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MASTER WORK PLAN VOLUME 2 OF 3 FOR INSTALLATION RESTORATION PROGRAM
MCRD PARRIS ISLAND SC
3/27/1998
BROWN AND ROOT ENVIRONMENTAL

Rev. 0
03/27/98

Master Work Plan

Marine Corps Recruit Depot

Parris Island, South Carolina
U.S. EPA Identification Number
SC6 170 022 762

Volume II of III

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888
Contract Task Order 0020

March 1998

Rev. 0
03/27/98

MASTER WORK PLAN

MARINE CORPS RECRUIT DEPOT
PARRIS ISLAND, SOUTH CAROLINA
U.S. EPA IDENTIFICATION NUMBER
SC6 170 022 762

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
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Naval Facilities Engineering Command
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CONTRACT NUMBER N62467-94-D-0888
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VOLUME II OF III

MARCH 1998

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PREFACE

Volume II Master Work Plan (MWP) is the second volume in a series of three MWPs used in support of installation restoration work at Marine Corps Recruit Depot (MCRD) Parris Island. Volume I MWP contains overall project scope and objectives, overall investigation strategies, project organization, and facility background information. Volume II MWP contains environmental field investigation methods and procedures. Volume III MWP outlines the framework for conducting installation restoration work at the MCRD.

The MWPs are reviewed periodically and revised as necessary. The MWPs incorporate generic environmental investigative procedures applicable to potential activities throughout the Depot. The MWP approach reduces time and cost associated with reproduction, shipping, and review of repetitious material that was previously reviewed and approved. The MWP is reviewed and approved by the U.S. Environmental Protection Agency (U.S. EPA), and the South Carolina Department of Health and Environmental Control (SCDHEC), thereby reducing the "in house" review time required for approval of site-specific plans.

The Volume II MWP consists of the following documents:

- The Master Field Sampling Plan (Master FSP)
- The Master Quality Assurance Plan (Master QAP)
- The Project Health & Safety Plan (Project HASP)

The Master FSP presents standard operating procedures for potential investigations at MCRD Parris Island. The Master FSP specifies requirements for all field work and serves as a complete guide for use in the field by all members of the field investigation team. The Master QAP defines and documents the quality assurance/quality control (QA/QC) system used to ensure that the precision, accuracy, representativeness, comparability, and completeness (the PARCC parameters) of the environmental data acquired are known, documented, and adequate to satisfy the data quality objectives addressed by each project. The Project HASP outlines procedures for the protection of personnel performing field investigation activities. The Project HASP specifies personnel responsibilities and restrictions, establishes requirements, and describes the use of evaluation techniques.

Site-specific addenda will be issued to provide the specific criteria for the investigation of individual sites at MCRD Parris Island. Site-specific addenda, referred to as Site-Specific Work Plans, will be developed by Brown & Root Environmental (B&R Environmental) under the Comprehensive Long-term Environmental Action Navy (CLEAN III), contract Number N62467-94-D-0888. The Site-Specific Work Plans will utilize the standard procedures and criteria established in the MWPs. Site-Specific Work Plans will include only the additional information required to execute field work at a given site, such as location and depth of soil borings, location and depth of monitoring wells, constituents being sampled, or any other condition or configuration applicable to the given site that may affect the execution of work. Site-Specific Work Plans will be issued as needed to support the ongoing field investigations at the Depot.

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RESPONSE TO REGULATORY
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MCRD PARRIS ISLAND, SOUTH CAROLINA

STATE OF SOUTH CAROLINA, HAZARDOUS WASTE SECTION
DIVISION OF HYDROGEOLOGY, BUREAU OF SOLID AND HAZARDOUS WASTE MANAGEMENT
RESPONSE TO COMMENTS TO THE DRAFT MASTER WORK PLAN, VOLUME II -
COMMENTS RECEIVED 11/20/96
MARINE CORPS RECRUIT DEPOT (MCRD)
PARRIS ISLAND, SOUTH CAROLINA

COMMENTS - Johnny Tapia, Environmental Engineering Associate

1. **Comment**: Section 1.0 and Section 2.1.1

Instead of "Project-Specific FSP Addendum" should be "Site-Specific FSP Addendum". Project is too broad and could be considered as the whole Base, but Site will appropriately make reference to every Solid Waste Management Unit (SWMU) or Area of Concern (AOC) specifically being worked on.

Response: Agree. The text will be revised .

2. **Comment**: Section 2.2.2

The text states that on test pit excavations, the removed soils should be "replaced". The text should be explicit as if the soils will be "replaced" or "put back in place." This section should be revised.

Response: Agree. The text will be revised .

3. **Comment**: Section 2.11, "Waste Handling"

The text of this section states the following: "Based on the activities and types of contaminants present, none of the residues are expected to represent a significant risk to Human Health or the Environment if properly managed." The only way to determine if a contaminant poses a "significant risk" to Human Health or the Environment is by performing a Baseline Risk Assessment. This section seems to be making a judgment based solely on preliminary information. All waste should be first characterized as hazardous or non-hazardous and disposed accordingly. If the waste is determined to be hazardous, it can not be stored on-site for more than 90 days.

Response: Agree. The sentence will be deleted.

4. **Comment**: Section 2.11.1 "Solid Investigation-Derived Waste"

This section states that if the IDW is determined to be non-hazardous, then may be "spread on the ground at the site." This Department does not agree with the concept of spreading IDW on the ground. Even if it has determined to be non-hazardous it might still contain some low concentrations of contaminants; reason why it will be more appropriate to use the phrase "put back in place" than "spread on the ground." This section should be revised.

Response: Agree. The section will be revised.

5. **Comment**: Section 3.0 "General Sampling Operations"

The introductory paragraph should be revised to explain that the analysis of samples will be performed by a South Carolina certified laboratory.

Response: Disagree. This section pertains to field sampling activities, outlining methods/ requirements for collecting samples of the various media, but does not discuss laboratory protocol. Analytical requirements are outlined in the MQAP. Section 2.3 of the MQAP specifies that labs must comply with state certification requirements. No change is proposed.

6. **Comment**: Master Quality Assurance Plan

Page ii, Section 1.1 of the Table of Contents has a typographical error.

Response: The typographical error will be corrected.

7. **Comment**: Preface

Page ii, last paragraph, there is a typographical error on the word "addendum".

Response: The typographical error will be corrected.

8. **Comment**: Section 2.1 and Figure 2.1

This section and figure list all the people involved in the project, including SCDHEC's personnel. These sections should be left blank or later revised to include the people assigned to the MCRD when determined.

Response: Agree. The text and table will be updated to reflect current assignments.

COMMENTS - Donald Hargrove, Hydrogeologist

1. **Comment**: Section 2.1 General Field Operations: Second paragraph, next to last sentence; This sentence should read "Groundwater flow is generally towards...". Please revise.

Response: The paragraph has been deleted in accordance with the response to Comment 2a (listed below).

2. Figure 2-1 Typical Geological Cross-Section

a. **Comment**: Revise to include well identifications.

Response: This information is redundant. Figure 2-1 and the second paragraph of section 2.1 will be deleted and replaced with a reference to Volume I MWP, Section 2.0 for geological information.

b. **Comment**: Typographical error: "St. Helens Island" should be St. Helena Island".

Response: See previous response.

c. **Comment**: Revise to include reference: Dames and Moore, 1986.

Response: See previous response.

3. **Comment**: Section 2.2.2 Test Pit Operations

Last sentence; Typographical error: "...pit log i(Single Sample Log Sheets)s...".

Response: The typographical error will be corrected.

4. **Comment**: Section 2.2.3 Direct-Push-Drilling

Direct push data is not acceptable for "No Further Action" (NFA) decisions. Direct push data can only be used for site characterization. Please revise to acknowledge.

Response: Agree. The text will be revised to indicate that DPD is a useful screening tool to help focus follow-up sampling activities.

5. **Comment**: Section 2.2.4 Rotasonic Drilling

Third paragraph, tenth sentence: "facilities" should be "facilitates".

Response: The typographical error will be corrected.

6. **Comment**: Section 2.3 Monitoring Well Construction and Installation

Please specify that the plug used at the base of the monitoring well casing will be made of a material compatible with the well screen (PVC, Teflon, etc...) and not wood.

Response: Agree. A statement will be added specifying that wood shall not be used as a plug material.

7. **Comment**: Figure 2-3 Typical At-Grade Monitoring Well

This figure should be revised to show the locking flush cover, and the minimum depth to the top of the cement/bentonite slurry (2 feet below ground surface).

Response: Agree. The figure will be revised. The minimum depth to the top of the slurry also applies to Figure 2-2

8. **Comment**: Section 2.10 Decontamination

The last sentence should be revised to state that "Decon efforts will comply with U.S. EPA Region 4 SOPs."

Response: Agree. The text will be revised.

9. **Comment**: Appendix A Monitoring Well Sheet

This sheet should be revised to include the depth of seal/top of bentonite, as well as the duration of hydration.

Response: Agreed. The well sheet will be revised accordingly.

10. Appendix B: B&R Environmental SOP GH-2.8 Groundwater Monitoring Point Installation

a. **Comment**: Section 4.0 Responsibilities: Please revise to specify that the driller must be certified by the State of South Carolina. This section should also state that in addition to obtaining required permits, the driller will notify the regulatory agencies of upcoming activity (seventy-two hour notice).

Response: Agree. The SOP will be appended to reflect that a State certified driller shall be used and notice will be given.

b. *Section 5.2.2 Riser Pipe and Screen Materials*

i. **Comment**: This section should be revised to address the issue of borehole size as it relates to casing diameters to ensure that the minimum annular space requirements are met. Section E.5.1 of the Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (SOP/QAM), 1991, by U.S. Environmental Protection Agency Region 4 covers this topic.

Response: Agree. The SOP will be appended to address that annular space requirements are met.

ii. **Comment**: This section also states the glued PVC may release organic contamination into the well. The possibility for release of organic contamination into the groundwater prohibits the use of glued casing as per R.61-71.11.C.1 of the South Carolina Well Standards and Regulations. Please revise to exclude all use of glued casing.

Response: The revised SOP (dated 3/1/96) contains this information and will be provided in Appendix B.

iii. **Comment**: Refer to Section E.5.3 of the U.S. EPA Region 4 SOP/QAM for guidance on filter pack and well screen design. A more detailed description of the design criteria is necessary to ensure a standard methodology for all future projects that will be referring to this Master Work Plan.

Response: The SOP will be appended to address screen/sand pack design.

c. *Section 5.3.1 Monitoring Wells in Unconsolidated Sediments*

i. **Comment**: Please revise this section so that the proper hydration time of bentonite is addressed. The current text implies that as soon as the bentonite pellets are installed, the grout can be mixed and tremied into the annulus. Section E.3.4 of the U.S. EPA Region 4 SOP/QAM suggests that "...bentonite pellets be tremied into the annulus and tamped to a minimum of 2 feet above the filter pack. The bentonite shall be allowed to hydrate a minimum of eight hours or the manufacturer's recommended hydration time, whichever is longer. At this point, the grout can be pumped by the tremie method into the annular space around the casing."

Response: Agree. The text will be revised.

ii. **Comment**: Refer to Section E.3.5 of the U.S. EPA Region 4 SOP/QAM for guidance concerning installation of grout. The grout should be pumped by tremie method into the annulus of the well to ensure that grout completely fills the annular space. Please revise the text to exclude pouring grout into the annulus.

Response: Agree. The text will be revised.

11. **Comment**: Appendix B B&R Environmental SOP GH-3.4, Ground Penetrating Radar Surveys

Pages 1-3 are missing from this section due to a photocopying error. Please replace.

Response: The complete SOP will be provided.

12. Master Quality Assurance Plan

a. **Comment**: Section 2.1 Program management and Project Organization: This section lists Ken Johnson as the SCDHEC Project Manager. Since Ken's position is still open to date, it is suggested that this be left open until the final MQAP is produced. At that point the position could be filled.

Response: Agree. The text and figure will be revised with the appropriate personnel.

b. **Comment**: Figure 2-1 should be updated to list D. Hargrove as the Hydrogeologist for SCDHEC and keep K. Johnson's slot open as per comment 12a above.

Response: Agree. The text and figure will be revised with the appropriate personnel.

c. **Comment**: Section 2.3 Laboratory Options: Any labs performing analyses must not only comply with State certification requirements, but must also be State certified. Please revise.

Response: Agree. The text will be revised accordingly.

d. **Comment**: Section 5.4 Fixed-Base Laboratories: See comment 12c above.

Response: Agree. The text will be revised accordingly.

U.S. EPA REGION 4
RESPONSE TO RPM COMMENTS TO THE DRAFT MASTER WORK PLAN, VOLUME II - COMMENTS RECEIVED 8/2/96
MCRD, PARRIS ISLAND, SOUTH CAROLINA

1. **Comment**: Page 2-26, Section 2.7.2

   Greater explanation of what is meant by "the aquifer response to pumping" is needed, particularly given the large range of proposed pumping test duration (e.g., what criteria would be used to determine that a r hour pumping test was sufficient?).

   Response: Agree. Criteria will be added to determine when pumping has continued for a sufficient period of time.

2. **Comment**: Page 2-27, Section 2.7.3

   Specific capacity test may not provide accurate measure of specific capacity if well development is still occurring during the test, though it may provide good indication of when well development is complete.

   Response: Noted. This paragraph explains that the test involves measuring drawdown when the water level stabilizes after pumping a well at a constant rate, which can be done for the purpose of developing or purging a well in addition to conducting the pumping test. No changes proposed.

3. **Comment**: Page 2-28, Section 2.8

   Regarding soil gas surveys, possibly consider collection of "long-term" samples (e.g. install absorptive material at sampling point, and retrieve for lab analysis after an extended period of time).

   Response: Agree. A paragraph discussing passive sorbent soil gas samplers will be added.

4. **Comment**: Page 3-3, Section 3.1.3

   For risk assessment purposes, surface soil samples should be collected either from the top 12" or from the most contaminated portion of that interval.

   Response: Agree: The text will be revised to specify this criteria.

5. **Comment**: Page 3-3, Section 3.1.4

   Maybe I missed something here, will all of these samples (collected a 5' intervals to water table) be sent to a lab for analysis? If not, what general procedures will be used to determine which need to be analyzed by a laboratory & which are used for other purposes?

   Response: This paragraph discusses typical subsurface soil sampling. The specific intervals and number of samples to be analyzed will be specified in the Site-Specific SAP. A sentence will be added stating that specific number and intervals will be specified in the Site-Specific SAP.

6. **Comment**: Page 2-1, Section 2.1

U.S. EPA RPM has OVERALL RESPONSIBILITY??! What happened to DOD/Navy as lead agency?

Response: Agree. The text will be revised to indicate that the Navy has overall responsibility.

7. **Comment**: Pages 5-4 through 5-13, Table 5-1

Many analytical options exist for each chemical class/group. Information, data which would provide means of distinguishing differences(/similarities) in the relative quality of these analyses (e.g. MDL, level of QA/QC) would facilitate future, site-specific decisions regarding which method(s) would be acceptable for decision-making purposes. Recommend providing such information in this table.

Response: Table 5-1 is meant to provide a summary of analytical methods which could potentially be considered for use for MCRD Parris Island investigations. Given the large number of methods included on Table 5-1 and the number of associated compounds/analytes which could be analyzed, a comparison of MDLs, QC requirements, etc. for all of the methods is beyond the scope of the Master QAPP. Analytical requirements will be determined based on regulatory requirements and data quality objectives on a site-specific basis. Specifics such as reporting limits and QC requirements will be provided in site-specific documents.

Note that Table 5-1 will also be revised based on the responses to comment 6 from the U.S. EPA Region 4 - Science and Ecology Support Division.

8. **Comment**: Page 5-14, Paragraph 1

Why CRQL for organics and CRDL for inorganics? How can a quantitation limit (e.g. PQL) be an expression of a detection limit (e.g. MDL, IDL)?

Response: The terms Contract Required Quantitation Limit (CRQL) and Contract Required Detection Limit (CRDL) were established by the U.S. EPA Contract Laboratory Program (CLP) for organic and inorganic analyses, respectively.

A practical quantitation limit (PQL) is based on the method detection limit (MDL, for organics) or instrument detection limit (IDL, for inorganics) by adjusting the MDL to a higher level to ensure that the precision and accuracy requirements of the method can be attained. The text regarding PQLs will be clarified.

9. Page 5-14, Paragraph 2

Questions on how the decision to use low-concentration methodologies, or other more stringent DQO methods, will be made:

a. **Comment**: Will each site investigation/sampling event have the flexibility to use different analytical methods/DQO levels to analyze different samples collected (e.g. depending on location of sampling point relative to contaminant source)?

Response: Site specific parameters will be defined based on site specific conditions. If different methods or a phased approach is warranted to answer the site specific questions the project team is looking to answer, the Site SAPs will provide what is required.

b. **Comment**: Will investigation have flexibility to add additional sampling rounds if discovery is made after the initial round that a higher DQO level is needed (e.g. to eliminate a site, or better define the magnitude of remediation efforts & selection of appropriate technology)?

Response: Site specific parameters will be defined based on site specific conditions. If different methods or a phased approach is warranted to answer the site specific questions the project team is looking to answer, the Site SAPs will provide what is required.

10. **Comment**: Pages 5-15 through 5-21, Table 5-3

Clarify: do these MDLs apply to all non-CLP methods, just SW-846 methods, or what? What about low-, medium-, high-SOW CRQLs for CLP?

Response: As noted in the second paragraph of page 5-14, Table 5-3 was meant to provide a comparison of CRQLs/CRDLs and MDLs as an example only. The parameters listed were for CLP parameters only. The CRQLs/CRDLs were taken from the multi-media/multi-concentration CLP SOW and represented standard CLP limits, not making any special adjustments for low- or medium-concentration samples. The MDLs represented typical laboratory MDLs. However, specific MDLs would vary based on the laboratory. Therefore, this table is considered to be of little value to the document and will be deleted from the Master QAPP.

11. **Comment**: Pages 6-1 through 6-3, Section 6.0

Clarify whether any of these QC checks vary with analytical method. With what frequency are surrogate spikes and blank spikes analyzed?

Response: Based on the wide variety of analytical methods which may potentially be used, the text in this section provides information regarding QC sample requirements that are generally applicable to all methods. The text will be clarified to specify that all QC checks will be performed based on the requirements of the specific analytical methods. Regarding surrogate spike frequency, the text currently states that surrogates are spiked into each sample, standard, and method blank for all organic chromatographic analyses. The frequency generally required for blank spike analysis (1 per 20 samples) will be added to the text.

12. **Comment**: Page 8-2, Section 8.4

Will the electronic data be submitted in a format which is compatible with U.S. EPA Region 4's?

Response: Pat Hooper of B&R Environmental spoke with Richard Hammond of U.S. EPA Region 4 concerning this issue on October 9, 1997 and all data sharing issues were resolved. Please refer to Mr. Hammond's U.S. EPA internal memo regarding this issue.

U. S. EPA REGION 4
RESPONSE TO ESD COMMENTS TO THE DRAFT MASTER WORK PLAN, VOLUME II - COMMENTS RECEIVED 8/2/96
MARINE CORPS RECRUIT DEPOT (MCRD)
PARRIS ISLAND, SOUTH CAROLINA

Master Field Sampling Plan

1. **Comment**: Section 2.2.3, p. 2-5.

   The Navy contractor should be made aware that DPD (specifically the Hydropunch) was not successful at NAVBASE Charleston due to the lithology.

   Response: Noted. DPD has been successfully used at the Dry Cleaners at Parris Island.

2. **Comment**: Section 2.10.1, p. 2-29

   PVC and other plastic materials must not be subjected to hot water or solvents. If "certified clean" materials are used, a fixed percentage must be subjected to equipment rinse blanks.

   Response: Noted. Only new clean well casing and screens will be installed. The text of Section 2.10.1 and 2.3 will be revised accordingly.

3. **Comment**: Section 3.1.1, p. 3-1

   Bailers may not be used for purging unless they consistently provide purge water of 10 NTU or less.

   Response: The Navy intends on primarily using low flow pumps for purging, but would not exclude the possibility of bailers if acceptable results could be achieved. No changes recommended.

4. **Comment**: Section 3.1.1, p. 3-2

   The intake of the purge pump must be placed at the top of the water column.

   Response: Agree. The text will be revised accordingly.

Master Quality Assurance Plan

5. **Comment**: Section 3.3, p. 3-4

   Blanks are also needed of the potable water used in any well installation, grout, mud and sand blanks are also required. The rinse water used for equipment decontamination must also be blanked. Preservative blanks are also needed.

Response: Equipment rinsate blanks are currently discussed in Section 3.3.4. The field blanks discussed in Section 3.3.2 will be re-titled as source water blanks. These are blanks of the potable water used for decontamination and steam cleaning as well as potable water used for well installation. The text will be revised to clarify this.

The contractor will provide certified-clean well construction materials. False positive detections have not been a historical problem. QA/QC blanks for grout, sand, and bentonite will be collected and held for analysis pending the analytical results of the field investigation. If it is suspected that inorganic contaminants have been introduced by well installation materials, the samples will be sent to the laboratory for analysis. For inorganics, holding times will not be exceeded because the holding time for inorganic analysis is considerably longer than the 3-week turn-around time anticipated for analytical results. For organics, material blank analysis is not anticipated because monitoring well purging and development activities should dissipate minor organic contamination if present. Discussion of the collection of these blanks will be added to the text.

Additionally, it is recommended that preservative QA/QC blanks not be taken. Trip blanks, field blanks, and rinsate blanks will all be collected. Each of the types of blanks contain the same preservatives as those used in environmental samples, and, therefore, provide a check of contamination of the preservatives. Historically, such blanks have very rarely shown positive detection of contaminants.

Standard Operating Procedures

6. **Comment**: SA-1.1, Section 5.5

Turbidity should also be routinely monitored. The sample should not be collected until purge water has reached 10 NTU or less and other parameters have stabilized.

Response: Agree in part. Turbidity should be monitored. The Navy believes that if the aquifer being sampled is turbid (i.e., the turbidity remains greater than 10 NTU after extended purging), that the turbid sample is representative of the aquifer and should be used. Filtered samples may be employed, if needed If less than 10 NTUs cannot be achieved, attempts to stabilize the turbidity at a constant value will be made.

7. **Comment**: SA-7.1, Section 5.1

Soap must also be used to clean drilling equipment.

Response: B&R Environmental standard procedure is to use high pressure steam which is considered appropriate.

8. **Comment**: SA-7.1, Section 5.2

Use of the EISOPQAM field decontamination procedures should be considered. These methods are effective, take much less time, are safer, and less expensive.

Response: Agree. The EISOPQAM will be considered.

9. **Comment**: SA-7.1, Section 5.2.2

Region 4 has several restrictions on the use of pumps for sampling. If the Navy contractor is intending to use pumps for sampling, specific procedures developed in accordance with the EISOPQAM must be proposed.

Response: The EISOPQAM criteria will be used.

10. **Comment**: SA-7.1, Section 5.5.3

Unlined mud pits are not permitted.

Response: Mud will not be used.

General Comments

11. **Comment**: The submitted documents contain no discussion of temporary wells. U.S. EPA Region 4 recommends the mapping of shallow contaminant plumes using temporary monitoring wells, sampling with peristaltic pump/vacuum jug, analysis in a mobile laboratory and real-time field mapping of results. This is a tested and proven method which is extremely cost-effective and time-saving. The methods are described in the EISOPQAM and I am available for questions.

Response: A discussion of temporary wells will be added to Section 2.3 of the MFSP.

U.S. EPA REGION 4 - PREPARED BY KHAFRA ENGINEERING CONSULTANTS, INC.
RESPONSE TO COMMENTS TO THE DRAFT MASTER WORK PLAN, VOLUME II - COMMENTS RECEIVED 8/2/96
MCRD PARRIS ISLAND, SOUTH CAROLINA

GENERAL COMMENTS

1. **Comment**: The Master Field Sampling Plan (MFSP), Section 2.0, Page 2-1, discusses the sampling for the investigation. According to the MWP, Parris Island has wetland concerns; however, this section does not address ecological sampling based on wetland concerns. The text should address the ecological investigation sampling issue in this section.

   Response: Ecological samples will be collected, as appropriate, as part of the site-specific SAPs. No additional discussion will be included in this section.

2. **Comment**: The MFSP, Section 2.0, Page 2-1, provides information on the soil and groundwater investigation. However, the text does not discuss how the background sample or control samples will be located. The text should be revised to provide information on the locations of background and control samples.

   Response: If background/control samples are appropriate, a discussion of how background/control samples will be collected will be included in the site-specific SAPs. No additional discussion will be included in this section.

3. **Comment**: The MFSP, Section 2.1, Page 2-1, Paragraph 2, Sentence 3, discusses a clay layer that is expected to be found between the surficial aquifer and the underlying confined aquifer at MCRD Parris Island. However, Figure 2-1 does not show the location of this clay layer. It is not clear whether the Hawthorn Formation is the referenced clay layer. The text should be modified to clarify the corresponding formation name for the clay layer. In addition, the location of the cross section should be presented in another figure.

   Response: This information is redundant (previously discussed in Vol. I), therefore this paragraph and Fig 2-1 will be deleted.

4. **Comment**: The MFSP, Section 2.2.1, Page 2-4, Paragraph 0, Sentence 3, states that head space analysis for soils will be performed after the sample container has been warmed for 15 minutes. However, a rationale for warming samples and a description of the heating procedure are not presented in the Master Work Plan. The procedures to be used for heating samples for headspace analysis should be presented.

   Response: The specifics of conducting headspace analysis will be removed from the text. Analysis will be conducted per SOPs.

5. **Comment**: The MFSP, Section 2.3, presents monitoring well construction and installation requirements. However, venting or sparging wells are not discussed. It is probable that at some point in the future, venting or air sparging will be applicable to one of the sites. Thus, typical details for venting and sparging wells should be discussed, and figures similar to Figure 2-2 should be presented.

Response: A discussion of extraction and injection wells will be added.

6. **Comment**: The MFSP, Section 2.3, gives a description of monitoring well installations. The text states that a cement/bentonite grout will be used to back fill the open hole. However, U.S. EPA ESD recommends that monitoring wells used for long-time use be grouted with pure bentonite to prevent deterioration of the grout. The MFSP should be revised based on recommendations from the U.S. EPA Environmental Service Division (ESD).

   Response: The Navy feels that the sealing of wells, as described in the MWP and SOPs is appropriate. The ESD provided comments, independent of Khafra, and this issue was not commented on. No changes will be made.

7. **Comment**: The MFSP, Section 2.11.1, Page 2-30, Paragraph 2, Sentence 2, states that one composite sample of solid Investigation Derived Waste (IDW) from each site will be collected and analyzed to determine if the IDW is hazardous or non-hazardous. The use of one composite sample for IDW for an entire site is unusual and may not be representative. This is especially true for sites where over 10 drums of solid IDW are generated. Grouping of IDW should be based on the estimated degree of contamination of the waste based on visual or other field observations and/or historical information. The text should be modified to indicate that IDW will be composited based upon the expected degree of contamination of the solids (by location, by background, etc.). Data from environmental samples may be used to help determine appropriate compositing provided the 90-day storage rule can still be met.

   Response: IDW will be separated and contained, according to the amount of contamination expected, in order to minimize the amount of waste that will require disposal as hazardous waste. Only one composite sample from each area is needed. A site is expected to comprise multiple areas that are segregated. The text will be clarified.

8. **Comment**: The MFSP, Section 3.0, identifies several landfills, storm sewer outfalls, and PCB spill areas in the site descriptions that were discussed in the MWP. However, the MFSP does not present a discussion in the General Sampling Operation on landfill, sewer, or PCB sampling. Because of the number of landfills and specialized sampling patterns employed during sewer and PCB sampling, the text should describe how the site will be investigated and sampled.

   Response: Site-specific sampling will be presented in the appropriate site-specific SAPs. No additional discussion will be included in this section.

9. **Comment**: The MFSP, Section 3.1.1, Page 3-1, Paragraph 4, states that in the event that recovery of a well is slow, samples will be collected within 24 hours of purging or as soon as possible after the water level has recovered to approximately 80% of its static level. However, as water reenters the well it may cascade down the well screen and strip volatile contaminants. The U.S. EPA SOPQAM recommends that, if possible, monitoring wells should not be pumped dry. If the wells are pumped dry, water that has been trapped in the sandpack may be sampled. The technique for collecting water samples should be revised accordingly.

   Response: The Navy recognizes that wells should not be pumped dry and will use care in minimizing the effect of pumping wells dry in the field. The text will be revised accordingly.

10. **Comment**: The MFSP, Section 3.1.1, Page 3-2, Paragraph 0, Sentence 3, states that it is ideal to purge wells until the turbidity is below 5 NTU. However, U.S. EPA ESD does not require measurement of turbidity in order to determine if a well is stabilized for sampling. The U.S. EPA SOPQAM only requires that water parameters (temperature, pH, and specific conductance) be stabilized before sampling. Turbidity does not determine if a well has stabilized. Thus, the text should be corrected.

    Response: The Navy will attempt to purge until turbidity is <10 NTU, consistent with ESD comments. If the aquifer can not be purged to <10 NTU, this condition will not preclude collecting a sample. The text will be revised to reflect 10 rather than 5 NTU.

11. **Comment**: The MFSP, Section 3.1.2, Page 3-2, Paragraph 5, discusses collection of surface water samples by dipping the sample bottles just below the surface. However, surface water samples should be collected at the 0.6 depth level (measured from the surface) for shallow waters and stream widths of less than 20 feet. Thus, the method described is not applicable in most cases. In addition, the timing at which preservatives will be added to sample bottles for analysis of volatile constituents should be described in more detail. The text should indicate that sampling will start at the least contaminated area and proceed to the most contaminated area (normally from downstream to upstream). Finally, the procedures for sampling in deeper waters (lakes, ponds, etc.) should be described, or the appropriate SOP should be referenced.

    Response: Specific sampling procedures are described in the referenced SOP. The specifics will be deleted from this section.

12. **Comment**: The MFSP, Appendix B, SOP SA-1.2, Section 5.2.2, Page 6 of 25, discusses the general procedures for locating surface water sampling points. However, the text discusses collection points, but not spacing. The U.S. EPA Region 4 SOPQAM indicates that along a stream or river, three sampling stations between any two points of a major river change should be chosen (U.S. EPA, 1991). A major change includes a point where a tributary enters, a point where wastewater is discharged, or any point where there is a major change in the characteristics of the river (major bends or rapids, etc.). The text should be modified to include these U.S. EPA EISOPQAM requirements.

    Response: Specific sampling locations will be described in the site-specific SAPs. Procedures outlined in the EISOPQAM will be referenced in the SAPs.

13. **Comment**: The MFSP, Appendix B, SOP SA-1.3, Section 5.2, provides a description of soil sampling procedures. However, there is no discussion regarding the method in which soil sample locations will be chosen. The U.S. EPA Region 4 SOPQAM lists three methods of soil sampling: random, biased, and grid-based (U.S. EPA, 1991). The general methods to decide which type of sampling will be done at sites at Parris Island are not described. These methods should be mentioned in Section 2 of the MFSP and in the general guidelines of the SAPs. Procedures outlined in the EISOPQAM will be referenced.

    Response: Soil sample locations will be identified in site-specific SAPs. Procedures outlined in the EISOPQAM will be referenced in the SAPs.

14. **Comment**: The MFSP, Appendix B, SOP SA-2.2, Section 5.2, Page 3 of 4, describes several types of air sampling devices. However, no diagrams are presented showing typical sampling instruments or sampling containers. This information would be useful as air sampling is a relatively uncommon

requirement at waste sites during investigations. Methods for determining wind direction and speed should also be included as this is critical in air sampling.

Response: The Navy agrees that air sampling as part of an IR investigation is very unlikely. This SOP was included for completeness. The Navy sees no value in adding a diagram(s) since it is unknown what instrument, if any will ever be used. Any specific requirements concerning air sampling, if implemented, will be included in the site-specific SAPs. No changes to this SOP are recommended

15. **Comment**: The MFSP, Page R-1, lists the references that were used to develop this document. However, the text does not list the U.S. EPA SOPQAM or U.S. EPA RF/FS Guidance as references. These references should also be listed for the development of the MFSP and SOP.

    Response: The references will be added.

16. **Comment**: The Master Quality Assurance Plan (MQAP), Section 3.3.1, Page 3-4, Paragraph 5, states that field duplicates are either two samples collected independently at a sampling location or a single sample homogenized and split into two portions. According to the U.S. EPA SOPQAM, the definition for duplicates is two or more samples collected simultaneously into separate containers form the same source under identical conditions (U.S. EPA, 1991). The definition for a split sample is a sample that has been positioned into two or more containers from a single sample container or sample mixing container (U.S. EPA, 1991). Thus, there is a difference between duplicate and split samples, but the text in this section does not make this distinction clear. Thus, the duplicate and the split samples should be addressed separately in the text.

    Response: The text will be revised accordingly to describe splits and duplicates.

SPECIFIC COMMENTS

Master Field Sampling Plan

1. **Comment**: MFSP, Section 2.3, Page 2-9, Paragraph 0, Sentence 1.

   This sentence states that the top of the screened intervals for monitoring wells should be positioned approximately 2 feet above the stabilized water level. However, information presented in the Master Work Plan indicates that the groundwater level can fluctuate over 6 feet over the year. When placing the top of the screen, seasonal variation should be considered. Thus, the MFSP should address this issue.

   Response: The text here and in the Master Work Plan will be clarified accordingly.

2. **Comment**: MFSP, Appendix A, Groundwater Level Measurement Sheet.

   A blank form showing the data to be collected for groundwater level measurements is presented in Appendix A. However, there is no column or row to indicate the amount of free product found in a well. A section for notes, or another method to record product level, should be presented on this sheet or in Appendix A.

   Response: A separate column is not intended to be provided. If free product is discovered, it can be annotated in the remarks entry.

3. **Comment**: MFSP, Appendix B, SOP SA-1.2, Section 5.3.5, Page 10 of 25, Paragraph 2, Bullet 6.

The text describes collection of samples in 40 ml septum bottles for volatile organic analysis. However, the timing for addition of preservatives is not presented. Sample water must either be added to a bottle already containing the preservative or the preservative added after sample collection. The time at which preservatives are added should be specified in the SOP.

Response: Sample preservation requirements are described in the MQAP, section 4.2. No change to the text of this SOP will be made.

4. **Comment**: MFSP, Appendix B, SOP SA-7.1, Section 5.2.1, Page 3 of 8.

This section describes the decontamination procedures for bailers and bailing lines. However, the material of construction of the bailer or lines is not mentioned. The Region 4 U.S. EPA SOPQAM requires different decontamination procedures for different materials of construction of the sampling equipment. The text should state the material of construction of the bailer and then use the appropriate U.S. EPA decontamination method for that material. In most cases, the U.S. EPA methods require wrapping of the equipment in aluminum foil at the end of the decontamination (especially if the equipment is stored or transported). The use of aluminum foil should be added to the cleaning procedures as outlined in the U.S. EPA SOPQAM.

Response: The MFSP requires that decon effort shall comply with Region 4 SOPs. This will be revised to specify the EISOPQAM.

5. **Comment**: MFSP, Appendix B, SOP GH-1.3, Figure 1, Page 22 of 29.

This figure shows the standard size of core barrels and casing. However, no acronym list is provided for the abbreviations listed in the table. These abbreviations should be listed.

Response: It is expected that the certified well drillers that would reference this table will be familiar with this nomenclature, therefore it is considered unnecessary to define the acronyms. No changes proposed.

Master Quality Assurance Plan

1. **Comment**: MQAP, Section 3.3.2, Page 3-5, Paragraph 1.

The text addresses field blanks sampling for the investigation. However, the importance for collection of the field blanks is not addressed here. According to U.S. EPA SOPQAM, the field blanks should be collected in dusty environments and/or from areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled (U.S. EPA, 1991). The text should address such importance for the collection of the field blanks in this section.

Response: The blanks currently described in the text as field blanks will be re-titled as source water blanks. These blanks are similar in concept to U.S. EPA Region IV organic/analyte free water blanks except that source water blanks will be collected for each source of water used in decontamination, steam cleaning, and well installation, not from a field organic/analyte free water generating system.

A description of and the requirements for field blanks, as defined by U.S. EPA Region IV, will also be added to the MCRD Parris Island project planning documents. (Note to Mark/Jason: This will also affect the FSP.)

2. **Comment**: The MQAP, Section 4, Table 4-1, Page 4-3.

The table presents preservation requirements; however, there are no column headings. The headings should be provided for each column.

Response: Table headings will be added.

References

United States Environmental Protection Agency, 1991, Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites, Office of Emergency and Remedial Response, Washington DC, EPA/540/P-91/001.

United States Environmental Protection Agency, 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Office of Emergency and Remedial Response, Washington, DC, EPA/540/6-89/004.

United States Environmental Protection Agency, 1994, Soil Screening Guidance, Office of Emergency and Remedial Response, Hazardous Site Control Division, Washington, DC, EPA/540/R-94/101, PB95-963529.

United States Environmental Protection Agency, 1991, Standard Operating Procedures and Quality Assurance Manual, U.S. EPA Region 4, Environmental Services Division, Athens, GA.

United States Environmental Protection Agency, 1994, Supplemental Guidance to RAGS: Region 4 Bulletin. Development of Health Based Preliminary Remediation Goals, Remedial Goal Options, and Remediation Levels. U.S. EPA Region 4, Waste Management Division, Atlanta, GA.

U.S. EPA REGION 4 - SCIENCE AND ECOLOGY SUPPORT DIVISION
RESPONSE TO COMMENTS TO THE DRAFT MASTER WORK PLAN, VOLUME II - COMMENTS RECEIVED 8/2/96
MCRD PARRIS ISLAND, SOUTH CAROLINA

Master QA Plan

1. **Comment**: Section 3.2.1

The formula for precision, expressed as %RPD, should appear as follows:

%RPD = [(OR-DR) / ((OR+DR) /2)] * 100

Response: The formula will be corrected.

2. **Comment**: Section 3.2.2

In this section, the term surrogate spike appears to be associated with a frequency of one per twenty samples of a like matrix. However, as detailed in '6.3, surrogate compounds are added to every sample in certain organic methods. The term should be stricken from this paragraph.

Response: The text will be clarified to indicate that surrogate spike analysis is performed for each sample analyzed using organic chromatographic analytical procedures.

3. **Comment**: Section 3.2.2, line 13

Reference should be made to the approved method specified for the particular project, rather than specifying the CLP Statement of Work as the resource for guidance in establishing recovery limits, since other methods (i.e. SW-846) contain different quality control limits.

Response: Agreed. Text will be revised accordingly.

4. **Comment**: Table 4-2

Because of the toxicity of mercury, the use of $HgCl_2$ as a preservative has been discontinued in all new methods (please refer to the applicable CLP SOW or Table 4-1, Chapter 4, p. 4-6 of SW-846, January, 1995, Rev. 3).

Response: Agreed. Text regarding use of $HgCL_2$ as a preservative will be deleted.

5. **Comment**: Section 5.4.1

The selection of analytical methodologies should be based on their applicability for the analytes and matrices of interest at the site, and their current acceptance by U.S. EPA. The latter requirement is to ensure that currently accepted quality control requirements, incorporated in the various methods, are included. The National Functional Guidelines, referenced in the paragraph cited, is a set of documents establishing data validation criteria under U.S. EPA's Contract Laboratory Program (CLP), but is not a resource for establishing the applicability or quality of analytical methods as the document implies.

Response: Agreed. Reference to the National Functional Guidelines will be removed from Section 5.4.1.

6. **Comment**: Table 5-1

Many of the methods listed in Table 5-2 are equivalent in terms of the analytes contained therein and their sensitivity to those analytes. The wastewater (600 series) methods do not include procedures for preparing soil or sediment matrices. In addition, there are other methods included in the list which are equivalent to each of these methods, and inclusive of both matrices. Similarly, the 200-series methods do not include as many options as the SW-846 methods for preparing solid matrices (e.g. microwave digestion). In addition, the quality assurance program and method-specific QC procedure requirements of SW-846 and the CLP are not present in the wastewater methods. Therefore, the majority of 200 and 600 methods may not need to be included in this table. The table should include, however, references to sample preparation procedures applicable to the matrices found on-site.

Response: References to 600- and 200-series methods will be removed from the table. References to sample preparation procedures will be added.

a. **Comment**: Method 8260 encompasses the target analytes and sensitivity of method 8240, and can be used for routine analyses as well as low level. In addition, method 8240 is a packed GC column method, whereas method 8260 is a capillary GC column method, with tighter QC criteria. Since nearly all laboratories use the capillary technique, these QC criteria should be specified. Therefore, method 8240 can be eliminated from the table. Methods 8080, 8140, and 8150 are packed GC column methods. The equivalent capillary GC column methods are 8081, 8141, and 8151 respectively, and should be substituted in the table.

Response: Method 8240 will be removed from the table. Methods 8080, 8140, and 8150 will be replaced by Methods 8081, 8141, and 8151.

a. **Comment**: Nearly all SW-846 analytical methods listed for solid matrices can also be applied to aqueous matrices. Exceptions include the cold vapor methods for mercury, and the cyanide methods.

Response: Agreed. Table will be revised accordingly.

b. **Comment**: The graphite furnace procedures for metals, useful for obtaining low detection limits and for eliminating most interferences, can be complemented by the trace ICP methods (ILM04.0 or 6010A, Rev. 2). The two techniques should be considered equivalent if a trace ICP is used.

Response: Agreed. Trace ICP will most likely be used unless a laboratory does not have trace ICP capabilities, or unless only one or two specific GFAA metals are of interest for a site.

c. **Comment**: It should be required that the most recent revision of any of these methods must be used. As such, it should be noted that the inorganic CLP SOW has been revised and is currently ILM04.0. Update III of the SW-846 methods is currently out for comment, and should become final later this year.

Response: The table will be updated to reference the most current analytical methods/SOWs.

d. **Comment**: In addition to a method for asbestos in solid media (p. 5-6), it may be advisable to also specify a method for air, which could be the polarized-light microscopic method, EPA600/M4-82, or ASTM D4240, a phase contrast microscopic method.

Response: It is believed that the references provided in the comment are not applicable for the analysis of asbestos in air samples. However, a method for asbestos in air, Transmission Electron Microscopy (TEM) EPA Level 2, will be added to the table.

e. **Comment**: It should be noted that method 6010, listed on p. 5-7 for tin and silver, is an ICP method, not a flame method.

Response: Agreed. Method 6010 is an ICP method. Since tin and silver, as well as boron, are already covered by the ICP Screen, these three individual analytes will be deleted from the table.

f. **Comment**: The methods remaining in Table 5-1, after the modifications recommended above (please refer to edited copy of Table 5-2, attached), are equally acceptable for achieving project DQOs. The SW-846 methods have the advantage of flexibility by including more choices for sample preparation. The CLP methods have the advantage of a prescribed data deliverable format. The CLP deliverables can be used to present SW-846 data, if modified to include appropriate QC limits. Therefore, it is recommended that SW-846 methods only be specified, with a modified CLP format deliverable.

Response: Although the remaining CLP and SW-846 methods are very similar, CLP methods will not be removed from the table in case their use is necessary to meet regulatory requirements. See the response to comment 12 regarding data package deliverables.

7. **Comment**: Section 5.5

This section should include the requirement that MDLs and IDLs must be instrument and/or matrix-specific, and should include a reference to the method of calculation (e.g. 40-CFR, Part 136, Appendix B).

Response: Text will be revised as requested.

8. **Comment**: Section 6

This section on internal QC checks should include discussion on interference check samples and serial dilutions for ICP analyses. In the discussion of interference check samples, it should be stressed that data must be provided for all of the elements in Interference Check Solution A,

especially arsenic, barium, cadmium, lead, and selenium, which are most affected by high levels of calcium, iron, and aluminum. In addition, if SW-846 methods are specified, the QA plan should require that duplicate injections and analytical spikes be done for graphite furnace methods.

Response: Information regarding interference check samples and serial dilutions for ICP analyses and duplicate injections and analytical spikes for GFAA analyses will be added to the text.

9. **Comment**: Sections 6.2 and 6.3

The reference to CLP SOW should be to the appropriate approved method.

Response: Agreed. Text will be revised

10. **Comment**: Section 6.4

No frequency is specified for the analysis of blank spike samples. It is recommended that one blank spike or laboratory control sample be analyzed per set of up to twenty samples. This type of sample should not be confused with the independent check or performance evaluation sample.

Response: A frequency of one blank spike or laboratory control sample per 20 samples, as applicable, will be added to the text. References to check samples will be removed from the text.

11. **Comment**: Section 6.5

No frequency is specified for method blanks. It is recommended that a method blank be prepared each day samples are prepared, or for each set of up to twenty samples prepared by a method.

Response: Section 6.5 currently states that method blanks are prepared and analyzed in accordance with the analytical method employed. However, the minimum requirement of one method blank per preparation blank and/or one per twenty samples will be added to the text.

12. **Comment**: Section 8

Data reduction and validation are greatly enhanced by complete summary information presented in a uniform format. This is the advantage of the CLP forms. As mentioned in paragraph 6, above, if SW-846 methods are specified, a modified CLP deliverable should be required.

Response: A discussion of the use of CLP-type deliverables for non-CLP data will be added to the text. However, as discussed in the second paragraph of Section 8.2, the level of data quality required will be determined by the project goals and intended use of data. Some data for certain sites may not require data validation. In turn, CLP-type data packages may not be required for all data. Therefore, deliverable requirements will be specified in project-specific planning documents.

13. **Comment**: Section 9

It is recommended that the use of performance evaluation (PE) samples be incorporated into the discussion of performance and system audits. Data from PE samples can be used to pre-qualify laboratories, and can serve as a routine check on laboratory performance.

Response: Laboratories are required to analyze performance evaluation (PE) samples as part of the Navy's laboratory evaluation process. A reference to these PE samples will be added to the text.

14. **Comment**: Section 12

A reference is made to U.S. EPA Region V. This should be changed to Region 4.

Response: The reference will be changed accordingly.

BROWN & ROOT ENVIRONMENTAL
RESPONSE TO COMMENTS TO THE DRAFT MASTER WORK PLAN, VOLUME II - COMMENTS RECEIVED 8/14/96
MCRD PARRIS ISLAND, SOUTH CAROLINA

GENERAL COMMENTS

1. **Comment**: Appendix B: SOPs have been revised. See attached SOPs for revised SOPs and additional SOPs pertaining to field work. Text referring to SOPs will need to be updated accordingly.

   Response: The most recent SOPs will be included and associated text will be revised accordingly.

SPECIFIC COMMENTS

Field Sampling Plan

1. **Comment**: Page 2-6, Section 2.2.4

   May want to discuss in separate paragraphs the typical drilling method (hollow-stem augers, cable-tool, and rotary drilling) mentioned in the first sentence.

   Response: A brief description of hollow-stem auger and rotary drilling will be included in the text of Section 2.2. At this time, cable-tool drilling is not likely to be used at the Depot and will be removed from the text. A complete description of these methods is provided in B&R Environmental Standard Operating Procedure GH-1.3, Soil and Rock Drilling Methods.

2. **Comment**: Page 2-11, Section 2.3, last paragraph, last sentence

   States development of wells shall be conducted by Southern Division Well Installation Standards. These standards need to be identified or an SOP referenced or use the paragraph inserted.

   Response: The reference to the Southern Division Standard will be replaced with the description provided.

3. **Comment**: Page 2-28, Section 2.9

   Reference to 1927 NAD and 1929 NGVD are made. It should be noted that 1982 datum information will be used.

   Response: The reference to 1927 NAD and 1929 NGVD will be replaced with 1982 datum.

4. **Comment**: Page 2-32, Figure 2-4

   This figure is referenced on Page 2-30 and should, therefore, appear as Page 2-31.

   Response: Agreed. The page numbers will be revised accordingly.

5. **Comment**: Appendix A

Field forms have been revised and are attached. Field forms for Well Development and Pump Testing, also attached, should be added.

Response: Agreed. Revised and additional forms will be included.

RESPONSE TO SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES (SCDNR) COMMENTS TO DRAFT FINAL MASTER WORK PLAN, VOLUME II - COMMENTS RECEIVED 1/2/98 MCRD, PARRIS ISLAND, SOUTH CAROLINA

COMMENTS - Robert E. Duncan, Environmental Programs Director

1. **Comment**: Volume II, Section 3.0 and Appendix B

   General Sampling Operations and Standard Operating Procedures for Tissue Sampling should be added.

   Response: The text will include a short section indicating that biological sampling at MCRD Parris Island is a possibility and that relevant Standard Operating Procedures (SOPs) are in Appendix B. The following SOPs will be added to those already part of Appendix B:

   SOP SA-4.1 Aquatic Ecological Inventory and Sampling
   SOP SA-4.4 Biological Sampling Equipment Calibration and Maintenance

   If tissue sampling is required at a site, specific instructions will be made part of the appropriate site work plan. The extent or nature of tissue sampling at MCRD Parris Island cannot be anticipated at this time.

2. **Comment**: Volume II, Appendix B.1, SA-1.2

   Even-numbered pages (2,4,6,8, and 10) are missing.

   Response: The missing pages will be distributed accordingly.

RESPONSE TO THE U.S. FISH AND WILDLIFE SERVICE
COMMENTS TO DRAFT FINAL MASTER WORK PLAN, VOLUME II - COMMENTS RECEIVED 2/26/98
MCRD PARRIS ISLAND, SOUTH CAROLINA

1. **Comment**: Page 3-1, Groundwater Sampling

   Whenever nonaqueous-phase liquids (NAPLs, dense or light) are suspected and/or detected in any groundwater monitoring well, samples should be collected and analyzed for both NAPLs and dissolved phase constituents.

   Response: Agreed. The text will be revised accordingly.

2. **Comment**: Page 3-2, Surface Water Sampling

   As discussed in Appendix B, Standard Operating Procedures, grab samples are only indicative of conditions near the surface and may not be a true representation of the total concentration that is distributed throughout the water column and in the cross-section. Also, sample depth is important as is tidal stage for many surface waterbodies at the Parris Island MCRD. Actual surface water sampling procedures, in accordance with the SOPs in Appendix B, must be determined on a case-by-case basis. The appropriateness of sample compositing should also be made on a case-by-case basis.

   Response: The Navy agrees that details of surface water sampling should be determined on a case-by-case basis. The text will be revised accordingly.

3. **Comment**: Page 3-3, Sediment Sampling

   As with surface water sampling, a sediment grab sample may not be appropriate at all sediment sampling locations, such as the Incinerator Landfill site. Core sampling would be more appropriate a some locations, with laboratory analyses of constituents at various identified depths. Appendix B indicates only scoop samplers and dredge samplers would be utilized. This should be modified to include vertical core sampling as well. Sampling methodology as well as the appropriateness of sample compositing must be made on a case-by-case basis.

   Response: The Navy agrees that details of sediment sampling should be determined on a case-by-case basis. If core samples are needed, a procedure will be included in the site-specific sampling plan. The text will be revised accordingly.

