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06.07-01/06/98-01782

LONG-TERM MONITORING WORK PLAN

OPERABLE UNIT NO. 5 (SITE 2)

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

Submission Date:

JANUARY 6, 1998

Prepared For:

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES
ENGINEERING COMMAND
Norfolk, Virginia

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	microgram per liter
EPA	U.S. Environmental Protection Agency - Region IV
FID	Flame Ionization Detector
LANTDIV	naval Facilities Engineering Command, Atlantic Division
MCB	Marine Corps Base
mg/L	milligram per liter
OU	Operable Unit
PID	Photoionization Detector
QA/QC	Quality Assurance/Quality Control
RI	Remedial Investigation
ROD	Record of Decision
SOP	Standard Operating Procedure
SVOC	Semivolatile Organic Compound
TDS	total dissolved solids
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compound
WQP	Water Quality Parameter

1.0 OBJECTIVE

The principal objective of this work plan is to describe groundwater monitoring activities which fulfill the requirements specified in the Record of Decision (ROD) for Operable Unit (OU) No. 5 (Site 2), Marine Corps Base (MCB) Camp Lejeune, North Carolina. The work plan describes groundwater monitoring activities to be performed at Site 2. An alternate objective of this work plan is to provide a current listing of implemented actions regarding the selected remedy for Site 2. Documents which pertain to the accepted remedial alternative for Site 2 are listed as follows:

- Final Remedial Investigation Report - June, 1994
- Final Feasibility Study - June, 1994
- Final Proposed Remedial Action Plan - June, 1994
- Final Record of Decision - September, 1994
- Corrective Action Plan - March, 1995

The ROD for OU No. 5 stipulates that groundwater monitoring, coupled with institutional controls be implemented at Site 2. The selected remedy includes periodic groundwater sampling of monitoring and supply wells and restriction of groundwater use in the vicinity of Site 2. The selected remedial alternative for Site 2 was approved by representatives of the following:

- Naval Facilities Engineering Command, Atlantic Division (LANTDIV)
- Marine Corps Base Camp Lejeune, North Carolina
- U.S. Environmental Protection Agency (EPA) - Region IV
- North Carolina Department of Environment and Natural Resources (NC DENR)

In addition to agency approval, a public meeting was held to solicit concerns from the community regarding the selected remedial alternative. A 30-day comment period followed the public meeting. The ROD was signed after a responsiveness summary and final version of the decision document had been prepared. The ROD was signed by MCB Camp Lejeune on September 15, 1994.

The remedy provided within the ROD for Site 2 is a permanent, long-term solution because contaminant levels in groundwater are minimal and periodic sampling is a reliable means of monitoring contaminant persistence and migration. Future modifications to the monitoring program will be recorded, once approved, and documented as amendments to this work plan. Additions and modifications to the monitoring program which have been implemented thus far are presented in the section which follows.

1.1 Monitoring Program Modifications

Monitoring activities were implemented at Site 2 during July of 1996. Based upon the accumulated monitoring data, the following modifications were implemented. Each of the following modifications were approved by representatives of NC DENR, EPA, MCB Camp Lejuene, and LANTDIV. Details regarding the additions or modifications which follow are presented in the monitoring reports for OU No. 5.

1.1.1 Sampling Frequency

The ROD for OU No. 5 stipulates that groundwater samples be collected on a quarterly basis. After the initial six quarterly sampling events, however, little change in the concentration and dispersion of contamination was noted. Based upon this information, the number of yearly sampling events was reduced from four to two. Semiannual sampling was implemented in January of 1997.

1.1.2 Sample Analyses

Due to a lack of detected metals in groundwater during the six initial sampling events, total metal analyses were eliminated from the monitoring program as of January 1997. Although iron and manganese were detected at concentrations which exceeded applicable North Carolina groundwater standards, their presence has been demonstrated to be the result of natural conditions. Total dissolved solid (TDS) and total suspended solid (TSS) analyses were also eliminated from the monitoring program. These analyses were not required to determine the migration of known volatile contaminants throughout the study area.

1.1.3 Sampling Scheme

Water supply wells HP-616, HP-646, and HP-647 were eliminated from the monitoring program in January of 1997. The three supply wells, located more than 1,200 feet from the study area, were sampled during the six initial quarterly sampling events with only one positive detection of a volatile organic compound (VOC). Methylene chloride, a common laboratory contaminant, was detected at a concentration of one microgram per liter (µg/L) during the third quarter of 1996. None of the total metals in samples obtained from the supply wells exceeded applicable water quality standards. In addition, all supply wells are currently sampled as part of an ongoing monitoring program administered by water resource personnel at MCB Camp Lejeune.

Shallow monitoring wells 02-GW06 and 02-GW09 were eliminated from the monitoring program during January of 1997. The two monitoring wells are not situated hydraulically downgradient of known groundwater contamination. The common laboratory contaminants methylene chloride and chloroform were detected only twice among samples obtained from 02-GW06 during the six initial sampling quarters. No other VOCs were detected among samples obtained from 02-GW06 and 02-GW09.

1.1.4 Monitoring Well Abandonment

Deep monitoring well 02-GW03DW was abandoned during February of 1997. Field observations noted during the initial six sampling events suggested that degradation of the well was occurring and, therefore, may have biased any findings. Bentonite clay had entered the screen and sandpack of 02-GW03DW. The bentonite clay had presumably clogged the screen and sandpack, limiting the ability of groundwater to enter the well. In addition, the presence of bentonite clay is believed to have falsely biased metal and TDS analyses. No VOCs were detected among samples obtained from deep monitoring well 02-GW03DW during the six initial sampling events.

Three of the five shallow monitoring wells installed during the 1986 Confirmation Study had begun to show signs of subsurface deterioration. The screens and sandpacks of monitoring wells 02-GW01, 02-GW02, and 02-GW04 were presumably clogged with fine-grained material from the surrounding formation. As a result of deterioration or obstruction, groundwater samples obtained from the three shallow monitoring wells were highly turbid and, therefore, misrepresented true groundwater conditions.

1.1.5 Monitoring Well Installation

In an effort to further delineate known VOC contamination at Site 2, an additional shallow monitoring well and intermediate monitoring well were installed in the southern portion of the study area. Intermediate monitoring well 02-GW03IW was installed within the area where known VOC contamination had consistently been detected in the uppermost portion of the surficial aquifer. The intermediate monitoring well was installed to determine if contamination had migrated to the lower portion of the surficial aquifer. The additional shallow monitoring well, 02-GW12, was installed downgradient of known VOC contamination in order to determine if the identified contaminants had begun to migrate horizontally.

2.0 BACKGROUND

Baker Environmental, Inc. conducted a Remedial Investigation (RI) of OU No. 5 to evaluate potential threats posed by the release or threatened release of hazardous substances, pollutants, and contaminants at Site 2. The field investigation phase of the RI was initiated in April 1993 and was concluded in June 1993. The field investigation phase consisted of a preliminary site survey; a geophysical investigation; a soil gas survey; a soil investigation; a groundwater investigation including monitoring well installation and two separate rounds of sampling; and a surface water and sediment investigation. Contaminants including pesticides, VOCs, and semivolatile organic compounds (SVOCs) were detected among soil, groundwater, surface water, and sediment samples obtained during the RI. A Time Critical Removal Action was immediately initiated, following the RI, to remove contaminated soil and sediment from the site. As a result, only VOCs in groundwater remained as potential contaminants of concern. The Final RI Report was submitted in June 1994. A Final Feasibility Study Report was also completed in June 1994.

The monitoring program presented herein is based upon previous investigation findings, previous monitoring data, and decision documents. The ROD for OU No. 5 stipulates that groundwater samples from 12 monitoring wells and 3 water supply wells be collected quarterly for the following analyses:

- Volatile Organic Analyses
- Selected Total Metal Analyses
- Total Suspended and Dissolved Solids

Monitoring activities at Site 2 were initiated in July 1995. As a result of analytical data generated during the previous quarterly sampling events, approved modifications to the sampling program were implemented. Four monitoring wells were abandoned during February 1997. Two additional monitoring wells were installed during February 1997 that more accurately delineate the vertical and horizontal extent of known VOCs. Additional amendments to the monitoring program at Site 2 have also been implemented. Two monitoring wells and three water supply wells that provided only extraneous analytical data were eliminated from the monitoring program. Groundwater samples from seven shallow monitoring wells and one intermediate monitoring well are now being employed to monitor the persistence and possible migration of known VOCs. The revised sampling locations have been selected within or immediately adjacent to portions of the site with known contamination.

Sample analyses have also been adjusted to reflect a more focussed sampling approach. Groundwater samples are no longer be submitted for metal, dissolved solid, and suspended solid analyses; the analyses are not necessary to monitor known organic contaminants within groundwater. Based upon minimal organic contamination, sampling at Site 2 was reduced from four quarterly events to two semiannual events. Section 3.0 presents the monitoring plan for Site 2, based upon the approved amendments to the monitoring program. Section 3.0 of this work plan also provides a detailed discussion of sampling locations and procedures.

Additional background information pertaining to Site 2 is provided within the following reports:

- Baker Environmental, Inc. Remedial Investigation Report, Operable Unit No. 5 (Site 2) for MCB Camp Lejeune, North Carolina. Final. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. June 1994.

- Baker Environmental, Inc. Corrective Action Plan., Operable Unit No. 5 (Site 2) for MCB Camp Lejeune, North Carolina. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. 1995.

- Environmental Science and Engineering, Inc. Site Summary Report. Final. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. ESE Project No. 49-02036. 1990.

- Water and Air Research, Inc. Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity. 1983.

2.1 Site History

Building 712, located within the study area, was used for storing, handling, and dispensing pesticides from 1945 to 1958. Building 712 was later used as a day care center for children. A storage area, located in the southern portion of Site 2, was used to stage bulk materials and vehicles. A railroad spur extended from the main rail line into the storage area.

3.0 MONITORING TASKS

Section 3.0 provides specific procedures for implementing the monitoring program at Site 2. In addition, sampling locations, sample analyses, and sample designations are included within this section. Based upon analytical data obtained during past monitoring events, a number of amendments to the monitoring program have been implemented. The sections which follow provide the number and location of groundwater samples to be obtained semiannually as part of the monitoring program at Site 2.

3.1 Sampling

Seven shallow wells and one intermediate well will be sampled as part of the monitoring program at Site 2. Shallow monitoring wells 02-GW03~~, 02-GW07~~, 02-GW08, and 02-GW12 are located within the southern portion of the study area. Intermediate monitoring well 02-GW03IW is also located within the southern portion of Site 2. Shallow monitoring wells 02-GW05, 02-GW10, and 02-GW11 are located adjacent to or downgradient of the known groundwater contamination. The seven shallow wells will be employed to monitor conditions within the uppermost portion of the surficial aquifer. Samples obtained from intermediate monitoring well 02-GW03IW will be representative of conditions within the deeper portion of the surficial aquifer. Table 3-1 provides construction details for each of the eight wells included in the monitoring program. The locations of monitoring wells throughout Site 2 are depicted in Figure 3-1.

3.2 Sample Designations

In order to identify and accurately track the groundwater samples, all samples collected during the monitoring program, including quality assurance and quality control (QA/QC) samples, will be designated with a unique identification number. The sample number will serve to identify the investigation, the site, the sample media, sampling location, QA/QC samples, and the quarter and year in which the samples were collected.

The sample designation format is as follows:

Site Number - Media and Station Number or QA/QC - Year and Quarter of Event

An explanation of each of these identifiers is given below.

Site Number	Monitoring activities will be conducted at Installation Restoration Program Site 2.
Media	GW = Groundwater
Station Number	Each sample location or monitoring well will be identified with a unique identification number. Single digit location numbers must be proceeded by a zero (e.g., 02-GW05).
QA/QC	TB = Trip Blank

Year	The number will reference the calendar year in which the sample was obtained (e.g., 98 would represent 1998).
Quarter	The last letter of the sample designation corresponds to the quarter of the calendar year in which the sample was collected. A = First quarter (January - March) B = Second quarter (April - June) C = Third quarter (July - September) D = Fourth quarter (October - November)

Under this sample designation format the sample number IR02-GW03IW-98A refers to:

IR02-GW03IW-98A	Installation Restoration Program
IR02-GW03IW-98A	Site 2
IR02-GW03IW-98A	Groundwater sample
IR02-GW03IW-98A	Monitoring well number 03
IR02-GW03IW-98A	Intermediate monitoring well
IR02-GW03IW-98A	Year 1998
IR02-GW03IW-98A	First quarter

Under this sample designation format the sample number IR02-TB01-97A

IR02-TB01-98A	Installation Restoration Program
IR02-TB01-98A	Site 2
IR02-TB01-98A	Trip Blank
IR02-TB01-98A	Sequential number, in order of collection. The total number will depend upon how many trip blanks are required.
IR02-TB01-98A	Year 1998
IR02-TB01-98A	First quarter

This sample designation format will be followed throughout the project. Additional details regarding sample naming conventions and data deliverable standards and procedures are provided within the standard operation procedures (SOPs) section, presented at the end of these work plans.

3.3 Sample Collection and Analyses

The following describes sample collection procedures and analytical requirements of the monitoring program. Periodic redevelopment of monitoring wells may be required prior to groundwater sample collection.

Groundwater samples will be collected from the identified monitoring wells at Site 2. The following details the low-flow purge and sampling procedure used to obtain groundwater samples:

1. Remove well cap, measure escaping gases from well head using a Photoionization Detector (PID) or Flame Ionization Detector (FID). The results of this test will determine if respiratory protection is required.

2. Allow groundwater level to stabilize, if a vent hole was not installed in the well.

3. Measure and record the static water level. Record total well depth from well construction tables. Calculate volume of water in well.

4. Lower unused sample tubing (i.e., 1/4-inch internal diameter polypropylene or polyethylene tubing) slowly into well, until the intake is within the screened interval of the well. Place water level probe just above the water, in well.

5. Commence purging using a peristaltic-type pump. Record the flow rate using a stopwatch and a calibrated container. The flow rate will be adjusted to ambient flow conditions (i.e., do not permit groundwater to be drawn down). Flow rates of less than 1 liter per minute are expected.

6. Investigation derived waste (i.e., purge water) will be discharged onto the ground surface.

7. Record water quality parameters (WQPs) including temperature, dissolved oxygen, turbidity, pH, and specific conductance at regular intervals. These measurements must be recorded in a field notebook.

8. Purging will be completed when a minimum of three well volumes have been removed and three successive WQP readings have stabilized, or there is no further discernable upward or downward trend. At low values, certain WQPs (such as turbidity and dissolved oxygen) may vary more than 10 percent, but have reached a stable plateau. Stability of WQPs may be defined as having less than 10 nephlometric turbidity units, pH measurements which remain constant within 0.1 standard units, specific conductance varying no more than 10 percent, and a constant temperature for at least three consecutive readings.

9. Upon WQP stabilization, collect groundwater samples for volatile organic analyses. Label and preserve containers prior to sample collection.

10. Store samples in a cooler with fresh ice until they are shipped to the laboratory.

The SOP for collection and sampling is located in the SOP section of this document. Table 3-1 provides a summary of well construction details for each well included in the monitoring program. Table 3-2 provides the sampling and analysis program for groundwater samples obtained at Site 2.

3.4 Quality Assurance and Quality Control

Quality assurance and quality control requirements for the monitoring program are limited to trip blanks.

- Trip blanks are defined as samples comprised of analyte-free water from the laboratory, which are shipped to the sampling site, kept with the investigative samples throughout the sampling event, and returned to the laboratory with the VOC samples. The blanks will only be analyzed for volatile organics. The purpose of a trip blank is to determine if samples were contaminated during storage and transportation back to the laboratory. One trip blank will accompany each cooler containing samples for volatile analyses.

Equipment rinsates, field blanks, field duplicates, and matrix spike and matrix spike duplicates will not be collected during the monitoring program. The samples collected during the program will be considered confirmatory only; therefore, extraneous QA/QC samples have been eliminated from the program.

TABLES

TABLE 3-1

SUMMARY OF WELL CONSTRUCTION DETAILS
LONG-TERM MONITORING PLAN
OPERABLE UNIT NO. 5 - SITE 2
MCB CAMP LEJEUNE, NORTH CAROLINA

Well Number	Date Installed	Top of Casing Elevation (feet, msl)	Ground Surface Elevation (feet, msl)	Boring Depth (feet, bgs)	Well Depth (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)	Stick-Up (feet, ags)
02-GW03	1984	35.40	33.00	NA	25.0	10.0 to 25.0	NA	NA	NA
02-GW03IW	1997	NA	NA	70.0	60.0	50.0 to 60.0	45.0	34.0	3.0
02-GW05	1984	33.72	31.80	NA	25.0	10.0 to 25.0	NA	NA	NA
02-GW07	1993	34.03	31.6	16.0	13.0	3.0 to 13.0	2.0	1.0	2.4
02-GW08	1993	34.92	31.90	12.5	12.5	2.5 to 12.5	1.5	0.5	3.0
02-GW10	1994	32.28	32.47	15.0	13.5	3.5 to 13.5	2.5	1.5	3.5
02-GW11	1994	35.20	33.94	15.0	14.0	1.0 to 14.0	3.0	2.0	3.0
02-GW12	1997	NA	NA	31.0	23.0	3.0 to 23.0	2.0	1.5	3.0

Notes:

ags = Above ground surface
bgs = Below ground surface
msl = Mean sea level
NA = Information not available

TABLE 3-2

SAMPLE SUMMARY MATRIX
LONG-TERM MONITORING PLAN
OPERABLE UNIT NO. 5 - SITE 2
MCB CAMP LEJEUNE, NORTH CAROLINA

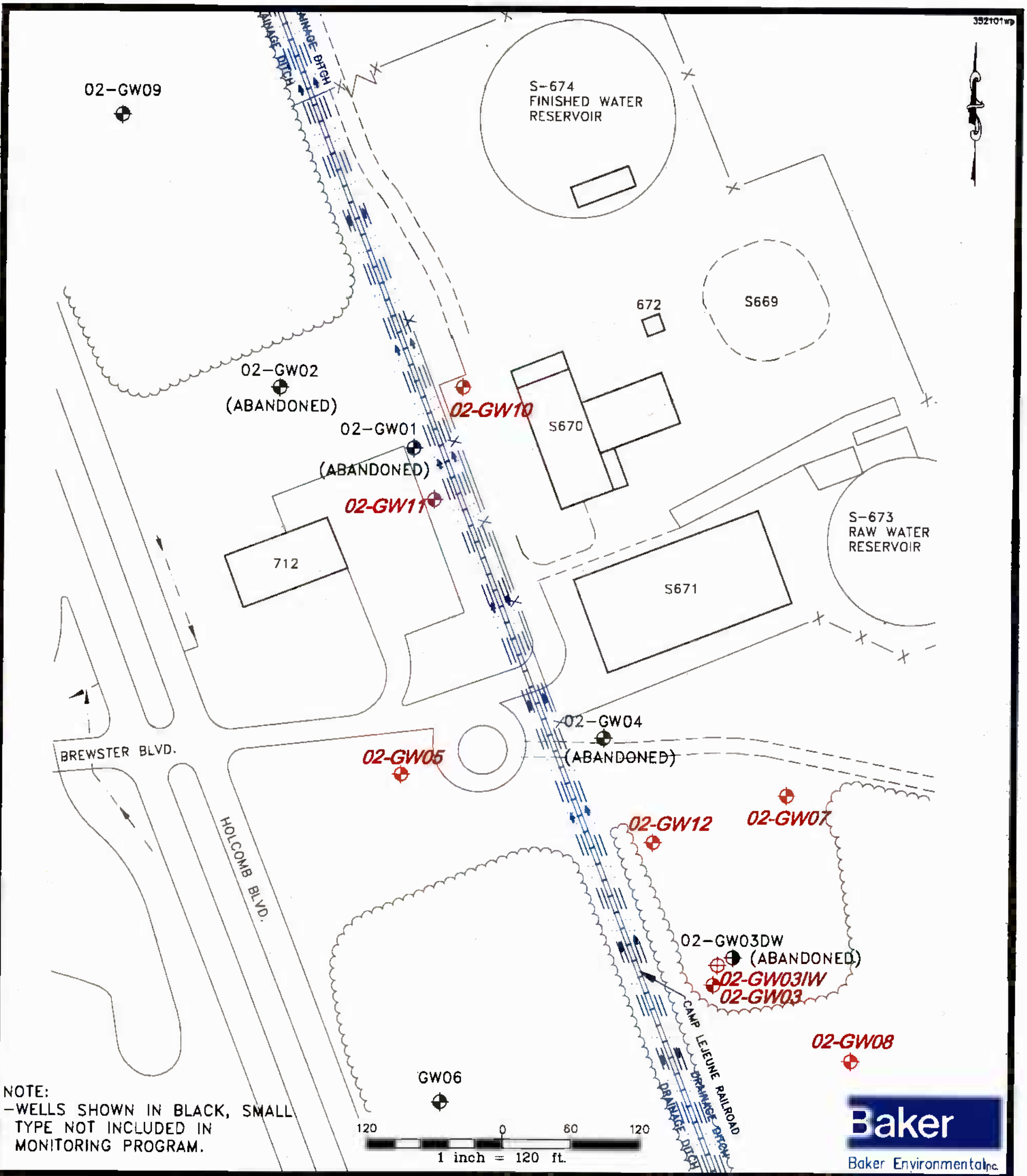
Sample Location	Media	TCL Volatiles[1]	Sample Designation
02-GW03	GW	X	IR02-GW03-**
02-GW03IW	GW	X	IR02-GW03IW-**
02-GW05	GW	X	IR02-GW05-**
02-GW07	GW	X	IR02-GW07-**
02-GW08	GW	X	IR02-GW08-**
02-GW10	GW	X	IR02-GW10-**
02-GW11	GW	X	IR02-GW11-**
02-GW12	GW	X	IR02-GW12-**

Notes:

(1) Target Compound List Organics by Solid Waste Method 8260A.

