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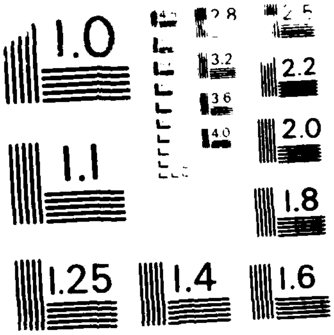

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NATIONAL BUREAU OF STANDARDS-1963-A

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INSTALLATION RESTORATION PROGRAM
PHASE II--CONFIRMATION/QUANTIFICATION

STAGE 1

Final Report

for

AIR FORCE PLANT 6, COBB COUNTY, GA.

U.S. AIR FORCE
OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY
Brooks Air Force Base, Tex.

August 1986

Prepared by:

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
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Gainesville, Fla. 32602-3052

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Brooks Air Force Base, Texas 78235-5501

Volume II

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Gainesville, FL 32602-3052

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Brooks Air Force Base, TX 78235

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Air Force Plant 6	Hazardous materials	Soils
DAFB	Ground water	Sediments
Hazardous waste	Surface water	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A Phase II, Stage 1 Installation Restoration Program was conducted for Air Force Plant 6, a Government-owned, contractor-operated facility run by Lockheed-Georgia Co. The objective of this study is to confirm the existence of potential contaminants at former and current disposal and storage sites identified by a Phase I Records Search and by Lockheed-Georgia Co.-sponsored environmental site assessments. Sixteen sites were investigated, including past and current landfills; the industrial waste treatment facility area; trichloroethylene (TCE), sodium dichromate, and fuel gas spill areas; the flightline area, and specific areas of contamination within the industrial facility.

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19. ABSTRACT Continued

Six additional monitoring wells were installed and water quality and soil samples collected and analyzed for various screening parameters, including total organic carbon (TOC), total organic halogens (TOX), oil and grease, pH, and specific conductance. More than 20 reports of past site investigations conducted under Lockheed-Georgia Co. sponsorship have been reviewed and data integrated into this assessment.

INSTALLATION RESTORATION PROGRAM

PHASE II--CONFIRMATION/QUANTIFICATION

Stage 1

AIR FORCE PLANT 6
COBB COUNTY, GA

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
P.O. Box ESE
Gainesville, Florida 32602-3052

August 1986

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Prepared for:

Major George R. New
OEHL Technical Monitor
Technical Services (TS) Division

UNITED STATES AIR FORCE
Occupational and Environmental Health Laboratory (USAFOEHL)
Technical Services Division (TS)
Brooks Air Force Base, Texas 78235-5501

NOTICE

This report has been prepared for the United States Air Force by Environmental Science and Engineering, Inc., for the purpose of aiding in the Implementation of the Air Force Installation Restoration Program. It is not an endorsement of any product. The views expressed herein are those of the contractor and do not necessarily reflect the official views of the publishing agency, the United States Air Force, or the Department of Defense.

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APPENDIX A

GLOSSARY OF TERMINOLOGY, ABBREVIATIONS, AND ACRONYMS

APPENDIX A

GLOSSARY OF TERMINOLOGY, ABBREVIATIONS, AND ACRONYMS

AFB	Air Force Base
AFESC	Air Force Engineering and Service Center
AFRES	Air Force Reserve
Ag	Chemical symbol for silver, a metal used in photographic emulsions and other industrial operations; toxic to humans and aquatic life at low concentrations
As	Chemical symbol for arsenic
AVGAS	Aviation gasoline
Ba	Chemical symbol for barium
°C	Degrees Celsius
Cd	Chemical symbol for cadmium, a metal used in batteries and other industrial applications; highly toxic to humans and aquatic life
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	Centimeter(s)
cm/sec	Centimeters per second
CN	Chemical symbol for cyanide
Contamination	Degradation of natural water quality to the extent that its usefulness is impaired; degree of permissible contamination depends on intended use of water
Cr	Chemical symbol for chromium, a metal used in plating, cleaning, and other industrial applications; highly toxic to aquatic life at low concentrations, toxic to humans at higher levels

Cu	Chemical symbol for copper
DAFB	Dobbins Air Force Base
DC	Direct current
DEQPPM	Defense Environmental Quality Program Policy Memorandum
Disposal of hazardous waste	Discharge, deposit, injection, dumping, spilling, or placing of any hazardous waste into or on land or water so that such waste, or any constituent thereof, may enter the environment, be emitted into the air, or be discharged into any waters, including ground water
DNR	Department of Natural Resources
DOD	Department of Defense
Downgradient	In the direction of decreasing hydraulic static head; the direction in which ground water flows
EM	Electromagnetic
EP	Extraction procedure
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
F	Chemical symbol for fluoride
°F	Degrees Fahrenheit
Fe	Chemical symbol for iron, a metal commonly found in water as a consequence of dissolution of geologic materials; relatively nontoxic
ft	Foot (feet)
gal	Gallon(s)
Georgia EPD	State of Georgia Environmental Protection Division
gpm	Gallon(s) per minute
GOCO	Government-owned Contractor-operated
HARM	Hazard Assessment Rating Methodology

Hazardous waste	As defined in RCRA, a solid waste or combination of solid wastes which because of its quantity, concentration, or physical, chemical, or infectious characteristics may cause or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible
Hazardous waste (Continued)	illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed
Hg	Chemical symbol for mercury
IIA	Initial Installation Assessment
IRP	Installation Restoration Program
JP-5	JP-5 aviation fuel
k	Hydraulic conductivity
Law	Law Engineering Co.
lb	Pound(s)
lb/ft^3	Pound(s) per cubic foot
LUST	Leaking Underground Storage Tank
MCL	Maximum contaminant level
MG	Million gallons
mg/l	Milligram(s) per liter
MSL	Mean sea level
MW	Monitoring well
NAS	Naval Air Station
NGVD	National Geodetic Vertical Datum
Ni	Chemical symbol for nickel, a metal used in batteries, plating, and other industrial applications; highly toxic to humans and aquatic life
NIPDWR	National Interim Primary Drinking Water Regulations

NO_3	Chemical formula for nitrate, a common anion in natural water
NPDES	National Pollutant Discharge Elimination System
NSDWR	National Secondary Drinking Water Regulations
OEHL	Occupational and Environmental Health Laboratory
OVA	Organic vapor analyzer
Pb	Chemical symbol for lead, a metal additive to gasoline and used in other industrial applications; toxic to humans and aquatic life; bioaccumulates
PCB	Polychlorinated biphenyls
pH	Negative logarithm of hydrogen ion concentration; an expression of acidity or alkalinity
POL	Petroleum, oils, and lubricants
ppb	Parts per billion
ppm	Parts per million
psi	Pounds per square inch
PVC	Polyvinyl chloride
QA/QC	Quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
Se	Chemical symbol for selenium, a metal with numerous applications as a catalyst; toxic to humans and aquatic life
SO_4	Chemical formula for sulfate, a common anion in sea water
SWL	Static water level
TCA	1,1,1-Trichloroethane
TCE	Trichloroethylene
TDS	Total dissolved solids

TOC	Total organic carbon
TOX	Total organic halogens
2,4-D	2,4-Dichlorophenoxyacetic acid
2,4,5-TP	2,4,5-Trichlorophenoxyacetic acid
ug/g	Microgram(s) per gram
ug/l	Microgram(s) per liter
umhos/cm	Micromhos per centimeter
USAF	U.S. Air Force
USCGS	U.S. Coast and Geodetic Survey
USGS	U.S. Geological Survey
Zn	Chemical symbol of zinc, a metal with a wide variety of industrial applications, particularly corrosion-resistant; highly toxic to aquatic life, slightly toxic to humans at high dose levels

APPENDIX B

RESUMES OF KEY PROJECT PERSONNEL

ESE

PROFESSIONAL RESUME

C. RICHARD NEFF, M.S.
Staff Engineer/Project Manager

SPECIALIZATION

Water Quality, Hydrology, Environmental Engineering

RECENT EXPERIENCE

Environmental Audits and Records Search of U.S. Air Force Facilities, Project Team Leader--Onsite environmental surveys to assess current and past waste management practice activities at Air Force installations.

Environmental Audits and Records Search of U.S. Army Facilities, Project Team Engineer--Onsite environmental surveys to assess current and past waste management activities at military installations. Team engineer inspects industrial operations, POL storage and transfer facilities, wastewater treatment facilities, RCRA status, and central records.

Environmental Licensing Study for Peat-Harvesting Project, Project Manager--Georgia-Pacific Corporation's 5,600-acre proposed peat-harvesting project in north central Florida.

Environmental Assessment for Proposed Peat Synthetic Fuels, Project Engineer--Peat Methanol Associates proposed peat-to-methanol conversion facilities in North Carolina.

Environmental Assessments, Project Manager--Environmental assessment of a 50,000-acre development in central Florida and for a water quality baseline study for a 15,000-acre east central Florida development. Responsibilities included operation of the Soil Conservation Service's TR-20 and WSP-2 hydrological models; permit preparation for several FDER and Corps of Engineers wetlands permits and SFWMD surface water management permit.

NPDES Studies, Project Manager--NPDES permit compliance studies for Tampa Electric Company's three generating stations.

Water Quality Studies, Project Manager--Escambia River mixing zone and water quality analyses study for Monsanto Textiles Company. Water quality and nonpoint source pollution studies on Kiawah Island, S.C.

EDUCATION

M.S.	1978	Civil Engineering	University of Virginia
B.S.	1976	Environmental Engineering	University of Florida

PUBLICATIONS

Neff, C.R. 1978. Characterizing Urban Sediments, Presented at the Virginia Section of the Water Pollution Control Federation Conference; Roanoke, Virginia.

THOMAS L. CROSS

Senior Engineer/Manager

EDUCATION: B.S., Civil Engineering, West Virginia University
M.S., Civil Engineering, West Virginia University
Graduate Study in Business Administration, Georgia State University

PROFESSIONAL MEMBERSHIP: American Society of Civil Engineers

PROFESSIONAL REGISTRATION: Professional Engineer in Alabama, Georgia, South Carolina, Tennessee, and West Virginia

CAREER SUMMARY

Mr. Cross joined Law Engineering in 1973. He has served as a Soils Engineer, Hydrologist, and Project Manager in the Marietta, Georgia branch office. He is currently a Senior Engineer/Manager in the Waste Management Services Program. Mr. Cross provides a variety of geotechnical engineering and hydrologic services on projects throughout the southeastern United States. He has also managed many special multi-disciplined projects involving waste management and permitting.

WASTE MANAGEMENT EXPERIENCE

Mr. Cross has engineered several ground water quality assessments of existing waste management facilities owned and operated by chemical and manufacturing industries. Representative projects include the evaluation of ground water conditions beneath a hazardous waste landfill and lagoon in West Virginia, a series of lagoons in eastern Tennessee, and an area of sludge ponds and landfilled wastes in western Tennessee. Mr. Cross has also provided testing and evaluation services for a proposed hazardous waste landfill in eastern Georgia. A remedial action plan was developed for an Atlanta client to clean up an underground leak of diesel fuel. Recent projects have included engineering consultation and preparation of a Part B Application for a waste treatment and storage facility in Jacksonville, Florida. Recent geotechnical work has included investigations to develop hazardous and non-hazardous landfills for a chemical company. A lagoon closure evaluation has recently been performed for a metal fabricating facility in South Carolina.

DAVID E. BRUDERLY, M.S., P.E.
National Program Manager

ESE
PROFESSIONAL RESUME

SPECIALIZATION

Hazardous Waste Management, Spill Assessment and Control, Solid Waste, Water and Wastewater Management, Environmental Permitting, Hydrology, Hydrography

RECENT EXPERIENCE

Project Management--Directed or managed seven major projects with fees exceeding $3 million. Served as project manager or engineer for more than 40 waste management and water resources investigations.

National Program Manager for Hazardous Waste--Responsible for development and coordination of corporate hazardous waste program, including health and safety, personnel training, and emergency response programs. Senior investigator for feasibility, study, and remedial design projects.

Remedial Investigations/Feasibility Studies at 22 State Hazardous Waste Sites, Project Manager--Responsibilites include coordinating simultaneous activities of eight project teams while conducting site investigations, field sampling, analysis, and evaluation of remedial action alternatives for 22 sites. Project conducted for Florida Department of Environmental Regulation.

Feasibility Study of the Sapp Battery Salvage Site for Florida Department of Environmental Regulation, Project Manager--While conducting an assessment of site investigation results, ESE performed risk analysis, determined required remedial action, and evaluated restoration alternatives. In addition, ESE monitored cleanup activities.

Ground Water Contamination Assessment and Remedial Action, Project Manager--Conducted field investigations, geophysical investigations, ground water monitoring, and evaluated remedial action alternatives for abandoned hazardous waste site.

Immediate Emergency Response, Tyson's Dump, Norristown, Pennsylvania, Project Director--ESE designed, installed, and monitored a 40-gallon-per-minute packed tower air stripper and supplied it to EPA subcontractors for removal of hazardous organic contaminants. Contaminants removed included toluene, xylene, and 1,1,1-trichloropropane. System was online within 10 days after authorization to proceed.

Remote Sensing, Drum Location and Analysis for Uncontrolled Disposal Site, Project Director--Responsible for location of burned drums using remote sensing techniques; sampling and analyses of well samples during preliminary assessment, drum removal, aquifer pump tests, and post drum removal.

Hazardous Materials Assessment-Republic of Egypt--Directed USAID program to evaluate hazardous materials and wastes at free trade zones in Cairo, Alexandria, and Port Said. Recommended policies and procedures for management of hazardous wastes.

Utility Waste Landfill--Directed detailed site investigation (geophysics, borings, water quality). Conducted leachate simulation and EP toxicity tests and evaluated liner/capping performance using Prickett-Lonquist simulations to help assess leachate plume behavior. Developed capping and closure system design criteria in cooperation with State personnel to protect ground water resources.

Basinwide/Areawide Water Quality Management--Managed areawide water quality assessments for Tallahassee, Florida and Macon, Georgia and supported projects in Calcasieu River, Louisiana, Tampa Bay, Florida, and southwest Florida. Developed baseline water quality data and estimated point and nonpoint source loadings using simulation models calibrated with site data.

Waste Treatment and Disposal--Served as project engineer on industrial waste treatment and disposal projects in Illinois, Texas, Louisiana, New Jersey, Delaware, Alabama, and Florida. Worked with state and federal officials to obtain construction and operation permits for wastewater discharges and landfills.

Commercial Waste Treatment Firm, Project Engineer--Conducted site investigation and provided input to design modifications to hazardous waste treatment system.

Langollen County Landfill, Project Engineer--Designed outfall for leachate recovery and treatment system for uncontrolled site in sand borrow pits.

Galveston Landfill, Project Engineer--Conducted site investigations for expansion of the City of Galveston municipal landfill on Pelican Island, Tx.

Lockheed Development Systems, Project Engineer--Assessed technical and economic feasibility of ship and barge mounted waste treatment systems for the Houston region.

EDUCATION

M.S.	1971	Ocean Engineering	Columbia University
B.S.	1969	Marine Engineering	U.S. Merchant Marine Adademy

REGISTRATIONS

Professional Engineer, Florida

PUBLICATIONS

Ten technical publications and presentations in area of environmental management, liquid and solid wastes, site selection, water quality management.

THOMAS A. BRISLIN, B.S.C.E./B.S. ERM
Senior Associate Engineer

ESE
PROFESSIONAL RESUME

SPECIALIZATION

Environmental/Civil Engineering: Municipal and Industrial Wastewater Treatment Processes; Environmental Surveys, Audits, and Wastewater Treatment Plant System Analyses; PAC, Polyelectrolyte and Flocculant Applications; Solids Concentration and Sludge Dewatering, PCB/Transformer Decommissioning, Decontamination, and Disposal; Hazardous/Toxic Waste Management, Remediation, and Disposal Strategies including thermal destruction technologies

RECENT EXPERIENCE

<u>Conceived and Designed an Advanced Wastewater Treatment System for Toxic/Hazardous Waste, Design Engineer</u>--Researched alternative technologies and conducted treatability studies to ascertain the best demonstrated technology for treatment/removal/disposal of toxic organics, heavy metals, and high brine concentrations for a 70 MG lagoon and ground water insurgent wells.

<u>Assessment of Fugitive Air Emissions from Hazardous Waste Facilities, Project Engineer</u>--Developed worst-case scenarios for toxic air emissions from treatment/storage/disposal facilities to be used for modeling predictions.

<u>Plant Closures/Environmental Audits, Project Coordinator</u>--Surveyed and evaluated several industrial facilities for compliances with RCRA and state solid waste regulations and instituted any appropriate sampling/monitor programs or site remediation to achieve closure certification.

<u>Upgrading Biological Treatment Processes, Field Engineer</u>--Assisted more than 30 clients in conducting system analyses to optimize performance on biological activated sludge or biooxidation processes, and compiling an operations manual.

<u>Evaluation of PACT® Systems, Project Engineer</u>--Conducted several extensive surveys and troubleshooting missions to optimize performance of biological/carbon reactors to optimize performance of improving removal of toxic organics and heavy metal chelants.

<u>Optimization of Physical/Chemical Unit Processes for Wastewater Treatment Systems, Field Engineer</u>--Performed more than 100 surveys for various industrial clients to ascertain the best cost/performing treatment schemes and operations for a multitude of waste streams and unit processes, in the petrochemical, refinery, paper processes, primary metals, and mineral processing industries throughout various locations in the United States and the world.

<u>Participated in Several Superfund Emergency Response Cleanup Actions with the U.S. Environmental Protection Agency, Field Engineer</u>--Assisted as a subcontractor in several cleanups involving waste characterization, extent of contamination surveys, excavation, and disposal of contaminated soil in a secure landfill.

Environmental Audits/Electrical Contact Installments Resulting in Hazardous Waste Disposal Options, Project Manager--Conducted environmental audits and evaluated alternative treatment technologies to develop best management and disposal programs or plant closures. Sites included Eastern Plating, Martins Ferry, Ohio; GTE, Gibson Electrical Contacts, Delmont, Pennsylvania; BFG Electroplating, Punxatancy, Pennsylvania; and Westinghouse Corporation, East Pittsburgh and Beaver, Pennsylvania.

Assisted in Many Hazardous/Toxic Waste Remediation Projects, Project Engineer--Assisted in many cleanup projects ranging from emergency spills, PCB transformer decommissioning, to extensive lagoon remediation or drum excavation programs for industrial clients.

Research and Development of Innovative Chemical Treatments for Both Industrial and Toxic Wastewater, Project Manager--Participated in several projects to investigate and develop new treatment schemes and chemical aids for detoxification and clarification of wastewater. One such project resulted in a patented polyelectrolyte amphoteric emulsion effective for removal of emulsified oils and heavy metal, particularly in the steel industry.

Technology Training and Transfer Seminars, Instructor--Lectured in more than 30 seminars for operators, consultants, and industrial clients on various physical/chemical/biological unit processes in wastewater and hazardous waste management strategies for disposal/remediation/treatment and thermal destruction.

EDUCATION

B.S.	1979	Environmental Resource Management/Engineering	Pennsylvania State Univ.
B.S.	1981	Civil Engineering (credit towards M.S.C.E.)	Bucknell University
Graduate Studies	1982-1983	Mineral Processing	Pennsylvania State Univ. (Continuing Education Dept.)
Graduate Studies	1984-present	MBA Program (6 courses)	Duquesne University

AFFILIATIONS

Water Pollution Control Federation
American Society of Civil Engineers
American Institute of Mining, Metalurgical, and Petroleum Engineers
Toastmasters International
Hazardous Waste Management Association

PATENTS

New amphoteric flocculant emulsion pending permit (CAL-82/027)

SECURITY CLEARANCE

Class L security clearance from Dept. of Energy/Navy

ESE PROFESSIONAL RESUME

MEREDITH T. PARK, M.S.
Trace Metals Group Leader

SPECIALIZATION

Hazardous Waste Characterization, Water Chemistry, Trace Metals Analysis, Wastewater Treatment, Hazardous Waste Treatment

RECENT EXPERIENCE

Department of Defense (DOD) Installation Restoration Program (IRP), Project Manager--Responsible for project/task management as well as task technical support within the program structure. IRP is the DOD identification and control program for past hazardous materials released at military facilities under CERCLA.

Rocky Mountain Arsenal, Environmental Program, Task Manager-- Managing ongoing task involving analtyical methods development and subsequent analysis of environmental soil and sediment samples.

West Virginia Ordnance Works Environmental Survey, Task Manager--Managing ongoing 10,000-manhour comprehensive environmental contamination survey for the above CERCLA (Superfund) site, ranked 86th on the National Priorities List (NPL).

Sharpe Army Depot, Task Manager--Managing ongoing chemical analysis task for ground water contamination assessment.

Maxwell Air Force Base, Environmental Survey, Task Manager--Managing ongoing 1,000 manhour environmental survey involving analysis of surface water, sediments, and hazardous wastes.

Aberdeen Proving Ground Environmental Survey, Project Manager--Managed 1,500-manhour exploratory ground water and surface water contamination survey at Edgewood Arsenal, Maryland.

Volunteer Army Ammunition Plant, Task Manager--Managed chemical analysis task involving testing of ground waters and soil samples.

Hazardous Waste Characterization for RCRA Compliance, Project Manager--On-going project providing analytical services for clients filing applications or fulfilling monitoring program requirements for RCRA compliance.

EDUCATION

M.S.	1976	Chemical Oceanography	Old Dominion University
B.A.	1968	Chemistry	Duke University

AFFILIATIONS

American Chemical Society
American Society of Limnology and Oceanography

PUBLICATIONS

Co-authored water quality monitoring technical report.

ESE
PROFESSIONAL
RESUME

MICHAEL J. GEDEN, B.S.
Water Resources

SPECIALIZATION

Geophysical Investigation, Geologic Structure and Process, Geomorphology, Field Sampling and Techniques

RECENT EXPERIENCE

Ohio Superfund Site, Task Manager--Conducted a multitechnique geophysical survey at an abandoned hazardous waste site in northeastern Ohio. Also supervised installation of monitoring wells.

Solite Corporation, Project Geologist--Conducted a geophysical survey at a hazardous waste site in northeast Florida. Sampled surface and ground water and installed monitoring wells.

Pinellas County, Subproject Manager--Geophysical survey of refuse-to-energy plant and active landfills. Design and installation of ground water monitoring wells. Aquifer testing and analysis through use of single well slug tests.

Geophysical Investigations for Uncontrolled Disposal Site, Scientist--Conducted investigations to locate buried drums using remote sensing techniques. More than 1,000 drums were located and excavated.

Midwest Manufacturer, Project Scientist--Installation and sampling of ground water monitor wells to determine extent of ground water contamination. Aquifer testing and analysis through use of single well slug tests.

Florida Manufacturer, Associate Scientist--Conducted multitechnique geophysical survey. Design, construction, aquifer analysis, and sampling of ground water monitoring system to determine extent of subsurface contamination.

Aero Corportion, Associate Scientist--Construction, aquifer analysis, and sampling of ground water monitor wells to determine effectiveness of wastewater treatment process.

Ida-Con Corporation, Associate Scientist--Design, siting, construction, and sampling of ground water monitor wells to test effectiveness of surface water retention ponds.

Seminole Electric Cooperative, Project Scientist--Installation and aquifer testing of ground water monitor wells as part of siting study for new electric-generating station.

Alabama Army Ammunitions Plant Ground Water Monitoring, Associate Scientist--Installation, development, and sampling of ground water monitor wells and piezometric clusters.

Georgia Pacific, Associate Scientist--Installation and development of ground water monitor wells and piezometric transects in Santa Fe Swamp.

USATHAMA-Ft. Navajo, Ft. Wingate, Bluegrass, Phoenix, AAAP, Lima, and Savannah Army Depots, Associate Scientist--Compilation and preparation of field drilling data for entry into U.S. Army computer system.

General Electric Company, Project Scientist--Monthly sampling of ground water monitor wells to monitor integrity of surface chemical retention ponds.

EDUCATION

B.S.	1979	Earth Science	Northeastern Illinois University

CHARLES A. SPIERS
Project Hydrogeologist

EDUCATION:	B.S., Geology, University of South Carolina, 1965
PROFESSIONAL MEMBERSHIP:	American Institute of Professional Geologists (A.I.P.G.) President, Georgia Section, 1983 Member of Subcommittee on State Affairs National Water Well Association (NWWA)
PROFESSIONAL REGISTRATION:	Registered Professional Geologist, State of Georgia

CAREER SUMMARY

Mr. Spiers joined Law Engineering in 1981. He has served as a Project Hydrogeologist in Law's salt dome investigations for the Department of Energy. He has also evaluated contaminant movement in the ground water system at landfills, on industrial firms, and at hazardous waste sites. Before joining Law, he was with the Water Resources Division of the U.S. Geological Survey for 14 years where he was a Project Chief on various water-resources-related projects.

NUCLEAR WASTE SITE INVESTIGATIONS

Mr. Spiers has been a Project Hydrogeologist with Law Engineering for the Department of Energy's Gulf Coast Salt Domes Project. He characterized major aquifer systems with respect to geochemical facies and determined hydraulic characteristics of both fresh and saline aquifers near the domes. He wrote reports culminating major findings of these studies. While with USGS, he served as Project Chief on salt dome studies in Mississippi. In South Carolina he served as a Staff Hydrogeologist on the Bedrock Waste Storage Project at the Savannah River Plant.

REPRESENTATIVE HAZARDOUS WASTE PROJECTS

Staff Hydrogeologist for a study of the Old Inger hazardous waste site near Baton Rouge, Louisiana. The project involved supervision of monitor well construction, soil sampling, and an evaluation of the hydrogeology of the site with respect to the contaminant movement.

Project Hydrogeologist in a study of the hydrogeology of the Union Carbide plant at Columbia, Tennessee. The scope of the project was to determine the direction and rate of ground water flow and the occurrence of a contaminant in the ground water system at two seepage points along the Duck River. Data from a surface resistivity survey, river profiling, and 25 wells were used to recommend an interceptor well system to prevent the contaminant from reaching the river.

Project Hydrogeologist for a study of the Tuscaloosa aquifer system at Olin Chemicals near Augusta, Georgia. The project was to define the degree of hydraulic interconnection between the shallow aquifers and deeper Tuscaloosa aquifers near a proposed new hazardous waste landfill.

Project Hydrogeologist in a study which involved preparation of UIC and hazardous waste permits for storage of waste in Vinton Salt Dome, Louisiana. The scope of the project was to characterize the hydrogeology of the dome and surrounding sediments so that both an Underground Injection Control (UIC) permit and a Part "B" hazardous waste permit could be prepared.

Site Investigations Manager for a hydrogeologic characterization of CECOS International's hazardous waste site in Puerto Rico. The scope of the project was to characterize the hydrogeology of the site and provide the necessary data to design the hazardous waste facility. Field activities consisted of surface and borehole geophysics, geologic mapping, test drilling, piezometer installation, monitoring well installation and aquifer testing.

REPRESENTATIVE NUCLEAR WASTE ISOLATION PROJECT

Project Hydrogeologist assigned to the Gulf Coast Salt Dome Project. Responsible for analyzing and reporting the results from aquifer tests in deep test wells near salt domes; designing, drilling, and testing procedures for hydrologic investigations in the Mississippi Salt Dome Basin; and participating in location characterization planning for the next phase of the salt dome investigations in Mississippi.

KENNETH J. SEEFRIED, JR.
Senior Engineer

EDUCATION:	B.S.C.E., The Citadel, 1965 M.S.C.E., University of Kentucky, 1966
PROFESSIONAL MEMBERSHIP:	National Society of Professional Engineers American Society of Civil Engineers (Member)
PROFESSIONAL REGISTRATION:	Registered Professional Engineer in Georgia, Florida, and Mississippi

CAREER SUMMARY

Mr. Seefried joined Law Engineering in 1966. He has had extensive experience in the planning and execution of investigations for ground water studies, geologic and technical investigations and hazardous waste evaluations. Mr. Seefried has managed large interdisciplinary projects requiring the coordination of engineers, scientists, geologists, technicians, geophysicists, and laboratory personnel. Such projects have included the Metropolitan Atlanta Rapid Transit System. In addition to his management of these investigations, he has been the principal engineer in the evaluation and reporting phases of various projects.

REPRESENTATIVE HAZARDOUS WASTE PROJECTS

Project Engineer for closure of waste lagoons at a site near Morristown, Tennessee. Responsible for water quality assessment, water quality monitoring, Closure Plan, and implementation.

Principal Investigator for large plant near Atlanta, Georgia, following leakage of solvent to ground water. Responsible for establishing monitoring program, characterizing hydrogeology of site, performing pump test, and recommending cleanup alternatives.

Principal Investigator of landfill site (Superfund) in central Georgia for one of the possible responsible parties (PRPs). Evaluated all field data, determined hydrogeologic characteristics, analyzed chemical data, reviewed U.S. EPA RI/FS Draft Work Plan. Provided recommendations for rewrite of plan.

STEPHEN A. DENAHAN, P.G.
Department Head, Geology and Geophysics Department

SPECIALIZATION

Engineering Geology, Hazardous Waste Site Evaluation, Geophysical Techniques, Mineral Resource Evaluation

RECENT EXPERIENCE

Geologic Environmental Assessment of Army Facilities, USATHAMA, Field Geologist--Conducted records search and environmental survey of existing and past waste disposal sites at more than 30 installations, to identify potential contamination. Assessed geohydrology of potential contamination sites and identified pollutant migration pathways. Corrective measures to mitigate pollutant transport were developed.

Feasibility Study of the Sapp Battery Salvage Site for FDER, Project Geohydrologist--While conducting an assessment of site investigation results, ESE will perform risk analysis, determine required remedial action, and evaluate restoration alternatives. Critical concentrations will be set for air, soil, sediments, surface water, and ground water as a basis for determination of significant contamination.

Geophysical Investigations for Uncontrolled Disposal Site, Project Manager--Responsible for location of buried drums using remote sensing techniques. Sampling and analyses of well samples, drum removal, aquifer pump tests, and past drum removal.

Initial Installation Assessment, Naval Facilities, Team Geologist--Interdisciplinary team evaluated the potential for environmental contamination from past and present activities at U.S. Naval Bases. Sites include Charleston Navy Base, South Carolina; Sewell's Point Naval Complex, Norfolk, Virginia. Responsibilities included identification of contaminated areas and recommendation of specific monitoring programs.

Evaluation of Risk, Project Manager--An assessment of risk to structures from geologic hazards specifically sinkholes was conducted at a hazardous waste facility. Geophysical and aerial photographic methods were employed.

Assessment of Ground Water Contamination, Project Manager--Responsibilities included design and execution of a multi-technique geophysical survey and design of a ground water monitoring system at an industrial site.

Design and Installation of Ground Water Monitoring System at an Industrial Site, Subproject Manager--A monitoring system was designed and installed to bring site into compliance with local and state regulations at a site in North Carolina.

Evaluation of Geophysical Techniques for Detection of Subsurface Cavities, Subproject Manager--Conducted field evaluation of several surface-remote geophysical methods for cavity detection at several sites representing different geologic settings.

Well Field Siting Using Geophysical Techniques in a Karst Area--The study involved locating a test well field for 17 MGD withdrawal and to minimize the effect of ground water withdrawal on rivers and springs. These systems are hydraulically connected to the aquifer through the sinkhole system in the area.

EDUCATION

B.S. 1968 Geology University of Florida

REGISTRATION

Registered Professional Geologist in Indiana

APPENDIX C

SCOPE OF WORK AS OUTLINED BY OEHL

24 JUN 1985

INSTALLATION RESTORATION PROGRAM
PHASE II - CONFIRMATION/QUANTIFICATION (STAGE 1)
AIR FORCE PLANT 6 GEORGIA

I. DESCRIPTION OF WORK

The purpose of this task is to undertake a field investigation at Air Force Plant 6 GA (1) to determine the presence or absence of contamination within the specified areas of investigation; (2) if contamination exists, determine the potential for migration of those contaminants in the various environmental media; (3) identify additional investigations necessary to determine the magnitude, extent, direction and rate of migration of discovered contaminants; and (4) identify potential environmental consequences and health risks of migrating pollutants.

The Phase I IRP Report (mailed under separate cover) incorporates the background and description of the sites for this task. To accomplish this survey effort, the contractor shall take the following actions:

A. General

1. The contractor shall monitor all exploratory well drilling and borehole operations with a photo-ionization meter or equivalent organic vapor detection device to identify potential generation of hazardous and/or toxic materials. In addition, the contractor shall monitor drill cuttings for discoloration and odor. During drilling operations, if soil cuttings are suspected to be hazardous, the contractor will place them in proper containers and test them for EP Toxicity and Ignitibility. Results of monitoring shall be included in boring logs. A maximum of five samples shall be collected for EP Toxicity and Ignitibility testing.

2. All water samples collected shall be analyzed on site by the contractor for pH, temperature, and specific conductance. Sampling, maximum holding time, and preservation of samples shall strictly comply with the following references: Standard Methods for The Examination of Water and Wastewater, 15th Ed. (1980), pp. 35-42; ASTM, Section II, Water and Environmental Technology; Methods for organic Chemical Analysis of Municipal and Industrial Wastewater, EPA-600/4-82-057; and Methods for Chemical Analysis of Waters and Wastes, EPA Manual 600/4-79-020, pp. xiii ro xix (1979). All chemical analyses (water and soil) shall meet the required limits of detection for the applicable EPA method identified in Attachment 1.

3. Locations where sediment samples are taken, or where soil exploratory borings are drilled shall be marked with a permanent marker, and the location marked on a project map of the site.

4. Field data collected for each site shall be plotted and mapped. The nature, magnitude, and potential for contaminant flow within each zone to receiving streams and ground waters shall be estimated. Upon completion of the sampling and analysis, the data shall be tabulated in the next R&D Status report as specified in Item VI below.

5. Determine the areal extent of the sites by reviewing available aerial photos, both historical and the most recent panchromatic and infrared.

6. Split all water and soil samples as part of the contractor's specific Quality Assurance/Quality Control (QA/QC) protocols and procedures. One set of samples shall be analyzed by the contractor and the other set of samples shall be forwarded for analysis through overnight delivery to:

USAF OEHL/SA
Bldg 140
Brooks AFB TX 78235-5501

The samples sent to the USAF OEHL/SA shall be accompanied by the following information:

(a) Purpose of sample (analyte)

(b) Installation name (base)

(c) Sample number (on containers)

(d) Source/location of sample

(e) Contract Task Numbers and Title of Project

(f) Method of collection (bailer, suction pump, air-lift pump etc.)

(g) Volumes revomed before sample taken

(h) Special Conditions (use of surrogate standard, etc.)

(i) Preservatives used (indicate if non-standard)

This infromation shall be forwarded with each sample by properly completing an AF Form 2752 (copy of form and instruction on proper completion mailed under separate cover). In addition, copies of field logs documenting sample collection should accompany the samples.

Chain-of-custody records for all samples, field blanks, and quality control duplicates shall be maintained.

7. An additional 10% of all samples, for each parameter, shall be analyzed for quality control purposes, as indicated in Attachment 1.

8. For ground water monitoring wells, comply with the U.S. EPA Publication 330/9-S1-0002, NEIC Manual for Ground Water/Subsurface Investigators at Hazardous Waste Sites for monitoring well installation. Only screw type joints shall be used. Additionally, monitoring wells shall be constructed in accordance with guidelines in the Georgia Department of

Natural Resorces Circular No. 5, "Monitoring Well Construction for Hazardous Waste Sites in Georgia."

9. Wells shall be of sufficient depth to collect samples representative of aquifer quality and to intercept contaminants if they are present. Well development shall proceed until the discharge water is clear and free of sediment to the fullest extent possible.

10. Elevations of all newly installed monitoring wells shall be surveyed with respect to bench mark on base to an accuracy of 0.05 feet. Horizontally locate the new wells to an accuracy of 10 feet and record on site maps.

11. Water levels shall be measured at all contractor installed wells to the nearest 0.01 feet, and locations recorded on a project map and specific site maps. Three ground-water elevation measurements shall be made at each new monitoring well; one when the well is developed, the second during ground water sampling, and the third approximately 1 month after sampling.

12. All monitor wells shall be drilled using the following specifications:

a. Each well shall be drilled with a 8-inch outside diameter drill bit using hollow-stem auger equipment. Samples shall be taken for stratigraphic control purposes at approximately 5-foot intervals. Each pilot boring log and well completion summaries shall be included in the Final Report (as specified in Item VI below).

b. The average depth of each of these wells shall be 50 feet. A total of 6 wells shall be drilled; therefore, total footage of wells shall not exceed 310 linear feet. Each well shall be constructed of Schedule 40 PVC casing using threaded, non-glued fittings. Each well shall be screened to a maximum of 30 feet, resulting in a total screening of 180 feet. The screen shall consist of two-inch diameter, PVC with up to 0.010 inch slots. The screen shall be capped at the bottom. All connections shall be flush-joint threaded. Each well shall be gravel-packed with washed and bagged rounded sand or gravel with a grain size distribution compatible with the screen and the formation. The pack will be emplaced from the bottom of the borehole to 5 feet above the top of the screen. Granulated or pelletized bentonite shall be tremied above the sand/gravel pack to a minimum thickness of three feet. Gelcement grout shall be emplaced from above the top of the bentonite seal to the land surface. Each well shall be completed with installation of a cap and locking hasp and shall be clearly numbered with an exterior paint.

13. Each well shall be developed using either a gasoline driven surface pump and hose or a 1-inch PVC pipe and foot valve until clean of suspended solids.

14. Wells shall be purged prior to sampling. Purging will be complete when three well volumes of water have been displaced or until the

pH, temperature, specific conductance, color, and odor of the discharge is noted to stabilize. Purging operations shall be conducted using a stainless steel or PVC bottom-discharge bailer or bladder pump. All sampling shall be conducted using a PVC bailer or bladder pump. As the first step of ground-water sampling operation at each well, water level measurements shall be taken to the nearest 0.01 foot with respect to an established surveyed mark-point on top of the well casing.

15. Shallow soil augering will be performed using a hand auger.

16. Attachment 3 summarizes sampling activities at all sites.

B. In addition to items delineated in A above, conduct the following specific actions at the following sites on AF Plant 6:

1. There are numerous sites under active study by Lockheed. These sites include the Surface Impoundment, B-10 Aeration Basin, Position 65 (C-5 Wash Rack), TCE Spill, JP-5 Fuel Spill No. 2, Past Landfill, Bldg. B-96, and Sanitary WWTP Sludge Disposal Area. The results of the studies on these sites shall be reviewed as follows:

a. Obtain, review, and analyze the reports of ongoing studies currently being conducted through Lockheed. Geologic and ground-water elevation data shall be analyzed to define the hydrogeologic conditions at the site. Groundwater quality data shall be analyzed to determine any statistical relationship between the various wells and public health, and regulatory implications of the data.

b. Hydrogeologic models (in the form of subsurface profiles) shall be prepared to aid in the characterization of the site.

2. Site 5, Stormwater Retention Basin No. 2

a. Perform 1 soil test boring to a depth not exceed 60 feet.

b. Collect 12 split spoon samples. Two of the samples shall be selected for classification testing according to ASTM procedures.

c. Collect 1 undisturbed soil sample and test for permeability and classification.

d. Complete the boring as a ground-water-quality monitoring well.

e. The well shall be sampled and analyzed for the parameters listed in Attachment 2.

f. Prepare hydorgeologic models (in the form of subsurface profiles) to aid in the characterization of the site.

3. Site 12, Sodium Dichromate Spill

a. Collect 3 sediment samples in the drainage ditch at 100 foot intervals begining at the spill site and continuing downstream. Samples will be a composite of the upper 6 inches of sediment. Samples shall be analyzed for leachable chromium, using the EP Toxicity Test Method.

b. Conduct EM-31 profiling with shallow resistivity soundings to locate the horizontal extent of the contaminated soil, if present.

c. Perform 4 soil test borings. Total footage of borings shall not exceed 200 feet.

d. Collect 40 split spoon samples. Eight of the samples shall be selected for classification testing according to ASTM procedures.

e. Collect 4 undisturbed soil samples. One of the samples shall be tested for permeability and classification.

f. Complete each boring as a ground-water-quality monitoring well.

g. Each well shall be sampled once, for a total of 4 samples. Analyze the samples for the parameters listed in Attachment 2; additionally, analyze each sample for chromium.

h. Prepare hydorgeologic models (in the form of subsurface profiles) to aid in the characterization of the site.

4. Site 10, JP-5 Fuel Spill No. 2: An OVA soil survey shall be performed to locate any contaminated soil.

5. Site 2, Existing Landfill

a. Conduct EM-31 profiling with shallow resistivity soundings to locate the leachate plume, if present.

b. Perform 1 test boring. Total footage of borings shall not exceed 50 feet.

c. Collect 10 split spoon samples. A maximum of 2 of the samples shall be selected for classification testing according to ASTM procedures.

d. Collect 1 undisturbed soil sample and test for permeability and classification.

e. Complete the boring as a ground-water-quality monitoring well.

f. The well shall be sampled once and analyzed for the parameters listed in Attachment 2.

g. Prepare hydrogeologic models (in the form of subsurface profiles) to aid in the characterization of the site.

6. Site 11, JP-5 Spill Site No. 1: Take 1 soil sample from the spill site area and analyze it for petroleum halocarbons.

7. Perform a screening parameter validity test to test the validity of the water-quality parameters used in Phase II, Stage 1 as screening parameters. This testing shall be conducted as follows :

a. Ground-water-quality data from the on-going studies at Air Force Plant 6 will be reviewed.

b. Five monitor wells installed under this contract shall be selected which range from high to low levels of chlorinated hydrocarbon solvent contamination for the testing.

c. Contractor shall coordinate with AF Plant 6 contractor's current well sampling/analysis to split water-quality samples with the contractor during one of his regularly scheduled sampling episodes.

d. Contractor shall analyze the samples for the parameters listed in Attachment 2 and compare these results with historical data from the well and specific parameters analyzed by the contractor.

e. Results of these analyses shall be reduced and sent to OEHL in the current R&D Status report.

8. Distributed Computing Model Application

a. Translate the Prickett-Lonnquist Aquifer Simulation Model (PLASM) ground-water flow model and the Prickett-Naymik-Lonnquist (1981) Random Walk Solute Transport Model for operation on USAF compatible microcomputers.

b. Provide all necessary software and documentation of the above models and data base (Item VI).

c. Provide a microcomputer based Data Management System (DMS) to be used for data reduction/analysis and data archival for all on-going studies. The following data shall be included in the system: Soil boring logs, well construction details, and chemical analysis data for each site. Outputs from the system shall include: well logs, lithologic cross-sections, contour maps, and tabulated analytical data in camera ready format.

d. Conduct ground-water modeling for the various contaminated sites using the above models to estimate ground-water flow directions, contaminant transport pathways and plume configurations/concentrations.

e. Provide a separate report addressing this modeling effort (Item VI, Sequence 4).

C. Well and Borehole Cleanup

All well and boring area drill cuttings shall be removed and the general area cleaned following the completion of each well and boring. Only those drill cuttings suspected as being a hazardous waste (based on discoloration, odor, or organic vapor detection instrument) shall be properly containerized by the contractor for disposal. The suspected hazardous waste shall be tested by the contractor for EP Toxicity and Ignitibility. The contractor is not responsibile for ultimate disposal of the drill cuttings. Disposal will be conducted by Lockheed personnel.

D. Data Review

Results of sampling and analysis shall be tabulated and incorporated in the Informal Technical Information Report (as specified in Item VI below) and forwarded to the USAF OEHL for review. Results shall also be forwarded as available in the next monthly R&D status report.

E. Reporting

1. A draft delineating all findings of this field investigation shall be prepared and forwarded to the USAF OEHL (as specified in item VI below) for Air Force review and comment. This report shall include a discussion of the regional/site specific hydrogeology, well and boring logs, data from water level surveys, ground-water surface and gradient maps, water quality and soil analysis results, available geohydrologic cross sections, and laboratory quality assurance information. The report shall follow the USAF OEHL supplied format (mailed under separate cover).

2. The recommendation section will address each site and list them by categories. Category I will consist of sites where no further action (including remedial action) is required. Data for these sites is considered sufficient to rule out unacceptable health or environmental risks. Category II sites are those requiring additional monitoring or work to quantify for further assess the extent of current or future contamination. Category III sites are sites that will require remedial actions (ready for IRP Phase IV actions). In each case, the contractor will summarize or present the results of field data, environmental or regulatory criteria, or other pertinent information supporting these conclusions.

F. Meetings

The contractor's project leader shall attend two meetings with Air Force headquarters and regulatory agency personnel to take place at a time to be specified by the USAF OEHL. The meeting shall take place at Air Force Plant 6 GA for a duration of two days (16 hours).

II. Site Location and Dates:

Air Force plant 6 GA
Date to be established

TABLE 1

Analytical Methods, Detection Limits and Number of Samples
(For Water Unless Otherwise Shown)

Parameter	Method	Detection Limit	Total Number Samples	QA	Total Sample
[a]Total Organic Carbon (TOC)	epa 415.1	1000 ug/L	11	2	13
Total Organic Halogens (TOX)	EPA 9020	5 ug/L	11	2	13
Oil and Grease (using IR)	EPA 413.2	100 ug/L	11	2	13
Petroleum Halocarbons	EPA 418.1	100 ug/g soil	1 Soil	0 soil	1 soil
Chromium	EPA 218.1	50 ug/L	4	0	4
Leachable Chromium	EPA 1310	50 ug/L	3 soil	0 soil	3 soil
pH	EPA 150.1	-	11	-	11
Specific Conductance	EPA 120.1	1 umho/cm	11	-	11
EP Toxicity	EPA 1310	b	3 soil	2 soil	5 soil
~~Ignitibility~~	~~EPA 1010~~	c	~~5 soil~~	~~1 soil~~	~~6 soil~~
Purgeable Hydrocarbons	EPA 601	d	5 grndwtr	2 grndwtr	7 grndwtr

a Detection limit for TOC must be 3 times the noise level of the instrument. Laboratory distilled water must show no response; if it shows a response, corrections for positive results must be made.

b

Metal	ug/L of solution
As	10
Ba	200
Cd	10
Cr	50
Pb	20
Hg	1
Se	10
Ag	10

c Find if sample is ignitible at 140 degrees Farenheit or below. If so, it is a hazardous waste.

d Detection limits for Volatile Organic Compounds shall be as specified for the compounds by EPA Method 601. Method 601 for volatile organic compounds requires positive confirmation by second chromatograhic columns. This must be done before reporting the positive values. Method 601 specifies the two columns to use. Second column confirmation is required where values exceed [illegible]

Attachment 2

LIST OF ANALYTICAL PARAMETERS AT AIR FORCE PLANT 6

Oil and Grease (O & G)
Total Organic Carbon (TOC)
Total Organic Halogens (TOX)
pH
Specific Conductance

Attachment 3

Site Sampling and EM-31 Profiling Summary

SITE	OVA SOIL SURVEY	WELLS (#, total ft.)	EM-31 PROF.	SPLIT SPOONS	UNDIST. SAMPLES	WATER * SAMPLES	SOIL * SAMPLES
Site 5, Stormwater Retention Basin No. 2		1,60		12	1	1	
Site 12, Sodium Dichromate Spill		4,200	X	40	4	4	3
Site 10, JP-5 Fuel Spill No. 2	X						
Site 2, Existing Landfill		1,50	X	10	1	1	
Site 11, JP-5 Spill Site No. 1							1
Screening Parameter Validity Test						5	
Drill Cuttings							5

* Excluding quality control samples.

III. BASE SUPPORT: None

IV. GOVERNMENT FURNISHED PROPERTY: None

V. GOVERNMENT POINTS OF CONTACT:

1. Maj George New
USAF OEHL/TSS
Brooks AFB TX 78235-5501
(512) 536-2158
AV 240-2158

2. Mr Joe Caldwell
AFPRO/PD
Chief, Manufacturing Assy Br
Lockheed-Georgia Co
Marietta, GA 30063
(404) 424-5480

3. Col Paul Fallon
HQ AFSC/SGPB
Andrews AFB DC 20334-5000
(301) 981-5235
AV 858-5235

VI. In addition to sequence numbers 1, 5, and 11 in Attachment 1 to the contract, which are applicable to all orders, the sequence numbers listed below are applicable to this order. Also shown are data applicable to this order.

Sequence No.	Block 10	Block 11	Block 12	Block 13	Block 14
3 (Atch 1)	O/Time	*	*		
4 (Atch 1)	One/R	85 Aug 09	85 Aug 09	85 Nov 12	**
1 (Atch 2)	O/Time	NA	85 Oct 31	85 Nov 12	1
2 (Atch 2)	One/R	NA	85 Oct 31	85 Nov 29	3

*Upon completion of analytical effort before submission of 1st draft report.

**Two draft reports will be required. After incorporating Air Force comments first draft report, the contractor shall supply the USAF OEHL with one copy of the second draft report. Upon acceptance of the second draft, the USAF OEHL will furnish a distribution list for the remaining 24 copies of the second draft. The contractor shall suppply 50 copies plus the original camera ready copy of the final report.

APPENDIX D

QUALITY ASSURANCE PLAN

APPENDIX D

QUALITY ASSURANCE PLAN

The purpose of the Quality Assurance (QA) Plan is to provide processes for controlling the validity of the data generated in all phases of the sampling and analysis efforts proposed under the scope of work. The procedures detailed as follows describe the general methodologies during the study and when implemented will provide documentation of the individual work elements and mechanism by which "data gaps" can be controlled. It should be noted that procedures outlined below may not apply to all circumstances which may arise during the course and scope of the study. Deviation from these procedures will be noted in the field logbooks and discussed with USAFOEHL personnel to determine corrective actions.

Two types of audit procedures will be used by QA to assess and document performance of project staff--system audits and performance audits. These are performed at frequent intervals under the direction of the Project QA Supervisor. These audits form one of the bases for corrective action requirements and constitute a permanent record of the conformance of measurement systems to QA requirements.

System audits are inspections of training status, records, Quality Control (QC) data, calibrations, and conformance to Standard Operating Procedures (SOPs) without the analysis of check samples. System audits will be performed periodically on laboratory and office operations or on field operations. The development and approval of the project Work Plan constitutes the initial system audit for this study.

The systems audit protocol is summarized as follows:

1. Field Operations--The Project QA Supervisor will periodically check:

a. Field notebooks, logsheets, bench sheets, tracking forms, and report any inconsistencies and/or omissions;

b. Field sampling plans; and

c. Sample site briefing package.

2. Laboratory Operations--The Project QA Supervisor will periodically check:

a. Parameter and/or laboratory notebooks;

b. Instrument logbooks;

c. Sample log-in, dispensing, and labeling for analysis;

d. Updating of QC criteria for spike recoveries; and

e. Final approval of data from each sample lot.

In addition, the Project QA Supervisor will monitor all analyses to assure complete adherence to approved analytical methods.

3. Final Reports--The Project QA Supervisor will review all final reports and deliverables to USAFOEHL.

Performance audits will include evaluation and analysis of check samples. A performance evaluation sample from EPA will be analyzed periodically along with the regular samples.

ESE's laboratory is certified for drinking water analysis by the Florida Department of Health and Rehabilitative Services according to the regulations set forth under the Florida Safe Drinking Water Act (Chapter 403.863, F.S.). ESE is also certified by the National Institute for Occupational Safety and Health (NIOSH) through their NIOSH Proficiency Analytical Testing (PAT) Program.

ESE routinely participates in performance test sample programs administered by:

1. EPA, EMSL-CI;
2. EPA, EMSL-RTP;
3. EPA, Region IV;
4. Florida Department of Environmental Regulation;

5. Florida Department of Health and Rehabilitative Services;
6. Alabama Department of Health;
7. U.S. Army Corps of Engineers, South Atlantic Division; and
8. American Industrial Hygiene Association (ESE is an AIHA-accredited laboratory).

The results of these interlaboratory studies will be periodically evaluated by the Project QA Supervisor during the project as part of the performance audits.

D.1 WELL DRILLING

Prior to drilling any test borings and installing any monitoring wells, each proposed drilling location will be cleared with facility engineering departments to avoid drilling into buried cables, pipes, etc. Facility engineering will approve all locations. If required, appropriate drilling permits will be acquired.

Each well will be fully described on a well log as it is being drilled. Transcription of the log from a field notebook to log form will not be permitted. Upon completion of each well, information from the well logs will be transferred to OEHL. Data included in the logs are listed below:

1. Depths will be recorded in feet and fractions thereof.
2. Soil descriptions, in accordance with the Unified Soil Classification System, will be prepared in the field by the Site Geologist.
3. Soil samples will be fully described on the log. For split-spoon samples, the description will include:
    a. Classification,
    b. Unified Soil Classification System symbol,
    c. Secondary components and estimated percentage,
    d. Color,
    e. Plasticity,
    f. Consistency (cohesive soil) or density (noncohesive soil),

g. Moisture content, and
h. Texture/fabric/bedding.

Cutting descriptions will include basic classification, secondary components, and other parameters that are apparent.

4. Numerical, visual estimates will be made of secondary soil constituents. If terms such as "trace," "some," or "several" are used, their quantitative meanings will be defined in a general legend.
5. The length of sample recovered for each sampled interval for drive (split-spoon) samples will be recorded.
6. Blow counts, hammer weight, and length of fall for split-spoon samples will be recorded.
7. Rock core, if obtained, will be fully described on the log. Core description will include:
   a. Classification by rock type,
   b. Lithologic characteristics,
   c. Bedding characteristics,
   d. Color,
   e. Hardness,
   f. Degree of cementation,
   g. Texture,
   h. Structure,
   i. Degree of weathering,
   j. Solution or void conditions,
   k. Primary and secondary permeability estimates and rationale, and
   l. Length of core recovered and rock quality designation (RQD).
8. The estimated interval for each sample will be specified.
9. Depth to water will be indicated along with the method of determination, as first encountered during drilling. Any distinct water-bearing zones below the first zone also will be noted.