Rev. 0
03/27/98

Master Field Sampling Plan

Marine Corps Recruit Depot

Parris Island, South Carolina
U.S. EPA Identification Number
SC6 170 022 762

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888
Contract Task Order 0020

March 1998

Rev. 0
03/27/98

MASTER FIELD SAMPLING PLAN

MARINE CORPS RECRUIT DEPOT
PARRIS ISLAND, SOUTH CAROLINA
U.S. EPA IDENTIFICATION NUMBER
SC6 170 022 762

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
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CONTRACT NUMBER N62467-94-D-0888
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NOVEMBER 1997

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A FIELD DOCUMENTATION FORMS

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PUMP TEST DATA SHEET
GROUNDWATER SAMPLE LOG SHEET
LOW FLOW PURGE DATA SHEET
GROUNDWATER LEVEL MEASUREMENT SHEET
SURFACE WATER SAMPLING LOG SHEET
SOIL AND SEDIMENT SAMPLE LOG SHEET
BORING LOG
MONITORING WELL SHEET
SINGLE SAMPLE LOG SHEET
CHAIN-OF-CUSTODY RECORD

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ACRONYMS/ABBREVIATIONS

ASTM	American Society for Testing and Materials
B&R Environmental	Brown & Root Environmental
CDP	Common Depth Point
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-term Environment Action Navy
COC	Chain-of-Custody
CPS	Counts Per Second
DIFP	Digital Instantaneous Floating Point
DOT	Department of Transportation
DPD	Direct-Push Drilling
ECD	Electron Capture Devices
EDM	Electronic Distance Measure
EISOPQAM	Environmental Investigations Standard Operating Procedures and Quality Assurance Manual
EM	Electromagnetic
emf	Electromotive Force
FDEM	Frequency Domain Electromagnetic
FID	Flame Ionization Detector
FOL	Field Operations Leader
FSP	Field Sampling Plan
FTMRs	Field Task Modification Records
GC	Gas Chromatograph
GPR	Ground-Penetrating Radar
GRM	Generalized Reciprocal Method
HASP	Health and Safety Plan
ID	Inside Diameter
IDW	Investigative-Derived Waste
IRP	Installation Restoration Program
MCLs	Maximum Contaminant Levels
MCRD	Marine Corps Recruit Depot
MHz	megaHertz
mmhos/m	Millimhos per Meter

MS	Mass Spectrometer
mS/m	milliSiemens per Meter
mV	milliVolts
MWP	Master Work Plan
NMO	Normal Move Out
NSF	National Sanitation Foundation
NTU	Nephelometric Turbidity Units
OD	Outside Diameter
OVA	Organic Vapor Analyzer
PC	Personal Computer
PID	Photoionization Detector
PPE	Personal Protective Equipment
ppt	Parts Per Thousand
PVC	Polyvinyl Chloride
P-wave	Primary Wave
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manager
QAP	Quality Assurance Plan
QAPP	Quality Assurance Project Plan
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RPM	Remedial Project Manager
SCDHEC	South Carolina Department of Health and Environmental Controls
SOPs	Standard Operating Procedures
SP	Spontaneous Potential
TDEM	Time Domain Electromagnetic
TOM	Task Order Manager
TSDF	Treatment, Storage, or Disposal Facility
U.S. EPA	United States Environmental Protection Agency
USCS	Unified Soil Classification System
VLF	Very Low Frequency
VOCs	Volatile Organic Compounds

1.0 INTRODUCTION

This Master Field Sampling Plan (Master FSP) outlines the standard sampling procedures to be used for investigations conducted at the Marine Corps Recruit Depot (MCRD) Parris Island. This Master FSP has been prepared by Brown & Root Environmental (B&R Environmental) for the Southern Division (SOUTHDIV) Naval Facilities Engineering Command (NAVFAC) under the Navy Comprehensive Long-term Environmental Action Navy (CLEAN) Program, Contract Number N62467-94-D-0888, Contract Task Order (CTO) 0020. The Master FSP specifies requirements for any field work that may be undertaken at the facility and serves as a complete guide for use in the field by all members of the field investigation team. Addenda (Site-Specific Field Sampling Plan) to this Master FSP will be written for site-specific projects. Investigations will comply with applicable South Carolina Department of Health and Environmental Controls (SCDHEC) and United States Environmental Protection Agency (U.S. EPA) regulations.

This Master FSP consists of three sections. Section 1.0 presents this introduction. Section 2.0 details the potential field operation tasks, including soil boring and well installation procedures, as well as decontamination and waste handling procedures. Section 3.0 details all aspects of the potential environmental sampling procedures. Contractor Field Documentation forms and Standard Operating Procedures (SOPs) for these potential activities are included in Appendices A and B, respectively.

2.0 FIELD OPERATIONS

2.1 GENERAL FIELD OPERATIONS

This section discusses the general sampling operations, procedures, and proper documentation for the potential field operations to be performed at MCRD Parris Island. Details of environmental sampling operations are discussed in Section 3.0.

2.1.1 Mobilization/Demobilization

Following approval of the site-specific FSP addendum, mobilization activities will start. All field team members will review the Master Work Plan (MWP) documents (Volumes I, II and III) as well as the Site-Specific Work Plans prior to the project mobilization. In addition, a field team orientation meeting will be held to ensure that personnel are familiar with the scope of the field activities.

The Field Operations Leader (FOL) is designated as the lead in coordinating all day-to-day site activities during the investigation. The FOL is responsible for ensuring that all field team members (including subcontractors) are familiar with the FSPs and Health and Safety Plans (HASPs). Additionally, the FOL is responsible for all sampling operations, Quality Assurance/Quality Control (QA/QC), field documentation requirements, and field change orders. The FOL will also regularly report to the Task Order Manager (TOM) regarding the status of field work and any problems that may occur.

Prior to the initiation of field work, the FOL will arrive at the site and coordinate onsite mobilization activities. These activities will include the clearing of drilling locations with utility personnel, coordination with base personnel, purchasing expendable equipment, and preparation of the field trailer (if applicable). After field activities are completed, the FOL will demobilize the equipment and field trailer.

All site preparation is coordinated through MCRD Parris Island personnel. When necessary, temporary barriers are installed and traffic control provided at work locations as a safety precaution.

Additional details regarding responsibilities and authorities of key personnel are presented in the Master Quality Assurance Plan (QAP) (Section 2.0) and the Quality Assurance Project Plan (QAPP) for site-specific applications.

2.1.2 Site Restoration

If investigation activities (e.g., monitoring well installation) disturb or alter the landscape, vegetation, or other features of a site, the site may require restoration to conditions prior to the investigation. If vegetation is stressed or damaged as a result of investigation activities, the affected area will be reseeded. Portions the sites will be regraded if investigation activities alter the natural contour of the sites. Additionally, all equipment used during the investigation and investigative-derived waste (IDW) will be removed from the sites.

2.2 SUBSURFACE INVESTIGATIONS

Soil borings are drilled to characterize subsurface lithology and soil contamination in accordance with SOP GH-1.3, contained in Appendix B. Some of the soil borings may be converted into groundwater monitoring wells. All well installation and groundwater sampling efforts shall comply with applicable state requirements.

2.2.1 Soil Borings

The hollow-stem auger drilling method is the preferred method for drilling soil borings. Soil samples are typically collected at 5-foot intervals from the ground surface, to the top of the water table, as referenced in specification ASTM-2686-84. The split-spoon samplers will have a minimum inside diameter (ID) of 2 inches and are at least 2 feet long to fulfill sample volume requirements for chemical analysis. The split-spoon sampler is driven to the required depth by means of a drill-rig-mounted hammer weighing 140 pounds for a 30-inch fall. The use of fluids is prohibited during soil boring activities.

All samples obtained from the boreholes are monitored with an organic vapor analyzer (OVA), photoionization detector (PID), or HNu, as specified in the HASP. Each split-spoon sampler is screened with the OVA or HNu immediately upon opening. These readings are recorded on the boring logs. As required, chemical analyses samples are obtained in accordance with the procedures outlined in Section 3.0. In addition to analytical samples, lithologic samples are collected at all sampling intervals. The lithologic samples are placed in an 8-ounce jar (provided by the drilling subcontractor), labeled, and the pertinent data recorded by the field geologist. All lithologic samples are discarded at the end of the field activities. The driller shall prepare a separate written boring log for each boring drilled. The driller's boring log is submitted to the field geologist at the conclusion of the daily field activities.

A lithologic description of each split-spoon sample and a complete log of each boring is maintained by the B&R Environmental geologist in accordance with SOP GH-1.5, contained in Appendix B. At a minimum, the boring log will contain the following information:

- Boring or Well Identification
- Name of Drilling Contractor
- Sample Numbers and Types
- Sample Depths
- Standard Penetration Test Data
- Sample Recovery/Sample Interval
- Soil Density or Cohesiveness
- Soil Color
- Unified Soil Classification System (USCS) Material Description
- Location of Boring
- Drilling and Well Construction Problems/Deviations from FSP and Installation Restoration Program (IRP) Handbook

In addition, depths of changes in lithology, sample moisture observations, depth to water, vapor readings, drilling methods, and total depth of each borehole are included on each log, as well as any other pertinent observations. An example of the boring log form is attached in Appendix A. Sample bottles containing soil samples collected for lithologic description are consecutively numbered starting with S-1. In addition, the following information is recorded on the lids of these sample jars:

- Job name and number
- Well/Boring number and sample number
- Date
- Depth of sample
- Blow counts

After the borings are drilled to the desired depth, they are grouted to the ground surface with a cement-bentonite slurry. A standard batch of slurry consists of approximately 94 pounds cement, not more than 4 pounds of bentonite powder, and not more than 6.5 gallons of potable water. The slurry is placed within the boring using a tremie pipe.

2.2.2 Test Pit Operations

Test pitting is an effective investigation technique for sampling and characterizing subsurface conditions. Test pitting can cover a broader area but is limited in vertical depth. Geophysical surveys can be used to help identify areas applicable for test pitting. Soil grab samples are collected from each test pit based upon visual observations and upon OVA or HNu readings obtained by the site geologist. Samples are collected directly from the backhoe bucket. If drums or unknown materials are encountered during test pit excavations, the test pit excavation will cease, and the removed soils will immediately be placed back in the excavation. Test pits are backfilled before completion of each day's work activities. A description of each test pit is completed by the field geologist. An example test pit log (Single Sample Log Sheet) is included in Appendix A.

Test pit sampling and excavation are performed in accordance with SOP SA-1.3, provided in Appendix B.

2.2.3 Drilling Methods

The following sections describe several drilling techniques that may be used during field activities at the MCRD Parris Island, South Carolina. These techniques are discussed in greater detail in B&R Environmental SOP GH-1.3, Soil and Rock Drilling Methods, in Appendix B.

2.2.3.1 Direct-Push Drilling

Direct-push drilling (DPD) (e.g., Geoprobe® and Hydropunch®) operations may be provided directly by the CLEAN contractor, or provided by a subcontractor. All subcontracted DPD operations will be overseen by the CLEAN contractor. DPD is a useful screening tool to help focus follow-up chemical sampling activities. Because of the advantages of DPD techniques, it is likely that the DPD procedure for sample collection will be used at MCRD Parris Island.

Most DPD equipment is mounted in cargo vans or on the bed of a pickup truck and includes a hydraulic-powered probe for driving and removal of hardened steel sample rods. Many DPD rigs are equipped with an additional air percussion option for penetrating dense material and an electric hammer for drilling through asphalt and concrete. A wide variety of sample rods are utilized by the DPD system for soil, soil-gas, and groundwater sampling. Groundwater samples are typically obtained using peristaltic pumps, vacuum-lift pumps, or miniature bailers. Some DPD subcontractors also provide field gas chromatographs (GCs) equipped with flame ionization detectors (FIDs), PIDs, and electron capture devices (ECD), for real-time analysis of environmental samples.

Advantages of DPD include the ability to obtain a vertical profile of contaminant concentrations, almost complete elimination of drill cuttings production, sampling in tight-access locations, reduced overhead clearance requirements, and real-time laboratory analyses. Disadvantages include a maximum penetration depth of approximately 15 to 40 feet in dense soils, inability of vehicles to access narrow spaces, reduced capability of obtaining accurate water-level measurements, and inability to install permanent groundwater monitoring wells.

2.2.3.2 Rotary Drilling

Direct rotary drilling includes air-rotary and fluid-rotary drilling. Air-rotary drilling is a method where the drill rig simultaneously turns and exerts a downward pressure on the drilling rod and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole.

Fluid-rotary drilling operates in a similar manner to air-rotary drilling except that a drilling fluid ("mud") or clean water is used in place of air to cool the drill bit and remove cuttings. There are a variety of fluids that can be used with this drilling method, including bentonite and synthetic slurries. If a drilling fluid other than water/cuttings is used, it must be a natural clay (e.g., bentonite), and a "background" sample of the fluid should be taken for analysis of possible organic or inorganic contaminants.

Rotary drilling is explained in further detail in B&R Environmental SOP GH-1.3, Soil and Rock Drilling Methods in Appendix B.

2.2.3.3 Hollow-Stem Auger Drilling

This method consists of inserting a rotating auger with a hollow stem into the ground. Cuttings are brought to the surface by the rotating action of the auger. This method is relatively quick and inexpensive. The hollow-stem auger is typically advanced by power-operated drilling machines that have sufficient torque and ram range to rotate and force the auger to the desired depth. Hollow-stem auger drilling is explained in further detail in B&R Environmental SOP GH-1.3, Soil and Rock Drilling Methods, in Appendix B.

2.2.3.4 Rotasonic Drilling

Rotasonic drilling provides a viable alternative method to hollow-stem augers and rotary drilling techniques. Drilling proceeds rapidly through all types of complex geology, unconsolidated or

consolidated, and provides a high-quality, continuous core sample for accurate lithologic and hydrologic information. IDW, such as drilling fluids and drill cuttings, is kept to a minimum.

The rotasonic technique combines vibrational and rotational forces to advance the drill stem. The high frequency vibration generated in the drill head can be adjusted for different drilling conditions so that penetration rates can be optimized.

The boring is advanced using two separate drill pipes. The drill bit is attached to the base of the 4-inch ID, 4.5-inch outside diameter (OD), 10-foot long core barrel. The core barrel is also available in 6-inch and 6.5-inch OD sizes. The core barrel is connected to drill pipe of the same OD. When the core barrel reaches the desired depth, a larger diameter outer drill pipe (5.875-, 6.25-, or 8.25-inch OD) is advanced to the same depth. The inner core barrel, inner pipe, and sample are then retrieved. The core sample is extruded from the core barrel using vibration and/or hydraulic pressure. The sample is collected in a plastic sheath as it is extruded from the core barrel. The core sample is therefore completely enclosed in the clear plastic sleeve. This facilitates lithologic classification, environmental sample collection, and vapor monitoring. In addition, it greatly reduces the exposure of the drill crew to potentially contaminated drill cuttings. The process is then repeated with the core barrel advancing ahead of the outer casing to ensure a representative sample. A rotasonic drill rig is capable of casing off three separate hydrologic units using different size casings.

Only small, controlled amounts of water are added, if needed, to the drill stem during drilling operations to flush out cuttings in the annular space between the two drill pipes, to flush out cuttings at the bottom of the borehole after sample collection, or for offsetting hydraulic pressures of heaving sands. Any excess water is collected in a container below the drilling platform.

Continuous soil samples are collected as discussed above through the inner core barrel. Additionally, thin-walled samplers can be used to collect undisturbed soil samples, and brass or stainless-steel sleeves can be inserted into the core barrel to collect samples for offsite analysis. Groundwater grab samples can be collected during drilling in a similar fashion to other drilling methods.

Rotasonic methods are well suited to monitoring well installation because the well materials are installed directly inside the casing to allow exact well and filter pack placement. In addition, the drill pipe holds the borehole open and acts as a barrier to cross-contamination between hydraulic units. The filter sand pack is poured directly into the drill casing. The resonance created from the head vibration settles the sand pack more consistently than during direct-pour or tremie pipe installations. Once the sand pack is installed, the casing is pulled up using vibration, and the installation depths are measured to confirm filter-

pack thickness. Additional sand is added as needed and the process is repeated. Typically, bentonite pellets are installed in a similar fashion. If the installation depth is greater than 30 feet below the water table, a bentonite slurry is installed through a 0.75- to 1.5-inch tremie pipe. Grout is also installed through the tremie pipe.

Typically, the Rotasonic drilling equipment is mounted on a 6 by 6 tandem truck. The total overhead clearance required for the drilling mast is 40 feet. The truck is approximately 10 feet wide and 40 feet long. For this reason, tight locations may not be accessible. The greater expense of mobilizing the Rotasonic drilling equipment is offset by the minimal amount of IDW generated. This method of drilling may not be cost effective if only a few shallow wells are drilled during the mobilization period.

2.3 MONITORING WELL CONSTRUCTION AND INSTALLATION

Monitoring wells will be installed and constructed in accordance with all applicable State of South Carolina regulations (e.g., Code of Laws of South Carolina 1976, Regulation 61-71 Well Standards) and the U.S. EPA Region 4 EISOPQAM (1996). Prior to the construction of any monitoring well, a formal request will be submitted to the SCDHEC for approval. The request will contain the following information:

- Proposed location(s) on a scaled map or plate
- Proposed construction detail
- Intended purpose of the monitoring well(s)

The state also requires a formal submission detailing the activity performed during the installation of the monitoring well(s). A monitoring well record form or other form provided and/or approved by the state shall be completed and submitted within 30 days after completion of each monitoring well. The form shall contain the following information:

(a) Name and address of the facility/owner
(b) Location of monitoring well(s) on a scaled map or plate
(c) Driller and certification number
(d) Date drilled
(e) Driller's or geologist's log
(f) Total depth
(g) Screened interval
(h) Diameter and construction details
(i) Depth to water table with date and time measures

(j) Surveyed elevation of measuring point with respect to an established benchmark

(k) State-certified professional geologist's seal and certification number

2.3.1 Overburden and At-Grade Monitoring Wells

Soil borings slated for monitoring wells will be converted to 2-inch polyvinyl chloride (PVC) monitoring wells. All monitoring wells will be constructed of 2-inch, PVC, flush-joint riser pipe and flush-joint, factory-slotted well screen and end caps. Each section of casing and screen will be National Sanitation Foundation (NSF) approved. Only new, clean well casings and screens will be installed. The end cap will be made of a material compatible with the well screen. Unless otherwise specified, state, U.S. EPA, Southern Division well installation requirements shall be followed for well installation activities. Figure 2-1 illustrates typical well construction details for overburden wells. The monitoring well borings will be drilled using hollow-stem augers of sufficient diameter to produce a 2-inch annular space between the casing and the borehole. The diameter of the borehole will be recorded for each installation.

Unless otherwise specified, the top of the screened interval will be positioned approximately 2 feet above the average, seasonal, stabilized water level. Well screens for shallow monitoring wells will be 10 feet long with 0.010-inch openings. Deep well screens will be 5 feet long with 0.020-inch openings. After the borings are drilled to the desired depth, the well will be installed through the augers. A silica sand pack will be installed into the boring annulus around the well screen. The sand pack will be installed flush with the bottom of the well to a minimum of 2 feet above the top of the well screen. The sand pack will be installed by pouring sand into the space between the riser pipe and hollow-stem augers. The hollow-stem augers act as a tremie pipe and are withdrawn from the boring as the sand is emplaced. The sand will be kept within the augers during withdrawal to ensure an adequate sand pack.

A weighted tape measure will be used during the installation to ensure that no bridging occurs and to maintain no more than 1 foot of sand above the bottom of the augers. In some of the shallower monitoring wells, it may be necessary to bring the sand pack up to only 1 foot above the top of the screen to allow enough room for a sufficient bentonite and grout seal. One hundred percent sodium bentonite pellets will be installed above the primary filter pack and allowed to hydrate in accordance with the manufacturer's recommendations. The depths of all backfill materials will be constantly monitored during the well installation process by means of a weighted, stainless-steel or plastic tape.

B&R Environmental SOP GH-2.8 (attached in Appendix B) provides guidance for different types of well constructions, such as confining layer monitoring wells, bedrock monitoring wells, and drive points. The site-specific WP will detail the exact well installation details required for that project.

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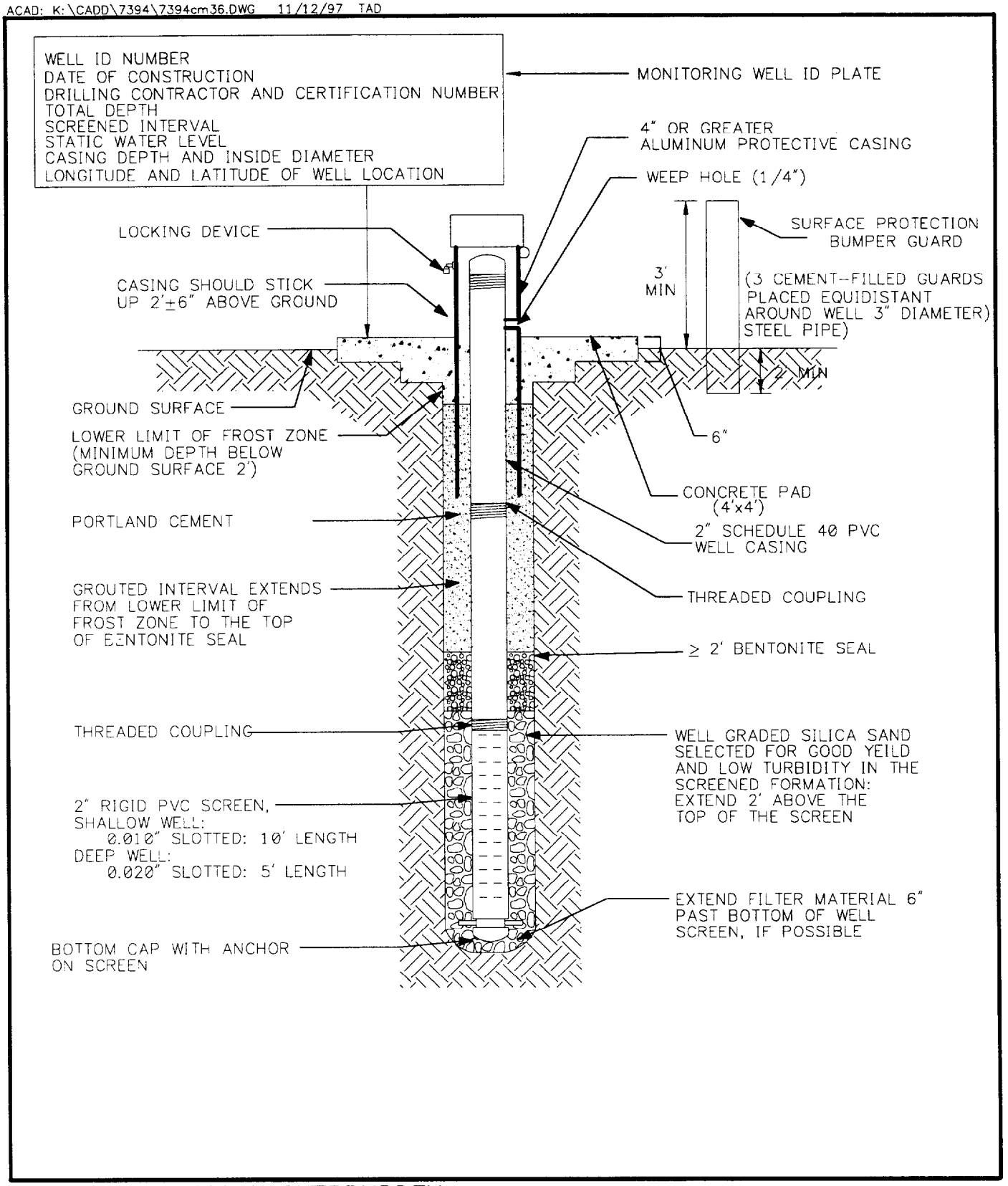

TYPICAL OVERBURDEN MONITORING WELL DETAIL
MCRD
PARRIS ISLAND, SOUTH CAROLINA
NOT TO SCALE

FIGURE 2-1

Brown & Root Environmental

An at-grade protective steel casing equipped with a sealing, locking cap will be installed around all wells in high-traffic areas. At-grade covers will be installed in accordance with state requirements. Figure 2-2 illustrates typical well construction details for an at-grade well.

For all other wells, a 4-inch-diameter, protective steel casing equipped with a locking steel cap will be installed. All protective casings will be grouted a minimum of 3 feet into the ground and will have at least one drain hole positioned approximately 0.5 feet above the ground surface. In addition, a concrete apron measuring 4 feet by 4 feet by 6 inches will be constructed equally portioned around the casing of each well. For stick-up casings in traffic areas, three marker posts (3-inch nominal diameter, 5-foot-long steel pipe filled with cement) will be embedded 2 feet into the ground and set in concrete, separate from the concrete apron around the well base. The marker posts will be positioned equidistant from one another. All locks supplied for the wells will be keyed alike. After installation, the top of the riser pipe, the top of the protective casing, and the ground surface elevation at the well location will be surveyed to within 0.01-foot vertical accuracy. In addition, the well will be surveyed to a 0.1-foot horizontal accuracy.

A 4-inch by 4-inch aluminum tag identification plate will be affixed to each well and will contain the following information.

(a) Well identification number
(b) Date of construction
(c) Drilling contractor and certification number
(d) Depth of well
(e) Screen interval
(f) Static water level
(g) Casing depth and inside diameter
(h) Longitude and latitude of site

A monitoring well construction diagram is completed for each well installed. A sample of the monitoring well construction form is provided in Appendix A.

2.3.2 Injection and Extraction Wells

Injection and extraction wells may also be used during installation restoration work at the Depot. A typical detail of such wells is presented in Figure 2-3. Such wells will be installed using hollow-stem auger techniques, when appropriate. All wells will be installed with a typical sand pack, bentonite seal, and

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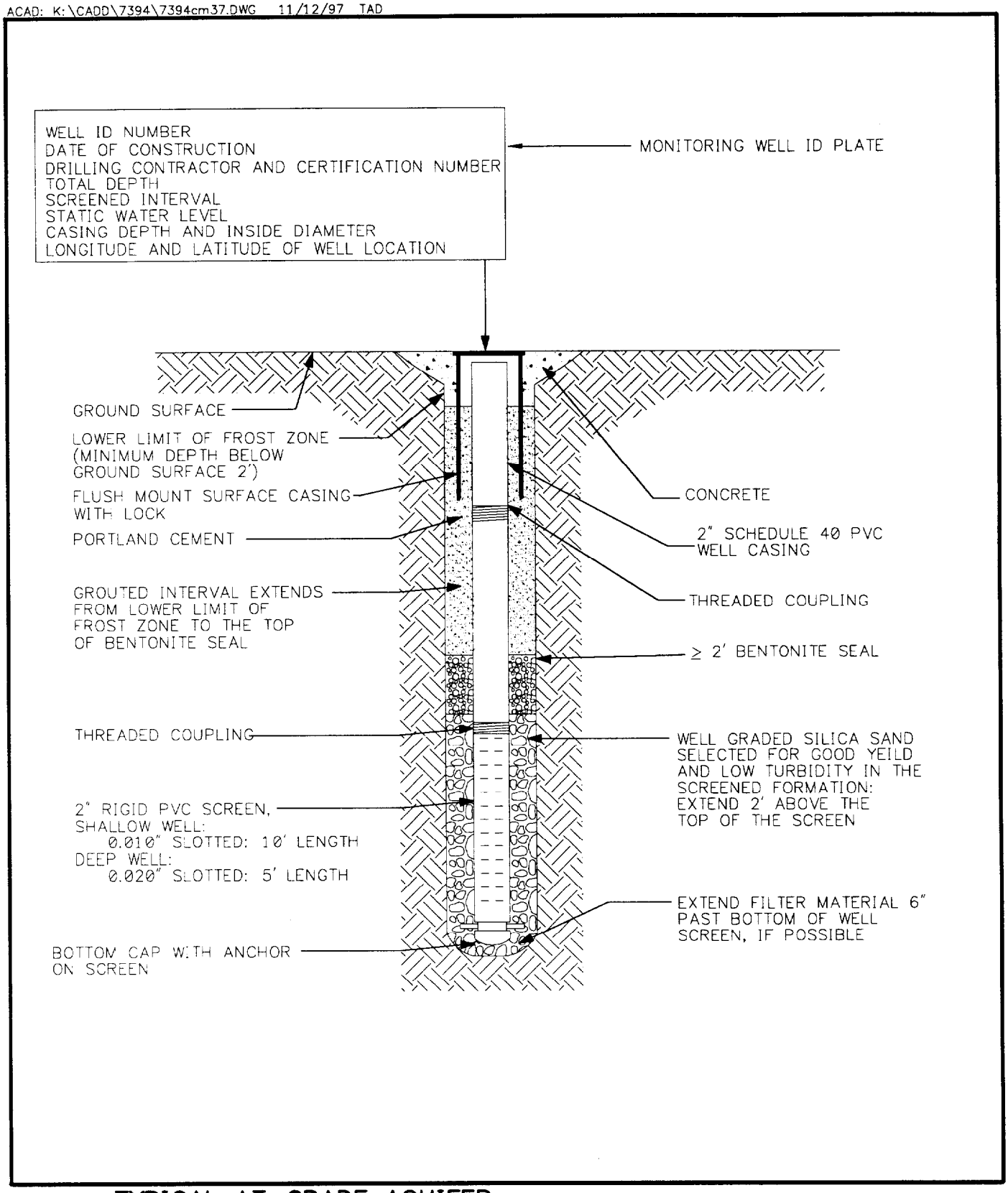

TYPICAL AT-GRADE AQUIFER MONITORING WELL DETAIL
MCRD
PARRIS ISLAND, SOUTH CAROLINA
NOT TO SCALE

FIGURE 2-2

Brown & Root Environmental

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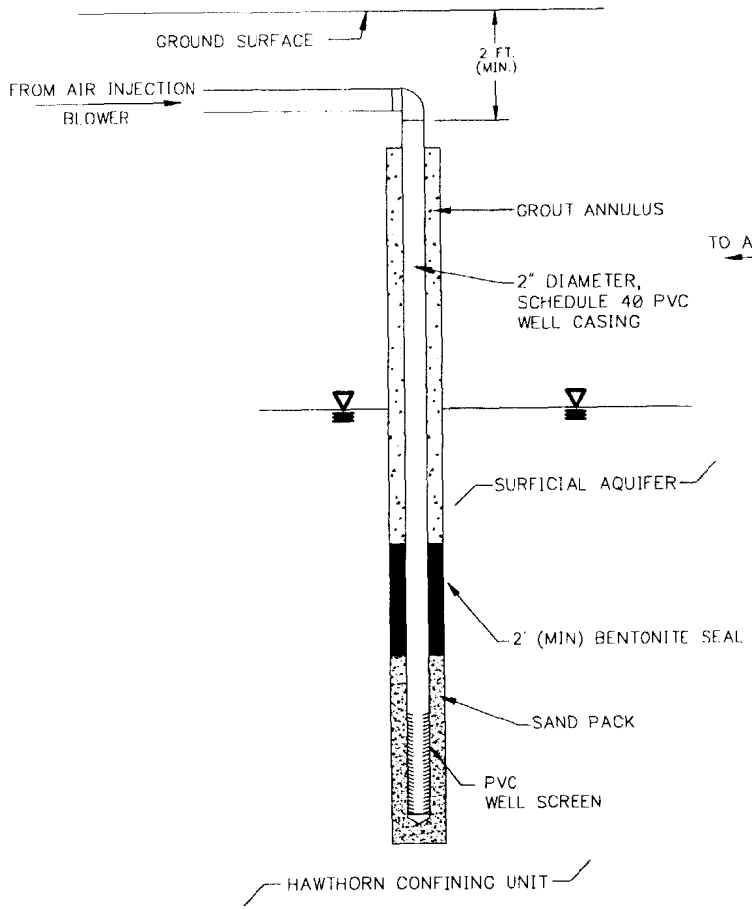
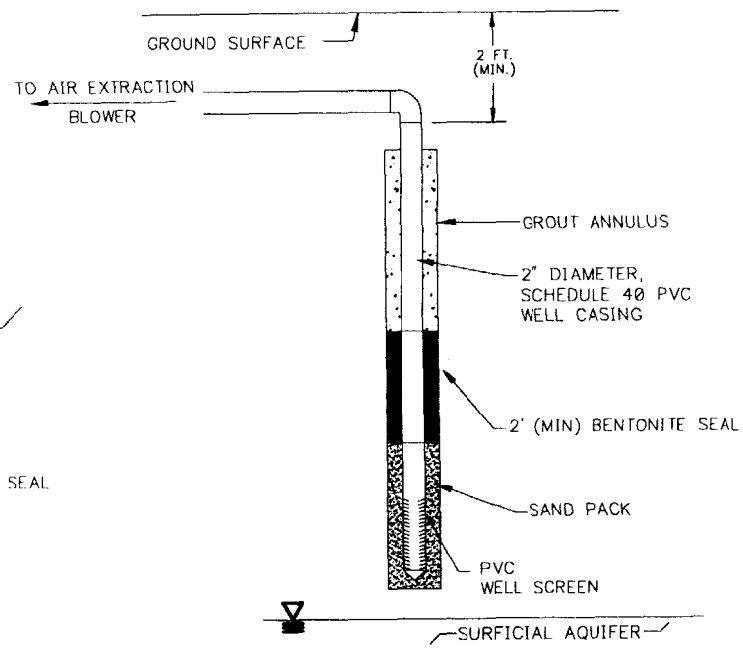


INJECTION WELL DETAIL (TYPICAL)
NOT TO SCALE



EXTRACTION WELL DETAIL (TYPICAL)
NOT TO SCALE

DRAWN BY TAD DATE 11-97	Brown & Root Environmental	CONTRACT NO. 7394	OWNER NO. ————
CHECKED BY DATE	TYPICAL INJECTION & EXTRACTION WELL DETAIL MCRD PARRIS ISLAND, SOUTH CAOLINA	APPROVED BY	DATE
COST/SCHED-AREA		APPROVED BY	DATE
SCALE NTS		DRAWING NO. FIGURE 2-3	REV. 0

FORM CADD NO. SOUTH_AV.DWG - REV 0 - 02/07/97

grouted annulus as discussed in Section 2.3.1 and will be constructed of 2-inch, Schedule 40 PVC with flush threaded joints.

2.3.3 Monitoring Well Development

Permanent monitoring wells will be developed no sooner than 24 hours after well completion to remove fine material from the area around the monitored interval of the well. Wells are developed by bailing and surging or by pumping, as determined by the field geologist. The pH, temperature, turbidity, and specific conductivity measurements are collected for the purged water after each borehole volume is removed. Wells are developed until these readings become stabilized. Water-quality stabilization is determined using the following criteria: temperature ±1.0°C, pH ±0.1 unit, and specific conductivity ±5 percent.

Following installation, each groundwater monitoring well will be developed in accordance with the B&R Environmental SOP GH-2.8 (Appendix B) to remove any mud pack, drill cuttings, or formation fines from the well screen. Based upon field conditions (i.e., a well goes dry), the site geologist may modify these protocols. The groundwater monitoring wells will be developed by the driller no sooner than 48 hours nor longer than 7 calendar days after well installation, and this will be accomplished by surging, bailing, and/or pumping, as determined by the B&R Environmental field geologist. Prior to development, a hydrocarbon interface probe will be used to determine the potential presence of both light and dense free product in the well. Groundwater monitoring wells with free product will not be developed.

A minimum of 5 times the standing water volume in the well casing plus 5 times the water volume in the saturated gravel pack (assume 30 percent porosity) will be removed. Turbidity will be measured during well development. An attempt will be made to develop the well to a turbidity of 10 nephelometric turbidity units (NTU). The wells will be developed until the discharge water is visibly clear, and temperature, pH, and specific conductivity have stabilized to within 10 percent variance for three consecutive measures, or as determined by the B&R Environmental field geologist. If a value of less than 10 NTUs cannot be achieved, attempts to stabilize the turbidity at a constant value will be made. All water quality measurements and the volumes removed will be recorded for each well on the well development form, attached in Appendix A.

2.3.4 Temporary Monitoring Wells

The description of temporary wells, as described in this section, is based on guidance contained in the U.S. EPA Region 4 EISOPQAM (1996). Such wells are best used for delineation of contaminant plumes, at a point in time, and for some site screening purposes. They are not intended to replace permanent

monitoring wells. The best use of temporary wells is in conjunction with a mobile laboratory where quick analytical results can be used to delineate contaminant plumes.

Several types of temporary monitoring well installation techniques have been demonstrated as acceptable and are described in further detail in the U.S. EPA Region 4 EISOPQAM (1996). Temporary wells are generally installed, purged, sampled, removed, and backfilled in a matter of hours. Because of the nature of construction, turbidity levels may initially be high; however, these levels may be reduced by low-flow purging in sampling techniques as discussed in B&R Environmental SOP SA-1.1, Groundwater Sample Acquisition and Onsite Water Quality Testing, in Appendix B.

Temporary monitoring well locations are not permanently marked, nor are their elevations normally determined. Sand pack materials may or may not be used, but typically there is no bentonite seal, grout, surface completion, or extensive development.

2.4 WATER-LEVEL MEASUREMENT

Synoptic water-level measurements are taken from all newly installed monitoring wells at the base. All measurements are taken within a 24-hour period of consistent weather conditions to minimize atmospheric/precipitation effects on groundwater levels. The sequence of measuring water levels is determined in the field by the site geologist.

Measurements are taken with an M-scope (electrical water-level indicator) using the top of the well casing as the reference point for determining depths to water in accordance with B&R Environmental SOP GH-1.2, contained in Appendix B. A notch is used at the top of the PVC to ensure that measurements are taken consistently between measuring events. Water-level measurements are recorded to the nearest 0.01 foot in the appropriate field log book and on a groundwater-level measurement form, attached in Appendix A.

2.5 FIELD MEASUREMENTS

Field measurements are recorded during field and sampling operations, including ambient air quality, groundwater temperature, pH, turbidity, and specific conductance. Ambient air quality measurements include monitoring of organic vapors in the breathing zone during intrusive field investigation activities and monitoring of organic vapors emanating from site sources such as soil samples and well casings. Instruments used in the field to record these data are calibrated according to the procedures described below.

2.5.1 Equipment Calibration

Several monitoring instruments may be used during field activities, including the following:

- OVA flame ionization detector or
- HNu photoionization detector
- Temperature probe
- Specific conductance meter
- pH meter
- Turbidity meter
- Electronic water-level indicator

Field instruments are calibrated according to the manufacturer's procedures and in accordance with the following:

- The pH meters are calibrated daily. At least two buffer solutions that bracket the expected sample pH shall be used (e.g., 4.0 and 7.0) to calibrate pH meters.

- Specific conductance meters are calibrated prior to each day's use.

- Thermometers are calibrated monthly. The expected range of sample temperatures is bracketed. This calibration shall be performed at the B&R Environmental equipment warehouse.

- Turbidity meters are calibrated at least daily using a standard within the expected range of sample turbidities.

- Duplicate measurements of pH, specific conductance, temperature, and turbidity are taken at a frequency of 1 in 10 samples and used to estimate the precision of the field analytical measurements.

- HNus or OVAs are calibrated prior to each day's use.

Calibration is documented on an Equipment Calibration Log (see Appendix A). During calibration, an appropriate maintenance check is performed on each piece of equipment. If damaged or defective parts are identified during the maintenance check and it is determined that the damage could have an impact on

the instrument's performance, the instrument is removed from service until the defective parts are repaired or replaced.

2.6 GEOPHYSICAL INVESTIGATIONS

The following subsections describe the basic procedures and requirements for various geophysical investigations that may be used at MCRD Parris Island. Geophysics shall be used in conjunction with other environmental and hydrogeological data (i.e., analytical data and soil boring logs) to help answer questions about subsurface conditions.

2.6.1 Geophysical Reference Grid

A geophysical reference grid will be installed at the site so that data can be accurately collected and reported. The grid will be staked at a constant interval in units of feet using a transit, electronic distance measure (EDM) or tape measure. Stakes will consist of pin flags or other semipermanent markings, which will be labeled with the grid coordinates in units of feet.

The reference grid will be tied into an existing site grid system, if present, and also to any permanent site features, such as buildings or fence corners. This will facilitate ease of re-occupation for subsequent subsurface investigations. Pin flags or other semipermanent markings will be left in place at the completion of the survey to also assist in the re-occupation of the grid for future investigations, if necessary. Notes taken during the establishment of the reference grid will be maintained in a field book, and copies will be submitted to the onsite representative, if requested.

2.6.2 Electromagnetics

2.6.2.1 High-Resolution Geonics EM31 Terrain Conductivity Survey

A Geonics EM31 Terrain Conductivity meter (EM31) and digital data logger may be used at this site to assist in the shallow (less than 15 feet deep) characterization of subsurface materials. The EM31 is a one-man-operated, frequency domain electromagnetic (FDEM) device that uses the principle of electromagnetic (EM) induction to measure the apparent conductivity and magnetic susceptibility of surface and subsurface materials and their pore fluids. The instrument is equipped with very low frequency (VLF) radio transmitter and receiver coil. These coils are separated by a distance of 12 feet and are located at the ends of a ridged, nonmetallic pole.

Quadrature and in-phase component data will be simultaneously collected at this site through the use of a digital data logger. Quadrature component data are a measure of the apparent electrical conductivity of the subsurface materials and their pore fluids. Quadrature component data are also commonly referred to as terrain conductivity or bulk conductivity data. A map of quadrature component data will assist in delineating areas of fill materials, contaminated soils, shallow contaminated groundwater, changes in soil types, changes in soil moisture content relative to undisturbed soils, and the presence of most buried ferrous and nonferrous metals. Quadrature component data are presented in units of conductivity, millimhos/meter (mmhos/m) or milliSiemens per meter (mS/m).

The EM31 device also records the in-phase component of the EM field. The in-phase component data are a measure of the presence of highly conductive material and are often referred to as the metal detection component. Buried metal within 15 feet of surface, such as steel drums or metallic pipes, can be mapped in this mode. In-phase data are presented in units of parts per thousand (ppt).

During this investigation, data will be collected with the instrument at waist height, held parallel to ground surface and with the coils vertically oriented. This will result in a depth of investigation of approximately 15 feet. Data will be collected along parallel survey lines. Data will be collected at a station spacing of 2 to 3 feet through the use of a digital data logger. Digital data will be downloaded daily through the use of a laptop computer and the manufacturer's software DAT31.

2.6.2.2 High-Resolution Geonics EM38 Terrain Conductivity Survey

A Geonics EM38 Terrain Conductivity meter (EM38) and digital data logger may be used at this site to assist in the characterization of the shallow (less than 5 feet deep) subsurface materials. The EM38 is a one-man-operated, FDEM device that uses the principle of EM induction to measure the apparent conductivity and magnetic susceptibility of surface and subsurface materials and their pore fluids. The instrument is equipped with a fixed frequency VLF radio transmitter and receiver coil. These coils are separated by a distance of approximately 3.3 feet and are located at the ends of the device's ridged, non-metallic frame.

Quadrature and in-phase data are collected separately through the use of a digital data logger. Quadrature data collected with this device are used to map subtle soil moisture content changes often associated with disturbed soils or fill materials, shallow soil stratigraphic changes, the presence of shallow metallic objects, and metallic pipes/utilities. The in-phase data are often used to further identify and confirm the presence of buried metallic objects, pipes, and utilities.

During this investigation, data will be collected with the instrument at ground surface, oriented parallel to the survey line and with the coils vertically oriented. This will result in a depth of investigation of approximately 5 feet. Data will be collected along parallel survey lines. Data will be collected at a station spacing of 1 to 2 feet through the use of a digital data logger. Digital data will be downloaded daily through the use of a laptop computer and the manufacturer's software DAT38.

2.6.2.3 Geonics EM34-3 Terrain Conductivity Survey

A Geonics EM34-3 Terrain Conductivity meter (EM34) and digital data logger may be used at this site to assist in the characterization of the subsurface materials to depths of approximately 25 to 200 feet below surface. The EM34 is a two-man-operated, FDEM device that uses the principle of EM induction to measure the apparent conductivity of surface and subsurface materials and their pore fluids. The instrument is equipped with a variable frequency VLF radio transmitter and receiver coil that are separated by a flexible reference cable. The EM34 has a variable coil separation of 32, 66, and 131 feet.

Data are often collected with the coil dipoles oriented horizontally, then vertically. Data are collected by adjusting the coil separation distance while maintaining the coils in the same geometric plane until an optimum instrument response is observed. Data collected when the coil dipoles are oriented vertically (vertical dipole mode) are extremely sensitive to errors as a result of coil alignment. Therefore, vertical dipole data collection can be difficult in areas of steep topography or dense brush. Data are recorded through the use of a digital data logger and by hand in the field notebook.

The depth of investigation of the EM34 is dependent upon the coil separation and the orientation of the coil dipole. The depth of investigation increases as the coil separation increases. The approximate depth of investigation with the coil dipoles oriented horizontally is 0.75 times the coil separation, whereas the depth of investigation with the coil dipole oriented vertically is 1.5 times the coil separation.

The EM34 is often used to map stratigraphic changes, such as the presence of buried sand channels, clay lenses, or the presence of contaminated groundwater. Data are generally collected at two or three coil separations at each station location and in the horizontal and vertical dipole mode. However, the instrument is very sensitive to the presence of anthropogenic features and of extremely electrically resistive soils when collecting data in the vertical dipole mode. Vertical dipole mode data collection are occasionally omitted in areas of potentially high cultural interference and where extremely resistive soils are present.

2.6.2.4 High-Sensitivity EM61 Metal Detection Survey

A Geonics EM61 high-sensitivity metal detection (EM61) and digital data logger may be used at this site to map the presence of buried metals, metallic pipes, and metallic utilities. These buried metals often may represent sources of contamination or may represent buried hazardous to future subsurface investigations. This device is a time domain electromagnetic (TDEM) instrument that uses the principles of electromagnetic induction to measure the presence of highly conductive ferrous and nonferrous materials in the subsurface. The device is equipped with a portable, 3.3-foot-square transmitter; a main receiver located coincident to the transmitter; and a focused receiver coil located 1.3 feet above the transmitter and main receiver coils. The transmitter and receiver coils are mounted onto a cart with plastic bicycle wheels and an electronic distance encoder. The power supply and electrical components are contained in a plastic backpack, which is worn by the operator.

TDEM equipment operates by rapidly extinguishing a transmitted signal and measuring the induced secondary signal in the ground, either at a specific point in time or as it decays with time. The EM61 transmitter coil generates a pulsed EM signal at a rate of 150 times per second. The two receiver coils measure the induced secondary EM field at a calibrated time in-between the transmitted signal pulses. The secondary EM signal induced from the presence of natural earthen materials rapidly decays before the receiver coils measure the response. The secondary EM signal induced from the presence of metals has a much longer decay time such that it is still present when the receiver coils begin to collect data. This results in the EM61's nonresponsiveness to the presence of changing soil conditions that can sometimes obscure buried metallic targets. This device has a depth of investigation that is dependent upon the surface area of metal which is present.

The EM61 uses a digital data logger to record the secondary EM signals received by the main and focused receiver coils. Data are recorded and presented in units of milliVolts (mV). The data from the main and focused receiver coils are stored in channels 2 and 1 of the data logger, respectively. Channel 1 data are a measurement of the presence of surface and very near surface metals. Channel 2 data are a measure of surface and deep metals. The effects of near-surface metals are minimized by subtracting channel 2's response from channel 1's response. This is referred to as the differential response and is very useful in mapping buried metals at noisy sites.

During this investigation, data will be collected along parallel survey lines and at a station spacing of approximately 1 foot. Data will be collected using a digital data logger and downloaded daily onto a laptop computer using the manufacturer's software DAT61.

2.6.2.5 EM Data Reduction and Presentation

The downloaded data will be preliminarily processed on site using the equipment manufacturer's software to help ensure that project objectives are achieved and that data coverage is sufficient. Digital data will be edited and viewed in profile format to assist the onsite geophysicist in making preliminary data interpretations prior to demobilization. Upon return of the geophysicist to the office, the raw data are converted into an ASCII "xyz" file format. The data are then imported into the software OASIS, where they are digitally filtered, if necessary. The data are then imported into GEOSOFT software, where a cubic, akima or linear spline is applied to the data, and they are gridded using the BIGRID algorithm. The data are then color contoured, assigned an equal area, linear or log-linear color zone, and reviewed in map view format. An AutoCADD DXF map of the site, if available at the time of the survey, will then be imported and overlain onto the color contour data. Observed anomalous responses will be annotated on each map, and a discussion of the interpretation of each anomaly will be provided in the text of the report. The final color contour map will be printed at a common engineering scale onto "B", "C," "D," or "E" size paper through the use of an HP-650C color printer.

2.6.3 Ground-Penetrating Radar (GPR)

A Mala Geoscience Ramac/GPR unit or similar device may be used to collect site data. The Ramac/GPR instrument is a digital GPR device that will be equipped with a 200 megaHertz (MHz) transducer. GPR has a very limited use in conductive materials or in areas with conductive surfaces or groundwater. GPR has a maximum depth of investigation of 70 to 100 feet under ideal conditions.

GPR techniques are based upon the repetitive transmission of EM signals (pulses) via a transducer into the subsurface. The EM signal travels through the subsurface and is reflected at stratigraphic interfaces where contrasts in the dielectric permittivity of the media are present. The reflected portion of the transmitted signal is received by the devices transducer. The two-way travel time and amplitude of the reflected signals verses the horizontal distance that the transducers traveled are digitally recorded.

The time it takes a signal to travel from the transducer, be reflected from a target, and return to the transducer is known as the two-way reflection time. Two-way reflection times are recorded in units of nanoseconds and vary dependent upon the electrical properties of the subsurface materials. As the subsurface material's permittivity increases, the two-way travel time increases, and the velocity of the GPR signal decreases. Areas of clayey soils, shales, or saline groundwater have high permittivities, relatively long two-way reflection times, and slow velocities. GPR signals in these materials also attenuate rapidly and thus result in depths of investigation that may be limited to a few feet or less. Conversely, dry,

sandy soils have low permittivities that result in relatively short, two-way reflection times and fast velocities. The depth of investigation is often much greater in dry, sandy soils relative to clayey soils.

Two-way reflection travel times can be converted into units of depth where signal propagation velocities are known or can be estimated. Signal propagation velocities can be estimated by collecting data over targets of known depths, performing a common mid-point sounding, or by estimating soil permittivities based upon known or published values.

Data will be digitally recorded using a laptop computer and preliminarily processed while on site using the manufacturer's software. Observed anomalous responses will be annotated on site using pin flagging or other semipermanent markings. The location of the anomalous response will be recorded into the field book and plotted onto the base map upon return to the B&R Environmental office. GPR data will presented in profile format.

It is proposed that only selected profile lines be presented in the final report because of the enormous amount of GPR data that are commonly generated during these investigation. These selected profile lines will demonstrate the various characteristics of GPR responses observed on site. A site map will be included in the final report that shows the location of all the GPR anomalies with an interpretation and correlation of the results.

2.6.4 Pipe and Cable Survey

A Schonstedt MAC51B or similar device may be used to assist in the identification of buried metallic pipes and utilities. This instrument works by inductively or actively coupling an electromagnetic transmitter coil to a known pipe location and tracing the feature with the device's receiver coil. Data for this instrument are not recorded digitally; rather, a qualitative audio output that is proportional to the magnetic gradient field intensity is observed. The subsurface anomalies identified with this instrument will be annotated on site with semipermanent markings, and anomaly locations will be recorded in the field book for subsequent reporting.

2.6.5 TDEM Survey

TDEM soundings can be used to qualitatively assess stratigraphy, saltwater intrusion, or the presence of conductive groundwater that may be associated with a contaminant plume. This method noninvasively maps the subsurface and is used to measure the lateral and vertical resistivity distributions (geo-electric section) of the subsurface to depths of 15 to 500+ feet. Electrical resistivity (the inverse of conductivity) is dependent on the physical properties of the soils and/or rock. This includes the following:

- The electrical conductance of the groundwater.
- Soil and/or rock type. Clays and shales are naturally conductive (less resistive) to electricity, whereas sands and limestones are poorly conductive (naturally resistive).

TDEM surveys, if appropriate, would be conducted at the site using a Geonics PROTEM47D TDEM device. The PROTEM47D system consists of a transmitter loop and a receiver coil. The transmitter is a square loop of single-turn, insulated wire, which is placed on the ground surface forming a square or rectangle. The depth of investigation is dependent on the size of the transmitter and the electrical resistivity of the subsurface. The larger the size of the transmitter loop, the greater the depth of penetration. Transmitter sizes commonly used are 20 by 20 or 40 by 40 meters.

The receiver is a small, vertical, magnetic dipole that is placed either in the center of the square transmitter loop or directly adjacent to the loop. A half-duty cycle, current wave form is driven through the transmitter, where a steady current is quickly terminated. The time-varying, primary, EM field of the transmitter induces eddy currents in the subsurface. The receiver measures the electromotive force (emf) resulting from the secondary magnetic field of these eddy currents during transmitter off-time.

Data are presented as a geo-electric section of the subsurface as a function of depth (feet or meters) and apparent resistivity (ohm meters). Vertical resolution is defined by the resistivity contrast between the hydrostratigraphic units. At the site, a significant contrast may occur between sand lenses, the clay layers, and possibly bedrock. The TDEM data should be collected between borehole locations and tied into the geologic and geophysical logging results.

The digital TDEM data are downloaded from the instrument's data logger using the manufacturer's software DATEM. The raw data are then imported into TEMIX software and plotted as time verses instrument response (in units of milliVolts) curves. The response curves are then digitally forward modeled based upon existing geophysical logging and geologic information, generally producing a "model to observed-data" fit error of less than 20 percent. Forward modeling allows the user to input the observed geo-electric conditions from near-by boreholes/monitoring wells and compare them to the observed TDEM data. The data are then inverse modeled until a fit error of generally less than 5 percent is achieved. The final results are presented as geo-electric sections showing depth verses apparent resistivity. The geo-electric sections are often plotted as geo-electric profiles incorporating geologic well-log information, where available.