GW = Groundwater
X = Requested Analysis
** = Year (e.g., 98 for 1998) and Quarter (e.g., A for January through march) in which the groundwater sample is obtained.

FIGURES



NOTE:
-WELLS SHOWN IN BLACK, SMALL TYPE NOT INCLUDED IN MONITORING PROGRAM.

LEGEND

02-GW02 ⊕	SHALLOW MONITORING WELL
02-GW03IW ⊕	INTERMEDIATE MONITORING WELL
02-GW03DW ⊕	DEEP MONITORING WELL
➔	DIRECTION OF SURFACE WATER FLOW
┼┼┼	RAILROAD
⌒⌒⌒	TREE LINE

SOURCE: LANTDIV, FEB. 1992

FIGURE 3-1
SAMPLING LOCATION MAP
OPERABLE UNIT NO. 5 – SITE 2
MONITORING WORK PLAN, CTO – 0352

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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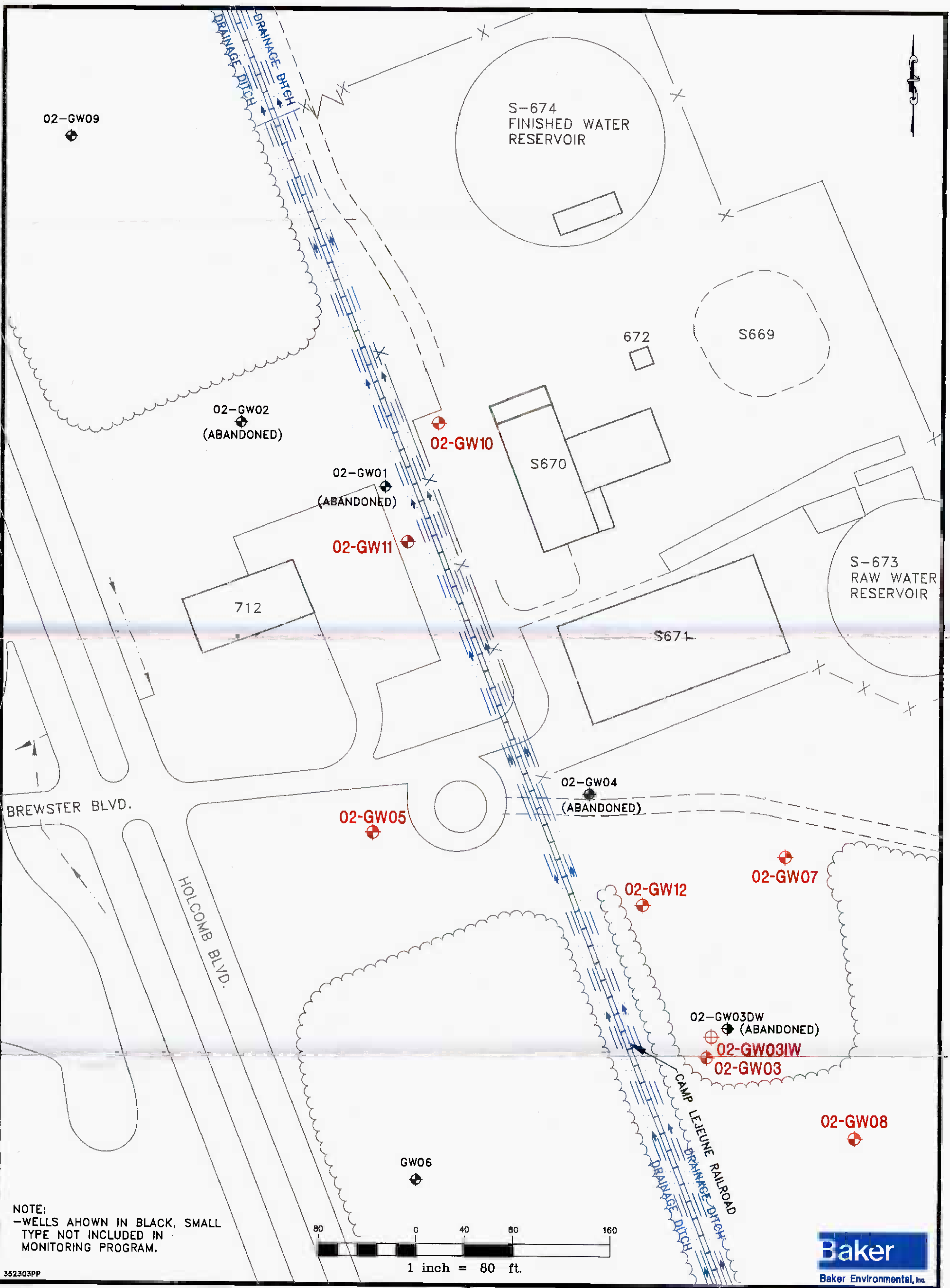
FIGURES



NOTE:
-WELLS AHOWN IN BLACK, SMALL TYPE NOT INCLUDED IN MONITORING PROGRAM.

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Baker Environmental, Inc.

LEGEND

02-GW02 ⊕	SHALLOW MONITORING WELL
02-GW03IW ⊕	INTERMEDIATE MONITORING WELL
02-GW03DW ⊕	DEEP MONITORING WELL
→	DIRECTION OF SURFACE WATER FLOW
┼┼┼	RAILROAD
⌒⌒⌒	TREE LINE

SOURCE: LANTDIV, FEB. 1992

FIGURE 3-1
SAMPLING LOCATION MAP
OPERABLE UNIT NO. 5 - SITE 2
MONITORING WORK PLAN, CTO - 0352

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

OU	Operable Unit
POL	Petroleum, Oil, and Lubricants
QA/QC	Quality Assurance/Quality Control
RI	Remedial Investigation
ROD	Record of Decision
SOP	Standard Operating Procedure
TAL	Target Analyte List
VOC	Volatile Organic Compound
WQP	Water Quality Parameter

1.0 OBJECTIVE

The objective of this long-term monitoring work plan is to fulfill requirements stipulated in the Record of Decision (ROD) for Operable Unit (OU) No. 1 (Sites 21, 24, and 78), signed on September 15, 1994. The work plan describes monitoring activities to be performed quarterly at Sites 24 and 78. As presented in the ROD, Site 21 does not require any further monitoring or remedial activities. Documents which pertain to the accepted remedial alternatives for Sites 21, 24, and 78 are as follows:

- Interim Remedial Action Report - September, 1992
- Corrective Action Plan - February, 1994
- Final Remedial Investigation Report - June, 1994
- Final Feasibility Study - July, 1994
- Final Proposed Remedial Action Plan - July, 1994
- Final Record of Decision - September, 1994

The ROD for OU 1 stipulates that long-term monitoring coupled with institutional controls and active remediation be implemented at both Sites 24 and 78. The selected remedy includes periodic groundwater sampling of existing monitoring wells, recovery wells, and supply wells in addition to the restriction of groundwater use in the vicinity of Sites 24 and 78. The selected remedy for Site 21 involves taking no further remedial actions. The selected remedial alternatives for Sites 21, 24, and 78 were approved by representatives of the following:

- Naval Facilities Engineering Command, Atlantic Division
- Marine Corps Base Camp Lejeune
- U.S. Environmental Protection Agency - Region IV
- North Carolina Department of Environment, Health, and Natural Resources

In addition to agency approval, a public meeting was held to solicit concerns from the community regarding the selected remedial alternatives. A 30-day comment period followed the public meeting. The ROD was signed after a responsiveness summary and final version of the decision document had been prepared. Remedies provided within the ROD for Sites 24 and 78 are permanent, long-term solutions because groundwater contaminants at each site are either being actively treated or permitted to naturally degrade and periodic sampling is a reliable means of monitoring contaminant persistence and migration. Future amendments or modifications to the monitoring program will need to be recorded, once approved, in a post-decision document file. Changes to the monitoring program will also need to be documented as amendments to this work plan.

2.0 BACKGROUND

In 1992 Baker Environmental, Inc. (Baker) prepared an Interim Remedial Action (IRA) report for the surficial aquifer at Site 78. The IRA report summarized and presented analytical data from previous investigations only; no additional field studies were conducted. As part of the IRA, three separate contaminant plumes were identified within the shallow aquifer at Site 78. One of the three contaminant plumes identified in the IRA report was associated with the former Hadnot Point Fuel Farm. The fuel-related contaminants associated with the fuel farm were already being addressed under a separate investigative program. The remaining two contaminant plumes were identified within the northern and southern portions of the Hadnot Point Industrial Area. As part of the IRA, separate on-site groundwater extraction and treatment systems were designed to remediate contaminants within the northern and southern plume areas.

During 1993, Baker conducted a Remedial Investigation (RI) of OU 1 to evaluate potential threats posed by the release or threatened release of hazardous substances, pollutants, and contaminants at Sites 21, 24, and 78. The RI was initiated in April 1993 and concluded in December 1993. The field program consisted of a preliminary site survey; a soil gas survey; a soil investigation; a groundwater investigation including monitoring well installation and sampling; and a surface water and sediment investigation. The Final RI Report was submitted in June 1994. A Corrective Action Plan was immediately initiated following the RI, to remove contaminated soil from Site 21 and to install three additional groundwater recovery wells. The three additional recovery wells were proposed to supplement nine existing recovery wells, constructed as part of the IRA, and to extract groundwater from areas with the highest observed contaminant concentrations. Only two of the three proposed recovery wells were installed, however.

Based upon findings presented in the RI and implemented corrective measures, a number of monitoring, supply, and recovery wells were identified for long-term sampling. Volatile organic compounds (VOCs) were identified during the RI among a select number of groundwater samples obtained from the surficial aquifer at Site 78. In addition to VOCs, the pesticide heptachlor epoxide was detected among three shallow groundwater samples obtained from Site 24. As a result, the ROD for OU 1 stipulates that groundwater samples from 25 monitoring wells, 8 supply wells, and all groundwater recovery wells be collected quarterly for the following analyses:

- Target Compound List Volatile Organic Analyses

- Target Analyte List Inorganic Analyses
- Total Suspended Solid and Dissolved Solid Analyses

The monitoring program presented herein is based upon previous investigation findings, long-term monitoring data, and decision documents. Monitoring activities at OU 1 were initiated in July 1995. As a result of analytical data generated during the previous quarterly sampling events, approved modifications to the sampling program have been implemented. One monitoring well within the Site 78 was abandoned during February 1997. Monitoring well 78-GW22-1 was located, prior to abandonment, within the former fuel farm area; the well had begun to exhibit signs of subsurface deterioration. In addition, three monitoring wells located within Site 78 have provided only extraneous analytical data. As a result, monitoring wells 78-GW05, 78-GW19, and 78-GW31-3 which are situated within or surrounding areas currently being addressed under separate investigative programs will no longer be sampled. Seven of the eight supply wells identified in the ROD have been abandoned; therefore, samples will not be obtained for analysis. The remaining supply well, HP-642, is being sampled periodically by MCB Camp Lejeune water resource personnel. Additional amendments to the monitoring program at Sites 24 and 78 have been implemented which pertain to sample analyses and sampling locations. The amendments are described in greater detail within quarterly monitoring reports prepared by Baker.

The monitoring program presented herein is based upon previous investigation findings, supplemental studies, and decision documents. Sampling locations have been selected within or immediately adjacent to portions of each site with known contamination. Fifteen shallow wells, two intermediate wells, and two deep wells have been selected to monitor the persistence and possible migration of known VOCs within Site 78. Three shallow wells were selected to monitor the status of known pesticide contaminants at Site 24. Groundwater sampling at Sites 24 and 78 will be conducted on a quarterly basis for selected analyses, as presented in Section 3.0 of this work plan. Section 3.0 of this work plan also provides a detailed discussion of sampling locations and procedures.

Additional background information pertaining to Sites 21, 24 and 78 is provided within the following reports:

- Baker Environmental, Inc. Quarterly Monitoring Reports, Unit No. 1 (Sites 24 and 78) for MCB Camp Lejeune, North Carolina. Prepared for the Department of the

Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. Ongoing submittals starting in November 1996.

- Baker Environmental, Inc. Remedial Investigation Report, Operable Unit No. 1 (Sites 21, 24, and 78) for MCB Camp Lejeune, North Carolina. Final. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. June 1994.

- Baker Environmental, Inc. Corrective Action Plan, Operable Unit No. 1 (Sites 21, 24, and 78) for MCB Camp Lejeune, North Carolina. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. February 1994.

- Environmental Science and Engineering, Inc. Site Summary Report. Final. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. ESE Project No. 49-02036. 1990.

- Water and Air Research, Inc. Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity. 1983.

2.1 Site History

The following subsections briefly describe the history of Sites 24 and 78.

2.1.1 Site 24

Site 24 was reportedly used for the disposal of fly ash, cinders, solvents, used pain stripping compounds, sewage sludge, and water treatment spiractor sludge from the late 1940s to 1980. Spiractor sludge from the Hadnot Point sewage treatment plant was reportedly disposed at this site during the late 1940s. Construction debris was reportedly disposed at the site in the 1960s. During 1972 to 1979, fly ash and cinders were dumped on the ground surface, and solvents used to clean out boilers were poured onto these piles. Furniture stripping wastes were also reported to be disposed in this area.

2.1.2 Site 78

The Hadnot Point Industrial Area was the first developed portion of MCB Camp Lejeune. It was comprised of approximately 75 buildings and facilities including: maintenance shops, gas stations, administrative offices, commissaries, snack bars, warehouses, and storage yards. Due to the industrial nature of the site, many spills and leaks have occurred over the years. Most of these spills and leaks have consisted of petroleum-related products and solvents from underground storage tanks, drums, and uncontained waste storage areas.

3.0 MONITORING TASKS

Section 3.0 provides specific procedures for implementing the monitoring program. In addition, sampling locations, sample analyses, and sample designations are included within this section.

3.1 Sampling

The sampling locations included in the monitoring program at Sites 24 and 78 are based upon laboratory results and observational data from both RI and previous sampling events. The following provides the number and location of samples to be obtained quarterly as part of the monitoring program at Sites 24 and 78.

3.1.1 Site 24

Three shallow wells will be sampled as part of the long-term monitoring program at Site 24. Shallow monitoring wells 24-GW08, 24-GW09, and 24-GW10 are located within suspected disposal portions of the study area. The shallow wells will be employed to monitor conditions within the uppermost portion of the surficial aquifer. Table 3-1 provides construction details for each of the three wells included in the monitoring program. The locations of monitoring wells throughout Site 24 are depicted in Figure 3-1.

3.1.2 Site 78

Fifteen shallow wells, two intermediate wells, and two deep wells will be sampled as part of the long-term monitoring program at Site 78. Shallow monitoring wells 78-GW21, 78-GW22, 78-GW23, 78-GW24-1, and 78-GW25 are located within the northern portion of the study area. Deep monitoring well 78-GW24-3 and intermediate well 78-GW24-2 are also located within the northern portion of Site 78. Shallow wells 78-GW14, 78-GW15, and 78-GW17-1 are located within the central portion of the study area. Shallow monitoring wells 78-GW01, 78-GW04-1, 78-GW08, 78-GW09-1, 78-GW10, and 78-GW11 are located within the southern portion of the study area. Deep monitoring well 78-GW09-3 and intermediate well 78-GW09-2 are also located within the southern portion of Site 78. An additional shallow monitoring well, 78-GW39, is located south of the Site 78. The shallow and intermediate wells will be employed to monitor conditions within the surficial aquifer. Samples obtained from the two deep monitoring wells will be representative of conditions within the deeper, Castle Hayne, aquifer. Table 3-1 provides construction details for each of the monitoring wells included in the monitoring program. The locations of monitoring wells throughout Site 78 are depicted in Figure 3-2.

3.2 Sample Designations

In order to identify and accurately track the various samples, all samples collected during the monitoring program, including quality assurance and quality control (QA/QC) samples, will be designated with a unique identification number. The sample number will serve to identify the investigation, the site, the sample media, sampling location, QA/QC samples, and the quarter and year in which the samples were collected.

The sample designation format is as follows:

Site Number - Media and Station Number or QA/QC - Year and Quarter of Event

An explanation of each of these identifiers is given below.

Site Number	Monitoring activities will be conducted at Sites 24 and 78.
Media	GW = Groundwater
Station Number	Each sample location or monitoring well will be identified with a unique identification number.
QA/QC	TB = Trip Blank
Year	The number will reference the calendar year the sample was obtained (e.g., 97 would represent 1997).

Quarter	The last letter of the sample designation corresponds to the quarter of the calendar year in which the sample was collected. A = First quarter (January - March) B = Second quarter (April - June) C = Third quarter (July - September) D = Fourth quarter (October - November)

Under this sample designation format the sample number 78-GW09DW-97A refers to:

78-GW09DW-97A	Site 89
78-GW09DW-97A	Groundwater sample
78-GW09DW-97A	Monitoring well number 09
78-GW09DW-97A	Deep monitoring well
78-GW09DW-97A	Year 1997
78-GW09DW-97A	First quarter

Under this sample designation format the sample number 78-TB01-97A

78-TB01-97A	Site 78
78-TB01-97A	Trip Blank
78-TB01-97A	Sequential number, in order of collection. The total number will depend upon how many trip blanks are required.
78-TB01-97A	Year 1997
78-TB01-97A	First quarter

This sample designation format will be followed throughout the project.

3.3 Sample Collection and Analyses

The following describes sample collection procedures and analytical requirements of the monitoring program.

3.3.1 Site 24

Groundwater samples will be collected from the identified monitoring wells at Site 24. The following is the low-flow purge and sampling procedure used to obtain groundwater samples:

1. Remove well cap, measure escaping gases from well head using a Photoionization Detector or Flame Ionization Detector. The results of this test will determine if respiratory protection is required.

2. Allow groundwater level to stabilize, if a vent hole was not installed in the well.

3. Measure and record the static water level. Record total depth from well construction tables. Calculate volume of water in well.

4. Lower unused sample tubing (i.e., virgin, 1/4-inch internal diameter polypropylene or polyethylene tubing) slowly into well, until the intake is within the screened interval. Place water level probe just above the water, in well.

5. Commence purging using a peristaltic-type pump. Record the flow rate using a stopwatch and a calibrated container. The flow rate will be adjusted to ambient flow conditions (i.e., do not permit groundwater to be drawn down). Flow rates of less than one liter per minute are expected.

6. Investigation derived waste (i.e., purge water) will be discharged onto the ground surface.

7. Record water quality parameters (WQPs) including temperature, dissolved oxygen, turbidity, pH, and specific conductance at regular intervals. These measurements must be recorded in a field notebook.