10. When drilling fluid is used, fluid losses, quantities lost, and the intervals over which they occur will be recorded.
11. The drilling equipment used will be described generally on each log, including such information as rod size, bit type, pump type, rig manufacturer, and model.
12. The drilling sequence will be recorded on each log.
13. All special problems will be recorded.
14. The dates for the start and completion of all borings will be recorded on the log.
15. Lithologic boundaries will be noted on the boring log.
16. The boring logs will be submitted to the OEHL within 10 working days after each individual boring is completed. In cases where a monitoring well is inserted into the boring hole, both the log for that boring and the installation sketch will be submitted within 10 working days.

Evaluation of the existing geologic and geohydrologic data at Air Force Plant 6 indicates that the six ground-water-sampling wells to be installed may be screened totally within a saturated-soil column, within a saturated-soil column and the uppermost fractured bedrock, or totally within the fractured bedrock. The screened interval will be determined by evaluation of the geologic data obtained during the drilling operations.

Fig. D-1 shows typical well configurations for overburden (i.e., soil) monitoring wells. The placement of the well screen in the saturated soil and/or uppermost bedrock will be determined in the field by the Site Geologist and will depend on the depth where ground water was encountered during the drilling process. The wells finished in the bedrock will be screened at a discrete depth interval within the bedrock. This interval will be determined by the water levels measured in the boreholes, the presence of fractures in the core samples, and/or permeable zones.

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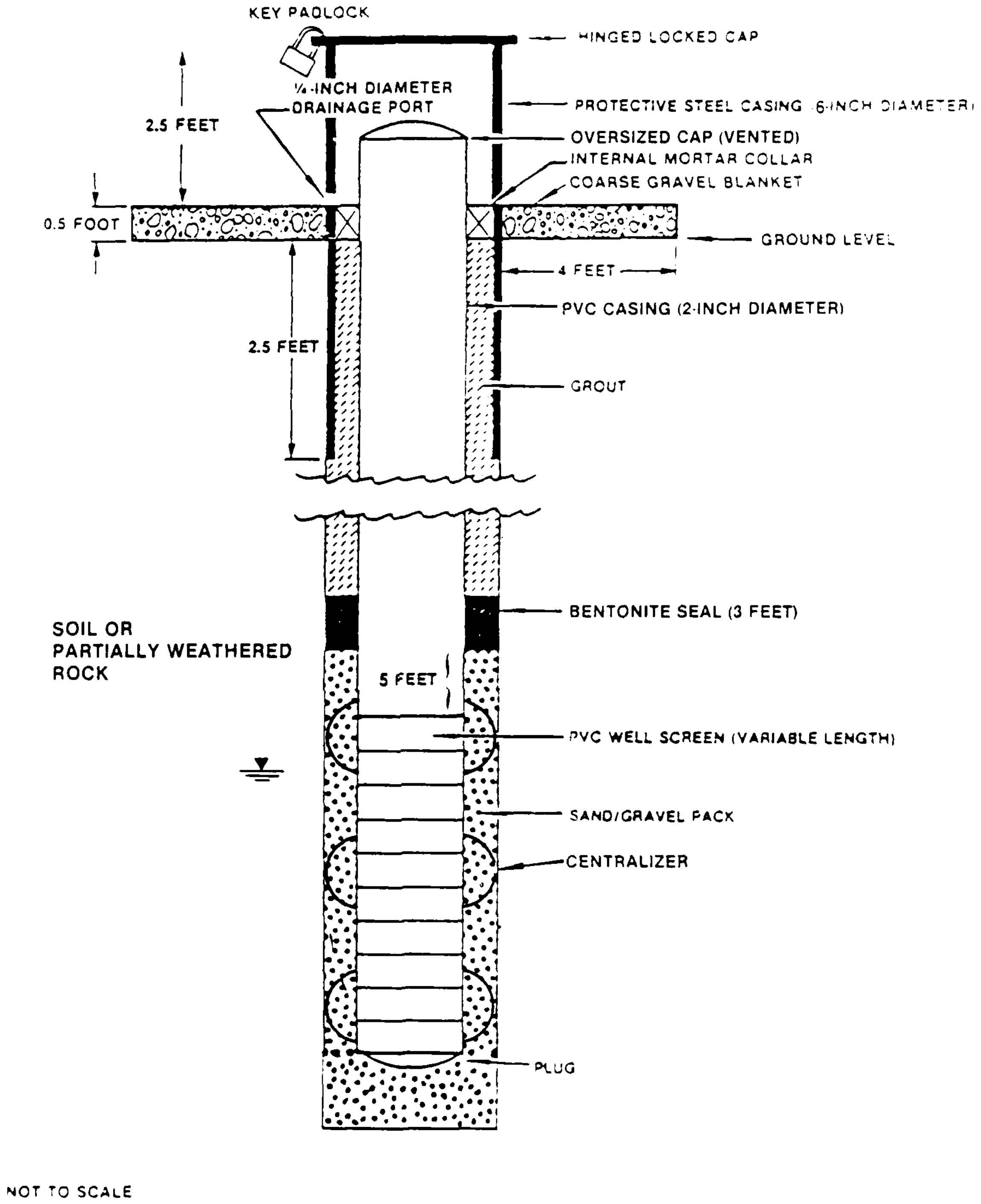


Figure D-1
TYPICAL MONITOR WELL CONSTRUCTION

SOURCE: ESE, 1984.

INSTALLATION
RESTORATION PROGRAM
Air Force Plant 6

When a boring is completed, the Site Geologist will visually inspect the hole to ensure plumbness and cleanliness. Plumbness will be obtained by careful leveling of the drill rig prior to commencement of the drilling. Additionally, the drilling will proceed in an efficient and controlled manner to eliminate wobble/chatter in the drill stem.

All well installations will begin within 48 hours of boring completion, and, once begun, will continue until completion. The well screen and casing will be carefully cleaned with base-supplied potable water from an approved source prior to installation in the hole. All well screens will have a solid bottom. Solid casing will extend from the screen to approximately 2 feet (ft) above land surface.

Centralizers and filter material will be installed around the well screen to approximately 5 ft above the well screen. As the 3-ft bentonite seal is placed on top of the filter material, water from the approved source will be added when necessary to assure that the pellets expand to form a tight seal.

The gel-cement grout seal will extend from the top of the bentonite seal to the land surface. Grouting will be completed as a continuous operation in the presence of the Site Geologist. The grout will be pumped into the annular space under pressure using a tremie pipe or hose placed above the top of the bentonite seal to ensure a continuous grout seal. The protective casing will be sealed in the grout. A coarse gravel pad, 0.5-ft thick, extending 4 ft radially from the protective casing, will be placed at each monitoring well.

The following materials will be used in well construction:

1. Casing used in the well will be threaded PVC Schedule 40, 2-in nominal inside diameter (I.D.). No PVC solvent will be used. The well screen will be factory slotted, with a slot width of 0.010 in.

2. Grout will be composed by weight of about 10 parts portland cement to one-half part bentonite, with a maximum of about 10 gallons (gal) of approved water per 94-pound (lb) bag of cement. Bentonite will be added after mixing of the cement and water.
3. Bentonite pellets used in the seal will be a commercially available product designed for well-sealing purposes.
4. Sand material used in the filter envelope around the well screen will be selected to be compatible with both the screen slot size and aquifer materials.
5. A 6-in protective steel casing will be installed around each well. This casing will extend approximately 2.5 ft above land surface and will be seated 2.5 ft into the well seal grout. This casing will be vented to the atmosphere via a lockable, hinged cap. This cap will prevent entry of water but will not be airtight. This way the well will be in open connection to the atmosphere to allow for water level stabilization. A 1/4-in diameter drainage port will be drilled about 1/2 in above the level of the internal monitor collar. The same key will be used for all padlocks at the site.
6. A sketch of the well installation will be included on the boring log and show, by depth, the bottom of the boring, screen location, granular backfill, seals, grout, cave-in, and height of riser above ground surface. The actual composition of the grout, seals, and granular backfill will be recorded on each sketch.
7. Well sketches will include the protective casing detail.
8. After the grout seal has set (approximately 24 hours), it will be checked for settlement, and additional grout (of approved composition) will be added to fill any depressions.

D.2 WELL DEVELOPMENT

The initial development or the purging of drilling fluid from monitoring wells will be recorded and submitted to the OEHL within 10 working days after development. The development will be performed, as soon as practical, after well installation. The following data will be recorded for development:

1. Well designation;
2. Date of well installation;
3. Date of development;
4. Static water level before and 24 hours after development;
5. Quantity of water loss during drilling and fluid purging, if water is used;
6. Quantity of standing water in well and annulus (30 percent porosity assumed for calculation) prior to development;
7. Specific conductivity, temperature, and pH measurements taken and recorded at the start, twice during, and at the conclusion of development. Calibration standards were run prior to and after each day's operation in the field;
8. Depth from top of well casing to bottom of well;
9. Screen length;
10. Depth from top of well casing to top of sediment inside well, before and after development;
11. Physical character of removed water, including changes during development in clarity, color, particulates, and odor;
12. Type and size/capacity of pump and/or well development equipment used;
13. Description of surge technique, if used;
14. Height of well casing above ground surface; and
15. Quantity of water removed and time for removal.

Development of wells will be accomplished using either a gasoline driven surface pump and hose or a 1-in PVC pipe and foot valve. The hose from the pump or PVC pumping equipment will be cleaned and rinsed with the approved drilling water prior to use in the next well.

Well development will begin no sooner than 48 hours after completion of the mortar collar placement. Development will proceed until the following conditions are met:

1. The well water is reasonably clear to the unaided eye,
2. The sediment thickness remaining in the well is less than 5 percent of the screen length,
3. At least 5 well volumes (including the saturated filter material in the annulus) have been removed from the well.

A 1-pt sample of the ground water obtained from the development process for each well will be obtained and stored so as not to freeze. The cap and all internal components of the well casing above the water table will be rinsed with well water to remove all traces of soil/sediment/cuttings. This washing will be conducted before and/or during development.

D.3 WATER-LEVEL MEASUREMENTS

All water-level measurements at the various wells at Air Force Plant 6 will be obtained using the USGS wetted-tape method. This procedure is accurate to 0.01 ft. The tape will be rinsed with water from the approved source, wiped with a fresh cloth, and allowed to air dry between consecutive water-level measurements.

At least one complete set of static water level measurements for all wells considered in this study will be made over a single, consecutive 10-hour period.

D.4 SAMPLING AND ANALYSES

D.4.1 GROUND WATER SAMPLING

Ground water sampling at Air Force Plant 6 will begin after the new monitor wells have been allowed to reach equilibrium (no less than 7 days after well development). The following procedures will be followed on the day of sampling:

1. The depth to water will be measured from the top of casing.
2. The well depth will be sounded and recorded. The depth of the water in the well will be calculated.
3. Samples will be taken after the fluid in the screen, well casing, and saturated annulus has been exchanged at least three times. In the event of low well yields (e.g., in the presence of fine-grained sediments and/or limited bedrock fracturing), some wells may have slow recovery rates. A decision to reduce the well purging to less than three volumes will be recommended by the Sampling Team Leader, only if excessive time would elapse attempting to collect one or two samples from low-yielding wells. This decision will be subject to approval by OEHL. The amount of fluid purge will be measured and recorded. Conductivity, pH, and temperature will be measured at the start, once during, and at the end of the fluid purging procedure. This data will be forwarded to the Contracting Officer at the end of sampling. Sampling will be accomplished by a bailer constructed of inert materials (PVC). No glue will be used in the construction of these bailers.
4. To protect the wells from contamination during sampling procedures, the following guidelines will be followed:
    a. A separate bailer will be supplied for each. If the wells are resampled, new bailers will be supplied for each well to preclude contamination of the original bailer during storage.
    b. If a pump is used to purge the standing water from the well, the pump and the hoses will be thoroughly cleaned between the samples, using the approved drilling water source. All sampling, however, will be performed by the dedicated bailer.
    c. All sampling equipment will be protected from ground water contact by polyethylene plastic sheeting to prevent soil contamination from tainting the ground water samples.

5. Onsite measurements of water quality obtained during the sampling trip will consist of conductivity, temperature, and pH. These data will be presented in the final report for the phase in which they were measured. Calibration standards will be run and recorded prior to, during, and after each sampling day.

Inert threaded PVC well casings will be used in this program. Adsorption of certain compounds on the plastic surface may affect the apparent ground water concentration. However, the following precaution will be taken to minimize adsorption of analytes by PVC. Each well will be purged and then sampled as soon as sufficient water returns. In this manner, the contact time between the water sample and the PVC will be kept to the shortest possible period.

During the sampling of each monitor well, information regarding the sampling will be kept in a notebook. The following data will be collected:

1. Well number;
2. Date;
3. Time;
4. Static water level;
5. Depth of well;
6. Number of bailer volumes removed, if applicable;
7. Pumping rate, if applicable;
8. Time of pumping, if applicable;
9. Drawn down water level;
10. In situ water quality measurements such as pH, specific conductance, and temperature;
11. Fractions sampled and preservatives;
12. Weather conditions and/or miscellaneous observations; and
13. Signature of sampler and date.

Samples will be collected in a manner which will minimize its aeration and prevent oxidation of reduced compounds. The containers for metals, phenols, cyanide, and extractibles (as appropriate) will be filled until they overflow and then tightly capped. For volatiles, the bottles will be checked to verify that no air has been entrained. Volatile samples will be collected in duplicate directly from the bailer at each well and placed in the canisters containing activated carbon provided to prevent contamination. If a volatile bottle is contaminated by dropping the septum or touching the septum or lips of the bottle, it will be discarded and a clean bottle issued and labeled. <u>Under no circumstances will volatile fractions be transferred from other sampling containers.</u>

Nitric acid and/or sulfuric acid preservation performed in the field will be carried out under conditions of adequate ventilation to prevent potential release of hydrogen cyanide. Care will be taken to ensure excess acid is not added. The pH will be tested using colorpHast® indicator sticks on the waste portions of each fraction.

Each sample will be carefully labeled so it can be identified by laboratory personnel. The sample label will include the project number, sample number, time and date, and sampler's initials. All samples will be identified with non-water-soluble ink on a standard preprinted and prenumbered label immediately after collection. Information concerning preservation methods, matrix, and sample location will be included on the label. Samples will be shipped in styrofoam ice chests and will be kept below 4°C from time of sample collection until analysis.

D.4.2 SURFACE WATER SAMPLING

Prior to surface water sampling, the following data will be noted and recorded in the field notebook:

1. Site number or location;
2. Date;
3. Time (24-hour system);
4. Antecedent weather conditions, if known;

5. *In situ* parameter measurements (temperature, conductivity, and pH);
6. Fractions and preservatives;
7. Any other pertinent observations (odor, fish, etc.); and
8. Signature of sampler and date.

At the conclusion of each day in the field, the Sampling Team Leader will review each page of the notebook for errors and omissions. He/she will then date and sign each reviewed page.

All field instrument calibrations will be recorded in a designated portion of the notebook at the time of the calibration. Adverse trends in instrument calibration behavior will be corrected.

The sample will be collected in a manner which will minimize its aeration and prevent oxidation of reduced compounds in the sample. The container will be filled until it overflows without air bubbles and then tightly capped. Special attention will be given to minimize air contact with the water sample. Sampling procedures and precautions for the volatile fraction collection are identical to the ground water procedures.

Each sample will be carefully labeled so it can be identified by laboratory personnel. The sample label will include the project number, sample number, time and date, and sampler's initials. All samples will be identified with non-water-soluble ink on a standard preprinted and prenumbered label immediately after collection. Information concerning preservation methods, matrix, and sample location will be included on the label. Samples will be preserved as described in the Ground Water Section. Samples will be shipped in styrofoam ice chests and will be kept below 4°C from time of sample collection until analysis.

D.4.3 SOIL AND SEDIMENT SAMPLING

Prior to soil and/or sediment sampling, the following data will be noted and recorded in the field notebook:

1. Site number, location, or designation;
2. Date;
3. Time (24-hours system);
4. Antecedent weather conditions, if known;
5. Any other pertinent observations (e.g., vegetation, substrate characteristics, etc.); and
6. Signature of sampler and date.

At the conclusion of each day in the field, the Sampling Team Leader will review each page of the notebook for errors and omissions. He/she will then date and sign each reviewed page.

D.4.4 SOIL SAMPLING

1. Prior to sampling, surface vegetation, rocks, leaves, and debris will be removed.
2. Appropriate point sampling or compositing techniques, as defined in the project sampling plan, will be used to ensure that the sample is representative of the area sampled and the type of information (e.g., depth of contamination) desired.
3. Soil samples will be placed in a glass wide-mouth jar with Teflon®-lined lid. Sample containers will be labeled with a preprinted label, chilled to 4°C, and shipped to the laboratory for analysis. Sampling equipment will be thoroughly cleaned between sampling locations with water from an approved source.
4. Sampling equipment will be rinsed and scrubbed with acetone and hexane after the water rinse and allowed to air dry. The acetone and hexane rinses will not be allowed to contaminate the ground or samples.
5. If a composite sample is required, a suitable compositing technique, such as that shown in Fig. D-2, will be used. Each composite soil sample will consist of a homogenized composite

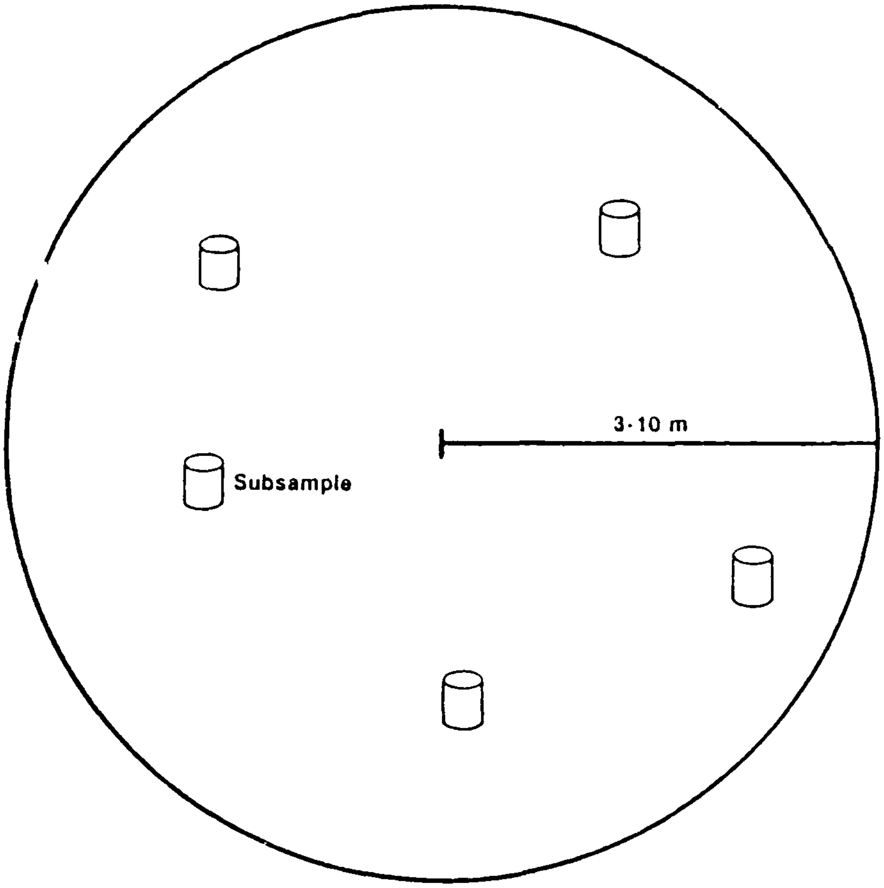


Figure D-2
SURFACE SOIL COMPOSITE SAMPLING METHOD

SOURCE: ESE, 1984.

INSTALLATION
RESTORATION PROGRAM
Air Force Plant 6

of five subsamples taken within a 10- to 30-ft radius at the selected sampling point. Each point sample taken from the surface to a specified depth should be quartered to approximately 1.0 lb and placed in the sample container.

6. Mixing of subsamples in the field to form a composite sample should be performed by placing the subsamples in a steel or aluminum tray lined with aluminum foil (dull side up). No plastic should be allowed to contact soil samples requiring organic analysis to avoid phthalate contamination.

D.4.5 SEDIMENT SAMPLING

1. All sediment samples will be collected with a hand piston sampler or other appropriate device.
2. After sampling, depth of water at each sampling point will be measured and recorded.
3. Sampling equipment will be thoroughly cleaned with water from an approved source and solvent rinsed with acetone and hexane and allowed to air dry.
4. Sediment samples will be placed in glass containers with Teflon®-lined lids, shipped under ice, and stored at 4°C.

D.4.6 LABORATORY

The Laboratory Task Manager is responsible for implementing the laboratory Quality Control (QC) procedures. The QA Supervisor will monitor the performance of the analysts and the Chemical Analysis Supervisor for implementation of proper QC checks and to final approve all data.

For analyses conducted in this project, the following QC checks will apply:

1. At least five standards for standard curve (three standards for organic analyses) [for GC/MS analyses and metals analyses by inductively coupled argon plasma (ICAP) one calibration

standard is run and a daily response factor is established after initial calibration],

2. Correlation coefficient for curve is greater than 0.995,
3. Percent recovery for spikes is within acceptance criteria as described below,
4. Samples are within range of standards,
5. At least 10 percent of the samples are replicates (except GC/MS),
6. At least 5 percent of the samples are spiked, and
7. For GC/MS analysis no replicates are analyzed but every sample is spiked with surrogate analytes.

For data generated using standard methods, the acceptance criteria for precision and accuracy is determined as follows:

$$\overline{R} = \overline{R}' \pm 3p$$

where:

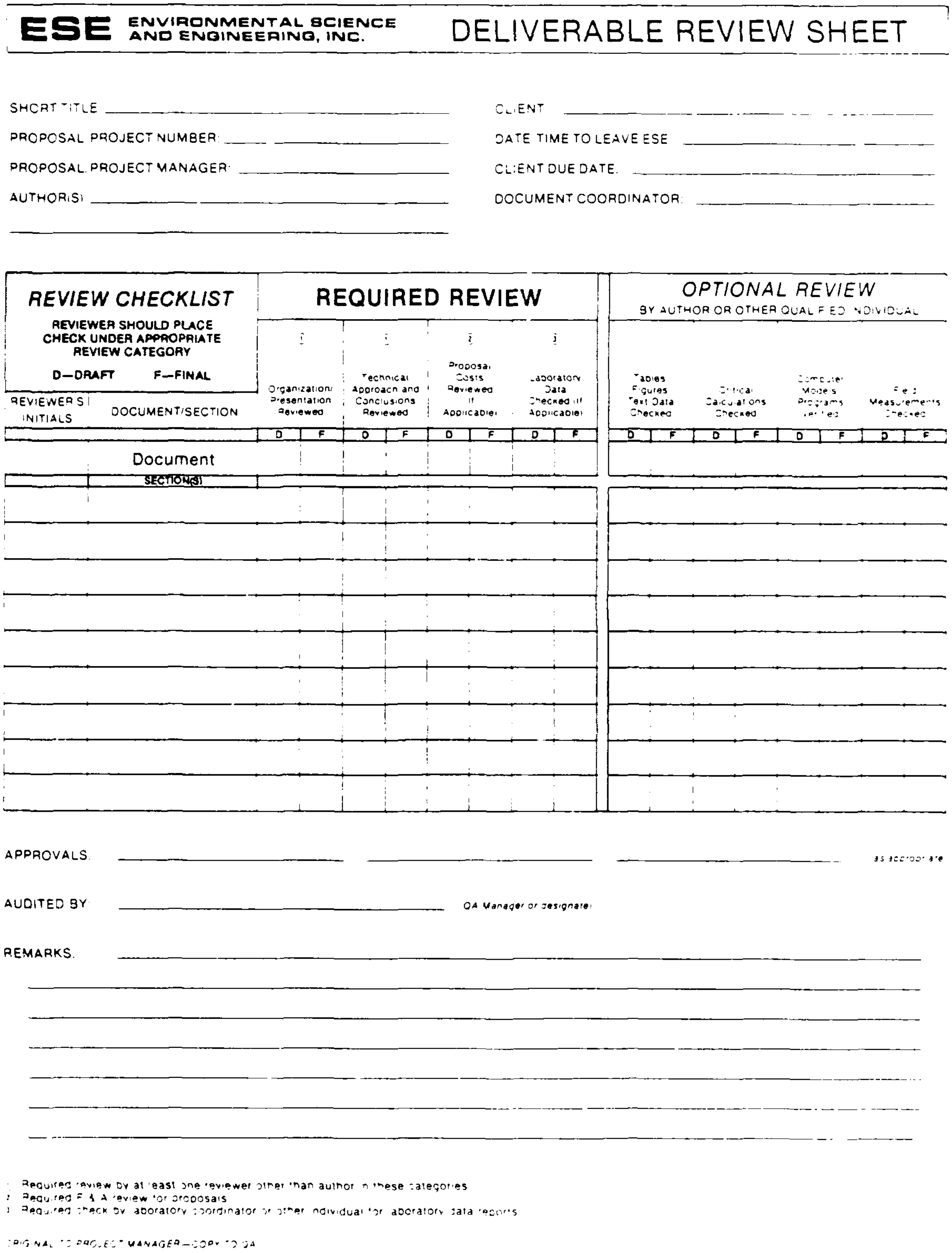
$\overline{R}$ = Average percent recovery from spiked sample data during the run;

$\overline{R}'$ = Average percent recovery for the particular analyte as obtained from Tables A, B, and C; and

p = Standard deviation (expressed as percent) for the particular analyte.

D.5 DATA ANALYSES AND REPORT REVIEW

Peer review of all deliverable reports and data supporting this project will be performed by technically qualified individuals from each major discipline represented in the particular deliverable. Fig. D-3 is a sample Deliverable Review Form to be used in this project.



ESE ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

DELIVERABLE REVIEW SHEET

SHORT TITLE ____________________

CLIENT ____________________

PROPOSAL PROJECT NUMBER ____________________

DATE TIME TO LEAVE ESE ____________________

PROPOSAL PROJECT MANAGER ____________________

CLIENT DUE DATE ____________________

AUTHOR(S) ____________________

DOCUMENT COORDINATOR ____________________

REVIEW CHECKLIST

REVIEWER SHOULD PLACE CHECK UNDER APPROPRIATE REVIEW CATEGORY

D—DRAFT F—FINAL

		REQUIRED REVIEW								OPTIONAL REVIEW BY AUTHOR OR OTHER QUALIFIED INDIVIDUAL							
REVIEWER'S INITIALS	DOCUMENT/SECTION	1 Organization/ Presentation Reviewed		1 Technical Approach and Conclusions Reviewed		2 Proposal Costs Reviewed (If Applicable)		3 Laboratory Data Checked (If Applicable)		Tables Figures Text Data Checked		Critical Calculations Checked		Computer Models Programs Verified		Field Measurements Checked	
		D	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F
	Document																
	SECTION(S)																

APPROVALS ____________ ____________ ____________ (as appropriate)

AUDITED BY ____________ (QA Manager or designate)

REMARKS ____________________

1 Required review by at least one reviewer other than author in these categories
2 Required F & A review for proposals
3 Required check by laboratory coordinator or other individual for laboratory data reports

ORIGINAL TO PROJECT MANAGER—COPY TO QA

Figure D-3
DELIVERABLE REVIEW SHEET

SOURCE: ESE, 1984.

INSTALLATION RESTORATION PROGRAM
Air Force Plant 6

APPENDIX E

SAFETY PLAN

APPENDIX E
SAFETY PLAN

This element consists of the activities necessary to ensure the safety of all ESE and subcontractor personnel and the general public during onsite and laboratory activities. This will be done by indoctrination of all personnel in the requirements of the Air Force Plant 6 safety plan prior to site activities and by ensuring that all personnel are adequately trained; provision of adequate safety equipment; medical surveillance for personnel exposed to potentially toxic chemicals; provision for safe, legal sample transport and handling; provision for the safe conduct of field inspections, construction, and well drilling operations; and provision, as necessary, of exclusion areas and decontamination activities to prevent contamination migration impact to onsite personnel, the general public, or the environment.

Principal physical hazards at Air Force Plant 6 during sampling and analysis involve the operation of the drilling rigs, operation of soil boring equipment, and operation of field testing equipment.

Chemical hazards at the site involve the potential inhalation of or skin contact by potentially high levels of chlorinated solvents during the drilling operations and the sampling of ground water. Also, the potential for injection of or skin contact with sediments potentially contaminated with chlorinated solvents and other nonspecific toxic materials is a concern at Air Force Plant 6.

It is anticipated that all sampling will be conducted using Level D protection. Level C protection (full-face canister masks equipped with organic vapor cartridges worn by samplers and drilling crew) will be required in these areas if organic vapors are detected in the atmosphere at breathing level during operations.

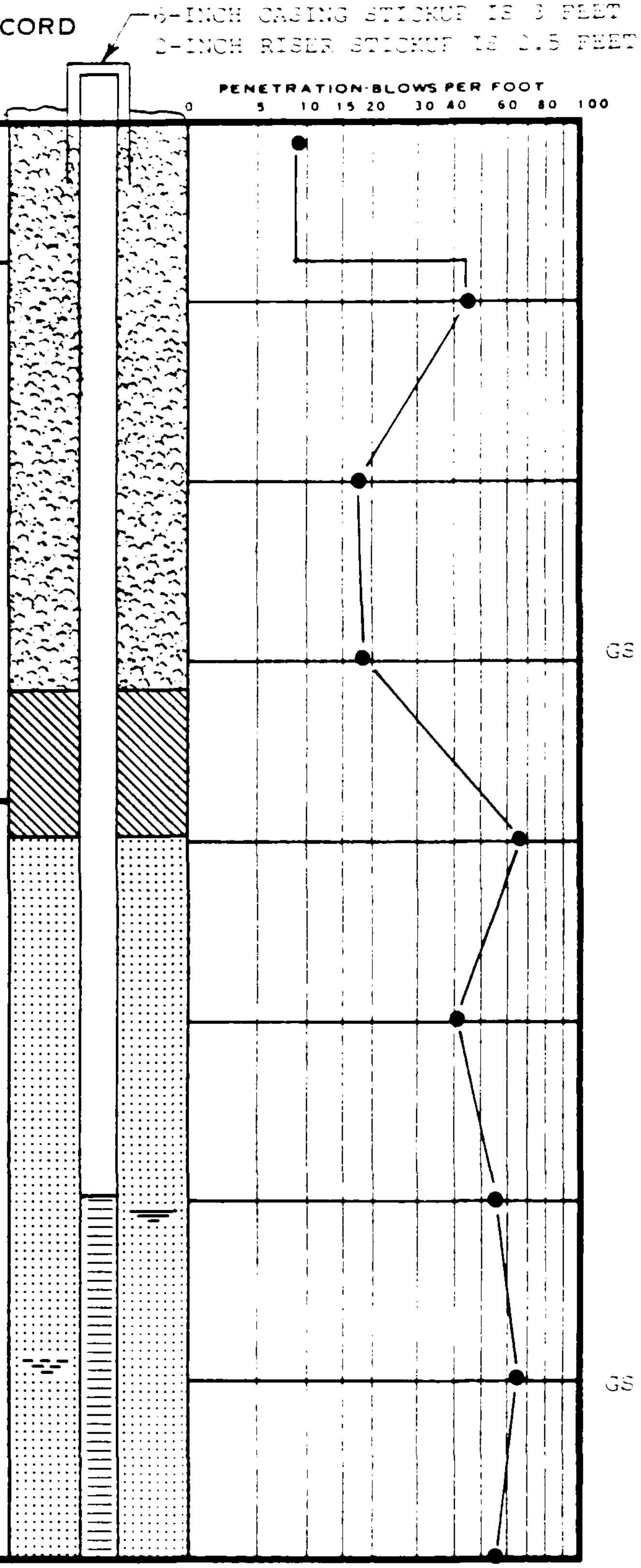
The decontamination assumptions for equipment such as drilling rigs which are costed into the proposed scope include the decontamination between borings or well installations using approved drilling water in an area provided by the Base Civil Engineer. It must be recognized, however, that although the above decontamination activities are considered to be sufficient to prevent hazard to the public health or onsite personnel, regulatory review of the work plan may result in additional requirements. These would impact the time requirement for decontamination of equipment, as well as introducing construction costs for building a separate decontamination wash rack, storage of drill cuttings, and providing for storage, treatment, and testing of the decontamination water. Additional costs would be required for such an upgraded decontamination program.

APPENDIX F

MONITORING WELL TEST BORING RECORDS

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
1061.8		STIFF RED FINE SANDY CLAYEY SILT - TILL
	4.0	
1056.8		DENSE AND FIRM BROWN SILTY MICACEOUS FINE SAND (SM)
1051.8		
1046.8		
	19.0	
1041.8		DENSE AND VERY DENSE BROWN, PINK, BLACK AND WHITE VERY SILTY MICACEOUS FINE TO MEDIUM SAND (SM)
1036.8		
1031.8		
1026.8		
1021.8	40.0	


6-INCH CASING STICKUP IS 3 FEET
2-INCH RISER STICKUP IS 2.5 FEET

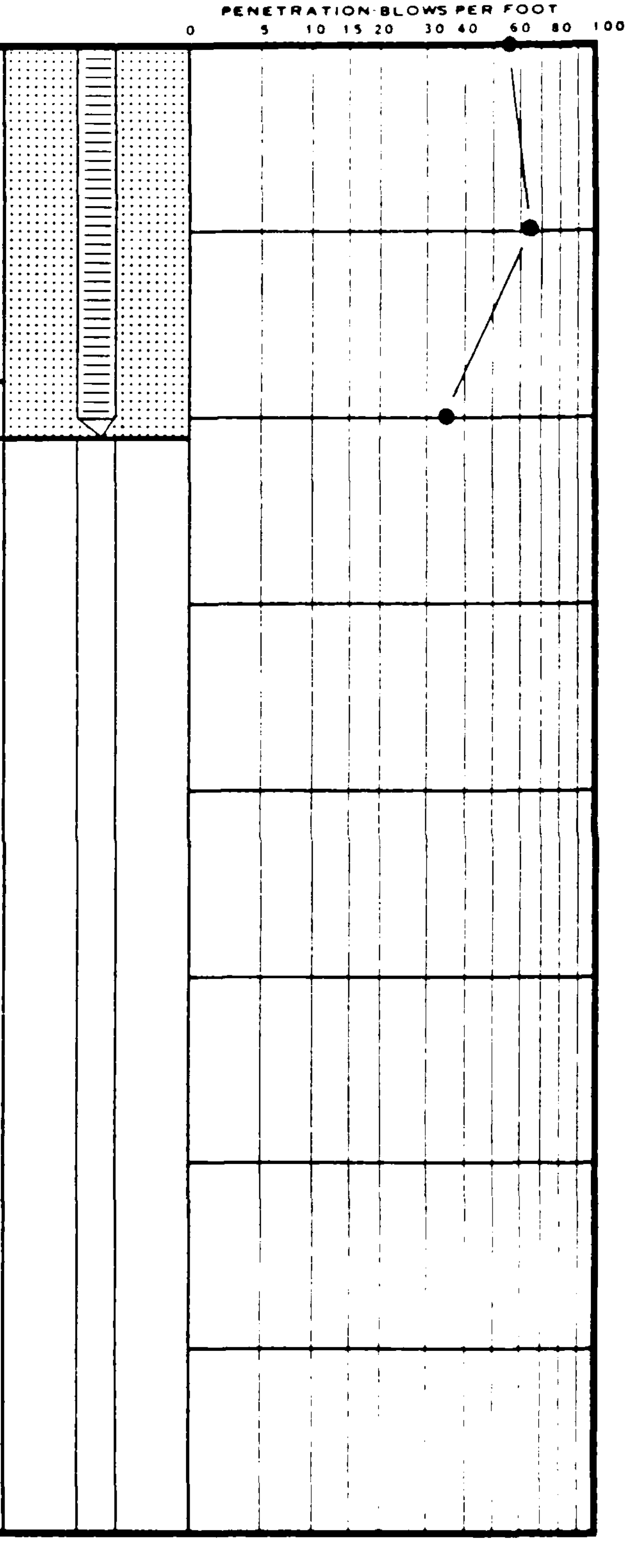
REMARKS:
LOCATION COORDINATES:
N 1,430,762
E [illegible]06,644

DRILLED BY RB
LOGGED BY WGG
CHECKED BY [illegible]

BORING NUMBER GS-5
DATE STARTED [illegible]
DATE COMPLETED [illegible]
JOB NUMBER MA4352

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
1021.8	40.0	DENSE TO VERY DENSE BROWN AND GRAY BROWN VERY SILTY MICACEOUS FINE TO MEDIUM SAND (SM)
1016.8		
	49.0	FIRM GRAY SILTY MICACEOUS FINE TO MEDIUM SAND * (SM)
1011.8		
	50.5	BORING TERMINATED
1006.8		



REMARKS:

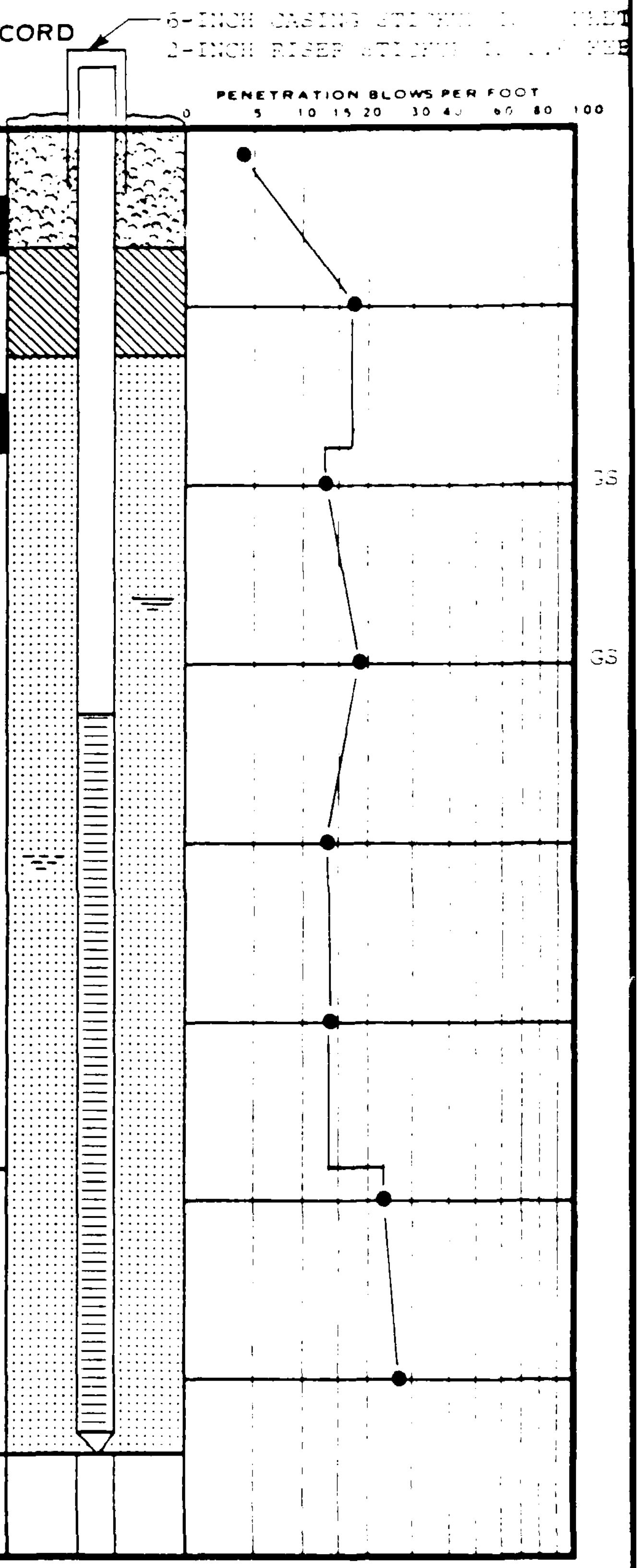
DRILLED BY RB
LOGGED BY WGG
CHECKED BY KJS

BORING NUMBER 35-5
DATE STARTED [illegible]
DATE COMPLETED [illegible]
JOB NUMBER [illegible]

Page 2 of 2

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
1039.0		SOFT RED-GRAY CLAYEY SANDY SILT FILL
1034.0	4.0	VERY STIFF RED-BROWN AND GRAY FINE TO MEDIUM SANDY MICACEOUS SILTY CLAY - FILL
	9.0	FIRM RED BROWN, BROWN, GRAY AND WHITE SILTY MICACEOUS FINE TO MEDIUM SAND (SM)
1029.0		
1024.0		
1019.0		
1014.0		
	29.0	VERY STIFF BROWN AND GRAY FINE SANDY SILT WITH A TRACE OF MICACEOUS FINE SANDY SILT
1009.0		
1004.0		
	37.0	BORING TERMINATED
999.0		



REMARKS:

UNDISTURBED SAMPLE ATTEMPTED FROM 2' TO 4', NO RECOVERY DUE TO ROCK.

UNDISTURBED SAMPLE RETAINED FROM 7' TO 9'.

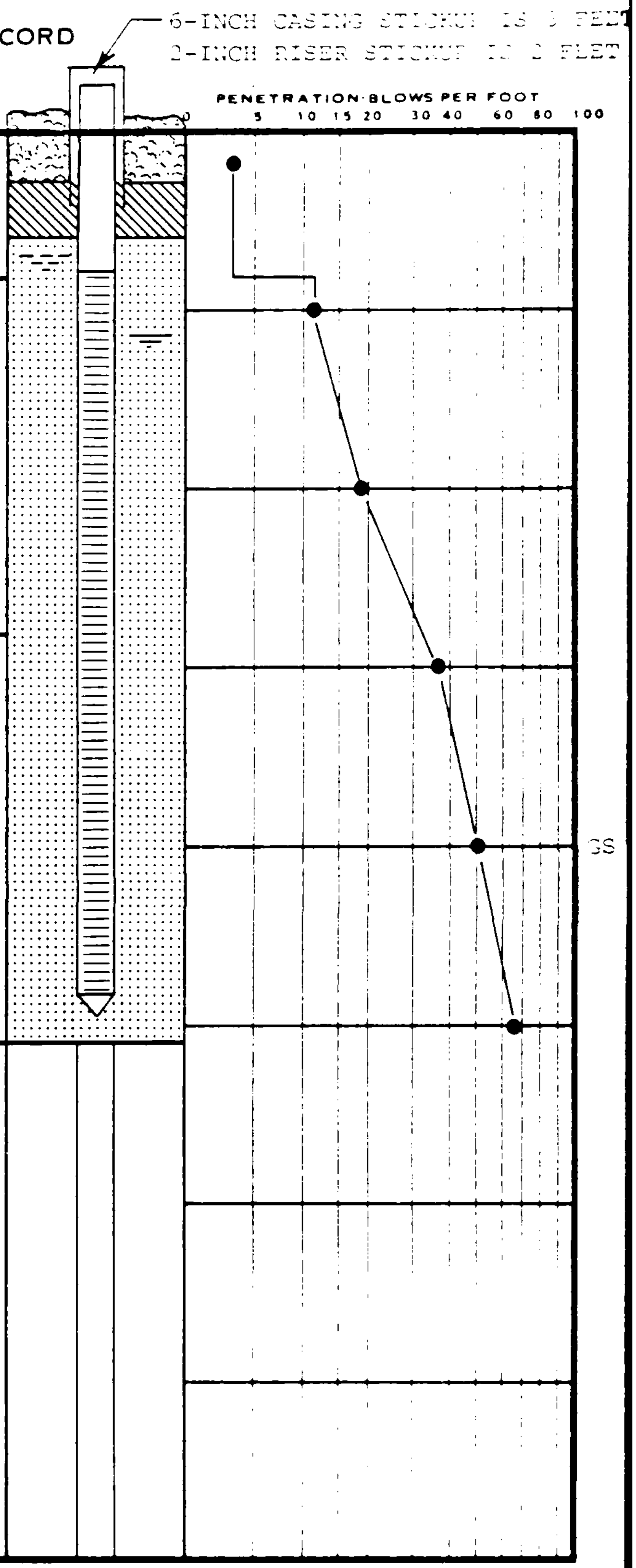
LOCATION COORDINATES:
N 1,430,716
E 390,733

DRILLED BY JC
LOGGED BY MGS
CHECKED BY KCS

BORING NUMBER B5-[illegible]
DATE STARTED [illegible]
DATE COMPLETED [illegible]
JOB NUMBER [illegible]

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
971.3		SOFT RED-BROWN AND BROWN MICACEOUS FINE SANDY SILT (ML)
966.3	4.0	FIRM GRAY-BROWN MICACEOUS SILTY FINE SAND (SM)
961.3		
956.3	14.0	DENSE TO VERY DENSE GRAY, WHITE, AND GOLD MICACEOUS SILTY FINE TO MEDIUM SAND (SM)
951.3		
946.3	25.5	BORING TERMINATED
941.3		



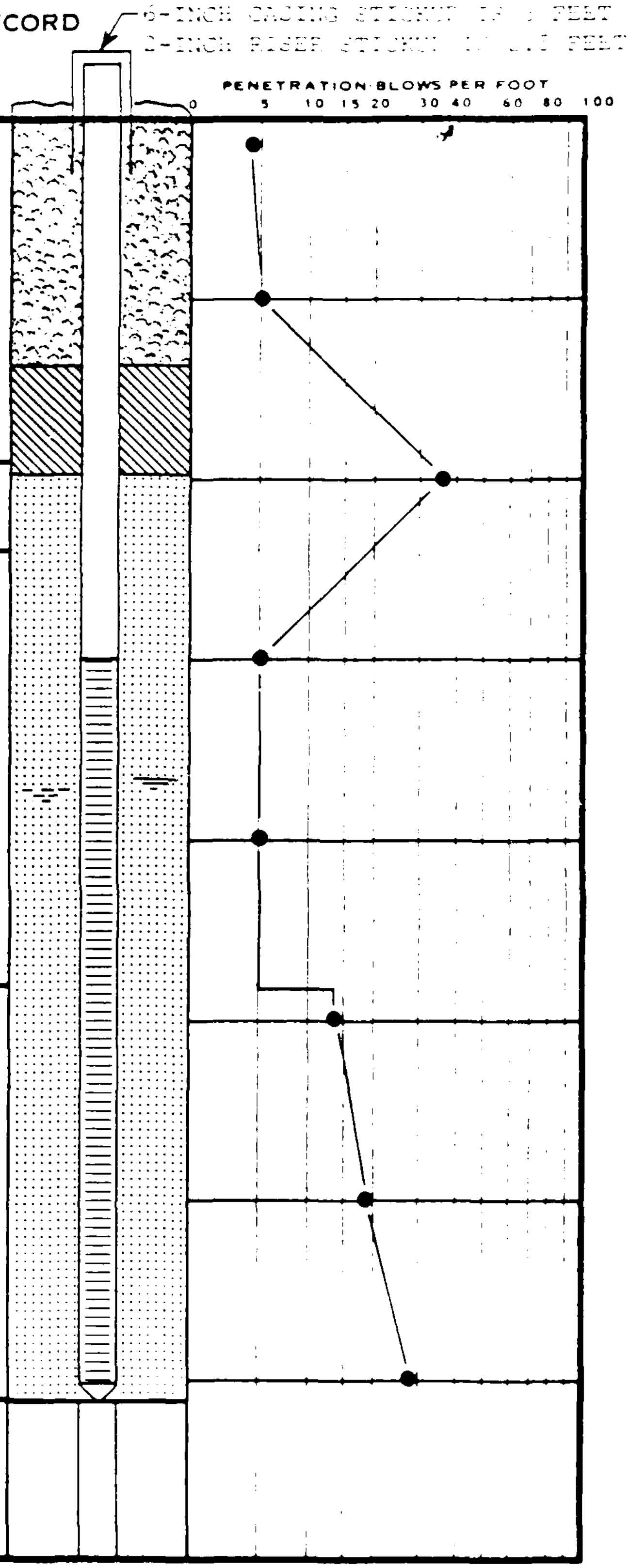
REMARKS:

LOCATION COORDINATES:
N 1,421,294
E [illegible]4,642

DRILLED BY RB
LOGGED BY SS
CHECKED BY [illegible]

BORING NUMBER [illegible]
DATE STARTED [illegible]
DATE COMPLETED [illegible]
JOB NUMBER [illegible]

TEST BORING RECORD



ELEV.	DEPTH FEET	DESCRIPTION
1006.4		SOFT TO FIRM RED-BROWN AND BROWN FINE TO COARSE SANDY CLAYEY SILT WITH OCCASIONAL GRAVEL - FILL
1001.4		
996.4	9.5	HARD RED FINE TO COARSE SANDY CLAYEY SILT AND FINE TO COARSE GRAVEL - FILL
	12.0	FIRM GRAY SLIGHTLY SANDY VERY CLAYEY SILT WITH SOME FINE GRAVEL-FILL
991.4		
986.4		
981.4	24.0	STIFF TO VERY STIFF BROWN AND GRAY MICACEOUS SILTY FINE TO MEDIUM SAND (SM)
976.4		
971.4		
	35.5	BORING TERMINATED
966.4		

REMARKS:

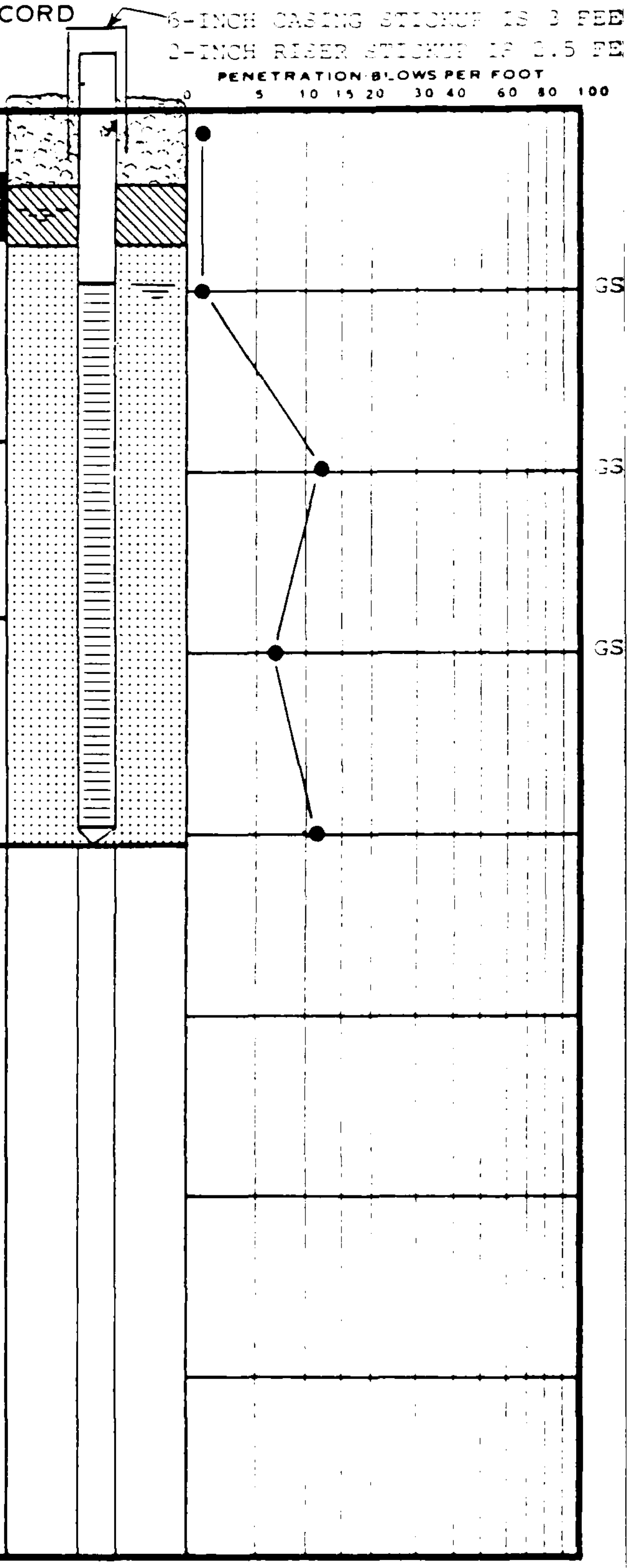
LOCATION COORDINATES:
N 1,422,017
E 393,7[illegible]

DRILLED BY RB
LOGGED BY WSB
CHECKED BY [illegible]

BORING NUMBER [illegible]
DATE STARTED [illegible]
DATE COMPLETED [illegible]
JOB NUMBER [illegible]

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
991.0		VERY LOOSE GRAY AND BROWN CLAYEY SILT FINE SAND (SM)
986.0		
981.0	9.0	FIRM GRAY AND BROWN SLIGHTLY CLAYEY SILTY MICACEOUS FINE TO MEDIUM SAND (SM)
976.0	14.0	LOOSE TO FINE GRAY, BLACK AND WHITE SILTY MICACEOUS FINE TO MEDIUM SAND (SM)
971.0	20.5	BORING TERMINATED
966.0		



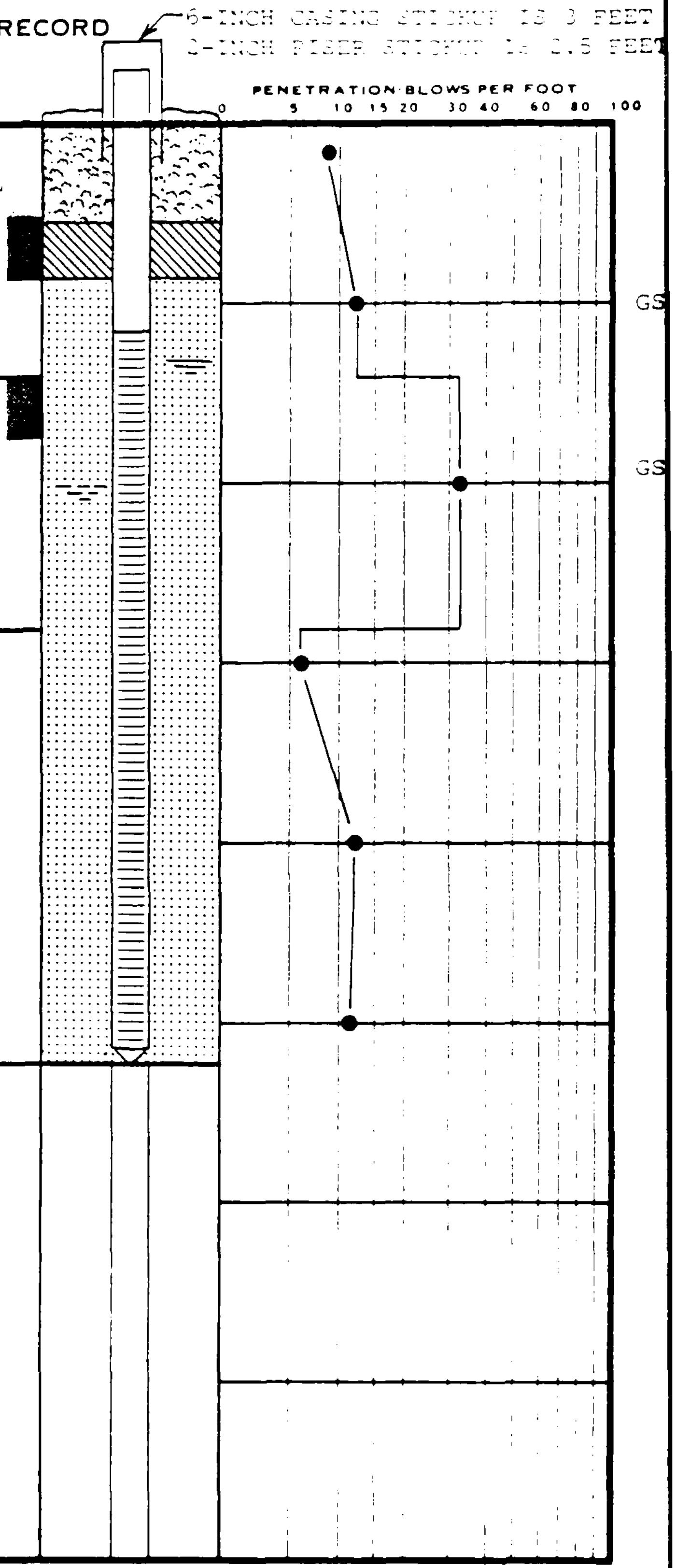
REMARKS:
UNDISTURBED SAMPLE OBTAINED
FROM 2' TO 4'.
LOCATION COORDINATES:
N 1,421,7[illegible]
E [illegible],7[illegible]

DRILLED BY JO
LOGGED BY WGS
CHECKED BY [illegible]

BORING NUMBER [illegible]
DATE STARTED [illegible]
DATE COMPLETED [illegible]
JOB NUMBER [illegible]

TEST BORING RECORD

ELEV.	DEPTH FEET	DESCRIPTION
993.0		STIFF RED BROWN AND BROWN SILTY FINE TO MEDIUM SANDY CLAY - FILL
988.0		
	7.0	DENSE LIGHT GRAY CLAYEY SILTY FINE TO MEDIUM SAND (SM)
983.0		
978.0	14.0	LOOSE TO FIRM GRAY, WHITE, AND BLACK SLIGHTLY SILTY MICACEOUS FINE TO MEDIUM SAND (SM)
973.0		
968.0		
	26.0	BORING TERMINATED
963.0		



REMARKS:

UNDISTURBED SAMPLES OBTAINED FROM 2' TO 4' AND 7' TO 9'.