2.6.6 Seismic Reflection Survey

A seismic reflection survey may be performed at the site to map the geologic stratigraphy at depths greater than 60 feet deep. Data will be collected using a 24-channel Geomatrix Strataview engineering seismograph or similar instrument and a 48-channel roll-along box. The Geometrix Strataview is equipped with digital instantaneous floating point (DIFP) amplifiers and built-in data logger to assist in acquiring data with high precision. DIFP amplifiers allow for an automatic and instantaneous setting of the amplifier based upon the observed seismic signal. Digital data loggers allow for large amounts of data to be stored and transmitted to a laptop computer, where preliminary onsite processing can be performed .

Reflection data will be collected with vertical, high-resolution geophones. A sledge hammer and steel plate will be used as a seismic source to generate compressional waves, which travel along the ground surface and within the ground. The seismic waves that travel in the subsurface will reflect at zones of contrasting acoustical impedance. These zones can correlate to changes in soil types, the presence of the water table, or the presence of bedrock.

Data will be acquired using the in-line common depth point (CDP) method of data collection and processing. The use of 48 geophones rolled into a 24-channel seismograph will result in 12-fold CDP coverage across a majority of the site. Data will be processed using the software SEISTRIX. SEISTRIX is a CDP seismic reflection processing package that is personal computer (PC) based. Raw seismic reflection data will be imported into the software, where they will be edited on a trace-by-trace basis. Data are then sorted into CDP gathers, where they are processed to correct for the source-to-geophone distance. A Normal Move Out (NMO) correction is applied to correct for depth calculation error due to the reflected ray path, and an FK migration is performed on the data. The traces are then summed or stacked within each CDP gather and filtered to enhance high-frequency responses. The data are then compared to borehole and geologic information to validate the velocity analysis results used during processing. Final results of the data will be presented as wiggle trace profile format showing interpreted depth and two-way reflection times verses horizontal distance.

2.6.7 Seismic Refraction Survey

A seismic refraction survey may be performed at a site to map buried bedrock topography, soil stratigraphy, or the water table. Twenty-four channel or greater seismic refraction data will be collected at this site. Data will be collected using the in-line refraction profiling technique and a constant geophone spacing. Data will be collected such that it can later be processed using the generalized reciprocal method (GRM) of interpretation. The GRM method allows the determination of depth to undulating

refractors through the analysis of refracted first arrivals. The GRM data collection and processing technique allows the bedrock depth to be determined beneath each geophone location.

Refraction data will be collected with a single, low-frequency (e.g., 14 Hz), vertical, high-resolution geophone per channel. A sledge hammer and steel plate will be used as a seismic source to generate compressional waves (P-waves), which travel along the ground surface and within the ground. The seismic waves that travel in the subsurface materials refract at interfaces where their velocities increase. These interfaces can correlate to changes in soil types, the presence of the water table, or the presence of bedrock.

Data will be collected using a 24-channel Geometrics Strataview engineering seismograph or similar instrument. The Geometrix Strataview is equipped with DIFP amplifiers and built-in data logger to assist in acquiring data with high precision. DIFP amplifiers allow for an automatic and instantaneous setting of the amplifier based upon the observed seismic signal. Digital data loggers allow for large amounts of data to be stored and transmitted to a laptop computer, where preliminary onsite processing can be performed .

During data collection, shots will be made in both a forward and a reverse direction of the 24-geophone spread. In addition, mid-point shots will be made within the spread to aid in the determination of the velocities of the upper layers. Approximately seven to nine shot locations per spread are required to provide complete GRM coverage of the bedrock surface. The seismic spread will be overlapped by two to three geophones, with the previous spread for QA/QC and data analysis requirements if more than one seismic spread is necessary at a profile location. For the far offset shots, it will be necessary to stack first arrivals. Stacking involves generating repeated seismic signals to amplify the refracted response while random noise events tend to deteriorate. At the completion of seismic data collection, each seismic line will be topographically surveyed to correct for changes in surface elevations.

The velocity and depth of refracting layers can be calculated by plotting arrival times on a time-distance graph for shots made at various offsets (distance of source to geophone). So that a refracting layer can be identified, it must meet the following criteria:

- Be of sufficient thickness relative to geophone spacing.
- Display a significant contrast in Primary wave (P-wave) velocity relative to adjacent layers.
- Possess a P-wave velocity of the refracting layer that is greater than the layer immediately above it.

Final data processing is carried out upon completion of data acquisition. The software VIEWSEIS, which is based upon the GRM method of interpretation, will be used to analyze the refraction data. VIEWSEIS is

a commercially available, PC-based, seismic refraction, processing and modeling software package that interfaces with all engineering seismograph data formats. Raw refraction data will be imported into VIEWSEIS software, where the geophysicist will edit the data headers files, make first-break picks, assign layer numbers, and analyze arrival times. The data for each seismic line will then be phantomed to create one forward and reverse response. A velocity analysis and XY analysis will be performed on the phantomed data such that arrival time and velocity can be converted to units of depth. The data will then be converted to profile depths using the GRM approximate velocity method or average upper layer velocity methods. All soil boring information will then be incorporated into the data to calibrated the observed response. The resulting velocity and depth analysis will be displayed as interpreted cross-sections of the overburden/bedrock interface. Data will be presented as annotated cross-sections showing bedrock topography.

2.6.8 Borehole Geophysics

Geophysical logging is commonly performed at complex sites to help augment the geologic logs and to assist in correlating stratigraphy between borehole locations. Four common geophysical logging techniques exist for mapping subsurface soil and rock properties in cased wells. These techniques are EM induction and natural gamma, gamma-gamma (density), and neutron (porosity) logs. The EM induction tool is not applicable in steel-cased wells. Numerous techniques exist for geophysically logging open boreholes.

Induction and natural gamma logs are the most commonly used non-nuclear probes for environmental surveys. These probes are often used to map stratigraphy and the presence of groundwater contamination. Common nuclear tools used for environmental surveys include neutron (porosity) and gamma-gamma (density logs). These logging tools contain nuclear sources, and special licensing must be obtained for storage, transportation, and use of these tools. Porosity logs are often used in environmental projects to delineate perched water tables or map stratigraphy based upon relative porosities. Density logs are often used to delineate stratigraphy based upon relative density changes and to support the porosity log data. Density log information can also be used to examine the presence of voids in the grout behind a wells casing; however, a cement bond log is often preferred.

2.6.9 Borehole Geophysics Instrumentation

The Geonics EM39-RT is a borehole induction and natural gamma logging device that is used frequently in environmental geophysical logging projects. This device is equipped with a small-diameter (approximately 1.5 inch diameter) induction tool, a hand or powered winch, and a console box. The

device also interfaces with a natural gamma tool that is less than 2 inches in diameter. The system is driven with a laptop computer that collects and graphically displays real-time data.

Mount Sopris Instruments has recently manufactured a portable (65 lbs.) digital logging system and logging tools for acquiring data in small ID (2-inch) groundwater monitoring wells. The MGX System is a portable, digital, borehole geophysical logging system designed for shallow (2,000 feet or less) environmental and engineering projects. The system is computer driven with a 386 notebook computer using the manufacturer's software ACQUIRE. The system consists of a motorized winch with a digital depth encoder attached to a component console.

The MGX System interfaces with slim-line tools for use in 2-inch+ ID groundwater monitors and water wells. The MGX system interfaces with the following probes: Geonics induction tool, natural gamma, Spontaneous Potential (SP), single-point resistance, motorized three-arm caliper, temperature, fluid resistivity, vertical flow meter, normal resistivity, porosity (neutron), and density (gamma-gamma) tools.

Data are graphically displayed on the computer screen during data collection such that anomalous responses can be immediately identified and revisited, if necessary. Preliminary field analysis and plots are made daily using the manufacturer's software ACQUIRE. Final analysis and data presentation are made using the software package VIEWLOG. The following geophysical probes may be used at this site:

2.6.9.1 EM Induction

EM induction tools measure the apparent electrical conductivity of subsurface materials and their pore fluid in units of mmhos/m or mS/m, respectively. Induction tools are equipped with a radio transmitter and receiver and have a radius of investigation of approximately 2.5 feet. The radio transmitter produces a primary EM signal that induces small eddy currents in the subsurface materials. The eddy currents produce a secondary EM field that, together with the primary signal, is sensed by the device's receiver. The relationship of the primary and secondary signals are linearly proportional to the apparent conductivity of the subsurface material.

The induction tool is configured such that the instrument's response increases radially away from the tool to a maximum response at a distance of 1 foot and then it decreases radially outward. This renders the device relatively insensitive to the influence of borehole fluids and well construction materials in small-diameter wells (2- to 8-inch diameter). Induction tools can be operated in PVC-cased or open boreholes and above or below the water column. Other electrical borehole tools must be used in open or uncased boreholes and require the presence of borehole fluids or muds.

Induction tools are very useful in mapping and delineating stratigraphy based upon contrasts of the ability of various soils or rocks to conduct electricity. Typically, clayey soils and rocks have high conductivities relative to sandy soils, limestones, dolostones, and sandstones, which generally have low conductivities. The device is also useful in mapping the presence, absence, or vertical extent of a conductive contaminant plume. However, a natural gamma tool is often used when the objectives are to map both a contaminant plume and stratigraphic changes. Natural gamma tools are often used because they are not sensitive to the presence of contaminant plumes but are sensitive to the presence of clayey soils and rocks.

2.6.9.2 Natural Gamma

Natural gamma tools measure the presence of naturally occurring gamma radiation in units of counts per second (CPS) through the use of a scintillation crystal (sodium iodide) and a photo-electric tube. The sodium iodide crystal emits light when in the presence of gamma radiation. The light is then converted to an electrical signal by the photo-electric tube. The electrical components measure the number of light flashes per second and digitally record them onto a laptop computer.

The principal sources of natural gamma radiation are from the uranium-thorium decay series and radioactive potassium (K40). Typically, clayey soils and rocks containing clay minerals often contain relatively large amounts of radionuclides when compared to sandy or carbonate soils and rocks. This makes the natural gamma tool an excellent device for mapping stratigraphy based upon the presence or absence of clay materials. Igneous and metamorphic rocks can also be mapped with the natural gamma device based upon contrasts in their felsic mineral content.

The device can be used to collect data above or below the water column and in PVC, steel-cased, or open boreholes. This device is often used in conjunction with an induction log, as it is not sensitive to changes in a subsurface materials conductivity. For example, if the induction log and the natural gamma log both show a high response across a zone, it can be interpreted that the zone contains clayey soils or rocks. However, if a high induction log response and a low natural gamma log response are observed across this zone, it can be interpreted that conductive pore fluids may be present, such as contaminated groundwater.

2.6.9.3 Neutron Log

A neutron tool is used to measure the relative amount of water present in the subsurface formations. The device operates through the use of a neutron source (radioactive source) and a neutron detector. Data are presented in units of CPS. The source emits neutrons that are absorbed by the presence of hydrogen

atoms. The neutron detector measures the presence of unabsorbed neutrons, which are inversely proportional to the amount of hydrogen (primarily from water) present. Values of low-neutron CPS responses are an indication of high water content. Values of high-neutron CPS responses are an indication of low amounts of water present. Neutron tools are also often used as indicators of the relative porosity of water-bearing formations. Clayey soils and rocks with abundant clay minerals often have high porosities that can result in a low-neutron response if groundwater is present in the pore space. As clay soils often have higher porosities (up to 40 percent) than sandy soils (generally 10 to 20 percent), it is not uncommon to have a lower neutron response at an unsaturated clay soil interval than at a saturated, sandy soil interval. The presence of hydrogen in methane gas will also result in a lower neutron CPS response, although not as low as if water or oil were present.

2.6.9.4 Gamma-Gamma Log

The gamma-gamma tool is used to measure the bulk density of subsurface materials. The gamma-gamma tools typically use a low-energy gamma source, such as cesium-137, and one to two scintillation detectors. The gamma radiation emitted by the source is scattered in the electron in the rock formation. The gamma radiation that is not scattered is measured by the scintillation detectors attached to the tool. The measured gamma radiation is inversely proportional to the electron density of the subsurface material. Density logs are often used for determination of porosity variations as a function of density, litiologic correlation, or subtle variations in depositional environments. Measurements are presented in units of CPS.

2.7 AQUIFER TESTING

2.7.1 Slug Tests

Slug tests are performed to determine the hydraulic characteristics in the immediate vicinity of the well screen/open borehole. Although slug tests typically require data logging equipment for rapidly recharging aquifers, they do not require pumping and are therefore applicable in low-yield aquifers or at locations where contaminated water disposal is prohibitively expensive.

Prior to performing the slug test, the static water level and well construction details are recorded. Both rising-head and falling-head tests are performed by either inserting a solid slug into the well to raise water levels and then measuring the rate of decline in water level (recovery), or by removing a slug of water and measuring the rate of rise in the water level back to equilibrium. The changes in water level are induced as quickly as possible, as the analysis assumes an instantaneous change in head. Falling-head tests are

not performed where the water level is within the screened interval. In addition, as slug tests are very sensitive to borehole skin effects, the well must be developed properly to obtain accurate data.

Slug test data are collected using an electronic data logger with pressure transducer and/or electronic water-level indicator (M-scope). To facilitate data graphing, the loggers are programmed to record measurements on a logarithmic time scale. It is ideal to record water-level data to at least 90 percent recovery in the well before terminating the test. The resulting plot of time (t)/head ratio (h/ho) on semilog paper should approximate a straight line. The test should be rerun if data scatter is excessive or if the straight-line approximation is not obtained.

Raw data from the loggers or field records are used to calculate values of hydraulic conductivity in the immediate vicinity of the well screen or open borehole. The data are analyzed using one or more of the following three methods:

- Hvorslev Method - Rapid, straight-line method for partially penetrating well screens.
- Bouwer and Rice Method - Rigorous, straight-line method for complex well geometries.
- Cooper et al Method - Type-curve method for low-permeability aquifers.

The above methods are analyzed relatively simply by hand. However, the Bouwer and Rice method, as well as the Cooper et al. method, may also be analyzed using the AQTESOLV Computer Program (Geraghty & Miller, Inc., 1994).

2.7.2 Pumping Tests

Pumping tests are performed to determine more complex and laterally extensive hydraulic properties of the aquifer. Although they require data logging equipment and pumping, they are more applicable to high-yield aquifers or to locations where water disposal does not create severe management issues.

Prior to performing the pumping test, the static water levels in all surrounding observation wells are recorded. Several wells can be pumped at different times to determine both the lateral and vertical response of the aquifer to the pumping of the wells. For each individual test, the duration of pumping is determined in the field based on the aquifer response to pumping, with a minimum duration of 4 hours and a maximum duration of 72 hours. A pumping test should be run long enough to gather sufficient pumping and observation well data with which to determine the aquifer properties/conditions that are required for the project. Data should be graphed in the field to evaluate time-drawdown and distance-drawdown responses and to determine when sufficient data has been gathered such that appropriate aquifer test

analysis methods can be employed with some confidence, and the future pattern of water level response can be predicted. It is ideal to stress the aquifer as much as possible near the pumping well without drawing the cone of depression below either the measuring device (in unconfined aquifers) or the confining layer (in confined aquifers). It is also important to maintain a consistent discharge rate from the pumping well. Considerations that must be factored into determining whether a pumping test has run for a sufficient period of time include:

- Time-drawdown trend of each well
- Distance-drawdown trends
- Presence of delayed yield effects
- Presence of hydrogeologic boundaries
- Outside influences (pumping wells, weather, etc.)
- Other factors, such as water treatment/storage capacity (if required), operational restrictions, etc.

A hydrogeologist experienced in pumping test performance and interpretation will monitor the test as it progresses and determine the appropriate duration.

Water levels are periodically measured in the pumping well and in the observation wells throughout the duration of each pumping test (including water-level recovery after pumping is halted). To facilitate data graphing, the loggers for nearby observation wells are programmed to record measurements on a logarithmic time scale. It is ideal to record water-level data to at least 90 percent recovery in the observation wells before terminating the test. The data gathered are evaluated using techniques developed for pumping tests specific to the aquifer. Aquifer parameters determined during pumping tests include hydraulic conductivity, transmissivity, and storativity. Because of the limitless number of analytical techniques possible for each specific aquifer, the exact method is determined upon completion of the test. Some analytical methods include the following:

- Cooper-Jacob Method - Rapid straight-line method for simple aquifer geometries.
- Theis Method - Type-curve method for complex aquifer geometries.
- Theis Recovery Method - Method used for analyzing well recovery data.
- Theis Method - Method for analyzing pumping test that have reached equilibrium conditions.

In addition, the AQTESOLV Computer Program (Geraghty & Miller, Inc., 1994) can also assist in the technical analysis of pumping test data.

2.7.3 Specific Capacity Testing

Specific capacity tests are used to determine a well's potential yield and to estimate hydraulic conductivity. These tests involve pumping a well at a constant rate and measuring the drawdown when the water level stabilizes. Specific capacity tests are advantageous because they are conducted while wells are being developed or purged for sampling, and automatic data logging equipment is not necessary.

During specific capacity tests, water-level measurements are collected using an electronic water-level indicator. An electronic submersible or peristaltic pump is used to pump the well. Aquifer parameters are calculated from the specific capacity test data using a computer program developed by Bradbury and Rothschild (1985) based on equations presented in Lohman (1972).

Drawdown data from the well are entered into the computer program along with required variables that characterize the aquifer (storage and well-loss coefficients), the pumping rate, and well dimensions. The program output will estimate specific capacity, transmissivity, and hydraulic conductivity.

2.8 SOIL-GAS SURVEYING

There are two types of active soil-gas surveys: a contaminant-specific survey using a portable GC unit and a reconnaissance-type survey using an OVA. Grid patterns are established within the area(s) to be covered by the soil-gas survey using pin flags in unpaved areas and tape in paved areas. The grid patterns are tied into local permanent features, such as building corners and roadway boundaries. Grid spacing is determined on a site-specific basis consistent with the sampling strategy.

In paved areas, a small pilot hole is drilled through the asphalt using a power drill with a 1/2- to 1-inch-diameter drill bit. The soil-gas boring is completed by driving a 1/2-inch-diameter, steel rod into the subsurface. The steel rod is advanced to the desired depth, extracted, and a Teflon tube is then lowered into the boring. A surface seal of inert material is used to seal the borehole annulus from the ambient atmosphere. The tube is then attached to the analytical instrument. The tube is purged of residual gas prior to sample collection at each sample location. The results are recorded in the field on site maps, and the survey modified based upon incoming data, with grid spacing adjusted accordingly.

Additionally, soil-gas surveys may be conducted using passive soil-gas samplers. The most common type of sorbent sampler used is known as a Petrex® tube, which consists of activated charcoal chemically fused to the tip of a Curie-point ferromagnetic wire and inserted into a glass tube. The collector is then buried at a depth of 2 to 4 feet in an inverted position with the glass tube acting as a flux chamber for an

optimal period of time as determined by the manufacturer's recommendations. Sample analysis is by thermal desorption onto a mass spectrometer (MS) or GC. This method is recommended when the contaminants are unknown and concentrations are expected to be low. Specialized sorbent samplers may require the use of a soil-gas subcontractor.

2.9 SURVEYING

All new groundwater wells, soil borings, and surface water/sediment sample locations are surveyed. Existing survey monuments within MCRD Parris Island will be used as reference points. Horizontal locations are referenced to 1982 North American Datum. Monitoring well and soil boring horizontal locations are surveyed to the nearest 0.10 foot.

Vertical elevations are referenced to 1982 National Geodetic Vertical Datum. For each groundwater well, the elevation is surveyed to the nearest 0.01 foot at the measuring point where the uncapped well riser is notched, and at the top of the protective casing. For all locations, ground surface elevations are surveyed to the nearest 0.1 foot.

2.10 DECONTAMINATION

The equipment involved in field sampling activities is decontaminated prior to beginning work, during drilling and sampling activities, and at the completion of the project. This equipment includes drilling rigs, downhole tools, augers, well casing and screens, and soil and water sampling equipment. Decon efforts will comply with U.S. EPA Region 4 EISOPQAM (U.S. EPA, 1996).

2.10.1 Major Equipment

All downhole purging equipment and drilling equipment, including downhole drilling tools, is cleaned with high-pressure hot water and Alconox (or equivalent) and rinsed with potable water prior to beginning work, between boreholes, whenever the drilling rig leaves the drill site prior to completing a boring, and at the conclusion of the drilling program.

Decontamination operations consist of washing equipment using a high-pressure steam wash from a potable water supply. All decontamination activities take place at a predetermined area within the Depot. Additional requirements for drilling equipment decontamination are found in SOP SA-7.1, provided in Appendix B.

2.10.2 Sampling Equipment

Nondisposable equipment used for collecting samples is decontaminated both prior to beginning field sampling and between samples in accordance with SOP SA-7.1, contained in Appendix B. Disposable equipment used for sampling activities shall be discarded.

Field analytical equipment, such as turbidity, pH, conductivity, and temperature instrument probes, will be rinsed with steam-distilled, deionized water first and then with the sample liquid.

2.11 WASTE HANDLING

Field investigations can generate both solid and liquid types of potentially contaminated residues; namely, soil cuttings, decontamination water, purge water, and personal protective equipment (PPE). Planned management of each of the residues is provided in the following. Development of this section was guided by "Management of Investigation-Derived Wastes During Site Inspections", EPA/540/G-91-009, May 1991, and through consultation with the U.S. EPA Region 4 and the SCDHEC. Additional requirements for waste handling and sources of contaminated materials are found in SOP SA-7.1, contained in Appendix B, and current Southern Division IDW Management guidance.

All IDW will be containerized in U.S. Department of Transportation (DOT) approved (Specification 17-C/H), 55-gallon drums and staged on wooden pallets in an area established by B&R Environmental personnel and MCRD Parris Island. All drums shall be sealed and properly identified with drum contents, well boring number or sample location, and date. See Figure 2-4 for a sample IDW label. All sampling operations and Quality Assurance measures shall be in accordance with Section 3.0 of this FSP and the QAPP respectively.

2.11.1 Solid Investigation-Derived Waste

Solid (e.g., soil, cuttings) waste will be evaluated and handled as follows:

To minimize the amount of waste that will require disposal as hazardous waste, IDW will be separated and containerized, according to the amount of contamination expected based on HNu/OVA readings. The IDW shall be evaluated to determining whether the waste is a Resource Conservation and Recovery Act (RCRA) listed waste or a characteristic waste (hazardous waste as defined in 40 Code of Federal Regulations (CFR) Part 261) based on knowledge of the generating process. If knowledge of the generating process is not sufficient to allow the certain characterization of the IDW, then one composite sample from each site will be collected and analyzed to determine whether the material is hazardous. If

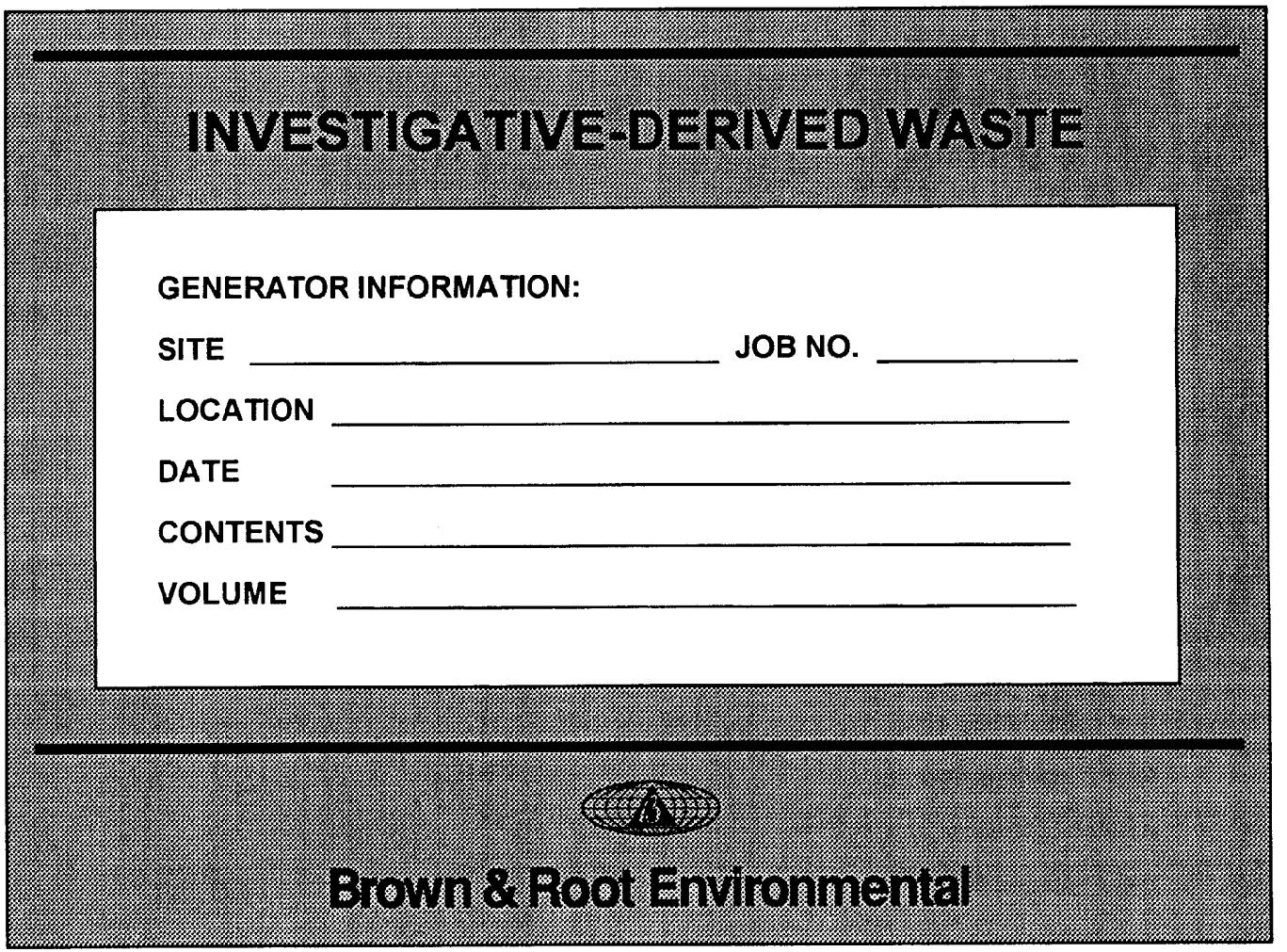


FIGURE 2-4

SAMPLE INVESTIGATIVE-DERIVED WASTE LABEL

MCRD PARRIS ISLAND, SOUTH CAROLINA

the material is determined to be hazardous, the IDW will be turned over to MCRD Parris Island personnel for proper disposal at a RCRA Subtitle C treatment, storage, or disposal facility (TSDF). Any hazardous waste removed from the site for disposal shall be removed in accordance with U.S. EPA's Comprehensive Environmental Response, Compsensation, and Liability Act (CERCLA) Off-Site Rule. If the material is determined not to be hazardous, the contaminant levels should be compared to U.S. EPA Region 3 risk-based concentrations (RBCs) (U.S. EPA, 1997) for residential area. If RBCs are not exceeded, the material will be put back in place at the site. If RBCs are exceeded, B&R Environmental personnel will arrange for proper disposal at a RCRA Subtitle D TSDF. If constituents are present that do not have Region III RBC limits, then RCRA action limits should be derived using RCRA 40 CFR Subpart S methodology. These action limits should then be applied as RBCs.

2.11.2 Liquid Investigation-Derived Waste

Liquid waste (e.g., purge water, decontamination water) will be evaluated and handled as follows:

The IDW shall be evaluated to determine whether the waste is a RCRA listed waste or a characteristic waste (hazardous waste as defined in 40 CFR Part 261) based on knowledge of the generating process. If knowledge of the generating process is not sufficient to allow the certain characterization of the IDW, then one composite sample from each site will be collected and analyzed to determine whether the liquid is hazardous. If the liquid is determined to be hazardous, the IDW will be turned over to MCRD Parris Island personnel for proper disposal at a RCRA Subtitle C TSDF, along with land disposal notification for liquid wastes. Any hazardous waste removed from the site for disposal shall be done in accordance with U.S. EPAs CERCLA Off-Site Rule. Alternatively, the liquid can be transported to the Depot Wastewater Treatment Facility, if the treatment facility will accept the IDW. If the liquid is determined not to be hazardous, the contaminant levels should be compared to maximum contaminant levels (MCLs) and U.S. EPA Region 4 fresh water screening levels. If MCLs and U.S. EPA Region 4 fresh water screening levels are met and no other potentially toxic constituents are detected, then the liquid may be poured on the ground at the site. If either MCLs or U.S. EPA Region 4 fresh water screening levels are exceeded, then the water must be routed to the Depot Wastewater Treatment Facility, if the treatment facility will accept the IDW. If not, the IDW must be sent to a permitted Subtitle D disposal facility.

If there are no MCLs for the potential contaminants, the liquid must be characterized by analysis for any other contaminants that potentially exist. The IDW may be poured on the ground at the site if no other contaminants are potentially present. Other contaminants, if present, must be properly characterized and evaluated relative to U.S. EPA Region 3 RBCs for potable water, U.S. EPA Region 4 fresh water screening criteria, and project-specific RBCs if no MCLs or RBCs exist for a constituent before it can be

poured on the ground. If no MCLs or RBCs for potable water exist, action levels can be derived per RCRA 40 CFR 264 Subpart S methodology, and used in place of U.S. EPA Region 3 RBCs. Depending on the volume of non-hazardous liquid being handled, it may be more advantageous to simply route the liquid to the Depot Wastewater Treatment Facility for disposal, rather than undergo the determination described above to justify disposal of the liquid onto the ground.

2.11.3 Other Drummed Waste

PPE and other waste trash that was generated and drummed during drilling and sampling will generally not be considered as hazardous and will be disposed of in a municipal landfill, depending on the nature of the investigation. If knowledge exists that waste trash has become contaminated, due to contact with known contaminated materials, the waste trash shall be handled and disposed of as hazardous material.

3.0 GENERAL SAMPLING OPERATIONS

3.1 GENERAL SAMPLING OPERATIONS

This section discusses the sampling methodology for all groundwater, surface water, soil, and sediment sampling activities performed at MCRD Parris Island. Analytical considerations for these samples are discussed in the site-specific FSP.

3.1.1 Groundwater Sampling

The objective of this section is to provide guidance for the proper sampling equipment and techniques for groundwater sample collection. All groundwater sampling shall be conducted in accordance with the requirements of the Site-Specific Work Plan and in accordance with SOP SA-1.1, contained in Appendix B.

Prior to obtaining a groundwater sample, the water level in the monitoring well is measured to within 0.01 foot accuracy from the marked location on the top of the well riser pipe. If volatile organic contamination is suspected, a head-space reading is obtained in the well's riser pipe using an organic vapor monitor. Depending on the intent of monitoring program and hydrogeological conditions, the well is typically purged prior to sample collection. If, however, nonaqueous-phase liquids (dense or light) are suspected and/or detected in the well, samples will be collected and analyzed for both nonaqueous-phase liquids and dissolved phase constituents.

Under standard conditions, the well is purged using a bailer or one of several types of pumps. Typical pump types include low-flow vacuum, peristaltic, and bladder pumps as well as high-flow centrifugal pumps. Vacuum and peristaltic pumps are limited to wells with water levels within 20 to 25 feet of the ground surface. If a bailer or high-flow pump is used to purge the well, typically three to six borehole volumes are removed. The previously referenced SOP provides guidance on calculating the borehole volume in gallons ($V=0.163\ Hr^2$). Care will be taken in minimizing drawdown on slow recovery wells so as to not purge the well dry. If the wells are purged dry with less than three well volumes removed, the water level in the well is allowed to recover to a level sufficient for sample acquisition; then a sample is collected. In the event that recovery is slow, samples are collected within 24 hours of purging or as soon as possible after the water level has recovered to approximately 80 percent of its static level.

Field measurements of pH, temperature, specific conductance, and turbidity are taken prior to purging each borehole volume. Stabilization of the above parameters is defined as follows: temperature ±1.0°C,

pH ±0.1 units, and specific conductance ±5 percent. It is ideal to purge wells until the turbidity is below 10 NTU. If measurements of pH, conductivity, and temperature do not stabilize after three volumes, as many as six volumes will be removed.

Dedicated stainless-steel or Teflon bailers with dedicated polyethylene bailing rope (and typically a Teflon-coated, stainless-steel leader) are used for sample collection. Immediately prior to sampling, the temperature, pH, specific conductance, and turbidity of the water sample is measured and recorded on the groundwater sample form (included in Appendix A). The samples are poured directly from the bailer into the appropriate sample bottles for analysis. Samples to be analyzed for volatile constituents are taken first and immediately sealed in a container so that no head space exists. Semivolatile and metal constituents are collected next and poured into the appropriate sample bottles for analysis. If filtered metal samples are collected, the use of an in-line, 0.45 micron, particulate filter is required. After the sample is filtered, it is preserved immediately to a pH less than 2. All samples will be cooled to 4°C for delivery to the laboratory.

For many projects, a procedure involving low-flow purging and sampling is recommended. Low-flow purging and sampling is designed to provide for collection of groundwater samples with minimum turbidity. A low-flow-type pump is lowered to a depth corresponding to the top of the water column. The pump should operate at a discharge rate that produces little or no drawdown in the well (approximately 0.2 to 0.5 liters per minute). If the well is still purged dry, the water level in the well is allowed to recover to a level sufficient for sample acquisition; then samples are collected. As before, field measurements of pH, temperature, specific conductance, and turbidity are taken every 3 to 5 minutes during low-flow purging. Stabilization of the above parameters and sample collection procedures are as previously defined.

3.1.2 Surface Water Sampling

Surface water samples are often collected as grab samples from surface water drainages, discharge ponds, and low, wet areas. However, under some conditions, grab samples may not be a true representation of the concentration of contaminants that are distributed throughout the water column. Actual sampling procedures will be determined on a case-by-case basis in accordance with SOP SA-1.2, contained in Appendix B.

Immediately prior to sampling, the temperature, pH, and conductivity of the water are measured and recorded on the surface water sample form (attached in Appendix A). Samples to be analyzed for volatile constituents are collected first and immediately sealed in a container so that no head space exists.

If there is an insufficient depth of water or access is difficult and remote sampling required, then a stainless-steel beaker set-up is used to fill the sample bottles. Sample beakers are decontaminated between samples.

Sample handling and chain-of-custody (COC) requirements are addressed in Sections 3.2.2 and 3.3 of this FSP. All pertinent field data are recorded using a surface water sample form (included in Appendix A) and recorded in the field logbook.

3.1.3 Surface Soil Sampling

Surface soil samples are collected from the ground surface to a depth not exceeding 12 inches in accordance with SOP SA-1.3, contained in Appendix B. A stainless-steel trowel or hand auger is used to collect the surface soil sample. All samples obtained are monitored with an organic vapor monitor and then collected for lithologic and/or chemical analysis. Upon sample retrieval, the samples to be analyzed for volatile constituents are taken first and immediately sealed. Samplers will be decontaminated between samples as described in this FSP. All pertinent field data are recorded using a soil sample form (included in Appendix A) and the field logbook.

3.1.4 Subsurface Soil Sampling

Subsurface soil samples are collected from soil borings drilled in accordance with SOP SA-1.3, contained in Appendix B. Soil samples are typically collected at 5-foot intervals from the ground surface to the water table. All samples obtained from the borehole are monitored with an organic vapor monitor and then collected for lithologic and/or chemical analysis. Actual numbers of samples for chemical analysis will be specified in the site-specific SAP. Upon sample retrieval, the samples to be analyzed for volatile constituents are taken first and immediately sealed. Samplers are decontaminated between samples as described in this FSP. All pertinent field data are recorded using a soil sample form (included in Appendix A) and the field logbook.

3.1.5 Sediment Sampling

Sediment samples are often collected as grab samples using scoops or dredges from pond perimeters and from stream/drainage bottoms in accordance with SOP SA-1.2, contained in Appendix B. The appropriateness of sample compositing and depth of sample collection is determined on a case-by-case basis. Upon sample retrieval, a sufficient volume is obtained for volatile organics analysis and sealed with no head space. The remaining material is homogenized and distributed to the remaining sample containers. Sample equipment is decontaminated between samples as described in this FSP. Grab

samples may not be appropriate at all sampling locations. Core sampling may be the most appropriate method at some locations. Actual procedures will be determined on a case-by-case basis. If core samples are needed, procedures will be described in the site-specific Field Sampling Plan.

All pertinent field data are recorded using a sediment sampling form (included in Appendix A) and the field logbook.

3.1.6 Head-Space Soil Sampling

If required, head-space soil analysis is performed. Upon split-spoon sample retrieval, a small quantity of the soil is removed from the sampler and immediately placed in a sealed container. The container is then warmed for 15 minutes to volatilize the potential contaminants in the soil sample. After 15 minutes, the tip of the OVA is pushed into or through the container or its lid, and a direct reading is obtained from the OVA. All head-space readings are recorded on the appropriate boring log and/or sample form.

3.1.7 Air Sampling

During routine field activities, air monitoring can aid in the selection of sample locations and screening of samples for a rapid qualitative determination of volatile contamination. The purpose of this section is to provide a general guide for the determination of volatile airborne contamination. All air sampling is performed in accordance with B&R Environmental SOP SA-2.2 (Air Monitoring and Sampling), provided in Appendix B. This section does not address air-quality monitoring and air sampling with regard to health and safety issues.

Continuous air monitoring is performed by drawing air samples from a fixed sampling point (e.g., screening of split-barrel samplers to select samples for laboratory analysis). Typical qualitative air monitoring equipment includes FIDs, PIDs, and colorimetric sorbent media (e.g., Draeger® tubes). It is important to choose the proper detector for the anticipated site contaminants and to account for air travel time required to move the contaminant from the source to the detector. It is sometimes advantageous to draw an air sample into a nonreactive sample bag (such as Mylar) for confirmatory, fixed-base analysis or for field analysis at a location away from potential site contaminants and temperature extremes. In addition, all field air monitoring equipment must be calibrated as required by the equipment manufacturer and by anticipated equipment usage.

Most air monitoring equipment is battery powered (requiring daily charging), lightweight, and water resistant. Some newer air monitors allow for chemical-specific calibration and data logging capabilities.

Advantages of qualitative air monitoring include immediate qualitative sample screening, the ability to obtain a general vertical profile of contaminant concentrations during drilling operations, and inexpensive screening of many samples to reduce expensive, fixed-base laboratory analyses. Disadvantages include a limited concentration range (both high and low), inability to detect some particular contaminants, sensitivity to site environmental conditions such as temperature and humidity, and limited battery life.

3.1.8 Biological Sampling

Biological sampling may be required when a screening-level ecological risk assessment indicates that there is enough potential for environmental harm to justify further sampling. The goal of the sampling would be to better characterize risk to ecological receptors, so that there would be adequate information for making risk management decisions regarding remediation. The type of work needed to better characterize environmental risk may include toxicity testing, tissue analysis, and population/community investigation. Biological sampling would be necessary for tissue analysis and population/community investigation, while toxicity testing is usually done on water, sediment, or soil samples. SOP SA-4.1 and SOP SA-4.4, contained in Appendix B, will be used for biological sampling. If tissue sampling is required at a site, specific instructions will be made part of the appropriate site work plan.

3.2 SAMPLE HANDLING

Sample handling includes the field-related considerations concerning the selection of sample containers, preservatives, allowable holding times, and analyses requested. Sample identification, preservation, packaging, and shipping are addressed in SOP SA-6.1, contained in Appendix B. Section 4.0 of the Master QAP discusses details concerning sample containers, volume requirements, preservatives, allowable holding times, and analyses requested.

3.2.1 Field Sample Documentation

Sample documentation consists of the completion of COC reports and matrix-specific sample logsheets. COC reports are detailed in Section 4.0 of the Master QAP. Completion of sample logsheets is discussed along with the matrix-specific sampling procedures presented in Section 2.0 of the Master Field Sampling Plan.

In addition, various hardcover, bound, record books are maintained for each field activity. The master Site Logbook serves as the overall record of field activities. Information included daily in the master Site Logbook includes weather conditions, identity and arrival and departure times of personnel, management

issues, etc. Various field notebooks are also maintained. For example, each geologist supervising drilling operations at a specific sampling location will maintain a field notebook.
The FOL is responsible for the maintenance and security of all field records. Eventually, all field records (COCs, sample logsheets, logbooks, and notebooks) are docketed and incorporated in the project central file.

One other type of standardized field documentation exists. Field Task Modification Records (FTMRs) are specific forms initiated when a change to or deviation from procedures provided for in the project planning documents occurs. The procedure for requesting and recording field changes follows:

- The FOL notifies the TOM of the need for the change.
- If necessary, the TOM discusses the change with the pertinent individuals [e.g., the Navy Remedial Project Manager (RPM), B&R Environmental Quality Assurance Manager (QAM)]. Verbal approval or denial of the proposed change is given at this time.
- The FOL then documents the change on an FTMR and forwards the form to the TOM at the earliest convenient time (e.g., end of the workweek).
- The TOM signs the form and distributes copies to the Navy RPM, B&R Environmental QAM, TOM, FOL, and project file.
- A copy of the completed FTMR is attached to the field copy of the affected document.

3.2.2 Sample Nomenclature

A sample numbering system is used in the field to identify each sample taken during the sampling program in accordance with SOP CT-04, contained in Appendix B. This coding system provides a tracking record to allow retrieval of information about a particular sample and to ensure that each sample is uniquely identified.

Each sample is identified by a unique code that indicates the site number, sample type, sample location, and sample depth indicator and sampling round as specified in B&R Environmental SOP CT-04 (Appendix B). The sample nomenclature system is devised such that the following objectives are attained:

- Sorting of data by matrix.
- Sorting of data by depth.
- Maintenance of consistency (field, laboratory, and data base sample numbers).
- Accommodation of all project-specific requirements on a global basis.
- Accommodation of laboratory sample-number length constraints.

3.2.3 Documentation, Sample Packaging and Shipping

Samples are packaged and shipped in accordance with B&R Environmental SOP SA-6.1, contained in Appendix B. The FOL is responsible for completion of the following forms:

- Sample labels
- COC forms
- Appropriate labels applied to shipping coolers
- COC labels
- Federal Express air bills

3.3 SAMPLE CUSTODY

Custody of samples is maintained and documented at all times. Chain of custody begins with the collection of the samples in the field. B&R Environmental SOP SA-6.1, contained in Appendix B, further details the chain-of-custody procedures. An example of the chain-of-custody record is included in Appendix A.

3.4 QUALITY CONTROL (QC) SAMPLES

In addition to periodic calibration of field equipment and appropriate documentation, quality control samples are collected or generated during environmental sampling activities. Quality control samples include field duplicates, field blanks, equipment rinsate blanks, and trip blanks. Each type of field quality control sample, as well as additional sample aliquots needed to accommodate laboratory QC analyses, is discussed in detail in the Master QAP (Section 3.0).

Unless otherwise provided for in the Project Plan documents for MCRD Parris Island projects, 10 percent duplication, 1 field blank per decontamination waste source, 1 trip blank per cooler containing volatile organic compound (VOC) samples, and 1 rinsate blank obtained per 20 samples collected by each type of sampling device will be observed as QA/QC measures.

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APPENDIX A

FIELD DOCUMENTATION FORMS

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APPENDIX A

Daily Activities Record
Equipment Calibration Log
Direct-Reading Instrument Response Data
Documentation of Field Calibration
Monitoring Well Development Record
Hydraulic Conductivity Testing Data Sheet
Pump Test Data Sheet
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Low Flow Purge Data Sheet
Groundwater Level Measurement Sheet
Surface Water Sampling Log Sheet
Soil and Sediment Sample Log Sheet
Boring Log
Monitoring Well Sheet
Single Sample Log Sheet
Chain-of-Custody Record

DAILY ACTIVITIES RECORD

PROJECT NAME: _____ **PROJECT NUMBER:** _____

CLIENT: _____ **LOCATION:** _____

DATE: _____ **ARRIVAL TIME:** _____

B&RE PERSONNEL: _____ **DEPARTURE TIME:** _____

CONTRACTOR: _____ **DRILLER:** _____

ITEM	QUANTITY ESTIMATE	QUANTITY TODAY	PREVIOUS TOTAL QUANTITY	CUMULATIVE QUANTITY TO DATE

COMMENTS: _____

_____

_____

_____

APPROVED BY:

_____ _____

B&RE REPRESENTATIVE DRILLER

DATE: _____

EQUIPMENT CALIBRATION LOG

JOB NAME/NUMBER: _____ INSTRUMENT NAME/MODEL: _____

SITE NAME: _____ MANUFACTURER: _____

LOCATION: _____ SERIAL NUMBER: _____

Date of Calibration	Time	Performed by	Calibration Standard		Instrument Setting		Instrument Reading		Remarks/ Comments
			Span/Conc.	Lot Number/ Exp. Date	Pre-Calibration	Post-Calibration	Pre-Calibration	Post-Calibration	

Brown & Root Environmental

DIRECT-READING INSTRUMENT RESPONSE DATA

SITE NAME: _____ PROJECT NO.: _____

PAGE _____ OF _____

Date and Time(s)	Instrument Operator Name	Instrument Used	Instrument Reading and Duration	Location (e.g., borehole vs breathing zone)	Operation(s) Being Performed	Personnel in Vicinity at Time of Readings and Level of PPE Worn

Brown & Root Environmental

DOCUMENTATION OF FIELD CALIBRATION

SITE NAME: _____ PROJECT NO.: _____

Date of Calibration	Instrument Name and Model	B & R Environmental Instrument I.D. Number	Person Performing Calibration	Instrument Settings		Instrument Readings		Calibration Standard (Lot Number)	Remarks/ Comments
				Pre-Calibration	Post-Calibration	Pre-Calibration	Post-Calibration		

MONITORING WELL DEVELOPMENT RECORD

Page ___ of ____

Well: _____
Site: _____
Date Installed: _____
Date Developed: _____
Dev. Method: _____
Pump Type: _____

Depth to Bottom (ft.): _____
Static Water Level Before (ft.): _____
Static Water Level After (ft.): _____
Screen Length (ft.): _____
Specific Capacity: _____
Casing ID (in.): _____

Responsible Personnel: _____
Drilling Co.: _____
Project Name: _____
Project Number: _____

Time	Estimated Sediment Thickness (Ft.)	Cumulative Water Volume (Gal.)	Water Level Readings (Ft. below TOC)	Temperature (Degrees C)	pH	Specific Conductance (Units _____)	Turbidity (NTU)	Remarks (odor, color, etc.)

HYDRAULIC CONDUCTIVITY TESTING DATA SHEET

PROJECT NAME: ..... WELL/BORING NO.: .....

PROJECT NO.: ..... GEOLOGIST: .....

WELL DIAMETER: ..... SCREEN LENGTH/DEPTH: ..... TEST NO.: .....

STATIC WATER LEVEL (Depth/Elevation): ..... DATE: .....

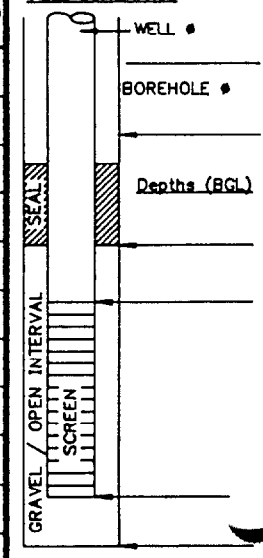
TEST TYPE (Rising/Falling/Constant Head): ..... CHECKED: .....

METHOD OF INDUCING WATER LEVEL CHANGE: ..... PAGE ..... OF .....

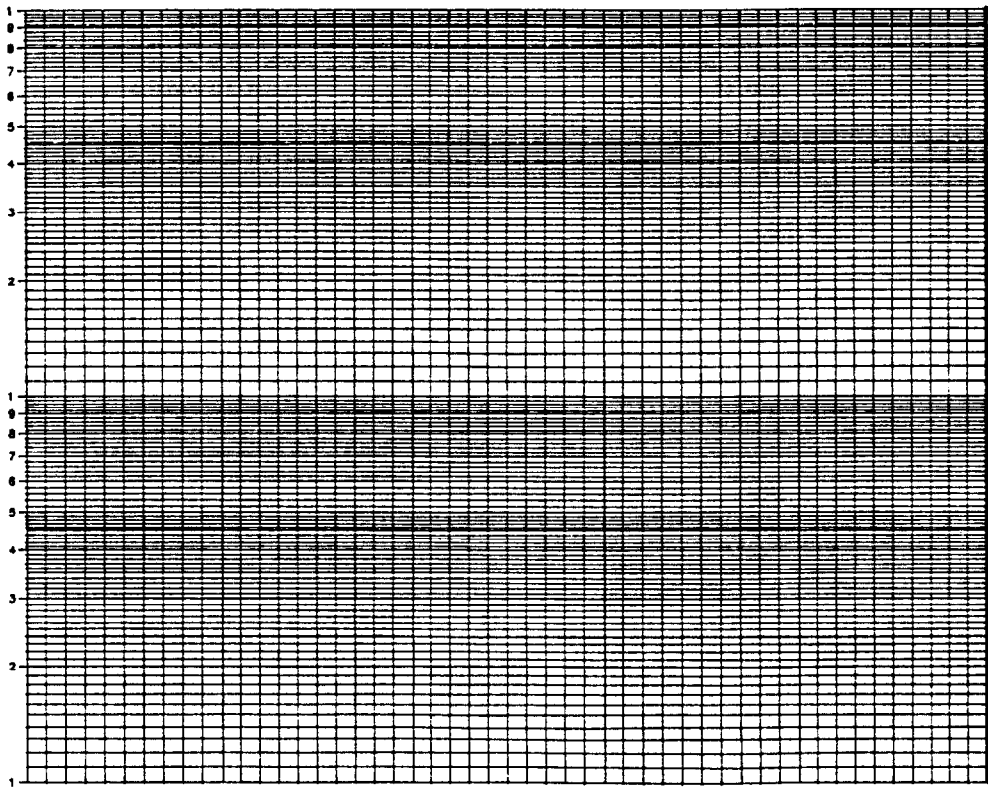
REFERENCE PT. FOR WL MEAS. (Top of Casing, Transducer, etc.): .....

ELAPSED TIME (min. or sec.)	MEASURED WATER LEVEL (feet)	DRAWDOWN OR HEAD (ΔH) (feet)	ELAPSED TIME (min. or sec.)	MEASURED WATER LEVEL (feet)	DRAWDOWN OR HEAD (ΔH) (feet)

WELL SCHEMATIC



▽ Indicate SWL Depth on Drawing



REMARKS:

.....

.....

.....

.....

.....

.....

.....