8. Purging will be completed when a minimum of three well volumes have been removed and three successive WQP readings have stabilized, or there is no further discernable upward or downward trend. At low values, certain WQPs (such as turbidity and dissolved oxygen) may vary more than 10 percent, but have reached a stable plateau. The U.S. Environmental Protection Agency - Region IV, defines stability of WQPs as having less than 10 nephelometric turbidity units, pH measurements which remain constant within 0.1 standard units, specific conductance varying no more than 10 percent, and a constant temperature for at least three consecutive readings.

9. Upon WQP stabilization, collect groundwater samples from the tubing discharge for target compound list volatile organic, semivolatile organic, and pesticide analyses. In addition, target analyte list metals and oil and grease analyses will be required. Label and preserve containers prior to sample collection.

10. Store samples in a cooler with fresh ice until they are shipped to the laboratory.

The standard operation procedure (SOP) for collection and sampling is located in the SOP section of this document. Table 3-1 provides a summary of well construction details for each well included in the monitoring program at Site 24. Table 3-2 provides the sampling and analysis program for groundwater samples obtained at Site 24.

3.3.2 Site 78

Groundwater samples will be collected from the identified monitoring wells at Site 78. With two exceptions, groundwater sampling procedures described for Site 24 should be followed for groundwater sampling at Site 78. The two exceptions to Site 24 sampling program activities are as follows:

1. Upon WQP stabilization, collect groundwater samples from the tubing discharge for target compound list volatile organic analyses.

2. Investigation derived waste (i.e., purge water) will be containerized and treated as non-hazardous waste liquid. Purge and development water may also be pumped into the on-site treatment system, if operational.

Table 3-1 provides a summary of well construction details for each well included in the monitoring program at Site 78. Table 3-2 provides the sampling and analysis program for groundwater samples obtained at Site 78.

3.4 Quality Assurance / Quality Control

Quality assurance and quality control requirements for the monitoring program are limited to trip blanks.

- Trip blanks are defined as samples comprised of analyte-free water from the laboratory, which are shipped to the sampling site, kept with the investigative samples throughout the sampling event, and returned to the laboratory with the VOC samples. The blanks will only be analyzed for volatile organics. The purpose of a trip blank is to determine if samples were contaminated during storage and transportation back to the laboratory. One trip blank will accompany each cooler containing samples for volatile analyses.

Equipment rinsates, field blanks, field duplicates, and matrix spike/matrix spike duplicates will not be collected during the monitoring program. The samples collected during the program will be considered confirmatory only; therefore, extraneous QA/QC samples have been eliminated from the program.

TABLES

TABLE 3-1

SUMMARY OF WELL CONSTRUCTION DETAILS
LONG-TERM MONITORING PLAN
OPERABLE UNIT NO. 1 - SITES 24 AND 78
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Top of Casing Elevation (feet, msl)	Ground Surface Elevation (feet, msl)	Boring Depth (feet, bgs)	Well Depth (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)	Stick-Up (feet, ags)
SITE 24									
24-GW08	1993	26.20	23.60	19.0	19.0	9.1-18.2	7.0	5.0	NA
24-GW09	1993	16.55	13.80	12.5	12.5	2.6-11.7	1.5	0.5	NA
24-GW10	1993	19.33	17.30	18.0	18.0	8.0-17.2	6.0	4.0	NA
SITE 78									
78-GW01	1986	NA	NA	27.0	25.0	5.0-25.0	3.0	2.0	1.80
78-GW04-1	1986	31.63	28.90	27.0	24.5	4.5-24.5	3.0	2.0	2.60
78-GW08	1986	28.72	26.30	27.0	25.0	5.0-25.0	3.0	2.0	3.12
78-GW09-1	1987	NA	NA	27.0	25.0	5.0-25.0	3.0	2.0	2.35
78-GW09-2	1987	27.60	25.40	152	150	130-150	105	100	1.92
78-GW09-3	1986	26.97	24.70	152	150	130-150	105	10.0	2.25
78-GW10	1986	28.13	25.70	27.0	25.0	5.0-25.0	3.0	2.0	2.22
78-GW11	1986	28.22	25.50	25.5	25.0	5.0-25.0	3.0	2.0	2.49
78-GW14	1986	27.32	25.00	25.5	25.0	5.0-25.0	3.0	2.0	1.92
78-GW15	1986	27.03	26.80	25.5	25.0	5.0-25.0	3.0	2.0	0.08
78-GW17-1	1986	30.00	27.50	25.5	25.0	5.0-25.0	3.0	2.0	2.16
78-GW21	1986	33.51	31.20	25.0	25.0	5.0-25.0	3.0	2.0	NA
78-GW22	1986	32.36	30.40	25.0	25.0	5.0-25.0	3.0	2.0	NA
78-GW23	1986	32.08	30.00	25.5	25.0	5.0-25.0	3.0	2.0	1.82
78-GW24-1	1986	32.84	30.50	25.5	25.0	5.0-25.0	3.0	2.0	1.55
78-GW24-2	1987	33.73	30.40	80.0	76.6	56.6-76.6	51.6	48.6	2.88
78-GW24-3	1987	32.32	30.50	155	148	128-148	90.0	84.0	2.24
78-GW25	1986	32.58	30.10	25.5	25.0	5.0-25.0	5.0	3.0	2.17
78-GW39	1993	19.44	16.80	20.0	20.0	10.0-20.0	8.0	6.0	19.44

Notes:

ags = Above ground surface
bgs = Below ground surface
msl = Mean sea level
NA = Information not available

TABLE 3-2

SAMPLE SUMMARY MATRIX
LONG-TERM MONITORING PLAN
OPERABLE UNIT NO. 1 - SITES 24 AND 78
MCB, CAMP LEJEUNE, NORTH CAROLINA

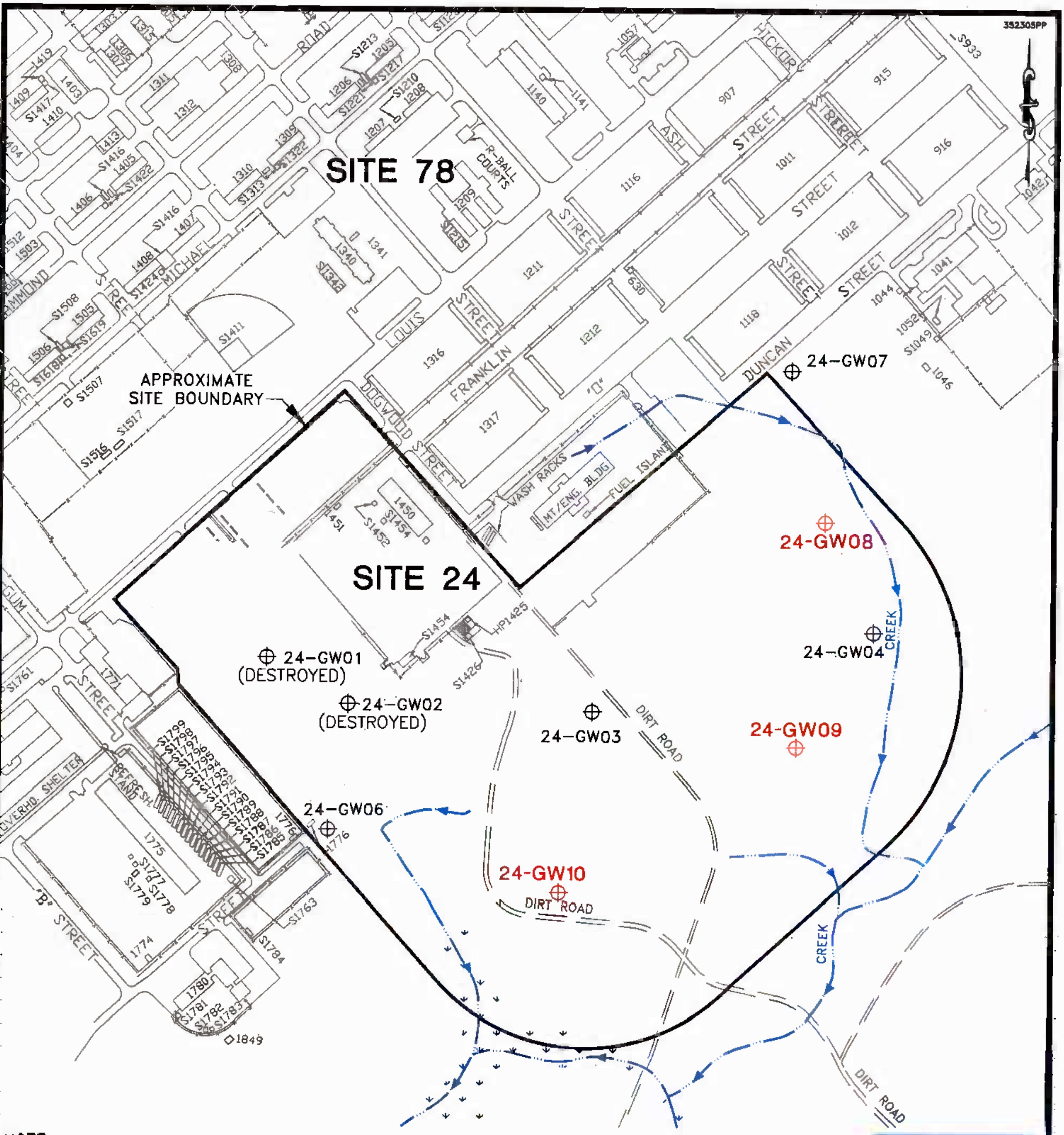
Location	Media	TCL Volatiles(1)	TCL Pesticides (2)	TAL Metals(3)	Oil & Grease(4)	Total Dissolved Solids(5)	Total Suspended Solids(5)
SITE 24							
24-GW08	GW	X	X	X	X	X	X
24-GW09	GW	X	X	X	X	X	X
24-GW10	GW	X	X	X	X	X	X
SITE 78							
78-GW01	GW	X					
78-GW04-1	GW	X					
78-GW08	GW	X					
78-GW09-1	GW	X					
78-GW09-2	GW	X					
78-GW09-3	GW	X					
78-GW10	GW	X					
78-GW11	GW	X					
78-GW14	GW	X					
78-GW15	GW	X					
78-GW19	GW	X					
78-GW21	GW	X					
78-GW22	GW	X					
78-GW23	GW	X					
78-GW24-1	GW	X					
78-GW24-2	GW	X					
78-GW24-3	GW	X					
78-GW25	GW	X					
78-GW39	GW	X					

Notes:

(1) Target Compound List Organics by Sold Waste Method 8260.
(2) Target Compound List Pesticides by U.S. EPA Contract Laboratory Program, Statement of Work, Document Number OLM018.0.
(3) Selected Target Analyte List Metals (Antimony, Arsenic, Beryllium, Chromium, Iron, Lead, Manganese, Mercury, Nickel) by USEPA SW-846 Method.
(4) Oil and Grease by Solid Waste Method 9070.
(5) Total Suspended and Dissolved Solids by Solid Waste Method 160.

GW = Groundwater
RW = Recovery Well
X = Requested Analysis

FIGURES



NOTE:
-WELLS SHOWN IN BLACK, SMALL TYPE NOT INCLUDED IN MONITORING PROGRAM.

500 0 250 500 1000

1 inch = 500 ft.

Baker

Baker Environmental, Inc.

LEGEND

GW08 ⊕	SHALLOW MONITORING WELL
— ◄ —	APPROXIMATE DIRECTION OF SURFACE WATER FLOW
———	APPROXIMATE SITE BOUNDARY

SOURCE: LANTDIV, FEB. 1992

FIGURE 3-1
SAMPLING LOCATION MAP
OPERABLE UNIT No. 1 – SITE 24
MONITORING WORK PLANS, CTO-0352

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01782.TJB1Y

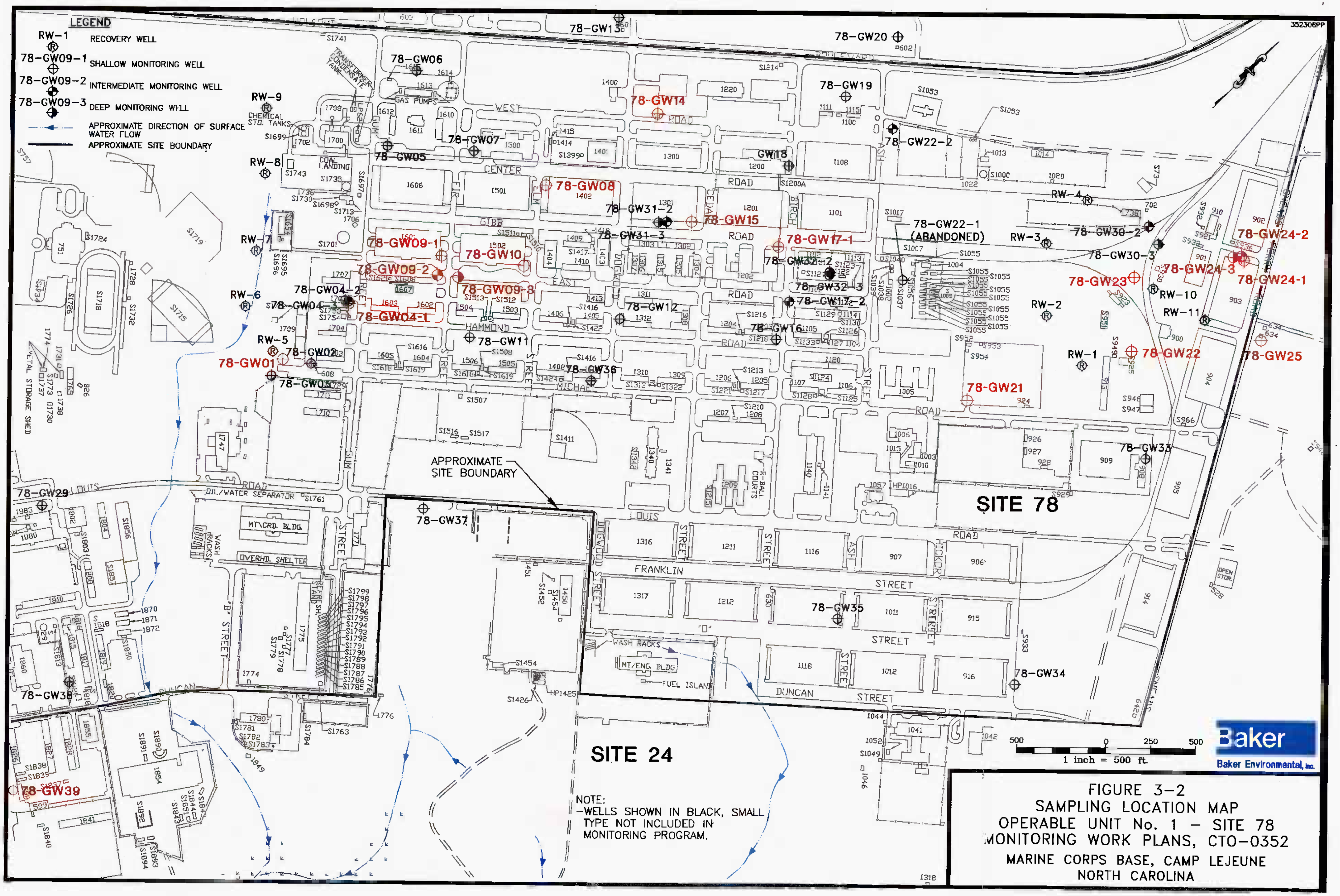


FIGURE 3-2
SAMPLING LOCATION MAP
OPERABLE UNIT No. 1 – SITE 78
MONITORING WORK PLANS, CTO-0352
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

TABLE OF CONTENTS

1.0 OBJECTIVES

The objective of this monitoring work plan is to fulfill the requirements of the final Record of Decision (ROD) for Operable Unit No. 4 (Sites 41 and 74), signed on December 5, 1995. Documents which pertain to the accepted remedial alternative for Sites 41 and 74 are as follows:

- Final Remedial Investigation Report - May 8, 1995
- Final Feasibility Study - May 8, 1995
- Final Proposed Remedial Action Plan - May 8, 1995
- Final Record of Decision - June 22, 1995
- Revised Final Record of Decision - October 17, 1995

The selected remedy for groundwater and surface water at Site 41 is the implementation of institutional controls and monitoring. In accordance with the ROD a groundwater, surface water, and sediment sampling program is required to: periodically sample existing groundwater monitoring wells, periodically collect surface water and sediment samples from the seeps, upgradient and downgradient locations in the unnamed tributary. This remedy provides a permanent long-term solution since the contaminant levels are marginal, and periodic sampling is a reliable means of tracking contaminant migration.

The selected remedy for groundwater at Site 74 is the implementation of institutional controls and monitoring, which will include periodic groundwater sampling of existing monitoring wells and the restriction of groundwater usage in the vicinity of the site. Due to the marginal contaminant levels, this periodic sampling is reliable means of tracking contaminant migration.

The selected remedial alternative for Sites 41 and 74 was approved by the following parties:

- LANTDIV - Naval Facilities Engineering Command, Atlantic Division
- Marine Corps Base Camp Lejeune
- USEPA, Region IV
- North Carolina Department of Environment, Health, and Natural Resources

The implementation of these monitoring plans and any modifications may require an amendment to the final ROD. In addition to the approval provided by these agencies a meeting was held to inform the public about the selected alternative for each of the sites. A thirty day comment period followed this meeting after which time the final ROD was signed.

In order to fulfill the remedial alternative provided in the final ROD, samples from five groundwater monitoring wells (41-GW11, 41-GW02, 41-GW12, 41-GW10, and 41-GW11DW) and eight surface water and sediment samples (three from Tank Creek, three from the unnamed tributary, and two from two separate drainage ditches) will be collected at Site 41. Additionally, four groundwater monitoring wells (74-GW01, 74-GW02, 74-GW03A, and 74-GW07) will be sampled at Site 74. The sampling will be conducted on a semiannual basis for selected analyses that are outlined in Section 3.3 of the Work Plan.

2.0 BACKGROUND

Baker Environmental, Inc. (Baker) initiated a Remedial Investigation (RI) to characterize potential environmental impacts and threats to human health resulting from previous storage, operational, and disposal activities at Sites 41 and 74. The RI was initiated in January 1994 and concluded in March 1994. In August 1994, selected monitoring wells at Sites 41and 74 were re-sampled using a low-flow purging technique to obtain representative groundwater samples for total and dissolved metals analyses. In addition, a second round of surface water and sediment samples were collected at Site 41 to better characterize potential ecological impacts. A final RI report was issued in May 1995. A Feasibility Study (FS) was performed from September 1994 through April 1995. A final FS was issued in May 1995. The final alternatives were documented in the final Record of Decision (ROD) issued on October 17, 1995 consisting of the following:

A groundwater, surface water, and sediment sampling program would be initiated at Site 41 under this alternative. The sampling would initially be conducted semiannually. Once a stable or decreasing trend in contaminant levels was observed, sampling would be reduced to an annual basis. Additionally, institutional controls would include providing restrictions in the Base Master Plan on groundwater usage and on the installation of potable water supply wells within a 500-foot radius of the site boundary.

A groundwater sampling program would be conducted at Site 74 on a semiannual basis until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, sampling would be reduced to an annual basis. Additionally, institutional controls would include providing restrictions in the Base Master Plan on groundwater usage and on the installation of potable water supply wells at the site.

Background information pertaining to Sites 41 and 74 has been documented in the following reports:

- Baker Environmental, Inc. Remedial Investigation Report, Operable Unit No. 4 (Sites 41 and 74) for MCB Camp Lejeune, North Carolina. Final. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. May 1995.

- Baker Environmental, Inc. <u>Baseline Long-Term Monitoring Study, Operable Unit No. 4 (Sites 41 and 74) for MCB Camp Lejeune, North Carolina</u>. Draft. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. 1996.

- Environmental Science and Engineering, Inc. <u>Site Summary Report</u>. Final. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. ESE Project No. 49-02036. 1990.

- Water and Air Research, Inc. <u>Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina</u>. Prepared for Naval Energy and Environmental Support Activity. 1983.

