish and add sufficient water to cover the soil. Allow to soak until all lumps have softened and the fines no longer adhere to the surfaces of the coarse particles (Note 9).

Note 9—In some cases, the cations of salts present in tap water will exchange with the natural cations in the soil and significantly alter the test results should tap water be used in the soaking and washing operations. Unless it is known that such cations are not present in the tap water, distilled or demineralized water should be used. As a general rule, water containing more than 100 mg/L of dissolved solids should not be used for washing operations.

10.1.2.2 When the sample contains a large percentage of material retained on the 425-μm (No. 40) sieve, perform the following washing operation in increments, washing no more than 0.5 kg (1 lb) of material at one time. Place the 425-μm (No. 40) sieve in the bottom of the clean pan. Pour the soil water mixture onto the sieve. If gravel or coarse sand particles are present, rinse as many of these as possible with small quantities of water from a wash bottle, and discard. Alternatively, pour the soil water mixture over a 2-mm (No. 40) sieve nested atop the 425-μm (No. 40) sieve, rinse the fine material through and remove the 2-mm (No. 10) sieve. After washing and removing as much of the coarser material as possible, add sufficient water to the pan to bring the level to about 13 mm (½ in.) above the surface of the 425-μm (No. 40) sieve. Agitate the slurry by stirring with the fingers while raising and lowering the sieve in the pan and swirling the suspension so that fine material is washed from the coarser particles. Disaggregate fine soil lumps that have not been slaked by gently rubbing them over the sieve with the fingertips. Complete the washing operation by raising the sieve above the water surface and rinsing the material retained with a small amount of clean water. Discard material retained on the 425-μm (No. 40) sieve.

10.1.2.3 Reduce the water content of the material passing the 425-μm (No. 40) sieve until it approaches the liquid limit. Reduction of water content may be accomplished by one or a combination of the following methods: (a) exposing the air currents at ordinary room temperature, (b) exposing to warm air currents from a source such as an electric hair dryer, (c) filtering in a Büchner funnel or using filter candles, (d) decanting clear water from surface of suspension, or (e) draining in a colander or plaster of paris dish lined with high retentivity, high wet-strength filter paper. 7 If a plaster of paris dish is used, take care that the dish never becomes sufficiently saturated that it fails to actively absorb water into its surface. Thoroughly dry dishes between uses. During evaporation and cooling, stir the sample often enough to prevent

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7 S and S 595 filter paper available in 32-cm circles, has proven satisfactory.
overdrying of the fringes and soil pinnacles on the surface of the mixture. For soil samples containing soluble salts, use a method of water reduction such as a or b that will not eliminate the soluble salts from the test specimen.

10.1.2.4 Thoroughly mix the material passing the 425-μm (No. 40) sieve on the glass plate using the spatula. Adjust the water content of the mixture, if necessary, by adding small increments of distilled or demineralized water or by allowing the mixture to dry at room temperature while mixing on the glass plate. The soil should be at a water content that will result in closure of the groove in 25 to 35 blows. Return the mixed soil to the mixing dish, cover to prevent loss of moisture, and allow to stand for at least 16 h. After the standing period, and immediately before starting the test, remix the soil thoroughly.

10.2 Dry Preparation:

10.2.1 Select sufficient soil to provide 150 to 200 g of material passing the 425-μm (No. 40) sieve after processing. Dry the sample at room temperature or in an oven at a temperature not exceeding 60°C until the soil clods will pulverize readily. Disaggregation is expedited if the sample is not allowed to completely dry. However, the soil should have a dry appearance when pulverized. Pulverize the sample in a mortar with a rubber tipped pestle or in some other way that does not cause breakdown of individual grains. When the coarse particles found during pulverization are concretions, shells, or other fragile particles, do not crush these particles to make them pass a 425-μm (No. 40) sieve, but remove by hand or other suitable means, such as washing.

10.2.2 Separate the sample on a 425-μm (No. 40) sieve, shaking the sieve by hand to assure thorough separation of the finer fraction. Return the material retained on the 425-μm (No. 40) sieve to the pulverizing apparatus and repeat the pulverizing and sieving operations as many times as necessary to assure that all finer material has been disaggregated and material retained on the 425-μm (No. 40) sieve consists only of individual sand or gravel grains.