CALCS, SKETCH MAPS, ETC.:

PUMPING TEST DATA SHEET
PUMPING WELL

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
PUMPING TEST: [ ]
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DATE(s): _____
STATIC H_2O LEVEL (ft) (SO) _____

PUMPING WELL NUMBER: _____
MEASURED WELL NUMBER: _____
STEP DRAW DOWN TEST [ ]
MONITORING POINT: _____
DEPTH CORRECTION (ft) _____
PUMP SETTING (Ft. below monitoring point): _____
DISTANCE FROM PUMPING WELL (ft) (r): _____

PUMPING TEST PERFORMED BY: _____
REMARKS: _____

MILITARY TIME	ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	CORRECTION (Ft.)	DRAW DOWN OR RECOVERY (Ft.)	FLOW METER READING (Gals.)	PUMPING RATE (GPM)	REMARKS

SIGNATURE(s): _____

GROUNDWATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Domestic Well Data
[] Monitoring Well Data
[] Other Well Type: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	%	NA
Method:								

PURGE DATA:

Date:	Volume	pH	S.C.	Temp. (C)	Turbidity	DO	Salinity	Other
Method:	Initial							
Monitor Reading (ppm):	1							
Well Casing Diameter & Material	2							
Type:	3							
Total Well Depth (TD):								
Static Water Level (WL):								
One Casing Volume(gal/L):								
Start Purge (hrs):								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: _____

PROJECT NUMBER: _____

WELL I.D.: _____

DATE: _____

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	Temp. (Celcius)	pH (S.U.)	Cond.	DO (mg/L)	Sal. %	Turb. (NTU)	Comments

SIGNATURE(S) _____

PAGE __ of __

GROUNDWATER LEVEL MEASUREMENT SHEET

Brown & Root Environmental

Project Name: _____ Project No.: _____
Location: _____ Personnel: _____
Weather: _____ Measuring Device: _____
Date: _____ Remarks: _____

Well Number	Time	(A) Elevation of Reference Point (feet)*	(B) Water Level Indicator Reading (feet)*	=(A)-(B) Groundwater Elevation (feet)*	Total Well Depth (feet)*	Comments

Notes: _____

*All measurements to the nearest 0.01 foot

Page ____ of ____

SURFACE WATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Stream
[] Spring
[] Pond
[] Lake
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	%	NA
Depth:								
Method:								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA:

Date:	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

BORING LOG

Page ___ of ___

PROJECT NAME: _____ BORING NUMBER: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	ID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): [ ]

Remarks: _____

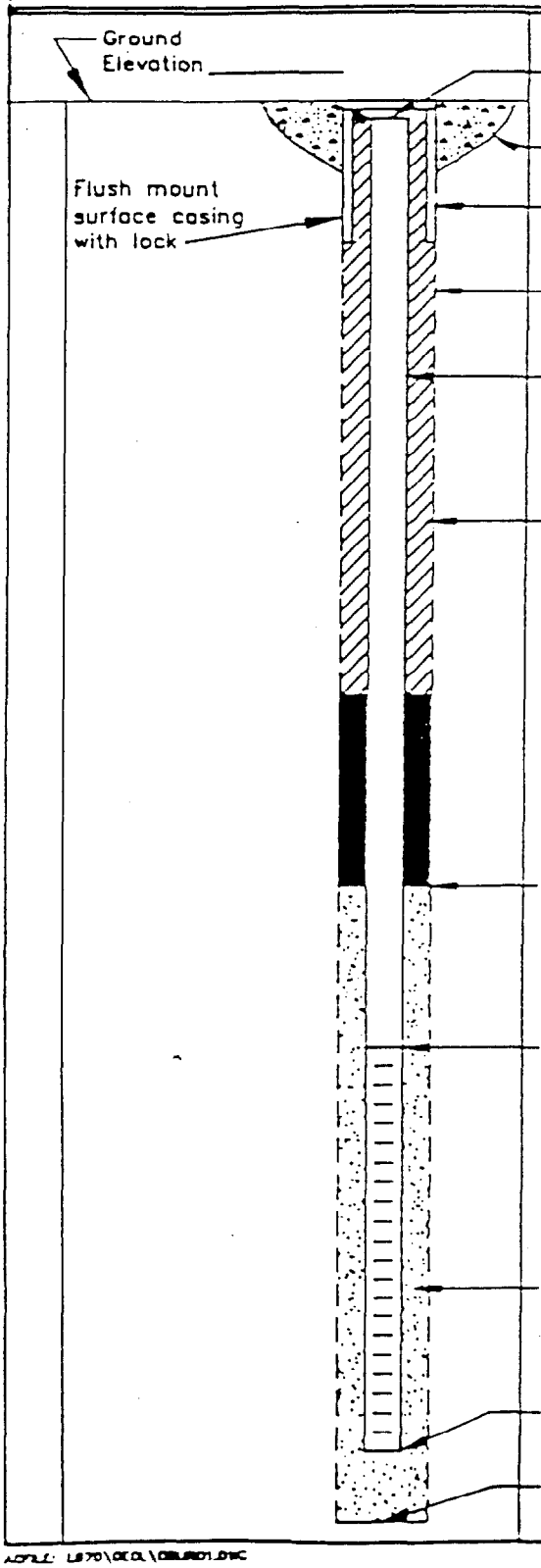
Converted to Well: Yes _____ No _____ Well I.D. #: _____

BORING NO.: _____

MONITORING WELL SHEET

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

Depth of Bentonite Seal - Top of Seal _____ / _____

Duration of Hydration _____ hrs

DEPTH/ELEVATION TOP OF SAND: _____ / _____

DEPTH/ELEVATION TOP OF SCREEN: _____ / _____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____

DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____

DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____

BACKFILL MATERIAL BELOW SAND: _____

SINGLE SAMPLE LOG SHEET

Page ___ of ___

Project Site Name: _____

Project No.: _____

- ☐ Surface Soil
- ☐ Subsurface Soil
- ☐ Sediment
- ☐ Other _____
- ☐ QA Sample Type: _____

Sample ID No.: _____

Sample Location: _____

Sampled By: _____

C.O.C. No.: _____

Sample Method:	Composite Sample Data		
	Sample	Time	Color/Description
Depth Sampled:			
Sample Date and Time:			
Type of Sample			
☐ Grab			
☐ Composite			
☐ Grab-Composite	Grab Sample Data		
☐ High Concentration	Color	Description: (Sand, Clay, Dry, Moist, Wet, etc.)	
☐ Low Concentration			

Analysis	Container Requirements	Collected (✓)	Map:

Observations/Notes:

Circle If Applicable:		Signature(s):
MS/MSD	Duplicate ID No:	

Brown & Root Environmental

CHAIN OF CUSTODY RECORD

PROJECT NO.:

SITE NAME:

SAMPLERS (SIGNATURE):

STATION NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS							REMARKS

RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):	RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):
RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):	RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED BY (SIGNATURE):
RELINQUISHED BY (SIGNATURE):	DATE/TIME:	RECEIVED FOR LABORATORY BY (SIGNATURE):	DATE/TIME:	REMARKS:	

RUS 440 24 0404

APPENDIX B

STANDARD OPERATING PROCEDURES

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APPENDIX B

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SA-1.1	Groundwater Sample Acquisition and Onsite Water Quality Testing
SA-1.2	Surface Water and Sediment Sampling
SA-1.3	Soil Sampling
SA-2.2	Air Monitoring and Sampling
SA-4.1	Aquatic Ecological Inventory and Sampling
SA-4.4	Biological Sampling Equipment and Maintenance
SA-6.1	Non-Radiological Sample Handling
SA-6.3	Field Documentation
SA-7.1	Decontamination of Field Equipment and Waste Handling
GH-1.2	Evaluation of Existing Monitoring Wells and Water Level Measurements
GH-1.3	Soil and Rock Drilling Methods
GH-1.5	Borehole and Sample Logging
GH-2.2	Packer Tests
GH-2.3	Aquifer Pumping Tests
GH-2.4	In-Situ Hydraulic Conductivity Testing
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GH-2.8	Groundwater Monitoring Point Installation
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GH-3.4	Ground-Penetrating Radar Surveys

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B.1 Brown & Root Environmental Standard Operating Procedures

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5.3 Example Sample Field Designations 4
5.4 Example Sample Numbers 6

1.0 PURPOSE

The purpose of this document is to specify a consistent sample nomenclature system that will facilitate subsequent data management in a cost-effective manner. The sample nomenclature system has been devised such that the following objectives can be attained:

- Sorting of data by matrix.
- Sorting of data by depth.
- Maintenance of consistency (field, laboratory, and data base sample numbers).
- Accommodation of all project-specific requirements on a global basis.
- Accommodation of laboratory sample number length constraints (10 characters).

2.0 SCOPE

The methods described in this procedure shall be used consistently for all projects requiring electronic data handling managed by personnel located in the Northeast Region of Brown & Root Environmental (Pittsburgh, Wayne, Holt, and Wilmington) and for any large contracts managed by the Northeast Region (e.g., NORTHDIV CLEAN, SOUTHDIV CLEAN, ARCS I, ARCS III, etc.). Smaller projects (as determined by Project Manager) are outside the scope of this SOP.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Program Manager - It shall be the responsibility of the Program Manager (or designee) to inform contract-specific Project Managers of the existence and requirements of this Standard Operating Procedure.

Project Manager - It shall be the responsibility of the Project Manager to determine the applicability of this Standard Operating Procedure based on: (1) program-specific requirements, and (2) project size and objectives. It shall be the responsibility of the Project Manager (or designee) to ensure that the sample nomenclature is thoroughly specified in the relevant project planning document (e.g., sampling and analysis plan) and is consistent with this Standard Operating Procedure if relevant. It shall be the responsibility of the project manager to ensure that the Field Operations Leader is familiar with the sample nomenclature system.

Field Operations Leader - It shall be the responsibility of the Field Operations Leader to ensure that all field technicians or sampling personnel are thoroughly familiar with this Standard Operating Procedure and the project-specific sample nomenclature system. It shall be the responsibility of the Field Operations Leader to ensure that the sample nomenclature system is used during all project-specific sampling efforts.

5.0 PROCEDURES

5.1 Introduction

The sample numbering system consists of 12 distinct alpha-numeric characters, only 10 of which will be provided to the laboratory on the sample labels and chain-of-custody forms. The sample number provided to the lab shall be as follows where "A" indicates "alpha," "N" indicates "numeric," and "E" indicates "either"):

$$\overline{E}\ \overline{E}\ \overline{E}\ \overline{A}\ \overline{A}\ \overline{E}\ \overline{E}\ \overline{E}\ \overline{N}\ \overline{N}$$

Once the analytical results are received from the laboratory the sample number will be revised by a subroutine such that the sample number is more user friendly (i.e., dashes will be inserted). The sample number will then appear as follows:

$$\overline{E}\ \overline{E}\ \overline{E}\ -\ \overline{A}\ \overline{A}\ -\ \overline{E}\ \overline{E}\ \overline{E}\ -\ \overline{N}\ \overline{N}$$

If multiple sampling events occur (or are planned) for a given matrix, a subroutine within the database will be used to append two additional characters such that the sample number will appear as follows:

$$\overline{E}\ \overline{E}\ \overline{E}\ -\ \overline{A}\ \overline{A}\ -\ \overline{E}\ \overline{E}\ \overline{E}\ -\ \overline{N}\ \overline{N}\ -\ \overline{N}\ \overline{N}$$

Site Type Location Depth Round

5.2 Sample Number Field Requirements

The various fields in the sample number will include the following:

- Site Identifier
- Sample Type
- Sample Location
- Sample Depth Indicator
- Sampling Round

The site identifier must be a three-character field (numeric characters, alpha characters, or a mixture of alpha and numeric characters may be used). A site number is necessary since many facilities/sites have multiple individual sites, SWMUs, operable units, etc.

The sample type must be a two-character alpha field. Suggested codes are provided in Section 5.3 of this SOP.

The sample location must be a three-character field (alpha, numeric, or a mixture).

The depth field must be provided for all samples, regardless if it is strictly applicable (as discussed in Section 5.3).

The sampling round is optional, but, if provided, must be two numeric characters.

5.3 Example Sample Field Designations

Examples of each of the fields are as follows:

Site Number - Examples of site numbers/designations are as follows:

A01 - Area of Concern Number 1
125 - Solid Waste Management Unit Number 125
000 - Base or Facility Wide Sample (e.g., upgradient well)
BBG - Base Background

The examples cited are only suggestions. Each Project Manager (or designee) must designate appropriate (and consistent) site designations for their individual project.

Sample Type - Examples of sample types are as follows:

AS - Air Sample
BS - Biota Sample (See Note)
CP - Composite Sample
CS - Chip Sample
DS - Drum Sample
DU - Dust Sample
FP - Free Product
ID - Investigation Derived Waste Sample
LT - Leachate Sample
MW - Monitoring Well
OF - Outfall Sample
RW - Residential Well Sample
SB - Soil Boring Sample
SD - Sediment Sample
SC - Scrape Sample
SG - Soil Gas Sample
SP - Seep Sample
SS - Surface Soil Sample
SU - Subsurface Soil Sample
SW - Surface Water Sample
TP - Test Pit Sample
TW - Temporary Well Sample
WC - Well Construction Material Sample
WI - Wipe Sample
WP - Well Point Sample
WS - Waste/Sludge Sample

Note: The biota sample designation may be contingent upon the type of biota sampled (e.g., BL - Lobster; BF - Finfish; BC - Clam; BO - Oyster). Numerous other examples can be cited but will be site-specific.

This field will also be used to designate field Quality Control Samples, as follows:

TB - Trip Blank
FB - Field Blank
RB - Rinsate Blank (Equipment Blank)
BB - Bottle Blank
AB - Ambient Condition Blank

Field quality control samples should be numbered sequentially (e.g., RB-001; FB-010, etc.).

Filtered/unfiltered surface water or groundwater samples shall be handled in an separate manner, as subsequently discussed.

Location - Examples of the location field are as follows:

A01 - Grid node A1
001 - Monitoring Well 1

It is important that consistency be maintained with respect to the use of the characters "0" and O. Data base subroutines will not sort correctly if a mixture are used (e.g, AO1 and A02).

Depth - Formerly, depth specifications were indicated with a four digit field (e.g., 0002 - 0 to 2 feet). While this is effective for depth sorting, it is difficult to include this level of detail in a 10-character lab number (FormMaster limitations). In addition, this approach will not accommodate non-integer depths (e.g., 2.5 feet to 4.5 feet).

Based on such potential problems, the following approach shall be used: Sample depths will simply represent the horizon from which the sample was obtained: For example, if ten split-spoon samples are collected from a boring, they will be numbered 01 through 10. The sample log sheet will be used to record the specific depth of the sample, and this information will be entered in a separator field in the data base.

Similar nomenclature will be used for depth-specific surface water and sediment samples, etc. If no depth information is required (e.g., groundwater samples), the field must still be filled (e.g., Ø, Ø).

This field will also be used for the designation of filtered and unfiltered samples. An unfiltered groundwater sample shall be designated as U0, if and only if, a corresponding filtered sample is collected. Such as sample shall be designated as F0.

Sampling Round - The sampling round field is straightforward. It can range from 01 to 99.

5.4 Example Sample Numbers

Examples of complete sample numbers (field/data base versus laboratory) are as follows:

Field/Data Base ID	Lab ID	Description
101-SB-A01-01	101SBA0101	The first sample (e.g., 0 to 2 feet) from soil boring A01 (grid) at Site 101.
101-SB-A01-02	101SBA0102	The second sample from boring A01 (could be the next depth interval or a duplicate of 101-SB-A01-01).
125-MW-001-01-01	125MW00101	A groundwater sample from monitoring well MW001 (first sampling round)
125-MW-001-02-01	125MW00102	A duplicate groundwater sample from monitoring well MW001 (first sampling round)
130-MW-003-U1-01	130MW003U1	An unfiltered groundwater sample from monitoring well MW003 (first sampling round)
130-MW-003-F1-01	130MW003F1	A filtered groundwater sample from monitoring well MW003 (first sampling round)
137-RB-001-00-01	137RB00100	The first rinsate blank collected at site 137.
137-TB-004-00-02	137TB00400	The fourth trip blank collected during the second sampling event at Site 137.
155-SW-003-01-01	155SW00301	A surface water sample collected from the surface of a pond at Site 155.
155-SW-003-02-01	155SW00302	A surface water sample collected from the bottom of the water column in a pond at Site 155.

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information regarding the sampling of groundwater wells.

2.0 SCOPE

This procedure provides information on proper sampling equipment, onsite water quality testing, 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 shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require modifications to methodology.

3.0 GLOSSARY

Conductance - The conductance of a conductor 1 centimeter long and 1 square centimeter in cross-sectional area. For groundwater measurements, a volume of water contained in a 1 cm x 1 cm sample container (the water acts as the conductor). Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only the current flows in the opposite direction due to the external source of applied voltage. Electrolytic cells are used in dissolved oxygen measurement.

Galvanic Cell - A electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit. Galvanic cells are used in dissolved oxygen measurement.

Ohm - Standard unit of electrical resistance (R). Used in specific conductance measurement. A siemen (or umho) is the standard unit of electrical conductance, the inverse of the ohm.

Oxidation-Reduction Potential (ORP) - A measure of the activity ratio of oxidizing and reducing species as determined by the electromotive force developed by a noble metal electrode, immersed in water, as referenced against a standard hydrogen electrode.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

pH Paper - Indicator paper that turns different colors depending on the pH of the solution to which it is exposed. Comparison with color standards supplied by the manufacturer will then give an indication of the solution's pH.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law, $E = IR$, where E is the potential difference, I is the current, and R is the resistance. Used in measurement of specific conductance.

4.0 RESPONSIBILITIES

Project Hydrogeologist - Responsible for selecting and detailing the specific groundwater sampling techniques, onsite water quality testing (type, frequency, and location), and equipment to be used, and providing detailed input in this regard to the project plan documents. The project hydrogeologist is also responsible for properly briefing and overseeing the performance of the site sampling personnel.

Project Geologist - is primarily responsible for the proper acquisition of the groundwater samples. He/she is also responsible for the actual analyses of onsite water quality samples, as well as instrument calibration, care, and maintenance. When appropriate, such responsibilities may be performed by other qualified personnel (e.g., field technicians).

5.0 PROCEDURES

5.1 General

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

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 isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach shall be followed prior to sample acquisition:

1. All monitoring wells shall be purged prior to obtaining a sample. Evacuation of three to five volumes is recommended prior to sampling. In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, extensive evacuation prior to sample withdrawal is not as critical.

2. For wells that can be purged dry, the well shall be evacuated and allowed to recover prior to sample acquisition. If the recovery rate is fairly rapid, evacuation of more than one volume of water is required.

3. For high-yielding monitoring wells which cannot be evacuated to dryness, there is no absolute safeguard against contaminating the sample with stagnant water. One of the following techniques shall be used to minimize this possibility:

   - A submersible pump or the intake line of a surface pump or bailer shall be placed just below the water surface when removing the stagnant water and lowered as the water level drops. Three to five volumes of water shall be removed to provide reasonable assurance that all stagnant water has been evacuated. Once this is accomplished, a bailer or other approved device may be used to collect the sample for analysis.

- The intake line of the sampling pump (or the submersible pump itself) shall be placed near the bottom of the screened section, and approximately one casing volume of water shall be pumped from the well at a low purge rate, equal to the well's recovery rate (low flow sampling).

Stratification of contaminants may exist in the aquifer. Concentration gradients as a result of mixing and dispersion processes, layers of variable permeability, and the presence of separate-phase product (i.e, floating hydrocarbons) may cause stratification. Excessive pumping or improper sampling methods can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column as it naturally occurs at that point, thus the result is the collection of a non-representative sample.

5.2 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with the guidelines expressed in SOP SA-6.1.

The following equipment shall be on hand when sampling ground water wells (reference SOPs SA-6.1 and SA-7.1):

- Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, appropriate sampling containers and filler, ice, labels and chain-of-custody documents.

- Field tools and instrumentation - Thermometer, pH paper/meter, camera and film (if appropriate), appropriate keys (for locked wells), engineer's rule, water level indicator, specific conductivity meter, and turbidity meter (as applicable).

- Pumps

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

  - Deep-well pumps: Submersible pump and electrical power-generating unit, or air-lift apparatus where applicable.

- Other sampling equipment - Bailers and inert line with tripod-pulley assembly (if necessary). Bailers or submersible centrifugal pumps shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.

- Pails - Plastic, graduated.

- Decontamination solutions - Deionized water, laboratory detergents, 10% nitric acid solution (as required), and analytical-grade solvents (e.g., methanol, acetone, hexane), as required.

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

5.3 Calculations of Well Volume

To insure that the proper volume of water has been removed from the well prior to sampling it is first necessary to know the volume of standing water in the well pipe. This volume can be easily calculated by the following method. Calculations shall be entered in the site logbook or field notebook or on a sample log sheet form (see SOP SA-6.3):

- Obtain all available information on well construction (location, casing, screens, etc.).
- Determine well or casing diameter.
- Measure and record static water level (depth below ground level or top of casing reference point).
- Determine depth of well by sounding using a clean, decontaminated, weighted tape measure.
- Calculate number of linear feet of static water (total depth or length of well pipe minus the depth to static water level).
- Calculate one static well volume in gallons $V = (0.163)(T)(r^2)$

  where:
  - V = Static volume of well in gallons.
  - T = Thickness of water table in the well measured in feet (i.e., linear feet of static water).
  - r = Inside radius of well casing in inches.
  - 0.163 = A constant conversion factor which compensates for the conversion of the casing radius from inches to feet, the conversion of cubic feet to gallons, and pi.
- Per evacuation volumes discussed above, determine the minimum amount to be evacuated before sampling.

5.4 Evacuation of Static Water (Purging)

5.4.1 General

The amount of purging a well shall 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. Alternately the well can be pumped until the parameters such as temperature, electrical conductance, pH, and turbidity (as applicable), have stabilized. Onsite measurements of these parameters shall be recorded in the site logbook, field notebook, or on standardized data sheets.

5.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment A provides guidance on the proper evacuation device to use for given sampling situations. 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 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.
- Bailers are inexpensive, and can be dedicated and hung in a well to reduce the chances of cross-contamination.
- There is minimal outgassing of volatile organics while the sample is in the bailer.
- Bailers are relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- It is time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

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 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 20 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps can cause significant loss of dissolved gases and volatile organics.

Air-Lift Samplers

This group of pump 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. Air (or gas)-lift samplers 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.

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 gas 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 2-inch-diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- They may have 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 can be difficult and time-consuming.

5.5 Onsite Water Quality Testing

This section describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen (DO) Concentration
- Oxidation Reduction Potential
- Certain Dissolved Constituents Using Specific Ion Elements
- Turbidity

This section is applicable for use in an onsite groundwater quality monitoring program to be conducted at a hazardous or nonhazardous site. The procedures and equipment described are applicable to groundwater samples and are not, in general, subject to solution interferences from color, turbidity, and colloidal material or suspended matter.

This section provides general information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

5.5.1 Measurement of pH

5.5.1.1 General

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment such as acid-base neutralization, water softening, and corrosion control is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required, and the pH meter when a more accurate measurement is needed. The response of a pH meter can be affected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In such cases, use of a pH meter is recommended.

5.5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or basicity of the solution created by the addition of the water sample reacting with the indicator compound on the paper. Various types of pH papers are available, including litmus (for general acidity or basicity determination) and specific pH range hydrion paper.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on establishment of a potential difference across a glass or other type of membrane in response to (in this instance, hydrogen) ion concentration across that membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to the ion concentration is generated and measured.

5.5.1.3 Equipment

The following equipment is needed for taking pH measurements:

- Stand-alone 150 portable pH meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Combination electrode with polymer body to fit the above meter (alternately a pH electrode and a reference electrode can be used if the pH meter is equipped with suitable electrode inputs).
- Buffer solutions, as specified by the manufacturer.
- pH indicator paper, to cover the pH range 2 through 12.
- Manufacturer's operation manual.

5.5.1.4 Measurement Techniques for Field Determination of pH

pH Meter

The following procedure is used for measuring pH with a pH meter (meter standardization is according to manufacturer's instructions):

- Inspect the instrument and batteries prior to initiation of the field effort.
- Check the integrity of the buffer solutions used for field calibration. Buffer solutions need to be changed often as a result of degradation upon exposure to the atmosphere.

- Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.

- If applicable, make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).

- Calibrate on a daily use basis following manufacturer's instructions. Record calibration data on an equipment calibration log sheet.

- Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a physical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.

- Read and record the pH of the solution. pH shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature.

- Rinse the electrode(s) with deionized water.

- Store the electrode(s) in an appropriate manner when not in use.

Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted.

pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper and proceed with successively narrower range paper until the sample pH is adequately determined.

5.5.2 Measurement of Specific Conductance

5.5.2.1 General

Conductance provides a measure of dissolved ionic species in water and can be used to identify the direction and extent of migration of contaminants in groundwater or surface water. It can also be used as a measure of subsurface biodegradation or to indicate alternate sources of groundwater contamination.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

5.5.2.2 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell may also be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

5.5.2.3 Equipment

The following equipment is needed for taking specific conductance (SC) measurements:

- Stand alone portable conductivity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

A variety of conductivity meters are available which may also be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment must be obtained to meet the specific requirement of the sampling program.

5.5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.

- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet. Potassium chloride solutions with a SC closest to the values expected in the field shall be used for calibration. Attachment B provides guidance in this regard.

- Rinse the cell with one or more portions of the sample to be tested or with deionized water.

- Immerse the electrode in the sample and measure the conductivity. Adjust the temperature setting to the sample temperature (if applicable).
- Read and record the results in a field logbook or sample log sheet.
- Rinse the electrode with deionized water.

If the specific conductance measurements become erratic, recalibrate the instrument and see the manufacturer's instructions for details.

5.5.3 Measurement of Temperature

5.5.3.1 General

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

5.5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury filled or dial-type thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature at great depths can be performed.

5.5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used to determine the temperature for a water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of cross-contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a field logbook or sample log sheet.

If a temperature meter or probe is used, the instrument shall be calibrated according to manufacturer's recommendations.

5.5.4 Measurement of Dissolved Oxygen Concentration

5.5.4.1 General

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time if the sample is not adequately preserved.

The monitoring method discussed herein is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible, and is not susceptible to interference caused by color, turbidity, colloidal material or suspended matter.

5.5.4.2 Principles of Equipment Operation

Dissolved oxygen probes are normally electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of highest nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed that is directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, while leaving the surface of the solution undisturbed.

Dissolved oxygen probes are relatively unaffected by interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide, which are not easily depolarized from the indicating electrode. If a gaseous interference is suspected, it shall be noted in the field log book and checked if possible. Temperature variations can also cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation is normally provided by the manufacturer.

5.5.4.3 Equipment

The following equipment is needed to measure dissolved oxygen concentration:

- Stand alone portable dissolved oxygen meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Sufficient cable to allow the probe to contact the sample.
- Manufacturer's operation manual.

5.5.4.4 Measurement Techniques for Dissolved Oxygen Determination

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration:

- The equipment shall be calibrated and have its batteries checked in the warehouse before going to the field.

- The probe shall be conditioned in a water sample for as long a period as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.

- The instrument shall be calibrated in the field according to manufacturer's recommendations or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment C).

- Record all pertinent information on an equipment calibration sheet.

- Rinse the probe with deionized water.

- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane by stirring the sample. Probes without stirrers placed in wells can be moved up and down.

- Record the dissolved oxygen content and temperature of the sample in a field logbook or sample log sheet.

- Rinse the probe with deionized water.

- Recalibrate the probe when the membrane is replaced, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable, since sample handling is not involved. This however, may not always be practical. Be sure to record whether the liquid was analyzed in-situ, or if a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

5.5.5 Measurement of Oxidation-Reduction Potential

5.5.5.1 General

The oxidation-reduction potential (ORP) provides a measure of the tendency of organic or inorganic compounds to exist in an oxidized state. The ORP parameter therefore provides evidence of the likelihood of anaerobic degradation of biodegradable organics or the ratio of activities of oxidized to reduced species in the sample.

5.5.5.2 Principles of Equipment Operation

When an inert metal electrode, such as platinum, is immersed in a solution, a potential is developed at that electrode depending on the ions present in the solution. If a reference electrode is placed in the same solution, an ORP electrode pair is established. This electrode pair allows the potential difference between the two electrodes to be measured and is dependent on the concentration of the ions in solution. By this measurement, the ability to oxidize or reduce species in solution may be determined. Supplemental measurements, such as dissolved oxygen, may be correlated with ORP to provide a knowledge of the quality of the solution, water, or wastewater.

5.5.5.3 Equipment

The following equipment is needed for measuring the oxidation-reduction potential of a solution:

- Portable pH meter or equivalent, with a millivolt scale.
- Platinum electrode to fit above pH meter.
- Reference electrode such as a calomel, silver-silver chloride, or equivalent.
- Reference solution as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring oxidation-reduction potential:

- The equipment shall be calibrated and have its batteries checked before going to the field.

- Check that the platinum probe is clean and that the platinum bond or tip is unoxidized. If dirty, polish with emery paper or, if necessary, clean the electrode using aqua regia, nitric acid, or chromic acid, in accordance with manufacturer's instructions.

- Thoroughly rinse the electrode with deionized water.

- Verify the sensitivity of the electrodes by noting the change in millivolt reading when the pH of the test solution is altered. The ORP will increase when the pH of the test solution decreases and the ORP will decrease if the test solution pH is increased. Place the sample in a clean container and agitate the sample. Insert the electrodes and note the ORP drops sharply when the caustic is added (i.e., pH is raised) thus indicating the electrodes are sensitive and operating properly. If the ORP increases sharply when the caustic is added, the polarity is reversed and must be corrected in accordance with the manufacturer's instructions. If the ORP does not respond as above when the caustic is added, the electrodes shall be cleaned and the above procedure repeated.

- After the assembly has been checked for sensitivity, wash the electrodes with three changes of water or by means of a flowing stream of deionized water from a wash bottle. Place the sample in a clean container and insert the electrodes. Set temperature compensator throughout the measurement period. Read the millivolt potential of the solution, allowing sufficient time for the system to stabilize and reach temperature equilibrium. Measure successive portions of the sample until readings on two successive portions differ by no more than 10 mV. A system that is very slow to stabilize properly will not yield a meaningful ORP. Record all results in a field logbook or sample logsheet, including ORP (to nearest 10 mV), sample temperature and pH at the time of measurement.

5.5.6 Measurement of Turbidity

5.5.6.1 General

Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and microscopic organisms, including plankton. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample.

It is important to obtain a turbidity reading immediately after taking a sample, since irreversible changes in turbidity may occur if the sample is stored too long.

5.5.6.2 Principles of Equipment Operation

Turbidity is measured by the Nephelometric Method. This method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the scattered light intensity, the higher the turbidity.

Formazin polymer is used as the reference turbidity standard suspension because of its ease of preparation combined with a higher reproducibility of its light-scattering properties than clay or turbid natural water. The turbidity of a specified concentration of formazin suspension is defined as 40 nephelometric units. This same suspension has an approximate turbidity of 40 Jackson units when measured on the candle turbidmeter. Therefore, nephelometric turbidity units (NTU) based on the formazin preparation will approximate units derived from the candle turbidimeter but will not be identical to them.

5.5.6.3 Equipment

The following equipment is needed for turbidity measurement:

- Stand alone portable turbidity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber.
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.6.4 Measurements Techniques for Specific Conductance

The steps involved in taking turbidity measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Check the expiration date (etc.) of the solutions used for field calibration.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the probe in the sample and measure the turbidity. The reading must be taken immediately as suspended solids will settle over time resulting in a lower, inaccurate turbidity reading.

- Read and record the results in a field logbook or sample log sheet. Include a physical description of the sample, including color, qualitative estimate of turbidity, etc.

- Rinse the electrode with deionized water.

5.6 Sampling

5.6.1 Sampling Plan

The sampling approach consisting of the following, shall be developed as part of the project plan documents which are approved prior to beginning work in the field:

- Background and objectives of sampling.

- Brief description of area and waste characterization.

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

- 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 shall be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.

- Sample preservation requirements.

- Work schedule.

- List of team members.

- List of observers and contacts.

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

5.6.2 Sampling Methods

The collection of a groundwater sample consists of the following steps:

1. The site Health & Safety Officer (or designee) will first open the well cap and use volatile organic detection equipment (PID or FID) on the escaping gases at the well head to determine the need for respiratory protection.

2. When proper respiratory protection has been donned, sound the well for total depth and water level (using clean equipment) and record these data on a groundwarer sampling log sheet (see SOP SA-6.3); then calculate the fluid volume in the well pipe (as previously described in this SOP).

3. Calculate well volume to be removed as stated in Section 5.3.

4. Select the appropriate purging equipment (see Attachment A). If an electric submersible pump with packer is chosen, go to Step 10.

5. Lower the purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (as applicable). Lower the purging device, as required, to maintain submergence.

6. Measure the rate of discharge frequently. A graduated bucket and stopwatch are most commonly used; other techniques include use of pipe trajectory methods, weir boxes or flow meters.

7. Observe the peristaltic pump intake for degassing "bubbles." If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. Never collect volatile organics samples using a vacuum pump.

8. Purge a minimum of three to five casing volumes before sampling. In low-permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Purged water shall be collected in a designated container and disposed in an acceptable manner.

9. 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.

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

11. In the event that recovery time of the well is very slow (e.g., 24 hours or greater), sample collection can be delayed until the following day. If the well has been purged early in the morning, sufficient 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 this occurrence in the site logbook.

12. Fill sample containers (preserve and label as described in SOP SA-6.1).

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

14. Process sample containers as described in SOP SA-6.1.

15. Decontaminate equipment as described in SOP SA-7.1.

5.7 Low Flow Purging and Sampling

5.7.1 Scope & Application

Low flow purging and sampling techniques are sometimes required for groundwater sampling activities. The purpose of low flow purging and sampling is to collect groundwater samples that contain

"representative" amounts of mobile organic and inorganic constituents in the vicinity of the selected open well interval, at near natural flow conditions. The minimum stress procedure emphasizes negligible water level drawdown and low pumping rates in order to collect samples with minimal alterations in water chemistry. This procedure is designed primarily to be used in wells with a casing diameter of 2 inches or more and a saturated screen, or open interval, length of ten feet or less. Samples obtained are suitable for analyses of common types of groundwater contaminants (volatile and semi-volatile organic compounds, pesticides, PCBs, metals and other inorganic ions [cyanide, chloride, sulfate, etc.]). This procedure is not designed to collect non-aqueous phase liquids samples from wells containing light or dense non-aqueous phase liquids (LNAPLs or DNAPLs), using the low flow pumps.

The procedure is flexible for various well construction types and groundwater yields. The goal of the procedure is to obtain a turbidity level of less than 5 NTU and to achieve a water level drawdown of less than 0.3 feet during purging and sampling. If these goals cannot be achieved, sample collection can take place provided the remaining criteria in this procedure are met.

5.7.2 Equipment

The following equipment is required (as applicable) for low flow purging and sampling:

- Adjustable rate, submersible pump (e.g., centrifugal or bladder pump constructed of stainless steel or Teflon). Peristaltic pumps may be used only for inorganic sample collection.
- Disposable clear plastic bottom filling bailers may be used to check for and obtain samples of LNAPLs or DNAPLs.
- Tubing - Teflon, Teflon lined polyethylene, polyethylene, PVC, tygon steel tubing can be used to collect samples for analysis, depending on the analyses to be performed and regulatory requirements.
- Water level measuring device, 0.01 foot accuracy, (electronic devices are preferred for tracking water level drawdown during all pumping operations).
- Flow measurement supplies.
- Interface probe, if needed.
- Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at a safe distance from the well so that the exhaust fumes do not contaminate the samples.
- Indicator parameter monitoring instruments - pH, turbidity, specific conductance, and temperature. Use of a flow-through cell is recommended. Optional Indicators - eH and dissolved oxygen, flow-through cell is required. Standards to perform field calibration of instruments.
- Decontamination supplies.
- Logbook(s), and other forms (e.g., well purging forms).
- Sample Bottles.

- Sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Well construction data, location map, field data from last sampling event.
- Field Sampling Plan.
- PID or FID instrument for measuring VOCs (volatile organic compounds).

5.7.3 Purging and Sampling Procedure

Use a submersible pump to purge and sample monitoring wells which have a 2.0 inch or greater well casing diameter.

Measure and record the water level immediately prior to placing the pump in the well.

Lower pump, safety cable, tubing and electrical lines slowly into the well so that the pump intake is located at the center of the saturated screen length of the well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of sediment that may be present in the bottom of the well. Collection of turbid free water samples may be difficult if there is three feet or less of standing water in the well.

When starting the pump, slowly increase the pump speed until a discharge occurs. Check water level. Adjust pump speed to maintain little or no water level drawdown. The target drawdown should be less than 0.3 feet and it should stabilize. If the target of less than 0.3 feet cannot be achieved or maintained, the sampling is acceptable if remaining criteria in the procedure are met. Subsequent sampling rounds will probably have intake settings and extraction rates that are comparable to those used in the initial sampling rounds.

Monitor water level and pumping rate every three to five minutes (or as appropriate) during purging. Record pumping rate adjustments and depths to water. Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During initial pump start-up, drawdown may exceed the 0.3 feet target and then recover as pump flow adjustments are made (minimum purge volume calculations should utilize stabilized drawdown values, not the initial drawdown). If the recharge rate of the well is less than minimum capability of the pump do not allow the water level to fall to the intake level (if the static water level is above the screen, avoid lowering the water level into the screen). Shut off the pump if either of the above is about to occur and allow the water level to recover. Repeat the process until field indicator parameters stabilize and the minimum purge volume is removed. The minimum purge volume with negligible drawdown (0.3 feet or less) is two saturated screen length volumes. In situations where the drawdown is greater than 0.3 feet and has stabilized, the minimum purge volume is two times the saturated screen volume plus the stabilized drawdown volume. After the minimum purge volume is attained (and field parameters have stabilized) begin sampling. For low yields wells, commence sampling as soon as the well has recovered sufficiently to collect the appropriate volume for all anticipated samples.

During well purging, monitor field indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every three to five minutes (or as appropriate). Purging is complete and sampling may begin when

all field indicator parameters have stabilized (variations in values are within ten percent of each other, pH +/- 0.2 units, for three consecutive readings taken at three to five minute intervals). If the parameters have stabilized, but turbidity remains above 5 NTU goal, decrease pump flow rate, and continue measurement of parameters every three to five minutes. If pumping rate cannot be decreased any further and stabilized turbidity values remain above 5 NTU goal record this information. Measurements of field parameters should be obtained (as per Section 5.5) and recorded.

VOC samples are preferably collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the water column in the pump tubing collapses (water does not completely fill the tubing) before exiting the tubing, use one of the following procedures to collect VOC samples: (1) Collect the non-VOCs samples first, then increase the flow rate incrementally until the water column completely fills the tubing, collect the sample and record the new flow rate; (2) reduce the diameter of the existing tubing until the water column fills the tubing either by adding a connector (Teflon or stainless steel), or clamp which should reduce the flow rate by constricting the end of the tubing; (3) insert a narrow diameter Teflon tube into the pump's tubing so that the end of the tubing is in the water column and the other end of the tubing protrudes beyond the pump's tubing, collect sample from the narrow diameter tubing.

Prepare samples for shipping as per SOP SA-6.1.

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ATTACHMENT A

PURGING EQUIPMENT SELECTION

Diameter Casing		Bailer	Peristaltic Pump	Vacuum Pump	Air-lift	Diaphragm "Trash" Pump	Submersible Diaphragm Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-Inch	Water level <25 feet		X	X	X	X			
	Water Level >25 feet				X				
2-Inch	Water level <25 feet	X	X	X	X	X	X		
	Water Level >25 feet	X			X		X		
4-Inch	Water level <25 feet	X	X	X	X	X	X	X	X
	Water Level >25 feet	X			X		X	X	X
6-Inch	Water level <25 feet				X	X		X	X
	Water Level >25 feet				X			X	X
8-Inch	Water level <25 feet				X	X		X	X
	Water Level >25 feet				X			X	X

ATTACHMENT A
PURGING EQUIPMENT SELECTION
PAGE 2

Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/ Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
BarCad Systems, Inc.	BarCad Sampler	Dedicated; gas drive (positive displacement)	1.5/16	PE, brass, nylon, aluminum oxide	0-150 with std. tubing	1 liter for each 10-15 feet of submergence	$220-350	Requires compressed gas; custom sizes and materials available; acts as piezometer.
Cole-Parmer Inst. Co.	Master Flex 7570 Portable Sampling Pump	Portable; peristaltic (suction)	<1.0/NA	(not submersible) Tygon®, silicone Viton®	0-30	670 mL/min with 7015-20 pump head	$500-600	AC/DC; variable speed control available; other models may have different flow rates.
ECO Pump Corp.	SAMPLifier	Portable; venturi	<1.5 or <2.0/NA	PP, PE, PVC, SS, Teflon®, Tefzel®	0-100	0-500 mL/min depending on lift	$400-700	AC, DC, or gasoline-driven motors available; must be primed.
Geltek Corp.	Bailer 219-4	Portable; grab (positive displacement)	1.66/38	Teflon®	No limit	1,075 mL	$120-135	Other sizes available.
GeoEngineering, Inc.	GEO-MONITOR	Dedicated; gas drive (positive displacement)	1.5/16	PE, PP, PVC, Viton®	Probably 0-150	Approximately 1 liter for each 10 feet of submergence	$185	Acts as piezometer; requires compressed gas.
Industrial and Environmental Analysts, Inc. (IEA)	Aquarius	Portable; bladder (positive displacement)	1.75/43	SS, Teflon®, Viton®	0-250	0-2,800 mL/min	$1,500-3,000	Requires compressed gas; other models available; AC, DC, manual operation possible.
IEA	Syringe Sampler	Portable; grab (positive displacement)	1.75/43	SS, Teflon®	No limit	850 mL sample volum e	$1,100	Requires vacuum and/or pressure from hand pump.
Instrument Specialties Co. (ISCO)	Model 2600 Well Sampler	Portable; bladder (positive displacement)	1.75/50	PC, silicone, Teflon®, PP, PE, Detrin®, acetal	0-150	0-7,500 mL/min	$990	Requires compressed gas (40 psi minimum).
Keck Geophysical Instruments, Inc.	SP-81 Submersible Sampling Pump	Portable; helical rotor (positive displacement)	1.75/25	SS, Teflon®, PP, EPDM, Viton®	0-160	0-4,500 mL/min	$3,500	DC operated.
Leonard Mold and Die Works, Inc.	GeoFilter Small Diameter Well Pump (#0500)	Portable; bladder (positive displacement)	1.75/38	SS, Teflon®, PC, Neoprene®	0-400	0-3,500 mL/min	$1,400-1,500	Requires compressed gas (55 psi minimum); pneumatic or AC/DC control module.
Oil Recovery Systems, Inc.	Surface Sampler	Portable; grab (positive displacement)	1.75/12	acrylic, Detrin®	No limit	Approximately 250 mL	$125-160	Other materials and models available; for measuring thickness of "floating" contaminants.
Q.E.D. Environmental Systems, Inc.	Well Wizard® Monitoring System (P-100)	Dedicated; bladder (positive displacement)	1.66/36	PVC	0-230	0-2,000 mL/min	$300-400	Requires compressed gas; piezometric level indicator; other materials available.

ATTACHMENT A
PURGING EQUIPMENT SELECTION
PAGE 3

Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/ Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
Randolph Austin Co.	Model 500 Vari-Flow Pump	Portable; peristaltic (suction)	<0.5/NA	(Not submersible) Rubber, Tygon®, or Neoprene®	0-30	See comments	$1,200-1,300	Flow rate dependent on motor and tubing selected; AC operated; other models available.
Robert Bennett Co.	Model 180	Portable; piston (positive displacement)	1.8/22	SS, Teflon®, Delrin® PP, Viton®, acrylic, PE	0-500	0-1,800 mL/min	$2,600-2,700	Requires compressed gas; water level indicator and flow meter; custom models available.
Slope Indicator Co. (SINCO)	Model 514124 Pneumatic Water Sampler	Portable; gas drive (positive displacement)	1.9/18	PVC, nylon	0-1,100	250 mL/ flushing cycle	$250-350	Requires compressed gas; SS available; piezometer model available; dedicated model available.
Solinst Canada Ltd.	5W Water Sampler	Portable; grab (positive displacement)	1.9/27	PVC, brass, nylon, Neoprene®	0-330	500 mL	$1,300-1,800	Requires compressed gas; custom models available.
TIMCO Mfg. Co., Inc.	Std. Bailer	Portable; grab (positive displacement)	1.66/Custom	PVC, PP	No limit	250 mL/ft of bailer	$20-60	Other sizes, materials, models available; optional bottom-emptying device available; no solvents used.
TIMCO	Air or Gas Lift Sampler	Portable; gas drive (positive displacement)	1.66/30	PVC, Tygon®, Teflon®	0-150	350 mL/ flushing cycle	$100-200	Requires compressed gas; other sizes, materials, models available; no solvents used.
Tole Devices Co.	Sampling Pump	Portable; bladder (positive displacement)	1.38/48	SS, silicone, Delrin®, Tygon®	0-125	0-4,000 mL/min	$800-1,000	Compressed gas required; DC control module; custom built.

Construction Material Abbreviations:

PE	Polyethylene
PP	Polypropylene
PVC	Polyvinyl chloride
SS	Stainless steel
PC	Polycarbonate
EPDM	Ethylene-propylene diene (synthetic rubber)

Other Abbreviations:

NA	Not applicable
AC	Alternating current
DC	Direct current

NOTE: Other manufacturers market pumping devices which could be used for groundwater sampling, though not expressly designed for this purpose. The list is not meant to be all-inclusive and listing does not constitute endorsement for use. Information in the table is from sales literature and/or personal communication. No skimmer, scavenger-type, or high-capacity pumps are included.

Source: Barcelona et al., 1983.

ATTACHMENT B

SPECIFIC CONDUCTANCE OF 1 MOLAR KCl AT VARIOUS TEMPERATURES[1]

Temperature (°C)	Specific Conductance (umhos/cm)
15	1,147
16	1,173
17	1,199
18	1,225
19	1,251
20	1,278
21	1,305
22	1,332
23	1,359
24	1,368
25	1,413
26	1,441
27	1,468
28	1,496
29	1,524
30	1,552

1 Data derived from the International Critical Tables 1-3-8.

ATTACHMENT C

VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.016
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008

ATTACHMENT C
VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY
PAGE TWO

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008
31	7.5					
32	7.4					
33	7.3					
34	7.2					
35	7.1					
36	7.0					
37	6.9					
38	6.8					
39	6.7					
40	6.6					
41	6.5					
42	6.4					
43	6.3					
44	6.2					
45	6.1					
46	6.0					
47	5.9					
48	5.8					
49	5.7					
50	5.6					

Note: In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore, used to correct measured D.O. concentration) using Attachment B.

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1.0 PURPOSE

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

2.0 SCOPE

The information presented in this guideline is generally applicable to all environmental sampling of surface waters (Section 5.3) and aquatic sediments (Section 5.5), except where the analyte(s) may interact with the sampling equipment. The collection of concentrated sludges or hazardous waste samples from disposal or process lagoons often requires methods, precautions and equipment different from those described herein.

3.0 GLOSSARY

Environmental Sample - a sample containing (or suspected to contain) low-level concentrations of contaminants, which does not require special handling or transport considerations as detailed in SOP SA-6.1.

Hazardous Waste Sample - a sample containing (or suspected to contain) higher concentrations of contaminants thus requiring special handling and/or transport considerations per SOP SA-6.1.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager has the overall responsibility for seeing that all surface water and sediment sampling activities are properly conducted by appropriately trained personnel.

Field Operations Leader - The Field Operations Leader (FOL) is responsible for the in-field supervision of the conduct of onsite water quality analyses, ensuring the completion and accuracy of all field documentation, and making sure that custody of all samples obtained is maintained according to proper procedures.

5.0 PROCEDURES

5.1 Introduction

Collecting a representative sample from surface water or sediments is difficult because of 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 characteristic 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 proper sample collection methods are important to ensure that a truly representative sample has been taken. Regardless of quality control applied during laboratory analyses and subsequent scrutiny of analytical data packages, reported data are not better than the confidence that can be placed in the representativeness of the samples.

5.2 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, physical characteristics of the water body (such as flow and mixing), 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 affect adsorption/desorption). The hydrogeologist developing the sampling plan must therefore know not only the mixing characteristics of streams and lakes, but also must understand the role of fluvial-sediment transport, deposition, and chemical sorption.

5.2.1 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 overland runoff, leachate influx to the waterbody, direct waste disposal (solid or liquid) into the water body; and groundwater flow influx from upgradient. 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 (and when they were 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 non-detectable concentrations. Such dispersion does not, however, always readily occur. For example, obtaining a representative sample of contamination from a main stream 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 (coves, river bends, deep spots, or even behind boulders) near or distant from the source 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 onto particulate matter. Nitrogen, phosphorus, and the heavy metals may also be transported by particulates. Samples must be collected with a representative amount of suspended material; transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

5.2.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and consideration of site conditions must be balanced against the costs of collection as controlled by accessibility. Bridges or piers are the first choice for locating a sampling station on a stream because bridges provide ready access and also permit the sampling technician to sample any point across the stream. 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. Wading for samples is not recommended unless it is known that contaminant levels are low so that skin contact will not produce adverse health effects. This provides a built in margin of safety in the event that wading boots or other protective equipment should fail to function properly. 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.

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 apply.

Under ideal and uniform contaminant dispersion conditions in a flowing stream, the same concentrations of each would occur at all points along the cross section. This situation is most likely downstream of areas of high turbulence. Careful site selection is needed in order to ensure, as nearly as possible, that samples are taken where uniform flow or deposition and good mixing conditions exist.

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

5.2.3 Frequency of Sampling

The sampling frequency and the objectives of the sampling event will be defined by the project plan documents. 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 is not often recommended. If samples are collected primarily for monitoring purposes (i.e., consisting of repetitive, continuing measurements to define variations and trends at a given location), water samples shall be collected at a pre-established and constant interval as specified in the project plans (often monthly or quarterly, and during droughts and floods). Samples of bottom material shall be collected from fresh deposits at least yearly, and preferably seasonally, during both spring and fall.

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

5.3 Surface Water Sample Collection

5.3.1 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) methods (see below).

Samples from different depths or cross-sectional locations in the watercourse taken 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 taken depend on the river's width, depth, discharge and on the suspended sediment the stream or river transports. The greater the number of individual points that are sampled, the 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 site 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, at least one vertical composite shall be taken with one sample each from just below the surface, at mid-depth, and just above the bottom. The measurement of DO, pH, temperature, conductivity, etc., shall be made on each aliquot of the vertical composite and on the composite itself. For rivers, several vertical composites shall be collected, as directed in the project plan documents.

5.3.2 Lakes, Ponds and Reservoirs

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

The number of water sampling sites 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 to be conducted on each aliquot of the vertical composite and on the composite itself. 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 composites shall be composited to form a single sample. These verticals are often taken 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 consists of several verticals with samples collected at various depths.

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

Many lake measurements are now 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.

5.3.3 Estuaries

Estuarine areas are by definition, zones where inland freshwaters (both surface and ground) mix with oceanic saline waters. Estuaries are generally categorized into three types dependent upon freshwater inflow and mixing properties. Knowledge of the estuary type is necessary to determine sampling locations. Each type of estuarine area is described below:

- 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 is normally 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 at 1- to 5-foot increments, coupled with vertical dissolved oxygen and temperature profiles.

5.3.4 Surface Water Sampling Equipment

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

- Open tube.
- Dip sampler.
- Weighted bottle.
- Hand pump.
- Kemmerer.
- Depth-Integrating Sampler.

The dip sampler and the weighted bottle sampler are used most often, and detailed discussions for these devices only (and the Kemmerer sampler) are addressed subsequently in this section.

The criteria for selecting a sampler include:

- Disposability and/or easy decontamination.
- Inexpensive cost (if the item is to be disposed).
- Ease of operation.
- Nonreactive/noncontaminating properties - Teflon-coated, glass, stainless-steel or PVC sample chambers are preferred (in that order).

As specified in the project plan document plan documents, each sample (grab or each aliquot collected for compositing) shall be measured for:

- Specific conductance.
- Temperature.
- pH.
- Dissolved oxygen (optional).

Sample measurements shall be conducted as soon as the sample is acquired. Measurement techniques described in SOP SA-1.1 shall be followed. All pertinent data and results shall be recorded in a field notebook or on sample logsheets (see SOP SA-6.3). These analyses will provide information on water mixing/stratification and potential contamination.

Dip Sampling

Water is often 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.

Weighted Bottle Sampling

A grab sample can also be taken using a weighted holder that allows a bottle 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 with this device is:

- 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 sampling 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. This bottle can be used as the sample container as long as the bottle is an approved container type.

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 (thus allowing 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.

5.3.5 Surface Water Sampling Techniques

Most samples taken during site investigations are grab samples. Typically, surface water sampling involves immersing the sample container in the body of water; however, the following suggestions are made to help ensure that the samples obtained are representative of site conditions:

- The most representative samples are obtained from mid-channel at a 0.6 foot stream depth in a well-mixed stream.

- Even though the containers used to obtain the samples are previously laboratory cleaned, it is suggested that the sample container be rinsed at least once with the water to be sampled before the sample is taken. This is not applicable when sample containers are provided "pre-preserved."

- 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. In general, work from zones suspected of low contamination to zones of high contamination.

- 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 node is combined into one sample, or several grid nodes are selected at random.

- Care should be taken to avoid excessive agitation of the water, as loss of volatile constituents could result.

- 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 of the septum faces in after the vial is filled and capped. The vial can be turned upside down to check for air bubbles.

- 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. When sample containers are provided "pre-preserved," use a dedicated, clean, un-preserved bottle for sampling and transfer to an appropriately-preserved container.

5.4 Onsite Water Quality Testing

Onsite water quality testing shall be conducted as described in SOP SA-1.1.