3.0 MONITORING TASKS

3.1 Sampling

The sampling locations included in the monitoring program at Sites 41 and 74 are based upon the results of laboratory analyses from both the remedial investigation and the baseline long-term monitoring study.

Results from each remedial investigation sampling round were compared to those of select media targeted in the baseline monitoring study. Sampling points stipulated in the baseline monitoring study were selected as a result of contaminant levels detected during the remedial investigation.

3.1.1 Site 41

Five groundwater monitoring wells at Site 41 will be sampled as part of the monitoring program. The selected wells include 41-GW02, 41-GW10, 41-GW11, 41-GW11DW, and 41-GW12, presented on Figure 3-1.

Surface water and sediment samples will be collected from eight locations at Site 41, as shown on Figure 3-2. These locations include the following:

●	Unnamed Tributary:	41-UT-SW01	41-UT-SD01
		41-UT-SW02	41-UT-SD02
		41-UT-SW03	41-UT-SD03
●	Tank Creek:	41-TC-SW10	41-TC-SD10
		41-TC-SW11	41-TC-SD11
		41-TC-SW12	41-TC-SD12
●	Drainage Ditches	41-DD-SW01	41-DD-SD01
		41-DD-SW02	41-DD-SD02

These sample identifications were established for the baseline monitoring study (Baker, 1996) and must be maintained throughout the monitoring program in order to correlate data obtained during this period.

3.1.2 Site 74

Four groundwater monitoring wells at Site 74 will be sampled as part of the long-term monitoring program. The groundwater wells selected for long-term monitoring include 74-GW01, 74-GW02, 74-GW03A, and 74-GW07.

3.2 Sample Designation

In order to identify and accurately track the various samples, all samples collected during this investigation, including QA/QC samples, will be designated with a unique number. The sample number will serve to identify the investigation, the site, the sample media, sampling location, the depth (sediment) or round (groundwater) of the sample, QA/QC qualifiers, and the quarter and year in which the samples were collected.

The sample designation format is as follows:

> Site #-Surface Water Body (optional)-Media and Station # or QA/QC-Year and event

An explanation of each of these identifiers is given below.

Site#	This investigation includes Sites 41 and 74
Surface Water	TC = Tank Creek UT = Unnamed Tributary DD = Drainage Ditch

Media	GW = Groundwater SW = Surface Water SD = Sediment
Station#	Each sample location or monitoring well will be identified with a unique identification number. Single digit location numbers must be proceeded by a 0 (i.e., 41-GW02)
QA/QC	(TB) = Trip Blank (ER) = Equipment Rinsate (FB) = Field Blank
Year	The number will reference the calendar year the sample was obtained. For example: 96 = 1996 97 = 1997
Quarter	The last letter of the sample designation corresponds to the quarter of the calendar year in which the sample was collected. A = First quarter (January - March) B = Second quarter (April - June) C = Third quarter (July - September) D = Fourth quarter (October - November)

Under this sample designation format the sample number 41-GW11DW-97A refers to:

41-GW11DW-97A	Site 41
41-GW11DW-97A	Groundwater sample
41-GW11DW-97A	Monitoring well #11

41-GW11DW-97A	Deep monitoring well
41-GW11DW-97A	Year 1997
41-GW11DW-97A	First quarter

Under this sample designation format the sample number 41-UT-SW08-97A

41-UT-SW08-97A	Site 41
41-UT-SW08-97A	Unnamed Tributary
41-UT-SW08-97A	Surface Water sample
41-UT-SW08-97A	Sampling Station #8
41-UT-SW08-97A	Year 1997
41-UT-SW08-97A	First quarter

Under this sample designation format the sample number 41-UT-SD08-97A

41-UT-SD08-97A	Site 41
41-UT-SD08-97A	Unnamed Tributary
41-UT-SD08-97A	Sediment sample
41-UT-SD08-97A	Sampling Station #8
41-UT-SD08-97A	Year 1997
41-UT-SD08-97A	First quarter

Under this sample designation format the sample number 41-TB01-97A

41-TB01-97A	Site 41
41-TB01-97A	Trip Blank
41-TB01-97A	Sequential number
41-TB01-97A	Year
41-TB01-97A	First quarter

This sample designation format will be followed throughout the project. Required deviations to this format in response to field conditions will be documented.

3.3 Sample Collection and Analyses

3.3.1 Site 41

Groundwater samples will be collected from the identified monitoring wells at Site 41. The following is the low-flow purge and sampling procedure to be used for obtaining the groundwater samples:

1. The well cap will be removed, and escaping gases will be measured at the well head using a Photoionization Detector (PID) or Flame Ionization Detector (FID). This will assist in determining the need for respiratory protection.

2. The well will be allowed to equilibrate to atmospheric pressure, in the event that a vent hole was not installed in the well.

3. The static water level will be measured. The total depth of the well will not be measured as to not stir up the sediment. The total depth will be obtained from boring logs. The water volume in the well will then be calculated.

4. The sampling device intake (virgin, 1/4 inch ID polypropylene or polyethylene tubing) Will slowly be lowered until the bottom end is 2 to 3 feet below the top of the water. Based on water levels, this depth will be a point within the screened interval. Next, the water level probe will be placed into the well, just above the water.

5. Purging will then begin. The discharge rate will be measured using a stopwatch and calibrated container. The flow rate will be adjusted to ambient flow conditions (i.e., no drawdown is observed in the well). Flow rates of less than 1 liter per minute (L/min) are expected.

6. Investigative Derived Waste (IDW) (i.e., purge water) will be discharged onto the ground surface at Site 41.

7. The water quality parameters (WQPs), including dissolved oxygen, turbidity, pH, and specific conductance will be measured frequently. Temperature must also be measured. These measurements must be recorded in a field log notebook.

8. Purging will be completed when a minimum of three well volumes have been removed and three successive WQP readings have stabilized within 10%, or there is no further discernable upward or downward trend. At low values, certain WQPs (such as turbidity and dissolved oxygen) may vary more than 10%, but have reached a stable plateau.

9. Upon WQP stabilization, groundwater samples will be collected. Samples for volatile organic analysis (VOAs) will be collected first, followed by metals, total dissolved solids (TDS), and total suspended solids (TSS). Sample containers will be labeled prior to collection.

10. The sample jars will be stored in a cooler on ice until they are shipped to the laboratory.

The standard operation procedure (SOP) for collection and sampling is located in the SOP section of this document. Table 3-1 provides a summary of the available well construction details for each well included in this monitoring program. Table 3-2 defines the sampling and analysis program for the groundwater monitoring wells at Site 41.

Surface water samples will be collected from eight discrete locations at Site 41. The following is the sampling method to be used to obtain the surface water samples:

1. Surface water samples must be collected from downstream to upstream locations to prevent potential migration of contaminants to downstream stations before sampling has been conducted, if required.

2. Samples will be collected by dipping the sample bottles directly into the water. An unpreserved, laboratory-decontaminated transfer bottle will be used to fill preserved bottles. Additionally, a transfer bottle will be used to fill all bottles if surface water is too shallow. Care will be taken when collecting samples for VOAs to avoid excessive agitation that could result in the loss of volatiles. Samples will be collected in the following order volatile organics then metals. Sample containers will be labeled prior to collection.

3. If sample containers do not contain preservative they should be rinsed at least once with the sample water prior to the final sample collection. In addition, the sampling container used to transfer the surface water into the sample bottles containing preservative will be rinsed once with the sample water.

4. Temperature, pH, specific conductance, and dissolved oxygen must be measured in the field at each sampling station immediately following sample collection.

5. The sample containers will be stored in a cooler with ice until laboratory shipment.

One sediment sample will be collected from eight discrete locations at Site 41. The following is the sampling method to be used to obtain the sediment samples:

1. At each station the sediment sample will be collected after the surface water sample has been collected.
2. Sediment samples will be collected from downstream to upstream locations to prevent potential migration of contaminants to downstream stations before sampling has been conducted.
3. One sediment sample from 0- to 6- inches.
4. The sediment sample interval at each station will be collected with a stainless steel hand-held coring instrument (sediment sleeve). A disposable clear plastic liner tube, fitted with and eggshell catcher to prevent sample loss, will be used at each station.
5. The coring sleeve will be pushed into the sediment to a depth of 6-inches or until refusal, which ever is encountered first. The sediment sample will be extruded from the liner with a decontaminated extruder and homogenized prior to being transferred to the laboratory containers. Samples for VOAs will not be homogenized.
6. Sediment for VOAs will be placed directly into the sample container. The sample container will be filled completely, without headspace, to minimize volatilization. The remaining sediment will be placed into a decontaminated stainless steel bowl and throughly mixed utilizing stainless steel spoons. The sample containers for the metal analysis will then be filled. Sample jars will be labeled prior to sample collection.
7. The sample containers will be stored in a cooler with ice until laboratory shipment.

The SOPs for surface water and sediment sampling are located in the SOP section of this document.

Table 3-2 defines the sampling and analysis program for surface water and sediment at Site 41. All sample locations will be displayed by placing a pin flag at the nearest bank or shore. The sample number will be marked on the pin flag with indelible ink.

3.3.2 Site 74

Groundwater samples will be collected from the identified monitoring wells at Site 74. With the following exception, groundwater sampling procedures for Site 41 should be followed for groundwater sampling at Site 74:

1. Upon WQP stabilization, groundwater samples for TAL metals should be collected first followed by TSS and TDS.

Table 3-1 provides a summary of the available well construction details for each well included in this monitoring program. Table 3-2 defines the sampling and analysis program for the groundwater monitoring wells at Site 74.

3.4 QA/QC

Quality assurance and quality control (QA/QC) requirement for this long-term monitoring program are limited to trip blanks which is defined below.

- Trip blanks are defined as samples which originate from the analyte-free water taken from the laboratory to the sampling site, kept with the investigative samples throughout the sampling event, and returned to the laboratory with the VOA samples. The blanks will only be analyzed for volatile organics. The purpose of a trip blank is to determine if samples were contaminated during storage and transportation back to the laboratory. One trip blank will accompany each cooler containing samples for VOA.

Equipment rinsates, field blanks, field duplicates, and matrix spike/matrix spike duplicates will not be collected during the long-term monitoring program. The samples collected during the program will be considered confirmatory only; therefore, the above QA/QC samples have been eliminated from the program.

TABLES

TABLE 3-1

SUMMARY OF WELL CONSTRUCTION DETAILS
LONG-TERM MONITORING PLAN - SITES 41 AND 74
MAC CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Top of PVC Casing Elevation (feet, above msl)$^{(1)}$	Ground Surface Elevation (feet, above msl)	Boring Depth (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Sand Pack Interval Depth (feet, below ground surface)	Bentonite Interval Depth (feet, below ground surface)	Stick-Up (feet, above ground surface)
Site 41									
41-GW02	NA	NA	NA	NA	NA	NA	NA	NA	NA
41-GW10	02/04/94	13.93	12.10	14.0	13.0	3.0 - 13.0	1.5 - 14.0	0.5 - 1.5	1.83
41-GW11	02/06/94	24.69	21.50	16.0	15.0	5.0 15.0	3.0 - 16.0	0.5 - 3.0	3.19
41-GW11DW	02/07/94	23.63	21.50	52.0	50.0	40.0 - 50.0	37.0 52.0	35.0 - 37.0	2.13
41-GW12	02/08/94	8.41	6.40	17.0	16.0	6.0 - 16.0	4.0 - 17.0	2.0 - 4.0	2.01
Site 74									
74-GW01	1984	NA	NA	NA	24.5	8.5 - 23.5	NA	NA	NA
74-GW02	1984	NA	NA	NA	26.5	12.5 - 27.5	NA	NA	NA
74-GW03A	1986	NA	NA	NA	26.5	11.5 - 26.5	NA	NA	NA
74-GW07	02/18/94	34.52	32.4	17.0	16.5	6.5 - 16.5	3.5 - 17.0	1.5 - 3.5	2.12

Notes:

NA = Information not available
(1) = msl - mean sea level
Horizontal positions are referenced to N.C. State Plane Coordinate System (NAD27) CF = 0.9999216 from USMC Monument Toney.
Vertical datum NGVD 29.

TABLE 3-2

SAMPLE SUMMARY MATRIX
LONG-TERM MONITORING PLAN - SITES 41 AND 74
MCB CAMP LEJEUNE, NORTH CAROLINA

Location	Media	TCL Volatiles (CLP SOW OLM01.8)	TAL Metals (CLP SOW ILM03.0)	Total Dissolved Solids	Total Suspended Solids
SITE 41 **Groundwater Samples**					
41GW02	GW	X	X	X	X
41GW10	GW	X	X	X	X
41GW11	GW	X	X	X	X
41GW11DW	GW	X	X	X	X
41GW12	GW	X	X	X	X
Surface Water Samples					
41-UT-SW01	SW	X	X		
41-UT-SW02	SW	X	X		
41-UT-SW03	SW	X	X		
41-TC-SW10	SW	X	X		
41-TC-SW11	SW	X	X		
41-TC-SW12	SW	X	X		
41-DD-SW01	SW	X	X		
41-DD-SW02	SW	X	X		
Sediment Samples					
41-UT-SD01	SD	X	X		
41-UT-SD02	SD	X	X		
41-UT-SD03	SD	X	X		
41-TC-SD10	SD	X	X		
41-TC-SD11	SD	X	X		
41-TC-SD12	SD	X	X		
41-DD-SD01	SD	X	X		
41-DD-SD02	SD	X	X		

TABLE 3-2 (Continued)

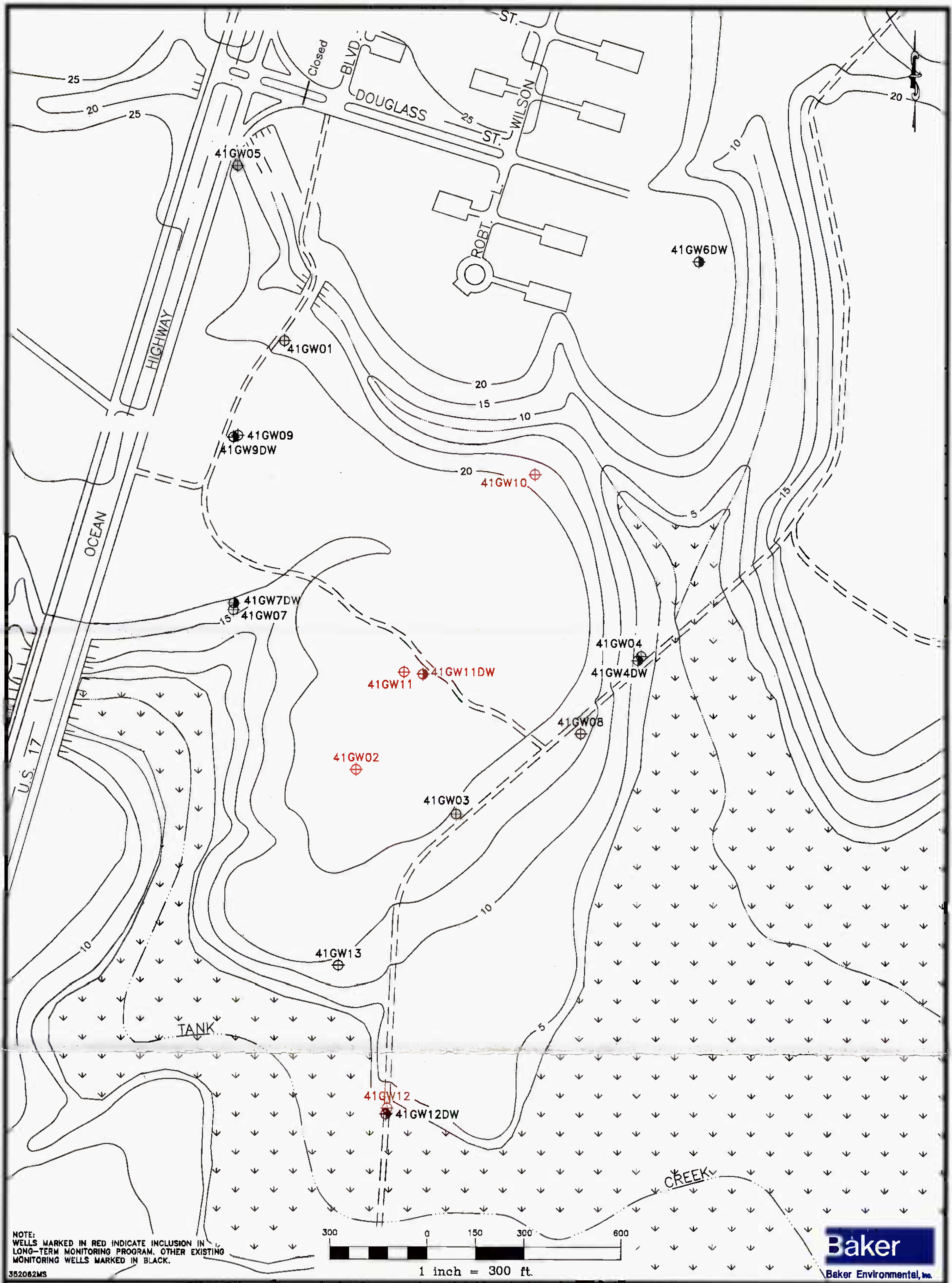
SAMPLE SUMMARY MATRIX
LONG-TERM MONITORING PLAN - SITES 41 AND 74
MCB CAMP LEJEUNE, NORTH CAROLINA

Location	Media	TCL Volatiles (CLP SOW OLM01.8)	TAL Metals (CLP SOW ILM03.0)	Total Dissolved Solids	Total Suspended Solids
SITE 74 **Groundwater Samples**					
74GW01	GW		X	X	X
74GW02	GW		X	X	X
74GW03A	GW		X	X	X
74GW07	GW		X	X	X
Totals		21	25	9	9

Notes:

GW = Groundwater
SW = Surface Water
SD = Sediment

FIGURES



NOTE:
WELLS MARKED IN RED INDICATE INCLUSION IN LONG-TERM MONITORING PROGRAM. OTHER EXISTING MONITORING WELLS MARKED IN BLACK.

352062MS

Baker Environmental, Inc.