10.2.3 Place material remaining on the 425-μm (No. 40) sieve after the final pulverizing operations in a dish and soak in a small amount of water. Stir the soil water mixture and pour over the 425-μm (No. 40) sieve, catching the water and any suspended fines in the washing pan. Pour this suspension into a dish containing the dry soil previously sieved through the 425-μm (No. 40) sieve. Discard material retained on the 425-μm (No. 40) sieve.

10.2.4 Adjust the water content as necessary by drying as described in 10.1.2.3 or by mixing on the glass plate, using the spatula while adding increments of distilled or demineralized water, until the soil is at a water content that will result in closure of the groove in 25 to 35 blows.

10.2.5 Put soil in the storage dish, cover to prevent loss of moisture and allow to stand for at least 16 h. After the standing period, and immediately before starting the test, thoroughly remix the soil (Note 8).

11. Procedure

11.1 Place a portion of the prepared soil in the cup of the liquid limit device at the point where the cup rests on the base, squeeze it down, and spread it into the cup to a depth of about 10 mm at its deepest point, tapering to form an approximately horizontal surface. Take care to eliminate air bubbles from the soil pat but form the pat with as few strokes as possible. Heap the unused soil on the glass plate and cover with the inverted storage dish or a wet towel.

11.2 Form a groove in the soil pat by drawing the tool, beveled edge forward, through the soil on a line joining the highest point to the lowest point on the rim of the cup. When cutting the groove, hold the grooving tool against the surface of the cup and draw in an arc, maintaining the tool perpendicular to the surface of the cup throughout its

FIG. 5 Grooved Soil Pat in Liquid Limit Device
FIG. 6 Soil Pat After Groove Has Closed

movement. See Fig. 5. In soils where a groove cannot be made in one stroke without tearing the soil, cut the groove with several strokes of the grooving tool. Alternatively, cut the groove to slightly less than required dimensions with a spatula and use the grooving tool to bring the groove to final dimensions. Exercise extreme care to prevent sliding the soil pat relative to the surface of the cup.

11.3 Verify that no crumbs of soil are present on the base or the underside of the cup. Lift and drop the cup by turning the crank at a rate of 1.9 to 2.1 drops per second until the two halves of the soil pat come in contact at the bottom of the groove along a distance of 13 mm (1/2 in.). See Fig. 6.

Note 10—Use the end of the grooving tool, Fig. 2, or a scale to verify that the groove has closed 13 mm (1/2 in.).

11.4 Verify that an air bubble has not caused premature closing of the groove by observing that both sides of the groove have flowed together with approximately the same shape. If a bubble has caused premature closing of the groove, reform the soil in the cup, adding a small amount of soil to make up for that lost in the grooving operation and repeat 11.1 to 11.3. If the soil slides on the surface of the cup, repeat 11.1 through 11.3 at a higher water content. If, after several trials at successively higher water contents, the soil pat continues to slide in the cup or if the number of blows required to close the groove is always less than 25, record that the liquid limit could not be determined, and report the soil as nonplastic without performing the plastic limit test.

11.5 Record the number of drops, N, required to close the groove. Remove a slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, place in a weighed container, and cover.

11.6 Return the soil remaining in the cup to the glass plate. Wash and dry the cup and grooving tool and reattach the cup to the carriage in preparation for the next trial.

11.7 Remix the entire soil specimen on the glass plate adding distilled water to increase the water content of the soil and decrease the number of blows required to close the groove. Repeat 11.1 through 11.6 for at least two additional trials producing successively lower numbers of blows to close the groove. One of the trials shall be for a closure requiring 25 to 35 blows, one for closure between 20 and 30 blows, and one trial for a closure requiring 15 to 25 blows.

11.8 Determine the water content, $W_N$, of the soil specimen from each trial in accordance with Method D 2216. Make all weighings on the same balance. Initial weighings should be performed immediately after completion of the test. If the test is to be interrupted for more than about 15 min, the specimens already obtained should be weighed at the time of the interruption.