5.5 Sediment Sampling

5.5.1 General

Sediment samples are usually collected at the same verticals at which water samples were collected. If only one sediment sample is to be collected, the sampling location shall be approximately at the center of the water body.

Generally, the coarser grained sediments are deposited near the headwaters of the reservoir. Bed sediments near the center of a water body will be composed of fine-grained materials which may, because of their lower porosity and greater surface area available for adsorption, contain greater concentrations of contaminants. The shape, flow pattern, bathometry (i.e., depth distribution), and water circulation patterns must all be considered when selecting sediment sampling sites. In streams, areas likely to have sediment accumulation (e.g., bends, behind islands or boulders, quiet shallow areas or very deep, low-velocity areas) shall be sampled while areas likely to show net erosion (i.e., high-velocity, turbulent areas) and suspension of fine solid materials, shall be avoided.

Chemical constituents associated with bottom material may reflect an integration of chemical and biological processes. Bottom samples reflect the historical input to streams, lakes, and estuaries with respect to time, application of chemicals, and land use. Bottom sediments (especially fine-grained material) may act as a sink or reservoir for adsorbed heavy metals and organic contaminants (even if water column concentrations are below detection limits). Therefore, it is important to minimize the loss of low-density "fines" during any sampling process.

All relevant information pertaining to sediment sampling shall be documented as applicably described in SOP SA-6.3.

5.5.2 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 onshore or offshore techniques.

When boats are used for sampling, life preservers must be provided and two individuals must undertake the sampling. An additional person shall remain onshore in visual contact at all times.

The following samplers may be used to collect bottom materials:

- Scoop sampler.
- Dredge samplers.

Each type of sampler is discussed subsequently.

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 best 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 the sampler 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.

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 sample 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 Peterson 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 permitting 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.

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1.0 PURPOSE

This procedure discusses the methods used to collect surface, near surface, and subsurface soil samples. Additionally, it describes the method for sampling of test pits and trenches to determine subsurface soil and rock conditions, and recover small-volume or bulk samples.

2.0 SCOPE

This procedure is applicable to the collection of surface, near surface and subsurface soils for laboratory testing, which are exposed through hand digging, hand augering, drilling, or machine excavating at hazardous substance sites.

3.0 GLOSSARY

Composite Sample - A composite sample exists as a combination of more than one sample at various locations and/or depths and times, which is homogenized and treated as one sample. This type of sample is usually collected when determination of an average waste concentration for a specific area is required. Composite samples are not to be collected for volatile organics analysis.

Grab Sample - One sample collected at one location and at one specific time.

Non-Volatile Sample - A non-volatile sample includes all other chemical parameters (e.g., semivolatiles, pesticides/PCBs, metals, etc.) and those engineering parameters that do not require undisturbed soil for their analysis.

Hand Auger - A sampling device used to extract soil from the ground in a relatively undisturbed form.

Thin-Walled Tube Sampler - A thin-walled metal tube (also called a Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outside diameter (OD) and from 18 to 54 inches in length.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into resistant materials using a drive weight mounted in the drilling string. A standard split-barrel sampler is typically available in two common lengths, providing either 20-inch or 26-inch longitudinal clearance for obtaining 18-inch or 24-inch-long samples, respectively. These split-barrel samplers commonly range in size from 2-inch OD to 3-1/2 inch OD. The larger sizes are commonly used when a larger volume of sample material is required.

Test Pit and Trench - Open, shallow excavations, typically rectangular (if a test pit) or longitudinal (if a trench), excavated to determine the shallow subsurface conditions for engineering, geological, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by machine (e.g., backhoe, clamshell, trencher excavator, or bulldozer).

Confined Space - As stipulated in 29 CFR 1910.146, a confined space means a space that: 1) is large enough and so configured that an employee can bodily enter and perform assigned work; 2) has limited or restricted means for entry or exit (for example tanks, vessels, silos, storage bins, hoppers, vaults, and pits, and excavations are spaces that may have limited means of entry.); and 3) is not designed for continuous employee occupancy. Brown & Root Environmental considers all confined space as permit-required confined spaces.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for determining sampling objectives, as well as, the field procedures used in the collection of soil samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager establishes the need for test pits or trenches, and determines their approximate locations and dimensions.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan. This will include (but not be limited to) performing air quality monitoring during sampling, boring and excavation activities, and to ensure that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO/designee may also be required to advise the FOL on other safety-related matters regarding boring, excavation and sampling, such as mitigative measures to address potential hazards from unstable trench walls, puncturing of drums or other hazardous objects, etc.

Field Operations Leader (FOL) - The FOL is responsible for finalizing the location of surface, near surface, and subsurface (hand and machine borings, test pits/trenches) soil samples. He/she is ultimately responsible for the sampling and backfilling of boreholes, test pits and trenches, and for adherence to OSHA regulations during these operations.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of soil samples and the completion of all required paperwork (i.e., sample log sheets, field notebook, boring logs, test pit logs, container labels, custody seals, and chain-of-custody forms).

Competent Person - A Competent Person, as defined in 29 CFR 1929.650 of Subpart P - Excavations, means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

5.0 PROCEDURES

5.1 Overview

Soil sampling is an important adjunct to groundwater monitoring. Sampling of the soil horizons above the groundwater table can detect contaminants before they have migrated into the water table, and can establish the amount of contamination sorbed on aquifer solids that have the potential of contributing to groundwater contamination.

Soil types can vary considerably on a hazardous waste site. These variations, along with vegetation, can effect the rate of contaminant migration through the soil. It is important, therefore, that a detailed record be maintained during the sampling operations, particularly noting the location, depth, and such characteristics as grain size, color, and odor. Subsurface conditions are often stable on a daily basis and may demonstrate only slight seasonal variation especially with respect to temperature, available oxygen and light penetration. Changes in any of these conditions can radically alter the rate of chemical reactions or the associated microbiological community, thus further altering specific site conditions. As a result, samples must be kept at their at-depth temperature or lower, protected from direct light, sealed tightly in approved glass containers and be analyzed as soon as possible.

The physical properties of the soil, its grain size, cohesiveness, associated moisture, and such factors as depth to bedrock and water table, will limit the depth from which samples can be collected and the method required to collect them. Often this information on soil properties can be obtained from published soil surveys available through the U.S. Geological Surveys and other government or farm agencies. It is the intent of this procedure to present the most commonly employed soil sampling methods used at hazardous waste sites.

5.2 Soil Sample Collection

5.2.1 Procedure for Collecting Volatile Soil Samples Volatile samples are only collected as grab samples and maintained and handled in as near an undisturbed state as possible. The sample is transferred directly into an approved glass container with a Teflon lined cap. The sample must be packed down as much as possible to reduce air space within the sample container to an absolute minimum. Also, a properly filled volatile organics sample container will have no head space.

5.2.2 Procedure for Collecting Non-Volatile Soil Samples

Non-volatile soil samples may be collected as either grab or composite samples. The non-volatile soil sample is thoroughly mixed in a stainless steel or disposable, inert plastic tray, using a stainless steel trowel or other approved tool, then transferred into the appropriate sample container(s). Head space is permitted in a non-volatile soil sample container to allow for sample expansion.

5.2.3 Procedure for Collecting Undisturbed Soil Samples (ASTM D1587-83)

When it is necessary to acquire undisturbed samples of soil for purposes of engineering parameter analysis (e.g., permeability), a thin-walled, seamless tube sampler (Shelby tube) will be employed. The following method will be used:

1. Remove all surface debris (e.g., vegetation, roots, twigs, etc.) from the specific sampling location and drill and clean out the borehole to the sampling depth, being careful to minimize the chance for disturbance of the material to be sampled. In saturated material, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and to maintain the water level in the hole at or above groundwater level.

2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the borehole shall not be allowed. Use of any side-discharge bits is permitted.

3. A stationary piston-type sampler may be required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler into the borehole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.

4. To minimize chemical reaction between the sample and the sampling tube, brass tubes may be required, especially if the tube is stored for an extended time prior to testing. While steel tubes coated with shellac are less expensive than brass, they're more reactive, and shall only be used when the sample will be tested within a few days after sampling or if chemical reaction is not anticipated. With the sampling tube resting on the bottom of the hole and the water level in the boring at groundwater level or above, push the tube into the soil by a

continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.

5. Upon removal of the sampling tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Clean filler must be placed in voids at either end of the tube prior to sealing with wax. Place plastic caps on the ends of the sample tube, tape the caps in place, and dip the ends in wax.

6. Affix label(s) to the tube as required and record sample number, depth, penetration, and recovery length on the label. Mark the "up" direction on the side of the tube with indelible ink, and mark the end of the sample. Complete Chain-of-Custody and other required forms (see SOP SA-6.3). Do not allow tubes to freeze, and store the samples vertically with the same orientation they had in the ground, (i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dennison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs, and therefore their use shall be weighed against the need for acquiring an undisturbed sample.

5.3 Surface Soil Sampling

The simplest, most direct method of collecting surface soil samples (most commonly collected to a depth of 6 inches) for subsequent analysis is by use of a stainless steel trowel.

In general, the following equipment is necessary for obtaining surface soil samples:

- Stainless steel trowel.
- Real-time air monitoring instrument (e.g., PID, FID, etc.).
- Latex gloves.
- Required Personal Protective Equipment (PPE).
- Required paperwork.
- Required decontamination equipment.
- Required sample container(s).
- Wooden stakes or pin flags.
- Sealable polyethylene bags (i.e., Ziploc baggies).
- Heavy duty cooler.
- Ice (if required) double-bagged in sealable polyethylene bags.
- Chain-of-custody records and custody seals.

When acquiring surface soil samples, the following procedure shall be used:

1. Carefully remove vegetation, roots, twigs, litter, etc., to expose an adequate soil surface area to accommodate sample volume requirements.

2. Using a decontaminated stainless steel trowel, follow the procedure cited in Section 5.2.1 for collecting a volatile soil sample.

3. Thoroughly mix (in-situ) a sufficient amount of soil to fill the remaining sample containers and transfer the sample into those containers utilizing the same stainless steel trowel employed above. Cap and securely tighten all sample containers.

4. Affix a sample label to each container. Be sure to fill out each label carefully and clearly, addressing all the categories described in SOP SA-6.3.

5. Proceed with the handling and processing of each sample container as described in SOP SA-6.2.

5.4 Near-Surface Soil Sampling

Collection of samples from near the surface (depth of 6-18 inches) can be accomplished with tools such as shovels and stainless steel trowels.

The following equipment is necessary to collect near surface soil samples:

- Clean shovel.
- Plus the equipment listed under Section 5.3 of this procedure.

To obtain near-surface soil samples, the following protocol shall be observed:

1. With a clean shovel, make a series of vertical cuts to the depth required in the soil to form a square approximately 1 foot by 1 foot.

2. Lever out the formed plug and scrape the bottom of the freshly dug hole with a decontaminated stainless steel trowel to remove any loose soil.

3. Follow steps 2 through 5 listed under Section 5.3 of this procedure.

5.5 Subsurface Soil Sampling With a Hand Auger

A hand augering system generally consists of a variety of all stainless steel bucket bits (i.e., cylinders 6-1/2" long, and 2-3/4", 3-1/4", and 4" in diameter), a series of extension rods (available in 2', 3', 4' and 5' lengths), and a cross handle. A larger diameter bucket bit is commonly used to bore a hole to the desired sampling depth and then withdrawn. In turn, the larger diameter bit is replaced with a smaller diameter bit, lowered down the hole, and slowly turned into the soil at the completion depth (approximately 6"). The apparatus is then withdrawn and the soil sample collected.

The hand auger can be used in a wide variety of soil conditions. It can be used to sample soil both from the surface, or to depths in excess of 12 feet. However, the presence of rock layers and the collapse of the borehole normally contribute to its limiting factors.

To accomplish soil sampling using a hand augering system, the following equipment is required:

- Complete hand auger assembly (variety of bucket bit sizes).
- Stainless steel mixing bowls.
- Plus the equipment listed under Section 5.3 of this procedure.

To obtain soil samples using a hand auger, the following procedure shall be followed:

1. Attach a properly decontaminated bucket bit to a clean extension rod and further attach the cross handle to the extension rod.

2. Clear the area to be sampled of any surface debris (vegetation, twigs, rocks, litter, etc.).

3. Begin augering (periodically removing accumulated soils from the bucket bit) and add additional rod extensions as necessary. Also, note (in a field notebook or on standardized data sheets) any changes in the color, texture or odor of the soil.

4. After reaching the desired depth, slowly and carefully withdraw the apparatus from the borehole.

5. Remove the soiled bucket bit from the rod extension and replace it with another properly decontaminated bucket bit. The bucket bit used for sampling is commonly smaller in diameter than the bucket bit employed to initiate the borehole.

6. Carefully lower the apparatus down the borehole. Care must be taken to avoid scraping the borehole sides.

7. Slowly turn the apparatus until the bucket bit is advanced approximately 6 inches.

8. Discard the top of the core (approximately 1"), which represents any loose material collected by the bucket bit before penetrating the sample material.

9. Fill volatile sample container(s), using a properly decontaminated stainless steel trowel, with sample material directly from the bucket bit. Refer to Section 5.2.1 of this procedure.

10. Utilizing the above trowel, remove the remaining sample material from the bucket bit and place into a properly decontaminated stainless steel mixing bowl and thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.

11. Follow steps 4 and 5 listed under Section 5.3 of this procedure.

5.6 Subsurface Soil Sampling With a Split-Barrel Sampler (ASTM D1586-84)

Split-barrel (split-spoon) samplers consist of a heavy carbon steel or stainless steel sampling tube that can be split into two equal halves to reveal the soil sample (see Attachment A). A drive head is attached to the upper end of the tube and serves as a point of attachment for the drill rod. A removable tapered nosepiece/drive shoe attaches to the lower end of the tube and facilitates cutting. A basket-like sample retainer can be fitted to the lower end of the split tube to hold loose, dry soil samples in the tube when the sampler is removed from the drill hole. This split-barrel sampler is made to be attached to a drill rod and forced into the ground by means of a 140-lb. or larger casing driver.

Split-barrel samplers are used to collect soil samples from a wide variety of soil types and from depths greater than those attainable with other soil sampling equipment.

The following equipment is used for obtaining split-barrel samples:

- Drilling equipment (provided by subcontractor).
- Split-barrel samplers (O.D. 2 inches, I.D. 1-3/8 inches, either 20 inches or 26 inches long); Larger O.D. samplers are available if a larger volume of sample is needed.
- Drive weight assembly, 140-lb. weight, driving head and guide permitting free fall of 30 inches.
- Stainless steel mixing bowls.
- Plus equipment listed under Section 5.3 of this procedure.

The following steps shall be followed to obtain split-barrel samples:

1. Remove the drive head and nosepiece, and open the sampler to reveal the soil sample. Immediately scan the sample core with a real-time air monitoring instrument (e.g., OVA, HNu, etc.). Carefully separate the soil core, with a decontaminated stainless steel knife or trowel, at about 6-inch intervals while scanning the center of the core for elevated readings. Also scan stained soil, soil lenses, and anomalies (if present), and record readings.

2. Collect the volatile sample from the center of the core where elevated readings occurred. If no elevated readings where encountered the sample material should still be collected from the core's center (this area represents the least disturbed area with minimal atmospheric contact). Refer to Section 5.2.1 of this procedure.

3. Using the same trowel, remove remaining sample material from the split-barrel sampler (except for the small portion of disturbed soil usually found at the top of the core sample) and place the soil into a decontaminated stainless steel mixing bowl. Thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.

4. Follow steps 4 and 5 listed under Section 5.3 of this procedure.

5.7 Excavation and Sampling of Test Pits and Trenches

5.7.1 Applicability

This subsection presents routine test pit or trench excavation techniques and specialized techniques that are applicable under certain conditions.

During the excavation of trenches or pits at hazardous waste sites, several health and safety concerns arise which control the method of excavation. No personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person (as defined in 29 CFR 1929.650 of Subpart P - Excavations). Whenever possible, all required chemical and lithological samples should be collected using the excavator bucket or other remote sampling apparatus. If entrance is still required, all test pits or excavations must be stabilized by bracing the pit sides using specifically designed wooden or steel support structures. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments. Any entry may constitute a Confined Space and must be done in conformance with all applicable regulations. In these cases, substantial air monitoring is required before entry, and appropriate respiratory gear and protective clothing is mandatory. There must be at least two persons present at the immediate site before entry by one of the investigators. The reader shall

refer to OSHA regulations 29 CFR 1926, 29 CFR 1910.120, 29 CFR 1910.134, AND 29 CFR 1910.146.

Excavations are generally not practical where a depth of more than about 15 feet is desired, and they are usually limited to a few feet below the water table. In some cases, a pumping system may be required to control water levels within the pit, providing that pumped water can be adequately stored or disposed. If data on soils at depths greater than 15 feet are required, the data are usually obtained through test borings instead of test pits.

In addition, hazardous wastes may be brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled according to any and all applicable federal, state, and local regulations.

5.7.2 Test Pit and Trench Excavation

These procedures describe the methods for excavating and logging test pits and trenches excavated to determine subsurface soil and rock conditions. Test pit operations shall be logged and documented as described in SOP SA-6.3.

Test pits and trenches may be excavated by hand or by power equipment to permit detailed description of the nature and contamination of the in-situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration.
- The space required for efficient excavation.
- The chemicals of concern.
- The economics and efficiency of available equipment.

Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table, which is based on equipment efficiencies, gives a rough guide for design consideration:

Equipment	Typical Widths, in Feet
Trenching machine	2
Backhoe	2-6
Track dozer	10
Track loader	10
Excavator	10
Scraper	20

The lateral limits of excavation of trenches and the position of test pits shall be carefully marked on area base maps. If precise positioning is required to indicate the location of highly hazardous waste materials, nearby utilities, or dangerous conditions, the limits of the excavation shall be surveyed. Also, if precise determination of the depth of buried materials is needed for design or environmental assessment purposes, the elevation of the ground surface at the test pit or trench location shall also be determined by survey. If the test pit/trench will not be surveyed immediately,

it shall be backfilled and its position identified with stakes placed in the ground at the margin of the excavation for later surveying.

The construction of test pits and trenches shall be planned and designed in advance as much as possible. However, field conditions may necessitate revisions to the initial plans. The final depth and construction method shall be determined by the field geologist. The actual layout of each test pit, temporary staging area and spoils pile will be predicated based on site conditions and wind direction at the time the test pit is made. Prior to excavation, the area can be surveyed by magnetometer or metal detector to identify the presence of underground utilities or drums.

As mentioned previously, no personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person. If entrance is still required, Occupational Safety and Health Administration (OSHA) requirements must be met (e.g., walls must be braced with wooden or steel braces, ladders must be in the hole at all times, and a temporary guardrail must be placed along the surface of the hole before entry). It is emphasized that the project data needs should be structured such that required samples can be collected without requiring entrance into the excavation. For example, samples of leachate, groundwater, or sidewall soils can be taken with telescoping poles, etc.

Dewatering may be required to assure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep the excavation dry. This is an important consideration for excavations in cohesionless material below the groundwater table. Liquids removed as a result of dewatering operations must be handled as potentially contaminated materials. Procedures for the collection and disposal of such materials should be discussed in the site-specific project plans.

5.7.3 Sampling in Test Pits and Trenches

5.7.3.1 General

Test pits and trenches are usually logged as they are excavated. Records of each test pit/trench will be made as described in SOP SA-6.3. These records include plan and profile sketches of the test pit/trench showing materials encountered, their depth and distribution in the pit/trench, and sample locations. These records also include safety and sample screening information.

Entry of test pits by personnel is extremely dangerous, shall be avoided unless absolutely necessary, and can occur only after all applicable Health and Safety and OSHA requirements have been met.

The final depth and type of samples obtained from each test pit will be determined at the time the test pit is excavated. Sufficient samples are usually obtained and analyzed to quantify contaminant distribution as a function of depth for each test pit. Additional samples of each waste phase and any fluids encountered in each test pit may also be collected.

In some cases, samples of soil may be extracted from the test pit for reasons other than waste sampling and chemical analysis, for instance, to obtain geotechnical information. Such information would include soil types, stratigraphy, strength, etc., and could therefore entail the collection of disturbed (grab or bulk) or relatively undisturbed (hand-carved or pushed/driven) samples, which can be tested for geotechnical properties. The purposes of such explorations are very similar to those of shallow exploratory or test borings, but often test pits offer a faster, more cost-effective method of sampling than installing borings.

5.7.3.2 Sampling Equipment

The following equipment is needed for obtaining samples for chemical or geotechnical analysis from test pits and trenches:

- Backhoe or other excavating machinery.
- Shovels, picks and hand augers, stainless steel trowels.
- Sample container - bucket with locking lid for large samples; appropriate bottleware for chemical or geotechnical analysis samples.
- Polyethylene bags for enclosing sample containers; buckets.
- Remote sampler consisting of 10-foot sections of steel conduit (1-inch-diameter), hose clamps and right angle adapter for conduit (see Attachment B).

5.7.3.3 Sampling Methods

The methods discussed in this section refer to test pit sampling from grade level. If test pit entry is required, see Section 5.7.3.4.

- Excavate trench or pit in several depth increments. After each increment, the operator will wait while the sampler inspects the test pit from grade level to decide if conditions are appropriate for sampling. (Monitoring of volatiles by the SSO will also be used to evaluate the need for sampling.) Practical depth increments range from 2 to 4 feet.
- The backhoe operator, who will have the best view of the test pit, will immediately cease digging if:
- Any fluid phase or groundwater seepage is encountered in the test pit.
- Any drums, other potential waste containers, obstructions or utility lines are encountered.
- Distinct changes of material are encountered.

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. Depending upon the conditions encountered, it may be required to excavate more slowly and carefully with the backhoe.

For obtaining test pit samples from grade level, the following procedure shall be followed:

- Remove loose material to the greatest extent possible with backhoe.
- Secure walls of pit if necessary. (There is seldom any need to enter a pit or trench which would justify the expense of shoring the walls. All observations and samples should be taken from the ground surface.)
- Samples of the test pit material are to be obtained either directly from the backhoe bucket or from the material once it has been deposited on the ground. The sampler or Field Operations Leader directs the backhoe operator to remove material from the selected depth or location within the test pit/trench. The bucket is brought to the surface and moved away from the pit.

The sampler and/or SSO then approaches the bucket and monitors its contents with a photoionization or flame ionization detector. The sample is collected from the center of the bucket or pile and placed in sample containers using a decontaminated stainless steel trowel or spatula.

- If a composite sample is desired, several depths or locations within the pit/trench are selected and a bucket is filled from each area. It is preferable to send individual sample bottles filled from each bucket to the laboratory for compositing under the more controlled laboratory conditions. However, if compositing in the field is required, each sample container shall be filled from materials that have been transferred into a mixing bucket and homogenized. Note that homogenization/compositing is not applicable for samples to be subjected to volatile organic analysis.

- Using the remote sampler shown in Attachment B, samples can be taken at the desired depth from the side wall or bottom of the pit. The face of the pit/trench shall first be scraped (using a long-handled shovel or hoe) to remove the smeared zone that has contacted the backhoe bucket. The sample shall then be collected directly into the sample jar, by scraping with the jar edge, eliminating the need to utilize samplers and minimizing the likelihood of cross-contamination. The sample jar is then capped, removed from the assembly, and packaged for shipment.

- Complete documentation as described in SOP SA-6.3.

5.7.3.4 <u>In-Pit Sampling</u>

Under rare conditions, personnel may be required to enter the test pit/trench. This is necessary only when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., excessive mixing of soils or wastes within the test pit/trench) or when samples from relatively small discrete zones within the test pit are required. This approach may also be necessary to sample any seepage occurring at discrete levels or zones in the test pit that are not accessible with remote samplers.

In general, personnel shall sample and log pits and trenches from the ground surface, except as provided for by the following criteria:

- There is no practical alternative means of obtaining such data.

- The Site Safety Officer and Competent Person determines that such action can be accomplished without breaching site safety protocol. This determination will be based on actual monitoring of the pit/trench after it is dug (including, at a minimum, measurements of volatile organics, explosive gases and available oxygen).

- A Company-designated Competent Person determines that the pit/trench is stable or is made stable (by grading the sidewalls or using shoring) prior to entrance of any personnel. OSHA requirements must be strictly observed.

If these conditions are satisfied, one person will enter the pit/trench. On potentially hazardous waste sites, this individual will be dressed in safety gear as required by the conditions in the pit, usually Level B. He/she will be affixed to a safety rope and continuously monitored while in the pit.

A second individual will be fully dressed in protective clothing including a self-contained breathing device and on standby during all pit entry operations. The individual entering the pit will remain therein for as brief a period as practical, commensurate with performance of his/her work. After removing the smeared zone, samples shall be obtained with a decontaminated trowel or spoon. As an added precaution, it is advisable to keep the backhoe bucket in the test pit when personnel are working below grade. Such personnel can either stand in or near the bucket while performing sample operations. In the event of a cave-in they can either be lifted clear in the bucket, or at least climb up on the backhoe arm to reach safety.

5.7.3.5 Geotechnical Sampling

In addition to the equipment described in Section 5.7.3.2, the following equipment is needed for geotechnical sampling:

- Soil sampling equipment, similar to that used in shallow drilled boring (i.e., open tube samplers), which can be pushed or driven into the floor of the test pit.
- Suitable driving (i.e., a sledge hammer) or pushing (i.e., the backhoe bucket) equipment which is used to advance the sampler into the soil.
- Knives, spatulas, and other suitable devices for trimming hand-carved samples.
- Suitable containers (bags, jars, tubes, boxes, etc.), labels, wax, etc. for holding and safely transporting collected soil samples.
- Geotechnical equipment (pocket penetrometer, torvane, etc.) for field testing collected soil samples for classification and strength properties.

Disturbed grab or bulk geotechnical soil samples may be collected for most soils in the same manner as comparable soil samples for chemical analysis. These collected samples may be stored in jars or plastic-lined sacks (larger samples), which will preserve their moisture content. Smaller samples of this type are usually tested for their index properties to aid in soil identification and classification, while larger bulk samples are usually required to perform compaction tests.

Relatively undisturbed samples are usually extracted in cohesive soils using open tube samplers, and such samples are then tested in a geotechnical laboratory for their strength, permeability and/or compressibility. The techniques for extracting and preserving such samples are similar to those used in performing Shelby tube sampling in borings, except that the sampler is advanced by hand or backhoe, rather than by a drill rig. Also, the sampler may be extracted from the test pit by excavation around the sampler when it is difficult to pull it out of the ground. If this excavation requires entry of the test pit, the requirements described in Section 5.7.3.4 of this procedure must be followed. The open tube sampler shall be pushed or driven vertically into the floor or steps excavated in the test pit at the desired sampling elevations. Extracting tube samples horizontally from the walls of the test pit is not appropriate, because the sample will not have the correct orientation.

A sledge hammer or the backhoe may be used to drive or push the sampler or tube into the ground. Place a piece of wood over the top of the sampler or sampling tube to prevent damage during driving/pushing of the sample. Pushing the sampler with a constant thrust is always preferable to driving it with repeated blows, thus minimizing disturbance to the sample. If the sample cannot be extracted by rotating it at least two revolutions (to shear off the sample at the bottom), hand-excavate to remove the soil from around the sides of the sampler. If hand-

excavation requires entry of the test pit, the requirements in Section 5.7.3.4 of this procedure must be followed. Prepare, label, pack and transport the sample in the required manner, as described in SOP SA-6.3.

5.7.4 Backfilling of Trenches and Test Pits

All test pits and excavations must be either backfilled, covered, or otherwise protected at the end of each day. No excavations shall remain open during non working hours unless adequately covered or otherwise protected.

Before backfilling, the onsite crew shall photograph all significant features exposed by the test pit and trench and shall include in the photograph a scale to show dimensions. Photographs of test pits shall be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph shall be entered in the site logbook. All photographs shall be indexed and maintained as part of the project file for future reference.

After inspection, backfill material shall be returned to the pit under the direction of the FOL.

If a low permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared in a proportion specified by the FOL (representing a permeability equal to or less than original conditions). Backfill can be covered by "clean" soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

5.8 Records

The appropriate sample log sheet (see SOP SA-6.3; Field Documentation) must be completed by the site geologist/sampler. All soil sampling locations must be documented by tying in the location of two or more nearby permanent landmarks (building, telephone pole, fence, etc.) and shall be noted the appropriate sample log sheet, site map, or field notebook. Surveying may also be necessary, depending on the project requirements.

Test pit logs (see SOP SA-6.3; Field Documentation) shall contain a sketch of pit conditions. In addition, at least one photograph with a scale for comparison shall be taken of each pit. Included in the photograph shall be a card showing the test pit number. Boreholes, test pits and trenches shall be logged by the field geologist in accordance with SOP GH-1.5.

Other data to be recorded in the field logbook include the following:

- Name and location of job.
- Date of boring and excavation.
- Approximate surface elevation.
- Total depth of boring and excavation.
- Dimensions of pit.
- Method of sample acquisition.
- Type and size of samples.
- Soil and rock descriptions.
- Photographs.
- Groundwater levels.

- Organic gas or methane levels.
- Other pertinent information, such as waste material encountered.

6.0 REFERENCES

American Society for Testing and Materials, 1987. ASTM Standards D1587-83 and D1586-84. ASTM Annual Book of Standards. ASTM. Philadelphia, Pennsylvania. Volume 4.08.

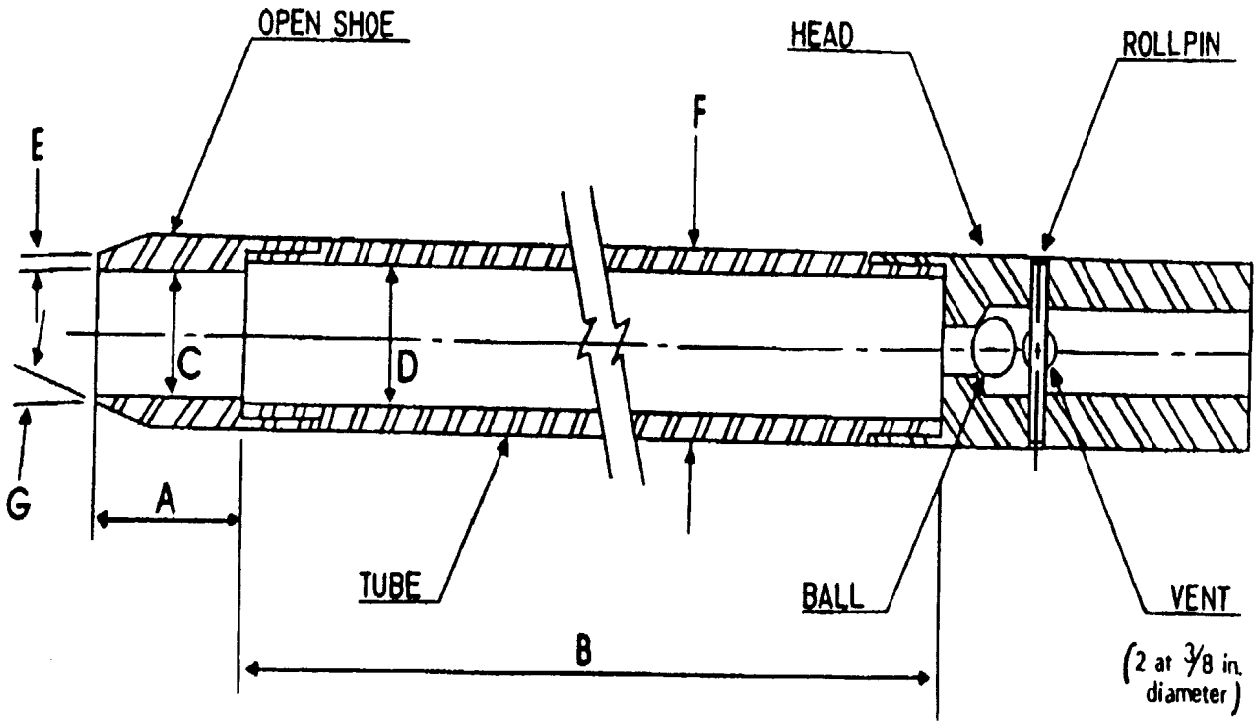
NUS Corporation, 1986. Hazardous Material Handling Training Manual.

NUS Corporation and CH2M Hill, August, 1987. Compendium of Field Operation Methods. Prepared for the U.S. EPA.

OSHA, Excavation, Trenching and Shoring 29 CFR 1926.650-653.

OSHA, Confined Space Entry 29 CFR 1910.146.

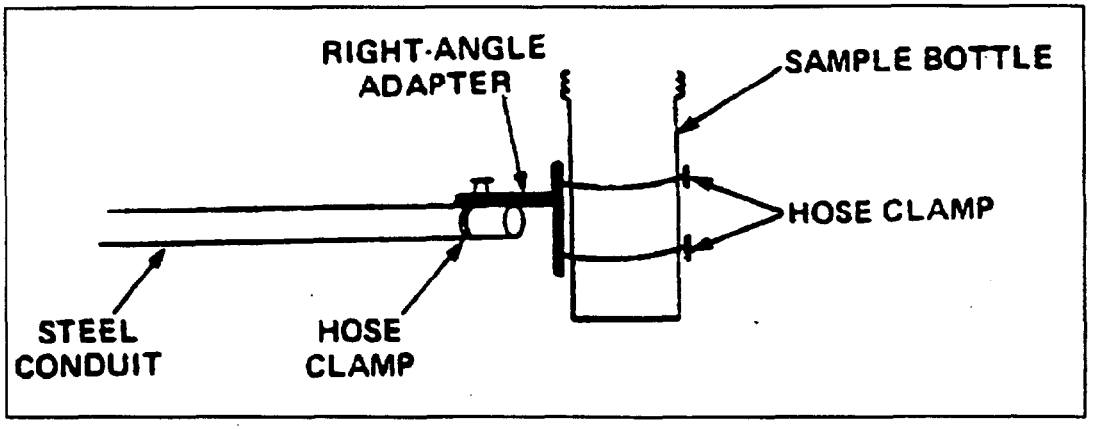
ATTACHMENT A
SPLIT-SPOON SAMPLER



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 – 0.00 in. (38.1 ± 1.3 – 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 – 0.00 in. (50.8 ± 1.3 – 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

ATTACHMENT B
REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING



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1.0 PURPOSE

The objective of this Standard Operating Procedure is to specify the proper approach and methodologies to identify and quantify airborne chemical contamination levels through the use of direct reading instrumentation and air sample collection. The results of these activities provide vital information for site characterization and risk assessment considerations.

2.0 SCOPE

Applies to all Brown & Root Environmental site activities where the potential for personnel exposures to respiratory health hazards exists.

3.0 GLOSSARY

Direct Reading Instruments (DRIs) - Instrumentation operating on various detection principles such as flame ionization or photoionization providing real time readings of ambient contaminants in air.

Personal/Area Air Sampling - Personal/area air sampling is conducted utilizing an air sampling pump and a specific collection media to quantify airborne contaminants.

Meteorological Considerations - Meteorological information must be collected on site to properly determine air sampling results, as well as aid in the characterization of contaminant potential plume migration and intensity. This information will also be used to support the selection of sampling locations and determine which samples should be analyzed. The meteorological information will be used to estimate downwind concentration levels based on short-term field levels encountered at the source.

4.0 RESPONSIBILITIES

Project Manager (PM) - Responsible for all aspects of project implementation and direction. The project manager is responsible for providing the necessary resources in support of all air monitoring and sampling applications.

Field Operations Leader (FOL) - Responsible for implementing the air monitoring program as detailed in approved project plans for the specific site. Air monitoring requirements will be included in both the Field Sampling and Analysis Plan (FSAP) and the site-specific Health and Safety Plan (HASP).

Health and Safety Officer (HSO) - The health and safety officer provides technical assistance to the FOL concerning air monitoring and sampling applications, collection methodologies, data interpretations, and establishes action items based on results. This information is further used to assess atmospheric migration of airborne chemical contaminants.

5.0 PROCEDURES

5.1 Introduction

Air monitoring is used to help establish criteria for worker safety, document potential exposures, and determine protective measures for the site personnel and the surrounding public. To accomplish this, it is necessary for an effective air surveillance program to be tailored to meet the conditions found at each work site.

During site operations, data are collected concerning air contaminants representative for site operations. Surveillance for vapors, gases, and particulates is performed using DRIs, air sampling systems, and meteorological considerations. DRIs can be used to detect many organics as well as a few inorganics and can provide approximate total concentrations through applications of relative response ratios of contaminants to reference standards. If specific chemicals (organics and inorganics) have been identified, then properly calibrated DRIs can be used for more accurate onsite assessments.

The most accurate method for evaluating any air contaminant is to collect samples and analyze them at a qualified laboratory. Although accurate, this method presents two disadvantages: (1) cost and (2) the time required to obtain results. Analyzing large numbers of laboratory samples can be expensive, especially if results are needed quickly. Onsite laboratories tend to reduce the turnaround time, but unless they can analyze other types of samples, they may also be costly. In emergencies, time is often not available for laboratory analysis of samples either on site or off site.

To obtain air monitoring data rapidly at the site, DRI utilizing flame ionization detectors (FIDs), photoionization detectors (PIDs), and other detection methodology can be used. Some of these may be used as survey instruments or operated as gas chromatographs. As gas chromatographs, these instruments can provide real-time, qualitative/quantitative data when calibrated with standards of known air contaminants. Combined with selective laboratory analysis of samples, they provide a tool for evaluating airborne organic hazards on a real-time basis and at a lower cost than analyzing samples in a laboratory.

5.2 Air Sampling

For more complete information about air contaminants, measurements obtained with DRIs can be supplemented by collecting and analyzing air samples. To assess air contaminants more thoroughly, air sampling devices equipped with appropriate collection media may be placed at various locations throughout the area and on persons within at-risk occupations. These samples provide air quality information for the period of time they are taken, and can indicate contaminant types and concentrations over the sampling period. As a result, careful selection of sampling types, numbers, and locations, by a qualified health and safety professional is essential to obtain representative information. As data is obtained (from the analysis of samples, DRIs, knowledge about materials involved, site operations, and the potential for airborne toxic hazards), adjustments can be in the types of samples, number of samples collected, frequency of sampling, and analysis required. In addition to air samplers, area monitoring stations may also include DRIs equipped with recorders and operated as continuous air monitors.

Area air sampling locations may be located as required by project and site needs in various places including, but not limited to:

- Upwind - Because many hazardous incidents occur near industries or highways that generate air pollutants, samples may be taken upwind of the site to establish background levels.

- Support Zone (SZ) - Samples may be taken near the command post or other support facilities to ensure that they are, in fact, located in an unaffected area, and that the area remains clean throughout operations at the site.

- Contamination Reduction Zone (CRZ) - Air samples may be collected along the decontamination line to ensure that decontamination workers are properly protected and that onsite workers are not removing their respiratory protective gear in a contaminated area.

- Exclusion Zone (EZ) - The Exclusion Zone presents the greatest risk of release/generation of contaminants and requires the highest concern for air sampling. The location of sampling stations shall be based upon factors such as hot-spots detected by DRIs, types of substances present, and potential for airborne contaminants. The data from these stations, in conjunction with intermittent walk-around surveys with DRIs, are used to verify the selection of proper levels of worker protection and EZ boundaries as well as to provide a continual record of air contaminants.

- Downwind - One or more sampling stations may be located downwind from the site to indicate if any air contaminants are leaving the site. If there are indications of airborne hazards in populated areas, appropriate response action must be taken and additional samplers should be placed downwind. Downwind locations are further determined based on meteorological considerations concerning generation, air plume migration, and intensity.

5.3 Media for Collecting Air Samples

Hazardous material incidents and abandoned waste sites can involve thousands of potentially dangerous substances, such as gases, vapors, and particulates that could become airborne. A variety of media are used to collect these substances. Sampling systems typically include a calibrated air sampling pump, which draws air into selected collection media. It is essential that appropriate, approved air sampling methodologies (such as those published by NIOSH, OSHA, and EPA) be followed for the collection of each specific analyte. Some of the most common types of samples and the collection media used for them are described in the following information:

One of the most common types of collection media is activated carbon which is an excellent adsorbent for most organic vapors. However, other solid adsorbents (such as Tenax, silica gel, and Florisil) are routinely used to sample specific organic compounds or classes of compounds that do not adsorb or desorb well on activated carbon. To avoid stocking a large number of sorbents for all substances anticipated, a smaller number is generally chosen for collecting the widest range of materials or for substances known to be present. The vapors are collected using an industrial hygiene personal sampling pump with either one sampling port or a manifold capable of simultaneously collecting samples on several sorbent tubes (provided that sampling parameters such as flow rates and sample volumes are satisfied). For example, in a manifold with four sorbent tubes (or on individual pumps with varying flow rates), the tubes might contain:

- Activated carbon to collect vapors of materials with a boiling point above zero degrees Centigrade. Common materials collected on activated carbon include organic vapors such as solvents, BTEX, and ketones.

- A porous polymer, such as Tenax or Chromosorb, to collect substances (such as high-molecular-weight hydrocarbons, organophosphorus compounds, and the vapors of certain pesticides) that adsorb poorly onto activated carbon. Some of these porous polymers also absorb organic materials at low ambient temperatures more efficiently than carbon.

- A polar sorbent, such as silica gel, to collect organic vapors (aromatic amines, for example) that exhibit a relatively high dipole moment.

- Another specialty absorbent selected for the specific site. For example, a Florisil tube could be used if polychlorinated biphenyls are expected.

- Liquid impingers - aldehydes, ketones, phosgene, phenols.

- Glass fiber filters, membrane filters, Teflon filters - Inorganics and other semivolatile compounds.

- Airborne particulates can be either solid or liquid. Examples of common particulate analytes include some metals, fibers such as asbestos, and condensed particulates such as welding fumes. Dusts, fumes, smoke, and fibers are dispersed solids; mists and fogs are dispersed liquids. For air sampling, most particulates are collected using glass fiber, mixed cellulose ester, or polyvinyl chloride filters, depending on the filter's ability to collect the subject material and its suitability for laboratory analysis. A cyclone is used to collect particles of respirable size. Atomic Absorption Spectrophotometry, Emission Spectroscopy, Phase Contrast Microscopy, and other techniques are used to analyze various types of particulates. Direct-reading monitors are also used to quantify particulate concentrations, and are usually based on the light-scattering properties of the particulate matter.

5.3.1 Other Methods

Colorimetric detector tubes can also be used with a sampling pump when monitoring for some specific compounds. Passive organic vapor monitors can be substituted for the active monitoring if they are available for the types of materials suspected to be present at a given site.

5.3.2 NIOSH Methods

The National Institute for Occupational Safety and Health's (NIOSH) Manual of Analytical Methods, 4th ed., contains acceptable methods for collecting and analyzing air samples for a variety of chemical substances. Consult these volumes for specific procedures.

5.4 Collection and Analysis

Collection and analysis of air samples is a multi-faceted task, and is part of the overall air surveillance program. The program is structured to cover the following air pathway analyses:

5.4.1 Selecting Monitoring Constituents

Applications within this program are accomplished using two considerations:

- Air surveillance for specific constituents is based on quantity of the pollutant and the likelihood for vapor release or generation.
- Controlling toxicity - These substances, even when represented in limited quantities, present the greatest threat to the public or worker safety, and influence environmental impact.

5.4.2 Specifying Meteorological Considerations

The following factors will influence sample collection:

- Wind direction and speed
- Sigma theta (atmospheric stability)
- Temperature
- Barometric pressure
- Humidity

These factors will provide information essential to properly arrive at accurate air sampling concentration results. This information is also used to identify how airborne chemical contaminants will react for modeling and for monitoring purposes. The results will provide indicators of plume movement, intensity, and dilution.

5.4.3 Design of Monitoring Network

The air surveillance network is structured to consider:

- Source characteristics (physical state; vapor release and/or generation; emission rates; and disturbance of the source impacting these aspects)
- Receptor sites (receptor sites are monitored and tracked based on priority)
- Meteorological consideration
- Air modeling input
- Data quality objectives

5.4.4 Air Monitoring Documentation/Data Reduction

5.4.4.1 Air Monitoring Documentation

Elements of the air surveillance program are used to provide documentation valuable to safely performing/containing site activities.

Air monitoring results from DRIs must be recorded, such as on instrument results reporting forms, or in the field logbook. This information, where applicable, will be correlated to air sampling information if/when collected.

Air sampling results for personnel and area measurement efforts must be validated, prior to notifying affected individuals. Personal air sampling results notification is accomplished through verbal or written communications.

Results of air monitoring/sampling activities can be identified on site maps. This information is used to structure operational zones and identify levels of protection.

5.4.4.2 Data Reduction

Data reduction combines and correlates the DRI results, air sampling results, and meteorological information to determine area and source airborne contaminant levels and movement.

All air sampling surveillance efforts must incorporate appropriate and approved NIOSH, OSHA, or EPA analytical methods. These procedures identify specific sample collection media, sampling methodologies, and analytical procedures. Sample analysis for health and safety considerations must be further supported by using American Industrial Hygiene Association accredited laboratories.

5.5 Personnel Monitoring

In addition to area atmospheric sampling, personnel monitoring -- both active and passive -- can be used to sample for air contaminants. Representative workers must be identified, and equipped with appropriate personal sampling systems to determine contaminants at specific locations or for specific work being performed. When sampling devices are placed on workers (generally within 1 foot of the mouth and nose) the results are used to indicate worker exposures.

5.6 Calibration

As a rule, the entire air sampling system shall be calibrated. Proper pre-and post-calibration activities are essential for correct operation and for accurate data. In some instances, additional calibration during the sampling period may be required. The overall frequency of calibration will depend upon the particular sampling event, including the general handling and use of a given sampling system. Pump mechanisms shall be calibrated after repair, when newly purchased, and following suspected abuse. All DRIs will be calibrated according to manufacturers instructions. All calibration activities for both air monitoring and sampling equipment must be properly documented, such as through the use of a calibration form. This form will be kept on site throughout the life of the project. The calibration log will be submitted as documentation that instrument calibration was performed on a regular basis.

5.7 Meteorological Considerations

Meteorological information is an integral part of an air surveillance program. Data concerning wind speed and direction, temperature, barometric pressure, and humidity (singularly or in combination) are needed for:

- Selecting air sampling locations
- Calculating accurate air sampling results
- Calculating air dispersion
- Calibrating instruments
- Determining population at risk or environmental exposure from airborne contaminants

Knowledge of wind speed and direction is necessary to effectively place air samplers. In source-oriented ambient air sampling, samplers need to be located downwind (at different distances) of the source and

others need to be placed to collect background samples. Shifts in wind direction must be known. Consequently, the samplers must be relocated or corrections made for these shifts. In addition, atmospheric simulation models for predicting contaminant dispersion and concentration need windspeed and direction as inputs for predictive calculations. Information may be needed concerning the frequency and intensity that winds blow from certain directions (windrose data). Consequently, the wind direction must be continually monitored when use of this type of data is contemplated.

Air sampling systems need to be calibrated before use. This must include corrections in the calibration curves for actual temperatures and pressures during the sampling event. After sampling, collected air volumes are also mathematically corrected for temperature and pressure conditions.

Air sampling is sometimes designed to assess population exposure (and frequently potential worker exposure). Air samplers are generally located in population centers, irrespective of wind direction. Even in these instances, however, meteorological data is needed for air dispersion modeling. Models are then used to predict or verify population-oriented sampling results.

Proper data is collected by having meteorological stations on site or by obtaining the information from one or more of several government or private organizations, which routinely collect this data. The choice of how information is obtained depends on the availability of reliable data at the location desired, resources needed to obtain meteorological equipment, accuracy of information needed, and use of information.

The collection, handling, and analysis of air samples is an intricate, involved process. Appropriate methodologies, media, and equipment must be used to collect accurate data. Furthermore, selection of appropriate numbers, types, and locations of samples is essential if the data collected are to be used for personnel exposure criteria. For these reasons, air sampling activities must be coordinated and conducted by properly qualified and experienced industrial hygiene professionals. Air monitoring activities also need to be established and monitored carefully. However, as the proper use of these instruments is not as complicated as air sampling, it is commonly acceptable to cross-train capable environmental professionals to use DRIs, with adequate technical support provided by health and safety professionals.

6.0 REFERENCES

Standard Operating Safety Guides, EPA, November 1984.
NIOSH Manual of Analytical Methods, 4th Edition.

7.0 ATTACHMENTS

None.

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1.0 PURPOSE

The purpose of this procedure is to present methodologies for surveying and sampling aquatic organisms at hazardous waste sites to determine potential impacts on organisms at higher trophic levels.

2.0 SCOPE

The methodologies presented in this procedure are appropriate for identifying aspects of aquatic ecological communities which suggest impact due to hazardous waste contamination; identifying potential trophic pathways and transport mechanisms for substances of public health concern; and providing useful input to evaluation of the feasibility and risks of remedial design alternatives. Not all of the methodologies presented herein are appropriate for all sites because of health and safety constraints which must be factored into all field sampling and analysis plans incorporating the methodologies included in this guideline.

3.0 GLOSSARY

Benthos - Organisms living on, in, or attached to the bottom of a water body.

Cladocera - Water fleas, a suborder within the class comprising an important food for fish.

Community - An assemblage of plant or animal species which appear to occur together or a given area.

Ecosystem - The biotic community and abiotic environment associated with a particular area.

Ichthyoplankton - Fish eggs and fish larvae sufficiently large to be captured by a 505-micron mesh plankton net.

Macrophytes - Essentially larger aquatic plants, or all plants except microscopic plants or algae.

Macrozooplankton - Larval and post larval animal plankton sufficiently large to be captured by a 505-micron mesh plankton net.

Periphyton - Organisms attached or clinging to submerged stems, leaves, rocks or other surfaces projecting above the substrate.

Plankton - Organisms which float with the current and generally lack swimming capability.

Trophic Pathway - A pattern of energy and material transfer from primary producers through successive levels of consumer organisms, and ultimately, to decomposers.

4.0 RESPONSIBILITIES

Site Manager - responsible for ensuring that a senior ecologist prepares, reviews, and oversees implementation of project-specific plans for projects where aquatic ecological inventorying and sampling are required, and that such plans conform to this procedure. The Site Manager is also responsible to assure that the plans are reviewed by the Health and Safety Officer for conformance with Health and Safety Guidelines.

5.0 PROCEDURES

5.1 PROGRAM DESIGN

The site-specific aquatic ecology field program is designed after the following tasks have been completed:

- Review and analysis of all available site-specific information.
- Review and understanding of program objectives.
- Review and understanding of the principles and procedures of each sampling and/or measurement method to be used (including review of specific equipment manuals).
- Consultation with the Site HSO (especially if there is a potential for sampling from a boat).

Program design will be dependent upon these factors and must be considered relevant to the type of environment being investigated (marine, estuarine, freshwater), in addition to program objectives. The sampling apparatus used for a specific project is dependent upon the type of environment since not all gear is applicable in all systems (e.g., electrofishing is ineffective in saline waters). Other considerations which may be relevant to sample survey design include:

- Emphasis on Indicator Species. Focusing the sampling effort on certain species may be of use as a quick aid to identifying stress in the environment. Additionally, observations of high incidences of pathological disorders in fish (e.g., fin rot) provides information on the probability of stress in a particular area.
- Collection of Specimens For Tissue Analysis. Chemical contaminants are often concentrated from one trophic level to the next, especially for fat soluble materials. Identification of the main food chains present in the study area will be useful in establishing which organisms to concentrate on relative to tissue analysis studies of bioaccumulation.
- Incorporation of Sampling. Concurrent sampling of biota and the physical/chemical environment (e.g., water quality) is important for interpreting presence/absence/ abundance data on species observed.
- Inclusion of Downstream (or Upstream) Sampling. Offsite sampling locations may be necessary to establish far field effects of contaminants, downgradients in species composition and recovery rates as contaminants are dispersed and diluted, or determine if differences between onsite and offsite biota are significant, and upgradient or similar but uncontaminated systems as controls.

- Tidal Fluctuations. Estuarine and marine environments experience tidal variations, and therefore require sampling in inter- and sub-tidal zones as well as during ebb and flood tides, to properly characterize the area. Inter-tidal zones possess unique species (spartina, mussels) which present trophic pathways to both aquatic and terrestrial organisms. These species should be considered for tissue analyses for evaluating environmental fate, effects, and risks.

- Stream and Lake Cross-sections. Depth and rate of flow vary, based on cross-section location.