LEGEND

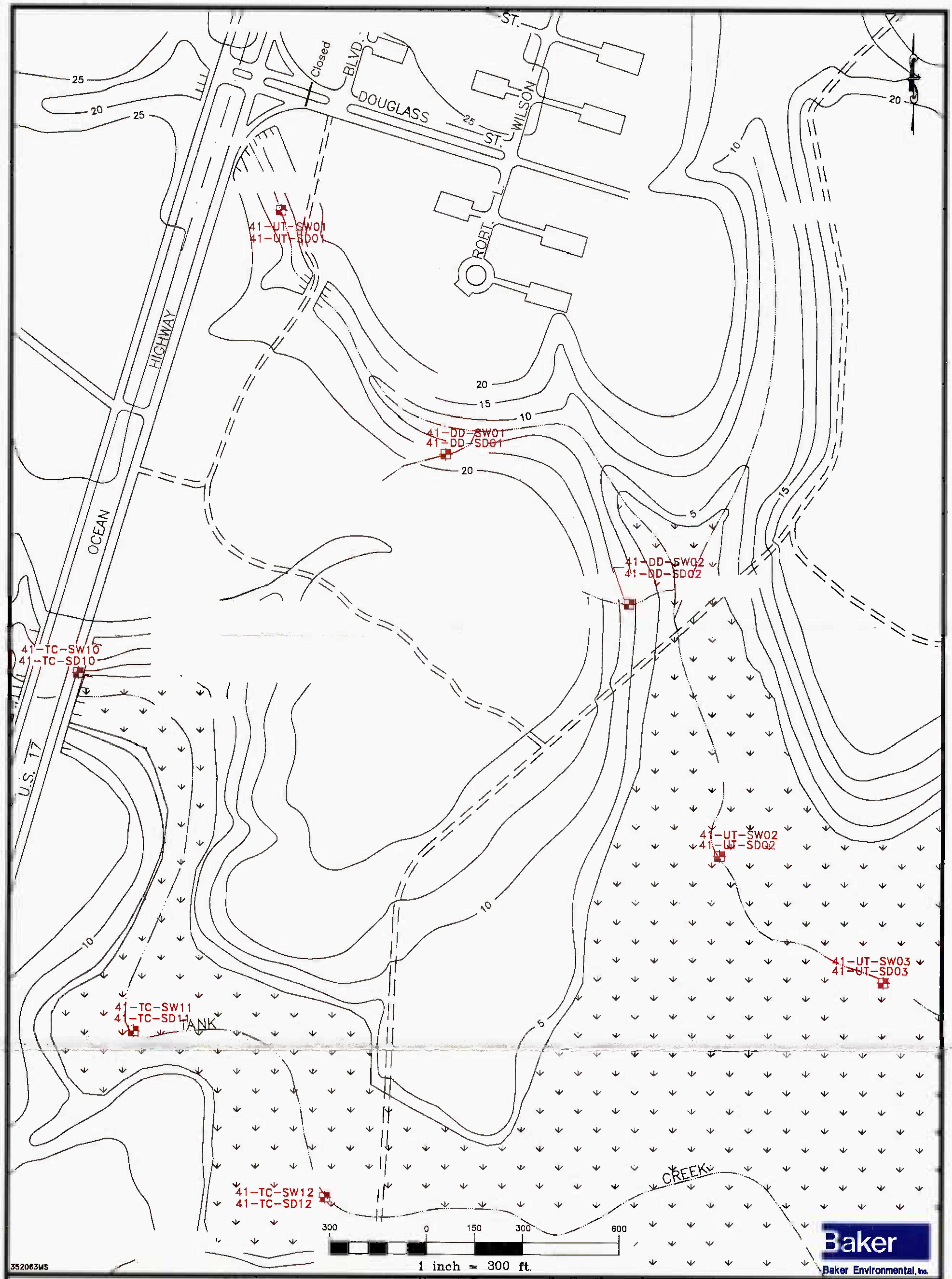
41GW11DW – DEEP MONITORING WELL
41GW01 – SHALLOW MONITORING WELL
– MARSH
5 – TOPOGRAPHIC ELEVATION LINES
– ROAD (IMPROVED)
– ROAD (UNIMPROVED)
– INTERMITTENT STREAM

SOURCE: LANTDIV. OCT. 1991

FIGURE 3-1
SHALLOW AND DEEP MONITORING WELL LOCATIONS
SITE 41 – CAMP GEIGER DUMP
NEAR FORMER TRAILER PARK
CTO-0352

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01782.I.I B2V



LEGEND

41-TC-SW01
41-TC-SD01 – SURFACE WATER/SEDIMENT SAMPLING STATIONS

5 – TOPOGRAPHIC ELEVATION LINES

– ROAD (IMPROVED)

– ROAD (UNIMPROVED)

– INTERMITTENT STREAM

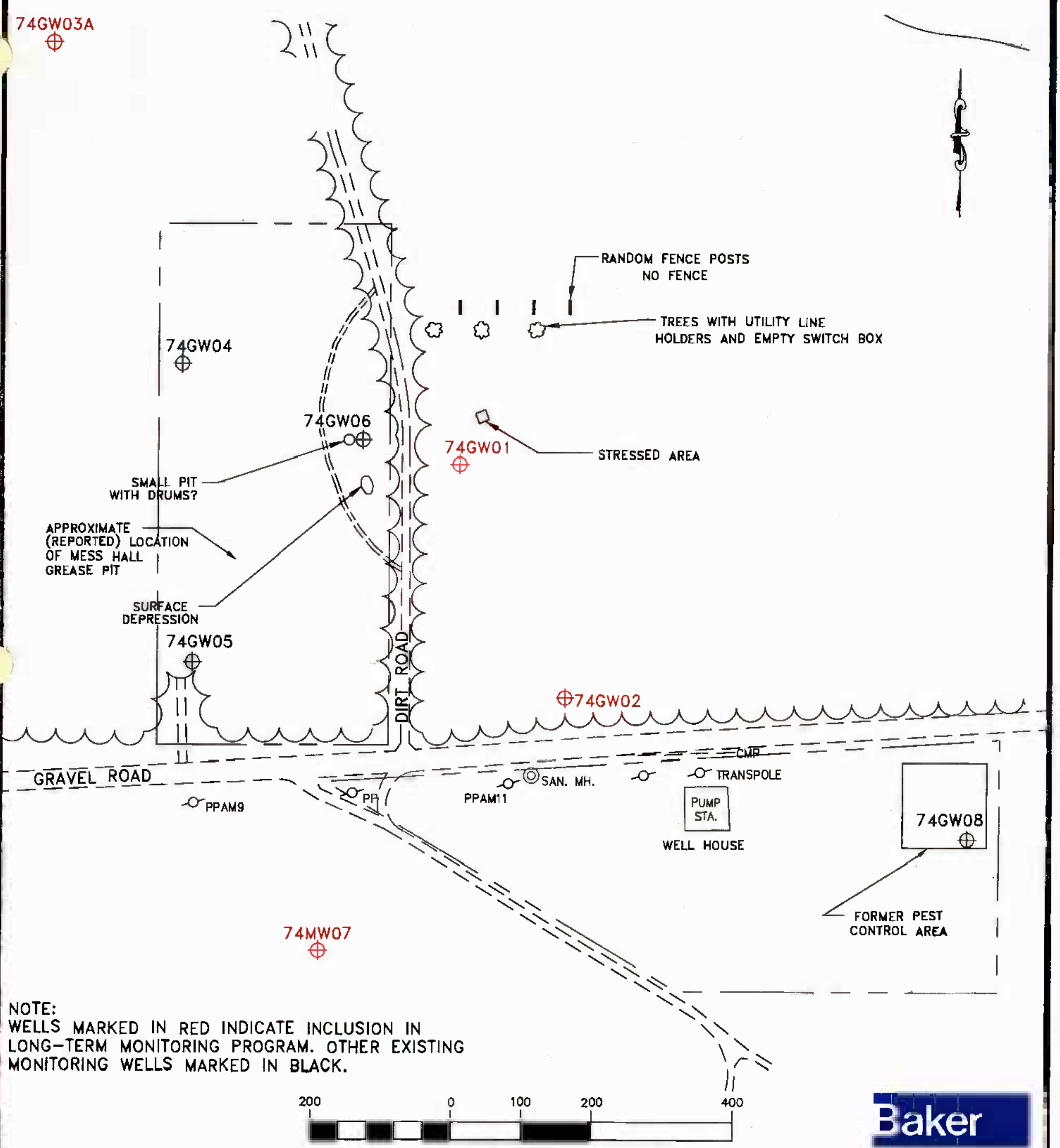
– MARSH

SOURCE: LANTDIV, OCT. 1991

FIGURE 3-2
SURFACE WATER/SEDIMENT SAMPLING LOCATIONS SITE 41 – CAMP GEIGER DUMP NEAR FORMER TRAILER PARK
CTO-0352

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

352060MS



NOTE:
WELLS MARKED IN RED INDICATE INCLUSION IN LONG-TERM MONITORING PROGRAM. OTHER EXISTING MONITORING WELLS MARKED IN BLACK.

Baker
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LEGEND

74GW01 ⊕ SHALLOW MONITORING WELL

ALL CONCENTRATIONS REPORTED IN MICROGRAMS PER LITER (ug/L).

SOURCE: REVISED FROM LANTDIV. OCT. 1991

FIGURE 3-3
GROUNDWATER MONITORING WELL LOCATIONS
SITE 74 – MESS HALL GREASE PIT
DISPOSAL AREA
CTO-0352

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

LIST OF ACRONYMS AND ABBREVIATIONS

OU	Operable Unit
FID	Flame Ionization Detector
PAH	Polycyclic Aromatic Hydrocarbons
PID	Photoionization Detector
QA/QC	Quality Assurance/Quality Control
RI	Remedial Investigation
ROD	Record of Decision
SOP	Standard Operating Procedure
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
WQP	Water Quality Parameter

1.0 OBJECTIVE

The objective of this long-term monitoring work plan is to fulfill requirements stipulated in the Record of Decision (ROD) for Operable Unit (OU) Number 12 (Site 3), signed on April 3, 1997. The work plan describes groundwater monitoring activities to be performed at Site 3. Documents which pertain to the accepted remedial alternative for Site 3 are as follows:

- Final Remedial Investigation Report - July, 1996
- Final Feasibility Study - August, 1996
- Final Proposed Remedial Action Plan - October, 1996
- Final Record of Decision - January, 1997

The ROD for OU No. 12 stipulates that the following items be implemented at Site 3: source removal and biological treatment of soil; establishment of aquifer restrictions; and periodic sampling of monitoring wells in the vicinity of the site. It should be noted that current plans include the source removal of the soil, however, on-site biological treatment may be modified to off-site disposal. In addition, the quarterly groundwater sampling frequency stated in the Final ROD, will be performed on a semiannual basis. The selected remedial alternative for Site 3 was approved by representatives of the following:

- Naval Facilities Engineering Command, Atlantic Division
- Marine Corps Base Camp Lejeune
- U.S. Environmental Protection Agency - Region IV
- North Carolina Department of Environment, Health, and Natural Resources

In addition to agency approval, a public meeting was held to solicit concerns from the community regarding the selected remedial alternative. A 30-day comment period followed the public meeting. The ROD was signed after a responsiveness summary and final version of the decision document had been prepared. The remedy provided within the ROD for Site 3 is a permanent, long-term solution because contaminant levels in groundwater are minimal. Removal of the soil and periodic sampling is a reliable means of eliminating the source and monitoring contaminant persistence and migration. Future amendments or modifications to the monitoring program will need to be recorded, once approved, in a post-decision document file. Changes to the monitoring program will also need to be documented as amendments to this work plan.

2.0 BACKGROUND

Site 3 encompasses approximately five acres, is generally flat and unpaved, and is intersected by a gravel access road. Access to the site is unrestricted directly from Holcomb Boulevard. The Camp Lejeune Railroad lies approximately 200 feet to the west of Site 3. During periods of heavy rain, the eastern portion of the site has several areas of standing water. Surface water runoff from the site flows in both an easterly and westerly direction; runoff ditches flank both the eastern and western edges of the site. To the east is a small drainage way in which ponded water is evident during periods of heavy rain. To the west of the site are drainage areas which parallel the Camp Lejeune Railroad and Holcomb Boulevard. At the present time, the northern portion of Site 3 is used as a staging area for trees and wooden debris created during cleanup from hurricanes in 1996. As a result, monitoring wells 03-MW03 and 03-MW08 are buried.

Baker Environmental, Inc. conducted a Remedial Investigation (RI) of OU No. 12 to evaluate potential threats posed by the release or threatened release of hazardous substances, pollutants, and contaminants at Site 3. The field portion of the RI was completed in three phases from 1994 through 1995. The field program consisted of surface and subsurface soil sampling and a groundwater investigation, including monitoring well installation. Results of the investigation demonstrated that polycyclic aromatic hydrocarbons (PAHs) were the most frequently detected organic contaminants in soil and groundwater. Petroleum constituents, such as ethylbenzene, and xylene, were also detected in surface and subsurface soil at the former treatment area.

In addition to the investigative activities associated with the RI, two baseline groundwater sampling events have been completed at OU No. 12; one in January 1997 and the second in July 1997. Groundwater samples were collected from the following monitoring wells: 03-MW02, 03-MW02IW, 03-MW02DW, 03-MW06, 03-MW11, 03-MW11IW, and 03-MW13. During both baseline events, the existing monitoring wells were sampled for volatile and semivolatile organic analyses. Volatile and semivolatile organic compounds were detected among groundwater samples from both sampling events at Site 3.

The monitoring program presented herein is based upon the previous investigation findings, the recent 1997 sampling data, and decision documents. The ROD for OU No. 12 stipulates that groundwater samples from seven monitoring wells including, 03-MW02, 03-MW02IW, 03-MW02DW, 03-MW06, 03-MW07, 03-MW08, 03-MW11, be collected quarterly for the following analyses:

- Volatile Organic Analyses
- Semivolatile Organic Analyses

Section 3.0 presents the monitoring plan for Site 3 and provides a detailed discussion of sampling locations and procedures.

Additional background information pertaining to Site 3 is provided within the following reports:

- Baker Environmental, Inc. Remedial Investigation Report, Operable Unit No. 12 (Site 3) MCB Camp Lejeune, North Carolina. Final. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. July 1996.

- Haliburton/NUS, 1991. Preliminary Draft Site Inspection Report for Site 3 Old Creosote Plant. Marine Corps Base, Camp Lejeune, North Carolina.

- Environmental Science and Engineering, Inc. Site Summary Report. Final. Marine Corps Base, Camp Lejeune, North Carolina. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. ESE Project No. 49-02036. 1990.

- Water and Air Research, Inc. Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity. 1983.

2.1 Site History

Site 3 was occupied by a creosote plant from 1951 to 1952 to supply treated lumber during construction of the Base railroad. Logs were cut into railroad ties at an on-site sawmill, then pressure treated with hot creosote stored in a railroad tank car. There is no indication of creosote disposal on site, and records show that creosote remaining in the pressure chamber at the end of the treatment cycle was stored for future use. Historical information indicates that the on-site sawmill was located to the north of the current gravel access road (Baker, 1994). Because creosote is comprised of primarily PAH compounds, the PAHs detected at Site 3 are believed to be associated with operations at the former creosote plant. The highest PAH concentrations in soil occurred in the treatment area of the site.

3.0 MONITORING TASKS

The section which follows provides specific procedures for implementing the monitoring program at OU No. 12, Site 3. In addition, sampling locations, sample analyses, and sample designations are included within this section. The sampling locations included in the monitoring program at Site 3 are based upon laboratory results and observational data from both the RI and previous monitoring events. The sections which follow provide the number and location of samples to be obtained semiannually as part of the monitoring program at Site 3.

3.1 Sampling

Groundwater samples will be collected from five shallow monitoring wells, two intermediate wells, and one deep monitoring well. Samples obtained from shallow and intermediate monitoring wells will be used to assess potential contaminant concentrations in both the upper and lower portions of the surficial aquifer. The groundwater sample obtained from the deep monitoring well will be used to confirm whether known contaminants are migrating from the surficial aquifer to the Castle Hayne Aquifer. The following monitoring wells will be included in the sampling program at Site 3: 03-MW02, 03-MW02IW, 03-MW02DW, 03-MW06, 03-MW07, 03-MW08, 03-MW11, 03-MW11IW, and 03-MW13. Although monitoring well 03-MW08 is included in the monitoring program, it is currently inaccessible and cannot be used for sampling. At the present time, it is buried beneath large piles of trees and wooden debris which have been staged in the northern portion of Site 3. If the debris is removed, and monitoring well 03-MW08 becomes available at a later date, sample collection can then be initiated at this monitoring well.

The sampling points are largely based upon the RI findings and the ROD, however, additions have been made based upon the baseline sampling data, groundwater flow direction, and site conditions. The monitoring wells were selected as sampling points based upon several items as outlined below:

- The majority of the selected monitoring wells are local to the impacted area identified during the RI.
- Recent sampling data noted positive detections in the majority of samples obtained from these monitoring wells.
- Groundwater flows to the west at Site 3, in the direction of Holcomb Blvd.
- The sampling locations allow for the assessment of site conditions at the source area as well as providing information concerning possible migration of contaminants off-site, both horizontally and vertically.

Table 3-1 provides construction details for each of the eight wells included in the monitoring program. The locations of monitoring wells throughout Site 3 are depicted in Figure 3-1.

3.2 Sample Designations

In order to identify and accurately track the various samples, all samples collected during the monitoring program, including quality assurance and quality control (QA/QC) samples, will be designated with a unique identification number. The sample number will serve to identify the investigation, the site, the sample media, sampling location, QA/QC samples, and the quarter and year in which the samples were collected.

The sample designation format is as follows:

Site Number - Media and Station Number or QA/QC - Year and Quarter of Event

An explanation of each of these identifiers is given below.

Site Number	Monitoring activities will be conducted at Site 3.
Media	GW = Groundwater
Station Number	Each sample location or monitoring well will be identified with a unique identification number. Single digit location numbers must be proceeded by a zero (e.g., 03-GW02).
QA/QC	TB = Trip Blank
Year	The number will reference the calendar year in which the sample was obtained (e.g., 98 would represent 1998).
Quarter	The last letter of the sample designation corresponds to the quarter of the calendar year in which the sample was collected. A = First quarter (January - March) B = Second quarter (April - June) C = Third quarter (July - September) D = Fourth quarter (October - November)

Under this sample designation format the sample number IR 03-GW02IW-98A refers to:

IR03-GW02IW-98A	Installation Restoration
IR03-GW02IW-98A	Site 3
IR03-GW02IW-98A	Groundwater sample
IR03-GW02IW-98A	Monitoring well number 02
IR03-GW02IW-98A	Intermediate monitoring well
IR03-GW02IW-98A	Year 1998
IR03-GW02IW-98A	First quarter

Under this sample designation format the sample number IR 03-TB01-98A

IR03-TB01-98A	Installation Restoration
IR 03-TB01-98A	Site 3
IR 03-TB01-98A	Trip Blank
IR 03-TB01-98A	Sequential number, in order of collection. The total number will depend upon how many trip blanks are required.
IR 03-TB01-98A	Year 1998
IR 03-TB01-98A	First quarter

This sample designation format will be followed throughout the project.

3.3 Sample Collection and Analyses

The following describes sample collection procedures and analytical requirements of the monitoring program. Periodic redevelopment of monitoring wells may be required prior to groundwater sample collection.

Groundwater samples will be collected from the identified monitoring wells at Site 3. The following is the low-flow purge and sampling procedure used to obtain groundwater samples:

1. Remove well cap, measure escaping gases from well head using a Photoionization Detector (PID) or Flame Ionization Detector (FID). The results of this test will determine if respiratory protection is required.

2. Allow groundwater level to stabilize, if a vent hole was not installed in the well.

3. Measure and record the static water level. Record total well depth from well construction tables. Calculate volume of water in well.

4. Lower unused sample tubing (i.e., virgin, 1/4-inch internal diameter polypropylene or polyethylene tubing) slowly into well, until the intake is within the screened interval of the well. Place water level probe just above the water, in well.

5. Commence purging using a peristaltic-type pump. Record the flow rate using a stopwatch and a calibrated container. The flow rate will be adjusted to ambient flow conditions (i.e., do not permit groundwater to be drawn down). Flow rates of less than 1 liter per minute are expected.

6. Investigation derived waste (i.e., purge water) will be discharged onto the ground surface.

7. Record water quality parameters (WQPs) including temperature, dissolved oxygen, turbidity, pH, and specific conductance at regular intervals. These measurements must be recorded in a field notebook.

8. Purging will be completed when a minimum of three well volumes have been removed and three successive WQP readings have stabilized, or there is no further discernable upward or downward trend. At low values, certain WQPs (such as turbidity and dissolved oxygen) may vary more than 10 percent, but have reached a stable plateau. The U.S. Environmental protection Agency - Region IV defines stability of WQPs as having less than 10 nephlometric turbidity units, pH measurements which remain constant within 0.1 standard units, specific conductance varying no more than 10 percent, and a constant temperature for at least three consecutive readings.

9. Upon WQP stabilization, collect groundwater samples for volatile organic analysis (VOAs). Label and preserve containers prior to sample collection.

10. Store samples in a cooler with ice until they are shipped to the laboratory.

The standard operation procedure (SOP) for collection and sampling is located in the SOP section of this document. Table 3-1 provides a summary of well construction details for each well included in the monitoring program at Site 3. Table 3-2 provides the sampling and analysis program for groundwater samples obtained at Site 3.

3.4 Quality Assurance/Quality Control

Quality assurance and quality control requirements for the monitoring program are limited to trip blanks.

- Trip blanks are defined as samples comprised of analyte-free water from the laboratory, which are shipped to the sampling site, kept with the investigative samples throughout the sampling event, and returned to the laboratory with the volatile organic compounds (VOC) samples. The blanks will only be analyzed for volatile organics. The purpose of a trip blank is to determine if samples were contaminated during storage and transportation back to the laboratory. One trip blank will accompany each cooler containing samples for volatile analyses.

Equipment rinsates, field blanks, field duplicates, and matrix spike and matrix spike duplicates will not be collected during the monitoring program. The samples collected during the program will be considered confirmatory only; therefore, extraneous QA/QC samples have been eliminated from the program.