12. Calculations

12.1 Plot the relationship between the water content, $W$, and the corresponding number of drops, N, of the cup on a semilogarithmic graph with the water content as ordinates on the arithmetical scale, and the number of drops as abscissas on the logarithmic scale. Draw the best straight line through the three or more plotted points.

12.2 Take the water content corresponding to the intersection of the line with the 25-drop abscissa as the liquid limit of the soil. Computational methods may be substituted for the graphical method for fitting a straight line to the data and determining the liquid limit.

ONE-POINT LIQUID LIMIT—PROCEDURES C AND D

13. Preparation of Test Specimens

13.1 Prepare the specimen in the same manner as described in Section 10, except that at mixing, adjust the water content to a consistency requiring 20 to 30 drops of the
TABLE 1 Factors for Obtaining Liquid Limit from Water Content
and Number of Drops Causing Closure of Groove

<table>
<thead>
<tr>
<th>N (Number of Drops)</th>
<th>K (Factor for Liquid Limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.974</td>
</tr>
<tr>
<td>21</td>
<td>0.979</td>
</tr>
<tr>
<td>22</td>
<td>0.985</td>
</tr>
<tr>
<td>23</td>
<td>0.990</td>
</tr>
<tr>
<td>24</td>
<td>0.995</td>
</tr>
<tr>
<td>25</td>
<td>1.000</td>
</tr>
<tr>
<td>26</td>
<td>1.005</td>
</tr>
<tr>
<td>27</td>
<td>1.009</td>
</tr>
<tr>
<td>28</td>
<td>1.014</td>
</tr>
<tr>
<td>29</td>
<td>1.018</td>
</tr>
<tr>
<td>30</td>
<td>1.022</td>
</tr>
</tbody>
</table>

liquid limit cup to close the groove.

14. Procedure

14.1 Proceed as described in 11.1 through 11.5 except that the number of blows required to close the groove shall be 20 to 30. If less than 20 or more than 30 blows are required, adjust the water content of the soil and repeat the procedure.

14.2 Immediately after removing a water content specimen as described in 11.5, reform the soil in the cup, adding a small amount of soil to make up for that lost in the grooving and water content sampling operations. Repeat 11.2 through 11.5, and, if the second closing of the groove requires the same number of drops or no more than two drops difference, secure another water content specimen. Otherwise, remix the entire specimen and repeat.

Note 11—Excessive drying or inadequate mixing will cause the number of blows to vary.

14.3 Determine water contents of specimens as described in 11.8.

15. Calculations

15.1 Determine the liquid limit for each water content specimen using one of the following equations:

\[ LL = \frac{W_N}{\sqrt{N/25}} \] or

\[ LL = K (W_N) \]

where:

\( N \) = the number of blows causing closure of the groove at water content,

\( W_N \) = water content, and

\( K \) = a factor given in Table 1.

The liquid limit is the average of the two trial liquid limit values.

15.2 If the difference between the two trial liquid limit values is greater than one percentage point, repeat the test.

PLASTIC LIMIT

16. Preparation of Test Specimen

16.1 Select a 20-g portion of soil from the material prepared for the liquid limit test, either after the second mixing before the test, or from the soil remaining after completion of the test. Reduce the water content of the soil to a consistency at which it can be rolled without sticking to the hands by spreading and mixing continuously on the glass plate. The drying process may be accelerated by exposing the soil to the air current from an electric fan, or by blotting with paper that does not add any fiber to the soil, such as hard surface paper towel ing or high wet-strength filter paper.

17. Procedure

17.1 From the 20-g mass, select a portion of 1.5 to 2.0 g. Form the test specimen into an ellipsoidal mass. Roll this mass between the palm or fingers and the ground-glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length (Note 12). The thread shall be further deformed on each stroke so that its diameter is continuously reduced and its length extended until the diameter reaches 3.2 ± 0.5 mm (0.125 ± 0.020 in.), taking no more than 2 min (Note 13). The amount of hand or finger pressure required will vary greatly, according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

Note 12—A normal rate of rolling for most soils should be 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position. This rate of rolling may have to be decreased for very fragile soils.