The objectives of certain hazardous waste site ecological studies can be met with utilization of available information and qualitative methodologies comprising a General Field Survey. In these instances, program design can be accomplished by the field biologist with review by the senior project ecologist and the site HSO. At those sites where qualitative information or sample collection is deemed necessary, the field program should be designed with input from statistician. This is required not only to ensure usefulness of data collected, but also to optimize time spent in the field.

5.2 DATA RECORDING

Standard aquatic ecology field data sheets (Attachment A) should be used for General Field Surveys. These sheets should be pre-printed on weather resistant paper to ensure data preservation under adverse field conditions, and include (but not be limited to) the following:

- Brown & Root Environmental Project Number, Site Name and Location
- Date and Time
- Recorder (Investigator)
- Station Location
- Sample description and/or sample number as appropriate.
- Weather conditions
- Record of any photographs taken

5.3 PRE-FIELD INVESTIGATION ANALYSES

Prior to the field effort, all relevant available information should be reviewed. This phase is particularly important for hazardous waste site studies because typically employed field accessories such as binoculars or cameras are difficult to use in combination with personnel protection requirements (respirators, SCBA, etc.). At most sites, the quality and quantity of information obtained will be limited by the investigator's ability to identify aquatic organisms and habitat through a respirator mask and by stress incurred from working in protective clothing. Hence, there is a strong need to make maximum use of available information prior to field investigation. Pre-field investigation should include the following:

- Preliminary map depicting water bodies on site or contained within drainage area that require investigation.

- Access routes (paths, trails accommodating all terrain vehicles, etc.) as well as emergency egress routes and safety stations.

- Existing background information on the study area including aquatic organisms that may be found, with emphasis on species which may be indicative of existing stress or contaminant vectors, from a public health standpoint.

Sources of information to be sought and consulted include the following:

- Aerial photography.
- USGS topographic maps.
- Observations and photographs obtained by previous investigators (e.g., FIT team or site reconnaissance survey).
- State field biologists.
- Published literature on aquatic ecosystems occurring on or near the site.
- Navigational and river maps, if applicable.
- Published references on materials and methods (e.g., References 1 and 2 or this guideline).
- State or federal endangered species specialists where appropriate.

5.4 FIELD PREPARATIONS

Complete any field-related activities that can be performed prior to actual conduct of the field study--this includes pre-labeling of sample containers, pre-recording certain information on data sheets (e.g., site and date), and preparing any anticipated sample preservatives to proper strength.

5.5 GENERAL FIELD SURVEY

The General Field Survey should rely largely on observational data obtained by the field biologist, utilizing a standard data sheet (sample shown in Attachment A) developed for each site. In some instances simple techniques such as dip netting, which utilize disposable nets, can be employed to provide qualitative information on species present, or for obtaining specimens for tissue analysis.

5.6 DETAILED FIELD SURVEY

A Detailed Field Survey should be performed where more specific information (e.g., species abundance and bottom composition) is needed and where safety levels permit more intensive types of sampling. This type of survey would normally be performed only at Level D or C sites. Data typically obtained from this survey can include:

- Water Quality
  - pH
  - Dissolved oxygen
  - Temperature
  - Conductivity or salinity
  - Transparency
- Flow
- Average width and depth
- Circulation
- Tidal stage
- Bottom Composition - sieved samples

- Invertebrates - grab samples, drift nets
- Plankton (phyto, zoo, ichthyo) - nets, pumps
- Canopy - percent cover
- Fish - electrofishing; seining; set nets; gill nets

Data typically obtained from this survey are recorded on the data sheet in Attachment B.

Health and safety considerations are in all cases a major part of designing a detailed field survey. Health and safety implications of field sampling techniques must be considered, as well as health risks to laboratory personnel performing any subsequent analyses.

5.7 QUANTITATIVE STUDIES

Quantitative estimates of species abundance may be difficult to obtain at some sites, due to health risks of the repeated sampling required for statistically sound data. If after consideration of program objectives and site-specific health and safety conditions, a quantitative study is deemed necessary, a sampling and/or monitoring program can be designed. Frequency of sampling, as well as number of stations and samples per station, should be developed on the basis of statistical advice, the site ecologist's understanding of on-site conditions, and the Site HSO's review.

Data sheets similar to those employed for Detailed Field surveys should be used, (Attachment C) and lab sheets should be developed as appropriate.

5.8 SPECIFIC METHODS AND MATERIALS

The methods described below are standard and, where health and safety conditions permit, appropriate for use at hazardous waste sites.

5.8.1 Benthic Invertebrates

Benthic invertebrates live on or in the waterbody substrate. They can constitute an important component of food chains of fish species, and consequently may link sediment-contained pollutants with the human food chain. Benthic macroinvertebrate communities are often used as indicators of stress on aquatic composition and density is largely determined by substrate types and local environmental conditions.

Many methods have been employed for obtaining benthic samples. An ideal collection technique minimizes disturbance, minimizes time during which captured organisms can escape, and provides a defined volume. Sampling devices include hand-held corers, scoops, various grabs or dredges (Ponar, Peterson, Smith-McIntyre) the Surber sampler, and artificial monitoring substrates (e.g., Hester-Dendy Sampler). Major advantages and limitations are the following:

	Area Sampled	*Advantages*	*Limitations*
Peterson and Smith-McIntyre grabs	700 cm^2	Will work in sand or gravel	Requires boat; unwieldy and heavy
Scoops	Variable	Simple	Nonquantitative; may require hand immersion

	Area Sampled	*Advantages*	*Limitations*
Surber Sample	1,000 cm^2	Semi-quantitative sample for streams appropriate for variety of substrates	Shallow water device (best when water 2' deep); requires hand immersion
Ponar Grab	500 cm^2	Manageable, quantitative sample	Requires boat; limited to soft sediment
Artificial Substrate (e.g., Hester-Dendy Sampler)	Series of small plates or materials of fixed area	Does not require substrate extraction, simpler lab processing; quantitative estimate of species and individuals per area	Only samples the community which develops during sampling interval no measure of natural substrate
Hand Corer	Various, up to 10 cm diameter	Takes undisturbed, quantitative samples; easy to use and can be used in relatively coarse sediments	Cannot be used on hard substrates; unwieldy. Restricted to shallow water; may lose portion of sediment; requires hand immersion
Ponar Grab	500 cm^2	Manageable, quantitative sample	Requires boat; limited to soft sediment

Grab samples are usually washed through sieves in the field to prevent the loss of small animals which die and decay rapidly. Choice of sieve size is usually based on sediment grain size, but it also determines the type and size of animals retained. The most commonly used mesh size for final sieving is 0.5 mm. The material retained by the sieve is preserved in 10 percent buffered formalin and labeled for laboratory analyses. Artificial substrates are removed from the array, bagged and preserved in total for lab picking and identification.

5.8.2 Plankton

5.8.2.1 Zooplankton

Zooplankton form a major food source for larval and adult fish as well as larger invertebrates. As they are typically microscopic, sampling procedures involve use of a net to strain them from the water. Nets are usually towed behind a boat, and fitted with flow meters (which measure volume of water filtered) if quantitative samples are required.

General procedures are:

- If metered, record start count (volume).
- Tow for approximately 5 minutes at 1-2 feet per second.
- If metered, record end count (volume).
- Empty contents of bucket into labeled sample container.
- Add preservative.

Nets are rinsed by splashing water through the net from the outside to concentrate collected material in a sample bucket. Contents of the bucket are then emptied into labeled jars containing

5% buffered formalin. The mesh of the bucket should also be rinsed from the outside in to ensure all collected material is transferred to the sample jar. Fresh water plankton should be preserved with sucrose/4% buffered formalin in order to preserve the cladocerans in a more easily identifiable form.

The primary variables involved in program design are (a) mesh size, (b) length of tow, (c) net diameter, (d) depth of tow, and (e) time of tow (day or night). Mesh sizes for environmental studies are relatively standard (202 micron) as are length of tow (5-10 minutes with minimum volume of 100 m^3). Nets are usually 0.5- or 1-meter diameter. Oblique tows sample all water depths and provide data representative of the entire water column.

5.8.2.2 Ichthyoplankton and Macrozooplankton

Ichthyoplankton and macrozooplankton include drifting organisms, typically fish eggs, larvae, and invertebrates of a size sufficient to be captured by a 505-micron mesh plankton net of 0.5- or 1-meter diameter.

Large mesh (505-micron) plankton nets with large mouths (0.5-1 meter) are usually towed behind a boat, although they can be anchored in a current. In order to obtain comparable data for different times and locations, similar quantities of water need to be filtered. This is generally assured by using flow meters to measure the quantity of water passing through the nets. For density estimates, flow meters are mandatory.

Samples should be preserved with 10% formalin and placed in labeled vials. Sampling procedures are similar to those described for zooplankton.

5.8.2.3 Phytoplankton

Phytoplankton are aquatic plants that can occur as unicellular, colonial or filamentous forms. They are a primary food source for herbivorous zooplankton and fish. Typical sampling gear consists of either bottles (Kemerer, Van Dorn, Niskin or Nansen) or net sampling which is either towed through the water or water is pumped through. Nets can be used to selectively sample nanoplankton ($<60\ \mu m$) or microplankton ($<10\ \mu m$). Samples may be preserved with buffered formalin (40mL/100mL of sample) merthiolate (36ml/11 of sample) or 95% alcohol (50/50 mix of alcohol and sample).

5.8.3 Periphyton

Two standard procedures are available for documenting occurrence and estimating abundance of periphyton. If information on natural substrate is required, scrape periphyton off representative natural substrates such as rocks or logs, and place the collection in a sample vial with preservative. Sampling of natural substrates provides a more complete inventory of species occurrence and can be quantified by selecting replicate rocks from each station and scraping measured areas.

For situations where in-situ scraping may be precluded by health and safety constraints, or more rigorously quantifiable estimates of abundance may be required, artificial substrates can be employed. These usually consist of racks of microscope slides held on edge with the long axis parallel to the current. Such arrays are anchored in the water for periods of 1 to 3 months, depending on study objectives.

Substrates (either natural or artificial) are preserved in 3% to 5% buffered formalin. Each individual substrate is preserved in its own labeled vial. Substrates to be used for dry weight analysis do not have preservatives added. Vials should be of a size that will keep the slides from being scraped or bumped in transport.

5.8.4 Macrophytes

Macrophytes, (large aquatic plants) are important to any aquatic system as food, substrate for algae and invertebrates, and fish habitat. Mapping of large areas can be most efficiently done using aerial photographs. After delineation of macrophyte beds on the photographs, the areas should be verified in the field. Spatial extent of the beds can then be determined using a planimeter. For smaller sites, the beds can be surveyed in the field.

5.8.5 Fish

Fish comprise an obvious and important part of the food chain for human beings as well as for wildlife such as waterfowl. The principal methods for sampling fish at hazardous waste sites will probably be seines, electroshocking, and gill netting.

5.8.5.1 Seines

Seine nets vary in length from 8 to 2,000 feet and in depth from 4 to 200 feet. The smaller seines (haul seines) are most frequently used for biological sampling in shallow water. Haul seines usually have a pole at each end and are drawn through the water by two people. Use of anything larger than 20 feet by 4 feet is not expected to be needed or practical at hazardous waste sites.

Entire reaches of streams can be sampled with a seine. One end of the seine is pulled along one shore while the other end is pulled (usually in the direction against the current) in a parallel fashion along the opposite shore. After a predetermined distance one end of the seine is worked to the opposite shore and the two ends beached.

Seining can also be employed to sample the shallow zones along lake, estuary, or stream banks. The technique is much the same as that described above except that one end is worked near shore and the other in deeper water. The offshore end should be slightly ahead of the nearshore end forming a "J." After a standard distance (25 feet is frequently used) to ensure comparability of different hauls (i.e., similar volumes of water scooped), the seine is beached.

Once beached, all fish in the net should be identified, counted, and measured (total length). If appropriate, reference specimens should be retained.

Haul seines are limited to use in water no more than waist deep. A clear shore for beaching should be chosen in advance. While seining the bottom the lead line should never come off the bottom and the float line should never go under the water. Substrate obstructions allow fish to escape under the net. Soft substrates allow the lead line to dig into the bottom making sampling difficult. Haul seines are selective for small, less mobile, fish.

5.8.5.2 Electroshocking

Electrofishing is used in freshwater sampling and can provide specimens for obtaining data on species composition, relative abundance, size distribution, or tissue chemistry.

Electroshocking involves producing an electric field between two electrodes immersed and placed in a water well or bucket in the water. Any fish entering the field are stunned which causes them to be captured with dipnets. After sampling, the fish should be measured, weighed, and identified or preserved in labeled bottles.

There are essentially two types of electrofishing equipment: those using AC current and those using DC current. With DC current fish are attracted to the anode, facilitating recovery by the sampler. The field produced using AC current has a larger effective range, but fish may be lost in turbid or swift waters, since they will not be attracted to the electrode. In addition there is a greater chance of killing the fish using AC.

If electrofishing by boat, move downstream at slow speeds especially when sampling deep pools or runs. Sample all habitats including bank areas. One person operates the boat and equipment, while another collects stunned fish from the bow of the boat with a net. Efficiency may be increased by having a second boat follow the electrofishing boat, to net any fish out of reach of the first.

If electrofishing on foot, the sampler wades upstream, taking care to sample all habitats. A second person follows to help net, carry the catch, or carry the cathode.

The electric current generated by shocking equipment (particularly AC devices) can cause serious injury to the user if safety precautions are not rigorously followed. Before field use, the investigator should become thoroughly familiar with the equipment manufacturer's instructions. Only devices with automatic cut-off (dead-man) switches should be used. Electroshocking crews should comprise three people, two samplers and an observer. Crew members entering the water or positioned on a boat must wear rubber boots and gloves. At least one member of the crew should be trained in First Aid and CPR (Cardiopulmonary Resuscitation).

5.8.5.3 Gill Nets

Gill nets are used in marine, estuarine and freshwater environments where fish movement is expected. Experimental gill nets typically measure 40 meters in length and consist of a graded series of (five) 8-meter panels with mesh sizes ranging from 19 mm to 62 mm square. Nets are set for a prescribed period of time (i.e., 24 hours). Captured fish are identified, enumerated, measured and weighed. (For onsite work, these nets should be considered expendable.)

5.8.5.4 Trawling

Trawls are nets used for sampling large deep water bodies, which may be present adjacent to a hazardous waste site. There are three basic trawl types: Try (permanent opening), otter (for demersel species), and mid-water (for various depths). Trawls are towed behind a boat against the prevailing surface current at a consistent speed and duration. Winches and booms are generallly needed to deploy and retrieve the nets. When retrieved, the cod end is opened and captured fish are identified, enumerated, measured, and weighed.

5.9 EQUIPMENT DECONTAMINATION, MAINTENANCE, AND STORAGE

Proper decontamination, maintenance and storage procedures should be followed.

6.0 REFERENCES

American Public Health Association. 1981. Standard Methods, 15th Edition. American Public Health Association, Washington, D.C.

U.S. EPA, 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. (C.I. Wever, editor). U.S. EPA, Cincinnati, Ohio.

7.0 ATTACHMENTS

Attachment A - General Field Survey Data Sheets (3 Sheets)
Attachment B - Detailed Field Survey Data Sheet
Attachment C - Quantitative Study Data Sheets (2 sheets)

ATTACHMENT A
GENERAL FIELD SURVEY DATA SHEETS

WATERBODY NAME OR DESCRIPTION
HYDROLOGY

ID

SITE NUMBER	
ON SITE	
OFF SITE	

FLOW (cfs)

DRY BED	(0)	
LOW	(1)	
MOD	(10)	
HIGH	(100)	
TIDAL	-	
N/A	-	

DEPTH (in)

DRY BED	(0)	
LOW	(6)	
MOD	(24)	
HIGH	(48)	
N/A	-	

SIZE (W') (Ac)

DRY BED	(0)	(0)	
LOW	(4)	(1)	
MOD	(12)	(5)	
HIGH	(25)	(10)	

SOURCE

GROUND/SPRINGS	
PRECIPITATION	
TRIBUTARY	
STORM SEWER	
SITE DRAINAGE	

ATTACHMENT A
GENERAL FIELD SURVEY DATA SHEETS
PAGE TWO

WATERBODY NAME OR DESCRIPTION
WATERBODY

ID

SITE NUMBER
ON SITE
OFF SITE

MORPHOMETRY

CHANNELIZATION
POOLS
RIFFLES
CHUTES
MEANDERS

BANKS

EROSION/STABILITY
TREES
SHRUBS
GRASSES/WEEDS
MACROPHYTES

SUBSTRATE

CLAY
SILT/MUD
SAND
GRAVEL
COBBLE
RUBBLE

POLLUTION

COLOR/TURBID
DEBRIS/JUNK
OIL SLICKS
FOAM/SUDS
ODOR

ATTACHMENT A
GENERAL FIELD SURVEY DATA SHEETS
PAGE THREE

WATERBODY NAME OR DESCRIPTION
LAND USE

ID

SITE NUMBER
ON SITE
ADJ TO SITE

OBSERVED LAND USES
UNDEVELOPED
RURAL
AGRICULTURAL
PARK
RESIDENTIAL
COMMERCIAL
INDUSTRIAL
REFUSE
ABADONED

IMPACT
PRIMARILY PAST
SIGNIF CONT

PRESENT ECOL/FISH
NONE
LOW
HIGH

POTENTIAL ECOL/FISH
LOW
MOD
HIGH
COMMENT # (see sep sheet)
PHOTO #

PERIPHYTON
TYPE
PERCENT COVER

INVERTEBRATES
TYPES
R.A.

ATTACHMENT B

RECORD SHEET FOR DATA OBTAINED FROM DETAILED FIELD REVIEW

DETAILED FIELD SURVEY DATA SHEET

STREAM SURVEY FISH COLLECTION

County: T _____ R _____ Sec _____

STREAM Township _____

Point of Examination	Section No.	Description
GEAR USED--Kind	SMITH-ROOT TYPE VII ELECTROFISHER	
Area Covered		
Immediate SHORE		
TEMPERATURE--Air		Water
Weather (present and preceding)		
WATER (color, saltiness, etc.)		
AVERAGE WIDTH AND DEPTH	Current Velocity	
BOTTOM	pH	
COVER	D.O.	
VEGETATION	Cond.	
	secchi	
NATURAL FOOD		

REMARKS

DATE Time Field No.

COLLECTOR

No.	GAME FISHES	Length	Weight	No.	FORAGE FISHES	Length	Weight
	Brook Trout						
	Brown Trout						
	Rainbow Trout						
No.	COARSE FISHES	Length	Weight				

ATTACHMENT C

QUANTITATIVE STUDY DATA SHEETS

QUANTITATIVE STUDY DATA SHEET

__of__

Date:[ ][ ] / [ ][ ] / [ ][ ] Site:_____
mo day year

Station:[ ][ ][ ] Collectors:_____

Temperature: AIR (deg. C) [ ][ ][ ][.][ ] Vegetation:_____

WATER (deg. C) [ ][ ][ ][.][ ]

% Cover: [ ][ ][ ] Average Width and Depth:_____

Secchi:[ ][ ][ ][.][ ]

pH: [ ][ ][.][ ] Field Calibration: [ ]

D.O. (mg/l): [ ][ ][.][ ] Field Calibration: [ ]

Conductivity (umhos):[ ][ ][ ][.][ ]

****POOL****

Width (m) [ ][ ][.][ ] % Periphyton Cover [ ][ ][ ]

	REP 1	REP 2	REP 3
Depth (cm):	[ ][ ][ ][.][ ] /	[ ][ ][ ][.][ ] /	[ ][ ][ ][.][ ]
Velocity (ft./sec.)	[ ][ ][.][ ]	[ ][ ][.][ ]	[ ][ ][.][ ]
SIEVES (kg)			
4 in. +	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
No. 5	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
No. 10	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
No. 18	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
No. 200	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
Benthos Bot.	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]

****RIFFLE****

Width (m) [ ][ ][.][ ] % Periphyton Cover [ ][ ][ ]

	REP 1	REP 2	REP 3
Depth (cm):	[ ][ ][ ][.][ ] /	[ ][ ][ ][.][ ] /	[ ][ ][ ][.][ ]
Velocity (ft./sec.)	[ ][ ][.][ ]	[ ][ ][.][ ]	[ ][ ][.][ ]
SIEVES (kg)			
4 in. +	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
No. 5	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
No. 10	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
No. 18	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
No. 200	[ ][.][ ][ ]	[ ][.][ ][ ]	[ ][.][ ][ ]
Benthos Bot.	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]	[ ][ ][ ][ ][ ]

REMARKS:_____

Reviewer: _____

ATTACHMENT C
QUANTITATIVE STUDY DATA SHEETS
PAGE TWO

QUANTITATIVE STUDY DATA SHEET (Cont'd)

SITE: _____
DATE: _____
STATION: _____

__of__
Periphytometer Installation: ( )( ) / ( )( ) / ( )( )
Periphytometer Removal: ( )( ) / ( )( ) / ( )( )

FISHERIES PROGRAM

Gear Used: Smith-Root Type VII Electrofisher
Time (24 hour clock) START: ( )( )( )( ) END: ( )( )( )( )

Species	Length (cm)	Weight (gm)	Bottle Number →
( )( )( )( )( )	( )( )( )( )	( )( )( )	( )( )( )( )( )
( )( )( )( )( )	( )( )( )( )	( )( )( )	( )( )( )( )( )
( )( )( )( )( )	( )( )( )( )	( )( )( )	( )( )( )( )( )
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A GENERAL RECOMMENDED DECONTAMINATION AND CALIBRATION METHODS FOR BIOLOGICAL SAMPLING EQUIPMENT 5

1.0 PURPOSE

The purpose of this procedure is to describe standard methods for the calibration and maintenance (including decontamination and storage) of biological sampling equipment used at hazardous waste sites. The objectives are to minimize equipment malfunction in the field and the possibility of contamination of samples and personnel.

2.0 SCOPE

This procedure presents general methods for decontaminating, calibrating, maintaining and storing biological sampling equipment used at hazardous waste sites.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Manager - Will be responsible for ensuring that methods and facilities employed for the decontamination and onsite storage of biological sampling equipment are in compliance with this guideline.

Project Biologist - Responsible for ensuring that equipment is properly calibrated prior to field use.

Government Property Administrator - Responsible for ensuring that equipment is properly maintained when stored offsite.

5.0 PROCEDURES

Proper decontamination, calibration, and maintenance and storage for biological equipment is necessary to ensure the health and safety of personnel coming in contact with the equipment, and consistent results. The following sections describe standard procedures for these functions.

5.1 DECONTAMINATION OF BIOLOGICAL EQUIPMENT

Selection of proper decontamination procedures for sampling equipment depends on the ability of the equipment to withstand the various cleaning processes. Decontamination of equipment capable of withstanding steam cleaning, immersion and/or solvent rinses. Equipment unable to withstand such procedures will require special techniques, unless the equipment cannot withstand any decontamination or extended reuse, a topic which is treated. Recommended decontamination procedures for specific equipment are summarized in Attachment A.

5.1.1 General Methods

Water sampler and biological sampling devices are decontaminated prior to, and again subsequent to sampling events. Equipment leaving the site will also be decontaminated as called for in the Health and Safety Plan.

Grab sampler (substrate and water) can be decontaminated by steam cleaning at a steam cleaning pit, the location of which should be designated in the Health and Safety Plan (HASP). After steam

cleaning grab samplers (substrate and water) contaminated with certain residues may require soap scrubbing prior to final rinsing with solvents (regionally specific) and distilled deionized water.

Other types of equipment (and grab samplers, if a steam cleaner is not available onsite) should be thoroughly cleaned using the following sequence:

1. Potable water rinse
2. Alconox/Liquidnox detergent wash
3. Potable water rinse
4. 10 percent nitric acid solution rinse for suspected metals
5. Distillated deionized water rinse
6. Reagent grade rinse if analyzing for organics
7. Distilled deionized water rinse
8. Air dry
9. Wrap with aluminum foil (dull side towards equipment)

Personnel directly involved in equipment decontamination will wear proper protective clothing and respiratory equipment as specified in the Health and Safety Plan.

5.1.2 Equipment Requiring Special Methods

Equipment such as D.O. meters or the electronic parts of electroshockers cannot be steam cleaned or washed without damaging the units. During field use, equipment of this type should be contained in non-permeable materials (e.g., a plastic bag or sleeve) which is then removed and properly discarded.
Caution must be exercised when using equipment such as gasoline-powered electroshockers, which may overheat or malfunction when operated in an enclosing non-permeable material.

Components such as D.O.probes, that must come in contact with potentially contaminated materials, may be either decontaminated under general procedures, or discarded. The field biologist and Health and Safety Officer, after consulting the equipment manufacturer's manuals, must establish isolation and decontamination procedures prior to project startup. Equipment requiring isolation is indicated in Attachment A.

5.1.3 Equipment Requiring Disposal or Limited Use

Some equipment cannot be decontaminated or isolated due to construction material and/or size. This includes most sampling devices constructed of or containing netting material. The decontamination procedure for such devices is site dedication and ultimate disposal. Equipment of this type may either be disposed of after each sample or re-used onsite for the duration of the sampling program. Equipment requiring dedication, along with an acceptable duration of use, must be identified by the field biologist and Health and Safety Officer during program initiation. Types of equipment requiring dedication are indicated in Attachment A.

5.2 CALIBRATION

Most measuring devices require calibration to ensure accurate results. This may involve field calibration before each sampling event, as well as a periodic (annual) factory calibration by the manufacturer or certified technician.

Frequency of calibration, for both field and factory, are specific for brand and model due to variation in construction and precision. Specific field calibration procedures and recommended frequencies presented in the manufacturer's manual should be reviewed and implemented.

Typical frequencies of both field and factory calibrations are presented in Attachment A. Once a calibration schedule is established for each instrument, conformance to it should be documented by a calibration log maintained for each instrument.

5.3 MAINTENANCE AND STORAGE

Proper maintenance and storage of biological equipment will help to ensure consistent functioning during field sampling. All equipment returned from the field to the in-house storage facility should be thoroughly decontaminated according to the health and safety procedure for equipment used at hazardous waste sites. Specific maintenance and storage requirements for each piece of equipment are elaborated in the manufacturer's manual, and should be consulted at project startup to establish a maintenance and storage program. A log sheet should be kept to document equipment maintenance activities.

General maintenance checks should be performed on all sampling devices on a routine basis and should include, where appropriate, testing of seals on equipment suspected of leaking, and inspection for:

- Checks or deformities in seals
- Properly functioning springs
- Cracks in cases or meter windows
- Missing screws, bolts, parts
- Broken or frayed wires
- Condensation forming inside meters
- Rust or corrosion
- Integrity of electrical components

In general, equipment storage requires:

- Thoroughly rinsing and drying all equipment prior to storing
- Storing in dry areas (except electrodes)
- Disconnecting probes and installing dust caps
- Maintaining recommended storage temperatures
- Storing in a secure location to prevent damage or discourage vandalism

Store electrodes for short terms (1 to 6 months, depending on recommendations in manufacturer's manual) in beakers with appropriate solution. For long-term storage of electrodes, moisten and replace end caps, fill liquid-filled probes with electrolyte, and remove batteries.

6.0 REFERENCES

None.

7.0 ATTACHMENTS

Attachment A - General Recommended Decontamination and Calibration Procedures for Biological Sampling Equipment

ATTACHMENT A

GENERAL RECOMMENDED DECONTAMINATION AND CALIBRATION METHODS FOR BIOLOGICAL SAMPLING EQUIPMENT

Sampling Device	Decontamination Method	Calibration		
		Frequency		Method (Field)
		Factory	Field	
Kemmerer	Steam/Decon			
Van Dorn	Steam/Decon			
Nansen	Steam/Decon			
Ponar	Steam/Decon			
Smith-McIntyre	Steam/Decon			
Shipeck	Steam/Decon			
Hand Corer	Steam/Decon			
D.O. Meter		6 to 12 months	Daily	As per manual
Probe Meter	Wash & Rinse Isolation Bag			
pH Meter		6 to 12 months	Daily	Standard Buffer
Probe Meter	Wash & Rinse Isolation Bag			
SCT Meter		6 to 12 months		
Probe Meter	Wash & Rinse Isolation Bag			
Flow Meter	Wash & Rinse	6 months		
Balance	Wash & Rinse	6 months		
Electrofisher				
Battery-type Generator	Isolation Bag Locate out of "Hot Zone"	1 month 12 months		
Seine Net	Disposal			
Gill Net	Disposal			
Trawl				
Net	Disposal			
Doors	Steam			
Plankton				
Nets	Disposal			
Meters	Wash & Rinse	6 months		
Sieves	Steam			
Surlier	Disposal			
Boat	Steam			

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		Effective Date 03/01/96	Revision 0
		Applicability B&R Environmental, NE	
		Prepared Earth Sciences Department	
Subject NON-RADIOLOGICAL SAMPLE HANDLING		Approved D. Senovich	

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide information on sample preservation, packaging, and shipping procedures to be used in handling environmental samples submitted for chemical constituent, biological, or geotechnical analysis. Sample chain-of-custody procedures and other aspects of field documentation are addressed in SOP SA-6.3. Sample identification is addressed in SOP CT-04.

2.0 SCOPE

This procedure:

- Describes the appropriate containers to be used for samples depending on the analyses to be performed, and the steps necessary to preserve the samples when shipped off site for chemical analysis.
- Provides instruction for sample packaging and shipping in accordance with current U.S. Department of Transportation (DOT) regulations.

3.0 GLOSSARY

Hazardous Material - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. Under 49 CFR, the term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials, as well as materials designated as hazardous under the provisions of §172.101 and §172.102 and materials that meet the defining criteria for hazard classes and divisions in Part 173.

Hazardous Waste - Any substance listed in 40 CFR, Subpart D (~~y~~261.30 et seq.), or otherwise characterized as ignitable, corrosive, reactive, or toxic (as defined by Toxicity Characteristic Leaching Procedure, TCLP, analysis) as specified under 40 CFR, Subpart C (~~y~~261.20 et seq.), that would be subject to manifest requirements specified in 40 CFR 262. Such substances are defined and regulated by EPA.

Marking - A descriptive name, identification number, instructions, cautions, weight, specification or UN marks, or combination thereof required on outer packaging of hazardous materials.

n.o.i - Not otherwise indicated (may be used interchangeably with n.o.s.).

n.o.s. - Not otherwise specified.

ORM - Other regulated material (see DOT 49 CFR 173.144).

Packaging - A receptacle and any other components or materials necessary for compliance with the minimum packaging requirements of 49 CFR 174, including containers (other than freight containers or overpacks), portable tanks, cargo tanks, tank cars, and multi-unit tank-car tanks to perform a containment function in conformance with the minimum packaging requirements of 49 CFR 173.24(a) & (b).

Placard - Color-coded, pictorial sign which depicts the hazard class symbol and name and which is placed on the side of a vehicle transporting certain hazardous materials.

Common Preservatives:

- Hydrochloric Acid - HCl
- Sulfuric Acid - H_2SO_4
- Nitric Acid - HNO_3
- Sodium Hydroxide - NaOH

Other Preservatives

- Zinc Acetate
- Sodium Thiosulfate - $Na_2S_2O_3$

Normality (N) - Concentration of a solution expressed as equivalent per liter, an equivalent being the amount of a substance containing 1 gram-atom of replaceable hydrogen or its equivalent. Thus, a one-molar solution of HCl, containing 1 gram-atom of H, is "one normal," whereas a one-molar solution of H_2SO_4, containing 2 gram-atoms of H, is "two normal."

Reportable Quantity (RQ) - For the purposes of this SOP, means the quantity specified in column 3 of the Appendix to DOT 49 CFR §172.101 for any material identified in column 1 of the appendix. A spill greater than the amount specified must be reported to the National Response Center.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the location and time of collection.

4.0 RESPONSIBILITIES

Field Operations Leader - Directly responsible for the bottling, preservation, labeling, packaging, shipping, and custody of samples up to and including release to the shipper.

Field Samplers - Responsible for initiating the Chain-of-Custody Record (per SOP SA-6.3), implementing the packaging and shipping requirements, and maintaining custody of samples until they are relinquished to another custodian or to the common carrier.

5.0 PROCEDURES

Sample identification, labeling, documentation, and chain-of-custody are addressed by SOP SA-6.3.

5.1 Sample Containers

Different types of chemicals react differently with sample containers made of various materials. For example, trace metals adsorb more strongly to glass than to plastic, whereas many organic chemicals may dissolve various types of plastic containers. Attachments A and B show proper containers (as well as other information) per 40 CFR 136. In general, the sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample warms during transport. However, for collection of volatile organic compounds, head space shall be omitted. The analytical laboratory will generally provide certified-clean containers for samples to be analyzed for chemical constituents. Shelby tubes or other sample containers are generally provided by the driller for samples requiring geotechnical analysis. Sufficient lead time shall be allowed for a delivery of bottle orders. Therefore, it is critical to use the correct container to maintain the integrity of the sample prior to analysis.

Once opened, the container must be used at once for storage of a particular sample. Unused but opened containers are to be considered contaminated and must be discarded; because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or a missing Teflon liner (if required for the container), shall be discarded.

5.2 Sample Preservation

Many water and soil samples are unstable and therefore require preservation to prevent changes in either the concentration or the physical condition of the constituent(s) requiring analysis. Although complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that inevitably take place after the sample is collected. Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/ freezing (certain biological samples only).

5.2.1 Overview

The preservation techniques to be used for various analytes are listed in Attachments A and B. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or be added in the field (in a clean environment). Only high purity reagents shall be used for preservation. In general, aqueous samples of low-concentration organics (or soil samples of low- or medium-concentration organics) are cooled to 4°C. Medium-concentration aqueous samples and high-hazard organics samples are typically not preserved. Low-concentration aqueous samples for metals are acidified with HNO_3, whereas medium-concentration and high-hazard aqueous metal samples are not preserved. Low- or medium-concentration soil samples for metals are cooled to 4°C, whereas high-hazard samples are not preserved.

The following subsections describe the procedures for preparing and adding chemical preservatives. Attachments A and B indicate the specific analytes which require these preservatives.

5.2.2 Preparation and Addition of Reagents

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade or purer and shall be diluted to the required concentration with deionized water before field sampling commences. To avoid uncontrolled reactions, be sure to Add Acid to water (not vice versa). A dilutions guide is provided below.

Acid/Base	Dilution	Concentration	Estimated Amount Required for Preservation
Hydrochloric Acid (HCl)	1 part concentrated HCl: 1 part double-distilled, deionized water	6N	5-10 mL
Sulfuric Acid (H_2SO_4)	1 part concentrated H_2SO_4: 1 part double-distilled, deionized water	18N	2 - 5 mL
Nitric Acid (HNO_3)	Undiluted concentrated HNO_3	16N	2 - 5 mL
Sodium Hydroxide (NaOH)	400 grams solid NaOH dissolved in 870 mL double-distilled, deionized water; yields 1 liter of solution	10N	2 mL

The amounts required for preservation shown in the above table assumes proper preparation of the preservative and addition of the preservative to one liter of aqueous sample (assuming that the sample is initially at pH 7, is poorly buffered, and does not contain particulate matter; as these conditions vary, more preservative may be required). Consequently, the final sample pH must be checked using narrow-range pH paper, as described in the generalized procedure detailed below:

- Pour off 5-10 mL of sample into a dedicated, clean container. Use some of this sample to check the initial sample pH using wide range (0-14) pH paper. Never dip the pH paper into the sample; always apply a drop of sample to the pH paper using a clean stirring rod or pipette.

- Add about one-half of the estimated preservative required to the original sample bottle. Cap and invert gently several times to mix. Check pH (as described above) using medium range pH paper (pH 0-6 or pH 7.5-14, as applicable).

- Cap sample bottle and seal securely.

Additional considerations are discussed below:

- To test if ascorbic acid must be used to remove oxidizing agents present in the sample before it can be properly preserved, place a drop of sample on KI-starch paper. A blue color indicates the need for ascorbic acid addition.

  If required, add a few crystals of ascorbic acid to the sample and retest with the KI-starch paper. Repeat until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 grams of ascorbic acid per each liter of sample volume.

  Continue with proper base preservation of the sample as described, generally, above.

- Samples for sulfide analysis must be treated by the addition of 4 drops (0.2 mL) of 2N zinc acetate solution per 100 ml of sample.

  The 2N zinc acetate solution is made by dissolving 220 grams of zinc acetate in 870 mL of double-distilled, deionized water to make 1 liter of solution.

  The sample pH is then raised to 9 using the NaOH preservative.

- To test of sodium thiosulfate must be added to remove residual chlorine from a sample, test the sample for residual chlorine using a field test kit especially made for this purpose.

  If residual chlorine is present, add 0.08 grams of sodium thiosulfate per liter of sample to remove the residual chlorine.

  Continue with proper acidification of the sample as described, generally, above.

For biological samples, 10% buffered formalin or isopropanol may also be required for preservation. Questions regarding preservation requirements should be resolved through communication with the laboratory <u>before</u> sampling begins.

5.3 Field Filtration

At times, field-filtration may be required to provide for the analysis of dissolved chemical constituents. Field-filtration must be performed prior to the preservation of samples as described above. General procedures for field filtration are described below:

- The sample shall be filtered through a non-metallic, 0.45-micron membrane filter, immediately after collection. The filtration system shall consist of dedicated filter canister, dedicated silicon tubing, and a peristaltic pump with pressure or vacuum pumping squeeze action (since the sample is filtered by mechanical peristalsis, the sample travels only through the tubing).

- To perform filtration, thread the silicon tubing through the peristaltic pump head. Attach the filter canister to the discharge end of the silicon tubing (note flow direction arrow); attach the aqueous sample container to the intake end of the silicon tubing. Turn the peristaltic pump on and perform filtration.

- Continue by preserving the filtrate (contained in the filter canister), as applicable and generally described above.

5.4 Sample Packaging and Shipping

Samples collected for shipment from a site shall be classified as either environmental or hazardous material samples. Samples from drums containing materials other than Investigative Derived Waste (IDW) and samples obtained from waste piles or bulk storage tanks are generally shipped as hazardous materials. A distinction must be made between the two types of samples in order to:

- Determine appropriate procedures for transportation of samples (if there is any doubt, a sample shall be considered hazardous and shipped accordingly.)

- Protect the health and safety of transport and laboratory personnel receiving the samples (special precautions are used by the shipper and at laboratories when hazardous materials are received.)

Detailed procedures for packaging environmental and hazardous material samples are outlined in the remainder of this section.

5.4.1 Environmental Samples

Environmental samples are packaged as follows:

- Place sample container, properly identified and with lid securely fastened in a plastic bag (e.g. Ziploc baggie), and seal the bag.

- Place sample in a cooler constructed of sturdy material which has been lined with a large, plastic (e.g. "garbage" bag).

- Pack with enough noncombustible, absorbent, cushioning materials such as vermiculite (shoulders of bottles must be iced if required) to minimize the possibility of the container breaking.

- If cooling is required (see Attachments A and B), double-bag ice in Ziploc baggies and place around container shoulders, and on top of absorbent packing material (minimum of 8 pounds of ice for a medium-size cooler).

- Seal (i.e., tape or tie top in knot) large liner bag.

- The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment.

- Close and seal outside of cooler as described in SOP SA-6.3. Signed custody seals must be used.

Coolers must be marked as containing "Environmental Samples." The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling is required; there are no DOT restrictions on mode of transportation.

5.4.2 Determination of Shipping Classification for Hazardous Material Samples

Samples not determined to be environmental samples, or samples known or expected to contain hazardous materials, must be considered hazardous material samples and transported according to the requirements listed below.

5.4.2.1 Known Substances

If the substance in the sample is known or can be identified, package, mark, label, and ship according to the specific instructions for that material (if it is listed) in the DOT Hazardous Materials Table, 49 CFR 172.101. (DOT Guide for shippers can be found in Attachment D of this document.)

To determine the proper shipping name, use the following steps to help locate the shipping name on the Hazardous Materials Table, DOT 49 CFR 172.101.

1. Look first for the chemical or technical name of the material, for example, ethyl alcohol. Note that many chemicals have more than one technical name, for example, perchloroethylene (not listed in 172.101) is listed as tetrachloroethylene (listed 172.101). It may be useful to consult a chemist for all possible technical names a material can have. If your material is not listed by its technical name, then . . .

2. Look for the chemical family name. For example, pentyl alcohol is not listed but the chemical family name is: alcohol, n.o.s. (not otherwise specified). If the chemical family name is not listed, then . . .

3. Look for a generic name based on end use. For example, Paint, n.o.s or Fireworks, n.o.s. If a generic name based on end use is not listed, then . . .

4. Look for a generic family name based on end use, for example, drugs, n.o.s. or cosmetics, n.o.s. Finally, if your material is not listed by a generic family name but you suspect or know the material is hazardous because it meets the definition of one or more hazardous classes, then . . .

5. You will have to use the general hazard class for a proper shipping name. For example, Flammable Liquid, n.o.s, or Oxidizer, n.o.s.

5.4.2.2 Unknown Substances

For samples of hazardous substances of unknown content, select the appropriate transportation category according to the DOT hazardous materials classification of a material having more than one hazard. This procedure is outlined in DOT Regulation 49 CFR 173.2a. (This can be found in Attachment C of this SOP.)

The correct shipping classification for an unknown sample is selected through a process of elimination, as outlined in DOT Regulation 49 CFR 172.101(c)(11). By using the provisions in this paragraph, the proper shipping name and description will be determined. A step-by-step guide is provided by the Department of Transportation (DOT) and can be found in Attachment D of this SOP.

5.4.3 Packaging and Shipping of Samples Classified as Flammable Liquid (or Solid)

5.4.3.1 Packaging

Applying the word "flammable" to a sample does not imply that it is in fact flammable. The word prescribes the class of packaging according to DOT regulations.

1. Containerize sample as required (see Attachments A and B). To prevent leakage, fill container no more than 90 percent full. Seal lid with teflon tape or wire.

2. Complete sample label and attach securely to sample container.

3. Seal container and place in 2-mil-thick (or thicker) polyethylene bag (e.g., Ziploc baggie), one sample per bag. Position sample identification label so that it can be read through bag. Seal bag.

4. For soil jars, place sealed bag inside metal can (available from laboratory or laboratory supplier) and cushion it with enough noncombustible, absorbent material (for example, vermiculite or diatomaceous earth) between the bottom and sides of the can and bag to prevent breakage and absorb leakage. Pack one bag per can. Use clips, tape, or other positive means to hold can lid securely, tightly and permanently. Mark can as indicated in Paragraph 1 of Section 5.3.4.2, below. Single 1-gallon bottles do not need to be placed in metal cans.

5. Place one or more metal cans (or a single 1-gallon bottle) into a strong outside container, such as a metal picnic cooler or a DOT-approved fiberboard box. Surround cans (or bottle) with noncombustible, absorbent cushioning materials for stability during transport. The absorbent material should be able to absorb the entire contents of the container. Mark container as indicated in Paragraph 2 below.

5.4.3.2 Marking/Labeling

1. Use abbreviations only where specified. Place the following information, either hand-printed or in label form, on the metal can (or 1-gallon bottle):

   - Laboratory name and address.

- Proper shipping name from the hazardous materials table (DOT Regulation CFR 49 172.101). Example: "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325." This will include packing group (see Section 5.3.4.2, No. 2.)

Not otherwise specified (n.o.s) is not used if the flammable liquid (or solid) is identified. If identified, the name of the specific material is listed before the category (for example, Acetone, Flammable Liquid), followed by its appropriate UN number found in the DOT Hazardous Materials table (49 CFR 172.101).

2. Determine packing group. The packing group is part of the proper shipping name and must be included on the shipping papers in the description section.

   I. Most Hazardous
   II. Medium Hazard
   III. Least Hazardous

   The packing group will be listed in the hazardous materials table, column 5.

3. Place all information on outside shipping container as on can (or bottle), specifically:

   - Proper shipping name
   - UN or NA number
   - Proper label(s)
   - Addressee and sender

   Place the following labels on the outside shipping container: "Cargo Aircraft Only" and DOT label such as: "Flammable Liquid" (or "Flammable Solid"). "Dangerous When Wet" label shall be used if the Flammable Solid has not been exposed to a wet environment. "Laboratory Samples" and "THIS SIDE UP" or "THIS END UP" shall also be marked on the top of the outside container, and upward-pointing arrows shall be placed on all four sides of the container.

5.4.3.3 Shipping Papers

1. Use abbreviations only where specified. Complete the carrier-provided bill of lading and sign certification statement. Provide the following information in the order listed (one form may be used for more than one exterior container):

   - Proper shipping name. (Example: "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325 Packing Group I, II, III").
   - "Limited Quantity" (or "Ltd. Qty."). (See No. 3, below.)
   - "Cargo Aircraft Only."
   - Net weight (wt) or net volume (vol), just before or just after "Flammable Liquid, n.o.s." or "Flammable Solid, n.o.s.," by item, if more than one metal can is inside an exterior container.
   - "Laboratory Samples" (if applicable).

2. Include Chain-of-Custody Record, properly executed in outside container; use custody seals.

3. "Limited Quantity" means the maximum amount of a hazardous material for which there is a specific labeling or packaging exception (DOT CFR 49 171.8). This may mean that packages are exempted from labeling requirements. To determine if your sample meets the Limited Quantity Exception, refer to DOT Regulation CFR 49 Subpart C 173.50 through 173.156. First, determine the proper classification and shipping name for the material; then refer to the exception requirements for that particular class of material beginning with 173.50.

   Example: "Flammable Liquid n.o.s. UN1993 Packing Group 1." The outer package can weigh no more than 66 pounds gross weight. The inner package or container can weigh no more than 0.1 gallon net capacity for each container.

   To determine whether the material can be shipped as a "Limited Quantity," you must check the specific requirement for that class of material.

5.4.3.4 Transportation

1. The majority of unknown hazardous substance samples will be classified as flammable liquids. The samples will be transported by rented or common carrier truck, railroad, or express overnight package services. Do not transport samples on any passenger-carrying air transport system, even if the system has cargo-only aircraft. DOT regulations permit regular airline cargo-only aircraft, but difficulties with most suggest avoiding them. Instead, ship by airline carriers that carry only cargo. If unsure of what mode of transportation to use, consult the FOL or Project Manager.[1]

2. For transport by government-owned vehicle, including aircraft, DOT regulations do not apply. However, procedures described above, with the exception of execution of the bill of lading with certification, shall still be followed.

3. Use the hazardous materials shipping check list (Attachment E) as a guidance to ensure that all sample-handling requirements are satisfied.

4. In some cases, various materials may react if they break during shipment. To determine if you are shipping such materials, refer to the DOT compatibility chart in Attachment F.

5.5 Shipment of Lithium Batteries

Monitoring well data are analyzed using either the Hermit SE 1000 or the Hermit SE 2000 environmental data logger. These instruments are powered by lithium batteries. The Department of Transportation has determined that lithium batteries are a hazardous material and are to be shipped using the following information:

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[1] Note: If you are unsure as how to ship the sample (hazardous or environmental sample), contact the FOL or Project Manager so that a decision can be made as to the proper shipping practices. The DOT penalties for improper shipment of a hazardous material are stringent and may include a prison term for intentional violations.

- Product Designation
  - Hermit SE 1000
  - Hermit SE 2000

- DOT Proper Shipping Name
  - Lithium batteries, contained in equipment, UN3091

- Classification or Division
  - Class 9

Shipment of equipment containing lithium batteries must be accompanied by shipping papers completed as indicated in Attachment G. The instrument will be shipped by Federal Express as a Hazardous Material. Place the instrument in the same container in which it was received. This container or case is a DOT-approved shipping container. For Federal Express procedures to ship hazardous materials, call 1-800-238-5355, extension 922-1666. In most cases, the return shipping papers and DOT labels will be shipped to you from the company warehouse or the vendor. An example of the types of labels used for shipment and the wording are shown in Attachment G. These labels will be attached to the outside container with the following wording:

- Lithium Batteries Contained in Equipment
  - UN-3091
  - Shipped Under CA-9206009

6.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater, 15th Edition. APHA, Washington, D.C.

U.S. Department of Transportation, 1993. Hazardous Materials Regulations, 49 CFR 171-177.

U.S. EPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020, U.S. EPA-EMSL, Cincinnati, Ohio.

ATTACHMENT A

GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Sample Type and Concentration		Container[1]	Sample Size	Preservation[2]	Holding Time[2]
WATER					
Organics (GC&GC/MS)	VOC Low	Borosilicate glass	2 x 40 mL	Cool to 4°C HCl to ≤ 2	14 days[9]
	Extractables (Low SVOCs and pesticide/PCBs)	Amber glass	2x2 L or 4x1 L	Cool to 4°C	7 days to extraction; 40 days after extraction
	Extractables (Medium SVOCs and pesticide/PCBs)	Amber glass	2x2 L or 4x1 L	None	7 days to extraction; 40 days after extraction
Inorganics	Metals Low	High-density polyethylene	1 L	HNO_3 to pH ≤2	6 months (Hg-28 days)
	Medium	Wide-mouth glass	16 oz.	None	6 months
	Cyanide Low	High-density polyethylene	1 L	NaOH to pH>12	14 days
	Cyanide Medium	Wide-mouth glass	16 oz.	None	14 days
Organic/ Inorganic	High Hazard	Wide-mouth glass	8 oz.	None	14 days
SOIL					
Organics (GC&GC/MS)	VOC	Wide-mouth glass with teflon liner	2 x 4 oz.	Cool to 4°C	14 days
	Extractables (Low SVOCs and pesticides/PCBs)	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
	Extractables (Medium SVOCs and pesticides/PCBs)	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
Inorganics	Low/Medium	Wide-mouth glass	8 oz.	Cool to 4°C	6 months (Hg - 28 days) Cyanide (14 days)
Organic/ Inorganic	High Hazard	Wide-mouth glass	8 oz.	None	NA
Dioxin/Furan	All	Wide-mouth glass	4 oz.	None	7 days until extraction; 40 days after extraction
TCLP	All	Wide-mouth glass	8 oz.	None	7 days until preparation; analysis as per fraction
AIR					
Volatile Organics	Low/Medium	Charcoal tube – 7 cm long, 6 mm OD, 4 mm ID	100 L air	Cool to 4°C	5 days recommended

(1) All glass containers should have Teflon cap liners or septa.
(2) See Attachment E. Preservation and maximum holding time allowances per 40 CFR 136.