TABLES

TABLE 3-1

SUMMARY OF WELL CONSTRUCTION DETAILS
LONG-TERM MONITORING PLAN
OPERABLE UNIT NO. 12 - SITE 3
MCB CAMP LEJEUNE, NORTH CAROLINA

Well Number	Date Installed	Top of Casing Elevation (feet, msl)	Ground Surface Elevation (feet, msl)	Boring Depth (feet, bgs)	Well Depth (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)	Stick-Up (feet, ags)
03-MW02	06/12/91	35.91	32.36	17.0	17.0	16.8 - 6.8	2.0	4.0	3.55
03-MW02IW	11/19/94	35.19	32.50	87.0	86.5	86.5 - 71.5	61.0	66.5	2.69
03-MW02DW	06/28/95	34.06	32.19	140.5	140.0	140.0 - 125.0	119.0	122.0	1.87
03-MW06	11/19/94	30.55	27.93	23.0	22.0	22.0 - 7.0	3.5	5.0	2.62
03-MW08	11/20/94	32.62	30.13	18.0	18.0	18.0 - 3.0	2.0	1.0	2.49
03-MW11	06/15/95	32.69	30.69	32.0	31.5	31.5 - 16.5	11.5	14.0	2.0
03-MW11IW	06/29/95	32.55	30.30	88.0	87.0	87.0 - 72.0	66.0	69.0	2.25
03-MW13	06/14/95	22.93	20.80	22.0	21.5	21.5 - 6.5	2.0	4.0	2.13

Notes:

ags = Above ground surface
bgs = Below ground surface
msl = Mean sea level
NA = Information not available

TABLE 3-2

SAMPLE SUMMARY MATRIX
LONG-TERM MONITORING PLAN
OPERABLE UNIT NO. 12 - SITE 3
MCB CAMP LEJEUNE, NORTH CAROLINA

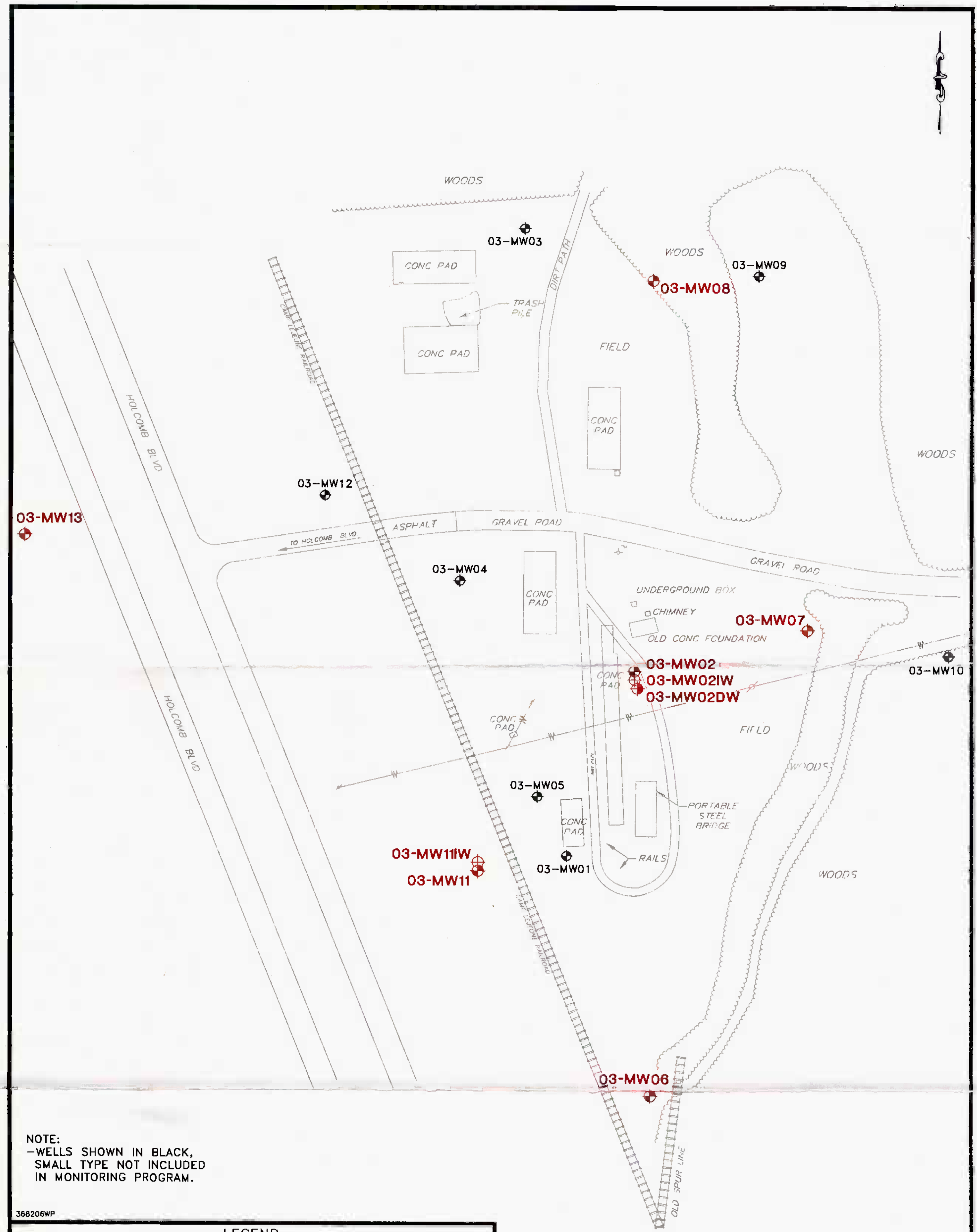
Sample Location	Media	TCL Volatiles[(1)]	TCL Semivolatiles[(2)]
03-MW02	GW	X	X
03-MW02IW	GW	X	X
03-MW02DW	GW	X	X
03-MW06	GW	X	X
03-MW08	GW	X	X
03-MW11	GW	X	X
03-MW11IW	GW	X	X
03-MW13	GW	X	X

Notes:

(1) Target Compound List Volatile Organics by Solid Waste Method 8260.
(2) Target Compound List Semivolatile Organics by Solid Waste Method 8270.

GW = Groundwater
X = Requested Analysis

FIGURES



NOTE:
-WELLS SHOWN IN BLACK,
SMALL TYPE NOT INCLUDED
IN MONITORING PROGRAM.

368206WP

LEGEND

〰 TREE LINE

▥ RAILROAD

03-MW02
⊕ SHALLOW MONITORING WELL

03-MW02IW
⊕ INTERMEDIATE MONITORING WELL

03-MW02DW
⊕ DEEP MONITORING WELL

SOURCE: W.K. DICKSON & Co., INC., JANUARY 1995

120 0 60 120
1 inch = 120 ft.

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FIGURE 3-1
SAMPLING LOCATION MAP
OPERABLE UNIT No. 12 - SITE 3
MONITORING WORK PLAN - CTO-0352

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01782JJ03Y

STANDARD OPERATING PROCEDURES (SOPS)

Groundwater Sample Acquisition

Surface Water and Sediment Sample Acquisition

GROUNDWATER SAMPLE ACQUISITION

GROUNDWATER SAMPLE ACQUISITION
TABLE OF CONTENTS

GROUNDWATER SAMPLE ACQUISITION

1.0 PURPOSE

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

2.0 SCOPE

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

3.0 DEFINITIONS

None.

4.0 PROCEDURES

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to minimize any changes in water quality parameters.

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.

2. Wells that can be pumped to dryness with the sampling equipment being used, shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from separation of flow streams by physical division (for example, around clay lenses) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Purging rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site-specific and must be addressed in the Sampling and Analysis Plan.

4.1 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment: Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.

2. Field tools and instrumentation: PID; Thermometer; pH meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; plastic sheeting; water-level indicator; calibrated buckets and, where applicable, flow meter.

3. Pumps

    a. Shallow-well pumps: Centrifugal, Packer Pumps, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.

    b. Deep-well pumps: Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.

4. Tubing: Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.

5. Other Sampling Equipment: Bailers, Packer Pumps, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

6. Pails: Plastic, graduated.

Ideally, sample withdrawal equipment should be completely inert, economical, easily cleaned, sterilized, and reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well purging and sample collection.

4.2 Calculations of Well Volume for Purging

The volume of the cylinder of water in a well is given by:

$$V_w = \pi r^2 h$$

Where:
V_w = volume of standing water in well (in cubic feet)
π = pi, 3.14
r = well radius (in feet)
h = standing water in well (in feet)

To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).

2. Determine well or casing diameter (D).

3. Measure and record static water level (DW-depth to water below ground level or top of casing reference point).

4. Determine the depth of the well (TD) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure, referenced to the top of PVC casing or ground surface.

5. Calculate number of linear feet of static water (total well depth minus the depth to static water level).

6. Calculate the volume of water in the casing:

$$V_{gal} = V_W \times 7.48 \text{ gallons/ft}^3$$

$$V_{purge} = Vgal\ (\#\ \text{Well Vol})$$

Where:

V_W = Volume of water standing in well in cubic feet (i.e., one well volume)
V_{gal} = Volume of water in well in gallons
V_{purge} = Volume of water to be purged from well in gallons
\# Well Vol. =Number of well volumes of water to be purged from the well (typically three to five)

7. Determine the minimum number of gallons to be evacuated before sampling. (Note: V_{purge} should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

Table 4-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameters.

TABLE 4-1
WELL VOLUMES

Diameter of Casing or Hole (in.)	Gallons per Foot of Depth	Cubic Feet per Foot of Depth
1	0.041	0.0055
2	0.163	0.0218
4	0.653	0.0873
6	1.469	0.1963
8	2.611	0.3491
10	4.080	0.5454

4.3 Evacuation of Static Water (Purging)

The amount of purging a well should receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from a wide area. Generally, three to five well volumes are considered effective for purging a well.

An alternative method of purging a well, and one accepted in EPA Region IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, and water temperature until the values stabilize. The well is considered properly purged when the values have stabilized.

If a well is dewatered before the required volume is purged, the sample should be collected from the well once as a sufficient volume of water has entered the well. In order to avoid stagnation, the well should not be allowed to fully recharge before the sample is collected. The field parameters (pH, conductance, and temperature) should be recorded when the well was dewatered.

4.3.1 Evacuation Devices

The following discussion is limited to those devices which are commonly used at hazardous waste sites. Note that all of these techniques involve equipment which is portable and readily available.

Bailers - Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line (e.g., Teflon-coated) is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate and use.

Limitations on the use of bailers include the following:

- Limited volume of sample.
- Time consuming to remove stagnant water using a bailer.
- Collection and transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.
- Unable to collect depth-discrete sample.

Suction Pumps - There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 10 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps will cause significant loss of dissolved gases, including volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

Gas-Lift Samples - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics. An inert gas such as nitrogen is generally used as a gas source.

Submersible Pumps - Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed air or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- Potentially low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

4.4 Sampling

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.

2. Brief description of area and waste characterization.

3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).

4. Sampling equipment to be used.

5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.

6. Sample preservation requirements.

7. Schedule.

8. List of team members.

9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

4.4.1 Sampling Methods

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNu or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.

2. When proper respiratory protection has been donned, measure the total depth and water level (with decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well .

3. Lower purging equipment or intake into the well to a distance just below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).

4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters. Record the method of discharge measurement.

5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics.

6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice.

Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.

7. Record measurements of specific conductance, temperature, and pH during purging to ensure that the groundwater level has stabilized. Generally, these measurements are made after the removal of three, four, and five well volumes.

8. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.

9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.

10. In the event that groundwater recovery time is very slow (e.g., 24 hours), sample collection can be delayed until the following day. However, it is preferred that such a well be bailed early in the morning so that sufficient volume of water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.

11. Add preservative if required. Label, tag, and number the sample bottle(s).

12. Volatile organics septum vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure. If the second attempt still produces air bubbles, note on Chain-of-Custody form and in field notebook and submit sample to the laboratory.

    Fill the remaining sample containers in order of decreasing volatilability (semivolatiles next, then pesticides, PCBs, inorganics, etc.).

13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.

14. Pack the samples for shipping. Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see SOP F302).

15. Decontaminate all equipment.

4.4.2 Sample Containers

For most samples and analytical parameters, either glass or plastic containers are satisfactory. Container requirements shall follow those given in NEESA 20.2 047B.

4.4.3 Preservation of Samples and Sample Volume Requirements

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. Sample volume and preservation requirements shall follow those given in NEESA 20.2-047B.

4.4.4 Handling and Transporting Samples

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage.

4.4.5 Sample Holding Times

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in NEESA 20.2-047B.

5.0 QUALITY ASSURANCE RECORDS

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).

- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

6.0 REFERENCES

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1996. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Region IV Environmental Services Division, Athens, Georgia.

ATTACHMENT A

ASTM D4448-85A
STANDARD GUIDE FOR SAMPLING GROUNDWATER MONITORING WELLS

Designation: D 4448 – 85a

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Guide for Sampling Groundwater Monitoring Wells[1]

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (1, 2).[2] The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for μg/L (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (3) and an EPA document (4) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

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[1] This guide is under the jurisdiction of ASTM Committee D-34 on Waste Disposal and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

Current edition approved Aug. 23 and Oct. 25, 1985. Published May 1986.

[2] The boldface numbers in parentheses refer to a list of references at the end of this guide.

TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program

Sample and Measurement	Volume Required (mL)	Container P—Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fe Pb/Se/ Ag/Mn/Na	1000–2000	P/G (special acid cleaning).	high purity nitric acid to pH <2	6 months
Mercury	200–300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % $K_2Cr_2O_7$	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500–1000	G	cool, 4°C H_2SO_4 to pH <2	28 days
Miscellaneous	1000–2000	P	cool, 4°C.	28 days
Fluoride	300–500	P		28 days
Chloride	50–200	P/G		28 days
Sulfate	100–500	P/G		48 hours
Nitrate	100–250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25–100	P/G	cool, 4°C or cool, 4°C HCl or H_2SO_4 to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluorocarbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000–2000	G/TFE-fluorocarbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocarbon-lined septum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

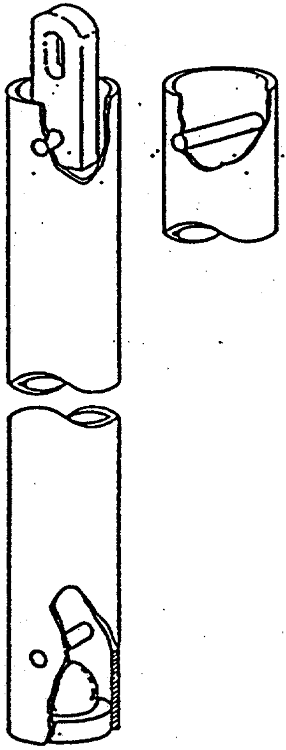
4. Well Flushing (Purging)

4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of samples with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Bailer

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

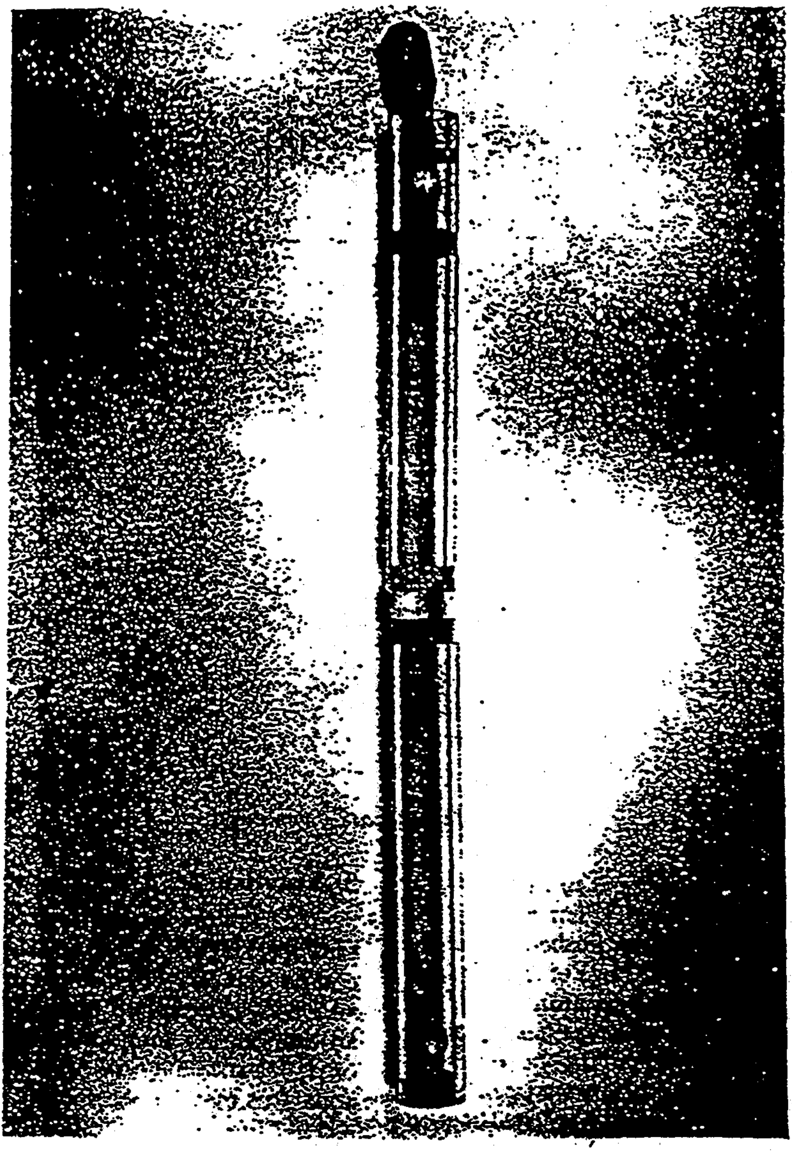
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis (μg/L levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Bailer

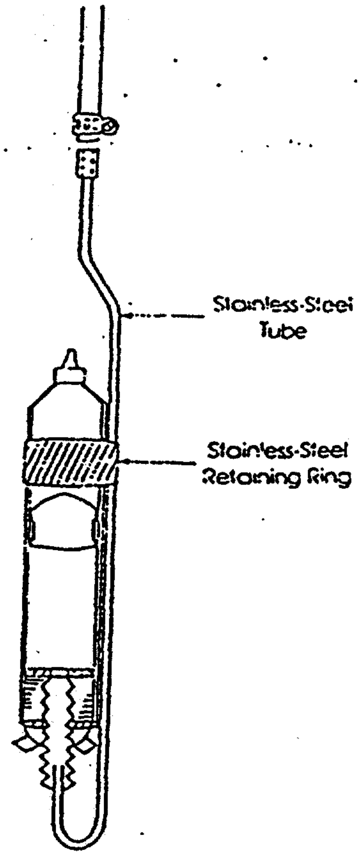
groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of cou glass sampling equipment must be handled carefully in field. Stainless steel is strongly and easily machined



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be nonplastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chemical Society's committee on environmental improvement h published guidelines for data acquisition and data evaluati which should be useful in such environmental evaluatio (10, 12).