Note 13—A 3.2-mm (3/32-in.) diameter rod or tube is useful for frequent comparison with the soil thread to ascertain when the thread has reached the proper diameter, especially for inexperienced operators.

17.1.1 When the diameter of the thread becomes 3.2 mm, break the thread into several pieces. Squeeze the pieces together, knead between the thumb and first finger of each hand, reform into an ellipsoidal mass, and roll. Continue this alternate rolling to a thread 3.2 mm in diameter, gathering together, kneading and rerolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a 3.2-mm diameter thread (See Fig. 7). It has no significance if the thread breaks into threads of shorter length. Roll each of these shorter threads to 3.2 mm in diameter. The only requirement for continuing the test is that they are able to be reformed into an ellipsoidal mass and rolled out again. The operator shall at no time attempt to produce failure at exactly 3.2 mm diameter by allowing the thread to reach 3.2 mm, then reducing the rate of rolling or the hand pressure, or both, while continuing the rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal mass nearer to the required 3.2-mm final diameter. If crumbling occurs when the thread has a diameter greater than 3.2 mm, this shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3.2 mm in diameter. Crumbling of the thread will manifest itself differently with the various types of soil. Some soils fall apart in numerous small aggregations of particles, others may form an outside tubular layer that starts splitting at both ends. The splitting progresses toward the middle, and finally, the thread falls apart in many small platy particles. Fat clay soils require much pressure to deform the thread, particularly as they approach the plastic limit. With these soils, the thread breaks into a series of barrel-shaped segments about 3.2 to 9.5 mm (3/16 to 3/8 in.) in length.

17.2 Gather the portions of the crumbled thread together and place in a weighed container. Immediately cover the container.
17.3 Select approximately 1.5 to 2.0 g portion of soil from the original 20-g specimen and repeat the operations described in 17.1 and 17.2 until the container has at least 6 g of soil.

17.4 Repeat 17.1 through 17.3 to make another container holding at least 6 g of soil. Determine the water content, in percent, of the soil contained in the containers in accordance with Method D 2216. Make all weighings on the same balance.

Note 14—The intent of performing two plastic limit trials is to verify the consistency of the test results. It is acceptable practice to perform only one plastic limit trial when the consistency in the test results can be confirmed by other means.

18. Calculations

18.1 Compute the average of the two water contents. If the difference between the two water contents is greater than two percentage points, repeat the test. The plastic limit is the average of the two water contents.

PLASTICITY INDEX

19. Calculations

19.1 Calculate the plasticity index as follows:

\[ PI = LL - PL \]

where:

- \( LL \) = the liquid limit,
- \( PL \) = the plastic limit.

Both \( LL \) and \( PL \) are whole numbers. If either the liquid limit or plastic limit could not be determined, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP.

20. Report

20.1 Report the following information:

20.1.1 Sample identifying information,
20.1.2 Any special specimen selection process used, such as removal of sand lenses from undisturbed sample,
20.1.3 Report sample as air-dried if the sample was air-dried before or during preparation,
20.1.4 Liquid limit, plastic limit, and plasticity index to the nearest whole number and omitting the percent designation. If the liquid limit or plastic limit tests could not be performed, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP,
20.1.5 An estimate of the percentage of sample retained on the 425-μm (No. 40) sieve, and
20.1.6 Procedure by which liquid limit was performed, if it differs from the multipoint method.

21. Precision and Bias

21.1 No interlaboratory testing program has as yet been conducted using this test method to determine multilaboratory precision.

21.2 The within laboratory precision of the results of tests performed by different operators at one laboratory on two soils using Procedure A for the liquid limit is shown in Table 2.

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>AVERAGE VALUE, ( x )</th>
<th>STANDARD DEVIATION, ( s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil A:</td>
<td>PL</td>
<td>21.9</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>27.9</td>
</tr>
<tr>
<td>Soil B:</td>
<td>PL</td>
<td>20.1</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>32.6</td>
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</tbody>
</table>
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