ATTACHMENT B

ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container(1)	Preservation(2)(3)	Maximum Holding Time(4)
INORGANIC TESTS:			
Acidity	P, G	Cool, 4°C	14 days
Alkalinity	P, G	Cool, 4°C	14 days
Ammonia - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Biochemical Oxygen Demand (BOD)	P, G	Cool, 4°C	48 hours
Bromide	P, G	None required	28 days
Chemical Oxygen Demand (COD)	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Chloride	P, G	None required	28 days
Chlorine, Total Residual	P, G	None required	Analyze immediately
Color	P, G	Cool, 4°C	48 hours
Cyanide, Total and Amenable to Chlorination	P, G	Cool, 4°C; NaOH to pH 12; 0.6 g ascorbic acid(5)	14 days(6)
Fluoride	P	None required	28 days
Hardness	P, G	HNO_3 to pH 2; H_2SO_4 to pH 2	6 months
Total Kjeldahl and Organic Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrate - Nitrogen	P, G	None required	48 hours
Nitrate-Nitrite - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrite - Nitrogen	P, G	Cool, 4°C	48 hours
Oil & Grease	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Total Organic Carbon (TOC)	P, G	Cool, 4°C; HCl or H_2SO_4 to pH 2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4°C	48 hours
Oxygen, Dissolved-Probe	G Bottle & top	None required	Analyze immediately
Oxygen, Dissolved-Winkler	G Bottle & top	Fix on site and store in dark	8 hours
Phenols	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Phosphorus, Total	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Residue, Total	P, G	Cool, 4°C	7 days
Residue, Filterable (TDS)	P, G	Cool, 4°C	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4°C	7 days
Residue, Settleable	P, G	Cool, 4°C	48 hours
Residue, Volatile (Ash Content)	P, G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days
Specific Conductance	P, G	Cool, 4°C	28 days
Sulfate	P, G	Cool, 4°C	28 days

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE TWO

Parameter Number/Name	Container[1]	Preservation[2][3]	Maximum Holding Time[4]
INORGANIC TESTS (Cont'd):			
Sulfide	P, G	Cool, 4°C; add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4°C	48 hours
METALS:[7]			
Chromium VI (Hexachrome)	P, G	Cool, 4°C	24 hours
Mercury (Hg)	P, G	HNO_3 to pH 2	28 days
Metals, except Chromium VI and Mercury	P, G	HNO_3 to pH 2	6 months
ORGANIC TESTS:[8]			
Purgeable Halocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$[5] HCl to pH 2 [9]	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$[5] adjust pH to 4-5 [10]	14 days
Phenols[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
Benzidines[11], [12]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction[13]
Phthalate esters[11]	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitrosamines[11], [14]	G, Teflon-lined cap	Cool, 4°C; store in dark; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
PCBs[11]	G, Teflon-lined cap	Cool, 4°C	7 days until extraction; 40 days after extraction
Nitroaromatics & Isophorone[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]; store in dark	7 days until extraction; 40 days after extraction
Polynuclear Aromatic Hydrocarbons (PAHs)[11],[14]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]; store in dark	7 days until extraction; 40 days after extraction
Haloethers[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
Dioxin/Furan (TCDD/TCDF)[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE THREE

Parameter Number/Name	Container(1)	Preservation(2)(3)	Maximum Holding Time(4)
RADIOLOGICAL TESTS:			
1-5 Alpha, beta and radium	P, G	HNO_3 to pH 2	6 months

(1) Polyethylene (P): generally 500 ml or Glass (G): generally 1L.
(2) Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.
(3) When any sample is to be shipped by common carrier or sent through the United States Mail, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172).
(4) Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for the longer periods, and has received a variance from the Regional Administrator.
(5) Should only be used in the presence of residual chlorine.
(6) Maximum holding time is 24 hours when sulfide is present. Optionally, all samples may be tested with lead acetate paper before pH adjustments are made to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.
(7) Samples should be filtered immediately on site before adding preservative for dissolved metals.
(8) Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.
(9) Sample receiving no pH adjustment must be analyzed within 7 days of sampling.
(10) The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.
(11) When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; samples preserved in this manner may be held for 7 days before extraction and for 40 days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re: the requirement for thiosulfate reduction of residual chlorine) and footnotes 12, 13 (re: the analysis of benzidine).
(12) If 1,2-diphenylthydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.
(13) Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.
(14) For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7-10 with NaOH within 24 hours of sampling.
(15) The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

ATTACHMENT C

DOT HAZARDOUS MATERIAL CLASSIFICATION
(49 CFR 173.2a)

1. Radioactive material (except a limited quantity)
2. Division 2.3, Poisonous Gases
3. Division 2.1, Flammable Gas
4. Division 2.2, Nonflammable gas
5. Division 6.1, Poisonous Liquids, Packing Group 1 (poison by inhalation only)
6. Division 4.2, Pyrophoric Material
7. Division 4.1, Self-Reactive Material
8. Class 3, Flammable Liquids*
9. Class 8, Corrosive Material
10. Division 4.1, Flammable Solid*
11. Division 4.2, Spontaneously Combustible Materials*
12. Division 4.3, Dangerous When Wet Materials*
13. Division 5.1, Oxidizers*
14. Division 6.1, Poisonous Liquids or Solids (other than Packing Group 1)*
15. Combustible liquid
16. Class 9, Miscellaneous Hazardous Materials

* If a material has or meets the criteria for more than one hazard class, use the precedence of hazardous table on the following page for Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1. The following table ranks those materials that meet the definition of Classes 3 and 8 and Divisions 4.1, 4.2, 4.3, 5.1, and 6.1.

ATTACHMENT C (Continued)

PRECEDENCE OF HAZARD TABLE

(Hazard Class and Packing Group)

Class	Packing Group	4.2	4.3	5.1 I[a]	5.1 II[a]	5.1 III[a]	6.1 I (Dermal)	6.1 I (Oral)	6.1 II	6.1 III	8 I (Liquid)	8 I (Solid)	8 II (Liquid)	8 II (Solid)	8 III (Liquid)	8 III (Solid)
3	I						3	3	3	3	3	[c]	3	[c]	3	[c]
3	II						3	3	3	3	8	[c]	3	[c]	3	[c]
3	III						6.1	6.1	6.1	3[d]	8	[c]	8	[c]	3	[c]
4.1	II[b]	4.2	4.3	5.1	4.1	4.1	6.1	6.1	4.1	4.1	[c]	8	[c]	4.1	[c]	4.1
4.1	III[b]	4.2	4.3	5.1	4.1	4.1	6.1	6.1	6.1	4.1	[c]	8	[c]	8	[c]	4.1
4.2	II		4.3	5.1	4.2	4.2	6.1	6.1	4.2	4.2	[c]	8	[c]	4.2	[c]	4.2
4.2	III		4.3	5.1	4.2	4.2	6.1	6.1	6.1	4.2	[c]	8	[c]	8	[c]	4.2
4.3	I			5.1	4.3	4.3	6.1	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
4.3	II			5.1	4.3	4.3	6.1	4.3	4.3	4.3	8	8	8	4.3	4.3	4.3
4.3	III			5.1	4.3	4.3	6.1	6.1	6.1	4.3	8	8	8	8	4.3	4.3
5.1	I[a]						5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
5.1	II[a]						6.1	5.1	5.1	5.1	8	8	8	5.1	5.1	5.1
5.1	III[a]						6.1	6.1	6.1	5.1	8	8	8	8	5.1	5.1
6.1	I, Dermal										8	6.1	6.1	6.1	6.1	6.1
6.1	I, Oral										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Inhalation										8	6.1	6.1	6.1	6.1	6.1
6.1	II, Dermal										8	6.1	8	6.1	6.1	6.1
6.1	II, Oral										8	8	8	6.1	6.1	6.1
6.1	III										8	8	8	8	8	8

(a) There are at present no established criteria for determining Packing Groups for liquids in Division 5.1. At present, the degree of hazard is to be assessed by analogy with listed substances, allocating the substances to Packing Group I, Great; Group II, Medium; or Group III, Minor Danger.
(b) Substances of Division 4.1 other than self-reactive substances.
(c) Denotes an impossible combination.
(d) For pesticides only, where a material has the hazards of Class 3, Packing Group III, and Division 6.1, Packing Group III, the primary hazard is Division 6.1, Packing Group III.

ATTACHMENT D

GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

USE OF GUIDE - This guide is presented as an aid to shippers of hazardous materials. It does not contain or refer to all of the DOT requirements for shipping hazardous materials. For specific details, refer to all of the DOT requirements for shipping hazardous materials, as provided in the Code of Federal Regulations (CFR), Title 49, Transportation, Parts 100-199.

The following is offered as a step-by-step procedure to aid in compliance with the applicable DOT regulations.

STEP 1 - DETERMINE THE PROPER SHIPPING NAME. The shipper must determine the proper shipping name of the materials as listed in the Hazardous Materials Table, 49 CFR 172.101, Column (2).

STEP 2 - DETERMINE THE HAZARD CLASS OR CLASSES.

a. Refer to the Table, 49 CFR 172.101, Column (3), and locate the hazard class of the material.
b. If more than one class is shown for the proper shipping name, determine the proper class by definition.
c. If the materials have more than one hazard, classify the material based on the order of hazards in 49 CFR 173.2.

STEP 3 - SELECT THE PROPER IDENTIFICATION NUMBERS.

a. Refer to the Table, 49 CFR 172.101, Column (3a), and select the Identification Number (ID) that corresponds to the proper shipping name and hazard class.
b. Enter the ID number(s) on the shipping papers and display them, as required, on packagings, placards and/or orange panels.

STEP 4 - DETERMINE THE MODE(S) OF TRANSPORT TO ULTIMATE DESTINATION.

a. As a shipper, you must assure yourself that the shipment complies with various modal requirements.
b. The modal requirements may affect the following: (1) Packaging; (2) Quantity per Package; (3) Marking; (4) Labeling; (5) Shipping Papers; and (6) Certification.

STEP 5 - SELECT THE PROPER LABEL(S) AND APPLY AS REQUIRED.

a. Refer to the Table, 49 CFR 172.101, Column (4) for required labels.
b. For details on labeling refer to (1) Additional Labels, 49 CFR 172.402; (2) Placement of Labels, 49 CFR 172.406; (3) Packagings (Mixed or Consolidated), 49 CFR 172.404(a) and (h); (4) Packages Containing Samples, 49 CFR 172.402(h); (5) Radioactive Materials, 49 CFR 172.403; and (6) Authorized Label Modifications, 49 CFR 172.405.

STEP 6 - DETERMINE AND SELECT THE PROPER PACKAGES.

a. Refer to the Table, 49 CFR 172.101, Column (5a) for exceptions and Column (5b) for specification packagings. Consider the following when selecting an authorized package: Quantity per Package; Cushioning Material, if required; Proper Closure and Reinforcement; Proper Pressure; Outage; etc., as required.
b. If packaged by a prior shipper, make sure the packaging is correct and in proper condition for transportation.

ATTACHMENT D (Continued)
GUIDE FOR HAZARDOUS MATERIALS SHIPPERS

STEP 7 - MARK THE PACKAGING (INCLUDING OVERPACKS).

a. Apply the required markings (49 CFR 172.300); Proper shipping name and ID number, when required (49 CFR 172.301); Name and address of Consignee or Consignor (49 CFR 172.306).
b. For details and other required markings, see 49 CFR 172.300 through 172.338.

STEP 8 - PREPARE THE SHIPPING PAPERS.

a. The basic requirements for preparing shipping papers include Proper Shipping Name; Hazard Class; ID Number; Total Quantity; Shipper's Certification; and Emergency Response Telephone Number.
b. Make all entries on the shipping papers using the information required and in proper sequence (49 CFR 172.202).

STEP 9 - CERTIFICATION.

a. Each shipper must certify by printing (manually or mechanically) on the shipping papers that the materials being offered for shipment are properly classified, described, packaged, marked and labeled, and in proper condition for transportation according to the applicable DOT Regulations (49 CFR 172.202).

STEP 10 - LOADING, BLOCKING, AND BRACING. When hazardous materials are loaded into the transport vehicle or freight container, each package must be loaded, blocked, and braced in accordance with the requirements for mode of transport.

a. If the shipper loads the freight container or transport vehicle, the shipper is responsible for the proper loading, blocking, and bracing of the materials.
b. If the carrier does the loading, the carrier is responsible.

STEP 11 - DETERMINE THE PROPER PLACARD(S). Each person who offers hazardous materials for transportation must determine that the placarding requirements have been met.

a. For Highway, unless the vehicle is already correctly placarded, the shipper must provide the required placard(s) and required ID number(s) (49 CFR 172.506).
b. For Rail, if loaded by the shipper, the shipper must placard the rail car if placards are required (49 CFR 172.508).
c. For Air and Water shipments, the shipper has the responsibility to apply the proper placards.

STEP 12 - HAZARDOUS WASTE/HAZARDOUS SUBSTANCE.

a. If the material is classed as a hazardous waste or hazardous substance, most of the above steps will be applicable.
b. Pertinent Environmental Protection Agency regulations are found in the Code of Federal Regulations, Title 40, Part 262.

As a final check and before offering the shipment for transportation, visually inspect your shipment. The shipper should ensure that emergency response information is on the vehicle for transportation of hazardous materials.

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Revised March 1995.

ATTACHMENT E

HAZARDOUS MATERIALS SHIPPING CHECK LIST

PACKAGING

1. Check DOT 173.24 for appropriate type of package for hazardous substance.
2. Check for container integrity, especially the closure.
3. Check for sufficient absorbent material in package.
4. Check for sample tags and log sheets for each sample and for chain-of-custody record.

SHIPPING PAPERS

1. Check that entries contain only approved DOT abbreviations.
2. Check that entries are in English.
3. Check that hazardous material entries are specially marked to differentiate them from any nonhazardous materials being sent using same shipping paper.
4. Be careful that all hazardous classes are shown for multiclass materials.
5. Check total amounts by weight, quantity, or other measures used.
6. Check that any limited-quantity exemptions are so designated on the shipping paper.
7. Check that certification is signed by shipper.
8. Make certain driver signs for shipment.

RCRA MANIFEST

1. Check that approved state/federal manifests are prepared.
2. Check that transporter has the following: valid EPA identification number, valid driver's license, valid vehicle registration, insurance protection, and proper DOT labels for materials being shipped.
3. Check that destination address is correct.
4. Check that driver knows where shipment is going.
5. Check that the driver is aware of emergency procedures for spills and accidents.
6. Make certain driver signs for shipment.
7. Make certain one copy of executed manifest and shipping document is retained by shipper.

ATTACHMENT F

DOT SEGREGATION AND SEPARATION CHART

Class or Division	Notes	1.1-1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3 gas Zone A*	2.3 gas Zone B*	3	4.1	4.2	4.3	5.1	5.2	6.1 liquids PG-I Zone A*	7	8 liquids only
Explosives ..... 1.1 and 1.2	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Explosives 1.3		*	*	*	*	*	X		X	X	X		X	X	X	X	X		X
Explosives 1.4		*	*	*	*	*	O		O	O	O		O				O		O
Very insensitive explosives 1.5	A	*	*	*	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X
Extremely insensitive explosives 1.6		*	*	*	*	*													
Flammable gases 2.1		X	X	O	X				X	O							O	O	
Non-toxic, non-flammable gases 2.2		X			X														
Poisonous gas - Zone A** 2.3		X	X	O	X		X				X	X	X	X	X	X			X
Poisonous gas - Zone B** 2.3		X	X	O	X		O				O	O	O	O	O	O			O
Flammable liquids 3		X	X	O	X				X	O					O		X		
Flammable solids 4.1		X			X				X	O							X		O
Spontaneously combustible materials 4.2		X	X	O	X				X	O							X		X
Dangerous-when-wet materials 4.3		X	X		X				X	O							X		O
Oxidizers 5.1	A	X	X		X				X	O	O						X		O
Organic peroxides 5.2		X	X		X				X	O							X		O
Poisonous liquids PG I - Zone A** .. 6.1		X	X	O	X		O				X	X	X	X	X	X			X
Radioactive materials 7		X			X		O												
Corrosive liquids 8		X	X	O	X				X	O		O	X	O	O	O	X		

No entry means that the materials are compatible (have no restrictions).

X These materials may not be loaded, transported, or stored together in the same vehicle or facility.
O The materials may not be loaded, transported, or stored together in the same vehicle or facility unless they are separated for 4 feet on all sides.
* Check the explosives compatibility chart in 49 CFR 179.848(f).
A Ammonium nitrate fertilizers may be stored with Division 1.1 materials.
** Denotes inhalation hazardous for poisons; consult field team leader or project manager if you encounter a material in this class before shipment.

ATTACHMENT G
LITHIUM BATTERY SHIPPING PAPERS

3224637861

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: *(delete non applicable)*

[illegible] | CARGO AIRCRAFT ONLY

Airport of Departure:

Airport of Destination: 19CYS

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

Shipment type: *(delete non-applicable)*

NON-RADIOACTIVE | [illegible]

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification						
Proper Shipping Name	Class or Division	UN or ID No.	Subsidiary Risk	Quantity and type of packing	Packing Inst.	Authorization
LITHIUM BATTERIES CONTAINED IN EQUIPMENT	9	UN3091		1 PLASTIC BOX X 55 GRAMS	912 II	PER CA-9206009

Additional Handling Information

1 HERMIT SERIES DATALOGGER X 55 GRAMS (11 GRAMS/CELL)

I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and are in all respects in the proper condition for transport by air according to the applicable International and National Government Regulations.

Name/Title of Signatory

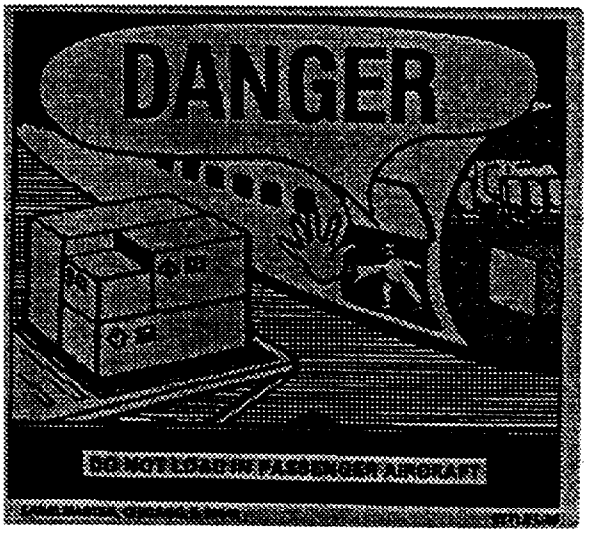
Place and Date

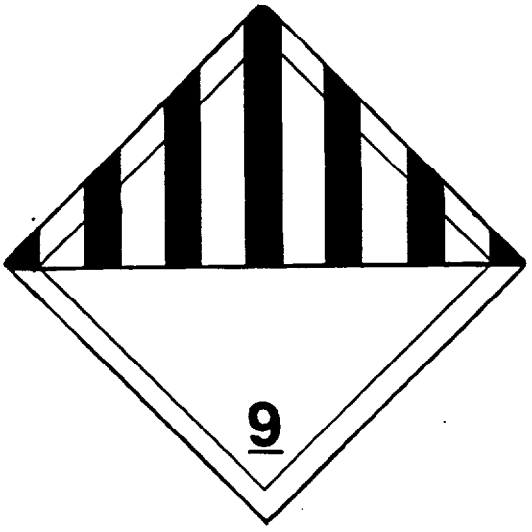
Signature *(see warning above)*

Emergency Telephone Number (Required for US Origin or Destination Shipments)
800-535-5053

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

ATTACHMENT G (CONTINUED)
LITHIUM BATTERY SHIPPING PAPERS





LITHIUM BATTERIES CONTAINED IN EQUIPMENT.
UN-3091.
SHIPPED UNDER CA-9206009

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to identify and designate the field data record forms, logs and reports generally initiated and maintained for documenting Brown & Root Environmental field activities.

2.0 SCOPE

Documents presented within this procedure (or equivalents) shall be used for all Brown & Root Environmental field activities, as applicable. Other or additional documents may be required by specific client contracts.

3.0 GLOSSARY

None

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for obtaining hardbound, controlled-distribution logbooks (from the appropriate source), as needed. In addition, the Project Manager is responsible for placing all forms used in site activities (i.e., records, field reports, and upon the completion of field work, the site logbook) in the project's central file.

Field Operations Leader (FOL) - The Field Operations Leader is responsible for ensuring that the site logbook, notebooks, and all appropriate forms and field reports illustrated in this guideline (and any additional forms required by the contract) are correctly used, accurately filled out, and completed in the required time-frame.

5.0 PROCEDURES

5.1 Site Logbook

5.1.1 General

The site logbook is a hard-bound, paginated controlled-distribution record book in which all major onsite activities are documented. At a minimum, the following activities/events shall be recorded (daily) in the site logbook:

- All field personnel present
- Arrival/departure of site visitors
- Arrival/departure of equipment
- Start or completion of borehole/trench/monitoring well installation or sampling activities
- Daily onsite activities performed each day
- Sample pickup information
- Health and Safety issues (level of protection observed, etc.)
- Weather conditions

A site logbook shall be maintained for each project. The site logbook shall be initiated at the start of the first onsite activity (e.g., site visit or initial reconnaissance survey). Entries are to be made for every day that onsite activities take place which involve Brown & Root Environmental or subcontractor personnel. Upon completion of the fieldwork, the site logbook must become part of the project's central file.

The following information must be recorded on the cover of each site logbook:

- Project name
- Brown & Root Environmental project number
- Sequential book number
- Start date
- End date

Information recorded daily in the site logbook need not be duplicated in other field notebooks (see Section 5.2), but must summarize the contents of these other notebooks and refer to specific page locations in these notebooks for detailed information (where applicable). An example of a typical site logbook entry is shown in Attachment A.

If measurements are made at any location, the measurements and equipment used must either be recorded in the site logbook or reference must be made to the site notebook in which the measurements are recorded (see Attachment A).

All logbook, notebook, and log sheet entries shall be made in indelible ink (black pen is preferred). No erasures are permitted. If an incorrect entry is made, the data shall be crossed out with a single strike mark, and initialed and dated. At the completion of entries by any individual, the logbook pages used must be signed and dated. The site logbook must also be signed by the Field Operations Leader at the end of each day.

5.1.2 Photographs

When movies, slides, or photographs are taken of a site or any monitoring location, they must be numbered sequentially to correspond to logbook entries. The name of the photographer, date, time, site location, site description, and weather conditions must be entered in the logbook as the photographs are taken. A series entry may be used for rapid-sequence photographs. The photographer is not required to record the aperture settings and shutter speeds for photographs taken within the normal automatic exposure range. However, special lenses, films, filters, and other image-enhancement techniques must be noted in the logbook. If possible, such techniques shall be avoided, since they can adversely affect the admissibility of photographs as evidence. Chain-of-custody procedures depend upon the subject matter, type of film, and the processing it requires. Film used for aerial photography, confidential information, or criminal investigation require chain-of-custody procedures. Adequate logbook notation and receipts must be compiled to account for routine film processing. Once processed, the slides of photographic prints shall be consecutively numbered and labeled according to the logbook descriptions. The site photographs and associated negatives must be docketed into the project's central file.

5.2 Site Notebooks

Key field team personnel may maintain a separate dedicated notebook to document the pertinent field activities conducted directly under their supervision. For example, on large projects with multiple investigative sites and varying operating conditions, the Health and Safety Officer may elect to maintain a separate site notebook. Where several drill rigs are in operation simultaneously, each site geologist assigned to oversee a rig must maintain a site notebook.

5.3 Sample Forms

A summary of the forms illustrated in this procedure is shown as the listing of Attachments in the Table of Contents for this SOP. Forms may be altered or revised for project-specific needs contingent upon client approval. Care must be taken to ensure that all essential information can be documented. Guidelines for completing these forms can be found in the related sampling SOP.

5.3.1 Sample Collection, Labeling, Shipment and Request for Analysis

5.3.1.1 Sample Log Sheet

Sample Log Sheets are used to record specified types of data while sampling. Attachments B-1 to B-4 are examples of Sample Log Sheets. The data recorded on these sheets are useful in describing the waste source and sample as well as pointing out any problems encountered during sampling. A log sheet must be completed for each sample obtained, including field quality control (QC) samples.

5.3.1.2 Sample Label

A typical sample label is illustrated in Attachment B-5. Adhesive labels must be completed and applied to every sample container. Sample labels can usually be obtained from the appropriate Program source or are supplied from the laboratory subcontractor.

5.3.1.3 Chain-of-Custody Record Form

The Chain-of-Custody (COC) Record is a multi-part form that is initiated as samples are acquired and accompanies a sample (or group of samples) as they are transferred from person to person. This form must be used for any samples collected for chemical or geotechnical analysis whether the analyses are performed on site or off site. One part of the completed COC form is retained by the field crew while the other two or three portions are sent to the laboratory. The original (top, signed copy) and extra carbonless copies of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment. An example of a Chain-of-Custody Record form is provided as Attachment B-6. A supply of these forms are purchased and stocked by the field department of the various Brown & Root Environmental offices. Alternately, COC forms supplied by the laboratory may be used. Once the samples are received at the laboratory, the sample cooler and contents are checked and any problems are noted on the enclosed COC form (any discrepancies between the sample labels and COC form and any other problems that are noted are resolved through communication between the laboratory point-of-contact and the Brown & Root Environmental Project Manager). The COC form is signed and one of the remaining two parts are retained by the laboratory while the last part becomes part of the samples' corresponding analytical data package. Internal laboratory chain-of-custody procedures are documented in the Laboratory Quality Assurance Plan (LQAP).

5.3.1.4 Chain-of-Custody Seal

Attachment B-7 is an example of a custody seal. The Custody seal is also an adhesive-backed label. It is part of a chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field and sealed in coolers for transit to the laboratory. The COC seals are signed and dated by the samplers and affixed across the opening edges of each cooler containing environmental samples. COC seals may be available from the laboratory; these seals may also be purchased from a supplier.

5.3.2 Geohydrological and Geotechnical Forms

5.3.2.1 Groundwater Level Measurement Sheet

A groundwater level measurement sheet, shown in Attachment C-1 must be filled out for each round of water level measurements made at a site.

5.3.2.2 Data Sheet for Pumping Test

During the performance of a pumping test (or an in-situ hydraulic conductivity test), a large amount of data must be recorded, often within a short time period. The pumping test data sheet (Attachment C-2) facilitates this task by standardizing the data collection format, and allowing the time interval for collection to be laid out in advance.

5.3.2.3 Packer Test Report Form

A packer test report form shown in Attachment C-3 must be completed for each well upon which a packer test is conducted following well installation.

5.3.2.4 Summary Log of Boring

During the progress of each boring, a log of the materials encountered, operation and driving of casing, and location of samples must be kept. The Summary Log of Boring (Attachment C-4) is used for this purpose and must be completed for each soil boring performed. In addition, if volatile organics are monitored on cores, samples or cuttings from the borehole (using HNU or OVA detectors), these results must be entered on the boring log (under the "Remarks" column) at the appropriate depth. The "Remarks" column can also be used to subsequently enter the laboratory sample number and the concentration of a few key analytical results. This feature allows direct comparison of contaminant concentrations with soil characteristics.

5.3.2.5 Monitoring Well Construction Details Form

A Monitoring Well Construction Details Form must be completed for every monitoring well piezometer or temporary well point installed. This form contains specific information on length and type of well riser pipe and screen, backfill, filter pack, annular seal and grout characteristics, and surface seal characteristics. This information is important in evaluating the performance of the monitoring well, particularly in areas where water levels show temporal variation, or where there are multiple (immiscible) phases of contaminants. Depending on the type of monitoring well (in overburden or bedrock), different forms are used (see Attachments C-5 through C-9). Similar forms are used for flush-mount well completions. The Monitoring Well Construction Details Form is not a controlled document.

5.3.2.6 Test Pit Log

When a test pit or trench is constructed for investigative or sampling purposes, a Test Pit Log (Attachment C-10) must be filled out by the responsible field geologist or sampling technician.

5.3.3 Equipment Calibration and Maintenance Form

The calibration or standardization of monitoring, measuring or test equipment is necessary to assure the proper operation and response of the equipment, to document the accuracy, precision or sensitivity of the measurement, and determine if correction should be applied to the readings. Some items of

equipment require frequent calibration, others infrequent. Some are calibrated by the manufacturer, others by the user.

Each instrument requiring calibration has its own Equipment Calibration Log (Attachment D) which documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device. An Equipment Calibration Log must be maintained for each electronic measuring device used in the field; entries must be made for each day the equipment is used.

5.4 Field Reports

The primary means of recording onsite activities is the site logbook. Other field notebooks may also be maintained. These logbooks and notebooks (and supporting forms) contain detailed information required for data interpretation or documentation, but are not easily useful for tracking and reporting of progress. Furthermore, the field logbook/notebooks remain onsite for extended periods of time and are thus not accessible for timely review by project management.

5.4.1 Weekly Status Reports

To facilitate timely review by project management, Xeroxed copies of logbook/notebook entries may be made for internal use. To provide timely oversight of onsite contractors, Daily Activities Reports are completed and submitted as described below.

It should be noted that in addition to the summaries described herein, other summary reports may also be contractually required.

5.4.2 Daily Activities Report

5.4.2.1 Description

The Daily Activities Report (DAR) documents the activities and progress for each day's field work. This report must be filled out on a daily basis whenever there are drilling, test pitting, well construction, or other related activities occurring which involve subcontractor personnel. These sheets summarize the work performed and form the basis of payment to subcontractors (Attachment E is an example of a Daily Activities Report).

5.4.2.2 Responsibilities

It is the responsibility of the rig geologist to complete the DAR and obtain the driller's signature acknowledging that the times and quantities of material entered are correct.

5.4.2.3 Submittal and Approval

At the end of the shift, the rig geologist must submit the Daily Activities Report to the Field Operations Leader (FOL) for review and filing. The Daily Activities Report is not a formal report and thus requires no further approval. The DAR reports are retained by the FOL for use in preparing the site logbook and in preparing weekly status reports for submission to the Project Manager.

6.0 ATTACHMENTS

Attachment A	TYPICAL SITE LOGBOOK ENTRY
Attachment B-1	EXAMPLE GROUNDWATER SAMPLE LOG SHEET
Attachment B-2	EXAMPLE SURFACE WATER SAMPLE LOG SHEET
Attachment B-3	EXAMPLE SOIL/SEDIMENT SAMPLE LOG SHEET
Attachment B-4	CONTAINER SAMPLE LOG SHEET FORM
Attachment B-5	SAMPLE LABEL
Attachment B-6	CHAIN-OF-CUSTODY RECORD FORM
Attachment B-7	CHAIN-OF-CUSTODY SEAL
Attachment C-1	EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET
Attachment C-2	EXAMPLE PUMPING TEST DATA SHEET
Attachment C-3	PACKER TEST REPORT FORM
Attachment C-4	EXAMPLE BORING LOG
Attachment C-5	EXAMPLE OVERBURDEN MONITORING WELL SHEET
Attachment C-5A	EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)
Attachment C-6	EXAMPLE CONFINING LAYER MONITORING WELL SHEET
Attachment C-7	EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL
Attachment C-8	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK
Attachment C-8A	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK (FLUSHMOUNT)
Attachment C-9	EXAMPLE TEST PIT LOG
Attachment D	EXAMPLE EQUIPMENT CALIBRATION LOG
Attachment E	EXAMPLE DAILY ACTIVITIES RECORD
Attachment F	FIELD TRIP SUMMARY REPORT

ATTACHMENT A
TYPICAL SITE LOGBOOK ENTRY

START TIME: _____ DATE: _____

SITE LEADER: _____

PERSONNEL:

BROWN & ROOT ENV.	DRILLER	EPA
_____	_____	_____
_____	_____	_____
_____	_____	_____

WEATHER: Clear, 68°F, 2-5 mph wind from SE

ACTIVITIES:

1. Steam jenney and fire hoses were set up.
2. Drilling activities at well ____ resumes. Rig geologist was _____. See Geologist's Notebook, No. 1, page 29-30, for details of drilling activity. Sample No. 123-21-S4 collected; see sample logbook, page 42. Drilling activities completed at 11:50 and a 4-inch stainless steel well installed. See Geologist's Notebook, No. 1, page 31, and well construction details for well _____.
3. Drilling rig No. 2 steam-cleaned at decontamination pit. Then set up at location of well _____.
4. Well _____ drilled. Rig geologist was _____. See Geologist's Notebook, No. 2, page ____ for details of drilling activities. Sample numbers 123-22-S1, 123-22-S2, and 123-22-S3 collected; see sample logbook, pages 43, 44, and 45.
5. Well _____ was developed. Seven 55-gallon drums were filled in the flushing stage. The well was then pumped using the pitcher pump for 1 hour. At the end of the hour, water pumped from well was "sand free."
6. EPA remedial project manger arrives on site at 14:25 hours.
7. Large dump truck arrives at 14:45 and is steam-cleaned. Backhoe and dump truck set up over test pit _____.
8. Test pit _____ dug with cuttings placed in dump truck. Rig geologist was _____. See Geologist's Notebook, No. 1, page 32, for details of test pit activities. Test pit subsequently filled. No samples taken for chemical analysis. Due to shallow groundwater table, filling in of test pit ___ resulted in a very soft and wet area. A mound was developed and the area roped off.
9. Express carrier picked up samples (see Sample Logbook, pages 42 through 45) at 17:50 hours. Site activities terminated at 18:22 hours. All personnel off site, gate locked.

_____
Field Operations Leader

ATTACHMENT B-1
EXAMPLE GROUNDWATER SAMPLE LOG SHEET

GROUNDWATER
SAMPLE LOG SHEET

Page ____ of ____

Project Site Name: _____

Project No.: _____

☐ Domestic Well Data
☐ Monitoring Well Data
☐ Other Well Type: _____
☐ QA Sample Type: _____

Sample ID No.: _____

Sample Location: _____

Sampled By: _____

C.O.C. No.: _____

Sampling Data

Date: / Time: / Method:	pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD	TBD

Purge Data

Date: / Method:	Volume	pH	S.C.	Temp.(°C)	Turbidity	Color	TBD	TBD
	Initial							
Monitor Reading (ppm):	1							
Well Casing Dia. & Material Type:	2							
	3							
Total Well Depth (TD):	4							
Static Water Level (WL):	5							
TD-WL (ft.) =								
One Casing Volume: (gal/L)								
Start Purge (hrs.):								
End Purge (hrs.):								
Total Purge Time (min):								
Total Amount Purged (gal/L):								

Analysis	Preservative	Container Requirements	Collected (✓)

Observations/Notes:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No:	

TBD: To Be Determined

ATTACHMENT B-2
EXAMPLE SURFACE WATER SAMPLING LOG SHEET

SURFACE WATER SAMPLING LOG SHEET

Page ____ of ____

Project Site Name: _____ Sample ID No.: _____

Project No.: _____ Sample Location: _____

☐ Spring ☐ Pond
☐ Stream ☐ Lake
☐ Other _____
☐ QA Sample Type: _____

Sampled By: _____

C.O.C. No.: _____

Sample Data							
Date and Time			Method			Depth	
pH	S.C.	Temp. (°C)	Turbidity	Color	TBD	TBD	TBD

Analysis	Preservative	Container Requirements	Collected (✓)

Observations/Notes:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No.:	

TBD: To Be Determined

ATTACHMENT B-3
EXAMPLE SOIL/SEDIMENT SINGLE SAMPLE LOG SHEET

SOIL/SEDIMENT
SINGLE SAMPLE LOG SHEET

Page ___ of ___

Project Site Name: _____

Project No.: _____

- ☐ Surface Soil
- ☐ Subsurface Soil
- ☐ Sediment
- ☐ Other _____
- ☐ QA Sample Type: _____

Sample ID No.: _____

Sample Location: _____

Sampled By: _____

C.O.C. No.: _____

Sample Method:	Composite Sample Data		
	Sample	Time	Color/Description
Depth Sampled:			
Sample Date and Time:			
Type of Sample			
☐ Grab			
☐ Composite			
☐ Grab-Composite	Grab Sample Data		
☐ High Concentration	Color	Description: (Sand, Clay, Dry, Moist, Wet, etc.)	
☐ Low Concentration			

Analysis	Container Type/Preservative	Collected @?	Map:

Observations/Notes:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No:	

ATTACHMENT B-4
CONTAINER SAMPLE LOG SHEET FORM

Brown & Root Environmental

Page ___ of _

☐ Container Data

Case #: _____

By: _____

Project Site Name: _____ Project Site No. _____

Brown & Root Env. Source No. _____ Source Location: _____

Container Source	Container Description
☐ Drum ☐ Bung Top ☐ Lever Lock ☐ Bolted Ring ☐ Other _____ ☐ Bag/Sack ☐ Tank ☐ Other _____	Color: _____ Condition: _____ Markings: _____ Vol. of Contents: _____ Other: _____

Disposition of Sample	Sample Description	Layer 1	Layer 2	Layer 3
☐ Container Sampled ☐ Container opened but not sampled. Reason: _____	Phase	☐Sol. ☐Liq.	☐Sol. ☐Liq.	☐Sol. ☐Liq.
	Color	_____	_____	_____
	Viscosity	☐L ☐M ☐H	☐L ☐M ☐H	☐L ☐M ☐H
☐ Container not opened. Reason: _____	% of Total Volume	_____	_____	_____
	Other	_____	_____	_____

Monitor Reading:	Type of Sample ☐ Grab ☐ Low Concentration ☐ Composite ☐ High Concentration ☐ Grab-composite
Sample Method:	

Sample Date & Time:	Sample Identification	Organic	Inorganic
Sampled by:			
Signature(s):			
	Date Shipped		
Analysis:	Time Shipped		
	Lab		
	Volume		

ATTACHMENT B-5

SAMPLE LABEL

Brown & Root Environmental PROJECT: _____

STATION LOCATION: _____

DATE: ____/____/____ TIME: _____ hrs.

MEDIA: WATER ☐ SOIL ☐ SEDIMENT ☐ _____ ☐

CONCENTRATION: LOW ☐ MEDIUM ☐ HIGH ☐

TYPE: GRAB ☐ COMPOSITE ☐

ANALYSIS	PRESERVATION
VOA ☐ BNAs ☐	Cool to 4°C ☐
PCBs ☐ PESTICIDES ☐	HNO_3 to pH < 2 ☐
METALS: TOTAL ☐ DISSOLVED ☐	NaOH to pH > 12 ☐
CYANIDE ☐	_____ ☐
_____ ☐	

Sampled by: _____

Remarks:

ATTACHMENT B-6

CHAIN-OF-CUSTODY RECORD FORM
(Original is 8.5 x 11")

PROJECT NO.	PROJECT NAME	NO. OF CONTAINERS	REMARKS
SAMPLERS: *(Signature)*			

STA NO.	DATE	TIME			STATION LOCATION							

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks:	

ATTACHMENT B-7

CHAIN-OF-CUSTODY SEAL

CUSTODY SEAL	**CUSTODY SEAL**
Date	**Date**
Signature	**Signature**

ATTACHMENT C-1
EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET

GROUNDWATER LEVEL MEASUREMENT SHEET

Page ___ of ___

PROJECT NAME: _____ LOCATION: _____
PROJECT NUMBER: _____ MEASURING DEVICE: _____
PERSONNEL: _____ ADJUSTMENT FACTOR: _____
DATE: _____ REMARKS: _____
WEATHER CONDITIONS: _____

Well or Piezometer Number	Time	Elevation of Reference Point (Feet)*	Water Level Indicator Reading (Feet)*	Groundwater Elevation (Feet)*	Comments

*Measurements to nearest 0.01 foot.

Signature(s): _____

ATTACHMENT C-2
EXAMPLE PUMPING TEST DATA SHEET

PUMPING TEST DATA SHEET

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
PUMPING TEST: [ ]
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DATE(s): _____
STATIC H_2O LEVEL (ft) (SO) _____

PUMPING WELL NUMBER: _____
MEASURED WELL NUMBER: _____
STEP DRAW DOWN TEST [ ]
MONITORING POINT: _____
DEPTH CORRECTION (ft) _____
PUMP SETTING (Ft. below monitoring point): _____
DISTANCE FROM PUMPING WELL (ft) (r): _____

PUMPING TEST PERFORMED BY: _____
REMARKS: _____

MILITARY TIME	ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	CORRECTION (Ft.)	DRAW DOWN OR RECOVERY (Ft.)	FLOW METER READING (Gals.)	PUMPING RATE (GPM)	REMARKS

SIGNATURE(s): _____

ATTACHMENT C-3

PACKER TEST REPORT FORM

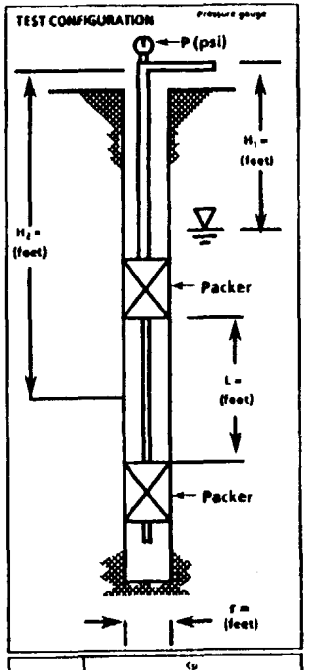
PROJECT: _____ PROJECT NO.: _____ TEST NO: _____ PAGE ____ OF ____

BORING NO.: _____ CASING DEPTH: _____ CONTRACTOR: _____ STATIC WATER LEVEL _____

TEST INTERVAL: _____ BY: _____ CHECKED: _____ PACKER PRESSURE _____

Flow Test					Calculated Results							
Pressure, p (psi)	Elapsed Time (min)	Flow Reading	Δ Flow, ΔQ (ft³)	Δ Flow, ΔQ (gal)	Flow Rate Q (gal/min)	H_1* (ft)	Hp(Ft) = 2.31·(psi)	H_2* (ft)	H = Hp + (H1 or H2)	Cp	K (ft/yr) = Cp Q/H	K (cm/sec) = 9.67 x 10⁻⁷ K (ft/yr)

TEST CONFIGURATION



Length of Test Section in feet, ℓ	Cp Drilling Bit Size			
	EX (1.5")	AX (1.875")	BX (2.3/4")	NX (3")
1	31,000	28,500	25,000	22,300
2	19,400	18,100	16,000	15,500
5	9,000	9,300	8,000	8,200
8	6,000	6,500	6,100	5,800
10	5,700	5,400	5,400	4,900
15	4,100	3,800	3,700	3,600
20	3,200	3,100	3,000	2,800

CP = (1/(2 π L)) ln(L/r) (70,315.5)
7.48 Gallons = 1 Ft³
1 psi = 2.31 ft head

* H_1 is used when the test length is below the water table.
H_2 is used when the test length is above the water table.

Remarks _____

ATTACHMENT C-4
EXAMPLE BORING LOG

BORING LOG Page___ of___

PROJECT NAME: _____ BORING NUMBER: _____
PROJECT NUMBER: _____ DATE : _____
DRILLING COMPANY: _____ GEOLOGIST: _____
WATER LEVEL DATA: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows/ 6" or RQD (%)	Sample Recovery/ Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	* U S C S	Remarks	PID or FID Reading (ppm)

*When rock coring enter rock brokeness.

CONVERTED TO WELL : ___ Yes ___ No; WELL I.D.#: _____
REMARKS: _____

Signature(s): _____

LEGEND

SOIL TERMS

UNIFIED SOIL CLASSIFICATION (USCS)

COARSE-GRAINED SOILS — More Than Half of Material is LARGER Than No. 200 Sieve Size

FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)			GROUP SYMBOL	TYPICAL NAMES
GRAVELS (50%(+)>1/4"Ø	CLEAN GRAVELS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
	GRAVELS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see ML)	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.
		Plastic fines (for identification procedures, see CL)	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
SANDS 50%(+)<1/4"Ø	CLEAN SANDS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	SW	Well graded sand, gravelly sands, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands, little or no fines.
	SANDS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see MCL)	SM	Silty sands, poorly graded sand-silt mixtures.
		Plastic fines (for identification procedures, see CL)	SC	Clayey sands, poorly graded sand-clay mixtures.

FINE-GRAINED SOILS — More Than Half of Material is SMALLER Than No. 200 Sieve Size

FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)	Identification Procedures on Fraction Smaller than No. 40 Sieve Size				GROUP SYMBOL	TYPICAL NAMES
		DRY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)		
SILTS AND CLAYS Liquid Limit <50		None to Slight	Quick to Slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
		Medium to High	None to Very Slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		Slight to Medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.
SILTS AND CLAYS Liquid Limit >50		Slight to Medium	Slow to None	Slight to Medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		High to Very High	None	High	CH	Inorganic clays of high plasticity, fat clays.
		Medium to High	None to very Slow	Slight to Medium	OH	Organic clays of medium to high plasticity.
HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.				Pt	Peat and other organic soils

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example, GW-GC, well graded gravel-sand mixture with clay binder.
All sieve sizes on this chart are U.S. Standard.

DENSITY OF GRANULAR SOILS

DESIGNATION	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT
Very Loose	0-4
Loose	5-10
Medium Loose	11-30
Dense	31-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	UNC COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT	FIELD IDENTIFICATION METHODS
Very Soft	Less than 0.25	0 to 2	Easily pentrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb.
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb.
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail.

ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)			ROCK BROKENESS		
Descriptive Terms	Screwdriver or Knife Effects	Hammer Effects	Descriptive Terms	Abbreviation	Spacing
Soft	Easily Gouged	Crushes when pressed with hammer	Very Broken	(V. Br.)	0-2"
Medium Soft	Can be Gouged	Breaks (one blow); crumbly edges	Broken	(Br.)	2" 1'
Medium Hard	Can be scratched	Breaks (one blow); sharp edges	Blocky	(Bl.)	1'-3"
Hard	Cannot be scratched	Breaks conchoidally (several blows); sharp edges	Massive	(M.)	3'-10'

LEGEND:

SOIL SAMPLES - TYPES

S-2" Split-Barrel Sample

ST-3" O.D. Undisturbed Sample

O - Other Samples, Specify in Remarks

ROCK SAMPLES - TYPES

X-NX (Conventional) Core (-2-1/8" O.D.)

Q-NQ (Wireline) Core (-1-7/8" O.D.)

Z - Other Core Sizes, Specify in Remarks

WATER LEVELS

12/10 ▼ 12.6' Initial Level w/Date & Depth

12/10 ▼ 12.6' Stabilized Level w/Date & Depth

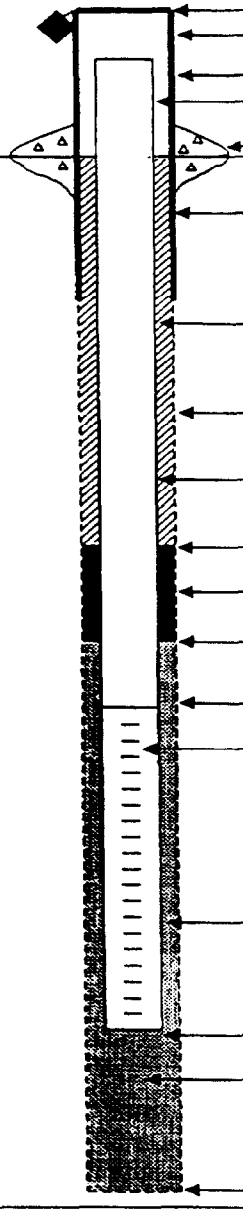
ATTACHMENT C-5
EXAMPLE OVERBURDEN MONITORING WELL SHEET

BORING NO.: _____

OVERBURDEN
MONITORING WELL SHEET

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION OF TOP OF SURFACE CASING : _____
ELEVATION OF TOP OF RISER PIPE: _____

STICK - UP TOP OF SURFACE CASING: _____
STICK - UP RISER PIPE : _____

TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____
TYPE OF SURFACE CASING: _____

RISER PIPE I.D. _____
TYPE OF RISER PIPE: _____

BOREHOLE DIAMETER: _____

TYPE OF BACKFILL: _____

ELEVATION / DEPTH TOP OF SEAL: _____ / _____

TYPE OF SEAL: _____

DEPTH TOP OF SAND PACK: _____

ELEVATION / DEPTH TOP OF SCREEN: _____ / _____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

I.D. OF SCREEN: _____

TYPE OF SAND PACK: _____

ELEVATION / DEPTH BOTTOM OF SCREEN: _____ / _____

ELEVATION / DEPTH BOTTOM OF SAND PACK: _____ / _____

TYPE OF BACKFILL BELOW OBSERVATION WELL: _____

ELEVATION / DEPTH OF HOLE: _____ / _____

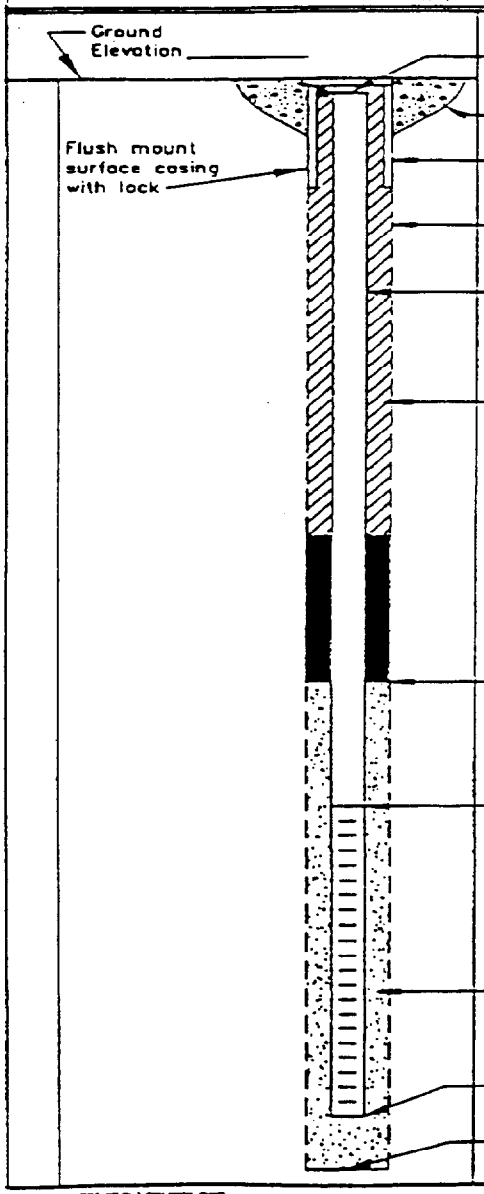
ATTACHMENT C-5A
EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)

BORING NO.: _____

MONITORING WELL SHEET

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

TYPE OF BACKFILL/SEAL: _____

_____

DEPTH/ELEVATION TOP OF SAND: _____/_____

DEPTH/ELEVATION TOP OF SCREEN: _____/_____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

DEPTH/ELEVATION BOTTOM OF SCREEN: _____/_____

DEPTH/ELEVATION BOTTOM OF SAND: _____/_____

DEPTH/ELEVATION BOTTOM OF HOLE: _____/_____

BACKFILL MATERIAL BELOW SAND: _____

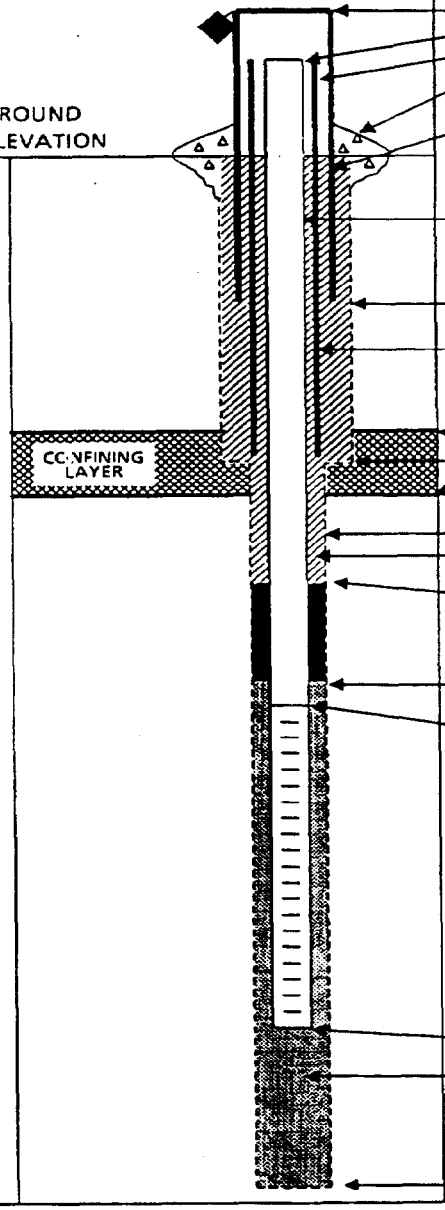
ATTACHMENT C-6
EXAMPLE CONFINING LAYER MONITORING WELL SHEET

BORING NO.: _____

CONFINING LAYER
MONITORING WELL SHEET

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION OF TOP OF SURFACE CASING : _____
ELEVATION OF TOP OF RISER PIPE: _____
ELEVATION TOP OF PERM. CASING: _____
TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____
TYPE OF SURFACE CASING: _____

RISER PIPE I.D. _____
TYPE OF RISER PIPE: _____

BOREHOLE DIAMETER: _____

PERM. CASING I.D. _____
TYPE OF CASING & BACKFILL: _____

ELEVATION / DEPTH TOP CONFINING LAYER: _____
ELEVATION / DEPTH BOTTOM OF CASING: _____
ELEVATION / DEPTH BOT. CONFINING LAYER: _____