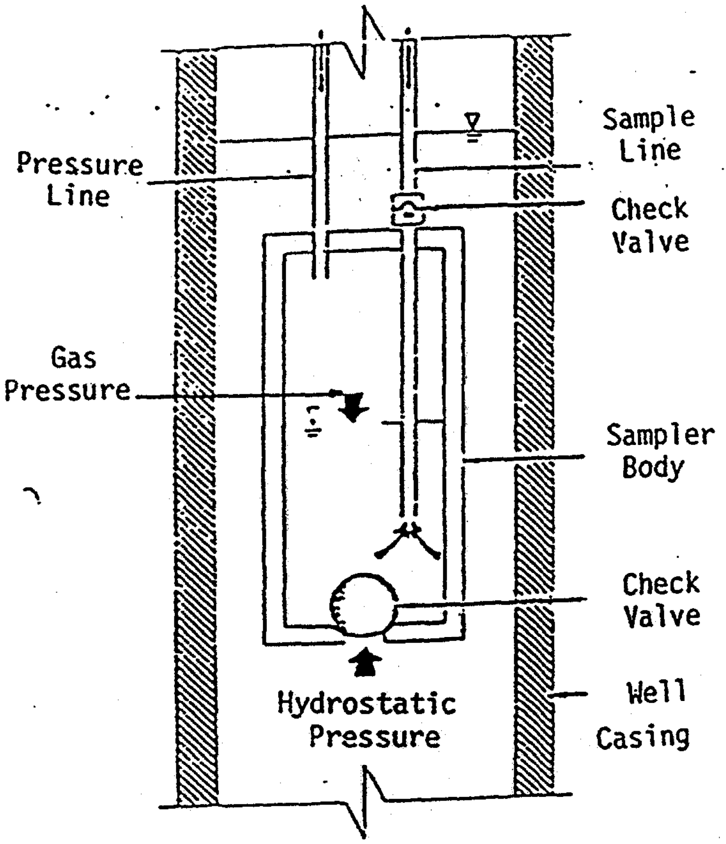
6. Sampling Equipment

6.1 There is a fairly large choice of equipment present available for groundwater sampling from single screen wells and well clusters. The sampling devices can be categ rized into the following eight basic types.

6.1.1 *Down-Hole Collection Devices:*

6.1.1.1 Bailers, messenger bailers, or thief samplers (1 14) are examples of down-hole devices that probably provi valid samples once the well has been flushed. They are n practical for removal of large volumes of water. The devices can be constructed in various shapes and sizes from variety of materials. They do not subject the sample t pressure extremes.

6.1.1.2 Bailers do expose part of the sample to th atmosphere during withdrawal. Bailers used for sampling volatile organic compounds should have a sample cock draft valve in or near the bottom of the sampler allowi withdrawal of a sample from the well below the expose surface of the water or the first few inches of the sampl should be discarded. Suspension lines for bailers and oth samplers should be kept off the ground and free of oth contaminating materials that could be carried into the wel Down-hole devices are not very practical for use in dee



NOTE—Taken from Ref (5).

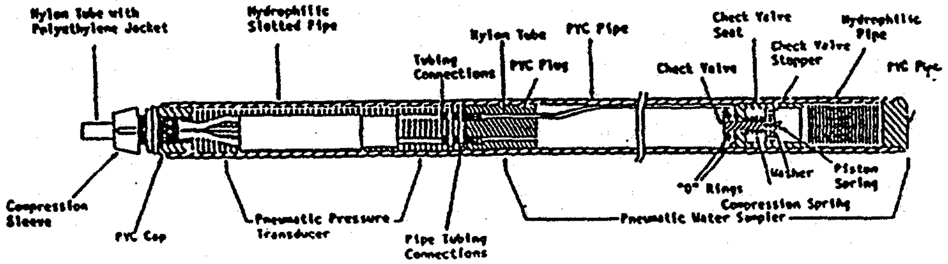
FIG. 4 The Principal of Gas Displacement Pumping

wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

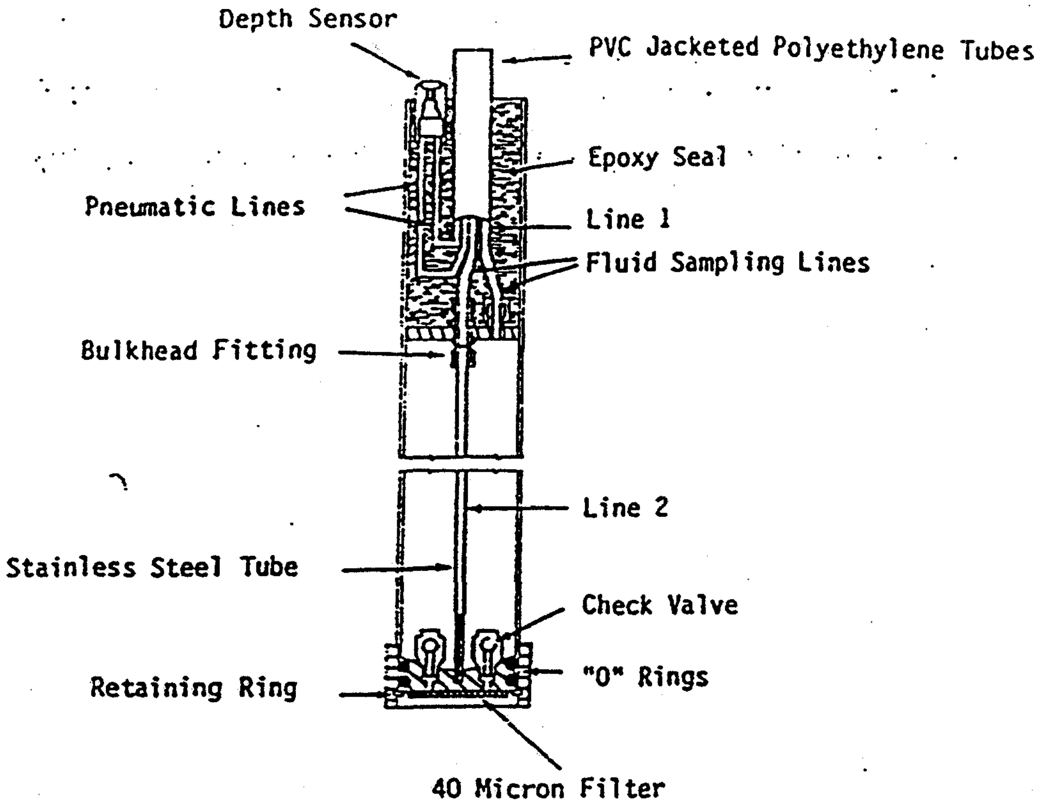
6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

6.1.1.5 A double check valve bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer



NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

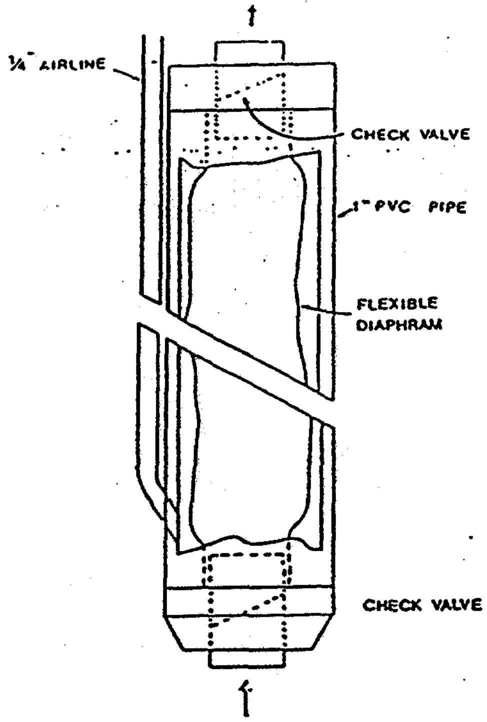
6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number of thief or messenger devices are available in variou materials and shapes.

6.1.2 *Suction Lift Pumps:*

6.1.2.1 Three types of suction lift pumps are the direc line, centrifugal, and peristaltic. A major disadvantage of an suction pump is that it is limited in its ability to raise wate by the head available from atmospheric pressure. Thus, if th surface of the water is more than about 25 ft below th pump, water may not be withdrawn. The theoretical suctio limit is about 34 ft, but most suction pumps are capable o maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water throug some sort of volute in which impellers, pistons, or othe devices operate to induce a vacuum. Such pumps ar probably unacceptable for most sampling purposes becaus they are usually constructed of common materials such a brass or mild steel and may expose samples to lubricants They often induce very low pressures around rotating vane or other such parts such that degassing or even cavitatio may occur. They can mix air with the sample via small leak in the casing, and they are difficult to adequately clea between uses. Such pumps are acceptable for purging o wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peri staltic pump. A peristaltic pump is a self-priming, lov volume suction pump which consists of a rotor with bal bearing rollers (21). Flexible tubing is inserted around th pump rotor and squeezed by heads as they revolve in circular pattern around the rotor. One end of the tubing i placed into the well while the other end can be connecte



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton[3] for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE flourocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

6.1.3 *Electric Submersible Pumps:*

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

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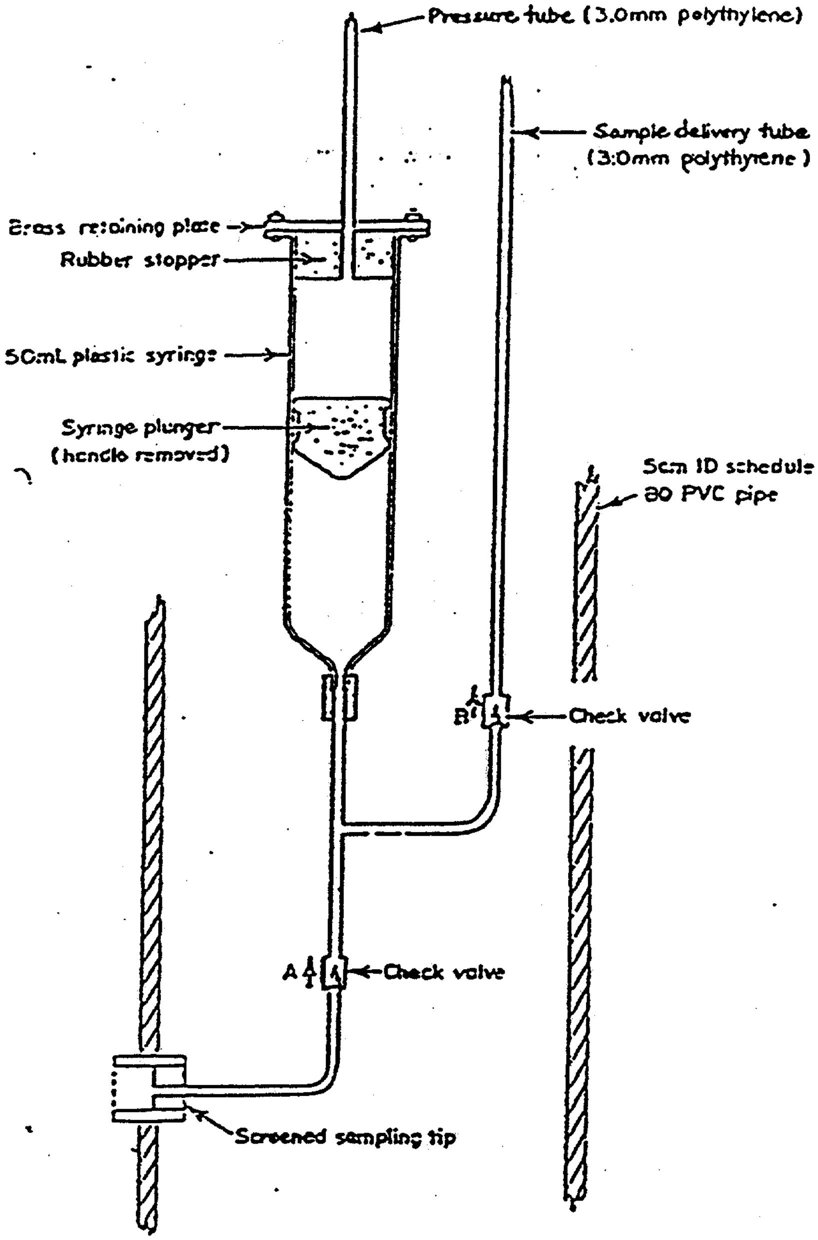
[3] Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

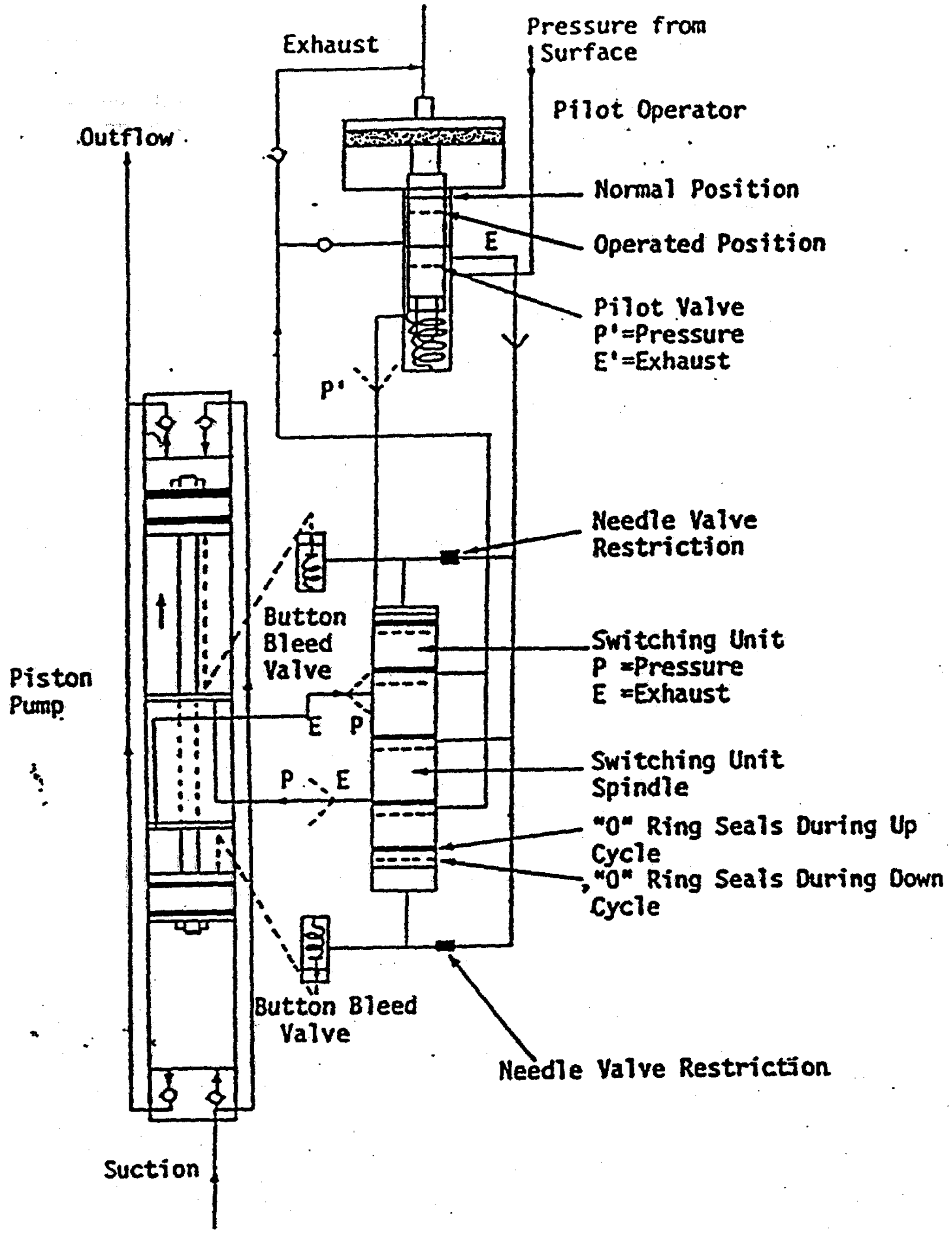
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

6.1.4 *Gas-Lift Pumps:*

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

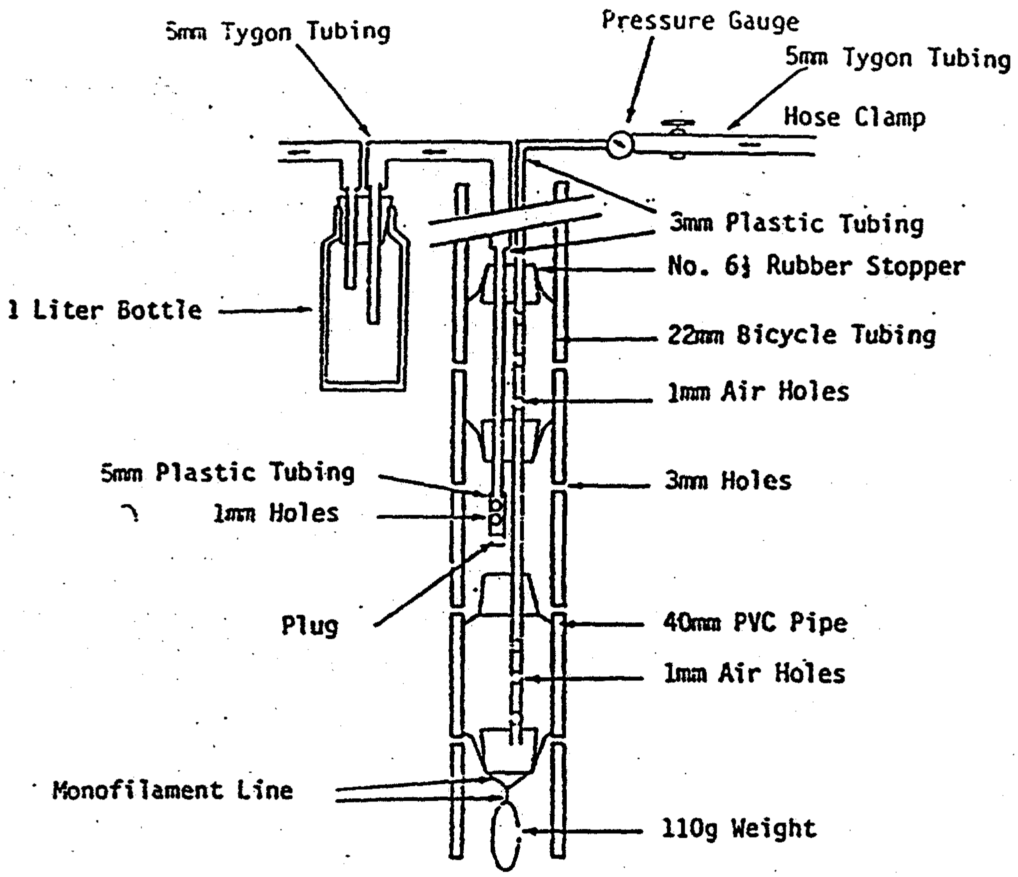
FIG. 9 Gas Driven Piston Pump

6.1.4.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, pressurized air bottles, and air compressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for volatile organics. The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (8) uncovered difficulties in sampling for inorganics. These difficulties were attributed to changes in redox, pH, and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

6.1.5 *Gas Displacement Pumps:*

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig Water fills the chamber. A positive pressure is applied to



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sample in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

6.1.6 *Bladder Pumps:*

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.[3] A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

6.1.7 *Gas Driven Piston Pumps:*

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8 gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

6.1.8 *Packer Pump Arrangement:*

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the formost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be spe[illegible] cases where it might be prudent to include a recor[illegible] thermometer in the sample shipment to verify the maximu[illegible] and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially precleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the labora[illegible] coordinator beforehand. This is especially the case s[illegible] some analyses and preservation measures must be performe[illegible] at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-flourocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are [illegible] be analyzed for acrolein or acrylonitrile (in which case [illegible] are to be analyzed within 3 days). For samples for sol[illegible] extractions (extractable organics-base neutrals, acids and pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

Note—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

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SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION

SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION
TABLE OF CONTENTS

SURFACE WATER AND SEDIMENT SAMPLE ACQUISITION

1.0 PURPOSE

This procedure describes methods and equipment commonly used for collecting environmental samples of surface water and aquatic sediment either for on-site examination and chemical testing or for laboratory analysis.

2.0 SCOPE

The information presented in this SOP is generally applicable to all environmental sampling of surface waters (Section 5.2) and aquatic sediments (Section 5.3), except where the analyte(s) may interact with the sampling equipment.

Specific sampling problems may require the adaptation of existing equipment or design of new equipment.

3.0 DEFINITIONS

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes.

Composite Sample - A sample collected over time that typically consists of a series of discrete samples which are combined or composited.

4.0 PROCEDURES

Collecting a representative sample from surface water or sediments is difficult due to water movement, stratification or patchiness. To collect representative samples, one must standardize sampling bias related to site selection; sampling frequency; sample collection; sampling devices; and sample handling, preservation, and identification.

Representativeness is a qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important quality not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location, selection, and collection methods are important to ensure that a truly representative sample has been collected. Regardless of scrutiny and quality control applied during laboratory analyses, reported data are only as good as the confidence that can be placed on the representativeness of the samples.