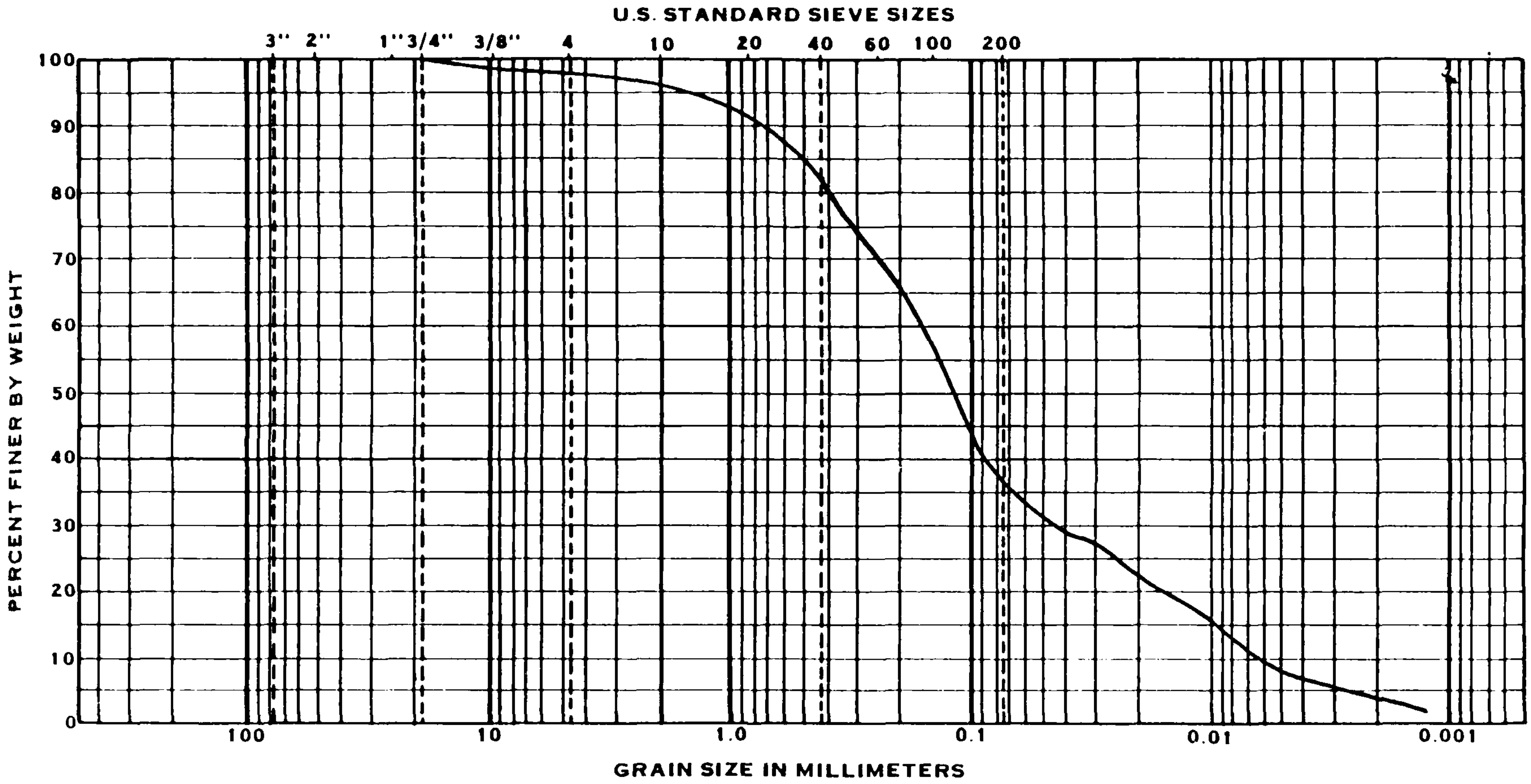
LOCATION COORDINATES:
N 1,421,[illegible]
E [illegible]

DRILLED BY [illegible]
LOGGED BY [illegible]
CHECKED BY [illegible]

BORING NUMBER [illegible]
DATE STARTED [illegible]
DATE COMPLETED [illegible]
JOB NUMBER [illegible]

APPENDIX G

GRAIN SIZE DISTRIBUTION



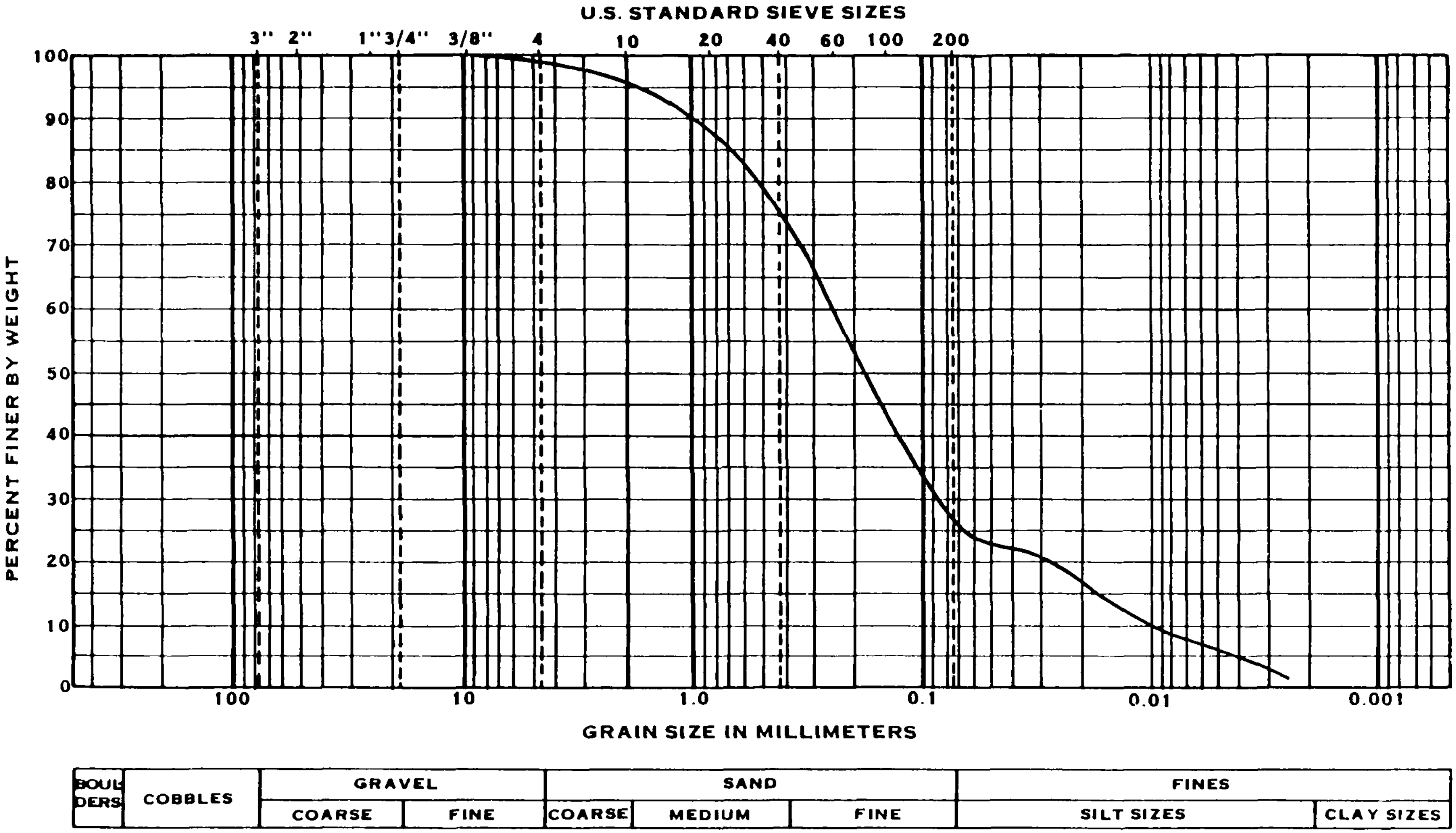
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
GB-5	34.0'-35.5'					Very silty fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. HA4352

LAW ENGINEERING
TESTING COMPANY

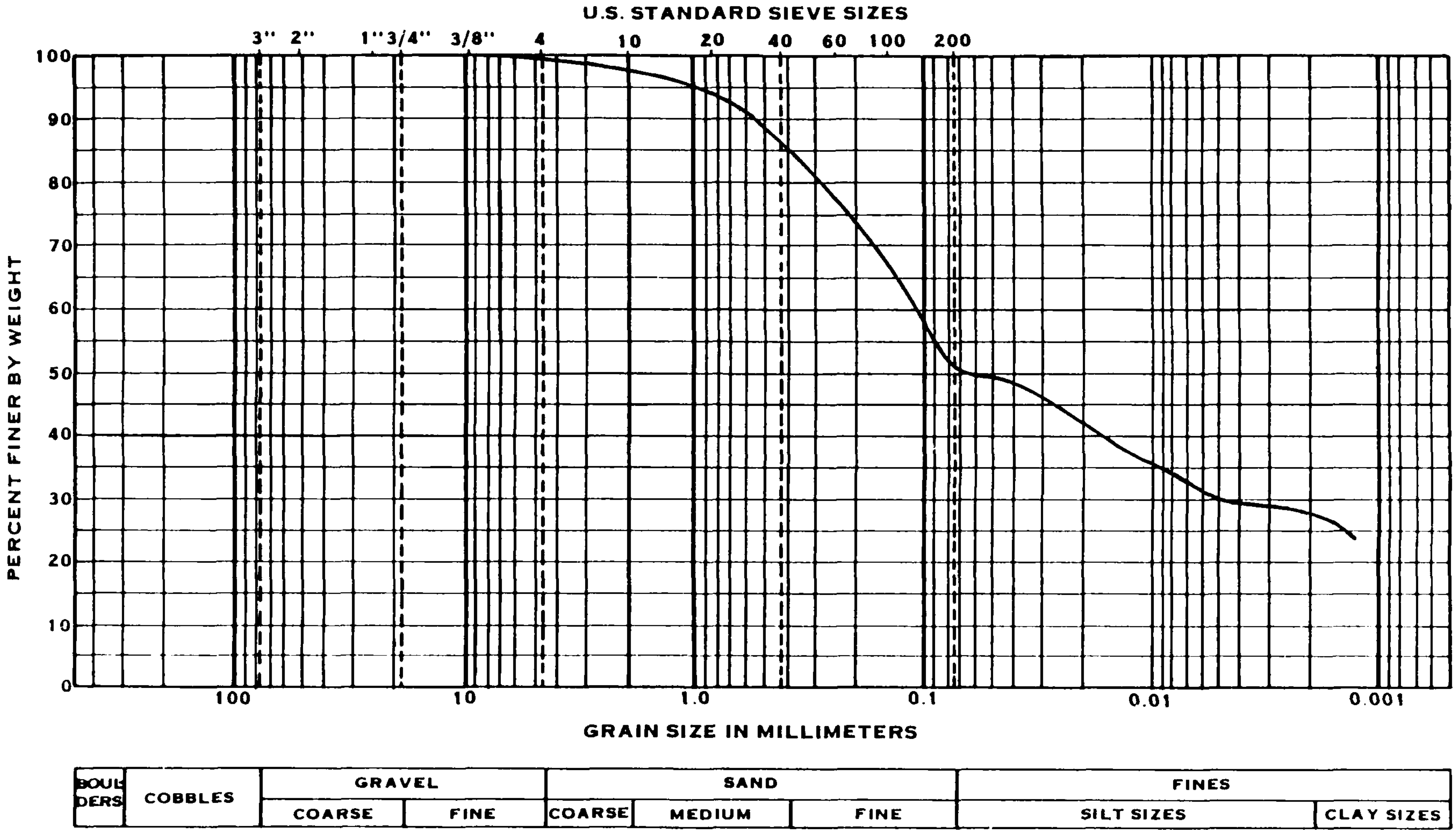


BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
[illegible]	14.0'-15.5'					Silty micaceous fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. HA4352

LAW ENGINEERING
TESTING COMPANY

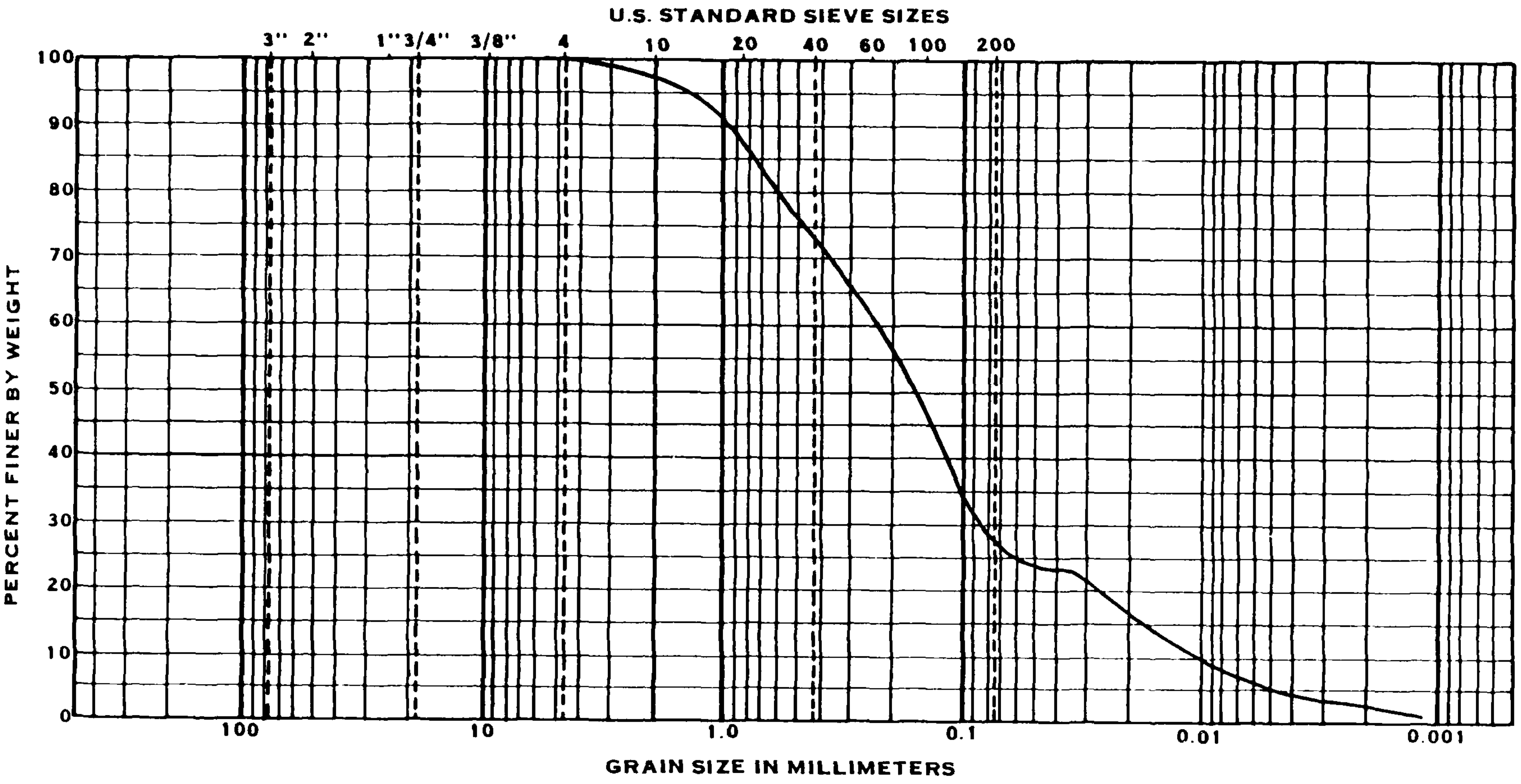


BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
65-6	7'-9'	19.6	59	41	18	Fine to medium sandy micaceous silt, CLAY - Fill

GRAIN SIZE DISTRIBUTION

JOB NO. MA4[illegible]

LAW ENGINEERING
TESTING COMPANY



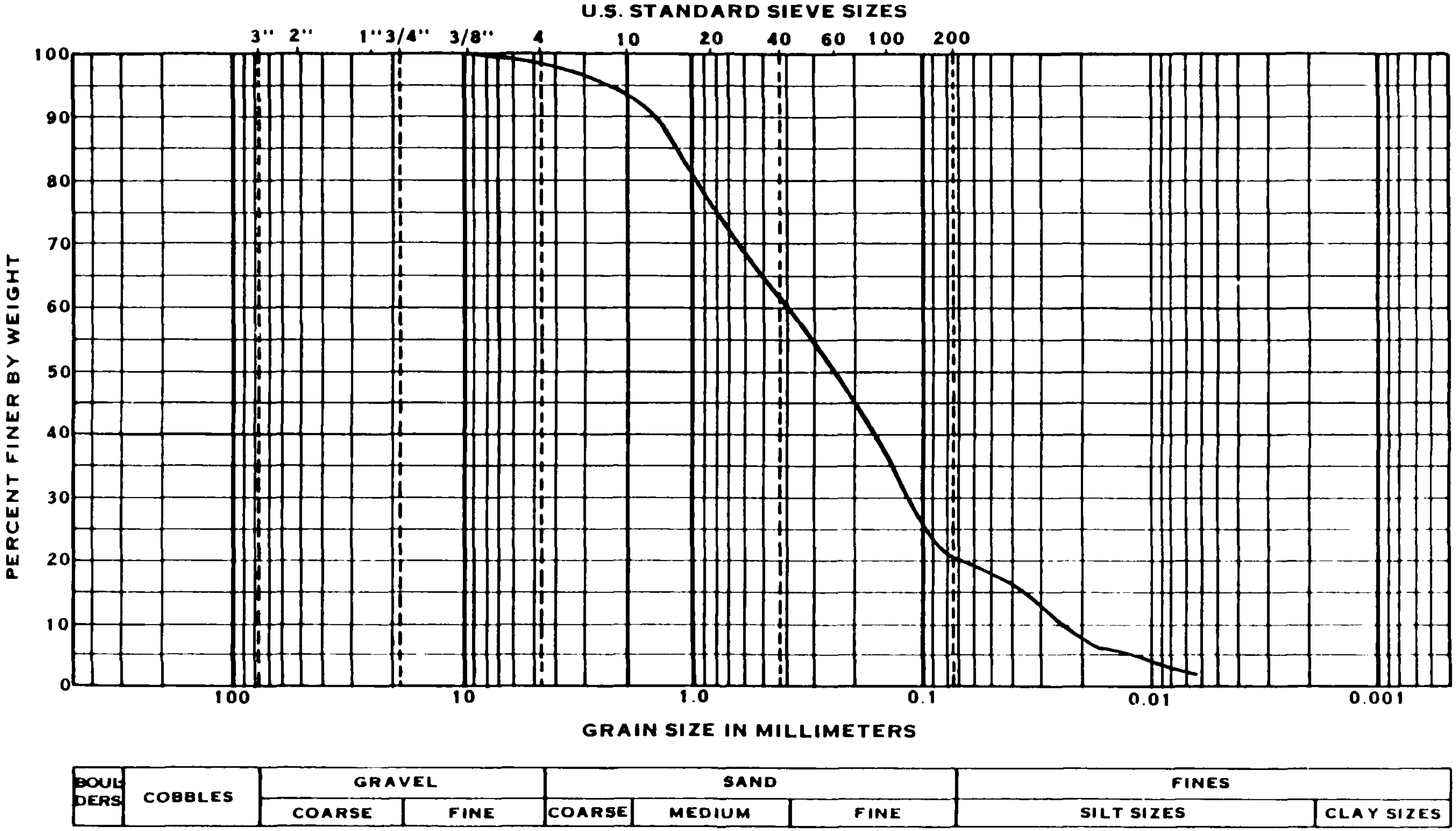
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
[illegible]	9.5'-10.5'					Silty micaceous fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. MA4352

LAW ENGINEERING
TESTING COMPANY

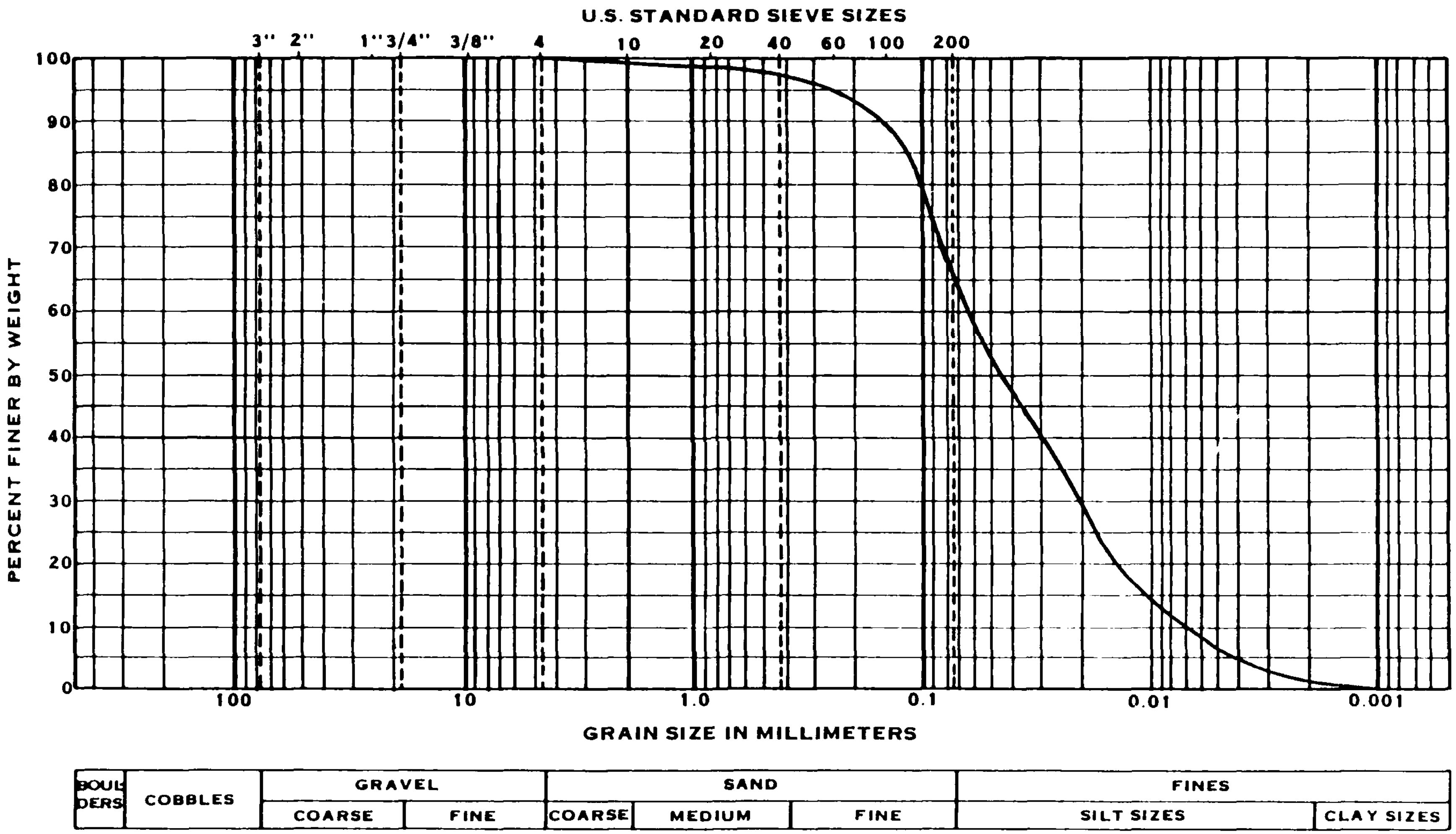


BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
G5-6	14.0'-15.5'					Silty micaceous fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. MA4352

LAW ENGINEERING
TESTING COMPANY

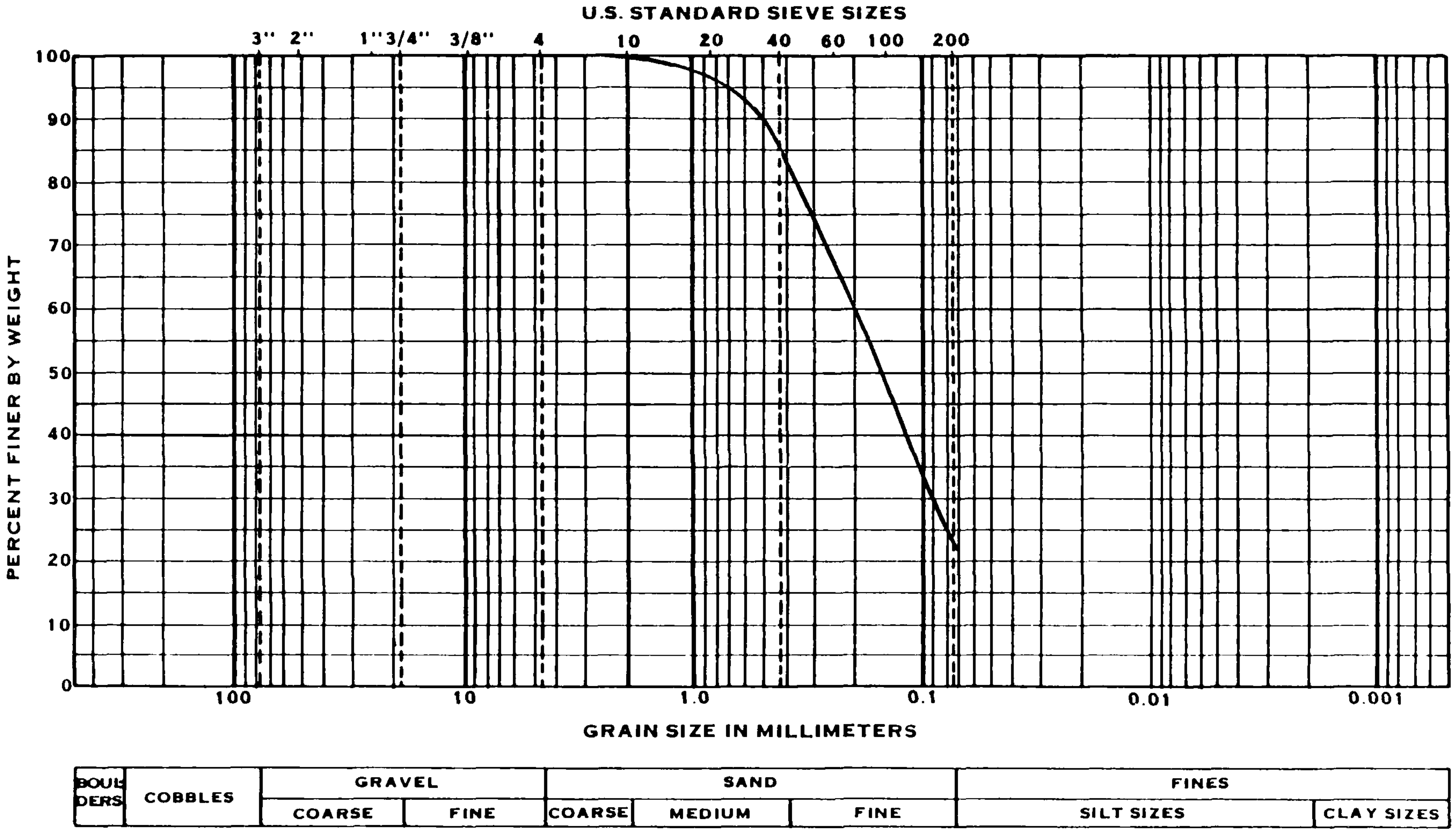


BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
B5-6	29.0'-30.5'					Fine sandy SILT with trace of mica (ML)

GRAIN SIZE DISTRIBUTION

JOB NO. MA4352

LAW ENGINEERING
TESTING COMPANY

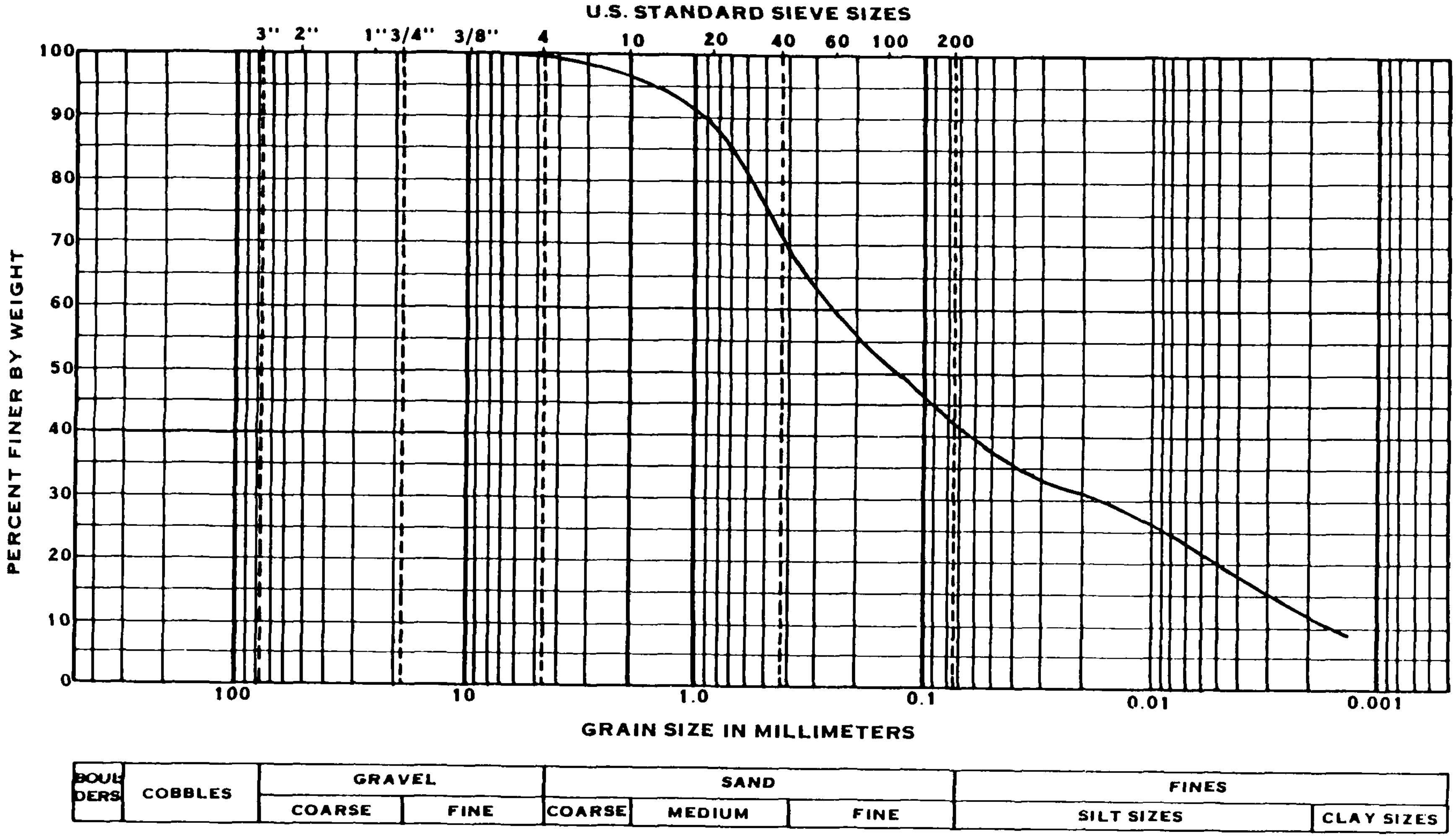


BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
G12-1	19.0'-20.5'					Silty fine micaceous SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. MA4352

LAW ENGINEERING
TESTING COMPANY

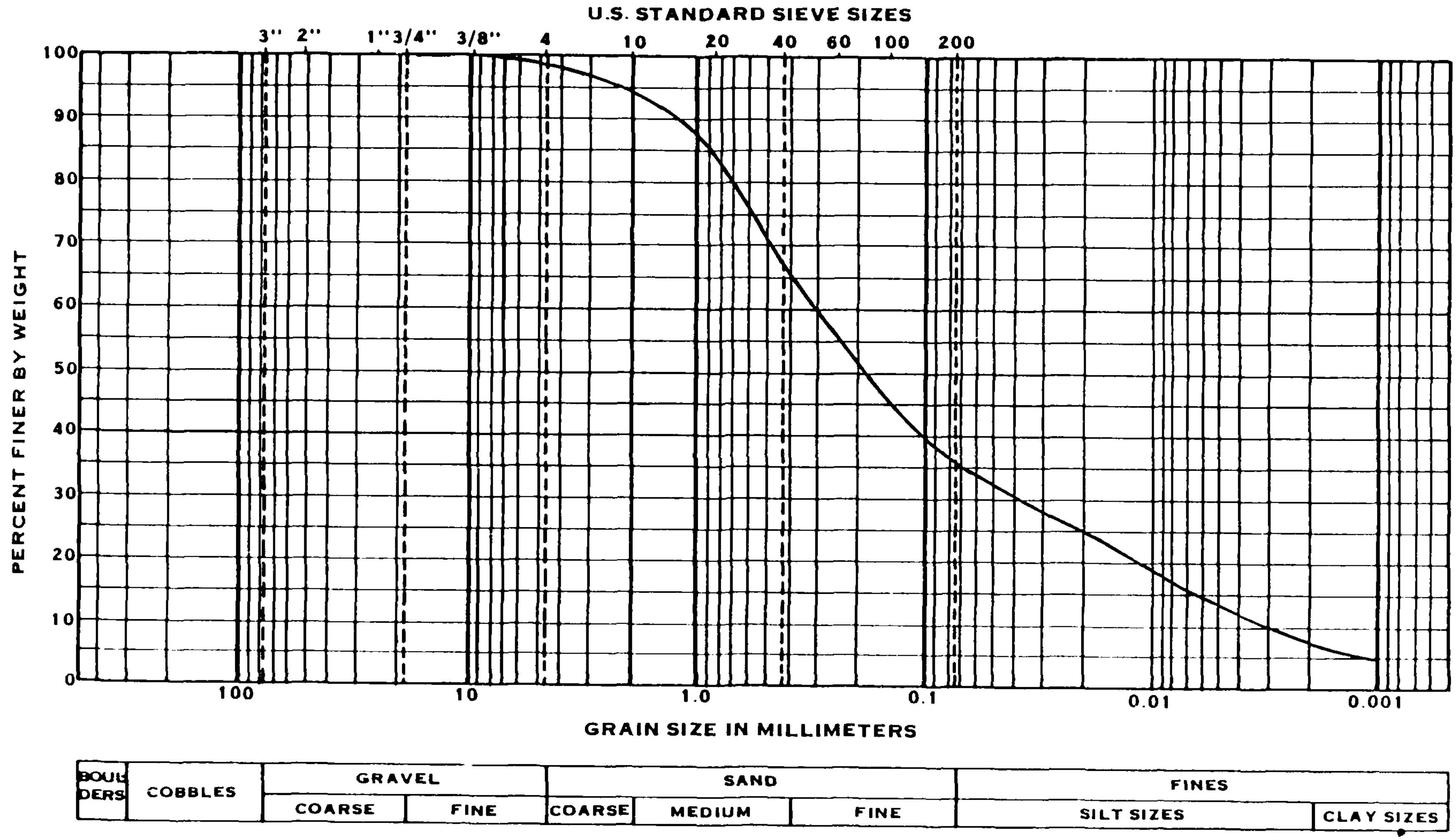


BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
[illegible]	4.0'-5.5'					Clayey silty fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. MA4352

LAW ENGINEERING
TESTING COMPANY

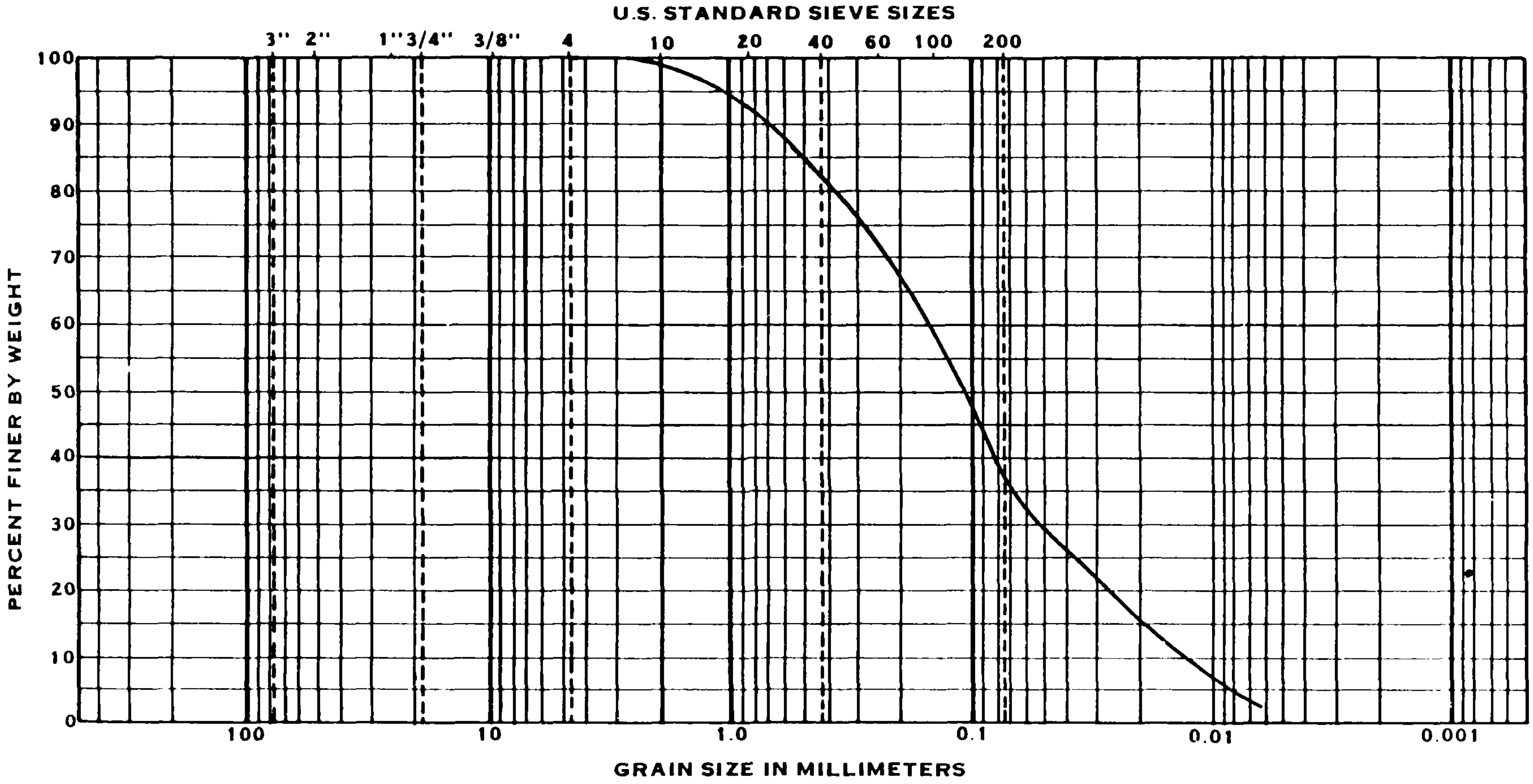


BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
H-3	9.0'-10.5'					Slightly clayey silty micaceous fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. MA4352

LAW ENGINEERING
TESTING COMPANY



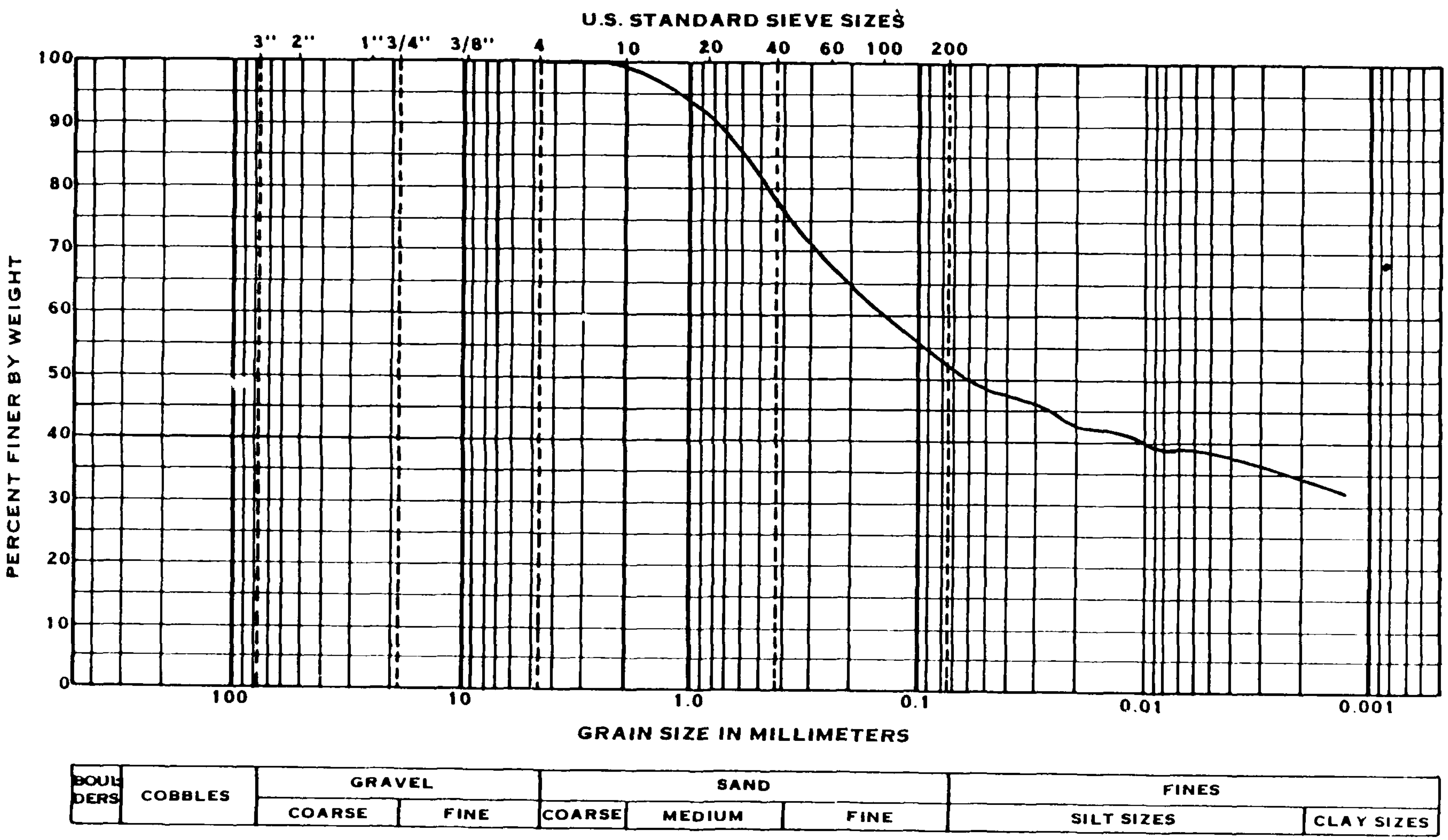
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
[illegible]	14.0' 15.5'					Silty micaceous fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. HA1351

LAW ENGINEERING
TESTING COMPANY

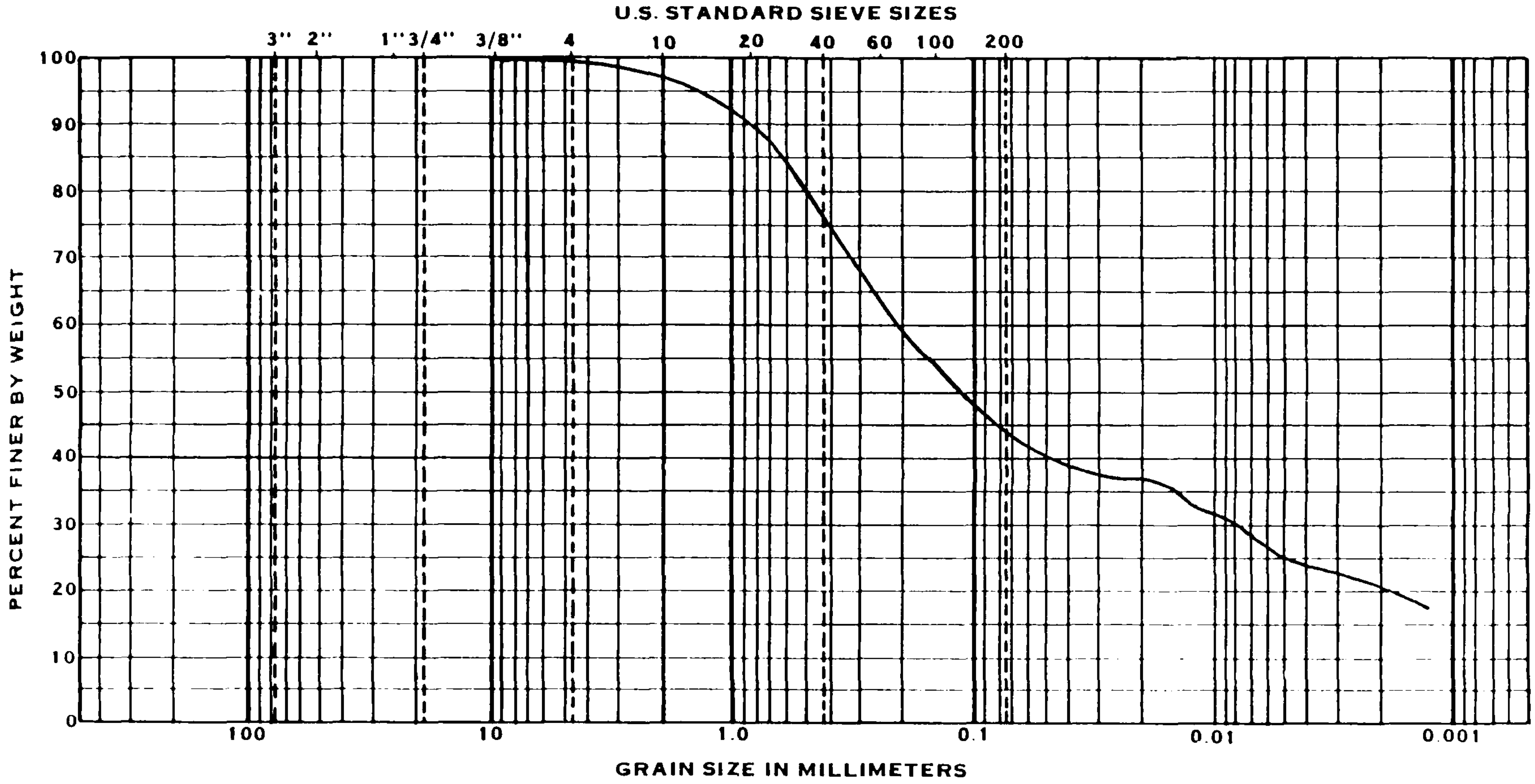


BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
512-4	4.0'-5.5'					Silty fine to medium sandy CLAY (CL)

GRAIN SIZE DISTRIBUTION

JOB NO. MA-1[illegible]

LAW ENGINEERING
TESTING COMPANY



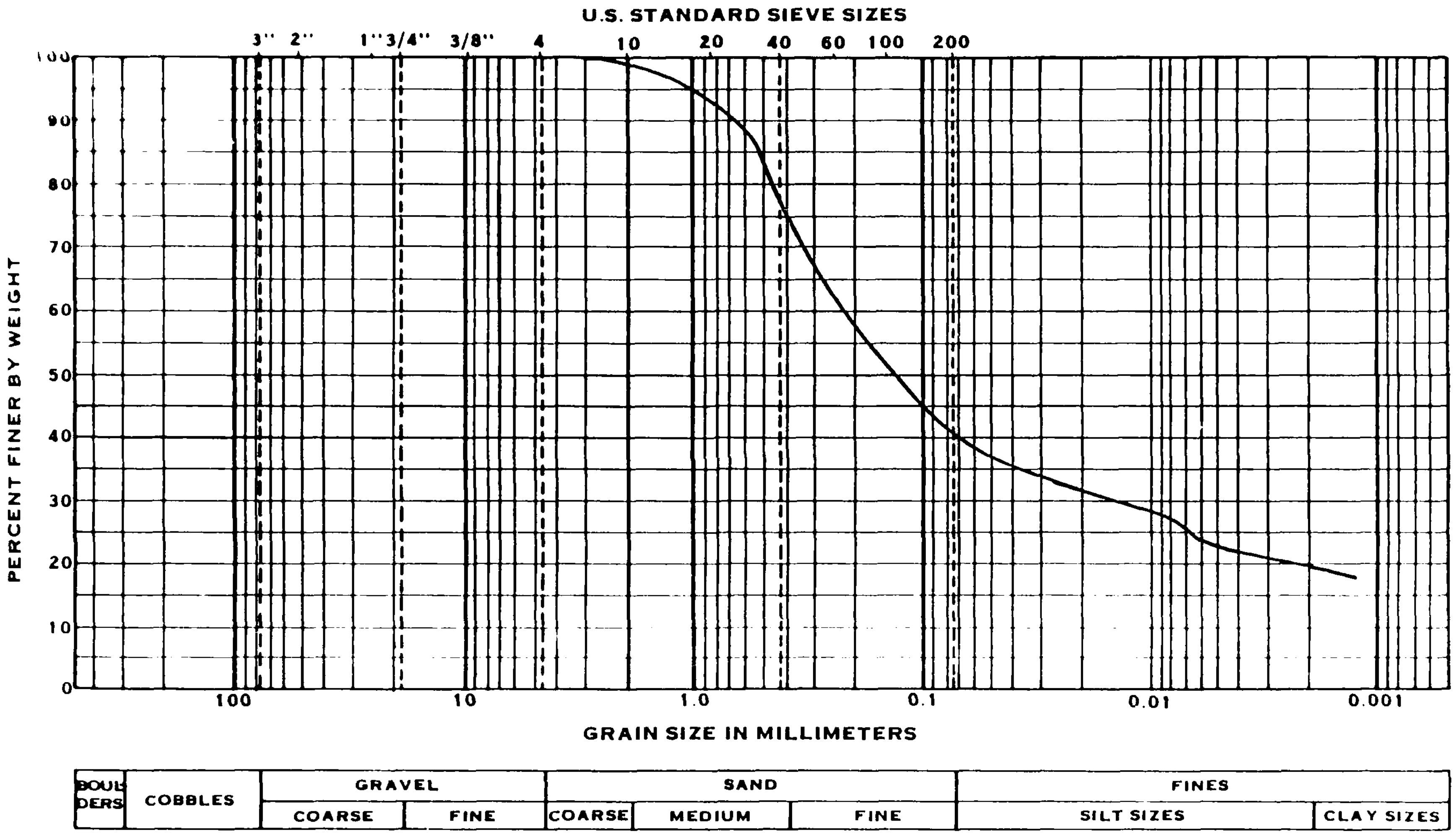
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
[illegible]	[illegible]'-9'	20.7	38.1	24	14	Clayey silty fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. [illegible]

LAW ENGINEERING
TESTING COMPANY



BORING NO.	ELEV. OR DEPTH	NAT WC	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
[illegible]12-4	9.0'-10.5'					Clayey silty fine to medium SAND (SM)

GRAIN SIZE DISTRIBUTION

JOB NO. MA[illegible]

LAW ENGINEERING
TESTING COMPANY

APPENDIX H

WELL DEVELOPMENT DATA

LAW ENGINEERING TESTING COMPANY JOB NAME GOCO JOB NO. [illegible]

BY [illegible] DATE 2-14-85 CK BAS DATE 2-28-85 SHEET ____ OF ____

WELL DEVELOPMENT DATA

1. WELL NO. G12-1

2. DATE OF INSTALLATION: 2-4-85

3. DATE OF DEVELOPMENT: 2-14-85

4. STATIC WATER LEVEL: BEFORE DEV. 6.29 FT ; 24 HOURS AFTER ________ FT

5. QUANTITY OF WATER LOSS DURING DRILLING, IF USED ________ GAL

6. QUANTITY OF STANDING WATER IN WELL AND ANNULUS BEFORE DEV. ________ GAL.

7.	START	DURING		END
		[illegible]	[illegible]	
SPECIFIC CONDUCTANCE (umhos/cm)	280	[illegible]	[illegible]	[illegible]
TEMPERATURE (°C)	13.0	8.0	15.0	[illegible]
pH (s.u)	7.63	7.75	7.65	[illegible]

8. DEPTH FROM TOP OF WELL CASING TO BOTTOM OF WELL 27.03 FT.

9. SCREEN LENGTH 20 FT.

10. DEPTH TO TOP OF SEDIMENT: BEFORE DEV. 22.83 FT., AFTER DEV. [illegible] FT.

11. PHYSICAL CHARACTER OF WATER: Initially brown w/ [illegible] of sediment. [illegible] clear w/ few suspended [illegible]

12. TYPE AND SIZE OF WELL DEVELOPMENT EQUIPMENT: 100 CFM [illegible] 1" triloc PVC pipe, 3/2" plastic tubing, 1" [illegible]

13. DESCRIPTION OF SURGE TECHNIQUE, IF USED: [illegible] compressor

14. HEIGHT OF WELL CASING ABOVE GROUND SURFACE: 3.03 FT.

15. QUANTITY OF WATER REMOVED: [illegible] GAL.

TIME FOR REMOVAL: [illegible] HR./MIN.

16. 1-PINT WATER SAMPLE COLLECTED: 5:00 (TIME)

* DEVELOPMENT CONDITIONS: 1) WELL WATER IS REASONABLY CLEAR
2) SEDIMENT THICKNESS < 5% OF SCREEN LENGTH
3) REMOVAL OF 5 WELL VOLUMES INCLUDING SATURATED FILTER ANNUL

LAW ENGINEERING TESTING COMPANY JOB NAME 3000 JOB NO. [illegible]
BY [illegible] DATE [illegible] CK CAS DATE 2-23-85 SHEET 1 OF

WELL DEVELOPMENT DATA

1. WELL NO. G12-2

2. DATE OF INSTALLATION: 2-6-85

3. DATE OF DEVELOPMENT: 2/13-15/85

4. STATIC WATER LEVEL: BEFORE DEV. 18.32 FT; 24 HOURS AFTER

5. QUANTITY OF WATER LOSS DURING DRILLING, IF USED GAL

6. QUANTITY OF STANDING WATER IN WELL AND ANNULUS BEFORE DEV. GAL.

7.	START	DURING (20 gal.	40 gal.)	END
SPECIFIC CONDUCTANCE (umhos/cm)	600	[illegible]	350	270
TEMPERATURE (°C)	12.5	1.5	1.5	2.5
pH (s.u)	8.00	[illegible]	8.28	7.21

8. DEPTH FROM TOP OF WELL CASING TO BOTTOM OF WELL 37.81 FT.

9. SCREEN LENGTH 20 FT.

10. DEPTH TO TOP OF SEDIMENT: BEFORE DEV. 36.4 FT., AFTER DEV. [illegible]

11. PHYSICAL CHARACTER OF WATER: Initially [illegible] w/ [illegible] sediment. Finally became clear w/ very little [illegible]

12. TYPE AND SIZE OF WELL DEVELOPMENT EQUIPMENT: 100 CFM [illegible] 1" [illegible] pvc pipe, 3/8" plastic tubing, 1" [illegible]

13. DESCRIPTION OF SURGE TECHNIQUE, IF USED: [illegible] compressor

14. HEIGHT OF WELL CASING ABOVE GROUND SURFACE: 2.81 FT.

15. QUANTITY OF WATER REMOVED: 130 GAL.

TIME FOR REMOVAL: 12 hr. HR./MIN.

16. 1-PINT WATER SAMPLE COLLECTED: 4:00 (TIME)

* DEVELOPMENT CONDITIONS: 1) WELL WATER IS REASONABLY CLEAR
2) SEDIMENT THICKNESS < 5% OF SCREEN LENGTH
3) REMOVAL OF 5 WELL VOLUMES INCLUDING SATURATED FILTER

LAW ENGINEERING TESTING COMPANY JOB NAME GOCO JOB NO. [illegible]

BY SN DATE 2-19-85 CK CMS DATE 2-28-85 SHEET ____ OF ____

WELL DEVELOPMENT DATA

1. WELL NO. G12-3

2. DATE OF INSTALLATION: 2-13-85

3. DATE OF DEVELOPMENT: 2-19-85

4. STATIC WATER LEVEL: BEFORE DEV. 5.94 FT ; 24 HOURS AFTER ________ FT

5. QUANTITY OF WATER LOSS DURING DRILLING, IF USED ________ GAL

6. QUANTITY OF STANDING WATER IN WELL AND ANNULUS BEFORE DEV. ________ GAL.

7.	START	DURING (30 GAL)	DURING [illegible]	END
SPECIFIC CONDUCTANCE (umhos/cm)	90	125	130	150
TEMPERATURE (°C)	11.5	13.0	13.0	[illegible]
pH (s.u)	7.21	7.75	7.76	7.74

8. DEPTH FROM TOP OF WELL CASING TO BOTTOM OF WELL 22.94 FT.

9. SCREEN LENGTH 15 FT.

10. DEPTH TO TOP OF SEDIMENT: BEFORE DEV. 18.01 FT., AFTER DEV. 22.77 FT

11. PHYSICAL CHARACTER OF WATER: Initially brown [illegible] of sediment. Finally clear w/ few grains of sand

12. TYPE AND SIZE OF WELL DEVELOPMENT EQUIPMENT: 100 CF[illegible] 1" [illegible] PVC pipe, 3/4" plastic tubing, 1" [illegible]

13. DESCRIPTION OF SURGE TECHNIQUE, IF USED: [illegible] [illegible] [illegible] compressor

14. HEIGHT OF WELL CASING ABOVE GROUND SURFACE: 2.94 FT.

15. QUANTITY OF WATER REMOVED: 100 GAL.

TIME FOR REMOVAL: 5 30 HR./MIN.

16. 1-PINT WATER SAMPLE COLLECTED: 3:30 (TIME)

* DEVELOPMENT CONDITIONS: 1) WELL WATER IS REASONABLY CLEAR
2) SEDIMENT THICKNESS < 5% OF SCREEN LENGTH
3) REMOVAL OF 5 WELL VOLUMES INCLUDING SATURATED FILTER ANN

LAW ENGINEERING TESTING COMPANY JOB NAME GOCO JOB NO. [illegible]

BY K[illegible] DATE 2-18-85 CK CAS DATE 2-23-85 SHEET ____ OF ____

WELL DEVELOPMENT DATA

1. WELL NO. G12-4

2. DATE OF INSTALLATION: 2-15-85

3. DATE OF DEVELOPMENT: 2-18-85/2-19-85

4. STATIC WATER LEVEL: BEFORE DEV. 7.45 FT; 24 HOURS AFTER ____

5. QUANTITY OF WATER LOSS DURING DRILLING, IF USED ____ GAL

6. QUANTITY OF STANDING WATER IN WELL AND ANNULUS BEFORE DEV. ____ GAL.

7.	START	DURING		END
		([illegible])	([illegible])	
SPECIFIC CONDUCTANCE (umhos/cm)	175	[illegible]	105	120
TEMPERATURE (°C)	16.0	[illegible]	12.0	13.5
pH (s.u)	6.97	7.21	7.01	6.5

8. DEPTH FROM TOP OF WELL CASING TO BOTTOM OF WELL 28.86 FT

9. SCREEN LENGTH 15 FT.

10. DEPTH TO TOP OF SEDIMENT: BEFORE DEV. 22.5 FT., AFTER DEV. ____

11. PHYSICAL CHARACTER OF WATER: Initially [illegible] w/ [illegible] of sediment. Fin[illegible], clear w/ little suspended [illegible]

12. TYPE AND SIZE OF WELL DEVELOPMENT EQUIPMENT: [illegible] 3/8" [illegible] tubing [illegible]

13. DESCRIPTION OF SURGE TECHNIQUE, IF USED: Occasionally [illegible] of compressor

14. HEIGHT OF WELL CASING ABOVE GROUND SURFACE: 2.86 FT.

15. QUANTITY OF WATER REMOVED: 120 GAL.

TIME FOR REMOVAL: 5 [illegible] HR./MIN.

16. 1-PINT WATER SAMPLE COLLECTED: [illegible] (TIME)

* DEVELOPMENT CONDITIONS:
1) WELL WATER IS REASONABLY CLEAR
2) SEDIMENT THICKNESS < 5% OF SCREEN LENGTH
3) REMOVAL OF 5 WELL VOLUMES INCLUDING SATURATED FILTER ANN

LAW ENGINEERING TESTING COMPANY JOB NAME [illegible] JOB NO. [illegible]

BY [illegible] DATE 2-15-85 CK CAS DATE 2-28-85 SHEET ____ OF ____

WELL DEVELOPMENT DATA

1. WELL NO. G5-5

2. DATE OF INSTALLATION: 2-7-85

3. DATE OF DEVELOPMENT: 2-15-85 /2-18-85 2-?-85

4. STATIC WATER LEVEL: BEFORE DEV. 24.75 FT ; 24 HOURS AFTER ____ FT

5. QUANTITY OF WATER LOSS DURING DRILLING, IF USED ____ GAL

6. QUANTITY OF STANDING WATER IN WELL AND ANNULUS BEFORE DEV. ____ GAL.

7.	START	DURING		END
		(20 gal)	([illegible])	
SPECIFIC CONDUCTANCE (umhos/cm)	30	35	30	25
TEMPERATURE (°C)	15.0	17.0	19.0	5.5
pH (s.u)	6.83	6.53	6.41	6.65

8. DEPTH FROM TOP OF WELL CASING TO BOTTOM OF WELL 53.0 FT

9 SCREEN LENGTH 20 FT.

10. DEPTH TO TOP OF SEDIMENT: BEFORE DEV. 50.75 FT, AFTER DEV. [illegible] FT

11. PHYSICAL CHARACTER OF WATER: clear, [illegible]
[illegible]

12. TYPE AND SIZE OF WELL DEVELOPMENT EQUIPMENT: [illegible]
1" [illegible] PVC pipe 3/8" [illegible] 1" [illegible]

13 DESCRIPTION OF SURGE TECHNIQUE IF USED: [illegible]
[illegible]

14. HEIGHT OF WELL CASING ABOVE GROUND SURFACE: [illegible] FT

15 QUANTITY OF WATER REMOVED: [illegible] GAL.

TIME FOR REMOVAL: 2 HR, MIN.

16. 1-PINT WATER SAMPLE COLLECTED: [illegible] TIME

* DEVELOPMENT CONDITIONS: 1) WELL WATER IS REASONABLY CLEAR
2) SEDIMENT THICKNESS < 5% OF SCREEN LENGTH
3) REMOVAL OF 5 WELL VOLUMES INCLUDING SATURATED FILTER ANN

LAW ENGINEERING TESTING COMPANY JOB NAME [illegible] JOB NO. [illegible]-52

BY [illegible] DATE 2-20-85 CK [illegible] DATE 2-28-85 SHEET ___ OF 1

WELL DEVELOPMENT DATA

1. WELL NO. G5-6
2. DATE OF INSTALLATION: 2-18-85
3. DATE OF DEVELOPMENT: 2-20-85
4. STATIC WATER LEVEL: BEFORE DEV. 13.57 FT ; 24 HOURS AFTER ______ FT
5. QUANTITY OF WATER LOSS DURING DRILLING, IF USED ______ GAL.
6. QUANTITY OF STANDING WATER IN WELL AND ANNULUS BEFORE DEV. ______ GAL.

	START	DURING		END
7. SPECIFIC CONDUCTANCE (umhos/cm)	240	575	600	600
TEMPERATURE (°C)	16.0	17.5	17.5	17.5
pH (s.u)	6.92	7.06	7.0[illegible]	7.12

8. DEPTH FROM TOP OF WELL CASING TO BOTTOM OF WELL 37.50 FT.
9. SCREEN LENGTH 20 FT.
10. DEPTH TO TOP OF SEDIMENT: BEFORE DEV. 36.15 FT. , AFTER DEV. 3[illegible] FT
11. PHYSICAL CHARACTER OF WATER: Initially brown [illegible] of Sediment. Finally clear [illegible] slight odor.
12. TYPE AND SIZE OF WELL DEVELOPMENT EQUIPMENT: [illegible] 1" poly PVC pipe, 3/8" [illegible] tubing, 1" [illegible]
13. DESCRIPTION OF SURGE TECHNIQUE IF USED: ______
14. HEIGHT OF WELL CASING ABOVE GROUND SURFACE: [illegible].82 FT.
15. QUANTITY OF WATER REMOVED: 140 GAL.

    TIME FOR REMOVAL: 4:30 HR./MIN.
16. 1-PINT WATER SAMPLE COLLECTED: [illegible] (TIME)

* DEVELOPMENT CONDITIONS: 1) WELL WATER IS REASONABLY CLEAR
2) SEDIMENT THICKNESS < 5% OF SCREEN LENGTH
3) REMOVAL OF 5 WELL VOLUMES INCLUDING SATURATED FILTER ANNUL

APPENDIX I

IN SITU PERMEABILITY (SLUG TESTS AND LABORATORY PERMEABILITY RESULTS)

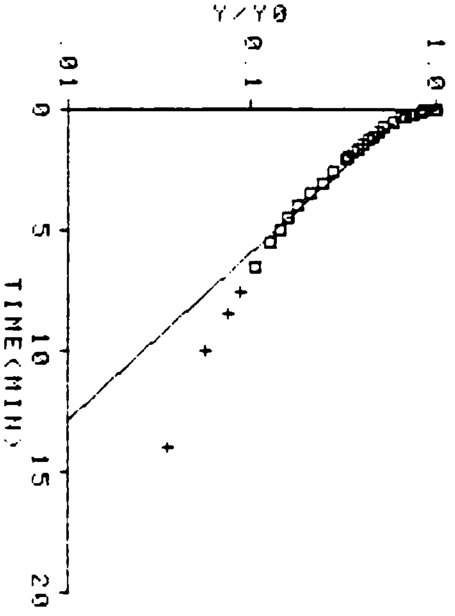
WELL NO G12-1 SLUG IN

2/22/85 3:40am

WELL CONSTANTS

STATIC WATER LEVEL 6.37 FT
R OR rc= .083 FT
L= 20.000 FT

POINT NO	TIME	WATER LEVEL	Δ WATER LEVEL
1	.0300	4.07	2.30*
2	.0333	4.38	1.99*
3	.1167	4.46	1.91*
4	.1833	4.64	1.73*
5	.2500	4.76	1.61*
6	.3333	4.87	1.50*
7	.5000	5.01	1.36*
8	.7500	5.16	1.21*
9	.9167	5.24	1.13*
10	1.0833	5.31	1.06*
11	1.2500	5.38	.99*
12	1.4167	5.43	.94*
13	1.5833	5.49	.88*
14	1.7500	5.54	.83*
15	1.9167	5.59	.78*
16	2.0000	5.61	.76*
17	2.5	5.72	.65*
18	3.0	5.81	.56*
19	3.5	5.89	.48*
20	4.0	5.95	.42*
21	4.5	6.00	.37*
22	5.0	6.04	.33*
23	5.5	6.08	.29*
24	6.5	6.13	.24*
25	7.5	6.17	.20
26	8.5	6.20	.17
27	10.0	6.24	.13
28	14.0	6.29	.08



HYDRAULIC CONDUCTIVITY

NAV-DOCK

K=3.17E-004 FT/MIN
K=1.61E-004 CM/SEC

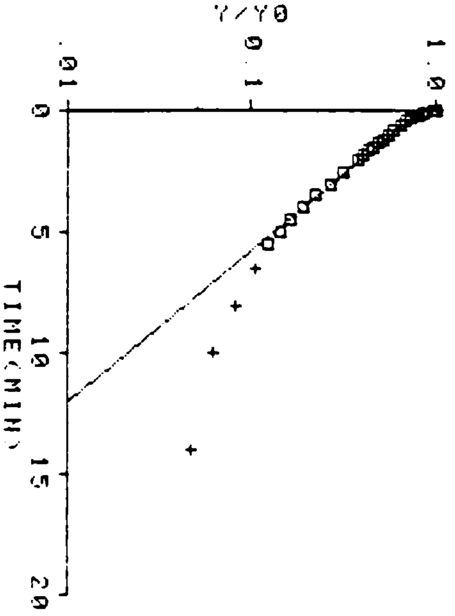
WELL NO G12-1 SLUG OUT

2/22/85 3:10am

WELL CONSTANTS

STATIC WATER LEVEL 6.37 FT
R OR rc= .083 FT
L= 20.000 FT

POINT NO	TIME	WATER LEVEL	Δ WATER LEVEL
1	.0267	8.96	2.59*
2	.0333	8.87	2.50*
3	.0833	8.63	2.26*
4	.1500	8.48	2.11*
5	.2167	8.38	2.01*
6	.3000	8.28	1.91*
7	.4167	8.18	1.81*
8	.5833	8.06	1.69*
9	.8333	7.91	1.54*
10	1.0000	7.81	1.44*
11	1.1667	7.72	1.35*
12	1.3333	7.64	1.27*
13	1.5000	7.56	1.19*
14	1.6667	7.49	1.12*
15	1.8333	7.42	1.05*
16	2.0000	7.36	.99*
17	2.5	7.19	.82*
18	3.0	7.06	.69*
19	3.5	6.95	.58*
20	4.0	6.86	.49*
21	4.5	6.79	.42*
22	5.0	6.74	.37*
23	5.5	6.69	.32*
24	6.5	6.64	.27
25	8.0	6.58	.21
26	10.0	6.53	.16
27	14.0	6.49	.12



HYDRAULIC CONDUCTIVITY

NAV-DOCK

K=3.48E-004 FT/MIN
K=1.77E-004 CM/SEC

WELL NO G12-2 SLUG OUT

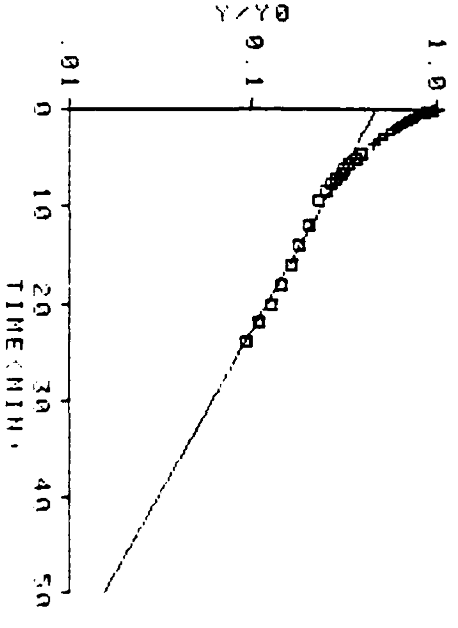
2/22/85 11:00AM

WELL CONSTANTS

STATIC WATER LEVEL 17.81 FT

R OR rc= .083 FT
L= 19.690 FT

POINT NO.	TIME	WATER LEVEL	∆ WATER LEVEL
1	.0233	20.58	2.77
2	.0333	20.50	2.69
3	.0833	20.43	2.62
4	.1167	20.35	2.54
5	.2000	20.26	2.45
6	.2667	20.20	2.39
7	.3333	20.15	2.34
8	.5000	20.05	2.24
9	.6667	19.97	2.16
10	.8333	19.89	2.08
11	.9167	19.85	2.04
12	1.0000	19.81	2.00
13	1.1667	19.74	1.93
14	1.3333	19.68	1.87
15	1.5000	19.62	1.81
16	1.6667	19.56	1.75
17	1.3333	19.50	1.69
18	2.0000	19.45	1.64
19	2.5	19.30	1.49
20	3.0	19.18	1.37
21	3.5	19.07	1.26
22	4.5	18.89	1.08*
23	5.0	18.82	1.01*
24	5.5	18.75	.94*
25	6.0	18.70	.89*
26	6.5	18.65	.84*
27	7.0	18.61	.80*
28	7.5	18.57	.76*
29	8.5	18.51	.70*
30	9.5	18.46	.65*
31	12.0	18.38	.57*
32	14.0	18.31	.50*
33	16.0	18.26	.45*
34	18.0	18.21	.40*
35	20.0	18.16	.35*
36	22.0	18.11	.30*
37	24.0	18.07	.26*



HYDRAULIC CONDUCTIVITY

NAV-DOCK

K=6.57E-005 FT/MIN
K=3.34E-005 CM/SEC

WELL NO G12-3 SLUG IN

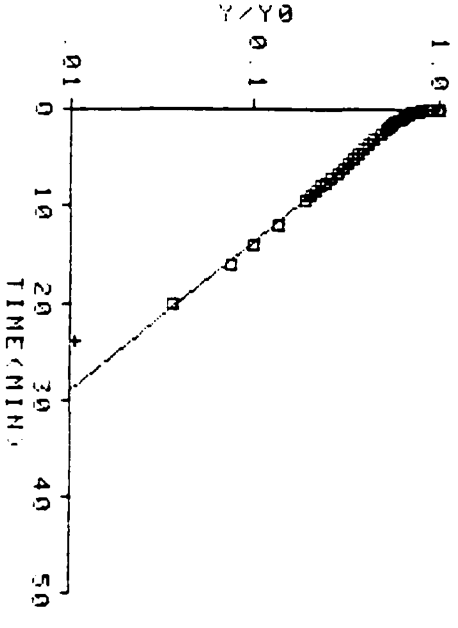
2/22/85 10:00am

WELL CONSTANTS

STATIC WATER LEVEL 5.24 FT

R OR rc= .083 FT
L= 15.000 FT

POINT NO	TIME	WATER LEVEL	∆ WATER LEVEL
1	.0333	2.46	2.78*
2	.0667	2.68	2.56*
3	.1000	3.01	2.23*
4	.1500	3.07	2.17*
5	.2000	3.13	2.11*
6	.2500	3.19	2.06*
7	.3167	3.24	2.00*
8	.4167	3.30	1.94*
9	.5833	3.38	1.86*
10	.7500	3.45	1.79*
11	.9167	3.50	1.74*
12	1.0833	3.56	1.68*
13	1.3333	3.63	1.61*
14	1.5833	3.69	1.55*
15	1.8333	3.75	1.49*
16	2.0000	3.79	1.46*
17	2.5	3.89	1.35*
18	3.0	3.98	1.26*
19	3.5	4.06	1.18*
20	4.0	4.14	1.10*
21	4.5	4.21	1.03*
22	5.0	4.27	.97*
23	5.5	4.33	.91*
24	6.0	4.39	.85*
25	6.5	4.45	.79*
26	7.0	4.50	.74*
27	7.5	4.55	.69*
28	8.0	4.59	.65*
29	8.5	4.63	.61*
30	9.0	4.67	.57*
31	9.5	4.71	.53*
32	12.0	4.86	.39*
33	14.0	4.96	.28*
34	16.0	5.03	.21*
35	20.0	5.14	.10*
36	24.0	5.21	.03



HYDRAULIC CONDUCTIVITY

NAV-DOCK

K=1.78E-004 FT/MIN
K=9.05E-005 CM/SEC

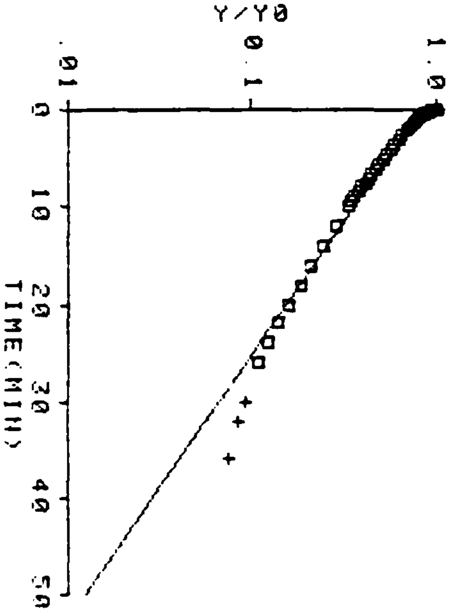
WELL NO. G12-3 SLUG OUT

2/22/85 10:30am

WELL CONSTANTS

STATIC WATER LEVEL 5.24 FT
R OR rc= .083 FT
L= 15.000 FT

POINT NO.	TIME	WATER LEVEL	Δ WATER LEVEL
1	.0267	8.07	2.83*
2	.0333	8.00	2.76*
3	.0833	7.89	2.65*
4	.1667	7.80	2.56*
5	.2333	7.75	2.51*
6	.3167	7.70	2.46*
7	.4167	7.65	2.41*
8	.5833	7.59	2.35*
9	.7500	7.53	2.29*
10	.9167	7.48	2.24*
11	1.0833	7.43	2.19*
12	1.2500	7.39	2.15*
13	1.4167	7.34	2.10*
14	1.6667	7.28	2.04*
15	1.9333	7.25	2.01*
16	2.0000	7.21	1.97*
17	2.5	7.11	1.87*
18	3.0	7.02	1.78*
19	3.5	6.93	1.69*
20	4.0	6.85	1.61*
21	4.5	6.78	1.54*
22	5.0	6.70	1.46*
23	5.5	6.64	1.40*
24	6.0	6.58	1.34*
25	6.5	6.52	1.29*
26	7.0	6.46	1.22*
27	7.5	6.41	1.17*
28	8.0	6.36	1.12*
29	8.5	6.31	1.07*
30	9.0	6.27	1.03*
31	9.5	6.22	.98*
32	10.0	6.18	.94*
33	12.0	6.05	.81*
34	14.0	5.93	.69*
35	16.0	5.84	.60*
36	18.0	5.76	.52*
37	20.0	5.69	.45*
38	22.0	5.64	.40*
39	24.0	5.59	.35*
40	26.0	5.55	.31*
41	30.0	5.50	.26
42	32.0	5.48	.24
43	36.0	5.45	.21



HYDRAULIC CONDUCTIVITY

NAV-DOCK

K=1.01E-004 FT/MIN
K=5.14E-005 CM/SEC

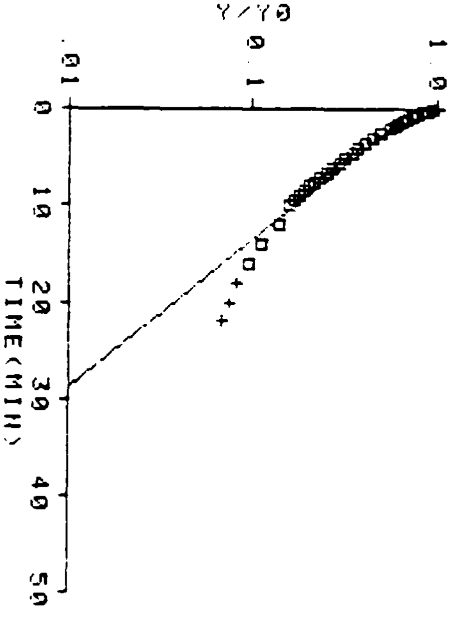
WELL NO. G12-4 SLUG OUT

2/22/85 11:45am

WELL CONSTANTS

STATIC WATER LEVEL 7.07 FT
R OR rc= .083 FT
L= 20.000 FT

POINT NO	TIME	WATER LEVEL	Δ WATER LEVEL
1	.0267	9.39	2.32
2	.0667	9.71	2.64*
3	.1167	9.61	2.54*
4	.2000	9.51	2.44*
5	.3000	9.41	2.34*
6	.4167	9.32	2.25*
7	.5833	9.22	2.15*
8	.7500	9.12	2.05*
9	.9167	9.04	1.97*
10	1.1667	8.92	1.85*
11	1.4167	8.81	1.74*
12	1.6667	8.72	1.65*
13	1.9167	8.63	1.56*
14	2.5	8.46	1.39*
15	3.0	8.33	1.26*
16	3.5	8.22	1.15*
17	4.0	8.12	1.05*
18	4.5	8.04	.97*
19	5.0	7.96	.89*
20	5.5	7.90	.83*
21	6.0	7.84	.77*
22	6.5	7.78	.71*
23	7.0	7.73	.66*
24	7.5	7.69	.62*
25	8.0	7.65	.58*
26	8.5	7.61	.54*
27	9.0	7.58	.51*
28	9.5	7.55	.48*
29	10.0	7.52	.45*
30	12.0	7.47	.40*
31	14.0	7.39	.32*
32	16.0	7.34	.27*
33	18.0	7.30	.23
34	20.0	7.28	.21
35	22.0	7.26	.19



HYDRAULIC CONDUCTIVITY

NAV-DOCK

K=1.43E-004 FT/MIN
K=7.29E-005 CM/SEC

WELL NO. G5-5 SLUG OUT

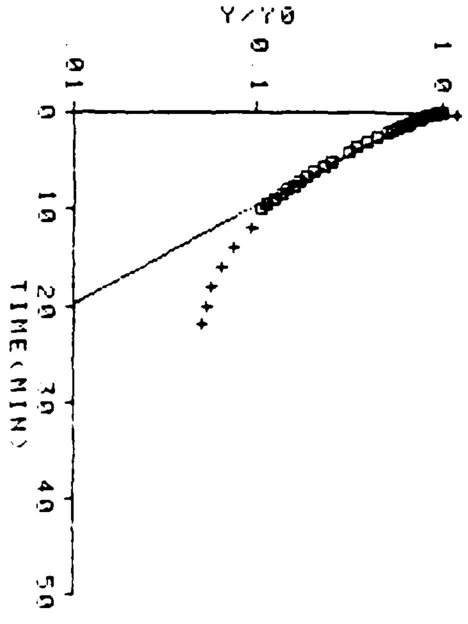
2/22/85 4:00pm

WELL CONSTANTS

STATIC WATER LEVEL 34.01 FT

R OR rc= .083 FT
L= 18.490 FT

POINT NO.	TIME	WATER LEVEL	▵ WATER LEVEL
1	.0300	36.82	2.81*
2	.1000	36.67	2.66*
3	.1667	36.56	2.55*
4	.2667	37.46	3.45
5	.3333	36.38	2.37*
6	.5000	36.24	2.23*
7	.6667	36.12	2.11*
8	.8333	36.01	2.00*
9	1.0000	35.91	1.90*
10	1.1667	35.82	1.81*
11	1.3333	35.73	1.72*
12	1.5833	35.62	1.61*
13	1.8333	35.51	1.50*
14	2.0000	35.44	1.43*
15	2.5	35.27	1.26*
16	3.0	35.12	1.11*
17	3.5	35.00	.99*
18	4.0	34.89	.88*
19	5.0	34.72	.71*
20	5.5	34.65	.64*
21	6.0	34.59	.58*
22	6.5	34.54	.53*
23	7.0	34.49	.48*
24	7.5	34.45	.44*
25	8.0	34.41	.40*
26	8.5	34.39	.38*
27	9.0	34.36	.35*
28	9.5	34.33	.32*
29	10.0	34.31	.30*
30	12.0	34.27	.26
31	14.0	34.22	.21
32	16.0	34.19	.18
33	18.0	34.17	.16
34	20.0	34.16	.15
35	22.0	34.15	.14



HYDRAULIC CONDUCTIVITY

NAV-DOCK

K=2.25E-004 FT/MIN
K=1.15E-004 CM/SEC

WELL NO. G5-6 SLUG IN

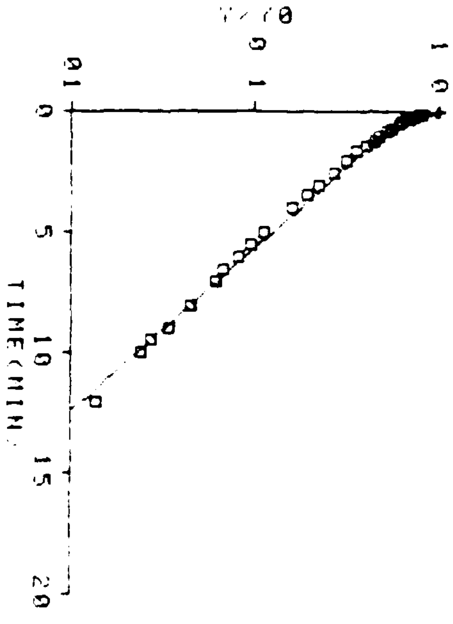
2/22/85 3:32pm

WELL CONSTANTS

STATIC WATER LEVEL 13.08 FT

R OR rc= .063 FT
L= 20.000 FT

POINT NO	TIME	WATER LEVEL	▵ WATER LEVEL
1	.0233	10.19	2.89
2	.0300	10.24	2.84
3	.0500	10.57	2.51
4	.0667	10.72	2.36*
5	.1333	10.82	2.26*
6	.2000	10.94	2.14*
7	.2667	11.05	2.03*
8	.3333	11.15	1.93*
9	.4167	11.23	1.85*
10	.5000	11.32	1.76*
11	.6667	11.46	1.62*
12	.8333	11.58	1.50*
13	1.0000	11.69	1.39*
14	1.1667	11.79	1.29*
15	1.4167	11.92	1.16*
16	1.6667	12.03	1.05*
17	2.0000	12.16	.92*
18	2.5	12.31	.77*
19	3.0	12.43	.65*
20	3.5	12.53	.55*
21	4.0	12.62	.46*
22	5.0	12.75	.33*
23	5.5	12.80	.28*
24	6.0	12.84	.24*
25	6.5	12.88	.20*
26	7.0	12.90	.18*
27	8.0	12.95	.13*
28	9.0	12.98	.10*
29	9.5	13.00	.08*
30	10.0	13.01	.07*
31	12.0	13.04	.04*
32	14.0	13.07	.01



HYDRAULIC CONDUCTIVITY

NAV-DOCK

K=3.25E-004 FT/MIN
K=1.65E-004 CM/SEC

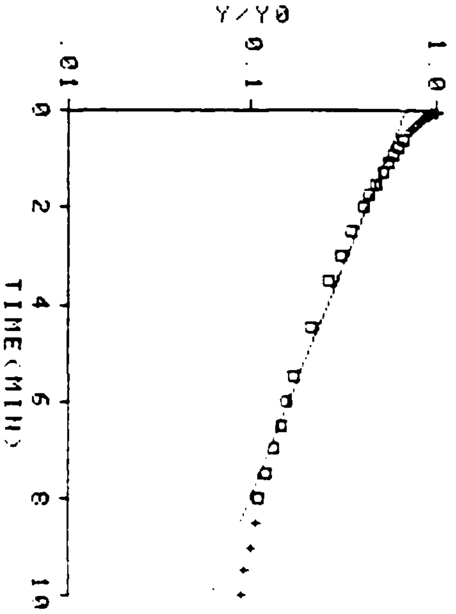
WELL NO G5-6 SLUG OUT

2/22/85 4:30pm

WELL CONSTANTS

STATIC WATER LEVEL 13.08 FT
R OR rc= .083 FT
L= 20.000 FT

POINT NO	TIME	WATER LEVEL	∆ WATER LEVEL
1	.0333	15.32	2.74
2	.0667	15.69	2.61
3	.1000	15.59	2.51
4	.1500	15.47	2.39
5	.2000	15.38	2.30
6	.2667	15.27	2.19
7	.3330	15.18	2.10
8	.4167	15.09	2.01
9	.5833	14.94	1.86*
10	.7500	14.81	1.73*
11	.9167	14.70	1.62*
12	1.0333	14.60	1.52*
13	1.2506	14.50	1.42*
14	1.5000	14.38	1.30*
15	1.7500	14.27	1.19*
16	2.0000	14.18	1.10*
17	2.5	14.03	.95*
18	3.0	13.91	.83*
19	3.5	13.80	.72*
20	4.5	13.65	.57*
21	5.5	13.54	.46*
22	6.0	13.50	.42*
23	6.5	13.47	.39*
24	7.0	13.44	.36*
25	7.5	13.41	.33*
26	8.0	13.39	.30*
27	8.5	13.37	.29
28	9.0	13.35	.27
29	9.5	13.33	.25
30	10.0	13.32	.24

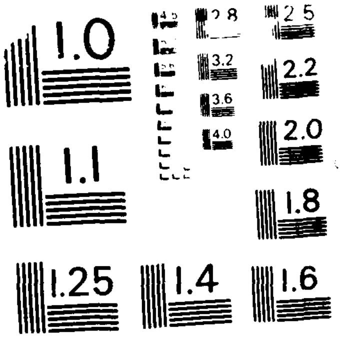


HYDRAULIC [illegible]

[illegible]

[illegible]
[illegible]

AD-A190 452 INSTALLATION RESTORATION PROGRAM PHASE 2 2/3
CONFIRMATION/QUANTIFICATION STAG..(U) ENVIRONMENTAL
SCIENCE AND ENGINEERING INC GAINESVILLE FL
UNCLASSIFIED C R NEFF ET AL 09 AUG 86 F/G 24/3 NL



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963

APPENDIX J

CHAIN-OF-CUSTODY DOCUMENTATION

ENVIRONMENTAL SCIENCE & ENGINEERING 02/12/85 *** FIELD LOGSHEET *** STORET MAP # 4686 GOCO1 DD:
PROJECT NUMBER: 84614500 PROJECT NAME: GOCO PLANT 6 LAB COORD. TOM PARK

ESE #	SITE/STA	HAZ?	FRACTIONS(CIRCLE)	DATE	TIME	AN. SUBSET	PH SU	COND UM/CM	T	
[✓ 480100]	2-1		[✓ 0] [✓ 0] 0 0 [✓ S] S [✓ X] [✓ X] X X	2-25-85	1420		4,3	33	16.6	
[✓ 480101]	5-1		[✓ 0] [✓ 0] 0 0 [✓ S] S [✓ X] [✓ X] X X	2-26-85	1045		4.9	139	15.9	
~~480102~~	8-1		0 0 0 0 S S X X X X							
[✓ 480103]	12-1		[✓ 0] [✓ 0] 0 0 [✓ S] S [✓ X] [✓ X] X X	2-27-85	1115		5.7	253	16.0	
[✓ 480104]	12-2		[✓ 0] [✓ 0] 0 0 [✓ S] S [✓ X] [✓ X] X X	2-26-85	1440		5.4	537	12.8	
[✓ 480105]	12-3		[✓ 0] [✓ 0] 0 0 [✓ S] S [✓ X] [✓ X] X X	2-26-85	1740		6.4	177	14.5	
[✓ 480106]	12-4		[✓ 0] [✓ 0] 0 0 [✓ S] S [✓ X] [✓ X] X X	2-26-85	1520		5.3	225	16.3	
480107	M-1		0 0 0 0 S S X X X X							
480108	M-2		0 0 0 0 S S X X X X							
480109	M-3		0 0 0 0 S S X X X X							
480110	M-4		0 0 0 0 S S X X X X							
480111	M-5		0 0 0 0 S S X X X X							
480112			0 0 0 0 S S X X X X							
480113			0 0 0 0 S S X X X X							

ENVIRONMENTAL SCIENCE & ENGINEERING 02/12/85 *** FIELD LOGSHEET *** STORET MAP # 4686 GOC01 DD:
PROJECT NUMBER: 84614500 PROJECT NAME: GOCO PLANT 6 LAB COORD. TOM PARK

ESE # SITE/STA HAZ? FRACTIONS(CIRCLE) DATE TIME AN. SUBSET PH SU COND UM/CM

NOTE -CHANGE OR ENTER SITE ID'S AS NECESSARY; UP TO 6 ALPHANUMERIC CHARACTERS MAY BE USED
-CIRCLE FRACTIONS COLLECTED. ENTER DATE,TIME,FIELD DATA (IF REQUIRED), HAZARD CODE AND NOTES
-HAZARD CODES: I=IGNITABLE C=CORROSIVE R=REACTIVE T=TOXIC WASTE H=OTHER ACUTE HAZARD; IDENTIFY SPECIFICS IF KNOWN
-PLEASE RETURN LOGSHEETS WITH SAMPLES TO ESE

	RELINQUISHED BY: (NAME/ORGANIZATION/DATE/TIME)	RECEIVED BY (NAME/ORGANIZATION/DATE/TIME)
1	ESE 2/27/85 2200	Kelly Bergdall /ESE/2/28/85 / 0900
2		
3		

OTHER FIELD NOTES:

ENVIRONMENTAL SCIENCE & ENGINEERING 02/12/85 *** FIELD LOGSHEET *** STORET MAP # 4607 GOCO2 OD:
PROJECT NUMBER: 84614500 PROJECT NAME: GOCO PLANT 6 LAB COORD.

ESE #	SITE/STA	HAZ?	FRACTIONS(CIRCLE)	DATE	TIME	AN. SUBSET				
480200	11-1		[✓ HC] HC	2-26	1600					
480201			HC HC							
480202			HC HC							

NOTE -CHANGE OR ENTER SITE ID'S AS NECESSARY; UP TO 6 ALPHANUMERIC CHARACTERS MAY BE USED
-CIRCLE FRACTIONS COLLECTED. ENTER DATE,TIME,FIELD DATA (IF REQUIRED), HAZARD CODE AND NOTES
-HAZARD CODES: I=IGNITABLE C=CORROSIVE R=REACTIVE T=TOXIC WASTE H=OTHER ACUTE HAZARD; IDENTIFY SPECIFICS IF KNOWN
-PLEASE RETURN LOGSHEETS WITH SAMPLES TO ESE

	RELINQUISHED BY: (NAME/ORGANIZATION/DATE/TIME)	RECEIVED BY (NAME/ORGANIZATION/DATE/TIME)
1	ESE 2/27/85 2200	Kelly Bergdoll/ESE, 2/28/85/0900
2		
3		

OTHER FIELD NOTES:

ENVIRONMENTAL SCIENCE & ENGINEERING 02/12/85 *** FIELD LOGSHEET *** STORET MAP # 4688 GOCO3 DD:
PROJECT NUMBER: 84614500 PROJECT NAME: GOCO PLANT 6 LAB COORD.

ESE #	SITE/STA	HAZ?	FRACTIONS(CIRCLE)	DATE	TIME	AN. SUBSET	pH	Cond	T	
480300	12-1		[✓ N] N	2-27-85	1115		5.7	253	16.0	
480301	12-2		[✓ N] N	2-26-85	1440		5.4	587	17.6	
480302	12-3		[✓ N] N	2-26-85	1245		6.4	177	14.5	
480303	12-4		[✓ N] N	2-26-85	1500		5.3	225	16.3	
480304			N N							
480305			N N							

NOTE -CHANGE OR ENTER SITE ID'S AS NECESSARY; UP TO 6 ALPHANUMERIC CHARACTERS MAY BE USED
-CIRCLE FRACTIONS COLLECTED. ENTER DATE,TIME,FIELD DATA (IF REQUIRED), HAZARD CODE AND NOTES
-HAZARD CODES: I=IGNITABLE C=CORROSIVE R=REACTIVE T=TOXIC WASTE H=OTHER ACUTE HAZARD; IDENTIFY SPECIFICS IF KNOWN
-PLEASE RETURN LOGSHEETS WITH SAMPLES TO ESE

	RELINQUISHED BY: (NAME/ORGANIZATION/DATE/TIME)	RECEIVED BY (NAME/ORGANIZATION/DATE/TIME)
1	ESE 2/27/85 2300	Kelly Bergdoll/ESE/2/28/85/090
2		
3		

OTHER FIELD NOTES:

ENVIRONMENTAL SCIENCE & ENGINEERING 02/12/85 *** FIELD LOGSHEET *** STORET MAP # 4689 GOCO4 DD:
PROJECT NUMBER: 84614500 PROJECT NAME: GOCO PLANT 6 LAB COORD. TOM PARK

ESE #	SITE/STA	HAZ?	FRACTIONS(CIRCLE)	DATE	TIME	AN. SUBSET				
[✓ 480400]	12-1		[✓ C] C AC AC	2 26 85	1620					
[✓ 480401]	12-2		[✓ C] C AC AC		1625					
[✓ 480402]	12-3		[✓ C] C AC AC		1630					
480403			C C AC AC							
480404			C C AC AC							

NOTE -CHANGE OR ENTER SITE ID'S AS NECESSARY; UP TO 6 ALPHANUMERIC CHARACTERS MAY BE USED
-CIRCLE FRACTIONS COLLECTED. ENTER DATE,TIME,FIELD DATA (IF REQUIRED), HAZARD CODE AND NOTES
-HAZARD CODES: I=IGNITABLE C=CORROSIVE R=REACTIVE T=TOXIC WASTE H=OTHER ACUTE HAZARD; IDENTIFY SPECIFICS IF KNOWN
-PLEASE RETURN LOGSHEETS WITH SAMPLES TO ESE

	RELINQUISHED BY: (NAME/ORGANIZATION/DATE/TIME)	RECEIVED BY (NAME/ORGANIZATION/DATE/TIME)
1	ESE 2/27/85 2300	Kelly Bergdahl/ESE/2/28/85/0900
2		
3		

OTHER FIELD NOTES:

ENVIRONMENTAL SCIENCE & ENGINEERING 07/19/85 *** FIELD LOGSHEET *** STORET MAP # 5276 GOCO5 GO:
PROJECT NUMBER: 84416401 PROJECT NAME: GOCO 6 LAB COORD. G. WIETER

ESE #	SITE/STA	HAZ?	FRACTIONS(CIRCLE)	DATE	TIME	AN. SUBSET	PH SU	COND UM/CM	W. TEMP C
							400	94	10
539300	6 5-6		[✓ V] [✓ V] [✓ V] V V V [✓ X] [✓ X] X X	7-22-85	1320		4.5	1710	15.5
539301	12-1		[✓ V] [✓ V] [✓ V] V V V X X X X	[illegible]	[illegible]		6.0	[illegible]	[illegible]
539302	12-2		[✓ V] [✓ V] [✓ V] V V V [✓ X] [✓ X] X X	7-22-85	1830		6.3	843	[illegible]
539303	12-3		[✓ V] [✓ V] [✓ V] V V V [✓ X] [✓ X] X X	[illegible] 85	1635		5.7	194	[illegible]
539304	G5-5		[✓ V] [✓ V] [✓ V] V V V [✓ X] [✓ X] X X	7-22-85	1300		4.8	65	18.1
539305			V V V V V V X X X X						
539306			V V V V V V X X X X						

NOTE -CHANGE OR ENTER SITE ID'S AS NECESSARY; UP TO 6 ALPHANUMERIC CHARACTERS MAY BE USED
-CIRCLE FRACTIONS COLLECTED. ENTER DATE,TIME,FIELD DATA (IF REQUIRED), HAZARD CODE AND NOTES
-HAZARD CODES: I=IGNITABLE C=CORROSIVE R=REACTIVE T=TOXIC WASTE H=OTHER ACUTE HAZARD; IDENTIFY SPECIFICS IF KNOWN
-PLEASE RETURN LOGSHEETS WITH SAMPLES TO ESE

RELINQUISHED BY: (NAME/ORGANIZATION/DATE/TIME)	RECEIVED BY (NAME/ORGANIZATION/DATE/TIME)
1 [illegible] ESE 7/24/85 [illegible]	[illegible]
2	D. Velin/ESE/7-24/1400
3	

OTHER FIELD NOTES:

-9218

APPENDIX K

ANALYTICAL RESULTS FOR GROUND WATER AND SOILS

[illegible] 03/[illegible]/85 STATUS: FINAL

[illegible]
[illegible]
[illegible]

PROJECT NAME: [illegible] PLANT [illegible]
PROJECT MANAGER: [illegible]
FIELD GROUP LEADER: [illegible]

		SAMPLE NUMBERS					
		2-1	5-1	12-1	12-2	12-3	12-4
PARAMETER	[illegible]	450100	450101	450103	450104	450105	450106
DATE		2/25/85	2/26/85	2/27/85	2/26/85	2/26/85	2/26/85
TIME		1420	1045	1115	144[illegible]	1745	15[illegible]0
[illegible] (MG/L)	[illegible]	3.0	3.2	16.3	3.5	2.0	3.3
TOX (UG/L-CL)	[illegible]	5330	530	460	120	24	52
[illegible] (MG/L)	[illegible]	2	<0.7	<0.0	4	<1.7	<0.7
PH [illegible]	[illegible]	4.35	4.33	5.70	5.40	6.40	5.30
SPEC. COND. (UMHOS/CM)	[illegible]	33.0	9.9	253	587	177	225
WATER TEMP (C)	[illegible]	15.5	15.9	16.0	17.6	14.5	16.3

```
[illegible]                                03/[illegible]/85        STATUS: FINAL

     PROJECT [illegible]                             PROJECT NAME: [illegible]
     [illegible]                                     PROJECT MANAGER: [illegible]
     [illegible]           [illegible] TYPES: ALL    FIELD GROUP LEADER: [illegible] VICT[illegible]

                                                       SAMPLE NUMBER
                                     II-1
 PARAMETER           [illegible]     930250
                     [illegible]
 DATE                               2/26/85

 TIME                                  1500

 MOISTURE([illegible])  [illegible]    25.6

 [illegible]            [illegible]    36.6
       [illegible]
```

[illegible] 03/2?/85 STATUS: FINAL

[illegible]
[illegible] 3
[illegible] ALL

[illegible]
[illegible]
[illegible]

SAMPLE [illegible]

PARAMETER	[illegible]	12-1 4?3300	12-2 465301	12-3 4?3302	12-4 4?3303
DATE		2/21/85	2/26/85	2/26/85	2/26/85
TIME		1115	14??	1745	15??
[illegible]	[illegible]	16	16	?.3	4.?
[illegible]	[illegible]	?.73	5.4?	6.9?	5.3?
SP. [illegible] ([illegible])	[illegible]	253	537	177	225
WATER TEMP (C)	[illegible]	16.0	17.0	14.5	16.3

[illegible]

STATUS: FINAL

[illegible]

PROJECT NAME: [illegible]
PROJECT MANAGER: [illegible]
FIELD GROUP LEADER: [illegible]

SAMPLE NUMBERS

	12-1 450400	12-2 450401	12-3 450402
DATE	2/26/85	2/26/85	2/26/85
TIME	1620	1625	1630
[illegible]	<15	<15	<15

[illegible] STATUS: FINAL

PROJECT [illegible] PROJECT NAME: [illegible]
FIELD [illegible] PROJECT MANAGER:
[illegible] FIELD GROUP LEADER: [illegible] VICTOR

SAMPLE NUMBERS

PARAMETER		05-5	12-1	12-2	12-3	05-5
		539300	539301	539302	539303	539304
DATE		7/22/85	7/23/85	7/22/85	7/22/85	7/22/85
TDS		1520	1445	1636	1625	1500
TOX (UG/L-CL)	[illegible]	153	240	65	23	3600
[illegible]	[illegible]	<1.00	<1.00	<1.00	<1.00	<1.00
[illegible] (UG/L)	[illegible]	<1.00	<1.00	<1.00	<1.00	<1.00
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
[illegible] (UG/L)	[illegible]	<1.0	<1.0	<1.0	<1.0	<1.0
[illegible] (UG/L)	[illegible]	<1.0	<1.0	<1.0	<1.0	<1.0
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
[illegible] (UG/L)	[illegible]	<1.0	<1.0	<1.0	<1.0	150
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
[illegible] (UG/L)	[illegible]	<1.00	<1.00	<1.00	<1.00	<1.00
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
[illegible] (UG/L)	[illegible]	<1.0	<1.0	<1.0	<1.0	2.7
[illegible] (UG/L)	[illegible]	<1.0	<1.0	<1.0	<1.0	<1.0
[illegible] (UG/L)	[illegible]	<1.0	<1.0	<1.0	<1.0	15
[illegible] (UG/L)	[illegible]	210	350	<1.0	<1.0	1500
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1

ENVIRONMENTAL [illegible] RESULTS 09/03/85 STATUS: FINAL

PROJECT [illegible]
FIELD [illegible]
PARAMETERS [illegible] : ALL

PROJECT [illegible]
PROJECT MANAGER:
FIELD GROUP LEADER: [illegible]

SAMPLE NUMBERS

PARAMETERS	[illegible]	03-5 53930	12-1 53931	12-2 53932	12-3 53933	05-? 53934
DATE		7/22/85	7/23/85	7/22/85	7/22/85	7/22/85
TIME		1320	1445	1630	1625	1300
CIS-1,2-[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
T-1,3-[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
METHYLENE CHL[illegible] (UG/L)	[illegible]	5	<2	<2	<2	<2
1,1,2,2-TE[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	<1
TETRACHLO[illegible] (UG/L)	[illegible]	15	<1.0	<1.0	<1.0	15
1,1,1-TRICH[illegible] (UG/L)	[illegible]	<1.0	<1.0	<1.0	<1.0	14
TRANS-1-[illegible] (UG/L)	[illegible]	<1.0	<1.0	<1.0	<1.0	<1.0
[illegible] (UG/L)	[illegible]	35	77	<1.0	<1.0	3500
[illegible] (UG/L)	[illegible]	<1	<1	<1	<1	27
[illegible] (UG/L)	[illegible]	3	57	<1	<1	<1
[illegible]		4.50	6.??	6.30	5.71	4.80
SPEC [illegible] ([illegible])		1710	458	643	134	55.0
WAT [illegible]		15.3	21.2	17.7	19.2	15.1

APPENDIX L

ANALYTICAL METHODS, DETECTION LIMITS, AND QUALITY CONTROL DATA SUMMARY

Parameter	Method	Units	Detection Limit	Spiked Sample	Initial Value	Spike Conc.	Percent Recovered	Split Sample	First Value	Second Value	Method Blank
Moisture	160.3(2)	%	1					MW3 #3 5-6.5'	.9	.9	
henolics	420.2(2)	μg/g	1.	MW3 #3 5-6.5'	46.1	99	89	MW3 #3 5-6.5'	134.1	133.3	*
OC	415.1(2)	μg/g	5.	MW3 #3 5-6.5'	2.4	2.	117.2	MW3 #3 5-6.5'	2527	2272	*
OX	9020(3)	μg/g	5.	MW3 #3 5-6.5'	*	18	52.(8)	MW3 #3 5-6.5'	*	*	*
rsenic	206.2(2)(7)	mg/L	0.01	Drum	*	.04762	99.9	Drum	*	*	*
arium	208.1(2)(7)	mg/L	0.1	Drum	*	0.47619	110.	Drum	*	*	*
admium	213.1(2)(7)	mg/L	0.02	Drum	*	.04762	105.4	Drum	.0202	*	*
hromium	218.1(2)(7)	mg/L	0.1	Drum	*	.19048	133.3	Drum	*	*	*
ead	239.2(2)(7)	mg/L	0.01	Drum	*	.476	3.(8)	Drum	*	*	*
ercury	245.1(2)(7)	mg/L	0.01	Drum	*	.1	98.5	Drum	*	*	*
elenium	270.2(2)(7)	mg/L	0.01	Drum	*	.04762	77.9	Drum	*	*	*
lver	272.1(2)(7)	mg/L	0.01	Drum	*	.04762	108.1	Drum	*	*	*
ldrin	608(4)	μg/g	0.01	MW1 20-20.5'	*	.04	130	MW1 20-20.5'	*	*	*
.p DDT	608(4)	μg/g	0.01	MW3 #3 5-6.5'	*	.05	116	MW1 20-20.5'	*	*	*
ieldrin	608(4)	μg/g	0.01	MW1 20-20.5'	*	0.1	117	MW1 20-20.5'	*	*	*
ndrin	608(4)	μg/g	0.01	MW1 20-20.5'	*	0.1	107	MW1 20-20.5'	*	*	*
eptachlor	608(4)	μg/g	0.01	MW1 20-20.5'	*	.04	118	MW1 20-20-.5'	*	*	*
indane	608(4)	μg/g	0.01	MW1 20-20.5'	*	.04	105	MW1 20-20.5'	*	*	*
,4-D	509B(5)	μg/g	0.01	MW1 20-20.5'	*	0.5	76	MW1 20-20-.5'	*	*	*
,4,5-T	509B(5)	μg/g	0.01	MW1 20-20.5'	*	0.5	88.1	MW1 20-20.5'	*	*	*
,5-TP (Silvex)	509B(5)	μg/g	0.01	MW1 20-20.5'	*	0.5	96	MW1 20-20.5'	*	*	*

page for footnotes

1) Results not corrected for recent moisture.

2) Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, revised in March 1983, modified for use with soil.

3) Test methods for Evaluating Solid Waste, SW-846, 2nd ed., July 1982, modified for use on O.I. Comp. Model 610 TOX Analysis with soil.

4) Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater, EPA 600/4-82-057, July 1982, modified for use with soil.

5) Standard Methods for the Examination of Water and Wastewater, 16th ed. 1985, modified for use with soil samples.

6) Test Methods for evaluating Solid Waste, SW-846, 2nd ed. July 1982.

7) Sample has been extracted for EP Toxicity according to method No. 1310 published in E.P.A. Publication No. SW-846.

8) The low recovery was checked by reanalysis and confirmed. A matrix effect is suspected.

The analytical technique between the Methods published in EPA-SW-846, EPA 600/4-79-020, and Standard Methods 16th ed. are the same.

Denotes Value less than the limit of detection.

Denotes the sample was not ignitable.

ESE Analytic Methods

Reference List

IRPANL LR
23 Jan 1985

IRP ANALYTICAL LIST

GENERAL WATER SAMPLES

PARAMETER		METHOD
GROUP A		
Ammonia		E350.1
Chemical Oxygen Demand (COD)		A508A
Kjeldahl Nitrogen		E351.2
Nitrate		E353.1
Nitrite		E353.1
Oil and Grease		E413.2
Organic Carbon, Total (TOC)		E415.1
Orthophosphate		E365.1
Phosphorous, Total		E365.1
Petroleum Hydrocarbon		E418.1
GROUP D		
Cyanide, Total		A412D
Cyanide, Free		A412D
GROUP E		
Phenols		E420.2
GROUP F		
Aluminum	Flame	E202.1
	Furnace	E202.2
Antimony	Flame	E204.1
	Furnace	E204.2
Arsenic	Furnace	E206.2
	Hydride	E206.3
Barium	Flame	E208.1
	Furnace	E208.2
	ICP	E200.7
Beryllium	Flame	E210.1
	Furnace	E210.2
Boron	Colorimetric	E212.3
Cadmium	Flame	E213.1
	Furnace	E213.2
Calcium	Flame	E215.1
Chromium (Total)	Flame	E218.1
	Furnace	E218.2
Chromium (Hexavalent)		A312B
Cobalt	Flame	E219.1
	Furnace	E219.2
Copper	Flame	E220.1
	Furnace	E220.2
Iron	Flame	E236.1
	Furnace	E236.2
Lead	Flame	E239.1

	Furnace	[illegible]
Magnesium	Flame	E242 1
Manganese	Flame	E243 1
	Furnace	E243 2
Mercury	Cold Vapor	E245 1
Molybdenum	Flame	E246 1
	Furnace	E246 2
Nickel	Flame	E249 1
	Furnace	E249 2
Potassium	Flame	E258 1
Selenium	Furnace	E270.2
	Hydride	E270.3
Silver	Flame	E272 1
	Furnace	E272 2
Sodium	Flame	E273.1
	Furnace	E273 2
Thallium	Flame	E279.1
	Furnace	E279 2
Titanium	Flame	E283 1
	Furnace	E283 2
Vanadium	Flame	E286 1
	Furnace	E286 2
Zinc	Flame	E289 1
	Furnace	E289 2
Trace Elements	ICP	E200 7
GROUP G		
Acidity, Total		E305
Alkalinity, Total		A403
Alkalinity, Bicarbonate		A403
Bromide		A405
Carbon Dioxide		A406
Chloride		E325 3
Color		E110.2
Fluoride		E340.2
Iodide		E345 1
Odor		E140 1
Residue, Total		E160 3
Residue, Filterable (TDS)		E160 1
Residue, Non-filterable		E160 2
Residue, Settleable		E160 5
Residue, Volatile		E160 4
Silica		E370 1
Specific Conductance (Ec)		E120 1
Sulfate		E375 4
Sulfite		E377 1
Surfactants-MBAS		E425 1
Temperature		E170 1
Turbidity		E180 1
GROUP J		
Sulfides		E376 2
PRIORITY POLLUTANTS (PP)		
Extractables, Base/Neutrals/Acids (GC/MS)		E625
Volatile Organic Compounds (VOC) (GC/MS)		E624
Metals (13)		E200 7
Total Cyanide		A421D
Asbestos		Trans Electron Microscope
All of the above, (129 PP) per Sample		
PP Extractables and Volatiles		
PP Extractables, Volatiles, and Metals		
PP Extractables Base/Neutrals		
PP Extractables Acids		
[illegible]		

Volatile Organic Compounds Isotope Dilution	E1624
Semivolatile Organic Compounds Isotope Dilution	E1625
ORGANICS	
Purgeable Halocarbons (GC)	E601
Purgeable Aromatics (GC)	E602
Acrolein and Acrylonitrile (GC)	E603
Phenols (GC)	E604
Benzidines (HPLC)	E605
Phthalate Esters (GC)	E606
Nitrosamines (GC)	E607
Organochlorine Pesticides and PCBs (GC)	E608
Nitroaromatics and Isophorone (GC)	E609
Polynuclear Aromatic Hydrocarbons (HPLC)	E610
Haloethers (GC)	E611
Chlorinated Hydrocarbons (GC)	E612
Trihalomethanes (Purge and Trap)	E501.1
Halogenated Chemical Indicators (Purge and Trap)	E502.1
Aromatic Chemical Indicators (Purge and Trap)	E503.1
Ethylene Glycol	ASTM D3695-82
PESTICIDES	
Organophospherous Insecticides	E614
Organochlorine Insecticides	E617
Carbamate Insecticides	E632
Phenoxy Herbicides	A509B

RCRA WASTE MONITORING

WASTE EVALUATION PROCEDURES (Solids and Semi-solids)	
Ignitability	SW1010 SW1020
Corrosivity	pH
Reactivity	SW Manual
EP Toxicity	SW Manual
Pesticides (Four)	
Herbicides (Two)	
Metals (Eight)	
Total Profile (all of above)	
Waste solvent identification (e.g. IR, GC, MS) Identify only those components 1% and above	
MONITORING, INORGANICS	
Sample Preparation	
Acid Digestion, Flame	SW3010
Acid Digestion, Furnace	SW3020
Acid Digestion of Oils, Greases, or Waxes	SW3030
Dissolution Procedure for Oils, Greases, or Waxes	SW3040
Acid Digestion of Sludges	SW3050

Alkaline Digestion, Solid Wastes		SW3060
Antimony	Flame	SW7040
	Furnace	SW7041
Arsenic	Furnace	SW7060
	Hydride	SW7061
Barium	Flame	SW7080
	Furnace	SW7081
Beryllium	Flame	SW7090
	Furnace	SW7091
Cadmium	Flame	SW7130
	Furnace	SW7131
Chromium	Flame	SW7190
	Furnace	SW7191
Copper	Flame	SW7210
	Furnace	SW7211
Lead	Flame	SW7420
	Furnace	SW7421
Mercury (Liquid)	Cold Vapor	SW7470
Mercury (Solid or Semisolid)		SW7471
Nickel	Flame	SW7520
	Furnace	SW7521
Selenium	Furnace	SW7740
	Hydride	SW7741
Silver	Flame	SW7760
	Furnace	SW7761
Thallium	Flame	SW7840
	Furnace	SW7841
Vanadium	Flame	SW7910
	Furnace	SW7911
Zinc	Flame	SW7950
	Furnace	SW7951
Multielement Method	ICP	SW6010
MONITORING, ORGANICS		
Sample Preparation		
Liquid-Liquid Extraction		SW3510
Continuous Liq-Liq Extraction		SW3520
Acid-Base Cleanup Extraction		SW3530
Soxhlet Extraction		SW3540
Sonication Extraction		SW3550
Sample Introduction		
Headspace		SW5020
Purge and Trap		SW5030
Halogenated Volatile Organics (GC)		SW8010
Nonhalogenated Volatiles (GC)		SW8015
Aromatic Volatile Organics (GC)		SW8020
Acrolein, Acrylonitrile, Acetonitrile (GC)		SW8030
Phenols (GC)		SW8040
Phthalate Esters (GC)		SW8060
Organochlorine Pesticides and PCBs (GC)		SW8080
Nitroaromatics and Cyclic Ketones (GC)		SW8090
Polynuclear Aromatics (GC)		SW8100
Chlorinated Hydrocarbons (GC)		SW8120
Organophosphorous Pesticides (GC)		SW8140
Chlorinated Herbicides (GC)		SW8150
Volatile Organics (GC/MS)		SW8240
Semivolatile Organics (GC/MS)		
Packed Column		SW8250
Capillary Column		SW8270
Polynuclear Aromatic Hydrocarbons (HPLC)		SW8310
MONITORING, MISCELLANEOUS		
Total and Amenable Cyanide		SW9010

Sulfides	SW9030
pH	SW9040
Specific Conductance (Ec)	SW9050
Total Organic Carbon (TOC)	SW9060
Oils and Grease	E413.2
Extraction	SW3550

MISCELLANEOUS CHEMICAL ANALYSES

POLYCHLORINATED DIBENZODIOXINS (PCDDs)	
HRGC/MS Analysis	
2,3,7,8-TCDD	
(2,3,7,8-Tetrachlorodibenzo-p-dioxin)	
in water	E613
in solid wastes	SW8280
Total TCDDs	
(2,3,7,8,-TCDD and all other TCDDs)	
in water	E613
in solid wastes	SW8280
Total PCDDs Screen	
(All PCDDs for Cl-1 to Cl-8, including determination of 2,3,7,8-TCDD)	
in water	E613
in solid wastes	SW8280
POLYCHLORINATED DIBENZOFURANS (PCDFs)	
HRGC/MS Analysis	
2,3,7,8-TCDF	
(2,3,7,8-Tetrachlorodibnezofuran)	
in water	E613
in solid wastes	SW8280
Total TCDFs	
(2,3,7,8-TCDF and all other TCDFs)	
in water	E613
in solid wastes	SW8280
Total PCDFs Screen	
(All PCDFs from Cl-1 to Cl-8, including determination of 2,3,7,8-PCDF)	
in water	E613
in solid wastes	SW8280

REFERENCES:

1 E100-E500 METHODS
METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES
USEPA
Environmental Monitoring and Support Laboratory
Cincinnati, OH 45268
EPA 600/4-79-020

2 E600 METHODS

METHODS FOR ORGANIC CHEMICAL ANALYSIS OF MUNICIPAL AND
INDUSTRIAL WATER
USEPA
Federal Register, Vol 29, No 209, 26 October 1984

3 E200 7 METHOD
INDUCTIVLEY COUPLED PLASMA-ATOMIC EMISSION SPECTROMETER
METHOD FOR TRACE ELEMENT ANALYSIS OF WATER AND WASTES
USEPA
Federal Register, Vol 29, No 209, 26 October 1984

4 E501-E503 METHODS
USEPA
Environmental Monitoring and Support Laboratory
Cincinnati, OH 45268
November 6, 1979

5 SW METHODS
TEST METHODS FOR EVALUATING SOLID WASTE
USEPA
Office of Solid Waste Management and Emergency Response
Washington, D C 20460
SW-846 Manual, July 1982, 2d Ed

6 A METHODS
STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER
AMERICAN PUBLIC HEALTH ASSOCIATION
1015 Fifteenth St N)W)
Washington, D C 20005
15th Edition

[2] Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.

[3] When any sample is to be shipped by common carrier or sent through the United States Mails, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4] Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for the longer time, and has received a variance from the Regional Administrator under § 136.3(e). Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show that this is necessary to maintain sample stability. See § 136.3(e) for details.

[5] Should only be used in the presence of residual chlorine.

[6] Maximum holding time is 24 hours when sulfide is present. Optionally all samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

[7] Samples should be filtered immediately on-site before adding preservative for dissolved metals.

[8] Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9] Sample receiving no pH adjustment must be analyzed within seven days of sampling.

[10] The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11] When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6–9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to the optional preservation and holding time procedure are noted in footnote 5 (re the requirement for thiosulfate reduction of residual chlorine), and footnotes 12, 13 (re the analysis of benzidine).

[12] If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.

[13] Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.

[14] For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7–10 with NaOH within 24 hours of sampling.

[15] The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

8. Appendices A, B, and C are added to Part 136 to read as follows:

APPENDIX A TO PART 136—METHODS FOR ORGANIC CHEMICAL ANALYSIS OF MUNICIPAL AND INDUSTRIAL WASTEWATER

Method 601—Purgeable Halocarbons

1. Scope and Application

1.1 This method covers the determination of 29 purgeable halocarbons.

The following parameters may be determined by this method:

Parameter	STORET No.	CAS No.
Bromodichloromethane	32101	75-27-4
Bromoform	32104	75-25-2
Bromomethane	34413	74-83-9
Carbon tetrachloride	32102	56-23-5
Chlorobenzene	34301	108-90-7
Chloroethane	34311	75-00-3
2-Chloroethylvinyl ether	34576	100-75-8
Chloroform	32106	67-66-3
Chloromethane	34418	74-87-3
Dibromochloromethane	32105	124-48-1
1,2-Dichlorobenzene	34536	95-50-1
1,3-Dichlorobenzene	34566	541-73-1
1,4-Dichlorobenzene	34571	106-46-7
Dichlorodifluoromethane	34668	75-71-8
1,1-Dichloroethane	34496	75-34-3
1,2-Dichloroethane	34531	107-06-2
1,1-Dichloroethene	34501	75-35-4
trans-1,2-Dichloroethene	34546	156-60-5
1,2-Dichloropropane	34541	78-87-5
cis-1,3-Dichloropropene	34704	10061-01-5
trans-1,3-Dichloropropene	34699	10061-02-6
Methylene chloride	34423	75-09-2
1,1,2,2-Tetrachloroethane	34516	79-34-5
Tetrachloroethene	34475	127-18-4
1,1,1-Trichloroethane	34506	71-55-6
1,1,2-Trichloroethane	34511	79-00-5
Trichloroethene	39180	79-01-6
Trichlorofluoromethane	34488	75-69-4
Vinyl chloride	39715	75-01-4

1.2 This is a purge and trap gas chromatographic (GC) method applicable to the determination of the compounds listed above in municipal and industrial discharges as provided under 40 CFR 136.1. When this method is used to analyze unfamiliar samples for any or all of the compounds above, compound identifications should be supported by at least one additional qualitative technique. This method describes analytical conditions for a second gas chromatographic column that can be used to confirm measurements made with the primary column. Method 624 provides gas chromatograph/mass spectrometer (GC/MS) conditions appropriate for the qualitative and quantitative confirmation of results for most of the parameters listed above.

1.3 The method detection limit (MDL, defined in Section 12.1) [1] for each parameter is listed in Table 1. The MDL for a specific wastewater may differ from those listed, depending upon the nature of interferences in the sample matrix.

1.4 Any modification of this method, beyond those expressly permitted, shall be considered as a major modification subject to application and approval of alternate test procedures under 40 CFR 136.4 and 136.5.

1.5 This method is restricted to use by or under the supervision of analysts experienced in the operation of a purge and trap system and a gas chromatograph and in the interpretation of gas chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

2. Summary of Method

2.1 An inert gas is bubbled through a 5-mL water sample contained in a specially-designed purging chamber at ambient temperature. The halocarbons are efficiently transferred from the aqueous phase to the vapor phase. The vapor is swept through a sorbent trap where the halocarbons are trapped. After purging is completed, the trap is heated and backflushed with the inert gas to desorb the halocarbons onto a gas chromatographic column. The gas chromatograph is temperature programmed to separate the halocarbons which are then detected with a halide-specific detector.[2,3]

2.2 The method provides an optional gas chromatographic column that may be helpful in resolving the compounds of interest from interferences that may occur.

3. Interferences

3.1 Impurities in the purge gas and organic compounds outgassing from the plumbing ahead of the trap account for the majority of contamination problems. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running laboratory reagent blanks as described in Section 8.1.3. The use of non-Teflon plastic tubing, non-Teflon thread sealants, or flow controllers with rubber components in the purge and trap system should be avoided.

3.2 Samples can be contaminated by diffusion of volatile organics (particularly fluorocarbons and methylene chloride) through the septum seal into the sample during shipment and storage. A field reagent blank prepared from reagent water and carried through the sampling and handling protocol can serve as a check on such contamination.

3.3 Contamination by carry-over can occur whenever high level and low level samples are sequentially analyzed. To reduce carry-over, the purging device and sample syringe must be rinsed with reagent water between sample analyses. Whenever an unusually concentrated sample is encountered, it should be followed by an analysis of reagent water to check for cross contamination. For samples containing large amounts of water-soluble materials, suspended solids, high boiling compounds or high organohalide levels, it may be necessary to wash out the purging device with a detergent solution, rinse it with distilled water, and then dry it in a 105°C oven between analyses. The trap and other parts of the system are also subject to contamination; therefore, frequent bakeout and purging of the entire system may be required.

4. Safety

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified [4-6] for the information of the analyst.

4.2 The following parameters covered by this method have been tentatively classified as known or suspected, human or mammalian carcinogens: carbon tetrachloride, chloroform, 1,4-dichlorobenzene, and vinyl chloride. Primary standards of these toxic compounds should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be worn when the analyst handles high concentrations of these toxic compounds.

5. Apparatus and Materials

5.1 Sampling equipment, for discrete sampling.

5.1.1 Vial—25-mL capacity or larger, equipped with a screw cap with a hole in the center (Pierce #13075 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C before use.

5.1.2 Septum—Teflon-faced silicone (Pierce #12722 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C for 1 h before use.

5.2 Purge and trap system—The purge and trap system consists of three separate pieces of equipment: a purging device, trap, and desorber. Several complete systems are now commercially available.

5.2.1 The purging device must be designed to accept 5-mL samples with a water column at least 3 cm deep. The gaseous head space between the water column and the trap must have a total volume of less than 15 mL. The purge gas must pass through the water column as finely divided bubbles with a diameter of less than 3 mm at the origin. The purge gas must be introduced no more than 5 mm from the base of the water column. The purging device illustrated in Figure 1 meets these design criteria.

5.2.2 The trap must be at least 25 cm long and have an inside diameter of at least 0.105 in. The trap must be packed to contain the following minimum lengths of adsorbents: 1.0 cm of methyl silicone coated packing (Section 6.3.3), 7.7 cm of 2,6-diphenylene oxide polymer (Section 6.3.2), 7.7 cm of silica gel (Section 6.3.4), 7.7 cm of coconut charcoal (Section 6.3.1). If it is not necessary to analyze for dichlorodifluoromethane, the charcoal can be eliminated, and the polymer section lengthened to 15 cm. The minimum specifications for the trap are illustrated in Figure 2.

5.2.3 The desorber must be capable of rapidly heating the trap to 180 °C. The polymer section of the trap should not be heated higher than 180 °C and the remaining sections should not exceed 200 °C. The desorber illustrated in Figure 2 meets these design criteria.

5.2.4 The purge and trap system may be assembled as a separate unit or be coupled to a gas chromatograph as illustrated in Figures 3 and 4.

5.3 Gas chromatograph—An analytical system complete with a temperature programmable gas chromatograph suitable for on-column injection and all required accessories including syringes, analytical columns, gases, detector, and strip-chart recorder. A data system is recommended for measuring peak areas.

5.3.1 Column 1—8 ft long x 0.1 in. ID stainless steel or glass, packed with 1% SP-1000 on Carbopack B (60/80 mesh) or equivalent. This column was used to develop the method performance statements in Section 12. Guidelines for the use of alternate column packings are provided in Section 10.1.

5.3.2 Column 2—6 ft long x 0.1 in. ID stainless steel or glass, packed with chemically bonded n-octane on Porasil-C (100/120 mesh) or equivalent.

5.3.3 Detector—Electrolytic conductivity or microcoulometric detector. These types of detectors have proven effective in the analysis of wastewaters for the parameters listed in the scope (Section 1.1). The electrolytic conductivity detector was used to develop the method performance statements in Section 12. Guidelines for the use of alternate detectors are provided in Section 10.1.

5.4 Syringes—5-mL glass hypodermic with Luerlok tip (two each), if applicable to the purging device.

5.5 Micro syringes—25-μL, 0.006 in. ID needle.

5.6 Syringe valve—2-way, with Luer ends (three each).

5.7 Syringe—5-mL, gas-tight with shut-off valve.

5.8 Bottle—15-mL, screw-cap, with Teflon cap liner.

5.9 Balance—Analytical, capable of accurately weighing 0.0001 g.

6. Reagents

6.1 Reagent water—Reagent water is defined as a water in which an interferent is not observed at the MDL of the parameters of interest.

6.1.1 Reagent water can ge generated by passing tap water through a carbon filter bed containing about 1 lb of activated carbon (Filtrasorb-300, Calgon Corp., or equivalent).

6.1.2 A water purification system (Millipore Super-Q or equivalent) may be used to generate reagent water.

6.1.3 Reagent water may also be prepared by boiling water for 15 min. Subsequently, while maintaining the temperature at 90 °C, bubble a contaminant-free inert gas through the water for 1 h. While still hot, transfer the water to a narrow mouth screw-cap bottle and seal with a Teflon-lined septum and cap.

6.2 Sodium thiosulfate—(ACS) Granular.

6.3 Trap Materials:

6.3.1 Coconut charcoal—6/10 mesh sieved to 26 mesh, Barnebey Cheney, CA-580-26 lot # M-2649 or equivalent.

6.3.2 2,6-Diphenylene oxide polymer—Tenax, (60/80 mesh), chromatographic grade or equivalent.

6.3.3 Methyl silicone packing—3% OV-1 on Chromosorb-W (60/80 mesh) or equivalent.

6.3.4 Silica gel—35/60 mesh, Davison, grade-15 or equivalent.

6.4 Methanol—Pesticide quality or equivalent.

6.5 Stock standard solutions—Stock standard solutions may be prepared from pure standard materials or purchased as certified solutions. Prepare stock standard solutions in methanol using assayed liquids or gases as appropriate. Because of the toxicity of some of the organohalides, primary dilutions of these materials should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be used when the analyst handles high concentrations of such materials.

6.5.1 Place about 9.8 mL of methanol into a 10-mL ground glass stoppered volumetric flask. Allow the flask to stand, unstoppered, for about 10 min or until all alcohol wetted surfaces have dried. Weigh the flask to the nearest 0.1 mg.

6.5.2 Add the assayed reference material:

6.5.2.1 Liquid—Using a 100 μL syringe, immediately add two or more drops of assayed reference material to the flask, then reweigh. Be sure that the drops fall directly into the alcohol without contacting the neck of the flask.

6.5.2.2 Gases—To prepare standards for any of the six halocarbons that boil below 30 °C (bromomethane, chloroethane, chloromethane, dichlorodifluoromethane, trichlorofluoromethane, vinyl chloride), fill a 5-mL valved gas-tight syringe with the reference standard to the 5.0-mL mark. Lower the needle to 5 mm above the methanol meniscus. Slowly introduce the reference standard above the surface of the liquid (the heavy gas will rapidly dissolve into the methanol).

6.5.3 Reweigh, dilute to volume, stopper, then mix by inverting the flask several times. Calculate the concentration in μg/μL from the net gain in weight. When compound purity is assayed to be 96% or greater, the weight can be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards can be used at any concentration if they are certified by the manufacturer or by an independent source.

6.5.4 Transfer the stock standard solution into a Teflon-sealed screw-cap bottle. Store, with minimal headspace, at −10 to −20 °C and protect from light.

6.5.5 Prepare fresh standards weekly for the six gases and 2-chloroethylvinyl ether. All other standards must be replaced after one month, or sooner if comparison with check standards indicates a problem.

6.6 Secondary dilution standards—Using stock standard solutions, prepare secondary dilution standards in methanol that contain the compounds of interest, either singly or mixed together. The secondary dilution standards should be prepared at concentrations such that the aqueous calibration standards prepared in Sections 7.3.1 or 7.4.1 will bracket the working range of the analytical system. Secondary dilution standards should be stored with minimal headspace and should be checked frequently for signs of degradation or evaporation, especially just prior to preparing calibration standards from them.

6.7 Quality control check sample concentrate—See Section 8.2.1.

7. Calibration

7.1 Assemble a purge and trap system that meets the specifications in Section 5.2. Condition the trap overnight at 180 °C by backflushing with an inert gas flow of at least 20 mL/min. Condition the trap for 10 min once daily prior to use.

7.2 Connect the purge and trap system to a gas chromatograph. The gas chromatograph must be operated using temperature and flow rate conditions equivalent to those given in Table 1. Calibrate the purge and trap-gas chromatographic system using either the external standard technique (Section 7.3) or the internal standard technique (Section 7.4).

7.3 External standard calibration procedure:

7.3.1 Prepare calibration standards at a minimum of three concentration levels for each parameter by carefully adding 20.0 µL of one or more secondary dilution standards to 100, 500, or 1000 mL of reagent water. A 25-µL syringe with a 0.006 in. ID needle should be used for this operation. One of the external standards should be at a concentration near, but above, the MDL (Table 1) and the other concentrations should correspond to the expected range of concentrations found in real samples or should define the working range of the detector. These aqueous standards can be stored up to 24 h, if held in sealed vials with zero headspace as described in Section 9.2. If not so stored, they must be discarded after 1 h.

7.3.2 Analyze each calibration standard according to Section 10, and tabulate peak height or area responses versus the concentration in the standard. The results can be used to prepare a calibration curve for each compound. Alternatively, if the ratio of response to concentration (calibration factor) is a constant over the working range (<10% relative standard deviation, RSD), linearity through the origin can be assumed and the average ratio or calibration factor can be used in place of a calibration curve.

7.4 Internal standard calibration procedure—To use this approach, the analyst must select one or more internal standards that are similar in analytical behavior to the compounds of interest. The analyst must further demonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Because of these limitations, no internal standard can be suggested that is applicable to all samples. The compounds recommended for use as surrogate spikes in Section 8.7 have been used successfully as internal standards, because of their generally unique retention times.

7.4.1 Prepare calibration standards at a minimum of three concentration levels for each parameter of interest as described in Section 7.3.1.

7.4.2 Prepare a spiking solution containing each of the internal standards using the procedures described in Sections 6.5 and 6.6. It is recommended that the secondary dilution standard be prepared at a concentration of 15 µg/mL of each internal standard compound. The addition of 10 µL of this standard to 5.0 mL of sample or calibration standard would be equivalent to 30 µg/L.

7.4.3 Analyze each calibration standard according to Section 10, adding 10 µL of internal standard spiking solution directly to the syringe (Section 10.4). Tabulate peak height or area responses against concentration for each compound and internal standard, and calculate response factors (RF) for each compound using Equation 1.

Equation 1.

$$RF = \frac{(A_s)(C_{is})}{(A_{is})(C_s)}$$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_{is} = Concentration of the internal standard.

C_s = Concentration of the parameter to be measured.

If the RF value over the working range is a constant (<10% RSD), the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to plot a calibration curve of response ratios, A_s/A_{is}, vs. RF.

7.5 The working calibration curve, calibration factor, or RF must be verified on each working day by the measurement of a QC check sample.

7.5.1 Prepare the QC check sample as described in Section 8.2.2.

7.5.2 Analyze the QC check sample according to Section 10.

7.5.3 For each parameter, compare the response (Q) with the corresponding calibration acceptance criteria found in Table 2. If the responses for all parameters of interest fall within the designated ranges, analysis of actual samples can begin. If any individual Q falls outside the range, proceed according to Section 7.5.4.

Note: The large number of parameters in Table 2 present a substantial probability that one or more will not meet the calibration acceptance criteria when all parameters are analyzed.

7.5.4 Repeat the test only for those parameters that failed to meet the calibration acceptance criteria. If the response for a parameter does not fall within the range in this second test, a new calibration curve, calibration factor, or RF must be prepared for that parameter according to Section 7.3 or 7.4.

8. Quality Control

8.1 Each laboratory that uses this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and an ongoing analysis of spiked samples to evaluate and document data quality. The laboratory must maintain records to document the quality of data that is generated. Ongoing data quality checks are compared with established performance criteria to determine if the results of analyses meet the performance characteristics of the method. When results of sample spikes indicate atypical method performance, a quality control check standard must be analyzed to confirm that the measurements were performed in an in-control mode of operation.

8.1.1 The analyst must make an initial, one-time, demonstration of the ability to generate acceptable accuracy and precision with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of advances that are occurring in chromatography, the analyst is permitted certain options (detailed in Section 10.1) to improve the separations or lower the cost of measurements. Each time such a modification is made to the method, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 Each day, the analyst must analyze a reagent water blank to demonstrate that interferences from the analytical system are under control.

8.1.4 The laboratory must, on an ongoing basis, spike and analyze a minimum of 10% of all samples to monitor and evaluate laboratory data quality. This procedure is described in Section 8.3.

8.1.5 The laboratory must, on an ongoing basis, demonstrate through the analyses of quality control check standards that the operation of the measurement system is in control. This procedure is described in Section 8.4. The frequency of the check standard analyses is equivalent to 10% of all samples analyzed but may be reduced if spike recoveries from samples (Section 8.3) meet all specified quality control criteria.

8.1.6 The laboratory must maintain performance records to document the quality of data that is generated. This procedure is described in Section 8.5.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 A quality control (QC) check sample concentrate is required containing each parameter of interest at a concentration of 10 µg/mL in methanol. The QC check sample concentrate must be obtained from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory in Cincinnati, Ohio, if available. If not available from that source, the QC check sample concentrate must be obtained from another external source. If not available from either source above, the QC check sample concentrate must be prepared by the laboratory using stock standards prepared independently from those used for calibration.

8.2.2 Prepare a QC check sample to contain 20 µg/L of each parameter by adding 200 µL of QC check sample concentrate to 100 mL of reagent water.

8.2.3 Analyze four 5-mL aliquots of the well-mixed QC check sample according to Section 10.

8.2.4 Calculate the average recovery ($\bar{X}$) in µg/L and the standard deviation of the recovery (s) in µg/L for each parameter of interest using the four results.

8.2.5 For each parameter compare s and $\bar{X}$ with the corresponding acceptance criteria for precision and accuracy, respectively, found in Table 2. If s and $\bar{X}$ for all parameters of interest meet the acceptance criteria, the system performance is acceptable and analysis of actual samples can begin. If any individual s exceeds the precision limit or any individual $\bar{X}$ falls outside the range for accuracy, then the system performance is unacceptable for that parameter.

Note: The large number of parameters in Table 2 present a substantial probability that one or more will fail at least one of the acceptance criteria when all parameters are analyzed.

8.2.6 When one or more of the parameters tested fail at least one of the acceptance criteria, the analyst must proceed according to Section 8.2.6.1 or 8.2.6.2.

8.2.6.1 Locate and correct the source of the problem and repeat the test for all parameters of interest beginning with Section 8.2.3.

8.2.6.2 Beginning with Section 8.2.3, repeat the test only for those parameters that failed to meet criteria. Repeated failure, however, will confirm a general problem with the measurement system. If this occurs, locate and correct the source of the problem and repeat the test for all compounds of interest beginning with Section 8.2.3.

8.3 The laboratory must, on an ongoing basis, spike at least 10% of the samples from each sample site being monitored to assess accuracy. For laboratories analyzing one to ten samples per month, at least one spiked sample per month is required.

8.3.1 The concentration of the spike in the sample should be determined as follows:

8.3.1.1 If, as in compliance monitoring, the concentration of a specific parameter in the sample is being checked against a regulatory concentration limit, the spike should be at that limit or 1 to 5 times higher than the background concentration determined in Section 8.3.2, whichever concentration would be larger.

8.3.1.2 If the concentration of a specific parameter in the sample is not being checked against a limit specific to that parameter, the spike should be at 20 μg/L or 1 to 5 times higher than the background concentration determined in Section 8.3.2, whichever concentration would be larger.

8.3.2 Analyze one 5-mL sample aliquot to determine the background concentration (B) of each parameter. If necessary, prepare a new QC check sample concentrate (Section 8.2.1) appropriate for the background concentrations in the sample. Spike a second 5-mL sample aliquot with 10 μL of the QC check sample concentrate and analyze it to determine the concentration after spiking (A) of each parameter. Calculate each percent recovery (P) as 100(A–B)%/T, where T is the known true value of the spike.

8.3.3 Compare the percent recovery (P) for each parameter with the corresponding QC acceptance criteria found in Table 2. These acceptance criteria were calculated to include an allowance for error in measurement of both the background and spike concentrations, assuming a spike to background ratio of 5:1. This error will be accounted for to the extent that the analyst's spike to background ratio approaches 5:1.[7] If spiking was performed at a concentration lower than 20 μg/L, the analyst must use either the QC acceptance criteria in Table 2, or optional QC acceptance criteria calculated for the specific spike concentration. To calculate optional acceptance criteria for the recovery of a parameter: (1) Calculate accuracy (X′) using the equation in Table 3, substituting the spike concentration (T) for C; (2) calculate overall precision (S′) using the equation in Table 3, substituting X′ for $\bar{X}$; (3) calculate the range for recovery at the spike concentration as (100 X′/T)±2.44(100 S′/T)%.[7]

8.3.4 If any individual P falls outside the designated range for recovery, that parameter has failed the acceptance criteria. A check standard containing each parameter that failed the criteria must be analyzed as described in Section 8.4.

8.4 If any parameter fails the acceptance criteria for recovery in Section 8.3, a QC check standard containing each parameter that failed must be prepared and analyzed.

Note: The frequency for the required analysis of a QC check standard will depend upon the number of parameters being simultaneously tested, the complexity of the sample matrix, and the performance of the laboratory. If the entire list of parameters in Table 2 must be measured in the sample in Section 8.3, the probability that the analysis of a QC check standard will be required is high. In this case the QC check standard should be routinely analyzed with the spiked sample.

8.4.1 Prepare the QC check standard by adding 10 μL of QC check sample concentrate (Sections 8.2.1 or 8.3.2) to 5 mL of reagent water. The QC check standard needs only to contain the parameters that failed criteria in the test in Section 8.3.

8.4.2 Analyze the QC check standard to determine the concentration measured (A) of each parameter. Calculate each percent recovery (P_s) as 100 (A/T)%, where T is the true value of the standard concentration.

8.4.3 Compare the percent recovery (P_s) for each parameter with the corresponding QC acceptance criteria found in Table 2. Only parameters that failed the test in Section 8.3 need to be compared with these criteria. If the recovery of any such parameter falls outside the designated range, the laboratory performance for that parameter is judged to be out of control, and the problem must be immediately identified and corrected. The analytical result for that parameter in the unspiked sample is suspect and may not be reported for regulatory compliance purposes.

8.5 As part of the QC program for the laboratory, method accuracy for wastewater samples must be assessed and records must be maintained. After the analysis of five spiked wastewater samples as in Section 8.3, calculate the average percent recovery ($\bar{P}$) and the standard deviation of the percent recovery (s_p). Express the accuracy assessment as a percent recovery interval from $\bar{P}-2s_p$ to $\bar{P}+2s_p$. If $\bar{p}=90\%$ and $s_p=10\%$, for example, the accuracy interval is expressed as 70–110%. Update the accuracy assessment for each parameter on a regular basis (e.g. after each five to ten new accuracy measurements).

8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to assess the precision of the environmental measurements. When doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as gas chromatography with a dissimilar column, specific element detector, or mass spectrometer must be used. Whenever possible, the laboratory should analyze standard reference materials and participate in relevant performance evaluation studies.

8.7 The analyst should monitor both the performance of the analytical system and the effectiveness of the method in dealing with each sample matrix by spiking each sample, standard, and reagent water blank with surrogate halocarbons. A combination of bromochloromethane, 2-bromo-1-chloropropane, and 1,4-dichlorobutane is recommended to encompass the range of the temperature program used in this method. From stock standard solutions prepared as in Section 6.5, add a volume to give 750 μg of each surrogate to 45 mL of reagent water contained in a 50-mL volumetric flask, mix and dilute to volume for a concentration of 15 ng/μL. Add 10 μL of this surrogate spiking solution directly into the 5-mL syringe with every sample and reference standard analyzed. Prepare a fresh surrogate spiking solution on a weekly basis. If the internal standard calibration procedure is being used, the surrogate compounds may be added directly to the internal standard spiking solution (Section 7.4.2).

9. Sample Collection, Preservation, and Handling

9.1 All samples must be iced or refrigerated from the time of collection until analysis. If the sample contains free or combined chlorine, add sodium thiosulfate preservative (10 mg/40 mL is sufficient for up to 5 ppm Cl_2) to the empty sample bottle just prior to shipping to the sampling site. EPA Methods 330.4 and 330.5 may be used for measurement of residual chlorine.[8] Field test kits are available for this purpose.

9.2 Grab samples must be collected in glass containers having a total volume of at least 25 mL. Fill the sample bottle just to overflowing in such a manner that no air bubbles pass through the sample as the bottle is being filled. Seal the bottle so that no air bubbles are entrapped in it. If preservative has been added, shake vigorously for 1 min. Maintain the hermetic seal on the sample bottle until time of analysis.

9.3 All samples must be analyzed within 14 days of collection.[3]

10. Procedure

10.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this table are estimated retention times and MDL that can be achieved under these conditions. An example of the separations achieved by Column 1 is shown in Figure 5. Other packed columns, chromatographic conditions, or detectors may be used if the requirements of Section 8.2 are met.

10.2 Calibrate the system daily as described in Section 7.

10.3 Adjust the purge gas (nitrogen or helium) flow rate to 40 mL/min. Attach the trap inlet to the purging device, and set the purge and trap system to purge (Figure 3). Open the syringe valve located on the purging device sample introduction needle.

10.4 Allow the sample to come to ambient temperature prior to introducing it to the syringe. Remove the plunger from a 5-mL syringe and attach a closed syringe valve. Open the sample bottle (or standard) and carefully pour the sample into the syringe barrel to just short of overflowing. Replace the syringe plunger and compress the sample. Open the syringe valve and vent any residual air while adjusting the sample volume to 5.0 mL. Since this process of taking an aliquot destroys the validity of the sample for future analysis, the analyst should fill a second syringe at this time to protect against possible loss of data. Add 10.0 μL of the surrogate spiking solution (Section 8.7) and 10.0 μL of the internal standard spiking solution (Section 7.4.2), if applicable, through the valve bore, then close the valve.

10.5 Attach the syringe-syringe valve assembly to the syringe valve on the purging device. Open the syringe valves and inject the sample into the purging chamber.

10.6 Close both valves and purge the sample for 11.0±0.1 min at ambient temperature.

10.7 After the 11-min purge time, attach the trap to the chromatograph, adjust the purge and trap system to the desorb mode (Figure 4), and begin to temperature program the gas chromatograph. Introduce the trapped materials to the GC column by rapidly heating the trap to 180 °C while backflushing the trap with an inert gas between 20 and 60 mL/min for 4 min. If rapid heating of the trap cannot be achieved, the GC column must be used as a secondary trap by cooling it to 30 °C (subambient temperature, if poor peak geometry or random retention time problems persist) instead of the initial program temperature of 45 °C

10.8 While the trap is being desorbed into the gas chromatograph, empty the purging chamber using the sample introduction syringe. Wash the chamber with two 5-mL flushes of reagent water.

10.9 After desorbing the sample for 4 min, recondition the trap by returning the purge and trap system to the purge mode. Wait 15 s then close the syringe valve on the purging device to begin gas flow through the trap. The trap temperature should be maintained at 180 °C After approximately 7 min, turn off the trap heater and open the syringe valve to stop the gas flow through the trap. When the trap is cool, the next sample can be analyzed.

10.10 Identify the parameters in the sample by comparing the retention times of the peaks in the sample chromatogram with those of the peaks in standard chromatograms. The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of a retention time for a compound can be used to calculate a suggested window size; however, the experience of the analyst should weigh heavily in the interpretation of chromatograms.

10.11 If the response for a peak exceeds the working range of the system, prepare a dilution of the sample with reagent water from the aliquot in the second syringe and reanalyze.

11. Calculations

11.1 Determine the concentration of individual compounds in the sample.

11.1.1 If the external standard calibration procedure is used, calculate the concentration of the parameter being measured from the peak response using the calibration curve or calibration factor determined in Section 7.3.2.

11.1.2 If the internal standard calibration procedure is used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.4.3 and Equation 2

Equation 2.

$$\text{Concentration } (\mu g/L) = \frac{(A_s)(C_{is})}{(A_{is})(RF)}$$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_{is} = Concentration of the internal standard.

11.2 Report results in μg/L without correction for recovery data. All QC data obtained should be reported with the sample results.

12. Method Performance

12.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.[1] The MDL concentrations listed in Table 1 were obtained using reagent water.[8] Similar results were achieved using representative wastewaters. The MDL actually achieved in a given analysis will vary depending on instrument sensitivity and matrix effects.

12.2 This method is recommended for use in the concentration range from the MDL to 1000 x MDL. Direct aqueous injection techniques should be used to measure concentration levels above 1000×MDL.

12.3 This method was tested by 20 laboratories using reagent water, drinking water, surface water, and three industrial wastewaters spiked at six concentrations over the range 8.0 to 500 μg/L.[9] Single operator precision, overall precision, and method accuracy were found to be directly related to the concentration of the parameter and essentially independent of the sample matrix. Linear equations to describe these relationships are presented in Table 3.

References

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4. "Carcinogens—Working With Carcinogens," Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Publication No. 77-206, August 1977.

5. "OSHA Safety and Health Standards, General Industry" (29 CFR 1910), Occupational Safety and Health Administration, OSHA 2206 (Revised, January 1976).

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7. Provost, L.P., and Elder, R.S. "Interpretation of Percent Recovery Data," *American Laboratory, 15,* 58–63 (1983). (The value 2.44 used in the equation in Section 8.3.3 is two times the value 1.22 derived in this report.)

8. "Methods 330.4 (Titrimetric, DPD-FAS) and 330.5 (Spectrophotometric, DPD) for Chlorine, Total Residual," Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268, March 1979.

9. "EPA Method Validation Study 23, Method 601 (Purgeable Halocarbons)," Report for EPA Contract 68-03-2856 (in preparation).

10. "Method Validation Data for EPA Method 601," Memorandum from B. Potter, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268, November 10, 1983.

TABLE 1.—CHROMATOGRAPHIC CONDITIONS AND METHOD DETECTION LIMITS

Parameter	Retention time (min)		Method detection limit (μg/L)
	Column 1	Column 2	
Chloromethane	1.50	5.28	0.08
Bromomethane	2.17	7.05	1.18
Dichlorodifluoromethane	2.62	nd	1.81
Vinyl chloride	2.67	5.28	0.18
Chloroethane	3.33	8.68	0.52
Methylene chloride	5.25	10.1	0.25
Trichlorofluoromethane	7.18	nd	nd
1,1-Dichloroethene	7.93	7.72	0.13
1,1-Dichloroethane	9.30	12.6	0.07
trans-1,2-Dichloroethene	10.1	9.38	0.10

TABLE 1.—CHROMATOGRAPHIC CONDITIONS AND METHOD DETECTION LIMITS—Continued

Parameter	Retention time (min)		Method detection limit (µg/L)
	Column 1	Column 2	
Chloroform	10.7	12.1	0.05
1,2-Dichloroethane	11.4	15.4	0.03
1,1,1-Trichloroethane	12.6	13.1	0.03
Carbon tetrachloride	13.0	14.4	0.12
Bromodichloromethane	13.7	14.6	0.10
1,2-Dichloropropane	14.9	16.6	0.04
cis-1,3-Dichloropropene	15.2	16.6	0.34
Trichloroethene	15.8	13.1	0.12
Dibromochloromethane	16.5	16.6	0.09
1,1,2-Trichloroethane	16.5	18.1	0.02
trans-1,3-Dichloropropene	16.5	18.0	0.20
2-Chloroethylvinyl ether	18.0	nd	0.13
Bromoform	19.2	19.2	0.20
1,1,2,2-Tetrachloroethane	21.6	nd	0.03
Tetrachloroethene	21.7	15.0	0.03
Chlorobenzene	24.2	18.8	0.25
1,3-Dichlorobenzene	34.0	22.4	0.32
1,2-Dichlorobenzene	34.9	23.5	0.15
1,4-Dichlorobenzene	35.4	22.3	0.24

Column 1 conditions: Carbopack B (60/80 mesh) coated with 1% SP-1000 packed in an 8 ft x 0.1 in. ID stainless steel or glass column with helium carrier gas at 40 mL/min flow rate. Column temperature held at 45 °C for 3 min then programmed at 8 °C/min to 220 °C and held for 15 min.

Column 2 conditions: Porasil-C (100/120 mesh) coated with n-octane packed in a 6 ft x 0.1 in. ID stainless steel or glass column with helium carrier gas at 40 mL/min flow rate. Column temperature held at 50 °C for 3 min then programmed at 6 °C/min to 170 °C and held for 4 min.

nd = not determined.

TABLE 2.—CALIBRATION AND QC ACCEPTANCE CRITERIA—METHOD 601 [a]

Parameter	Range for Q (µg/L)	Limit for s (µg/L)	Range for $\bar{X}$ (µg/L)	Range P, P_s (%)
Bromodichloromethane	15.2–24.8	4.3	10.7–32.0	42–172
Bromoform	14.7–25.3	4.7	5.0–29.3	13–159
Bromomethane	11.7–28.3	7.6	3.4–24.5	D–144
Carbon tetrachloride	13.7–26.3	5.6	11.8–25.3	43–143
Chlorobenzene	14.4–25.6	5.0	10.2–27.4	38–150
Chloroethane	15.4–24.6	4.4	11.3–25.2	46–137
2-Chloroethylvinyl ether	12.0–28.0	8.3	4.5–35.5	14–186
Chloroform	15.0–25.0	4.5	12.4–24.0	49–133
Chloromethane	11.9–28.1	7.4	D–34.9	D–193
Dibromochloromethane	13.1–26.9	6.3	7.9–35.1	24–191
1,2-Dichlorobenzene	14.0–26.0	5.5	1.7–38.9	D–208
1,3-Dichlorobenzene	9.9–30.1	9.1	6.2–32.6	7–187
1,4-Dichlorobenzene	13.9–26.1	5.5	11.5–25.5	42–143
1,1-Dichloroethane	16.8–23.2	3.2	11.2–24.6	47–132
1,2-Dichloroethane	14.3–25.7	5.2	13.0–26.5	51–147
1,1-Dichloroethene	12.6–27.4	6.6	10.2–27.3	28–167
trans-1,2-Dichloroethene	12.8–27.2	6.4	11.4–27.1	38–155
1,2-Dichloropropane	14.8–25.2	5.2	10.1–29.9	44–156
cis-1,3-Dichloropropene	12.8–27.2	7.3	6.2–33.8	22–178
trans-1,3-Dichloropropene	12.8–27.2	7.3	6.2–33.8	22–178
Methylene chloride	15.5–24.5	4.0	7.0–27.6	25–162
1,1,2,2-Tetrachloroethane	9.8–30.2	9.2	6.6–31.8	8–184
Tetrachloroethene	14.0–26.0	5.4	8.1–29.6	26–162
1,1,1-Trichloroethane	14.2–25.8	4.9	10.8–24.8	41–138
1,1,2-Trichloroethane	15.7–24.3	3.9	9.6–25.4	39–136
Trichloroethene	15.4–24.6	4.2	9.2–26.6	35–146
Trichlorofluoromethane	13.3–26.7	6.0	7.4–28.1	21–156
Vinyl chloride	13.7–26.3	5.7	8.2–29.9	28–163

Q = Concentration measured in QC check sample, in µg/L (Section 7.5.3).
s = Standard deviation of four recovery measurements, in µg/L (Section 8.2.4).
$\bar{X}$ = Average recovery for four recovery measurements, in µg/L (Section 8.2.4).
P, P_s = Percent recovery measured (Section 8.3.2, Section 8.4.2).
D = Detected; result must be greater than zero.
[a] Criteria were calculated assuming a QC check sample concentration of 20 µg/L.

Note: These criteria are based directly upon the method performance data in Table 3. Where necessary, the limits for recovery have been broadened to assure applicability of the limits to concentrations below those used to develop Table 3.