4.1 Defining the Sampling Program

Many factors must be considered in developing a sampling program for surface water or sediments including study objectives; accessibility; site topography; flow, mixing and other physical characteristics of the water body; point and diffuse sources of contamination; and personnel and equipment available to conduct the study. For waterborne constituents, dispersion depends on the vertical and lateral mixing within the body of water. For sediments, dispersion depends on bottom current or flow characteristics, sediment characteristics (density, size) and geochemical properties (which effect adsorption/desorption). The sampling plan must therefore reflect not only the mixing characteristics of streams and lakes, but also the role of fluvial-sediment transport, deposition, and chemical sorption.

4.1.1 Sampling Program Objectives

The objective of surface water sampling is to determine the surface water quality entering, leaving or remaining within the site. The scope of the sampling program must consider the sources and potential pathways for transport of contamination to or within a surface water body. Sources may include point sources (leaky tanks, outfalls, etc.) or nonpoint sources (e.g., spills). The major pathways for surface water contamination (not including airborne deposition are: (a) overland runoff; (b) leachate influx to the waterbody; (c) direct waste disposal (solid or liquid) into the water body; and (d) groundwater flow influx to the water body. The relative importance of these pathways, and therefore the design of the sampling program, is controlled by the physiographic and hydrologic features of the site, the drainage basin(s) which encompass the site, and the history of site activities.

Physiographic and hydrologic features to be considered include slopes and runoff direction, areas of temporary flooding or pooling, tidal effects, artificial surface runoff controls such as berms or drainage ditches (when constructed relative to site operation), and locations of springs, seeps, marshes, etc. In addition, the obvious considerations such as the location of man-made discharge points to the nearest stream (intermittent or flowing), pond, lake, estuary, etc., shall be considered.

A more subtle consideration in designing the sampling program is the potential for dispersion of dissolved or sediment-associated contaminants away from the source. The dispersion could lead to a more homogeneous distribution of contamination at low or possibly nondetectable concentrations. Such dispersion does not, however, always readily occur throughout the entire body of water; the mixing may be limited to specific flow streams within the water body. For example, obtaining a representative sample of contamination from the center of a channel immediately below an outfall or a tributary is difficult because the inflow frequently follows a stream bank with little lateral mixing for some distance. Sampling alternatives to overcome this situation are: (1) move the site far enough downstream to allow for adequate mixing, or (2) collect integrated samples in a cross section. Also, nonhomogeneous distribution is a particular problem with regard to sediment-associated contaminants which may accumulate in low-energy environments while higher-energy areas (main stream channels) near the source may show no contaminant accumulation.

The distribution of particulates within a sample itself is an important consideration. Many organic compounds are only slightly water soluble and tend to adsorb on particulate matter. Nitrogen, phosphorus, and the heavy metals also may be transported by particulates. Samples will be collected with a representative amount of suspended material; transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

The first step in selecting sampling locations; therefore, is to review site history, define hydrologic boundaries and features of the site, and identify the sources, pathways and potential distribution of contamination based on these considerations. The numbers, types and general locations of required samples upgradient, on site and downgradient can then be identified.

4.1.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and description of site conditions must be balanced against the costs of collection as controlled by accessibility. Wading or sampling from a stream bank often is sufficient for springs, seeps, and small streams. Bridges or piers are the first choice for locating a sampling station on a larger stream or small river; they provide ready access and also permit the sampling technician to sample any point across the stream or river. A boat or pontoon (with an associated increase in cost) may be needed to sample locations on lakes and reservoirs, as well as those on larger rivers. Frequently, however, a boat will take longer to cross a water body and will hinder manipulation of the sampling equipment.

If it is necessary to wade into the water body to obtain a sample, the sampler shall be careful to minimize disturbance of bottom sediments and must enter the water body downstream of the sampling location. If necessary, the sampling technician shall wait for the sediments to settle before taking a sample. Use of boats or wading to collect samples requires the use of U. S. Coast Guard approved personal flotation devices (PFDs).

Sampling in marshes or tidal areas may require the use of an all-terrain-vehicle (ATV). The same precautions mentioned above with regard to sediment disturbance will apply.

The availability of stream flow and sediment discharge records can be an important consideration in choosing sampling sites in streams. Stream flow data in association with contaminant concentration data are essential for estimating the total contaminant load carried by the stream. If a gaging station is not conveniently located on a selected stream, obtaining stream flow data by direct or indirect methods shall be explored.

4.1.3 Frequency of Sampling

The sampling frequency and the objectives of the sampling event will be defined. For single-event, site- or area-characterization sampling, both bottom material and overlying water samples shall be collected at the specified sampling stations. If valid data are available on the distribution of the contaminant between the solid and aqueous phases it may be appropriate to sample only one phase, although this often is not recommended. If samples are collected primarily for monitoring purposes, consisting of repetitive, continuing measurements to define variations and trends at a given location, water samples shall be collected at established and consistent intervals, as specified in the Sampling and Analysis Plan (often monthly or quarterly), and during droughts and floods. Samples of bottom material shall be collected from fresh deposits at least yearly, and preferably during both spring and fall seasons.

The variability in available water quality data shall be evaluated before deciding on the number and collection frequency of samples required to maintain an effective monitoring program.

4.2 Surface Water Sample Collection

This section presents methods for collection of samples from various surface water bodies, as well as a description of types of surface water sampling equipment. The guidance in this section should be used to develop specific sampling procedures based on site conditions and investigation goals. A summary of sampling techniques and procedures is given in Section 5.2.5.

4.2.1 Streams, Rivers, Outfalls and Drainage Features (Ditches, Culverts)

Methods for sampling streams, rivers, outfalls and drainage features at a single point vary from the simplest of hand sampling procedures to the more sophisticated multi-point sampling techniques known as the equal-width-increment (EWI) method or the equal-discharge-increment (EDI) method.

Samples from different depths or cross-sectional locations, collected during the same sampling episode, shall be composited. However, samples collected along the length of the watercourse or at different times may reflect differing inputs or dilutions and therefore shall not be composited. Generally, the number and type of samples to be collected depend on the river's width, depth, discharge, and amount of suspended sediment. With a greater number of individual points sampled, it is more likely that the composite sample will truly represent the overall characteristics of the water.

In small streams less than about 20 feet wide, a sampling location can generally be found where the water is well mixed. In such cases, a single grab sample taken at mid-depth in the center of the channel is adequate to represent the entire cross-section.

For larger streams greater than three feet in depth, two samples at each station shall be taken from just below the surface, and just above the bottom.

4.2.2 Lakes, Ponds and Reservoirs

Lakes, ponds, and reservoirs have a much greater tendency to stratify according to physical or chemical differences than rivers and streams. The relative lack of mixing requires that more samples be obtained.

The number of water sampling locations on a lake, pond, or impoundment will vary with the size and shape of the basin. In ponds and small lakes, a single vertical composite at the deepest point may be sufficient. Similarly, the measurement of DO, pH, temperature, etc., is conducted on each aliquot of the vertical composite. In naturally-formed ponds, the deepest point may have to be determined empirically; in impoundments, the deepest point is usually near the dam.

In lakes and larger reservoirs, several vertical grab samples shall be composited to form a single sample. These vertical samples often are collected along a transect or grid. In some cases, it may be of interest to form separate composites of epilimnetic and hypolimnetic zones. In a stratified lake, the epilimnion is the thermocline which is exposed to the atmosphere. The hypolimnion is the lower, "confined" layer which is only mixed with the epilimnion and vented to the atmosphere during seasonal "overturn" (when density stratification disappears). These two zones may thus have very different concentrations of contaminants if input is only to one zone, if the contaminants are volatile (and therefore vented from the epilimnion but not the hypolimnion), or if the epilimnion only is involved in short-term flushing (i.e., inflow from or outflow to shallow streams). Normally, however, a composite sample consists of several vertical samples collected at various depths.

As it is likely that poor mixing may occur in lakes with irregular shape (with bays and coves that are protected from the wind), separate composite samples may be needed to adequately represent water quality. Similarly, additional samples are recommended where discharges, tributaries, land use characteristics, and other such factors are suspected of influencing water quality.

Many lake measurements now are made in-situ using sensors and automatic readout or recording devices. Single and multi-parameter instruments are available for measuring temperature, depth, pH, oxidation-reduction potential (ORP), specific conductance, dissolved oxygen, some cations and anions, and light penetration.

4.2.3 Estuaries

Estuarine areas are by definition among those zones where inland freshwaters (both surface and ground) mix with marine waters. Estuaries generally are categorized into three types dependent upon freshwater inflow and mixing properties. Knowledge of the estuary type is necessary to determine sampling locations:

- Mixed estuary - characterized by the absence of a vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically this type of estuary is shallow and is found in major freshwater sheetflow areas. Being well mixed, the sampling locations are not critical in this type of estuary.

- Salt wedge estuary - characterized by a sharp vertical increase in salinity and stratified freshwater flow along the surface. In these estuaries the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally, back and forth, with the tidal phase. If contamination is being introduced into the estuary from upstream, water sampling from the salt wedge may miss it entirely.

- Oceanic estuary - characterized by salinities approaching full strength oceanic waters. Seasonally, freshwater inflow is small with the preponderance of the fresh-saline water mixing occurring near, or at, the shore line.

Sampling in estuarine areas normally is based upon the tidal phases, with samples collected on successive slack tides (i.e., when the tide turns). Estuarine sampling programs shall include vertical salinity measurements coupled with vertical dissolved oxygen and temperature profiles.

4.2.4 Surface Water Sampling Equipment

The selection of sampling equipment depends on the site conditions and sample type required. The most frequently used samplers are:

- Dip sampler
- Weighted bottle
- Kemmerer
- Depth-Integrating Sampler

The dip sampler and the weighted bottle sampler are used most often.

The criteria for selecting a sampler include:

- Disposable and/or easily decontaminated
- Inexpensive (if the item is to be disposed of)
- Ease of operation
- Nonreactive/noncontaminating - Teflon-coating, glass, stainless steel or PVC sample chambers are preferred (in that order)

Each sample (grab or each aliquot collected for compositing) shall be measured for: specific conductance; temperature; pH; and dissolved oxygen (optional) as soon as it is recovered. These analyses will provide information on water mixing/stratification and potential contamination.

4.2.4.1 Dip Sampling

Water often is sampled by filling a container, either attached to a pole or held directly, from just beneath the surface of the water (a dip or grab sample). Constituents measured in grab samples are only indicative of conditions near the surface of the water and may not be a true representation of the total concentration that is distributed throughout the water column and in the cross section. Therefore, whenever possible it is recommended to augment dip samples with samples that represent both dissolved and suspended constituents, and both vertical and horizontal distributions. Dip sampling often is the most appropriate sampling method for springs, seeps, ditches, and small streams.

4.2.4.2 Weighted Bottle Sampling

A grab sample also can be taken using a weighted holder that allows a sample to be lowered to any desired depth, opened for filling, closed, and returned to the surface. This allows discrete sampling with depth. Several of these samples can be combined to provide a vertical composite. Alternatively, an open bottle can be lowered to the bottom and raised to the surface at a uniform rate so that the bottle collects sample throughout the total depth and is just filled on reaching the surface. The resulting sample using either method will roughly approach what is known as a depth-integrated sample.

A closed weighted bottle sampler consists of a stopped glass or plastic bottle, a weight and/or holding device, and lines to open the stopper and lower or raise the bottle. The procedure for sampling is as follows:

- Gently lower the sampler to the desired depth so as not to remove the stopper prematurely (watch for bubbles).

- Pull out the stopper with a sharp jerk of the sampler line.
- Allow the bottle to fill completely, as evidenced by the absence of air bubbles.
- Raise the sampler and cap the bottle.
- Decontaminate the outside of the bottle. The bottle can be used as the sample container (as long as original bottle is an approved container).

4.2.4.3 Kemmerer

If samples are desired at a specific depth, and the parameters to be measured do not require a Teflon coated sampler, a standard Kemmerer sampler may be used. The Kemmerer sampler is a brass, stainless steel or acrylic cylinder with rubber stoppers that leave the ends open while being lowered in a vertical position to allow free passage of water through the cylinder. A "messenger" is sent down the line when the sampler is at the designated depth, to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill sample bottles.

4.2.5 Surface Water Sampling Techniques

Most samples taken during site investigations are grab samples. Typically, surface water sampling involves immersing the sample container directly in the body of water. The following suggestions are applicable to sampling springs, seeps, ditches, culverts, small streams and other relatively small bodies of water, and are presented to help ensure that the samples obtained are representative of site conditions:

- The most representative samples will likely be collected from near mid-stream, the center of flow in a culvert, etc.
- Downstream samples shall be collected first, with subsequent samples taken while moving upstream. Care shall be taken to minimize sediment disturbance while collecting surface water samples. If necessary, sediment samples shall be collected after the corresponding surface water sample.
- Samples may be collected either by immersing the approved sample container or a glass or nalgene beaker into the water. Sample bottles (or beakers) which do not contain preservatives shall be rinsed at least once with the water to be sampled prior to sample collection.
- Care shall be taken to avoid excessive agitation of the water which may result in the loss of volatile constituents. Additionally, samples for volatile organic analyses shall be collected first, followed by the samples for other constituents.
- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate, shall be collected immediately following sample collection for laboratory analyses.

- The sampling location shall be marked via wooden stake placed at the nearest bank or shore. The sampling location number shall be marked with indelible ink on the stake.

- The following information shall be recorded in the field logbook:

    - Project location, date and time.
    - Weather.
    - Sample location number and sample identification number.
    - Flow conditions (i.e., high, low, in flood, etc.) and estimate of flow rate.
    - Visual description of water (i.e., clear, cloudy, muddy, etc.).
    - On-site water quality measurements.
    - Sketch of sampling location including boundaries of water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake.
    - Names of sampling personnel.
    - Sampling technique, procedure, and equipment used.

General guidelines for collection of samples from larger streams, ponds or other water bodies are as follows:

- The most representative samples are obtained from mid-channel at mid- stream depth in a well-mixed stream.

- For sampling running water, it is suggested that the farthest downstream sample be obtained first and that subsequent samples be taken as one works upstream. Work may also proceed from zones suspected of low contamination to zones of high contamination.

- It is suggested that sample containers which do not contain preservative be rinsed at least once with the water to be sampled before the sample is taken.

- To sample a pond or other standing body of water, the surface area may be divided into grids. A series of samples taken from each grid is combined into one composite sample, or several grids are selected at random.

- Care should be taken to avoid excessive agitation of the water that would result in the loss of volatile constituents.

- When obtaining samples in 40 ml septum vials for volatile organics analysis, it is important to exclude any air space in the top of the bottle and to be sure that the Teflon liner faces inward. The bottle can be turned upside down to check for air bubbles after the bottle is filled and capped.

- Do not sample at the surface unless sampling specifically for a known constituent which is immiscible and on top of the water. Instead, the sample container should be inverted, lowered to the approximate depth, and held at about a 45-degree angle with the mouth of the bottle facing upstream.

- Measurements for temperature, pH, specific conductance, or other field parameters, as appropriate shall be collected immediately following sample collection for laboratory analysis.

- Items to be recorded in the field logbook are the same as those described above for small streams.

4.3 Sediment Sampling

Sediment samples usually are collected at the same locations as surface water samples. If only one sediment sample is to be collected, the sample location shall be approximately at the center of the water body. If, however, multiple samples are required, sediment samples should be collected along a cross-section to characterize the bed material. A common procedure for obtaining multiple samples is to sample at quarter points along the cross-section of flow. As with surface water samples, sediment samples should be collected from downstream to upstream.

4.3.1 Sampling Equipment and Techniques

A bottom-material sample may consist of a single scoop or core or may be a composite of several individual samples in the cross section. Sediment samples may be obtained using on-shore or off-shore techniques.

When boats are used for sampling, U. S. Coast Guard approved personal flotation devices must be provided and two individuals must undertake the sampling. An additional person shall remain on-shore in visual contact at all times.

The following samplers may be used to collect bottom materials:

- Scoop sampler
- Dredge samplers
- Bucket/hand auger
- Stainless steel spoon or trowel

4.3.1.1 Scoop Sampler

A scoop sampler consists of a pole to which a jar or scoop is attached. The pole may be made of bamboo, wood or aluminum and be either telescoping or of fixed length. The scoop or jar at the end of the pole is usually attached using a clamp.

If the water body can be sampled from the shore or if it can be waded, the easiest and "cleanest" way to collect a sediment sample is to use a scoop sampler. This reduces the potential for cross-contamination. This method is accomplished by reaching over or wading into the water body and, while facing upstream (into the current), scooping in the sample along the bottom in the upstream direction. It is very difficult not to disturb fine-grained materials of the sediment-water interface when using this method.

4.3.1.2 Dredges

Dredges are generally used to sample sediments which cannot easily be obtained using coring devices (i.e., coarse-grained or partially-cemented materials) or when large quantities of materials are required. Dredges generally consist of a clam shell arrangement of two buckets. The buckets may either close upon impact or be activated by use of a messenger. Most dredges are heavy (up to several hundred pounds) and require use of a winch and crane assembly for sample retrieval. There are three major types of dredges: Peterson, Eckman and Ponar dredges.

The Peterson dredge is used when the bottom is rocky, in very deep water, or when the flow velocity is high. The dredge shall be lowered very slowly as it approaches bottom, because it can force out and miss lighter materials if allowed to drop freely.

The Eckman dredge has only limited usefulness. It performs well where bottom material is unusually soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky, and hard bottoms and is too light for use in streams with high flow velocities.

The Ponar dredge is a Peterson dredge modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends thus reducing the "shock wave" and permits direct access to the secured sample without opening the closed jaws. The Ponar dredge is easily operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates. Access to the secured sample through the covering screens permits subsampling of the secured material with coring tubes or Teflon scoops, thus minimizing the chance of metal contamination from the frame of the device.

4.3.1.3 Bucket (Hand) Auger

Bucket (hand) augering is a viable method for collecting sediment samples in narrow, intermittent streams or tidal flats. Typically, a 4-inch auger bucket with a cutting head is pushed and twisted into the ground and removed as the bucket is filled. The auger hole is advanced one bucket at a time, to a depth specified in the project plans.

When a specific vertical sampling interval is required, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a new bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of sediment should be removed from the bucket to minimize the changes of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples.

4.3.1.4 Stainless Steel Spoon or Trowel

For loosely packed sediments, a stainless steel scoop or trowel can be used to collect a representative sample, in narrow intermittent streams or tidal flats.

Use the scoop or trowel to collect the sample from a desired depth. Remove heavy debris, rocks, and twigs before collecting the sample. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, chain-of-custody record, and other required forms.

4.3.2 Sediment Sampling Procedure

The following general procedure should be used, where applicable, for sampling sediment from springs, seeps, small streams, ditches, or other similar small bodies of water. Procedures sampling larger bodies of water (i.e., rivers, lakes, estuaries, etc.) should be developed on a project-specific basis, as needed.

- Sediment samples shall be collected only after the corresponding surface water sample has been collected, if one is to be collected.
- Sediment samples shall be collected from downstream locations to upstream locations.
- Samples shall be collected by excavating a sufficient amount of bottom material using a scoop, beaker, spoon, trowel, or auger. Samples should be collected with the sampling device facing upstream and the sample collected from downstream to upstream. Care should be taken to minimize the loss of fine-grained materials from the sample.
- The sample shall be transferred to the appropriate sample containers. Sampling personnel shall use judgment in removing large plant fragments to limit bias caused by bio-organic accumulation.
- The sampling location shall be marked via a wooden stake placed at the nearest bank or shore. The sample location number shall be marked on the stake with indelible ink.
- The following information shall be recorded in the field logbook:
    - Project location, date and time.
    - Weather.
    - Sample location number and sample identification number.
    - Flow conditions.
    - Sketch of sampling location including boundaries of water body, sample location, water depth, sample collection depth, relative position with respect to the site, location of wooden identifier stake.
    - Chemical analyses to be performed.

5.0 QUALITY ASSURANCE RECORDS

The description of the sampling event in the field logbook shall serve as a quality assurance record. Other records include chain-of-custody and sample analysis request forms.

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