TABLE 3.—METHOD ACCURACY AND PRECISION AS FUNCTIONS OF CONCENTRATION—METHOD 601

Parameter	Accuracy, as recovery, X' (µg/L)	Single analyst precision, s_r' (µg/L)	Overall precision, S' (µg/L)
Bromodichloromethane	1.12C − 1.02	$0.11\bar{X}+0.04$	$0.20\bar{X}+1.00$
Bromoform	0.96C − 2.05	$0.12\bar{X}+0.58$	$0.21\bar{X}+2.41$
Bromomethane	0.76C − 1.27	$0.28\bar{X}+0.27$	$0.36\bar{X}+0.94$
Carbon tetrachloride	0.98C − 1.04	$0.15\bar{X}+0.38$	$0.20\bar{X}+0.39$
Chlorobenzene	1.00C − 1.23	$0.15\bar{X}-0.02$	$0.18\bar{X}+1.21$
Chloroethane	0.99C − 1.53	$0.14\bar{X}-0.13$	$0.17\bar{X}+0.63$
2-Chloroethylvinyl ether [a]	1.00C	$0.20\bar{X}$	$0.35\bar{X}$
Chloroform	0.93C − 0.39	$0.13\bar{X}+0.15$	$0.19\bar{X}-0.02$
Chloromethane	0.77C + 0.18	$0.28\bar{X}-0.31$	$0.52\bar{X}+1.31$
Dibromochloromethane	0.94C + 2.72	$0.11\bar{X}+1.10$	$0.24\bar{X}+1.68$
1,2-Dichlorobenzene	0.93C + 1.70	$0.20\bar{X}+0.97$	$0.13\bar{X}+6.13$

TABLE 3.—METHOD ACCURACY AND PRECISION AS FUNCTIONS OF CONCENTRATION—METHOD 601—Continued

Parameter	Accuracy, as recovery, X' (μg/L)	Single analyst precision, s_r' (μg/L)	Overall precision S' (μg/L)
1,3-Dichlorobenzene	$0.95C+0.43$	$0.14\bar{X}+2.33$	$0.26\bar{X}+2.34$
1,4-Dichlorobenzene	$0.93C-0.09$	$0.15\bar{X}+0.29$	$0.20\bar{X}+0.41$
1,1-Dichloroethane	$0.95C-1.08$	$0.08\bar{X}+0.17$	$0.14\bar{X}+0.94$
1,2-Dichloroethane	$1.04C-1.06$	$0.11\bar{X}+0.70$	$0.15\bar{X}+0.94$
1,1-Dichloroethene	$0.98C-0.87$	$0.21\bar{X}-0.23$	$0.29\bar{X}-0.40$
trans-1,2-Dichloroethene	$0.97C-0.16$	$0.11\bar{X}+1.46$	$0.17\bar{X}+1.46$
1,2-Dichloropropane [a]	$1.00C$	$0.13\bar{X}$	$0.23\bar{X}$
cis-1,3-Dichloropropene [a]	$1.00C$	$0.18\bar{X}$	$0.32\bar{X}$
trans-1,3-Dichloropropene [a]	$1.00C$	$0.18\bar{X}$	$0.32\bar{X}$
Methylene chloride	$0.91C-0.93$	$0.11\bar{X}+0.33$	$0.21\bar{X}+1.43$
1,1,2,2-Tetrachloroethane	$0.95C+0.19$	$0.14\bar{X}+2.41$	$0.23\bar{X}+2.79$
Tetrachloroethene	$0.94C+0.06$	$0.14\bar{X}+0.38$	$0.18\bar{X}+2.21$
1,1,1-Trichloroethane	$0.90C-0.16$	$0.15\bar{X}+0.04$	$0.20\bar{X}+0.37$
1,1,2-Trichloroethane	$0.86C+0.30$	$0.13\bar{X}-0.14$	$0.19\bar{X}+0.67$
Trichloroethene	$0.87C+0.48$	$0.13\bar{X}-0.03$	$0.23\bar{X}+0.30$
Trichlorofluoromethane	$0.89C-0.07$	$0.15\bar{X}+0.67$	$0.26\bar{X}+0.91$
Vinyl chloride	$0.97C-0.36$	$0.13\bar{X}+0.65$	$0.27\bar{X}+0.40$

X' = Expected recovery for one or more measurements of a sample containing a concentration of C, in μg/L.
s_r' = Expected single analyst standard deviation of measurements at an average concentration found of $\bar{X}$, in μg/L.
S' = Expected interlaboratory standard deviation of measurements at an average concentration found of $\bar{X}$, in μg/L.
C = True value for the concentration, in μg/L.
$\bar{X}$ = Average recovery found for measurements of samples containing a concentration of C, in μg/L.
[a] Estimates based upon the performance in a single laboratory.[10]

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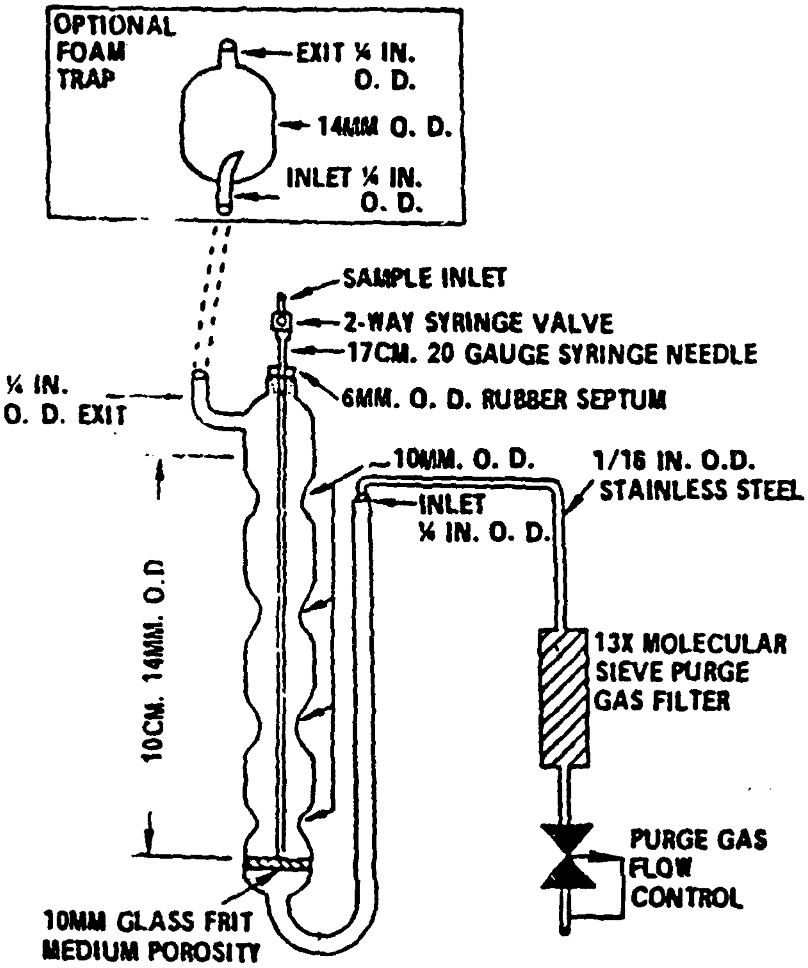


Figure 1. Purging device.

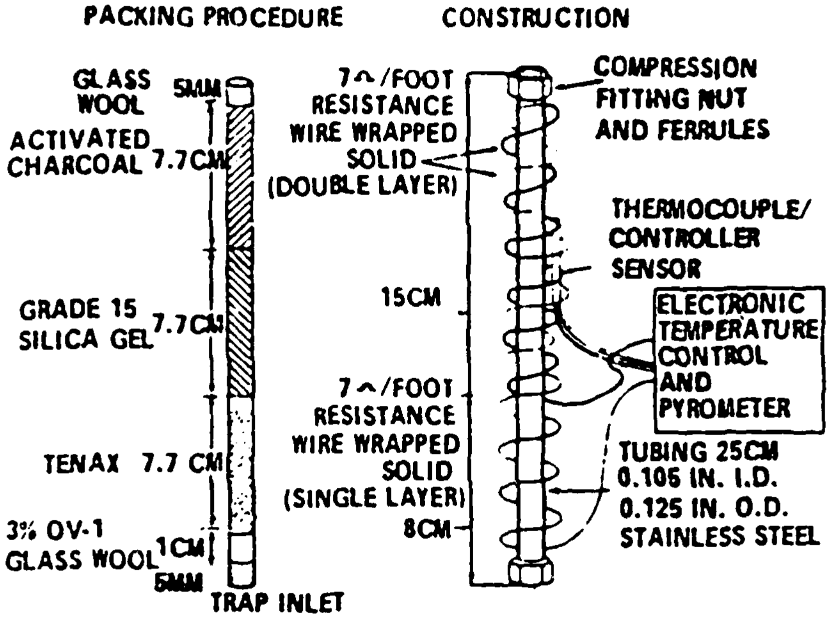
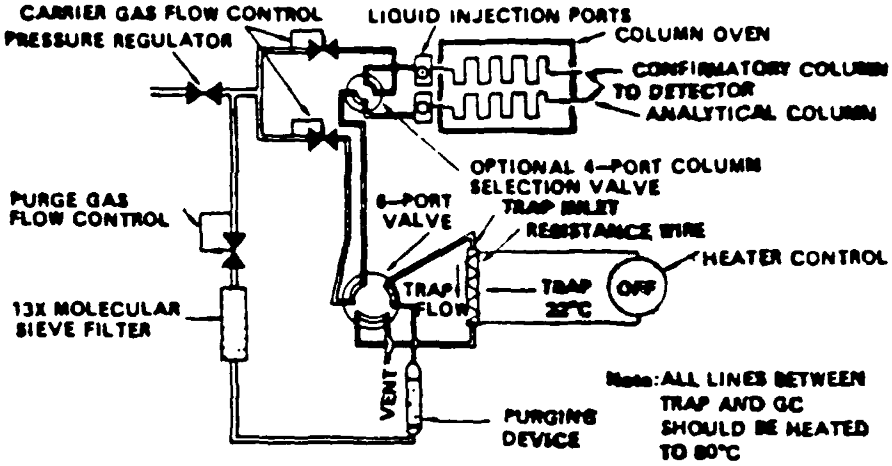
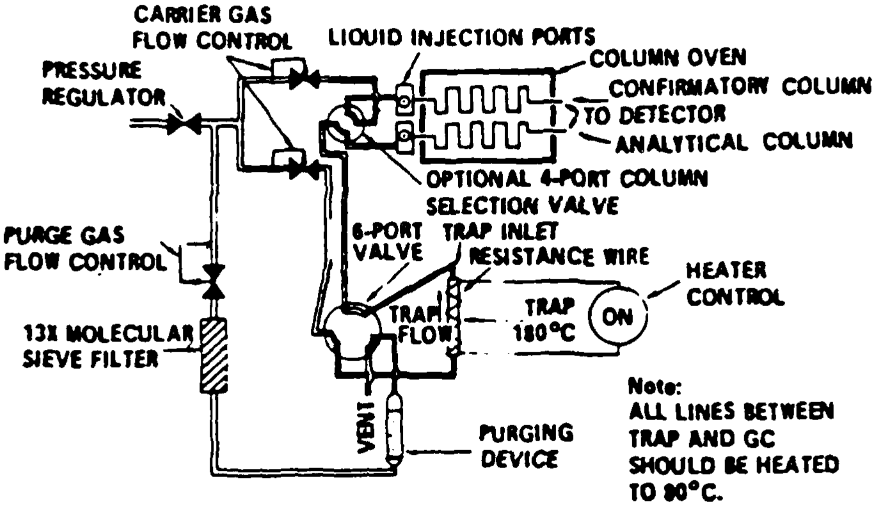


Figure 2. Trap packings and construction to include desorb capability



Note: ALL LINES BETWEEN TRAP AND GC SHOULD BE HEATED TO 80°C

Figure 3. Purge and trap system-purge mode.



Note: ALL LINES BETWEEN TRAP AND GC SHOULD BE HEATED TO 80°C.

Figure 4. Purge and trap system - desorb mode.

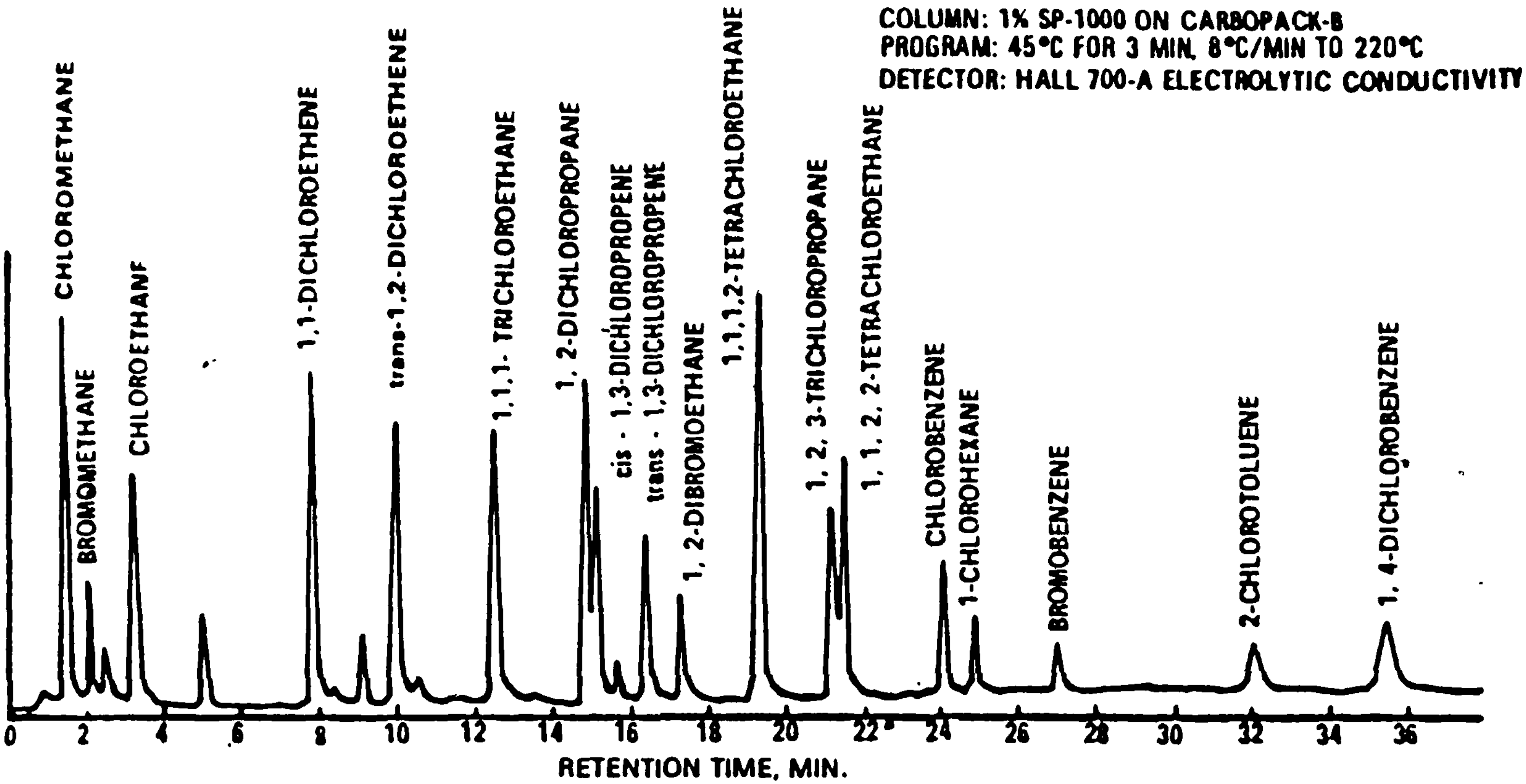


Figure 5. Gas chromatogram of purgeable halocarbons.

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Method 602—Purgeable Aromatics

1. Scope and Application

1.1 This method covers the determination of various purgeable aromatics. The following parameters may be determined by this method:

Parameter	STORET No.	CAS No.
Benzene	34030	71-43-2
Chlorobenzene	34301	108-90-7
1,2-Dichlorobenzene	34536	95-50-1
1,3-Dichlorobenzene	34566	541-73-1
1,4-Dichlorobenzene	34571	106-46-7
Ethylbenzene	34371	100-41-4
Toluene	34010	108-88-3

1.2 This is a purge and trap gas chromatographic (GC) method applicable to the determination of the compounds listed above in municipal and industrial discharges as provided under 40 CFR 136.1. When this method is used to analyze unfamiliar samples for any or all of the compounds above, compound identifications should be supported by at least one additional qualitative technique. This method describes analytical conditions for a second gas chromatographic column that can be used to confirm measurements made with the primary column. Method 624 provides gas chromatograph/mass spectrometer (GC/MS) conditions appropriate for the qualitative and quantitative confirmation of results for all of the parameters listed above.

1.3 The method detection limit (MDL, defined in Section 12.1) [1] for each parameter is listed in Table 1. The MDL for a specific wastewater may differ from those listed, depending upon the nature of interferences in the sample matrix.

1.4 Any modification of this method, beyond those expressly permitted, shall be considered as a major modification subject to application and approval of alternate test procedures under 40 CFR 136.4 and 136.5.

1.5 This method is restricted to use by or under the supervision of analysts experienced in the operation of a purge and trap system and a gas chromatograph and in the interpretation of gas chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

2. Summary of Method

2.1 An inert gas is bubbled through a 5-mL water sample contained in a specially-designed purging chamber at ambient temperature. The aromatics are efficiently transferred from the aqueous phase to the vapor phase. The vapor is swept through a sorbent trap where the aromatics are trapped. After purging is completed, the trap is heated and backflushed with the inert gas to desorb the aromatics onto a gas chromatographic column. The gas chromatograph is temperature programmed to separate the aromatics which are then detected with a photoionization detector. [2, 3]

2.2 The method provides an optional gas chromatographic column that may be helpful in resolving the compounds of interest from interferences that may occur.

3. Interferences

3.1 Impurities in the purge gas and organic compounds outgassing from the plumbing ahead of the trap account for the majority of contamination problems. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running laboratory reagent blanks as described in Section 8.1.3. The use of non-Teflon plastic tubing, non-Teflon thread sealants, or flow controllers with rubber components in the purge and trap system should be avoided.

3.2 Samples can be contaminated by diffusion of volatile organics through the septum seal into the sample during shipment and storage. A field reagent blank prepared from reagent water and carried through the sampling and handling protocol can serve as a check on such contamination.

3.3 Contamination by carry-over can occur whenever high level and low level samples are sequentially analyzed. To reduce carry-over, the purging device and sample syringe must be rinsed with reagent water between sample analyses. Whenever an unusually concentrated sample is encountered, it should be followed by an analysis of reagent water to check for cross contamination. For samples containing large amounts of water-soluble materials, suspended solids, high boiling compounds or high aromatic levels, it may be necessary to wash the purging device with a detergent solution, rinse it with distilled water, and then dry it in an oven at 105 °C between analyses. The trap and other parts of the system are also subject to contamination; therefore, frequent bakeout and purging of the entire system may be required.

4. Safety

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified [**] for the information of the analyst.

4.2 The following parameters covered by this method have been tentatively classified as known or suspected, human or mammalian carcinogens: benzene and 1,4-dichlorobenzene. Primary standards of these toxic compounds should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be worn when the analyst handles high concentrations of these toxic compounds.

5. Apparatus and Materials

5.1 Sampling equipment, for discrete sampling.

5.1.1 Vial—25-mL capacity or larger, equipped with a screw cap with a hole in the center (Pierce #13075 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C before use.

5.1.2 Septum—Teflon-faced silicone (Pierce #12722 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C for 1 h before use.

5.2 Purge and trap system—The purge and trap system consists of three separate pieces of equipment: A purging device, trap, and desorber. Several complete systems are now commercially available.

5.2.1 The purging device must be designed to accept 5-mL samples with a water column at least 3 cm deep. The gaseous head space between the water column and the trap must have a total volume of less than 15 mL. The purge gas must pass through the water column as finely divided bubbles with a diameter of less than 3 mm at the origin. The purge gas must be introduced no more than 5 mm from the base of the water column. The purging device illustrated in Figure 1 meets these design criteria.

5.2.2 The trap must be at least 25 cm long and have an inside diameter of at least 0.105 in.

5.2.2.1 The trap is packed with 1 cm of methyl silicone coated packing (Section 6.4.2) and 23 cm of 2,6-diphenylene oxide polymer (Section 6.4.1) as shown in Figure 2. This trap was used to develop the method performance statements in Section 12.

5.2.2.2 Alternatively, either of the two traps described in Method 601 may be used, although water vapor will preclude the measurement of low concentrations of benzene.

5.2.3 The desorber must be capable of rapidly heating the trap to 180 °C. The polymer section of the trap should not be heated higher than 180 °C and the remaining sections should not exceed 200 °C. The desorber illustrated in Figure 2 meets these design criteria.

5.2.4 The purge and trap system may be assembled as a separate unit or be coupled to a gas chromatograph as illustrated in Figures 3, 4, and 5.

5.3 *Gas chromatograph*—An analytical system complete with a temperature programmable gas chromatograph suitable for on-column injection and all required accessories including syringes, analytical columns, gases, detector, and strip-chart recorder. A data system is recommended for measuring peak areas.

5.3.1 Column 1—6 ft long x 0.082 in. ID stainless steel or glass, packed with 5% SP-1200 and 1.75% Bentone-34 on Supelcoport (100/120 mesh) or equivalent. This column was used to develop the method performance statements in Section 12. Guidelines for the use of alternate column packings are provided in Section 10.1.

5.3.2 Column 2—8 ft long x 0.1 in ID stainless steel or glass, packed with 5% 1,2,3-Tris(2-cyanoethoxy)propane on Chromosorb W-AW (60/80 mesh) or equivalent.

5.3.3 Detector—Photoionization detector (h-Nu Systems, Inc. Model PI-51-02 or equivalent). This type of detector has been proven effective in the analysis of wastewaters for the parameters listed in the scope (Section 1.1), and was used to develop the method performance statements in Section 12. Guidelines for the use of alternate detectors are provided in Section 10.1.

5.4 Syringes—5-mL glass hypodermic with Luerlok tip (two each), if applicable to the purging device.

5.5 Micro syringes—25-µL, 0.006 in. ID needle.

5.6 Syringe valve—2-way, with Luer ends (three each).

5.7 Bottle—15-mL, screw-cap, with Teflon cap liner.

5.8 Balance—Analytical, capable of accurately weighing 0.0001 g.

6. Reagents

6.1 Reagent water—Reagent water is defined as a water in which an interferent is not observed at the MDL of the parameters of interest.

6.1.1 Reagent water can be generated by passing tap water through a carbon filter bed containing about 1 lb of activated carbon (Filtrasorb-300, Calgon Corp., or equivalent).

6.1.2 A water purification system (Millipore Super-Q or equivalent) may be used to generate reagent water.

6.1.3 Reagent water may also be prepared by boiling water for 15 min. Subsequently, while maintaining the temperature at 90 °C, bubble a contaminant-free inert gas through the water for 1 h. While still hot, transfer the water to a narrow mouth screw-cap bottle and seal with a Teflon-lined septum and cap.

6.2 Sodium thiosulfate—(ACS) Granular.

6.3 Hydrochloric acid (1+1)—Add 50 mL of concentrated HCl (ACS) to 50 mL of reagent water.

6.4 *Trap Materials:*

6.4.1 2,6-Diphenylene oxide polymer—Tenax (60/80 mesh), chromatographic grade or equivalent.

6.4.2 Methyl silicone packing—3% OV-1 on Chromosorb-W (60/80 mesh) or equivalent.

6.5 Methanol—Pesticide quality or equivalent.

6.6 Stock standard solutions—Stock standard solutions may be prepared from pure standard materials or purchased as certified solutions. Prepare stock standard solutions in methanol using assayed liquids. Because of the toxicity of benzene and 1,4-dichlorobenzene, primary dilutions of these materials should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be used when the analyst handles high concentrations of such materials.

6.6.1 Place about 9.8 mL of methanol into a 10-mL ground glass stoppered volumetric flask. Allow the flask to stand, unstoppered, for about 10 min or until all alcohol wetted surfaces have dried. Weigh the flask to the nearest 0.1 mg.

6.6.2 Using a 100-µL syringe, immediately add two or more drops of assayed reference material to the flask, then reweigh. Be sure that the drops fall directly into the alcohol without contacting the neck of the flask.

6.6.3 Reweigh, dilute to volume, stopper, then mix by inverting the flask several times. Calculate the concentration in µg/µL from the net gain in weight. When compound purity is assayed to be 96% or greater, the weight can be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards can be used at any concentration if they are certified by the manufacturer or by an independent source.

6.6.4 Transfer the stock standard solution into a Teflon-sealed screw-cap bottle. Store at 4 °C and protect from light.

6.6.5 All standards must be replaced after one month, or sooner if comparison with check standards indicates a problem.

6.7 Secondary dilution standards—Using stock standard solutions, prepare secondary dilution standards in methanol that contain the compounds of interest, either singly or mixed together. The secondary dilution standards should be prepared at concentrations such that the aqueous calibration standards prepared in Sections 7.3.1 or 7.4.1 will bracket the working range of the analytical system. Secondary solution standards must be stored with zero headspace and should be checked frequently for signs of degradation or evaporation, especially just prior to preparing calibration standards from them.

6.8 Quality control check sample concentrate—See Section 8.2.1.

7. Calibration

7.1 Assemble a purge and trap system that meets the specifications in Section 5.2. Condition the trap overnight at 180 °C by backflushing with an inert gas flow of at least 20 mL/min. Condition the trap for 10 min once daily prior to use.

7.2 Connect the purge and trap system to a gas chromatograph. The gas chromatograph must be operated using temperature and flow rate conditions equivalent to those given in Table 1. Calibrate the purge and trap-gas chromatographic system using either the external standard technique (Section 7.3) or the internal standard technique (Section 7.4).

7.3 External standard calibration procedure:

7.3.1 Prepare calibration standards at a minimum of three concentration levels for each parameter by carefully adding 20.0 µL of one or more secondary dilution standards to 100, 500, or 1000 mL of reagent water. A 25-µL syringe with a 0.006 in. ID needle should be used for this operation. One of the external standards should be at a concentration near, but above, the MDL (Table 1) and the other concentrations should correspond to the expected range of concentrations found in real samples or should define the working range of the detector. These aqueous standards must be prepared fresh daily.

7.3.2 Analyze each calibration standard according to Section 10, and tabulate peak height or area responses versus the concentration in the standard. The results can be used to prepare a calibration curve for each compound. Alternatively, if the ratio of response to concentration (calibration factor) is a constant over the working range (<10% relative standard deviation, RSD), linearity through the origin can be assumed and the average ratio or calibration factor can be used in place of a calibration curve.

7.4 Internal standard calibration procedure—To use this approach, the analyst must select one or more internal standards that are similar in analytical behavior to the compounds of interest. The analyst must further demonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Because of these limitations, no internal standard can be suggested that is applicable to all samples. The compound, α,α,α,-trifluorotoluene, recommended as a surrogate spiking compound in Section 8.7 has been used successfully as an internal standard.

7.4.1 Prepare calibration standards at a minimum of three concentration levels for each parameter of interest as described in Section 7.3.1.

7.4.2 Prepare a spiking solution containing each of the internal standards using the procedures described in Section 6.6 and 6.7. It is recommended that the secondary dilution standard be prepared at a concentration of 15 µg/mL of each internal standard compound. The addition of 10 µl of this standard to 5.0 mL of sample or calibration standard would be equivalent to 30 µg/L.

7.4.3 Analyze each calibration standard according to Section 10, adding 10 µL of internal standard spiking solution directly to the syringe (Section 10.4). Tabulate peak height or area responses against concentration for each compound and internal standard, and calculate response factors (RF) for each compound using Equation 1.

Equation 1.

$$RF = \frac{(A_s)(C_{is})}{(A_{is})(C_s)}$$

where:

A_s = Response for the parameter to be measured.
A_{is} = Response for the internal standard.
C_{is} = Concentration of the internal standard
C_s = Concentration of the parameter to be measured.

If the RF value over the working range is a constant (<10% RSD), the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to plot a calibration curve of response ratios, A_s/A_{is}, vs. RF.

7.5 The working calibration curve, calibration factor, or RF must be verified on each working day by the measurement of a QC check sample.

7.5.1 Prepare the QC check sample as described in Section 8.2.2.

7.5.2 Analyze the QC check sample according to Section 10.

7.5.3 For each parameter, compare the response (Q) with the corresponding calibration acceptance criteria found in Table 2. If the responses for all parameters of interest fall within the designated ranges, analysis of actual samples can begin. If any individual Q falls outside the range, a new calibration curve, calibration factor, or RF must be prepared for that parameter according to Section 7.3 or 7.4.

8. Quality Control

8.1 Each laboratory that uses this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and an ongoing analysis of spiked samples to evaluate and document data quality. The laboratory must maintain records to document the quality of data that is generated. Ongoing data quality checks are compared with established performance criteria to determine if the results of analyses meet the performance characteristics of the method. When results of sample spikes indicate atypical method performance, a quality control check standard must be analyzed to confirm that the measurements were performed in an in-control mode of operation.

8.1.1 The analyst must make an initial, one-time, demonstration of the ability to generate acceptable accuracy and precision with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of advances that are occurring in chromatography, the analyst is permitted certain options (detailed in Section 10.1) to improve the separations or lower the cost of measurements. Each time such a modification is made to the method, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 Each day, the analyst must analyze a reagent water blank to demonstrate that interferences from the analytical system are under control.

8.1.4 The laboratory must, on an ongoing basis, spike and analyze a minimum of 10% of all samples to monitor and evaluate laboratory data quality. This procedure is described in Section 8.3.

8.1.5 The laboratory must, on an ongoing basis, demonstrate through the analyses of quality control check standards that the operation of the measurement system is in control. This procedure is described in Section 8.4. The frequency of the check standard analyses is equivalent to 10% of all samples analyzed but may be reduced if spike recoveries from samples (Section 8.3) meet all specified quality control criteria.

8.1.6 The laboratory must maintain performance records to document the quality of data that is generated. This procedure is described in Section 8.5.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 A quality control (QC) check sample concentrate is required containing each parameter of interest at a concentration of 10 µg/mL in methanol. The QC check sample concentrate must be obtained from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory in Cincinnati, Ohio, if available. If not available from that source, the QC check sample concentrate must be obtained from another external source. If not available from either source above, the QC check sample concentrate must be prepared by the laboratory using stock standards prepared independently from those used for calibration.

8.2.2 Prepare a QC check sample to contain 20 µg/L of each parameter by adding 200 µL of QC check sample concentrate to 100 mL of reagent water.

8.2.3 Analyze four 5-mL aliquots of the well-mixed QC check sample according to Section 10.

8.2.4 Calculate the average recovery ($\bar{X}$) in µg/L, and the standard deviation of the recovery (s) in µg/L, for each parameter of interest using the four results.

8.2.5 For each parameter compare s and $\bar{X}$ with the corresponding acceptance criteria for precision and accuracy, respectively, found in Table 2. If s and $\bar{X}$ for all parameters of interest meet the acceptance criteria, the system performance is acceptable and analysis of actual samples can begin. If any individual s exceeds the precision limit or any individual $\bar{X}$ falls outside the range for accuracy, the system performance is unacceptable for that parameter.

Note.—The large number of parameters in Table 2 present a substantial probability that one or more will fail at least one of the acceptance criteria when all parameters are analyzed.

8.2.6 When one or more of the parameters tested fail at least one of the acceptance criteria, the analyst must proceed according to Section 8.2.6.1 or 8.2.6.2.

8.2.6.1 Locate and correct the source of the problem and repeat the test for all parameters of interest beginning with Section 8.2.3.

8.2.6.2 Beginning with Section 8.2.3, repeat the test only for those parameters that failed to meet criteria. Repeated failure, however, will confirm a general problem with the measurement system. If this occurs, locate and correct the source of the problem and repeat the test for all compounds of interest beginning with Section 8.2.3.

8.3 The laboratory must, on an ongoing basis, spike at least 10% of the samples from each sample site being monitored to assess accuracy. For laboratories analyzing one to ten samples per month, at least one spiked sample per month is required.

8.3.1 The concentration of the spike in the sample should be determined as follows:

8.3.1.1 If, as in compliance monitoring, the concentration of a specific parameter in the sample is being checked against a regulatory concentration limit, the spike should be at that limit or 1 to 5 times higher than the background concentration determined in Section 8.3.2, whichever concentration would be larger.

8.3.1.2 If the concentration of a specific parameter in the sample is not being checked against a limit specific to that parameter, the spike should be at 20 µg/L or 1 to 5 times higher than the background concentration determined in Section 8.3.2, whichever concentration would be larger.

8.3.2 Analyze one 5-mL sample aliquot to determine the background concentration (B) of each parameter. If necessary, prepare a new QC check sample concentrate (Section 8.2.1) appropriate for the background concentrations in the sample. Spike a second 5-mL sample aliquot with 10 µL of the QC check sample concentrate and analyze it to determine the concentration after spiking (A) of each parameter. Calculate each percent recovery (P) as 100(A−B)%/T, where T is the known true value of the spike.

8.3.3 Compare the percent recovery (P) for each parameter with the corresponding QC acceptance criteria found in Table 2. These acceptance criteria were calculated to include an allowance for error in measurement of both the background and spike concentrations, assuming a spike to background ratio of 5:1. This error will be accounted for to the extent that the analyst's spike to background ratio approaches 5:1.[7] If spiking was performed at a concentration lower than 20 µg/L, the analyst must use either the QC acceptance criteria in Table 2, or optional QC acceptance criteria calculated for the specific spike concentration. To calculate optional acceptance criteria for the recovery of a parameter: (1) Calculate accuracy (X') using the equation in Table 3, substituting the spike concentration (T) for C; (2) calculate overall precision (S') using the equation in Table 3, substituting X' for $\bar{X}$; (3) calculate the range for recovery at the spike concentration as (100 X'/T) ± 2.44(100 S'/T)%.[7]

8.3.4 If any individual P falls outside the designated range for recovery, that parameter has failed the acceptance criteria. A check standard containing each parameter that failed the criteria must be analyzed as described in Section 8.4.

8.4 If any parameter fails the acceptance criteria for recovery in Section 8.3, a QC check standard containing each parameter that failed must be prepared and analyzed.

Note: The frequency for the required analysis of a QC check standard will depend upon the number of parameters being simultaneously tested, the complexity of the sample matrix, and the performance of the laboratory.

8.4.1 Prepare the QC check standard by adding 10 µL of QC check sample concentrate (Sections 8.2.1 or 8.3.2) to 5 mL of reagent water. The QC check standard needs only to contain the parameters that failed criteria in the test in Section 8.3.

8.4.2 Analyze the QC check standard to determine the concentration measured (A) of each parameter. Calculate each percent recovery (P_s) as 100 (A/T)%, where T is the true value of the standard concentration.

8.4.3 Compare the percent recovery (P_s) for each parameter with the corresponding QC acceptance criteria found in Table 2. Only parameters that failed the test in Section 8.3 need to be compared with these criteria. If the recovery of any such parameter falls outside the designated range, the laboratory performance for that parameter is judged to be out of control, and the problem must be immediately identified and corrected. The analytical result for that parameter in the unspiked sample is suspect and may not be reported for regulatory compliance purposes.

8.5 As part of the QC program for the laboratory, method accuracy for wastewater samples must be assessed and records must be maintained. After the analysis of five spiked wastewater samples as in Section 8.3, calculate the average percent recovery ($\bar{P}$) and the standard deviation of the percent recovery (s_p). Express the accuracy assessment as a percent recovery interval from $\bar{P}-2s_p$ to $\bar{P}+2s_p$. If $\bar{P}=90\%$ and $s_p=10\%$, for example, the accuracy interval is expressed as 70–110%. Update the accuracy assessment for each parameter on a regular basis (e.g. after each five to ten new accuracy measurements).

8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to assess the precision of the environmental measurements. When doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as gas chromatography with a dissimilar column, specific element detector, or mass spectrometer must be used. Whenever possible, the laboratory should analyze standard reference materials and participate in relevant performance evaluation studies.

8.7 The analyst should monitor both the performance of the analytical system and the effectiveness of the method in dealing with each sample matrix by spiking each sample, standard, and reagent water blank with surrogate compounds (e.g. α, α, α,-trifluorotoluene) recommended to encompass the range of the temperature program used in this method. From stock standard solutions prepared as in Section 6.6, add a volume to give 750 μg of each surrogate to 45 mL of reagent water contained in a 50-mL volumetric flask, mix and dilute to volume for a concentration of 15 mg/μL. Add 10 μL of this surrogate spiking solution directly into the 5-mL syringe with every sample and reference standard analyzed. Prepare a fresh surrogate spiking solution on a weekly basis. If the internal standard calibration procedure is being used, the surrogate compounds may be added directly to the internal standard spiking solution (Section 7.4.2).

9. Sample Collection, Preservation, and Handling

9.1 The samples must be iced or refrigerated from the time of collection until analysis. If the sample contains free or combined chlorine, add sodium thiosulfate preservative (10 mg/40 mL is sufficient for up to 5 ppm Cl_2) to the empty sample bottle just prior to shipping to the sampling site. EPA Method 330.4 or 330.5 may be used for measurement of residual chlorine.[8] Field test kits are available for this purpose.

9.2 Collect about 500 mL of sample in a clean container. Adjust the pH of the sample to about 2 by adding 1+1 HCl while stirring. Fill the sample bottle in such a manner that no air bubbles pass through the sample as the bottle is being filled. Seal the bottle so that no air bubbles are entrapped in it. Maintain the hermetic seal on the sample bottle until time of analysis.

9.3 All samples must be analyzed within 14 days of collection.[3]

10. Procedure

10.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this table are estimated retention times and MDL that can be achieved under these conditions. An example of the separations achieved by Column 1 is shown in Figure 6. Other packed columns, chromatographic conditions, or detectors may be used if the requirements of Section 8.2 are met.

10.2 Calibrate the system daily as described in Section 7.

10.3 Adjust the purge gas (nitrogen or helium) flow rate to 40 mL/min. Attach the trap inlet to the purging device, and set the purge and trap system to purge (Figure 3). Open the syringe valve located on the purging device sample introduction needle.

10.4 Allow the sample to come to ambient temperature prior to introducing it to the syringe. Remove the plunger from a 5-mL syringe and attach a closed syringe valve. Open the sample bottle (or standard) and carefully pour the sample into the syringe barrel to just short of overflowing. Replace the syringe plunger and compress the sample. Open the syringe valve and vent any residual air while adjusting the sample volume to 5.0 mL. Since this process of taking an aliquot destroys the validity of the sample for future analysis, the analyst should fill a second syringe at this time to protect against possible loss of data. Add 10.0 μL of the surrogate spiking solution (Section 8.7) and 10.0 μL of the internal standard spiking solution (Section 7.4.2), if applicable, through the valve bore, then close the valve.

10.5 Attach the syringe-syringe valve assembly to the syringe valve on the purging device. Open the syringe valves and inject the sample into the purging chamber.

10.6 Close both valves and purge the sample for 12.0±0.1 min at ambient temperature.

10.7 After the 12-min purge time, disconnect the purging device from the trap. Dry the trap by maintaining a flow of 40 mL/min of dry purge gas through it for 6 min (Figure 4). If the purging device has no provision for bypassing the purger for this step, a dry purger should be inserted into the device to minimize moisture in the gas. Attach the trap to the chromatograph, adjust the purge and trap system to the desorb mode (Figure 5), and begin to temperature program the gas chromatograph. Introduce the trapped materials to the GC column by rapidly heating the trap to 180 °C while backflushing the trap with an inert gas between 20 and 60 mL/min for 4 min. If rapid heating of the trap cannot be achieved, the GC column must be used as a secondary trap by cooling it to 30 °C (subambient temperature, if poor peak geometry and random retention time problems persist) instead of the initial program temperature of 50 °C.

10.8 While the trap is being desorbed into the gas chromatograph column, empty the purging chamber using the sample introduction syringe. Wash the chamber with two 5-mL flushes of reagent water.

10.9 After desorbing the sample for 4 min, recondition the trap by returning the purge and trap system to the purge mode. Wait 15 s, then close the syringe valve on the purging device to begin gas flow through the trap. The trap temperature should be maintained at 180 °C. After approximately 7 min, turn off the trap heater and open the syringe valve to stop the gas flow through the trap. When the trap is cool, the next sample can be analyzed.

10.10 Identify the parameters in the sample by comparing the retention times of the peaks in the sample chromatogram with those of the peaks in standard chromatograms. The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of a retention time for a compound can be used to calculate a suggested window size; however, the experience of the analyst should weigh heavily in the interpretation of chromatograms.

10.11 If the response for a peak exceeds the working range of the system, prepare a dilution of the sample with reagent water from the aliquot in the second syringe and reanalyze.

11. Calculations

11.1 Determine the concentration of individual compounds in the sample.

11.1.1 If the external standard calibration procedure is used, calculate the concentration of the parameter being measured from the peak response using the calibration curve or calibration factor determined in Section 7.3.2.

11.1.2 If the internal standard calibration procedure is used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.4.3 and Equation 2.

Equation 2.

$$\text{Concentration } (\mu g/L) = \frac{(A_s)(C_{is})}{(A_{is})(RF)}$$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_{is} = Concentration of the internal standard.

11.2 Report results in μg/L without correction for recovery data. All QC data obtained should be reported with the sample results.

12. Method Performance

12.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.[1] The MDL concentrations listed in Table 1 were obtained using reagent water.[9] Similar results were achieved using representative wastewaters. The MDL actually achieved in a given analysis will vary depending on instrument sensitivity and matrix effects.

12.2 This method has been demonstrated to be applicable for the concentration range from the MDL to 1000 x MDL.[9] Direct aqueous injection techniques should be used to measure concentration levels above 1000 x MDL.

12.3 This method was tested by 20 laboratories using reagent water, drinking water, surface water, and three industrial wastewaters spiked at six concentrations over the range 2.1 to 550 μg/L.[9] Single operator precision, overall precision, and method accuracy were found to be directly related to the concentration of the parameter and essentially independent of the sample matrix. Linear equations to describe these relationships are presented in Table 3.

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7. Provost, L.P., and Elder, R.S. "Interpretation of Percent Recovery Data," *American Laboratory, 15*, 58-63 (1983). (The value 2.44 used in the equation in Section 8.3.3. is two times the value 1.22 derived in this report.)

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9. "EPA Method Validation Study 24, Method 602 (Purgeable Aromatics)," Report for EPA Contract 68-03-2856 (In preparation).

TABLE 1.—CHROMATOGRAPHIC CONDITIONS AND METHOD DETECTION LIMITS

Parameter	Retention time (min)		Method detection limit (µg/L)
	Column 1	Column 2	
Benzene	3.33	2.75	0.2
Toluene	5.75	4.25	0.2
Ethylbenzene	8.25	6.25	0.2
Chlorobenzene	9.17	8.02	0.2
1,4-Dichlorobenzene	16.8	16.2	0.3
1,3-Dichlorobenzene	18.2	15.0	0.4
1,2-Dichlorobenzene	25.9	19.4	0.4

Column 1 conditions: Supelcoport (100/120 mesh) coated with 5% SP-1200/1.75% Bentone-34 packed in a 6 ft x 0.085 in. ID stainless steel column with helium carrier gas at 36 mL/min flow rate. Column temperature held at 50 °C for 2 min then programmed at 6 °C/min to 90 °C for a final hold.

Column 2 conditions: Chromosorb W-AW (60/80 mesh) coated with 5% 1,2,3-Tris(2-cyanoethyoxy)propane packed in a 6 ft x 0.085 in. ID stainless steel column with helium carrier gas at 30 mL/min flow rate. Column temperature held at 40 °C for 2 min then programmed at 2 °C/min to 100 °C for a final hold.

TABLE 2.—CALIBRATION AND QC ACCEPTANCE CRITERIA—METHOD 602 [a]

Parameter	Range for Q (µg/L)	Limit for s (µg/L)	Range for $\bar{X}$ (µg/L)	Range for P, P_s (%)
Benzene	15.4–24.6	4.1	10.0–27.9	39–150
Chlorobenzene	16.1–23.9	3.5	12.7–25.4	55–135
1,2-Dichlorobenzene	13.6–26.4	5.8	10.6–27.6	37–154
1,3-Dichlorobenzene	14.5–25.5	5.0	12.8–25.5	50–141
1,4-Dichlorobenzene	13.9–26.1	5.5	11.6–25.5	42–143
Ethylbenzene	12.6–27.4	6.7	10.0–28.2	32–160
Toluene	15.5–24.5	4.0	11.2–27.7	46–148

Q = Concentration measured in QC check sample, in µg/L (Section 7.5.3).
s = Standard deviation of four recovery measurements, in µg/L (Section 8.2.4).
$\bar{X}$ = Average recovery for four recovery measurements, in µg/L (Section 8.2.4).
P_s, P = Percent recovery measured (Section 8.3.2, Section 8.4.2).
[a] Criteria were calculated assuming a QC check sample concentration of 20 µg/L.

Note: These criteria are based directly upon the method performance data in Table 3. Where necessary, the limits for recovery have been broadened to assure applicability of the limits to concentrations below those used to develop Table 3.

TABLE 3.—METHOD ACCURACY AND PRECISION AS FUNCTIONS OF CONCENTRATION—METHOD 602

Parameter	Accuracy, as recovery, X′ (µg/L)	Single analyst precision, s′ (µg/L)	Overall precision, S′ (µg/L)
Benzene	0.92C+0.57	$0.09\bar{X}+0.59$	$0.21\bar{X}+0.56$
Chlorobenzene	0.95C+0.02	$0.09\bar{X}+0.23$	$0.17\bar{X}+0.10$
1,2-Dichlorobenzene	0.93C+0.52	$0.17\bar{X}-0.04$	$0.22\bar{X}+0.53$
1,3-Dichlorobenzene	0.96C−0.04	$0.15\bar{X}-0.10$	$0.19\bar{X}+0.09$
1,4-Dichlorobenzene	0.93C+0.09	$0.15\bar{X}+0.28$	$0.20\bar{X}+0.41$
Ethylbenzene	0.94C+0.31	$0.17\bar{X}+0.46$	$0.26\bar{X}+0.23$
Toluene	0.94C+0.65	$0.09\bar{X}+0.48$	$0.18\bar{X}+0.71$

X′ = Expected recovery for one or more measurements of a sample containing a concentration of C, in µg/L.
s′ = Expected single analyst standard deviation of measurements at an average concentration found of $\bar{X}$, in µg/L.
S′ = Expected interlaboratory standard deviation of measurements at an average concentration found of $\bar{X}$, in µg/L.
C = True value for the Concentration, in µg/L.
$\bar{X}$ = Average recovery found for measurements of samples containing a concentration of C, in µg/L.

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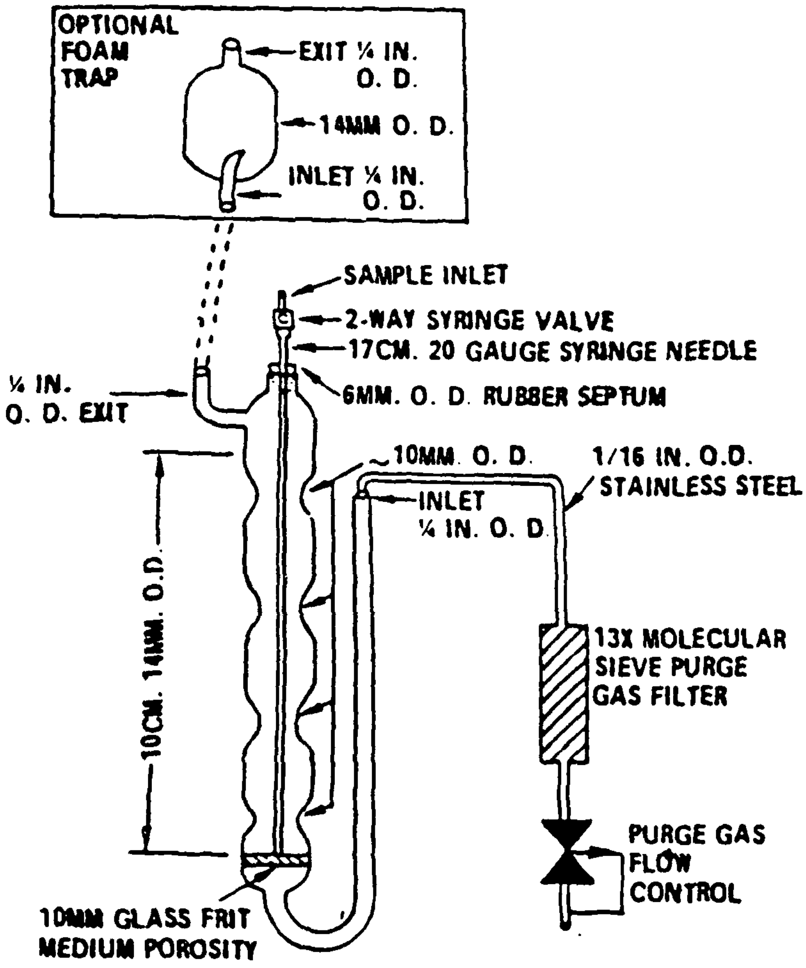

Figure 1., Purging device.

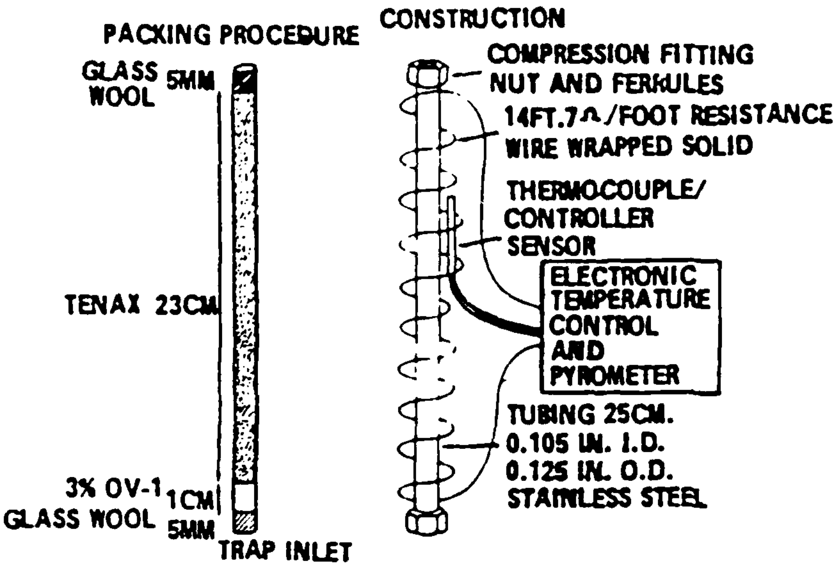

Figure 2. Trap packings and construction to include desorb capability.

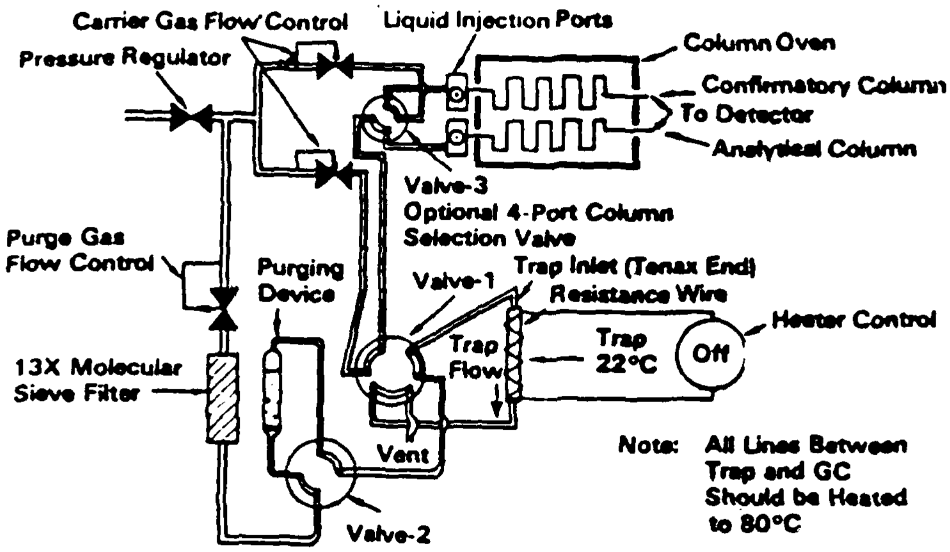

Figure 3. Purge and trap system - purge mode.

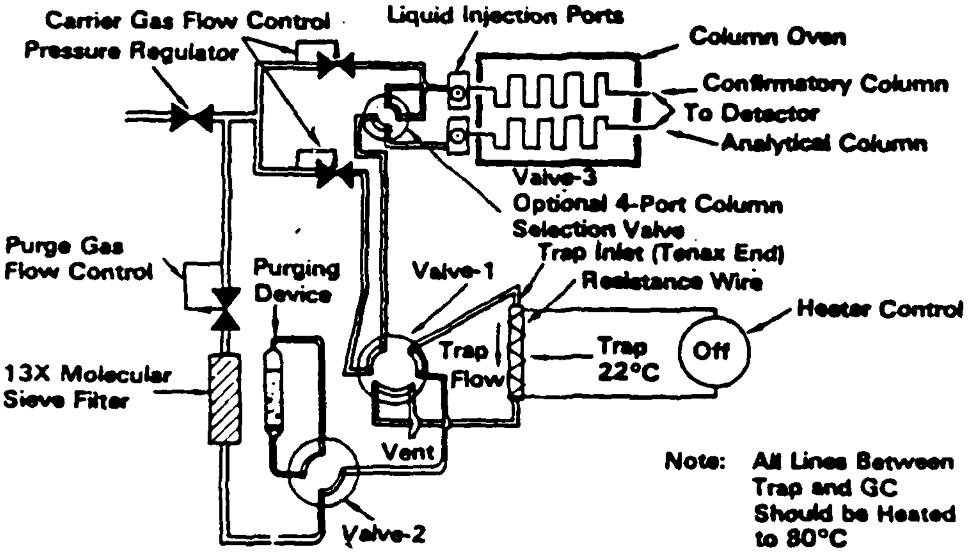

Figure 4. Purge and trap system-dry mode.

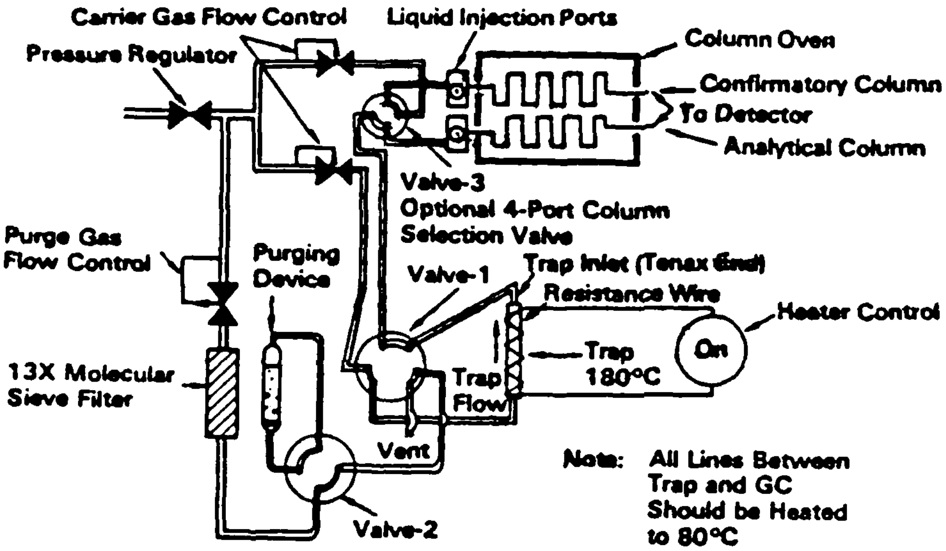

Figure 5. Purge and trap system-desorb mode.

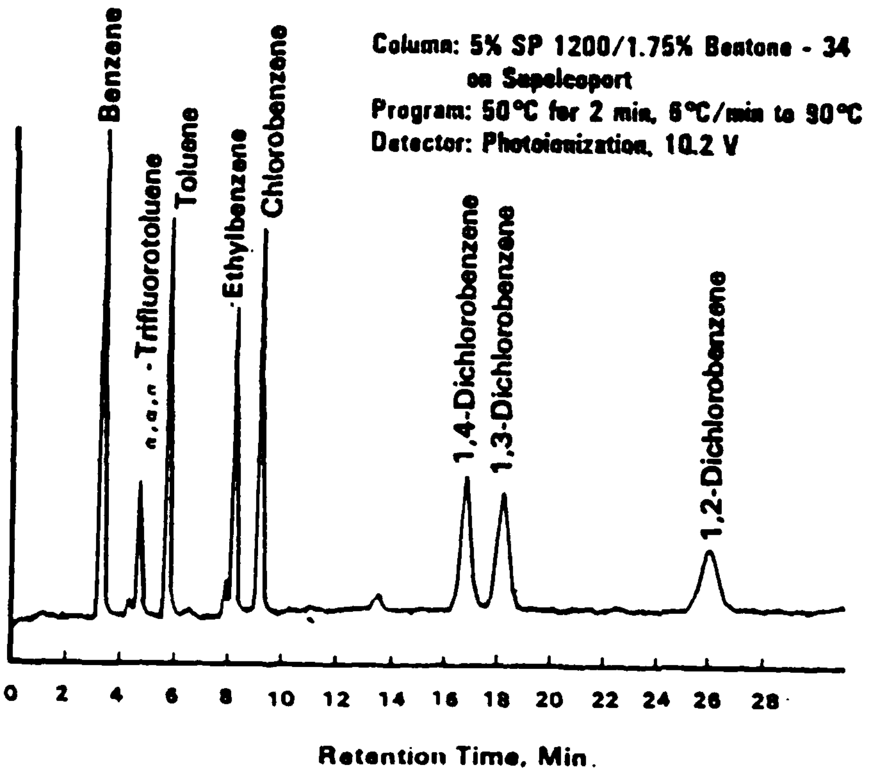

Figure 6. Gas chromatogram of purgeable aromatics.

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TOC Determinations in Ground Water

by Michael J. Barcelona[a]

ABSTRACT

Determinations of total organic carbon (TOC) can provide valuable diagnostic evidence of the extent of ground-water contamination by organic compounds. The usefulness of conventional TOC results in monitoring efforts is limited by the bias introduced during the purging of inorganic carbon prior to analysis. A modified TOC procedure has been evaluated to permit the quantitation of the volatile organic carbon (VOC) fraction in water samples. The methodology consists of trapping the VOC in a manner analogous to commercial purge and trap instruments which are used for specific organic compound separations. The method has been found to be sensitive, accurate and reasonably precise for TOC determinations of standard solutions as well as on ground-water samples. Volatile organic carbon levels can range from 9-50% of the TOC in both uncontaminated and contaminated ground waters. The reporting of the volatile and nonvolatile fractions of the TOC will enhance both monitoring and research efforts, since it permits more complete characterization of the organic carbon content of ground-water samples.

INTRODUCTION

Monitoring total organic carbon (TOC) in ground-water samples is useful because contamination by synthetic organic compounds may be indicated when TOC concentrations are detected above background levels. This surrogate parameter provides a rapid, inexpensive indication of the extent of organic contamination and has been used extensively in studies of contaminant plume migration (Robertson and others, 1974; Spiker and Rubin, 1975; Leenheer and others, 1976; Kimmel and Braids, 1980). In this respect, TOC determinations permit the screening of samples prior to specific organic compound identification and quantitation.

TOC measurements are considered superior to laborious manual determinations of chemical (COD) or biological (BOD) oxygen demand as the latter methodologies may be significantly biased by the presence of reducing agents, refractory compounds or toxic materials. For these and other reasons, TOC determinations are frequently required by regulatory agencies for compliance monitoring (for example, RCRA, NPDES or CERCLA programs). The usefulness of TOC data has been limited though, because it is an operationally defined parameter which may be representative of the total dissolved organic carbon content of a water sample.

The nonvolatile organic carbon levels of uncontaminated ground water are generally observed to be quite low, 0.1-4 mg/l (Leenheer and others, 1974; Junk and others, 1980). Inorganic carbon, comprised of aqueous carbon dioxide, bicarbonate and carbonate ions, may exceed 100-200 mg/l, depending on the pH, temperature and partial pressure of CO_2. The routine TOC procedure consists of three steps. Firstly, acidification and purging of the water sample are performed to remove inorganic carbon species as CO_2. CO_2 purging is followed by an oxidation procedure to convert organic carbon to CO_2. The principal procedures in use are wet-chemical oxidation (Menzel and Vaccaro, 1964; Sharp, 1973; Goulden and Anthony, 1978) and ultraviolet photooxidation (Collins and Williams, 1977; Mueller and

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Bandaranayake, 1983), as well as high-temperature oxidation. The relative oxidation efficiencies of these procedures may vary relative to the mixture of organic compounds making up the TOC (Gershey and others, 1979). Thirdly, the quantitation of the CO_2 produced in the oxidation step is then usually performed by infrared absorption spectrometry.

Regardless of the oxidation or quantitation steps employed in various instrumental methods, a common source of bias in TOC measurements results from purging volatile forms of organic carbon along with inorganic carbon. Variations in CO_2 purging methodologies may explain, in part, the poor interlaboratory comparisons of TOC measurement performance which has resulted in suggestions that TOC be dropped entirely from recommended methods for landfill leachate analysis (De Walle and others, 1981). Several authors have recognized the fact that such TOC data must be reported as a lower limit, since only the nonvolatile fraction of the organic carbon is available after purging (Baedeker and Back, 1979; Kimmel and Braids, 1980).

There are instruments commercially available which determine both the volatile (VOC, purged with CO_2 on acidification) and nonvolatile fractions of total dissolved organic carbon (NVOC). Several of these instrument designs are quite sensitive. These instruments convert the CO_2 produced by oxidation of organic materials to methane which is then detected by a flame ionization detector. However, many laboratories have earlier instrument designs which are limited to the determination of NVOC. VOC concentrations have not been reported, since standard methodologies do not distinguish between the two fractions of TOC (USEPA, 1979). Therefore, the available data on the organic carbon content of ground water are biased by the omission of the VOC fraction.

Knowledge of the volatile organic carbon fraction of TOC in ground-water samples is important for several reasons. Interconversion of TOC between the volatile and nonvolatile fractions due to chemical reaction or microbial activity limits the capability to quantitatively assess net organic compound migration if only NVOC is reported. Moreover, volatile organic solvents are among the most frequently observed substances in untreated ground-water supplies for potable uses (Dyksen and Hess, 1982). These compounds are mobile in the subsurface since they are water-soluble, and they frequently appear as early indicators of con- [illegible] transport. Observed levels of volatile compounds in ground-water supplies have been reported to be two to three orders of magnitude higher than those in surface supplies (CEQ, 1981).

Therefore, a study was undertaken of the determination of TOC (VOC and NVOC) in ground-water samples. Emphasis was focused on the development and application of a precise, accurate methodology which was verifiable for volatile and nonvolatile organic compounds previously identified in ground water. It was therefore necessary to identify standard compounds which show comparable analytical performance in both carbon fractions.

METHODS AND MATERIALS

The 12 compounds chosen for this study, in addition to the usual TOC standard, potassium hydrogen phthalate (KHP), are shown in Table 1. They range from volatile halocarbon and aromatic solvents frequently observed in ground-water samples to low molecular weight, carboxylic acids which have been identified in landfill leachate (Colenutt, 1979; Chian, 1977). Acetone and trichlorophenol were included as partially volatile standards for both the VOC and NVOC fractions.

The modified TOC procedure was developed on an Oceanography International Model 524 Total Organic Carbon Analyzer with standard direct injection module (DIM), purging and glass ampoule sealing units. Five ml water samples were first acidified and purged with oxygen for five minutes at 80 ml/min in a flow system incorporating a 25 cm × 2.5 mm i.d. stainless steel trap filled with Tenax-GC® support (60-80 mesh) which adsorbed the volatile organics and allowed H_2O and inorganic CO_2 to vent. The volatile compounds were desorbed from the trap in an oxygen stream (140 ml/min) into the combustion tube (950°C) of the DIM module for conversion to CO_2. The purging step and subsequent reversal of gas flow through the trap as it was heated (180°C) for five minutes (to desorb the volatiles) is analogous to

Table 1. Model Compounds Used in This Study

Chloroform	Acetaldehyde
Trichloroethylene	Dimethylformamide
Benzene	Acetic acid
Dichloromethane	Propionic acid
Toluene	Pentanoic acid
Trichlorophenol	Potassium hydrogen phthalate
Acetone	

the routine purge and trap separation of volatile organics in the priority pollutant analytical protocols (Bellar and Lichtenberg, 1974; EPA, 1982). From the combustion tube, the gases passed through a series of columns to remove water (anhydrous magnesium perchlorate) and hydrochloric acid (finely divided tin particles) prior to entering the infrared detector. After purging the TOC samples of the volatile fraction and inorganic CO_2, the ampoules were sealed and processed for NVOC by the usual persulfate wet oxidation procedure. Standard solutions (0.05-10 mg-C/l) of the model compounds were made by careful dilution of 50-1,000 mg-C/l stock solutions gravimetrically prepared in 10^{-3} N bicarbonate solution immediately prior to use. All standards and most samples were processed in triplicate where volume permitted. All TOC determinations on model compound solutions were calculated relative to calibration curves determined for KHP.

RESULTS AND DISCUSSION

TOC Method Performance

The primary objectives of the work were to develop and apply a TOC methodology which would reproducibly recover the volatile organic carbon fraction of water samples. In the concentration range of 0.1 to 10.0 mg-Cl, acetone and trichlorophenol were found to be the most suitable combined VOC and NVOC standards. Both of these compounds exhibited better than 90% recovery throughout the TOC procedure and an average 30% higher sensitivity than did KHP standards. Details of the relative performance of the method for acetone are shown in Table 2. The volatile fraction of aqueous acetone standards averaged 9% of the TOC. No significant differences in VOC were noted in parallel standard runs made with a 10^{-3} M $NaHCO_3$ background solution. Therefore, no observable carryover of inorganic CO_2 occurred through the trapping, desorption and combustion steps. Trichlorophenol results were comparable to those for acetone. The slight losses of volatile organic carbon in the desorption and combustion steps were more than compensated for by the more complete wet oxidation of both trichlorophenol and acetone relative to KHP. Trichlorophenol standard solutions were found to be less stable than those for acetone and for this reason acetone was chosen as a more suitable volatile standard compound.

A comparison of the TOC results for the model compounds is presented in Table 3. The percent volatile carbon for each compound was determined by the difference between purged and unpurged standard solutions as described above, for acetone and trichlorophenol. In general, the volatile fraction observed for each volatile organic solvent standard was quite similar to that predicted from purging efficiencies reported by previous workers (Bellar and Lichtenberg, 1974; Kuo and others, 1977).

The sensitivity of the modified method for volatile compounds was found to be very dependent on the ease of persulfate oxidation. Compounds which were less volatile under the test

Table 2. Average Performance Data for Acetone in the TOC Procedure

Standard concentration (mg-C/l)	*Standard concentration* (µg-C/5 ml)	*Percent volatile**	Percent: *High temperature combustion efficiency**	Percent: *Trapping/ desorption efficiency***	Percent: *Overall procedure efficiency****
1.0	5	8.2	98	88	133
2.0	10	8.6	94	88	149
5.0	25	9.3	91	84	120
10.0	50	9.9	93	78	118
Mean		9.0	94	85	130 ± 11% (relative standard deviation)
(N)		(12)	(12)	(24)	(12)

* Determined by difference between purged and unpurged standards after wet combustion relative to KHP

* $$\frac{\text{Carbon recovered by vapor injections}}{\text{Volatile carbon}} \times 100$$

** $$\frac{\text{Carbon recovered by purging, trapping and desorption}}{\text{Volatile carbon}} \times 100\text{, corrected for combustion efficiency}$$

*** Instrument response for acetone (VOC + NVOC) relative to KHP

Table 3. Average Performance Data for Model Compounds in the TOC Procedure (mg-C/l) (relative to KHP)

Compound	Volatile fraction (%)	Sensitivity* (integrator counts/μg-C)	Recovery** (% bias)	[illegible] quantitation •
Chloroform	84	143 ± 69	21	0.52
Trichloroethylene	59	115 ± 54	9.8	0.65
Benzene	53	113 ± 16	−19	0.66
Dichloromethane	48	51 ± 28	−17	1.46
Toluene	46	91 ± 55	−13	0.82
Trichlorophenol	8.8	208 ± 80	9.1	0.36
Acetone	9.0	196 ± 38	10	0.38
Acetaldehyde	<0.1	178 ± 33	16	0.42
Dimethylformamide	<0.1	202 ± 32	21	0.37
Acetic acid	<0.1	199 ± 29	9.5	0.38
Propanoic acid	<0.1	165 ± 28	10	0.45
Pentanoic acid	<0.1	155 ± 21	−9.0	0.48
KHP	<0.1	150 ± 17	−	0.50
All compounds		151 ± 32	4.0	0.57

* Average sensitivity for TOC values between 1 and 10 mg-C/l. Mean value and the relative standard deviation in percent are tabulated.

** Recoveries calculated as percent bias from the mean value relative to KHP at the 1.0 mg-C/l level.

• Defined as the equivalent carbon content of 10^{-3} M $NaHCO_3$ solution blanks plus 10 times the standard deviation of the blank values.

conditions and resistant to persulfate oxidation showed marked reductions in sensitivity relative to KHP or acetone. Nonetheless, the sensitivity for all model compounds with the exception of dichloromethane and toluene was within two relative standard deviations of the value for KHP. The average recoveries varied ±20% from the KHP standard. The limits of quantitation (ACS, 1980) of the modified TOC procedure for the model compounds (excepting dichloromethane) were quite comparable to that of KHP, acetone or trichlorophenol. The average quantitation limit of 0.57 mg-C/l may be accepted as the lowest TOC concentration that can be reliably determined by infrared detection methods. Since most shallow ground-water samples have exhibited NVOC values alone greater than 0.5 mg-C/l, this is not a serious drawback for screening purposes.

The preceding performance data on the modified TOC procedure establish that, within experimental error, volatile organic carbon represented by a range of model compounds can be reliably determined on a routine basis. Overall, precision and accuracy for replicate carbon standards at 1.0-10 mg-C/l over an 18-month period averaged less than ±20% relative standard deviation and ±20% bias, respectively. Sample analysis times for the modified TOC procedure were approximately 20 minutes, excluding setup and overnight wet chemical oxidation. The need to individually process each sample for VOC results in longer sample analysis times, but the value of complete TOC data seems to be well worth it. This is particularly true when TOC is used as a surrogate parameter for contaminant plume definition (Leenheer and others, 1976), a contamination screening tool (Hughes and others, 1974), or as a basis for evaluating the reactivity of the organic carbon in ground-water samples—for example, sorption interactions (Humenick and Mattox, 1978).

TOC Determinations on Ground-Water Samples

The analysis and reporting of both VOC and NVOC have potential application for the screening of volatile organic carbon contaminant plumes, particularly when "background" VOC levels are quite low. The modified TOC procedure described above was applied to selected ground-water samples. Ground-water samples were collected in 40-ml Teflon-sealed vials directly from the pump outputs. The intent in this part of the study was to determine both the amount of volatile organic carbon present in shallow ground-water samples in the absence of organic contamination, as well as in a situation where large amounts of organic matter have been introduced anthropogenically.

Replicate TOC determinations were made on 11 samples of ground water from a residential area in northern Illinois. The wells were privately-owned, steel cased wells, finished between 60-70 feet (18.3 m) in sand and gravel outwash deposits, described by Berg and others (1981). The

Table 4. TOC Determinations in Shallow Ground Water (mg C/l)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	0.23	3.20	3.43	6.6
2	0.21	2.24	2.45	8.4
3	0.39	3.57	3.96	9.8
4	0.33	2.34	2.67	12.3
5	0.31	3.25	3.56	8.6
6	0.18	2.60	2.78	6.6
7	0.10	2.60	2.70	3.7
8	0.25	2.10	2.35	10.5
9	0.31	2.16	2.47	12.6
10	0.35	2.72	3.07	11.4
11	0.31	2.68	2.99	10.4
Limit of quantitation*	0.10	0.24	0.34	–
Mean TOC			2.95	
Average percent VOC				9.2

* Limit of quantitation defined as blank value in μg-C + 10 σ (relative standard deviation) relative to the response for KHP.

analytical results from these samples are compiled in Table 4. The levels of TOC in these samples averaged 2.95 mg-C/l of which 0.27 mg-C/l or 9.2% was present as VOC. Precision of the modified TOC determination on these samples was better than ±5% (relative standard deviation) from triplicate analytical runs. The improved precision for natural samples relative to acetone (Table 2) was probably the result of less handling prior to analysis. Parallel determinations of conductivity, pH, TDS, nitrate and Kjeldahl nitrogen were performed on these samples, and the results showed essentially no correlation with the TOC data. Although the volatile organic carbon contents of these TOC results was low, each was above the limit of quantitation established for the procedure. Therefore, a significant percentage of VOC may be expected in uncontaminated ground-water samples.

Complete TOC determinations can provide valuable diagnostic evidence of contaminated subsurface situations. Two examples of the application of the modified TOC procedure include the investigation of the effects of organic drilling fluids and natural organic substances (petroleum) on ground-water organic content.

In the course of establishing a ground-water research field site near Havana, Illinois, in Mason County, an array of large-diameter PVC observation wells was installed in shallow sand and gravel deposits (Naymik and Sievers, 1983). Several of these wells were rotary drilled using an organic drilling fluid (Revert ®), while the bulk of the wells were constructed by either hollow-stem auger or driven sand point techniques. Those wells drilled with [illegible] were [illegible] [illegible] 1982. Figure 1 shows the results of TOC determinations on ground-water samples from the site for one year after construction. Augured or driven wells screened through two water-yielding strata showed an average background TOC level of 4.38 mg-C/l (N = 6) with a relative standard deviation (r.s.d.) of 11%. The VOC made up an average of 15 ± 40% r.s.d. of the total organic carbon. The wells drilled with the organic fluid, however, showed average TOC levels two to three times the background concentrations (● SR1 and ○ SR2) during a three to six month period after construction. VOC made up nearly 95% of the TOC in samples collected prior to November 1982. Thereafter, the TOC content of the rotary-drilled well samples increased to over five times the background, and the VOC fraction gradually decreased to within background levels of 0.4-1.0 mg/l. Although exhaustive pumping of wells SR1 and SR2 in April 1983 yielded samples that were only twice the background levels, the effect of the

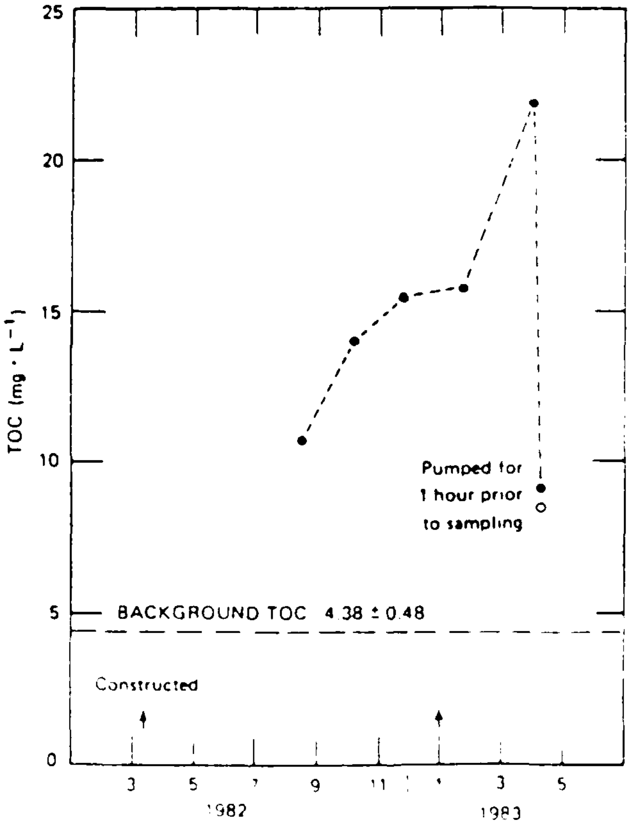

Fig. 1. Drilling mud effects on TOC levels in ground water (● SR1, ○ SR2 wells drilled with Revert ®)

introduction of foreign organic matter during the drilling operation was clearly persistent. Major cations, anions and alkalinity showed little or no correlation with the variations in TOC or VOC concentrations. Total iron, however, showed significant increases which may be linked to organic carbon content.

The TOC results after well construction demonstrate the impact of organic drilling muds on ground-water quality. High levels of VOC during this period may have been the result of the initial breakdown of the drilling mud near the well bore by microorganisms. If this indeed occurred, then the TOC increases over the later study period may be due to the release of nonvolatile, soluble organic materials or other biotransformation products. The large increases in TOC over background levels could have important effects on the separation and identification of specific organic compounds, given the shift in organic carbon from predominately volatile to nonvolatile forms.

The second example of the diagnostic application of TOC determinations in contaminated shallow ground-water systems involved the investigation of a complaint of an abrupt change in taste and odor of a private well supply near Sullivan, Illinois, in rural Moultrie County. The 36 foot (11 m) steel-cased well was finished in glacial till, and provided the potable and livestock water for a farmstead. Initial measurements of TOC showed that 50% of the total organic carbon (1.4 ± 0.2 mg-C/l) was volatile. Samples taken several months later were analyzed, and TOC levels were significantly higher than the previous results (3.23 ± 0.1 mg-C/l). **Greater than 95% of the observed increase was due to volatiles** (excluding methane which was present at 11 ml/l). It was known that investigation of shallow petroleum deposits in the area using seismic prospecting methods had been conducted about six months before the water quality change was noticed. Dynamiting during the prospecting activity may have permitted the migration of petroleum-related constituents into formations intercepted by the potable-water well

CONCLUSIONS

The routine wet digestion IR detection procedure for TOC determinations in ground-water samples has been modified to include the volatile organic fraction. The method was validated for model organic compounds and applied to [illegible] ground-water samples. The performance [illegible] [illegible] pounds was [illegible]

quite comparable [illegible] TOC standard (potassium hydrogen p[illegible]

The value of TOC determinations [illegible] screening tool for contaminated ground-water situations is markedly improved by the quantitation of VOC, as well as NVOC. The VOC fraction can make up from 9-50% of the total organic carbon in ground-water samples. The usefulness and reliability of future monitoring efforts can be significantly enhanced by the determination of volatile organic carbon.

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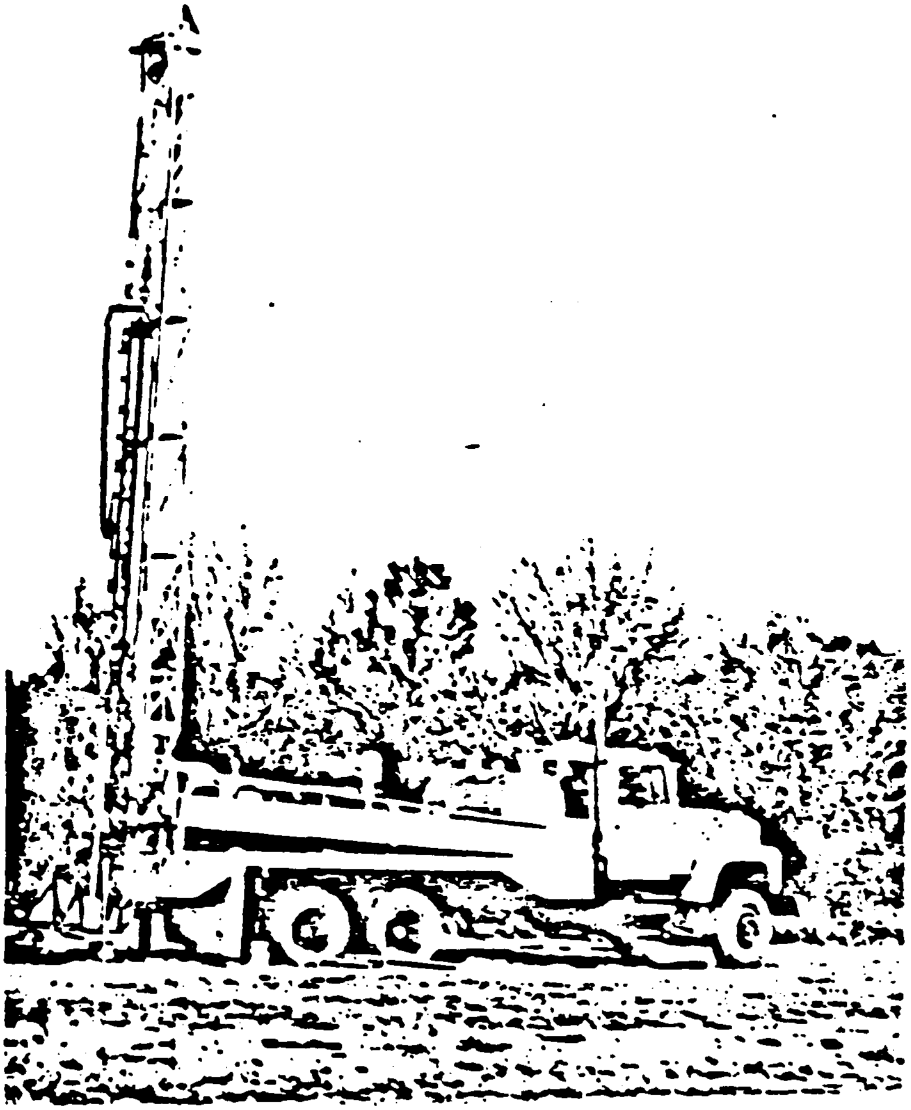
APPENDIX M

MONITORING WELL CONSTRUCTION FOR HAZARDOUS WASTE SITES IN GEORGIA

MONITORING WELL CONSTRUCTION FOR HAZARDOUS-WASTE SITES IN GEORGIA

by

William H. McLemore



Department of Natural Resources
Environmental Protection Division
Georgia Geologic Survey

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Circular 5

MONITORING WELL CONSTRUCTION FOR HAZARDOUS-WASTE SITES IN GEORGIA

by

William H. McLemore

Department of Natural Resources
J. D. Tanner, Commissioner

Environmental Protection Division
J. Leonard Ledbetter, Director

Georgia Geologic Survey
William H. McLemore, State Geologist

1981

MONITORING WELL CONSTRUCTION FOR HAZARDOUS-WASTE SITES IN GEORGIA

by

William H. McLemore

INTRODUCTION

In the past year, the Georgia Geologic Survey has been called upon on several occasions either to drill or comment upon the drilling and construction of monitoring wells. Typically, these wells were designed to evaluate the hydrology and geochemistry of the ground-water regime at existing or proposed hazardous waste facilities. With the above in mind, it is appropriate that we delimit our philosophy by which we construct monitoring *wells or* by which we would evaluate monitoring wells constructed by others. Obviously, because monitoring wells are designed to "look-at" the ground-water regime as well as gather water samples, local geologic conditions will play an important role in actual well construction, and rigid adherence to any set of criteria is neither practical nor prudent. Rather, our only objective in summarizing our philosophy in this Circular is to establish a set of "side-boards" that would be expected in a monitoring well construction program, which nevertheless, could be modified as local conditions dictate. The approaches set forth in the following sections are based on the experiences of the author in drilling and constructing many hundreds of monitoring wells in various parts of the country. The narrative is written in simple practical terms for geologists or engineers already familiar with the science of ground-water hydrology as well as well-drilling procedures. Lengthy technical descriptions are not provided; rather, the reader is referred to numerous USGS, EPA (especially a document such as EPA Manual SW-611) and other technical documents for such descriptions.

DRILLING SUPERVISION

Drilling and construction of monitoring wells should be under the close supervision of an experienced geologist or engineer. Changes in lithology, bedrock voids, pinchouts and so forth are rarely appreciated or observed by drillers. Obviously, as such variations affect hydrologic conditions, the geology of any site should be well understood.

For example, the author worked on a project to monitor a contamination plume at a manufacturing facility in the Coastal Plain of a mid-Atlantic state. At the manufacturing site, the shallow unconfined aquifer was separated from a deeper artesian aquifer by a dense clay. Also, the shallow aquifer was at a higher head than the deeper aquifer. Flow direction in the shallow aquifer was toward the northeast, whereas in the deeper aquifer, flow was toward the southwest. However, the detailed notes and observations of the field geologist indicated that the clay was thinning in a northeasterly direction; and apparently, the clay pinched-out immediately offsite and the two aquifers merged. As the site geologist had made careful observations and had taken good notes, it could be postulated that the plume was moving to the northeast, flowing over the lip of the pinchout into the deeper but lower head artesian aquifer, and thence moving to the southwest back underneath the manufacturing facility. Such an interpretation never could have been developed without having an experienced geologist continuously observing drilling operations and collecting cuttings.

Based on my experience, a single well-trained (i.e., at least one year of rig time) geologist or engineer can supervise two drilling rigs as long as they are not too far apart (i.e., a walk or drive of 5 minutes or less) and no other ancillary duties are required. If water sampling, pump testing, well development and so forth are scheduled, additional personnel would be necessary.

Drilling supervision by an experienced geologist or engineer also permits monitoring wells to be constructed to rather precise tolerances. By using a weighted steel measuring tape, sand/gravel packs, seals and so forth can be placed with an accuracy of ± ½ foot. Similarly, a competent geologist or engineer should know the depth within ± 1 foot of the boring at any time. And by collecting cuttings or noting variations in drilling progress/speed, the geologist or engineer should be able to make accurate predictions regarding changes in lithology, in those portions of the boring where samples are not being collected.

SELECTION OF THE DRILLING RIG

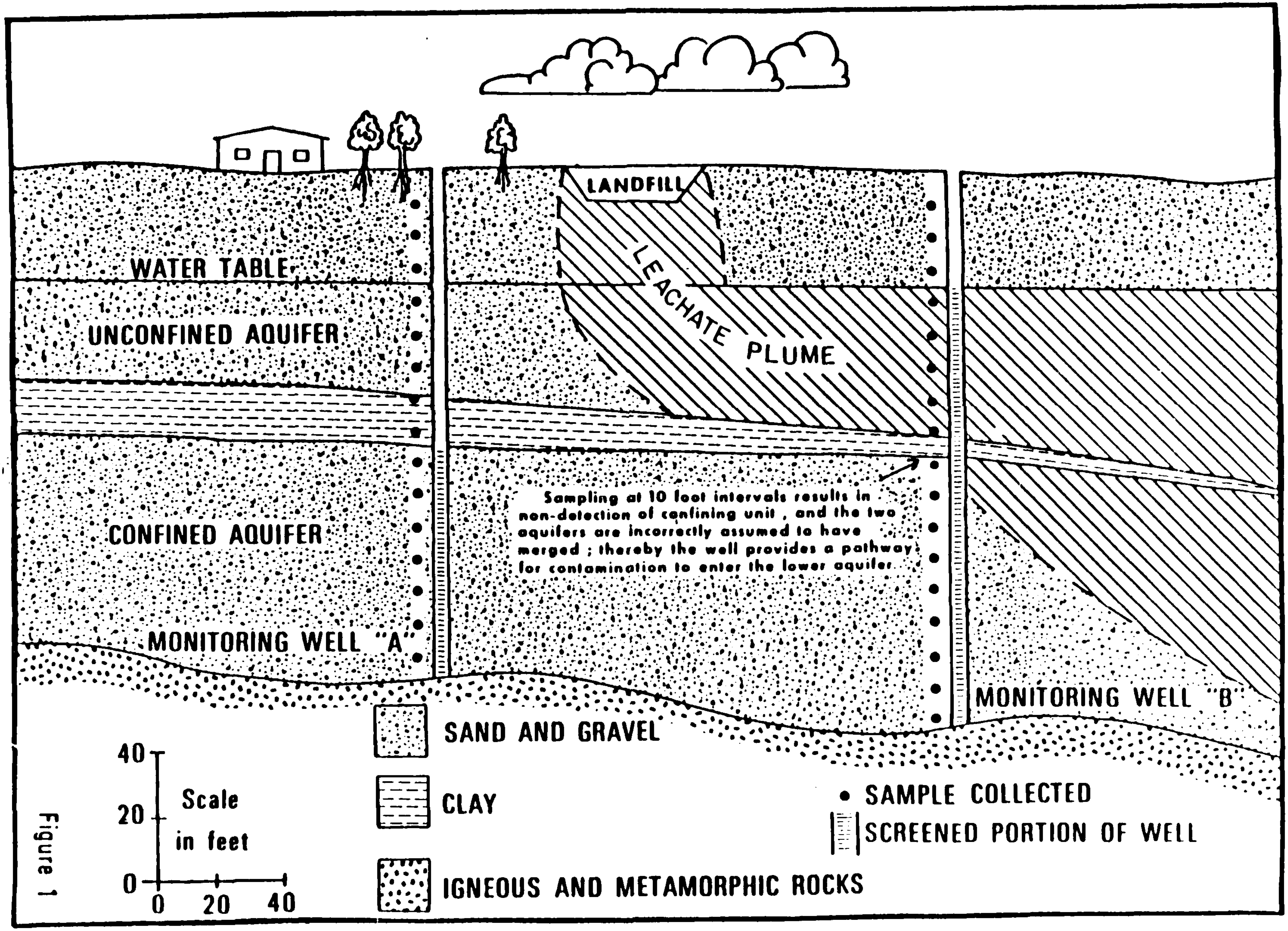
Selection of the drilling rig is extremely important. Because placement of screens and seals is extremely crucial in properly evaluating specific geologic horizons, the drill rig must have the capability to collect samples. Also, because porosity and permeability measurements, grain size, or strength tests may be necessary, the drill rig also should have the ability to collect undisturbed samples.

Cleanliness is another important criterion for the drill rig. Typically, drill rigs used for the construction of monitoring wells are contracted; and often they are covered with grease and grime from many different projects. As such grease and grime may contain a wide variety of solvents, metals or other chemicals, one cannot discount the possibility that trace amounts of contaminants may be introduced to the well. The author is aware of a situation where a drill rig was used for soil borings at a petrochemical complex in New Jersey and subsequently was employed for the construction of monitoring wells at a New York manufacturing plant. When unusual hydrocarbon compounds were detected in some of the monitoring wells at the manufacturing plant, management became quite concerned, as these hydrocarbon compounds were neither used nor stored at the plant. Finally, after much frustration, it was recognized that the hydrocarbon compounds had been "carried" by the drill rig from the petrochemical complex to the manufacturing plant. Such a situation easily can be mitigated by using a clean drill rig. The simplest way to obtain a high level of cleanliness is to steam clean the drilling rig. Steam jennys can be found almost everywhere; and steam cleaning of the drill rig more or less eliminates the possibility of "carrying" contaminants onto the site.

Thirdly, any drill rig used in the drilling and construction of monitoring wells should be free of oil and fuel leaks. Any oil or fuel leaking into the mud pad or adjacent to the bore hole will almost certainly enter the well. If this were to occur, total organic carbon (TOC) levels or detection of fuels and greases in ground-water samples might be spurious. Introduction of oils and fuels into the ground-water regime can be prevented by the site geologist or engineer performing a daily inspection of the drill rig and insisting that the driller tighten all parts, replace gaskets, and so forth.

SAMPLING

Sampling is especially important in any program of monitoring well construction. The reason for this is quite simple; namely, without a good understanding of lithologic variations, the screens and seals, which are so important in monitoring well construction, cannot be properly placed. Such samples also are useful in evaluating permeability, porosity, or subtle changes in facies. Moreover, an improperly constructed monitoring well can be a vehicle for interaquifer contamination. For example, as illustrated in Figure 1, an inappropriate sampling program can lead to an incorrect interpretation of stratigraphy, with resultant improper well construction. The author has found that, at those sites where comprehensive and rigid sampling programs were performed, well construction problems were minimal. Conversely, where sampling was de-



Sampling at 10 foot intervals results in non-detection of confining unit, and the two aquifers are incorrectly assumed to have merged; thereby the well provides a pathway for contamination to enter the lower aquifer.

Figure 1

emphasized, wells commonly were improperly drilled or located, and in some cases had to be drilled-out and plugged. The costs saved by curtailing or minimizing sampling are only imaginary. Drilling-out wells is prohibitively expensive as well as being emotionally quite frustrating. Rather, it is much more simple to initiate a comprehensive sampling program from the beginning.

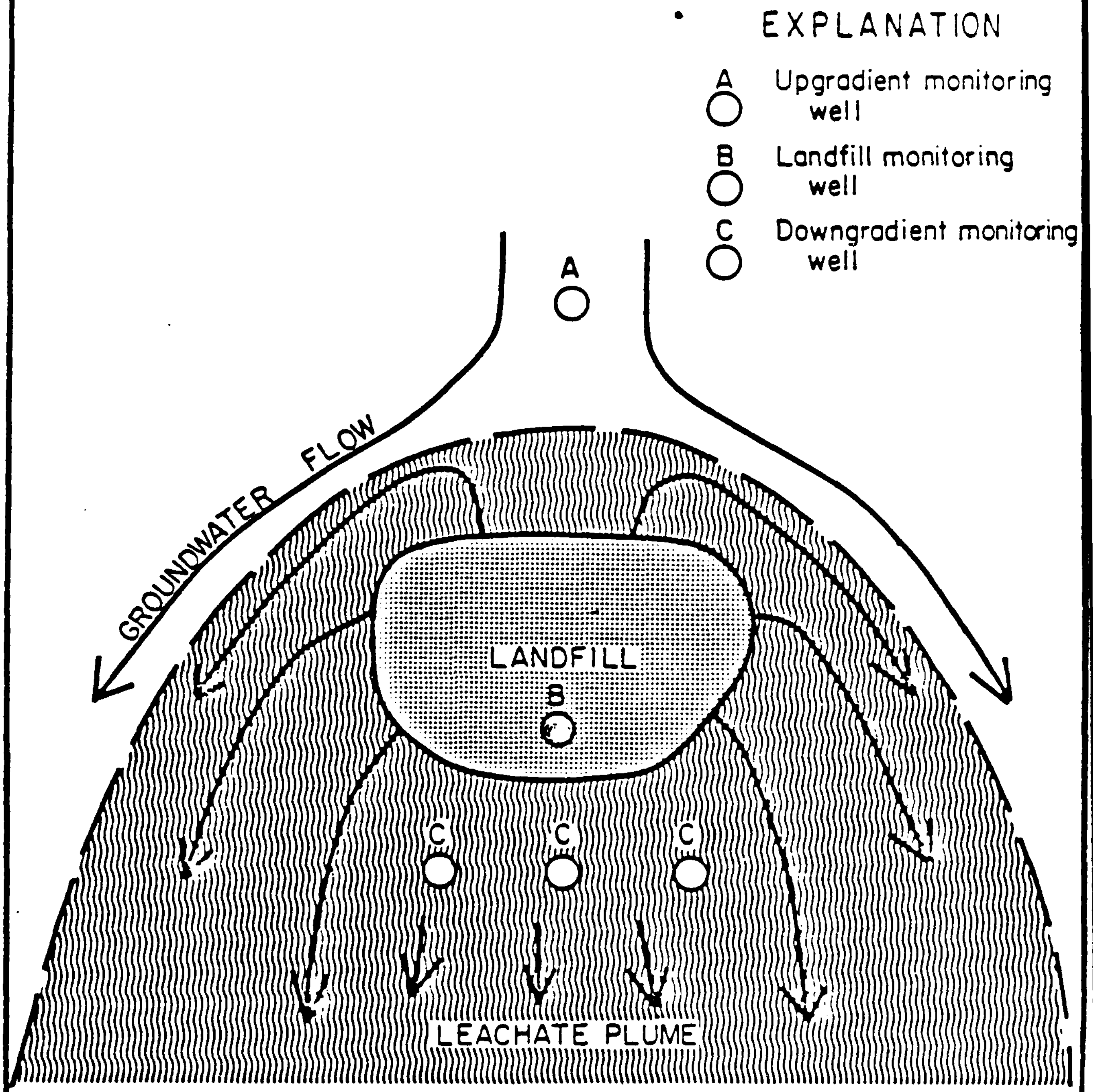
SELECTION OF MONITORING WELL SITES

One of the greatest mistakes any program of monitoring wells can incur is to "cut-corners" and drill an inadequate number of monitoring wells to properly assess or monitor the flow regime at the site. As an absolute minimum and where the site hydrology is simple and relatively well understood, five wells per aquifer system are necessary. Figure 2 illustrates a typical but yet quite simple arrangement of monitoring wells.

In the winter and spring of 1980, the Georgia Geologic Survey conducted a monitoring well program at a ten-acre hazardous waste facility in Wilkinson County, Georgia. The following description, which is from the report describing the results of this program, provides insight into how monitoring wells can be located:

> ... The first three Tuscaloosa aquifer wells (#1, #3, and #5) were selected to bracket the waste disposal trenches and establish the general direction of ground-water flow. Well #1 was drilled upslope from the burial trenches in order to penetrate a maximum (complete) thickness of the Twiggs Clay. Wells #3 and #5 were positioned downslope from the burial trenches at locations which, from field observations, appeared compatible for intercepting any potential migrating leachate.
>
> As these three wells generally form an equilateral triangle, true direction of ground-water flow within the Tuscaloosa can be established by performing a simple "3-point problem". (Note: from geometry, we know that 3 points determine a plane; hence the potentiometric surface, which is more or less a plane, also can be estimated.) Once the general direction of ground-water flow was established, wells #7 and #8 were drilled at locations that would be favorable for intercepting any leachate migrating from the trenches.
> In summary:
>
> (1) Wells #1, #3 and #5 were used to establish the general direction of ground-water flow in the Tuscaloosa as well as serve as monitoring wells.
>
> (2) Wells #7 and #8 were located at positions (identified from the direction of ground-water flow) favorable for intercepting any potential migrating leachate.
>
> ... Shallow wells #2, #4, and #6 were designed to evaluate the sandy zone at the base of the "upper" Twiggs Clay. For convenience, the shallow wells were placed adjacent to existing Tuscaloosa wells.
>
> Well depths for the first three Tuscaloosa wells were such that the wells penetrated a minimum of 20 feet of water bearing Tuscaloosa. After development, it was noticed that the water level in well #3 had dropped and was significantly lower than the levels in wells #1 and #5. This suggested perched water conditions; therefore, wells #7 and #8 were drilled through a minimum of 50 feet of water bearing Tuscaloosa. Also, in these latter two wells, steel casing was installed into a lignitic clay, thereby permitting us to assess the hydrogeological regime in the main water bearing zone of the Tuscaloosa beneath the lignitic clay....

In summary, indiscriminant drilling of monitoring wells on a site is counterproductive. Wells clearly need to be placed in locations favorable for intercepting any actual or potential plumes. Where the general flow patterns are not well understood, it is recommended that the initial wells be drilled to establish the hydrogeological regime. The latter wells, in turn, should be drilled to monitor specific facilities or potential contaminant sources. Considering the size of the facility in question, the number of potential onsite and offsite contaminant sources, as well as the geologic complexity of the site area, the number of wells could range from five to perhaps several hundred.



Typical arrangement or placement of monitoring wells (modified from EPA document SW-611).

Figure 2

MONITORING WELL CONSTRUCTION

General

Monitoring wells may be of a variety of sizes, but 4-inch diameter wells are considered optimum as they are most versatile. A well of such diameter provides an opening adequate for the installation of a 3-inch submersible pump suitable for either well evacuation or water sampling. Also, such a diameter is amenable for gamma logging. Smaller diameter wells (i.e., 3-inch or 2-inch) are useful only where the water level is within about 30 feet of the surface as they typically are evacuated or sampled by means of a centrifugal pump.

The principal advantage of small diameter wells (namely 2-inch or smaller) is that they can be installed through the auger-flights of a hollow stem auger drilling rig. More complicated rotary drilling methods are required for 3 and 4 inch wells.* On the other hand, augers have great difficulty penetrating gravel zones or saprock, which is the partially decomposed but ~~still~~ resistant bedrock characteristic of much of the Piedmont of Georgia. Tables I and II provide general guidelines used by the Georgia Geologic Survey regarding selection of drilling rig as well as selection of monitoring well diameter. The guidelines presented in Tables I and II are intended to be practical rather than actual. That is, a good driller with an inappropriate drilling rig probably can accomplish more than an incompetent driller with an ideal rig. Therefore, the guidelines should be considered merely as a tool for optimum drill rig and well diameter selection.

The following descriptions and illustrations are for 4-inch diameter wells; naturally, wells of other dimensions would be somewhat different. Nevertheless, the descriptions provide the reader with insight into the necessary precision expected of hazardous waste monitoring wells.

Monitoring Wells in the Piedmont or Blue Ridge:

Typical Piedmont or Blue Ridge monitoring wells are illustrated in Figure 3. In general, ground water in these two physiographic provinces is unconfined, artesian conditions are rare, and the soil (either saprolite or colluvium) and rock aquifers are hydraulically interconnected. Three types of monitoring wells are anticipated in the Piedmont and Blue Ridge: (1) saprolite or colluvium wells, (2) combined soil and rock wells, and (3) rock wells. Each of these is described below:

(1) *Saprolite or Colluvium Wells* - The recommended well construction involves:

- Drilling an 8-inch diameter boring into hard rock;

- Confirming that the boring has bottomed in hard rock (rather than saprock) by NX-coring 5 feet into hard rock with at least 50 percent recovery.* (Note: a good driller often can accurately identify hard rock merely by "feeling" the change in drilling progress; if the driller is capable of making such identification, this coring step may be omitted).

---

* The author is aware that 6-inch hollow stem augers are now available. Obviously such a large auger would be extremely versatile and could be used to construct 4-inch wells. Nevertheless, since 6-inch hollow stem augers are so rare in Georgia, I will not address them further.

* The author recognizes that rock coring at the base of a relatively large diameter boring is quite difficult and often involves the use of casing, which potentially may become stuck in the hole. It is not the intent of the author to add a burdensome or unnecessary drilling task, but rather to emphasize the importance of accurately defining the soil-rock interface. If coring can be avoided without compromising the identification of this interface, then by all means do so.

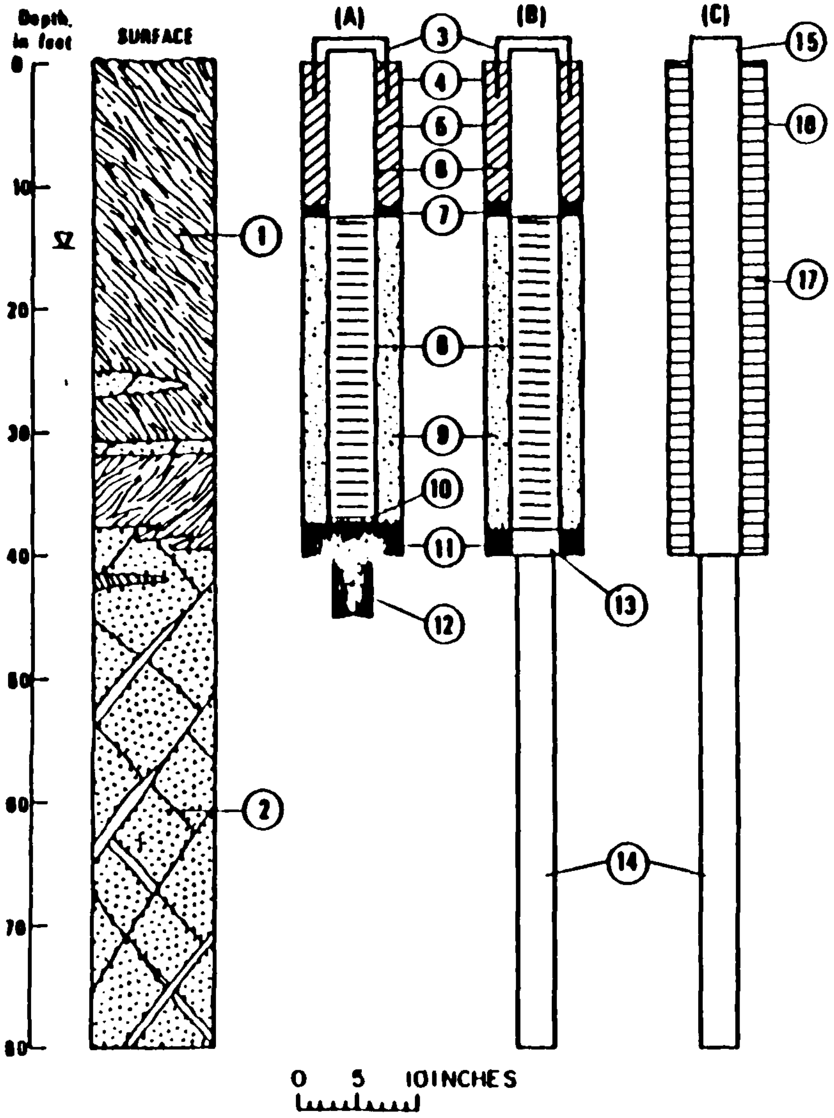
Table I. Guidelines For Drilling Rig Selection

Anticipated Drilling Conditions For Well Construction Program	Optimum Drill Rig	
	Auger	Rotary
(1) Shallow water table (less than 30 feet)	Yes	Yes
(2) Deep water table (greater than 30 feet)	No	Yes
(3) Gravel and resistant zones	No	Yes
(4) Loose sand or thick clays	Difficult	Yes
(5) Undisturbed samples required	Difficult	Yes
(6) Disturbed samples required	Yes	Yes
(7) Depth to bedrock less than 80 feet	Yes	Yes
(8) Depth to bedrock greater than 80 feet	Difficult	Yes
(9) Rock coring	Yes	Many rotary rigs are not capable of coring
(10) Seals and screens to be placed at specific intervals	Difficult	Yes

Table II. *Guidelines For Selection Of Monitoring Well Diameter*

Anticipated Drilling Conditions For Well Construction Program	Monitoring Well Diameter		
	2-inch	3-inch	4-inch
(1) Shallow water table (less than 30 feet)	Yes	Yes	Yes
(2) Deep water table (greater than 30 feet)	No	Possibly	Yes
(3) Well to be considered for decontamination or dewatering	No	Possibly	Yes
(4) Well to be sampled on frequent basis	Possibly	Possibly	Yes
(5) Water level recorder to be installed	No	Difficult	Yes
(6) Clayey soils that may be difficult to develop	No	Possibly	Yes
(7) Bedrock coring NX-sized or overburden to be cased-off.	No	No	Yes
(8) Gamma logging anticipated	No	Yes	Yes

TYPICAL PIEDMONT OR BLUE RIDGE MONITORING WELLS



EXPLANATION

(1) Saprolite/colluvium (soil), usually highly weathered near surface, progressively less weathered at depth.

(2) Crystalline bedrock, grading from partially weathered saprock to virtually unweathered rock; fracture porosity.

(3) Protective steel casing with locking cap.

(4) 8 inch boring.

(5) Bentonite-cement mixture tremie grouted into annular space between PVC casing and edge of bore hole.

(6) Blank 4 inch PVC casing.

(7) Bentonite pellet seal placed into annular space between PVC casing and edge of bore hole.

(8) 4 inch PVC screen with appropriately sized slots; top of screen is placed above unconfined water table surface and takes both seasonal and multi year fluctuations in water levels into account.

(9) Sand/gravel pack.

(10) PVC cap.

(11) Bentonite pellet seal; for saprolite/colluvium (soil) wells, the seal fills both the drilled and cored portion of the boring thereby isolating and separating the soil and rock aquifers; for combined soil and rock wells, the seal is placed in the annular space opposite a short piece of blank PVC at the base of the drilled portion of the boring, thereby preventing the overlying sand/gravel pack as well as rock debris from *"falling into the cored portion of the boring"*.

(12) NX sized core hole to confirm character of bedrock.

(13) Short piece of blank 4 inch PVC casing, opposite which a bentonite pellet seal is placed.

(14) NX sized core hole.

(15) 4 inch steel casing with locking cap.

(16) 8 inch boring.

(17) Neat cement pressure grouted into annular space between 4 inch steel casing and edge of bore hole; if well is shallow, a bentonite cement mixture may be tremie grouted into the annular space.

(A) Saprolite/colluvium (soil) well.

(B) Combined soil/rock well.

(C) Rock well.

∇ Unconfined water level.

NOTE: Horizontal scale only applied to wells; no horizontal scale implied for lithologic section.

Unless otherwise stated, porosity is intergranular.

Figure 3

- Backfilling with expandable bentonite pellets to slightly above the soil-rock contact. By doing such, the boring can be hydraulically separated from the rock aquifer.

- Installing slotted PVC screen of appropriate size from the bottom of the boring to several feet above the water table. The base of the screen should be capped; and the top of the slotted portion of the screen should take into account both seasonal as well as multi-year fluctuations in water levels. Blank PVC casing is extended from the top of the screen to one or two feet above ground surface.

- Filling the annular space between the bore hole and the PVC screen with an appropriate sand/gravel pack.

- Placing a one or two foot thick bentonite pellet seal above the sand/gravel pack.

- Tremie-grouting a bentonite-cement mixture to the ground surface in the annular space between the bore hole and the PVC casing.

- Cementing in a 5-foot (3-feet below ground and 2-feet above ground) section of protective 6-inch steel pipe with a locking cap.

(2) *Combined Soil and Rock Wells* - In this case, well construction is similar to that for saprolite/colluvium wells except that the NX-sized coring is not stopped at 5 feet, but rather is continued until an adequate section of saturated rock is penetrated. (Based on the author's experience in Georgia, the saturated rock portion of the well should be at least 40 feet.) Also, recommended at the base of the soil portion of the well is a 2-3 foot section of blank PVC casing, with a 2-3 foot bentonite pellet seal in the opposite annular space. Such casing and seal often are necessary to prevent rock and/or the sand/gravel pack from sloughing-off into the cored portion of the well. Combined soil and rock wells are difficult to drill and construct, and often it is most prudent to drill two separate wells (a soil well and a rock well) side by side at a few feet apart.

(3) *Rock Wells* - For this type of well, the recommended well construction involves:

- Drilling an 8-inch diameter boring into the hard rock.

- Confirming that the boring has bottomed into hard rock by NX-*coring 5 feet* into rock with at least 50 percent recovery (refer to earlier descriptions regarding identification of soil/rock interface).

- Cementing-in, by pressure grout methods, 4-inch steel casing.

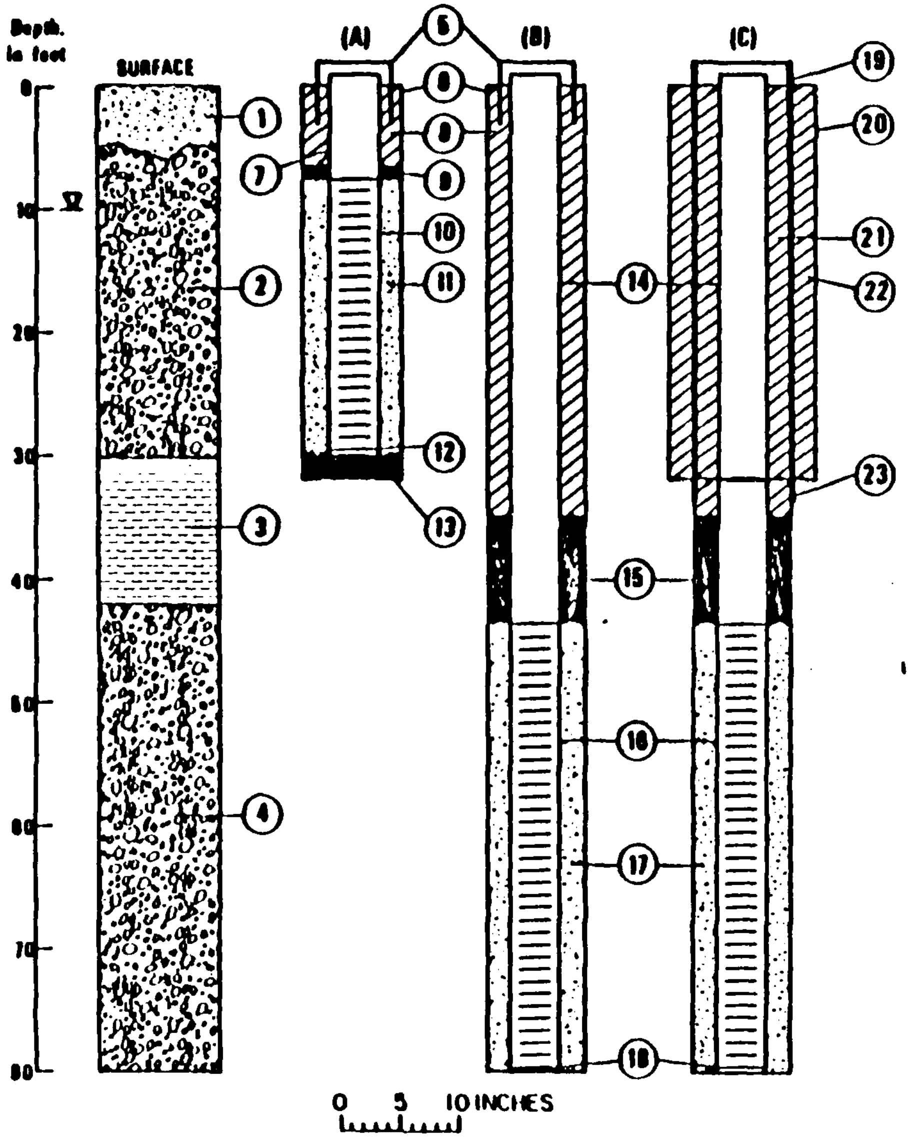
- NX-coring an appropriate depth into rock.

- Attaching a locking cap to the 4-inch steel casing.

Monitoring Wells in the Coastal Plain:

Typical Coastal Plain monitoring wells are illustrated in Figure 4. In the Georgia Coastal Plain, the shallow aquifer is typically unconfined and underlain by one or more artesian aquifers. Two types of monitoring wells are anticipated in the Coastal Plain: (1) shallow aquifer wells and (2) deeper (artesian) aquifer wells. The deeper wells are of two types: a simple construction and a more complex construc-

TYPICAL COASTAL PLAIN MONITORING WELLS



EXPLANATION

(1) Uppermost sandy soils.
(2) Shallow unconfined aquifer.
(3) Confining unit.
(4) Deeper artesian aquifer.
(5) Protective steel casing with locking cap.
(6) 8 inch boring.
(7) Blank 4 inch PVC casing.
(8) Bentonite-cement mixture tremie-grouted into annular space between PVC casing and edge of bore hole.
(9) Bentonite pellet seal placed into annular space between PVC casing and edge of bore hole.
(10) 4 inch PVC screen with appropriately sized slots; top of screen is placed above unconfined water table surface and takes both seasonal and multi-year fluctuations in water levels into account.
(11) Sand/gravel pack.
(12) PVC cap.
(13) Bentonite pellet seal back fill to slightly above the contact between base of shallow aquifer and top of confining unit.
(14) Blank 4 inch PVC casing.
(15) Thick bentonite pellet seal placed into annular space between PVC casing and edge of bore hole opposite confining unit.
(16) 4 inch PVC screen with appropriately sized slots; top of screen is slightly below contact between base of confining unit and top of deeper aquifer.
(17) Sand/gravel pack.
(18) PVC cap.
(19) 8 inch steel casing with locking cap.
(20) 12 inch boring.
(21) Bentonite-cement mixture tremie-grouted into annular space between PVC casing and 8 inch steel casing.
(22) Bentonite-cement mixture tremie-grouted into annular space between 8 inch steel casing and edge of bore hole.
(23) 8 inch steel casing either driven or spun into confining unit.
(A) Shallow unconfined aquifer well.
(B) Deeper artesian aquifer well (simple construction).
(C) Deeper artesian aquifer well (complex construction).
▽ Unconfined water level.

NOTE: Horizontal scale only applies to wells; no horizontal scale implied for lithologic section.

Unless otherwise stated, porosity is intergranular.

Figure 4

tion, for which steel casing is extended into the confining unit separating the shallow from the deeper aquifer. USE OF STEEL PROTECTIVE CASING IS RECOMMENDED WHENEVER THERE IS ANY POTENTIAL, NO MATTER HOW SMALL, FOR CONTAMINATED WATER TO MOVE FROM ONE AQUIFER TO ANOTHER. SPECIAL CARE SHOULD BE EXERCISED SO THAT MONITORING WELLS DO NOT ACT AS PATHWAYS FOR CONTAMINATION. Each of the aforementioned types of monitoring wells is described below:

(1) *Shallow Aquifer Wells* - The recommended well contruction involves:

- Drilling an 8-inch diameter boring to hard rock, to a lower confining unit (illustrated), or until an appropriate section of aquifer has been penetrated (at least 40 feet of saturated material).
- Confirming the lithologic character of the geologic materials at the base of the boring. This may be done by coring, split spoon sampling, Shelby tubes, etc.
- Backfilling with bentonite pellets to slightly above the contact between the shallow aquifer and the lower confining unit or the hard rock. This step may be omitted for those wells merely penetrating saturated material.
- Installing slotted PVC screen of appropriate size from the bottom of the boring to several feet above the water table. The base of the screen should be capped; and the top of the slotted portion of the screen should take into account both seasonal and multi-year fluctuations in water levels. Blank PVC casing is extended from the top of the screen to one or two feet above ground surface.
- Filling the annular space between the bore hole and the PVC screen with an appropriate sand/gravel pack.
- Placing a one or two foot thick bentonite pellet seal above the sand/gravel pack.
- Tremie-grouting a bentonite-cement mixture to the ground surface in the annular space between the bore hole and the PVC casing.
- Cementing in a 5-foot (3-feet below ground and 2-feet above ground) section of protective 6-inch steel pipe with a locking cap.

(2) *Deeper (Artesian) Aquifer Wells* - The recommended simple well involves:

- Drilling an 8-inch diameter boring until an adequate section of the deeper aquifer is penetrated (at least 40 feet).
- Confirming the lithologic character of the geologic materials at the base of the boring. This may be done by coring, split spoon sampling, Shelby tubes, etc.
- Installing slotted PVC screen of appropriate size from the base of the boring to slightly below the contact between the deeper aquifer and overlying confining unit. The base of the screen should be capped. Blank PVC casing is extended from the top of the screen to one or two feet above ground surface.
- Filling the annular space between the bore hole and the PVC screen with an appropriate sand/gravel pack.

- Placing a thick bentonite pellet seal above the sand/gravel pack. This seal is quite important in separating the shallow aquifer from the deeper aquifer, and should be of sufficient thickness to insure that the bore hole does not act as a pathway between the shallow and deeper aquifers.

- Tremie-grouting a bentonite-cement mixture to the ground surface between the bore hole and the PVC casing.

- Cementing in a 5-foot (3-feet below ground and 2-feet above ground) section of protective 6-inch steel pipe with a locking cap.

The recommended complex well construction is quite similar except that an oversized (about 12 inches) boring is drilled to the top of the confining unit. Once the presence of the confining unit is established by sampling, 8-inch steel casing is driven-in or spun-into the confining unit. Next, a bentonite-cement mixture is tremie-grouted into the annular space between the bore hole and the steel casing, thereby hydraulically separating the shallow aquifer from the bore hole. The remaining steps are identical to those described above for the simple well construction program except that the locking steel cap can be attached to the 8-inch casing.

Monitoring Wells in the Valley and Ridge:

Typical monitoring wells in the Valley and Ridge are illustrated in Figure 5. From a general hydrogeologic point of view, Valley and Ridge aquifers are quite similar to Coastal Plain aquifers except that the former commonly are steeply dipping and characterized by fracture porosity. From a practical point of view, Valley and Ridge dips are of little consequence in monitoring well construction. When considering the relative small size of the well (only a few inches in diameter), geologic contacts only affect a few inches of bore hole and are of minor concern. Fractures in confining units can easily be isolated from the bore hole by careful use of bentonite pellet seals. For example, the reader should note that bentonite pellet seals illustrated for Valley and Ridge monitoring wells (Figure 5) are substantially thicker than the seals illustrated for Coastal Plain wells (Figure 4). Thus, except for seal placement, Valley and Ridge monitoring wells are constructed in a similar fashion to Coastal Plain monitoring wells.

DEVELOPMENT

Development involves removal of drilling fluids and formational fines from around the bore hole so that the well will produce clear water.

Development adds an insurance factor to minimize the potential that trace amounts of contaminants will be "carried" from one bore hole to the next.* This is the result of fluids in closest proximity to the well (i.e., drilling fluids and ground water immediately outside the bore hole) being removed by the development process. Also, as development removes drilling fluids and formational fines, the water level within the well commonly changes as the well comes into more direct hydraulic intercommunication with the ground-water regime. Thus the water levels in the well more closely reflect the potentiometric surface. Moreover, some metals and organics will preferentially sorb onto fine particulates or be concentrated in the drilling process. Development, therefore, also insures that analytical bias will not occur and that the water samples collected for chemical analyses will be representative of ground water in the vicinity of the well. In summary, IT IS THE OPINION OF THE AUTHOR THAT CHEMICAL AND HYDROLOGIC MEASUREMENTS MADE FROM UNDEVELOPED WELLS ARE SUSPECT AND CANNOT BE RELIED UPON.

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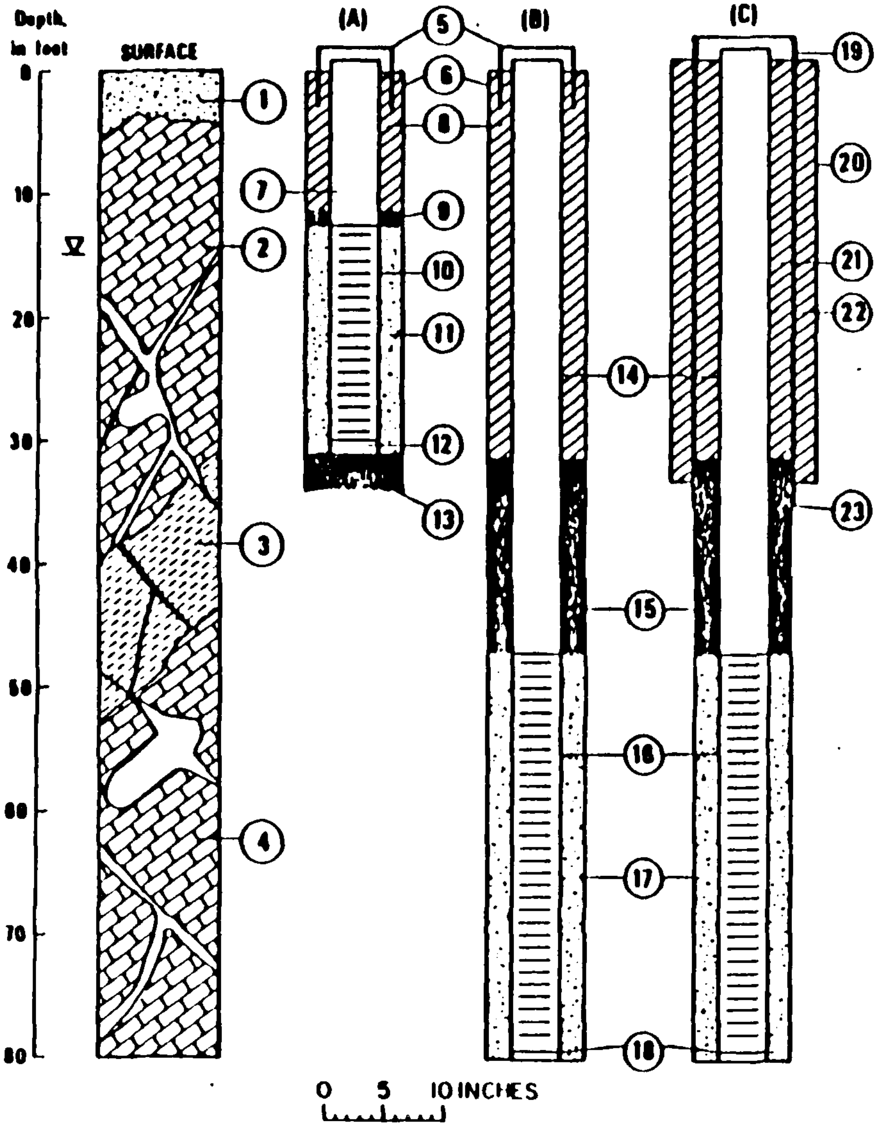
* The anomalous hydrocarbon compounds previously discussed in the Selection of the Drilling Rig section were removed from the monitoring wells at the manufacturing plant by extensive well development.

TYPICAL VALLEY AND RIDGE MONITORING WELLS



EXPLANATION

(1) Uppermost sandy soils.
(2) Dipping shallow unconfined aquifer; may have intergranular, fracture, and solution cavity porosity.
(3) Dipping confining unit with some fractures.
(4) Dipping artesian aquifer; may have intergranular, fracture, and solution cavity porosity.
(5) Protective steel casing with locking cap.
(6) 8 inch boring.
(7) Blank 4 inch PVC casing.
(8) Bentonite-cement mixture tremie-grouted into annular space between PVC casing and edge of bore hole.
(9) Bentonite pellet seal placed into annular space between PVC casing and edge of bore hole.
(10) 4 inch PVC screen with appropriately sized slots; top of screen is placed above unconfined water table and takes both seasonal and multi year fluctuations in water levels into account.
(11) Sand/gravel pack.
(12) PVC cap.
(13) Bentonite pellet seal back fill to slightly above contact between base of shallow aquifer and top of confining unit.
(14) Blank 4 inch PVC casing.
(15) Bentonite pellet seal placed into annular space between PVC casing and edge of bore hole opposite confining unit; because of the often fractured character of Valley and Ridge confining units, especial care should be exercised in placing of this seal; if possible and appropriate, the entire confining unit should be sealed off.
(16) 4 inch PVC screen with appropriately sized slots; top of screen is slightly below contact between base of confining unit and top of deeper aquifer.
(17) Sand/gravel pack.
(18) PVC cap.
(19) 8 inch steel casing with locking cap.
(20) 12 inch boring
(21) Bentonite-cement mixture tremie grouted into annular space between PVC casing and 8 inch steel casing.
(22) Bentonite-cement mixture tremie grouted into annular space between 8 inch steel casing and edge of bore hole.
(23) 8 inch steel casing either driven or spun into confining unit.
(A) Shallow unconfined aquifer well.
(B) Deeper artesian aquifer well (simple construction).
(C) Deeper artesian aquifer well (complex construction).
∇ Unconfined water level.

NOTE: Horizontal scale only applies to wells; no horizontal scale implied for lithologic section.

Figure 5

DOWNHOLE GEOPHYSICAL LOGGING

Borehole geophysical logging, such as spontaneous potential (SP), resistivity, or gamma, is recommended for all Coastal Plain wells and those wells in the Valley and Ridge where stratigraphic interpretations are important. On the other hand, borehole logging is not a particularly useful test in Piedmont and Blue Ridge wells where the saprolite-bedrock interface is gradational and/or ill-defined.

GENERAL SUMMARY

The text and illustrations that have been presented are not meant to be inclusive; rather, the author is attempting merely to stress that monitoring wells for hazardous waste facilities should never be drilled in a haphazard fashion. The reader should clearly understand that monitoring wells are, in effect, rather sophisticated scientific instruments, and as such, require a high degree of technical expertise to be properly constructed.

Perhaps no greater mistake can be made than to regard monitoring wells as simply "wells", which can be more or less drilled by anyone. Such an attitude can, at worst, result in interaquifer contamination or, at best, result in the gathering of meaningless information.

For convenience in selecting our reports from your bookshelves, they are color-keyed across the spine by subject as follows:

Red	Valley and Ridge mapping and structural geology
Dk. Purple	Piedmont and Blue Ridge mapping and structural geology
Maroon	Coastal Plain mapping and stratigraphy
Lt. Green	Paleontology
Lt. Blue	Coastal Zone studies
Dk. Green	Geochemical and geophysical studies
Dk. Blue	Hydrology
Olive	Economic geology Mining directory
Yellow	Environmental studies Engineering studies
Dk. Orange	Bibliographies and lists of publications
Brown	Petroleum and natural gas
Black	Field trip guidebooks
Dk. Brown	Collections of papers

Colors have been selected at random, and will be augmented as new subjects are published.

APPENDIX N

MONITORING WELL INVENTORY FOR
AIR FORCE PLANT 6

MONITORING WELL INVENTORY
AIR FORCE PLANT 6

	WELL IDENTIFICATION	LOCATION	GRID COORDINATES		GROUND ELEVATION	TOP CASING ELEVATION	WELL DEPTH, FT	BEDROCK DEPTH, FT
			NORTH	EAST				
	B-1✓	Truck Fuel Farm	1,427,130	389,670	1085.10		40	33
Site G6-- B-10 Aeration Basin	B-2✓	Truck Fuel Farm	1,427,050	389,310	1091.10		33	26
	B-4✓	Truck Fuel Farm	1,427,240	389,600	1092.20		40	40+
	B-5✓	Truck Fuel Farm	1,427,100	389,470	1087.00		32	24
	B-8✓	Truck Fuel Farm	1,427,150	389,500	1088.00		35	35+
	B-9✓	Truck Fuel Farm	1,427,130	389,450	1088.00		31	31+
	A-1✓	Truck Fuel Farm	1,427,130	389,500	1086.90			
	A-2✓	Truck Fuel Farm	1,427,030	389,770	1082.90			
	B-1	Industrial Waste Disposal Basin	1,428,320	392,550	1064.60	1066.65	43	28
	B-2	Industrial Waste Disposal Basin	1,428,020	392,200	1052.40	1055.60	30	30+
	B-3	Industrial Waste Disposal Basin	1,427,970	392,350	1051.30	1052.57	35	35+
	B-4	Industrial Waste Disposal Basin	1,428,960	392,500	1050.00	1051.05	30	30+
Site G1-- Surface Impoundment	B-5	Industrial Waste Disposal Basin	1,428,560	392,530	1070.80	1082.30	43	33
	B-6	Industrial Waste Disposal Basin	1,428,070	392,800		1057.10	34	35
	B-7	Industrial Waste Disposal Basin	1,428,560	392,360		1066.61	56	57
	D-1	Industrial Waste Disposal Basin	1,427,800	392,320		1029.87	30	25
	D-2	Industrial Waste Disposal Basin	1,427,890	392,670		1041.03	67	67
	D-3	Industrial Waste Disposal Basin	1,427,820	392,150		1036.39	40	46
	D-4	Industrial Waste Disposal Basin	1,427,690	392,520		1033.48	47	50
	D-5	Industrial Waste Disposal Basin	1,427,900	392,830		1054.22	75	80+
	D-6	Industrial Waste Disposal Basin	1,428,050	393,000		1036.51	46	48
	D-7	Industrial Waste Disposal Basin	1,427,390	392,850		1043.92	48	51
	E-1	Industrial Waste Disposal Basin	1,428,500	392,860	1052.52	1053.77	57	64
	E-2	Industrial Waste Disposal Basin	1,428,090	393,270	1031.20	1032.12	37	37
	E-3	Industrial Waste Disposal Basin	1,427,560	393,380	997.13	998.76	27	27
	E-4	Industrial Waste Disposal Basin	1,427,540	392,170	1056.53	1058.63	48	48
	E-5	Industrial Waste Disposal Basin	1,427,870	391,870	1073.94	1058.63	52	50

MONITORING WELL INVENTORY
AIR FORCE PLANT 6
(Continued)

	WELL IDENTIFICATION	LOCATION	GRID COORDINATES NORTH	GRID COORDINATES EAST	GROUND ELEVATION	TOP CASING ELEVATION	WELL DEPTH, FT	BEDROCK DEPTH, FT
Site G1-- Surface Impoundment	E-6	Industrial Waste Disposal Basin	1,428,370	391,930	1065.28	1067.20	45	40
	E-7	Industrial Waste Disposal Basin	1,427,640	392,330	1019.75	1021.33	8.6	8+
	E-8	Industrial Waste Disposal Basin	1,427,790	392,250	1029.28	1030.40	6.3	6+
	BR-1	Industrial Waste Disposal Basin	1,428,480	392,370	1066.00	1067.10	93	21
	BR-2	Industrial Waste Disposal Basin	1,427,780	392,330	1029.12	1030.22	80	18
	BR-3	Industrial Waste Disposal Basin	1,427,778	392,360	1029.91	1031.58	225	14
	MW-12	Industrial Waste Disposal Basin	1,428,440	392,500	1070±		26	26+
Site G6-- B-10 Aeration Basin	MW-8	IWTF Aeration Basin	1,427,820	389,110	1109.38	1111.60	45	45+
	MW-9	IWTF Aeration Basin	1,427,580	389,750	1079.11	1081.30	34	34+
	MW-22	IWTF Aeration Basin	1,427,500	389,230	1097.96	1100.37	41	40
	MW-23	IWTF Aeration Basin	1,427,260	389,750	1090.81	1094.11	40	40
	MW-24	IWTF Aeration Basin	1,427,290	389,880	1088.31	1091.19	45	45+
	MW-25	IWTF Aeration Basin	1,427,450	389,840	1081.51	1083.97	37	37+
Miscellaneous UG Tanks	MW-3	Fuel Tank SW of B-1 Building	1,429,040	387,680			20	18
	MW-4	NW Side of B-1 Building	1,429,910	388,510			35	25
	MW-10	B-64 Parking Lot (Avionics Bldg)	1,428,210	391,450	1080±		42	17
	MW-11	SW B-64 (Avionics Building)	1,428,140	391,330	1070±		24	17
	MW-19	Georgia Tech Parking Lot L-2	1,422,530	391,130			16	16+
	MW-20	North of L-11 Jet Star Assem.	1,421,180	392,030			22	22+
	MW-21	South of L-11 Jet Star Assem.	1,420,690	392,020			14	14+
Site G9 TCE Spill at B-76	MW-1	West of B-30	1,430,120	390,110	1096±		55	25
	MW-2	West of B-77	1,429,080	389,670	1111±		50	18
	MW-5	West of B-43	1,429,990	390,550	1087±		66	30
	MW-6	B-8 Gas Pumps	1,429,780	390,340	1107±		55	55+
	MW-26	B-76 Chemical Storage	1,429,600	389,940	1109.64	1112.39	50	50+

MONITORING WELL INVENTORY
AIR FORCE PLANT 6
(Continued)

	WELL IDENTIFICATION	LOCATION	GRID COORDINATES NORTH	GRID COORDINATES EAST	GROUND ELEVATION	TOP CASING ELEVATION	WELL DEPTH, FT	BEDROCK DEPTH, FT
Site G9--TCE Spill at B-76	MW-27	East of B-30	1,429,990	390,260	1094.13	1097.25	55	49
	MW-28	Roadway East of B-43	1,429,870	390,800	1074.40	1076.95	34	35+
Site G5--Stormwater Retention Basin No. 2	MW-29	Landfill Sedimentation Pond	1,430,440	390,820	1039.91	1042.84	30	30+
	MW-30	Dike of Stormwater Basin #2	1,430,800	391,070	1027.32	1030.57	25	25+
	MW-31	Access Road to Basin #2	1,430,190	390,980	1063.10	1065.74	30	30+
	MW-16	North Position 22	1,423,570	392,640	1025±		12	12+
	MW-17	B-98 Fuel Tanks	1,423,490	392,040	1057±		48	45
Site G14--Position 19--Fuel/Defuel Station	MW-18	Position 19	1,423,490	392,200	1030.5±		16	16+
	MW-35	Position 19	1,423,580	392,210	1030.78	1033.61	30	30+
	MW-36	Position 19	1,423,580	392,290	1029.91	1032.84	30	30+
	MW-37	Position 19	1,423,530	392,230	1030.76	1033.47	30	30+
	MW-38	Position 19	1,423,440	392,200	1030.51	1033.34	24	19
	MW-39	Position 19	1,423,420	392,190	1030.82	1033.52	26	24
	MW-40	Position 19 (Not Drilled)	1,423,510	392,180				
	MW-41	Position 19	1,423,420	392,160	1015.13	1019.70	7	7+
	MW-42	Position 19	1,423,470	392,300	1031.05	1031.05	30	30+
Site G7--Position 65--C-5 Wash Rack Ponds	MW-14	C-5 Wash Racks	1,420,720	394,400	1021.29	1024.33	28	28+
	MW-32	C-5 Wash Racks	1,420,810	394,320	1015.63	1018.35	33	33+
	MW-33	C-5 Wash Racks	1,420,590	394,310	1015.21	1018.33	35	35+
	MW-34	C-5 Wash Racks	1,420,700	394,260	1014.26	1017.04	30	30+
Site G16--B-104 Gas Pump Station	MW-15	B-104 Gas Pump Area	1,420,870	394,130				
	MW-43	B-104 Gas Pump Area	1,420,800	394,460	995.77	997.79	16	16+
	MW-44	B-104 Gas Pump Area	1,420,930	394,120	1009.51	1012.16	35	35+
	MW-45	B-104 Gas Pump Area	1,420,800	394,160	1011.54	1013.97	28	28
	MW-46	B-104 Gas Pump Area	1,420,920	394,230	1006.61	1008.85	32	32+
	MW-47	B-104 Gas Pump Area	1,421,000	394,380	995.22	997.44	20	20+

STATE - PLANE COORDINATES OF MONITORING WELLS

Site G12-- Position 71-- Sodium Dichromate Spill

WELL NO.	NORTHING	EASTING	DATUM ELEVATION* (FT, NGVD)
G12-1	1,421,294	394,642	973.34
G12-2	1,422,017	393,789	1008.88
G12-3	1,421,760	393,739	993.45
G12-4	1,421,873	393,770	995.47
G5-5	1,430,782	390,644	1064.32
G5-6	1,430,716	390,733	1041.04

* DATUM IS TOP OF PVC CASING

Site G15-- B-58 Wing Tank Seal Test Facility

MW-7
MW-52
MW-53
MW-54
MW-55
MW-56

Site G13-- Position 58-- Fuel/Defuel Station

MW-13
MW-48
MW-49
MW-50
MW-51

TABLE III-2
GROUNDWATER ELEVATIONS

	WELL	GROUND ELEVATION	DEPTH TO WATER	GROUNDWATER ELEVATION
	1	1096±	41.0	1055±
	2	1111±	26.8	1084
	3		18.2	
	4		23.8	
	5	1087±	40.6	1046±
	6	1107±	49.8	1057
	7	1100±	21.2	1078±
	8	1110±	31.3	1079
	9	1070±	15.5	1054
	10	1080±	22.5	1057
	11	1070±	9.5	1060
	12	1070±	20.5	1049
	13	985±	11.7*	973±
	14	1026±	22.3	1004±
	15	1006±	17.8	988±
	16	1025±	5.67*	1019±
	17	1057±	29.75*	1027±
	18	1030±	12.6*	1017±
	19		10.6*	
	20		8.58*	
	21		3.92*	
Fuel Farm:				
	B-1	1085.1	21.0	1064.1
Site G6-- B-10 Aeration Basin	B-2	1091.1	25.0	1066.1
	B-4	1092.2	24.25	1067.9
	B-5	1087	20.7	1066.3
	B-8	1088	22.7	1065.3
	B-9	1088	21.7	1066.3
	A-1	1086.9	21.2	1065.7
	A-2	1082.9	23.3	1059.6
Waste Basin:				
Site G1-- Surface Impoundment	B-1	1064.6	23.75	1040.8
	B-2	1052.4	14.75	1037.6
	B-3	1051.3	18.42	1032.9
	B-4	1050.0	17.08	1032.9
	B-5	1070.8	21.5	1049.3

*Note: Top of casing data. Three feet is subtracted from field data for approximately ground reference.

Table 6
SUMMARY OF MONITORING WELL LOCATIONS

Well No.	Location	Depth to Ground Water (ft-bls)[a]
1	Building B-30	41.5
2	West of Building B-77	23.0
3	Southwest of Building B-1	18.0
4	Northwest of Building B-1	22.5
5	West of Building B-43	Not Encountered
6	East of Building B-99	51.0
7	North of Building B-58	26.0
8	Northeast of Building B-27	31.0
9	Southeast of Building B-91	15.5
10	B-64 Parking Lot	24.0
11	Southwest of Building B-64	12.0
12	East of Building B-90	21.0
13	West of C-5 Fuel Storage	13.0
14	C-5 Washrack	24.0
15	Southwest of Building B-104	19.0
16	West of Fuel Weighing Station	6.5
17	Position 19	31.0
18	Position 19	12.5
19	Northeast of L-2	11.0
20	North of L-11	9.0
21	South of L-11	5.0
B-1	North of Surface Impoundment	28.6
B-2	South of Surface Impoundment	18.1
B-3	South of Surface Impoundment	22.9
B-4	South of Surface Impoundment	23.7
B-5	North of Surface Impoundment	27.0

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[a] bls = Below land surface.

Source: Federer-Sailors and Associates, Inc.
Ground-Water Monitoring Wells
AF Plant 6
Marrietta, Georgia

and

Law Engineering Testing Company
Report of Subsurface Exploration and Preliminary Ground-Water Monitoring Program
AF Plant 6
Lockheed-Georgia Company
Marrietta, Georgia

APPENDIX O

PORTIONS OF GROUND WATER QUALITY ASSESSMENT REPORT FROM WILSON AND CO.

LOCKHEED-GEORGIA COMPANY
A DIVISION OF LOCKHEED CORPORATION
MARIETTA, GEORGIA

GROUNDWATER QUALITY ASSESSMENT REPORT
SURFACE IMPOUNDMENT
(Industrial Waste Sludge Disposal Basin)

AIR FORCE PLANT NO. 6
MARIETTA, GEORGIA

By
TM Christy
BL Johnson

No. 6778
12-31-84
Robert P. S

WILSON LABORATORIES
KANSAS CERTIFIED E-101

No. 537
DON A. WATSON

10 OCTOBER 1984
(84-031)
(84-9533)

WILSON
& COMPANY
Engineers &
Architects

SECTION I - EXECUTIVE SUMMARY

A groundwater quality assessment has been performed at the hazardous waste surface impoundment at Air Force Plant No. 6, Marietta, Georgia. This investigation was undertaken in response to previous analytical data gathered from an existing groundwater monitoring system installed at the subject surface impoundment. These data indicated that contamination may be emanating from the surface impoundment, triggering regulatory requirements for a groundwater quality assessment.

The groundwater quality assessment was performed in a hierarchial manner; beginning with indicator studies yielding information about the contaminant plume, expected groundwater flow patterns and water quality from various sources within the study area, and ending with the installation and sampling of monitor wells to confirm the limits of contamination proceeding from the impoundment.

Contamination is migrating from the surface impoundment. These migrating contaminants form a plume which flows southwest from the impoundment and discharge into an adjacent stream. The maximum extent of groundwater contamination from the surface impoundment is approximately 600 feet south of the impoundment.

Contaminants migrating from the impoundment include heavy metals, organic priority pollutants, and common salts. The contaminant plume from the impoundment discharges into the stream where contaminants are both diluted and removed to environmentally safe levels. Data gathered during the course of this study indicate that the receiving stream meets all known safe drinking water limits prior to leaving the site.

The distribution of volatile compounds at the site was found to be extremely complex, owing to the apparent presence of several contaminant sources other than the subject hazardous waste surface impoundment.

This document satisfies the requirement for groudwater quality assessment, but does not include results of Appendix VIII analyses. These data will be furnished separately in the near future.

Recommendations presented in this report include the following:

a. Modifications should be made at the B-90 building in order to abate existing sources of contamination.

b. The extent of the volatile organic contaminant plume to the northeast of the impoundment should be determined. This determination is outside the scope of this project.

c. The source of the contaminant plume on the west bank of the impoundment should be determined and abated. This work is outside the scope of this project.

d. Regular monitoring should be performed at the stream prior to the point of exiting the study area in order to assure that the quality of this discharge does not exceed tolerable contaminant limits.

e. The treatment and delisting of the hazardous waste impoundment contents should be investigated as an alternate means of closing this facility.

SECTION IV - CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION.

Previous sections of this report have presented investigative methodology and analytical data. Interpretation of these data has been limited to the development of flow patterns in the residual soil and bedrock in the surface impoundment area. This section provides assessment of the distribution of contaminants across the site, their origin and eventual fate.

B. DISTRIBUTION AND CONCENTRATION OF INORGANIC CONTAMINANTS.

The apparent distribution of inorganic contaminants is well-defined across the site. Data suggest contaminants migrate from the surface impoundment and travel through the plume area indicated on Plate IV-1, discharging into the stream. The apparent boundaries for the discharge zone of this plume have been established by the stream survey. Apparent boundaries of this plume in the residual soil have been established by well analyses. The reader is referred to Section III for complete tabulations of analytical data from individual wells and stream points.

Data suggest Wells D-1, B-2, B-3 and B-4 are all contaminated with leachate from the surface impoundment. Concentrations of nearly all of the common ions are elevated within the plume area though sodium and sulfate are predominate. Sodium and chloride concentrations, useful tracers in the flow of contaminants in the impoundment area, are shown on Plate IV-2. By contrast, concentrations in monitor wells D-3, D-4, D-7 and E-4 are representative of background water quality. A band of elevated sodium and chloride concentrations does extend through B-1 and B-6. Flow patterns show that these slightly elevated concentrations are not from the surface impoundment. Their most likely source is the septic tank leach field east of the B-90 building.

Concentrations of zinc and cadmium are slightly elevated in the plume area. The maximum concentration of zinc is .22 mg/l in Well B-4. The maximum concentration of cadmium is .0009 mg/l in B-4, far below the drinking water limit for this metal.

Lead concentrations are also elevated in the plume area. The lead concentration in Well D-1 is 0.083 mg/l which exceeds the safe drinking water limit of 0.05 mg/l.

Analysis of Well BR-1 indicates that groundwater intercepted by the open bore hole interval in bedrock (29-79') is contaminated with inorganics from the surface impoundment. However, this contamination does not extend to the 130-229 foot bedrock interval monitored by Well BR-3.

C. DISTRIBUTION AND CONCENTRATION OF ORGANIC CONTAMINANTS.

Organic compounds encountered at the site include phenols and volatile, base neutral and acid priority pollutants. The occurrence and distribution of these compounds across the site indicate that sources of organic contaminants other than the surface impoundment are present.

A summary of organic compounds detected at the site is shown in Table IV-1. It should be noted that the "B" and "D" series wells along with BR-1 and BR-2 were analyzed for phenols and volatile, base neutral and acid compounds. The "E" series wells and BR-3 were analyzed for volatile and base neutral compounds only.

TABLE IV-1
SUMMARY OF DETECTION LOCATIONS FOR ORGANIC COMPOUNDS

Compound	Detection Limit	Locations Detected
Phenols (mg/l)	.005	D-5, D-6, D-7, B-2, B-3, BR-2
Volatile Compounds (µg/l)		
Chlorobenzene	5.	B-2, B-4, B-6, E-5
1,1,2-Trichloroethane	5.	B-5, E-8
1,1-Dichloroethane	5.	D-1, B-2, B-3, B-4, BR-2, E-8
1,1-Dichloroethylene	5.	Pump 6, BR-2, E-1, D-1, B-1, B-2, B-3, B-4, B-5, E-8
Methylene Chloride	5.	D-1, D-2, E-5, D-4, B-4, Pump 6, BR-2, E-8
1,2-Transdichloroethylene	5.	Pump 6, BR-2, E-5, D-1, D-2, E-7, E-8, SP-1, D-3, D-4, B-2, B-3, B-4
1,1,1-Trichloroethane	5.	E-1, D-1, B-1, B-2, B-3, B-4, B-5, BR-2, E-7, E-8
Trichloroethylene	5.	B-3, B-4, B-5, B-6, B-7, BR-1, BR-2, E-1, E-5, D-1, D-2, D-3, D-4, D-5, D-6, B-1, B-2, E-6, E-7, E-8, SP-1
Vinyl Chloride	5.	E-5, D-1, D-2, B-1, B-2, B-3, B-4, Pump 6, BR-2, E-8
Chloroform	5.	D-2, D-4
1,2-Dichloroethane	5.	D-2, D-4, B-1, E-5, E-3, E-7, E-6
1,2-Dichloropropane	5.	D-2, D-4, D-6, B-4, B-6, E-7, E-8
Base Neutrals (µg/l)		
Bis (2-Ethylhexyl) Phthalate	5.	B-7, BR-1, BR-2, E-6, E-4, E-7, E-8, E-2, E-3, D-1, D-2, D-3, D-5, B-1, B-3, B-4, B-5, B-6, Pond

TABLE IV-1 (Continued)

Compound	Detection Limit	Locations Detected
Di-N-Butyl Phthalate	5.	D-1, D-3, D-5, B-1, B-5
1,2-Dichlorobenzene	5.	D-2, D-4, BR-2, E-5, E-8
Di-N-Octylphthalate	5.	B-1
Diethylphthalate	5.	B-7, E-2, E-8
Acid Compounds (μg/l)		
Pentachlorophenol	5.	BR-2, B-3

The distribution of organic compounds across the site, their origin and residence time, is a complex puzzle, the solution of which is beyond the scope of this project.

Two sources of organic compounds, besides the surface impoundment, are apparently present in the study area. A third extraneous source is suspected.

Analyses confirm that organic compounds have entered the groundwater at the B-90 building. This source is believed to have been in existence long enough to contribute organic compounds to the groundwater beneath the impoundment area prior to the construction of the impoundment. Onto this pre-existing plume is superimposed the impoundment leachate. The seepage mound of the impoundment precludes any further flow under the impoundment from the B-90 building, diverting the pre-existing plume to the east, creating a wider area of contamination.

A second source of contamination is believed to exit on the west bank of the stream. This source may be the materials landfilled in this area, or industrial leakage to the west and north.

A third source of organic contaminants may exist and be the source of contaminants in the (B-6)-(D-2)-(D-4) area. An alternate explanation is that these contaminants originated at the B-90 building. Flow patterns and inorganic analyses in the (B-6)-(D-2)-(D-4) area suggest that contaminants in this area are not from the impoundment.

The distribution of organic compounds across the site is not consistent with the distribution of inorganic compounds from the surface impoundment or the flow patterns in the impoundment area. Distributions for the various compounds are discussed individually in the following paragraphs:

1. Phenols were detected at only five locations among the "B" and "E" series wells. Although phenols do appear to be migrating from the impoundment as indicated by their detection in wells B-2 and B-3, the detection of these compounds in wells D-5, D-6 and D-7 indicate the presence of a second source. Flow from the impoundment does not appear to be capable of transporting phenols to D-5, D-6 and D-7. The concentration of phenol in B-2 and B-3 is 0.026 and 0.011 mg/l, respectively. The concentration of phenols at D-5 and D-6 is 0.005 and 0.006 mg/l, respectively.

The highest concentration of phenol is encountered above the seep area (point SA-1) near the head of the stream, apparently from an extraneous source. The phenol concentration at this point is 0.066 mg/l. Phenols are rapidly diluted after SA-1, but remain above the detection limit through stream station S-13. Phenols are below the detection limit (0.005 mg/l) at stream station S-1.

2. Volatile Priority Pollutants. Twelve separate volatile compounds were detected in the study area. Distribution plots have been developed for the eight volatile compounds displaying the highest concentrations in the study area:

a. 1,1-Dichloroethane. A distribution plot for this compound is shown on Plate IV-3. This compound appears to be migrating from the surface impoundment. Detectable levels of this compound are not found outside of the impoundment plume.

b. 1,1-Dichloroethylene. A distribution plot for this compound is shown on Plate IV-4. This compound is found across the site in a wide band from E-1 southwest to the stream. Two separate plumes are shown for this compound, one apparently originating from the B-90 building and adjacent septic tank leach field, and one originating at the surface impoundment. Prevailing flow patterns should eventually carry this compound from the (B-1)-(E-1) area to Wells B-6, D-2, D-5 and D-6. 1,1,-Dichloroethylene is found in the stream in a pattern which confirms the distribution of the contaminant plume on Plate IV-1. The peak stream concentration being attained at the culvert (stream station S-18) and then diminishing from that point downstream.

c. 1,1,1-Trichloroethane. Plate IV-5 depicts the distribution of this compound in the study area. This plume is similar to the pattern obtained for 1,1-Dichloroethylene, contaminants being found in an area extending from the (E-5)-(E-1) area southwest to the stream. This plume appears to be the result of two separate sources. The northeast portion of the plume originating at the B-90 building and the southwest portion originating at the surface impoundment. Contaminants from the impoundment should move in the already established plume area south and east of the impoundment. The northeast portion of the plume can be expected to move south to the (D-2)-(B-6)-(D-6) area. The extreme northeast tip of the plume should move to the southeast.

d. 1,2-Dichloropropane. This compound has a distribution concentrated in a narrow area southeast of the surface impoundment as shown on Plate IV-6. Because 1,2-Dichloropropane was not found in the impoundment pore waters it is doubtful that the concentration of 1,2-Dichloropropane in Well B-4 originated from the impoundment. The lack of any inorganic contamination in Wells B-4, D-2, D-5 and D-6 strongly implicate a second source. This plume probably originated in the landfill. This plume does interact with the stream as indicated by the stream survey. 1,2-Dichloropropane in B-4 can be expected to move within the impoundment contaminant plume boundary in a southwest direction to the stream. The portion of the plume at D-6 can be expected to move southeast to be intercepted by the site secondary stream.

e. Trichloroethylene. Analyses indicate the presence of four separate sources for this plume. Present data do not facilitate the development of isocons at each of these sources. However, the contamination from the surface impoundment is apparently well defined. Isocons have been drawn for the highest concentrations of trichloroethylene in the study area. These are shown on Plate IV-7.

One source of Trichloroethylene contamination is believed to occur at the B-90 building, resulting in low level concentrations in B-7, B-6, E-1 and BR-1. A second source or sources appears responsible for trichloroethylene contamination in E-5, D-3 and E-6. Both of the areas are located so as to preclude the flow of water from the surface impoundment. Inorganic constituents at both locations indicate that contamination from the surface impoundment has not occurred. Flow from the (E-5)-(E-6) area will be east to the secondary stream. Flow from the B-90 area should be south to the (D-2)-(B-6)-(D-6) area, with the east side of the plume area at E-1 moving east.

Trichloroethylene in the (B-2)-(B-3)-(B-4)-(D-1) area is probably from the impoundment. The lack of any inorganic contaminants in the (D-5)-(D-2)-(D-4) area strongly favors a separate source for the contamination found in this area. The extent of trichloroethylene in areas downgradient and southeast of the surface impoundment has probably achieved its maximum extent, while contaminants at D-6 will apparently migrate southeast to be intercepted by the secondary stream.

f. 1,2-Transdichloroethylene. The distribution of this compound is shown on Plate IV-8. Two basic areas of contamination are shown: an area south of the surface impoundment and an area on the west bank of the stream. The area on the west bank favors a source other than the surface impoundment.

D. RATE AND EXTENT OF CONTAMINATION.

Wilson Laboratories believes that the actual extent of both inorganic and organic contamination from the surface impoundment is equivalent to the area defined on Plate IV-1. This area is surrounded on the north, east and southeast by contaminants apparently derived from other sources. It would appear that a plume or plumes from other sources also exists on the west bank of the stream.

The contaminant plume from the surface impoundment is believed to have established its maximum extent as shown on Plate IV-1 The rate of flow within this plume varies from approximately 17 to 90 feet per year. The plume is intersected by and discharges into the stream.

Data suggest constituents contributed to the stream by the impoundment are either diluted, as in the case of inorganics, or removed, as in the case of volatile priority pollutants, prior to the stream leaving the study area. Data indicate the stream water leaving the site is free from harmful concentrations of any constituent and would be considered a safe drinking water supply by any standard.

Data gathered from the three bedrock wells installed at the site indicate that contaminants from the residual soil mantle have entered the site bedrock. Contamination was detected in the upgradient position bedrock Well BR-1, which penetrated to a depth of 93 feet below ground surface. Contamination was found in downgradient Well BR-2 which penetrated to a depth of 79 feet below ground surface. Well BR-3 which penetrates to a depth of 230 feet was found to be free from contamination. This well sampled formation water at a depth of 183-223 feet.

As discussed in Section III, the flow pattern of groundwater through the bedrock is ill-defined.

In general, it can be said that the net transport of water through the bedrock will closely parallel flow in the residual soils; moving toward the center and down the valley. The impoundment plume is located adjacent to the stream which serves as a groundwater discharge zone from the bedrock. For this reason solutes from the impoundment have little impetus to enter the bedrock. The bedrock surface is irregular and can be expected to be recharged from the directly overlying residual soils. The pumping of Wells BR-1 and BR-2 for sampling purposes may have induced contaminant flow into these wells from the residual soils.

This document satisfies the requirements of the groundwater quality assessment plan with the exception of Appendix VIII analysis data. Pursuant to the 21 September letter[7] from Georgia EPD to Lockheed, these data will be provided separately in the near future.

E. RECOMMENDATIONS.

The following recommendations are forwarded based on the analytical results and conclusion of this study:

1. The B-90 building should be modified such that the disposal of all industrial wastes will be to the Lockheed Industrial Waste Plant rather than to the existing septic tank-leach field system. In addition, an enclosed industrial solvent storage area should be constructed for this building and administrative steps taken to assure that all personnel are instructed in and carry out the safe disposal of solvents.

2. The extent and fate of the plume extending east from the B-90 building should be determined, but this is considered outside the scope of this project.

3. The source or sources of contaminants to the stream west bank should be determined and, if possible, abated. This work is also outside the scope of this project.

4. The stream should be monitored at station S-0 and analysis made for common ions, heavy metals, organic priority pollutants and phenolic compounds in order to assure that the present high quality of water leaving the site is maintained. This monitoring should be performed in accordance with Georgia EPD requirements. No remedial action other than that provided by the natural environment is recommended.

5. Analysis of the impoundment contents shows that these materials would not meet the definition of a hazardous waste if the organic priority pollutants were removed. Removal of these compounds and delisting of the sludge would allow the disposal of this sludge in a permitted industrial landfill. Such disposal would, in all probability, be more economical than disposal in a hazardous waste landfill, as well as being environmentally safer. For these reasons, we recommend that Lockheed-Georgia undertake an engineering and economic investigation of this treatment and disposal option.

GEOTECHNICAL ENGINEERING REPORT

WASTE IMPOUNDMENT
LOCKHEED-GEORGIA COMPANY
MARIETTA, GEORGIA

Prepared By

Hanson Engineers Incorporated
1525 South Sixth Street
Springfield, Illinois 62703

Prepared For

Wilson & Company
631 E. Crawford Avenue
P.O. Box 1648
Salina, Kansas 67401

August 9, 1984

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22 October 1984

Lockheed-Georgia Company
86 S. Cobb Drive
Marietta, GA 30063

Attn: J.H. Lucas
Dept. 49-11

Re: Dike Structural Integrity
Groundwater Assessment Plan Implementation
Purchase Order No. CA 95072
Register No. B5454
Subcontract Agreement No. 03 84 528
WCEA File: 84-031

Dear Mr. Lucas:

It is our opinion that the Geotechnical Engineering Report on Lockheed's Surface Impoundment prepared for us by Hanson Engineers, Incorporated, satisfies the intent of 40 CFR Part 264.226(c). This report is included in our Groundwater Quality Assessment Report as Appendix B.

Our opinion is based on the fact that the Hanson Report is a certified document by a qualified engineer (George F. Jameson, Georgia P.E., Registration No. 14604) who states the following:

1. "The investigation and subsequent stability analyses indicated that adequate stability factors of safety exist for the idealized cross sections that were studied. Considerations of the seepage conditions (as they relate to the structural integrity of the embankments) indicate no apparent areas that may adversely influence the embankments' structural integrity." (Second and third sentences of the synopsis appearing immediately after the Table of Contents.)

2. ". . ., it is Hanson Engineers' opinion that the embankment is in a structurally stable condition." (Portion of last sentence on page 17 of paragraph titled Results.)

3. "This seepage, though important in considering possible contamination of the groundwater, does not appear to adversely influence the embankment stability." (Fifth sentence on page 17 of paragraph titled Seepage Considerations.)

4. "It is not considered necessary to modify the existing embankment to improve its structural integrity or seepage conditions (as they relate to stability)." (First sentence on page 18 of only paragraph in section entitled RECOMMENDATIONS.)

The Hanson Report addresses the horizontal stability of the dike and the affect of seepage and provides backup data and calculations to support the opinions therein as required by 40 CFR Part 264.226(c). We therefore submit that the entire Hanson Report included as Appendix B of our Groundwater Quality Assessment Plan is the required certification of dike stability by a qualified engineer.

In the eight copies of the report furnished you for permit application purposes, Mr. Jameson's seal did not reproduce. Therefore, we are enclosing ten copies of the page on which his seal did reproduce.

If you have any questions or require additional information, please contact us.

WILSON & COMPANY

Herbert H. Bassett, P.E.

-slw

HANSON
ENGINEERS
INCORPORATED

August 9, 1984

Wilson & Company
631 E. Crawford Avenue
P.O. Box 1648
Salina, Kansas 67401

Re: Waste Impoundment
Lockheed-Georgia Company
Marietta, Georgia

Gentlemen:

Enclosed are four copies of our Geotechnical Engineering Report for the existing Waste Impoundment at the Lockheed Plant in Marietta, Georgia. This work was completed in accordance with your authorization for engineering services issued in April 1984.

We are pleased to have had the opportunity to perform this work. If you have any questions concerning the report, or if Hanson Engineers may be of additional service to you on this project, either during the finalization of remedial measures or during construction, please do not hesitate to call.

Very truly yours,

HANSON ENGINEERS INCORPORATED

David E. Daniels
David E. Daniels
Senior Associate

George F. Jamison
George F. Jamison
Associate Partner
Georgia P.E. No. 14604

Approved by
for Donald D. Oglesby
Vice President

gfj/lb

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APPENDIX I

Field Boring Logs

APPENDIX II

Grain Size Distribution Data and Plots
Permeability Test Data
Direct Shear Envelopes
Standard Proctor Curve

SYNOPSIS

A geotechnical investigation was conducted by Hanson Engineers, Inc. to investigate the stability and seepage conditions for the embankments of the existing Waste Impoundment at the Lockheed-Georgia Company in Marietta, Georgia. The investigation and subsequent stability analyses indicated that adequate stability factors-of-safety exist for the idealized cross sections that were studied. Considerations of the seepage conditions (as they relate to the structural integrity of the embankments) indicate no apparent areas that may adversely influence the embankments' structural integrity.

APPENDIX P

REFERENCES

APPENDIX P

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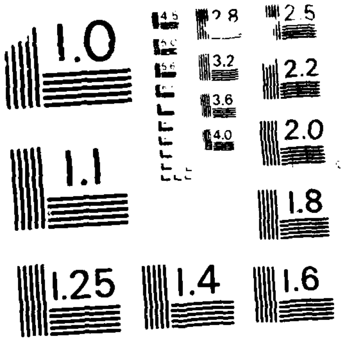

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