BOREHOLE DIA. BELOW CASING: _____
TYPE OF BACKFILL: _____

ELEVATION / DEPTH TOP OF SEAL: _____
TYPE OF SEAL: _____

DEPTH TOP OF SAND PACK: _____

ELEVATION/DEPTH TOP OF SCREEN: _____
TYPE OF SCREEN: _____

TYPE OF SAND PACK: _____

ELEVATION / DEPTH BOTTOM OF SCREEN: _____

ELEVATION / DEPTH BOTTOM OF SAND PACK: _____
TYPE OF BACKFILL BELOW OBSERVATION WELL: _____

ELEVATION / DEPTH OF HOLE: _____

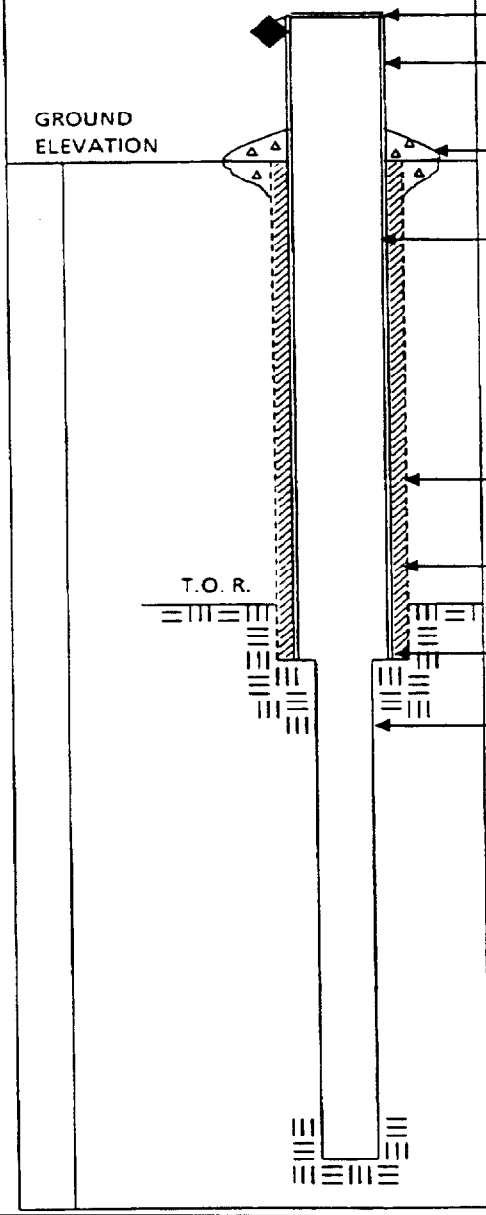
ATTACHMENT C-7
EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL

BORING NO.: _____

BEDROCK
MONITORING WELL SHEET
OPEN HOLE WELL

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION OF TOP OF CASING: _____

STICK UP OF CASING ABOVE GROUND SURFACE: _____

TYPE OF SURFACE SEAL: _____

I.D. OF CASING: _____

TYPE OF CASING: _____

TEMP. / PERM.: _____

DIAMETER OF HOLE: _____

TYPE OF CASING SEAL: _____

DEPTH TO TOP OF ROCK: _____

DEPTH TO BOTTOM CASING: _____

DIAMETER OF HOLE IN BEDROCK: _____

DESCRIBE IF CORE / REAMED WITH BIT:

_____

DESCRIBE JOINTS IN BEDROCK AND DEPTH:

_____

ELEVATION / DEPTH OF HOLE: _____ / _____

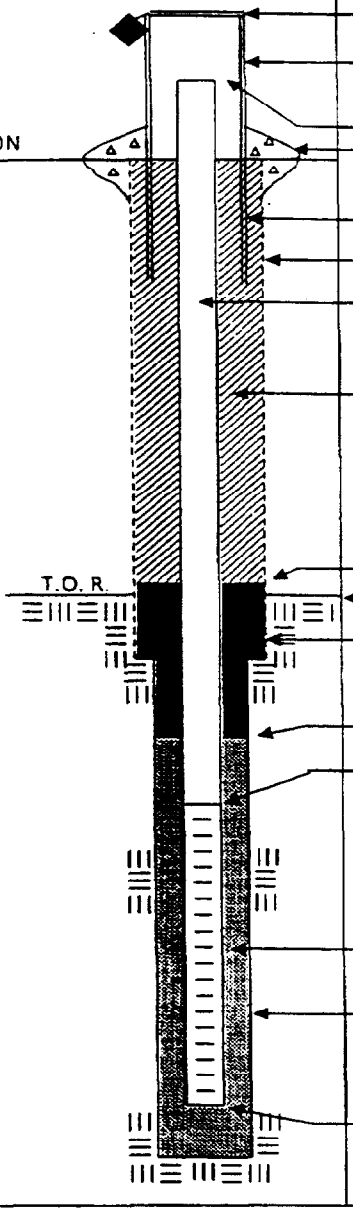
ATTACHMENT C-8
EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK

BORING NO.: _____

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

PROJECT _____ LOCATION _____
PROJECT NO. _____ BORING _____
ELEVATION _____ DATE _____
FIELD GEOLOGIST _____

DRILLER _____
DRILLING METHOD _____
DEVELOPMENT METHOD _____



ELEVATION OF TOP OF SURFACE CASING: _____

STICK UP OF CASING ABOVE GROUND SURFACE: _____

ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____

DIAMETER OF HOLE: _____

RISER PIPE I.D.: _____

TYPE OF RISER PIPE: _____

TYPE OF BACKFILL: _____

ELEVATION / DEPTH TOP OF SEAL: ____/____

ELEVATION / DEPTH TOP OF BEDROCK: ____/____

TYPE OF SEAL: _____

ELEVATION / DEPTH TOP OF SAND: ____/____

ELEVATION / DEPTH TOP OF SCREEN: ____/____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

I.D. SCREEN: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK:

CORE / REAM: _____

ELEVATION / DEPTH BOTTOM SCREEN: ____/____

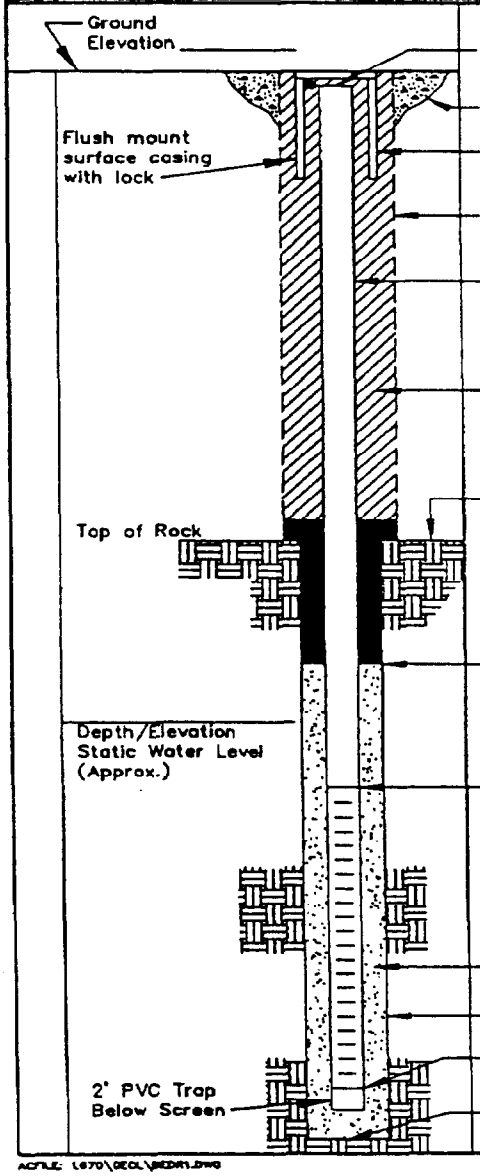
ELEVATION / DEPTH BOTTOM OF HOLE: ____/____

ATTACHMENT C-8A
EXAMPLE BEDROCK MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK (FLUSHMOUNT)

BORING NO.: _____

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

PROJECT: _____ LOCATION: _____ DRILLER: _____
PROJECT NO.: _____ BORING: _____ DRILLING METHOD: _____
ELEVATION: _____ DATE: _____ DEVELOPMENT METHOD: _____
FIELD GEOLOGIST: _____



ELEVATION TOP OF RISER: _____
TYPE OF SURFACE SEAL: _____
TYPE OF PROTECTIVE CASING: _____
I.D. OF PROTECTIVE CASING: _____
DIAMETER OF HOLE: _____
TYPE OF RISER PIPE: _____
RISER PIPE I.D.: _____
TYPE OF BACKFILL/SEAL: _____
_____
DEPTH/ELEVATION TOP OF BEDROCK: _____ / _____
DEPTH/ELEVATION TOP OF SAND: _____ / _____
DEPTH/ELEVATION TOP OF SCREEN: _____ / _____
TYPE OF SCREEN: _____
SLOT SIZE x LENGTH: _____
TYPE OF SAND PACK: _____
DIAMETER OF HOLE IN BEDROCK: _____
DEPTH/ELEVATION BOTTOM OF SCREEN: _____ / _____
DEPTH/ELEVATION BOTTOM OF SAND: _____ / _____
DEPTH/ELEVATION BOTTOM OF HOLE: _____ / _____
BACKFILL MATERIAL BELOW SAND: _____

ACFILE: L070\GEOL\BEDR1.DWG

ATTACHMENT C-9
EXAMPLE TEST PIT LOG

TEST PIT LOG

Brown & Root Environmental

PROJECT: _____ TEST PIT NO.:
PROJECT NO _____ DATE: _____
LOCATION: _____
FIELD GEOLOGIST: _____

DEPTH (ft.)	LITHOLOGY CHANGE (Depth/ft.)	MATERIAL DESCRIPTION (Soil Density / Consistency, Color)	USCS	REMARKS

Test Pit Cross Section and / or Plan View

REMARKS _____

PHOTO LOG _____ TEST PIT _____

PAGE ____ OF ____

ATTACHMENT D
EXAMPLE EQUIPMENT CALIBRATION LOG

Brown & Root Environmental

EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME / MODEL : _____

JOB NAME : _____

MANUFACTURER : _____

JOB NUMBER : _____

CALIBRATION DATE	INITIAL SETTINGS	STANDARDS USED	PROCEDURE	ADJUSTMENTS MADE	FINAL SETTINGS	SIGNATURE	COMMENTS

ATTACHMENT E
EXAMPLE DAILY ACTIVITIES RECORD

Brown & Root Environmental

DAILY ACTIVITIES RECORD

PROJECT _____ LOCATION _____
CLIENT _____ ARRIVAL TIME _____ JOB NO. _____
DATE _____ DEPARTURE TIME _____
CONTRACTOR _____ DRILLER _____
BORING NO. _____ HNUS REPRESENTATIVE _____

ITEM	QUANTITY ESTIMATE	QUANTITY TODAY	PREVIOUS TOTAL QUANTITY	CUMULATIVE QUANTITY TO DATE

COMMENTS: _____

APPROVED BY:

_____ HNUS FIELD REPRESENTATIVE

_____ DRILLER OR REPRESENTATIVE

ATTACHMENT F
FIELD TRIP SUMMARY REPORT
PAGE 1 OF 2

SUNDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

MONDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

TUESDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

WEDNESDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

ATTACHMENT F
PAGE 2 OF 2
FIELD TRIP SUMMARY REPORT

THURSDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

FRIDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

SATURDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

_____

_____

_____

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ATTACHMENTS

A TWO TYPES OF MUD PITS USED IN WELL DRILLING 9

1.0 PURPOSE

The purpose of this procedure is to provide guidelines regarding the appropriate procedures to be followed when decontaminating drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment.

2.0 SCOPE

This procedure addresses drilling equipment and monitoring well materials decontamination, as well as chemical sampling and field analytical equipment decontamination. This procedure also provides general reference information on the control of contaminated materials.

3.0 GLOSSARY

Acid - For decontamination of equipment when sampling for trace levels of inorganics, a 10% solution of nitric acid in deionized water should be used. Due to the leaching ability of nitric acid, it should not be used on stainless steel.

Alconox/Liquinox - A brand of phosphate-free laboratory-grade detergent.

Deionized Water - Deionized (analyte free) water is tap water that has been treated by passing through a standard deionizing resin column. Deionized water should contain no detectable heavy metals or other inorganic compounds at or above the analytical detection limits for the project.

Potable Water - Tap water used from any municipal water treatment system. Use of an untreated potable water supply is not an acceptable substitute for tap water.

Solvent - The solvent of choice is pesticide-grade Isopropanol. Use of other solvents (methanol, acetone, pesticide-grade hexane, or petroleum ether) may be required for particular projects or for a particular purpose (e.g. for the removal of concentrated waste) and must be justified in the project planning documents. As an example, it may be necessary to use hexane when analyzing for trace levels of pesticides, PCBs, or fuels. In addition, because many of these solvents are not miscible in water, the equipment should be air dried prior to use. Solvents should not be used on PVC equipment or well construction materials.

4.0 RESPONSIBILITIES

Project Manager - Responsible for ensuring that all field activities are conducted in accordance with approved project plan(s) requirements.

Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved Standards Operating Procedures or as otherwise dictated by the approved project plan(s).

5.0 PROCEDURES

To ensure that analytical chemical results reflect actual contaminant concentrations present at sampling locations, the various drilling equipment and chemical sampling and analytical equipment used to acquire the environment sample must be properly decontaminated. Decontamination minimizes the potential for cross-contamination between sampling locations, and the transfer of contamination off site.

5.1 Drilling Equipment

Prior to the initiation of a drilling program, all drilling equipment involved in field sampling activities shall be decontaminated by steam cleaning at a predetermined area. The steam cleaning procedure shall be performed using a high-pressure spray of heated potable water producing a pressurized stream of steam. This steam shall be sprayed directly onto all surfaces of the various equipment which might contact environmental samples. The decontamination procedure shall be performed until all equipment is free of all visible potential contamination (dirt, grease, oil, noticeable odors, etc.) In addition, this decontamination procedure shall be performed at the completion of each sampling and/or drilling location, including soil borings, installation of monitoring wells, test pits, etc. Such equipment shall include drilling rigs, backhoes, downhole tools, augers, well casings, and screens. Where the drilling rig is set to perform multiple borings at a single area of concern, the steam-cleaning of the drilling rig itself may be waived with proper approval. Downhole equipment, however, must always be steam-cleaned between borings. Where PVC well casings are to be installed, decontamination is not required if the manufacturer provides these casings in factory-sealed, protective, plastic sleeves (so long as the protective packaging is not compromised until immediately before use).

The steam cleaning area shall be designed to contain decontamination wastes and waste waters and can be a lined excavated pit or a bermed concrete or asphalt pad. For the latter, a floor drain must be provided which is connected to a holding facility. A shallow above-ground tank may be used or a pumping system with discharge to a waste tank may be installed.

In certain cases such an elaborate decontamination pad is not possible. In such cases, a plastic lined gravel bed pad with a collection system may serve as an adequate decontamination area. Alternately, a lined sloped pad with a collection pump installed at the lower end may be permissible. The location of the steam cleaning area shall be onsite in order to minimize potential impacts at certain sites.

Guidance to be used when decontaminating drilling equipment shall include:

- As a general rule, any part of the drilling rig which extends over the borehole, shall be steam cleaned.
- All drilling rods, augers, and any other equipment which will be introduced to the hole shall be steam cleaned.
- The drilling rig, all rods and augers, and any other potentially contaminated equipment shall be decontaminated between each well location to prevent cross contamination of potential hazardous substances.

Prior to leaving at the end of each work day and/or at the completion of the drilling program, drilling rigs and transport vehicles used onsite for personnel or equipment transfer shall be steam cleaned, as practicable. A drilling rig left at the drilling location does not need to be steam cleaned until it is finished drilling at that location.

5.2 Sampling Equipment

5.2.1 Bailers and Bailing Line

The potential for cross-contamination between sampling points through the use of a common bailer or its attached line is high unless strict procedures for decontamination are followed. For this reason, it is preferable to dedicate an individual bailer and its line to each sample point, although this does not

eliminate the need for decontamination of dedicated bailers. For non-dedicated sampling equipment, the following conditions and/or decontamination procedures must be followed.

Before the initial sampling and after each successive sampling point, the bailer must be decontaminated. The following steps are to be performed when sampling for organic contaminants. Note: contract-specific requirements may permit alternative procedures.

- Potable water rinse
- Alconox or Liquinox detergent wash
- Scrubbing of the line and bailer with a scrub brush (may be required if the sample point is heavily contaminated with heavy or extremely viscous compounds)
- Potable water rinse
- Rinse with 10 percent nitric acid solution*
- Deionized water rinse
- Pesticide-grade isopropanol (unless otherwise required)
- Pesticide-grade hexane rinse**
- Copious distilled/Deionized water rinse
- Air dry

If sampling for volatile organic compounds (VOCs) only, the nitric acid, isopropanol, and hexane rinses may be omitted. Only reagent grade or purer solvents are to be used for decontamination. When solvents are used, the bailer must be thoroughly dry before using to acquire the next sample.

In general, specially purchased pre-cleaned disposable sampling equipment is not decontaminated (nor is an equipment rinsate blank collected) so long as the supplier has provided certification of cleanliness. If decontamination is performed on several bailers at once (i.e., in batches), bailers not immediately used may be completely wrapped in aluminum foil (shiny-side toward equipment) and stored for future use. When batch decontamination is performed, one equipment rinsate is generally collected from one of the bailers belonging to the batch before it is used for sampling.

It is recommended that clean, dedicated braided nylon or polypropylene line be employed with each bailer use.

5.2.2 Sampling Pumps

Most sampling pumps are low volume (less than 2 gpm) pumps. These include peristaltic, diaphragm, air-lift, pitcher and bladder pumps, to name a few. If these pumps are used for sampling from more than one sampling point, they must be decontaminated prior to initial use and after each use.

The procedures to be used for decontamination of sampling pumps compare to those used for a bailer except that the 10 percent nitric acid solution is omitted. Each of the liquid factions is to be pumped through the system. The amount of pumping is dependent upon the size of the pump and the length of the intake and discharge hoses. Certain types of pumps are unacceptable for sampling purposes. For peristaltic pumps, the tubing is replaced rather than cleaned.

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* Due to the leaching ability of nitric acid on stainless steel, this step is to be omitted if a stainless steel sampling device is being used and metals analysis is required with detection limits less than approximately 50 ppb.

** If sampling for pesticides, PCBs, or fuels.

An additional problem is introduced when the pump relies on absorption of water via an inlet or outlet hose. For organic sampling, this hose should be Teflon. Other types of hoses leach organics (especially phthalate esters) into the water being sampled or adsorb organics from the sampled water. For all other sampling, the hose should be Viton, polyethylene, or polyvinyl chloride (listed in order of preference). Whenever possible, dedicated hoses should be used. It is preferable that these types of pumps not be used for sampling, only for purging.

5.2.3 Filtering Equipment

On occasion, the sampling plan may require acquisition of filtered groundwater samples. Field-filtering is addressed in SOP SA-6.1 and should be conducted as soon after sample acquisition as possible. To this end, three basic filtration systems are most commonly used: the in-line disposable Teflon filter, the inert gas over-pressure filtration system, and the vacuum filtration system.

For the in-line filter, decontamination is not required since the filter cartridge is disposable, however, the cartridge must be disposed of in an approved receptacle and the intake and discharge lines must still be decontaminated or replaced before each use.

For the over-pressure and the vacuum filtration systems, the portions of the apparatus which come in contact with the sample must be decontaminated as outlined in the paragraphs describing the decontamination of bailers. (Note: Varieties of both of these systems come equipped from the manufacturer with Teflon-lined surfaces for those that would come into contact with the sample. These filtration systems are preferred when decontamination procedures must be employed.)

5.2.4 Other Sampling Equipment

Field tools such as trowels and mixing bowls are to be decontaminated in the same manner as described above.

5.3 Field Analytical Equipment

5.3.1 Water Level Indicators

Water level indicators that come into contact with groundwater must be decontaminated using the following steps:

- Rinse with potable water
- Rinse with deionized water
- Pesticide-grade isopropanol (unless otherwise directed by manufacturer)
- Rinse with deionized water

Water level indicators that do not come in contact with the groundwater but may encounter incidental contact during installation or retrieval need only undergo the first and last steps stated above.

5.3.2 Probes

Probes (e.g., pH or specific-ion electrodes, geophysical probes, or thermometers) which would come in direct contact with the sample, will be decontaminated using the procedures specified above unless manufacturer's instructions indicate otherwise (e.g., dissolved oxygen probes). Probes that contact a volume of groundwater not used for laboratory analyses can be rinsed with deionized water. For probes which make no direct contact, (e.g., OVA equipment) the probe is self-cleaning when exposure to

uncontaminated air is allowed and the housing can be wiped clean with paper-towels or cloth wetted with alcohol.

5.4 Waste Handling

For the purposes of these procedures, contaminated materials are defined as any byproducts of field activities that are suspected or known to be contaminated with hazardous substances. These byproducts include such materials as decontamination solutions, disposable equipment, drilling muds, well-development fluids, and spill-contaminated materials and Personal Protection Equipment (PPE).

The procedures for obtaining permits for investigations of sites containing hazardous substances are not clearly defined at present. In the absence of a clear directive to the contrary by the EPA and the states, it must be assumed that hazardous wastes generated during field activities will require compliance with Federal agency requirements for generation, storage, transportation, or disposal. In addition, there may be state regulations that govern the disposal action. This procedure exclusively describes the technical methods used to control contaminated materials.

The plan documents for site activities must include a description of control procedures for contaminated materials. This planning strategy must assess the type of contamination, estimate the amounts that would be produced, describe containment equipment and procedures, and delineate storage or disposal methods. As a general policy, it is wise to select investigation methods that minimize the generation of contaminated spoils. Handling and disposing of potentially hazardous materials can be dangerous and expensive. Until sample analysis is complete, it is assumed that all produced materials are suspected of contamination from hazardous chemicals and require containment.

5.5 Sources of Contaminated Materials and Containment Methods

5.5.1 Decontamination Solutions

All waste decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site unless there are analytical or other data to the contrary. The waste solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.

Containerized waste rinse solutions are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. Larger equipment such as backhoes and tractors must be decontaminated in an area provided with an impermeable liner and a liquid collection system. A decontamination area for large equipment could consist of a bermed concrete pad with a floor drain leading to a buried holding tank.

5.5.2 Disposable Equipment

Disposable equipment that could become contaminated during use typically includes PPE, rubber gloves, boots, broken sample containers, and cleaning-wipes. These items are small and can easily be contained in 55-gallon drums with lids. These containers should be closed at the end of each work day and upon project completion to provide secure containment until disposed.

5.5.3 Drilling Muds and Well-Development Fluids

Drilling muds and well-development fluids are materials that may be used in groundwater monitoring well installations. Their proper use could result in the surface accumulation of contaminated liquids and muds

that require containment. The volumes of drilling muds and well-development fluids used depend on well diameter and depth, groundwater characteristics, and geologic formations. There are no simple mathematical formulas available for accurately predicting these volumes. It is best to rely on the experience of reputable well drillers familiar with local conditions and the well installation techniques selected. These individuals should be able to estimate the sizes (or number) of containment structures required. Since guesswork is involved, it is recommended that an slight excess of the estimated amount of containers required will be available.

Drilling muds are mixed and stored in what is commonly referred to as a mud pit. This mud pit consists of a suction section from which drilling mud is withdrawn and pumped through hoses, down the drill pipe to the bit, and back up the hole to the settling section of the mud pit. In the settling section, the mud's velocity is reduced by a screen and several flow-restriction devices, thereby allowing the well cuttings to settle out of the mud/fluid.

The mud pit may be either portable above-ground tanks commonly made of steel (which is preferred) or stationary in-ground pits as depicted in Attachment A. The above-ground tanks have a major advantage over the in-ground pits because the above-ground tanks isolate the natural soils from the contaminated fluids within the drilling system. These tanks are also portable and can usually be cleaned easily.

As the well is drilled, the cuttings that accumulate in the settling section must be removed. This is best done by shoveling them into drums or other similar containers. When the drilling is complete, the contents of the above-ground tank are likewise shoveled or pumped into drums, and the tank is cleaned and made available for its next use.

If in-ground pits are used, they should not extend into the natural water table. They should also be lined with a bentonite-cement mixture followed by a layer of flexible impermeable material such as plastic sheeting. Of course, to maintain its impermeable seal, the lining material used would have to be nonreactive with the wastes. An advantage of the in-ground pits is that well cuttings do not necessarily have to be removed periodically during drilling because the pit can be made deep enough to contain them. Depending on site conditions, the in-ground pit may have to be totally excavated and refilled with uncontaminated natural soils when the drilling operation is complete.

When the above-ground tank or the in-ground pit is used, a reserve tank or pit should be located at the site as a backup system for leaks, spills, and overflows. In either case, surface drainage should be such that any excess fluid could be controlled within the immediate area of the drill site.

The containment procedure for well-development fluids is similar to that for drilling muds. The volume and weight of contaminated fluid will be determined by the method used for development. When a new well is pumped or bailed to produce clear water, substantially less volume and weight of fluid result than when backwashing or high-velocity jetting is used.

5.5.4 Spill-Contaminated Materials

A spill is always possible when containers of liquids are opened or moved. Contaminated sorbents and soils resulting from spills must be contained. Small quantities of spill-contaminated materials are usually best contained in drums, while larger quantities can be placed in lined pits or in other impermeable structures. In some cases, onsite containment may not be feasible and immediate transport to an approved disposal site will be required.

5.6 Disposal of Contaminated Materials

Actual disposal techniques for contaminated materials are the same as those for any hazardous substance, that is, incineration, landfilling, treatment, and so on. The problem centers around the assignment of responsibility for disposal. The responsibility must be determined and agreed upon by all involved parties before the field work starts. If the site owner or manager was involved in activities that precipitated the investigation, it seems reasonable to encourage his acceptance of the disposal obligation. In instances where a responsible party cannot be identified, this responsibility may fall on the public agency or private organization investigating the site.

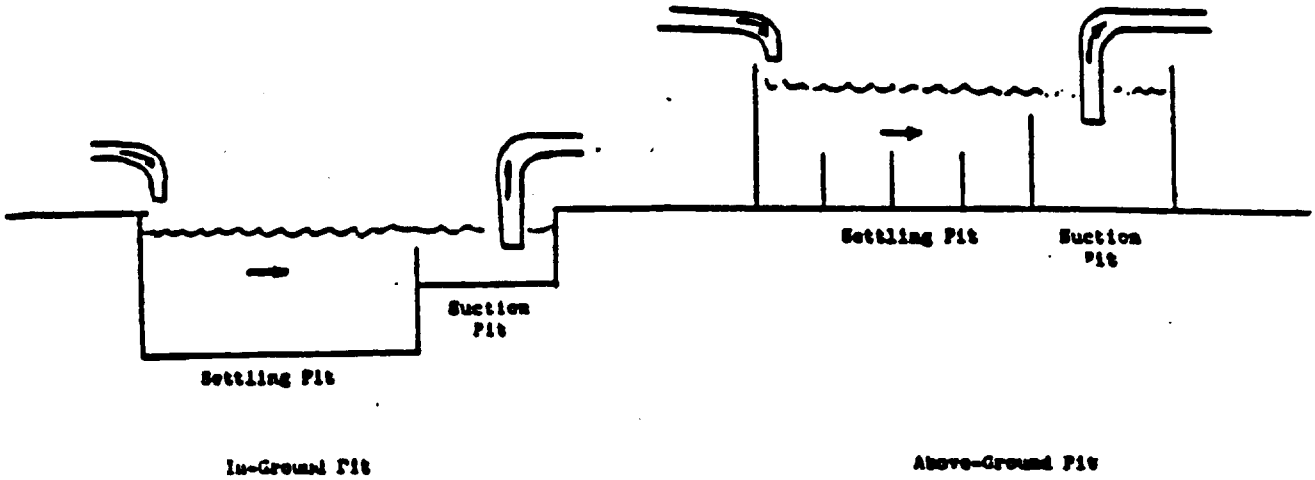
Another consideration in selecting disposal methods for contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable onsite disposal structure is expected, contaminated materials generated during the investigation should be stored at the site for disposal with other site materials. In this case, the initial containment structures should be evaluated for use as long-term storage structures. Also, other site conditions such as drainage control, security, and soil type must be considered so that proper storage is provided. If onsite storage is expected, then the containment structures should be specifically designed for that purpose.

6.0 REFERENCES

Brown & Root Environmental: Standard Operating Procedure No. 4.33, Control of Contaminated Material.

ATTACHMENT A

TWO TYPES OF MUD PITS USED IN WELL DRILLING



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1.0 PURPOSE

The purpose of this procedure is to provide reference information regarding the proper methods for evaluating existing monitoring wells, and determining water level measurements.

2.0 SCOPE

The procedures described herein are applicable to all existing monitoring wells and, for the most part, are independent of construction materials and methods.

3.0 GLOSSARY

Hydraulic Head - The height to which water will rise in a well.

Water Table - A surface in an unconfined aquifer where groundwater pressure is equal to atmospheric pressure (i.e., the pressure head is zero).

4.0 RESPONSIBILITIES

Site Geologist/Hydrogeologist - Has overall responsibility for obtaining water level measurements and developing groundwater contour maps. The site geologist/hydrogeologist (in concurrence with the Project Manager) shall specify the reference point from which water levels are measured (usually a specific point on the upper edge of the inner well casing), the number of data points needed and which wells shall be used for a contour map, and how many complete sets of water levels are required to adequately define groundwater flow directions (e.g., if there are seasonal variations).

Field Personnel - Must have a basic familiarity with the equipment and procedures involved in obtaining water levels, and must be aware of any project-specific requirements.

5.0 PROCEDURES

Accurate, valid and useful groundwater monitoring requires that four important conditions be met:

- Proper characterization of site hydrogeology.
- Proper design of the groundwater monitoring program, including adequate numbers of wells installed at appropriate locations and depths.
- Satisfactory methods of groundwater sampling and analysis to meet the data quality objectives (DQOs).
- The assurance that specific monitoring well samples are representative of water quality conditions in the monitored interval.

To insure that these conditions are met, adequate descriptions of subsurface geology, well construction methods and well testing results must be available. The following steps will help to insure that the required data are available to permit an evaluation of the utility of existing monitoring wells for collecting additional samples.

5.1 Preliminary Evaluation

A necessary first step in evaluating existing monitoring well data is the study and review of the original work plan for monitoring well installation (if available). This helps to familiarize the site geologist/hydrogeologist with site-specific conditions, and will promote an understanding of the original purpose of the monitoring wells.

The next step of the evaluation should involve a review of all available information concerning borehole drilling and well construction. This will allow interpretation of groundwater flow conditions and area geology, and will help to establish consistency between hydraulic properties of the well and physical features of the well or formation. The physical features which should be identified and detailed, if available, include:

- The well identification number, permit number and location by referenced coordinates, the distance from prominent site features, or the location of the well on a map.
- The installation dates, drilling methods, well development methods, and contractors.
- The depth to bedrock -- where rock cores were not taken, auger refusal, drive casing refusal or penetration test results (blow counts for split-barrel sampling) may be used to estimate bedrock interface.
- The soil profile and stratigraphy.
- The borehole depth and diameter.
- The elevation of the top of the protective casing, the top of the well riser, and the ground surface.
- The total depth of the well.
- The type of well materials, screen type, slot size, and length, and the elevation/depths of the screen, interval, and/or monitored interval.
- The elevation/depths of the tops and bottom of the filter pack and well seals and the type and size.

5.2 Field Inspection

During the onsite inspection of existing monitoring wells, features to be noted include:

- The condition of the protective casing, cap and lock.
- The condition of the cement seal surrounding the protective casing.
- The presence of depressions or standing water around the casing.
- The presence of any electrical cable and its connections.

If the protective casing, cap and lock have been damaged or the cement collar appears deteriorated, or if there are any depressions around the well casing capable of holding water, surface water may have

infiltrated into the well. This may invalidate previous sampling results since the time when leakage started is unknown.

The routine physical inspection must be followed by a more detailed investigation to identify other potential routes of contamination or sampling equipment malfunction. Any of these occurrences may invalidate previously-collected water quality data. If the monitoring well is to be used in the future, considerations shown in the steps described above should be rectified to rehabilitate the well. After disconnecting any wires, cables or electrical sources, remove the lock and open the cap. Check for the presence of organic vapors with a photoionization detector (PID) or flame-ionization detector (FID) and combustible gas meter to determine the appropriate worker safety level. The following information should be noted:

- Cap function.
- Physical characteristics and composition of the inner casing or riser, including inner diameter and annular space.
- Presence of grout between the riser and outer protective casing and the existence of drain holes in the protective casing.
- Presence of a riser cap, method of attachment to casing, and venting of the riser.
- Presence of dedicated sampling equipment; if possible, remove such equipment and inspect size, materials of construction and condition.

The final step of the field inspection is to confirm previous hydraulic or physical property data and to obtain data not previously available. This includes the determination of static water levels, total well depth and well obstruction. This may be accomplished using a weighted tape measure which can also be used to check for sediment (the weight will advance slowly if sediment is present, and the presence of sediment on the weight upon removal should be noted). If sediment is present, the well be should be redeveloped before sampling.

Lastly, as a final step, the location, condition and expected water quality of the wells should be reviewed in light of their usefulness for the intended purpose of the investigation.

5.3 Water Level (Hydraulic Head) Measurements

5.3.1 General

Groundwater level measurements can be made in monitoring wells, private or public water wells, piezometers, open boreholes, or test pits (after stabilization). Groundwater measurements should generally not be made in boreholes with drilling rods or auger flights present. If groundwater sampling activities are to occur, groundwater level measurements shall take place prior to well evacuation or sampling.

All groundwater level measurements shall be made to the nearest 0.01 foot, and recorded in the site geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment A), along with the date and time of the reading. The total depth of the well shall be measured and recorded, if not already known. Weather changes that occur over the period of time during which water levels are being taken, such as precipitation and barometric pressure changes, should be noted.

In measuring groundwater levels, there shall be a clearly-established reference point of known elevation, which is normally identified by a mark on the upper edge of the inner well casing. The reference point shall be noted in the field notebook. To be useful, the reference point should be tied in with an established USGS benchmark or other properly surveyed elevation datum. An arbitrary datum could be used for an isolated group of wells, if necessary.

Cascading water within a borehole or steel well casings can cause false readings with some types of sounding devices (chalked line, electrical). Oil layers may also cause problems in determining the true water level in a well. Special devices (interface probes) are available for measuring the thickness of oil layers and true depth to groundwater, if required.

Water level readings shall be taken regularly, as required by the site geologist/hydrogeologist. Monitoring wells or open-cased boreholes that are subject to tidal fluctuations should be read in conjunction with a tidal chart (or preferably in conjunction with readings of a tide staff or tide level recorder installed in the adjacent water body); the frequency of such readings shall be established by the site hydrogeologist. All water level measurements at a site used to develop a groundwater contour map shall be made in the shortest practical time to minimize affects due weather changes, and at least during the same day.

5.3.2 Water Level Measuring Techniques

There are several methods for determining standing or changing water levels in boreholes and monitoring wells. Certain methods have particular advantages and disadvantages depending upon well conditions. A general description of these methods is presented, along with a listing of various advantages and disadvantages of each technique. An effective technique shall be selected for the particular site conditions by the site geologist/hydrogeologist.

In most instances, preparation of accurate potentiometric surface maps require that static water level measurements be obtained to a precision of 0.01 feet. To obtain such measurements in individual accessible wells, chalked tape or electrical water level indicator methods have been found best, and thus are the most often utilized. Other, less precise methods, such as the popper or bell sound, or bailer line methods, may be appropriate for developing preliminary estimates of hydraulic conditions. When a large number of (or continuous) readings are required, time-consuming individual readings are not usually feasible. In such cases, it is best to use the float recorder or pressure transducer methods. When conditions in the well limit readings (i.e., turbulence in the water surface or limited access through small diameter tubing), less precise, but appropriate methods such as the air line or capillary tubing methods can be used (see subsequent SOP section for discussion of these devices).

5.3.3 Methods

Water levels can be measured by several different techniques, but the same steps shall be followed in each case. The proper sequence is as follows:

1. Check operation of recording equipment above ground. Prior to opening the well, don personal protective equipment, as required.

2. Record all information specified below in the geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment A):

   - Well number.

- Water level (to the nearest 0.01 foot; 0.3 cm). Water levels shall be taken from the surveyed reference mark on the top edge of the inner well casing.

- Time and day of the measurement.

Water level measuring devices with permanently marked intervals shall be used when possible. If water level measuring devices marked by metal or plastic bands clamped at intervals along the measuring line are used, the spacing and accuracy of these bands shall be checked frequently as they may loosen and slide up or down the line, resulting in inaccurate reference points.

5.3.4 Water Level Measuring Devices

Chalked Steel Tape

The water level is measured by chalking a weighted steel tape and lowering it a known distance (to any convenient whole foot mark) into the well or borehole. The water level is determined by subtracting the wetted chalked mark from the total length lowered into the hole.

The tape shall be withdrawn quickly from the well because water has a tendency to rise up the chalk due to capillary action. A water finding paste may be used in place of chalk. The paste is spread on the tape the same way as the chalk, and turns red upon contacting water.

Disadvantages to this method include the following: depths are limited by the inconvenience of using heavier weights to properly tension longer tape lengths; ineffective if borehole/well wall is wet or inflow is occurring above the static water level; chalking the tape is time-consuming; difficult to use during periods of precipitation.

Electric Water Level Indicators

These devices consist of a spool of small-diameter cable and a weighted probe attached to the end. When the probe comes in contact with the water, an electrical circuit is closed and a meter, light, and/or buzzer attached to the spool will signal the contact.

There are a number of commercial electric sounders available, none of which is entirely reliable under all conditions likely to occur in a contaminated monitoring well. In conditions where there is oil on the water, groundwater with high specific conductance, water cascading into the well, steel well casing, or a turbulent water surface in the well, measuring with an electric sounder may be difficult.

For accurate readings, the probe shall be lowered slowly into the well. The electric tape is marked at the measuring point where contact with the water surface was indicated. The distance from the mark to the nearest tape band is measured using an engineer's folding ruler or steel tape, and added to the band reading to obtain the depth to water. If the band is not a permanent marking band, spacing shall be checked periodically as described in Section 5.3.6.

Popper or Bell Sounder

A bell- or cup-shaped weight that is hollow on the bottom is attached to a measuring tape and lowered into the well. A "plopping" or "popping" sound is made when the weight strikes the surface of the water. An accurate reading can be determined by lifting and lowering the weight in short strokes, and reading the tape when the weight strikes the water. This method is not sufficiently accurate to obtain water levels to 0.01 feet, and thus is more appropriate for obtaining only approximate water levels quickly.

Float Recorder

A float or an electromechanically actuated water-seeking probe may be used to detect vertical changes of the water surface in the hole. A paper-covered recording chart drum is rotated by the up and down motion of the float via a pulley and reduction gear mechanism, while a clock drive moves a recording pen horizontally across the chart. To ensure continuous records, the recorder shall be inspected, maintained, and adjusted periodically. This type of device is useful for continuously measuring periodic water level fluctuations, such as tidal fluctuations or influences of pumping wells.

Air Line

An air line is especially useful in pumped wells where water turbulence may preclude the use of other devices. A small-diameter weighted tube of known length is installed from the surface to a depth below the lowest water level expected. Compressed air (from a compressor, bottled air, or air pump) is used to purge the water from the tube, until air begins to escape the lower end of the tube, and is seen (or heard) to be bubbling up through the water in the well. The pressure needed to purge the water from the air line multiplied by 2.307 (feet of water for 1 psi) equals the length in feet of submerged air line. The depth to water below the center of the pressure gauge can be calculated by subtracting the length of air line below the water surface from the total length of the air line.

The disadvantages to this method include the need for an air supply and lower level of accuracy (unless a very accurate air pressure gauge is used, this method cannot be used to obtain water level readings to the nearest 0.01 ft).

Capillary Tubing

In small diameter piezometer tubing, water levels are determined by using a capillary tube. Colored or clear water is placed in a small "U"-shaped loop in one end of the tube (the rest of the tube contains air). The other end of the capillary tube is lowered down the piezometer tubing until the water in the loop moves, indicating that the water level has been reached. The point is then measured from the bottom of the capillary tube or recorded if the capillary tube is calibrated. This is the best method for very small diameter tubing monitoring systems such as Barcad and other multilevel systems. Unless the capillary tube is calibrated, two people may be required to measure the length of capillary tubing used to reach the groundwater. Since the piezometer tubing and capillary tubing usually are somewhat coiled when installed, it is difficult to accurately measure absolute water level elevations using this method. However, the method is useful in accurately measuring differences or changes in water levels (i.e., during pumping tests).

Pressure Transducer

Pressure transducers can be lowered into a well or borehole to measure the pressure of water and therefore the water elevation above the transducer. The transducer is wired into a recorder at the surface to record changes in water level with time. The recorder digitizes the information and can provide a printout or transfer the information to a computer for evaluation (using a well drawdown/recovery model). The pressure transducer should be initially calibrated with another water level measurement technique to ensure accuracy. This technique is very useful for hydraulic conductivity testing in highly permeable material where repeated, accurate water level measurements are required in a very short period of time. A sensitive transducer element is required to measure water levels to 0.01 foot accuracy.

Borehole Geophysics

Approximate water levels can be determined during geophysical logging of the borehole (although this is not the primary purpose for geophysical logging and such logging is not cost effective if used only for this purpose). Several logging techniques will indicate water level. Commonly-used logs which will indicate saturated/unsaturated conditions include the spontaneous potential (SP) log and the neutron log.

5.3.5 Data Recording

Water level measurements, time, data, and weather conditions shall be recorded in the geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet. All water level measurements shall be measured from a known reference point. The reference point is generally a marked point on the upper edge of the inner well casing that has been surveyed for an elevation. The exact reference point shall be marked with permanent ink on the casing since the top of the casing may not be entirely level. It is important to note changes in weather conditions because changes in the barometric pressure may affect the water level within the well.

5.3.6 Specific Quality Control Procedures for Water Level Measuring Devices

All groundwater level measurement devices must be cleaned before and after each use to prevent cross contamination of wells. Manufacturer's instructions for cleaning the device shall be strictly followed. Some devices used to measure groundwater levels may need to be calibrated. These devices shall be calibrated to 0.01 foot accuracy and any adjustments/corrections shall be recorded in the field logbook/notebook. After the corrections/adjustments are made to the measuring device and entered in the field logbook/notebook, the corrected readings shall be entered onto the Groundwater Level Measurement Sheet (Attachment A). Elevations will be entered on the sheet when they become available.

5.4 Health and Safety Considerations

Groundwater contaminated by volatile organic compounds may release toxic vapors into the air space inside the well pipe. The release of this air when the well is initially opened is a health/safety hazard which must be considered. Initial monitoring of the well headspace and breathing zone concentrations using a PID (e.g., HNu) or FID (e.g., OVA) and combustible gas meters shall be performed to determine required levels of protection.

6.0 RECORDS

A record of all field procedures, tests and observations must be recorded in the site logbook or designated field notebook. Entries in the log/notebook should include the individuals participating in the field effort, and the date and time. The use of annotated sketches may help to supplement the evaluation.

ATTACHMENT A
EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET

GROUNDWATER LEVEL MEASUREMENT SHEET

Page ___ of ___

PROJECT NAME: _____ LOCATION: _____
PROJECT NUMBER: _____ MEASURING DEVICE: _____
PERSONNEL: _____ ADJUSTMENT FACTOR: _____
DATE: _____ REMARKS: _____
WEATHER CONDITIONS: _____

Well or Piezometer Number	Time	Elevation of Reference Point (Feet)*	Water Level Indicator Reading (Feet)*	Groundwater Elevation (Feet)*	Comments

*Measurements to nearest 0.01 foot.

Signature(s): _____

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1.0 PURPOSE

The purpose of this procedure is to describe the methods and equipment necessary to perform soil and rock borings and identify the equipment, sequence of events, and appropriate methods necessary to obtain soil, both surface and subsurface, and rock samples during field sampling activities.

2.0 SCOPE

This guideline addresses most of the accepted and standard drilling techniques, their benefits, and drawbacks. It should be used generally to determine what type of drilling techniques would be most successful depending on site-specific geologic conditions and the type of sampling required.

The sampling methods described within this procedure are applicable to collecting surface and subsurface soil samples, and obtaining rock core samples for lithologic and hydrogeologic evaluation, excavation/foundation design and related civil engineering purposes.

3.0 GLOSSARY

Rock Coring - A method in which a continuous solid cylindrical sample of rock or compact rock-like soil is obtained by the use of a double tube core barrel that is equipped with an appropriate diamond-studded drill bit which is advanced with a hydraulic rotary drilling machine.

Wire-Line Coring - As an alternative to conventional coring, this technique is valuable in deep hole drilling, since this method eliminates trips in and out of the hole with the coring equipment. With this technique, the core barrel becomes an integral part of the drill rod string. The drill rod serves as both a coring device and casing.

4.0 RESPONSIBILITIES

Project Manager - In consultation with the project geologist, the Project Manager is responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and geologic conditions at the site. The Project Manager also determines the disposal methods for products generated by drilling, such as drill cuttings and well development water, as well as any specialized supplies or logistical support required for the drilling operations.

Field Operations Leader (FOL) - The FOL is responsible for the overall supervision and scheduling of drilling activities, and is strongly supported by the project geologist.

Project Geologist - The project geologist is responsible for ensuring that standard and approved drilling procedures are followed. The geologist will generate a detailed boring log for each test hole. This log shall include a description of materials, samples, method of sampling, blow counts, and other pertinent drilling and testing information that may be obtained during drilling (see SOPs SA-6.3 and GH-1.5). Often this position for inspecting the drilling operations may be filled by other geotechnical personnel, such as soils and foundation engineers, civil engineers, etc.

Determination of the exact location for borings is the responsibility of the site geologist. The final location for drilling must be properly documented on the boring log. The general area in which the borings are to be located will be shown on a site map included in the Work Plan and/or Sampling and Analysis Plan.

Drilling Subcontractor - Operates under the supervision of the FOL. Responsible for obtaining all drilling permits and clearances, and supplying all services (including labor), equipment and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment except as stated in signed and approved subcontracts.

The driller must report any major technical or analytical problems encountered in the field to the FOL within 24 hours of determination, and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the FOL (with the concurrence of the Project Manager).

The drilling subcontractor is responsible for following decontamination procedures specified in the project plan documents. Upon completion of the work, the driller is responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

5.0 PROCEDURES

5.1 General

The purpose of drilling boreholes is:

- To determine the type, thickness, and certain physical and chemical properties of the soil, water and rock strata which underlie the site.
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned between samples and borings using appropriate decontamination procedures as outlined in SOP SA-7.1. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the rig geologist as they proceed (see SOPs SA-6.3 and GH-1.5). Situations where logging would not be required would include installation of multiple well points within a small area, or a "second attempt" boring adjacent to a boring that could not be continued through resistant material. In the latter case, the boring log can be resumed 5 feet above the depth at which the initial boring was abandoned, although the rig geologist should still confirm that the stratigraphy at the redrilled location conforms essentially with that encountered at the original location. If significant differences are seen, each hole should be logged separately.

5.2 Drilling Methods

The selected drilling methods described below apply to drilling in subsurface materials, including, but not limited to, sand, gravel, clay, silt, cobbles, boulders, rock and man-made fill. Drilling methods should be selected after studying the site geology and terrain, the waste conditions at the site, and reviewing the purpose of drilling and the overall subsurface investigation program proposed for the site. The full range of different drilling methods applicable to the proposed program should be identified with final selection based on relative cost, availability, time constraints, and how well each method meets the sampling and testing requirements of the individual drilling program.

5.2.1 Continuous-Flight Hollow-Stem Auger Drilling

This method of drilling consists of rotating augers with a hollow stem into the ground. Cuttings are brought to the surface by the rotating action of the auger. This method is relatively quick and inexpensive. Advantages of this type of drilling include:

- Samples can be obtained without pulling the augers out of the hole. However, this is a poor method for obtaining grab samples from thin, discrete formations because of mixing of soils which occurs as the material is brought to the surface. Sampling of such formations requires the use of split-barrel or thin-wall tube samplers advanced through the hollow core of the auger.

- No drilling fluids are required.

- A well can be installed inside the auger stem and backfilled as the augers are withdrawn.

Disadvantages and limitations of this method of drilling include:

- Augering can only be done in unconsolidated materials.

- The inside diameter of hollow stem augers used for well installation should be at least 4 inches greater than the well casing. Use of such large-diameter hollow-stem augers is more expensive than the use of small-diameter augers in boreholes not used for well installation. Furthermore, the density of unconsolidated materials and depths become more of a limiting factor. More friction is produced with the larger diameter auger and subsequently greater torque is needed to advance the boring.

- The maximum effective depth for drilling is 150 feet or less, depending on site conditions and the size of augers used.

- In augering through clean sand formations below the water table, the sand will tend to flow into the hollow stem when the plug is removed for soil sampling or well installation. If the condition of "running" or "flowing" sands is persistent at a site, an alternative method of drilling is recommended, in particular for wells or boreholes deeper than 25 feet.

- Hollow-stem auger drilling is the preferred method of drilling. Most alternative methods require the introduction of water or mud downhole (air rotary is the exception) to maintain the open borehole. With these other methods, great care must be taken to ensure that the method does not interfere with the collection of a representative sample (which is the objective of the borehole construction. With this in mind, the preferred order of choice of drilling method after hollow-stem augering (HSA) is:

  - Cable tool
  - Casing drive (air)
  - Air rotary
  - Mud rotary
  - Rotosonic
  - Drive and wash
  - Jetting

However, the use of any method will also depend on efficiency and cost-effectiveness. In many cases, mud rotary is the only feasible alternative to hollow-stem augering. Thus, mud rotary drilling is generally acceptable as a first substitute for HSA.

The procedures for sampling soils through holes drilled by hollow-stem auger shall conform with the applicable ASTM Standards: D1587-83 and D1586-84. The guidelines established in SOP SA-1.3 shall also be followed. The hollow-stem auger may be advanced by any power-operated drilling machine having sufficient torque and ram range to rotate and force the auger to the desired depth. The machine must, however, be equipped with the accessory equipment needed to perform required sampling, or rock coring.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation. However, when drilling below the water table, specially designed plugs which allow passage of formation water but not solid material shall be used (see Reference 1 of this guideline). This drilling configuration method also prevents blow back and plugging of the auger when the plug is removed for sampling.

Alternately, it may be necessary to keep the hollow stem full of water, at least to the level of the water table, to prevent blowback and plugging of the auger. If water is added to the hole, it must be sampled and analyzed to determine if it is free from contaminants prior to use. In addition, the amount of water introduced, the amount recovered upon attainment of depth, and the amount of water extracted during well development must be carefully logged in order to ensure that a representative sample of the formation water can be obtained. Well development should occur as soon after well completion as practicable (see SOP GH-2.8 for well development procedures). If gravelly or hard material is encountered which prevents advancing the auger to the desired depth, augering should be halted and either driven casing or hydraulic rotary methods should be attempted. If the depth to the bedrock/soil interface and bedrock lithology must be determined, then a 5-foot confirmatory core run should be conducted (see Section 5.2.9).

At the option of the Field Operations Leader (in communication with the Project Manager), when resistant materials prevent the advancement of the auger, a new boring can be attempted. The original boring must be properly backfilled and the new boring started a short distance away at a location determined by the site geologist. If multiple water bearing strata were encountered, the original boring must be grouted. In some formations, it may be prudent to also grout borings which penetrate only the water table aquifer, since loose soil backfill in the boring may still provide a preferred pathway for surface liquids to reach the water table.

5.2.2 Continuous-Flight Solid-Stem Auger Drilling

This drilling method is similar to hollow-stem augering. Practical application of this method is severely restricted compared to use of hollow-stem augers. Split-barrel (split-spoon) sampling cannot be performed without pulling the augers out, which may allow the hole to collapse. The continuous-flight solid-stem auger drilling method is therefore very time consuming and is not cost effective. Also, augers would have to be withdrawn before installing a monitoring well, which again, may allow the hole to collapse. Furthermore, geologic logging by examining the soils brought to the surface is unreliable, and depth to water may be difficult to determine while drilling.

There would be very few situations where use of a solid-stem auger would be preferable to other drilling methods. The only practical applications of this method would be to drill boreholes for well installation where no lithologic information is desired and the soils are such that the borehole can be expected to

remain open after the augers are withdrawn. Alternatively, this technique can be used to find depth to bedrock in an area when no other information is required from drilling.

5.2.3 Rotary Drilling

Direct rotary drilling includes air-rotary and fluid-rotary drilling. For air or fluid-rotary drilling, the rotary drill may be advanced to the desired depth by any power-operated drilling machine having sufficient torque and ram range to rotate and force the bit to the desired depth. The drilling machine must, however, be equipped with any accessory equipment needed to perform required sampling, or coring. Prior to sampling, any settled drill cuttings in the borehole must be removed.

Air-rotary drilling is a method of drilling where the drill rig simultaneously turns and exerts a downward pressure on the drilling rods and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole. Advantages of this method include:

- The drilling rate is high (even in rock).
- The cost per foot of drilling is relatively low.
- Air-rotary rigs are common in most areas.
- No drilling fluid is required (except when water is injected to keep down dust).
- The borehole diameter is large, to allow room for proper well installation procedures.

Disadvantages to using this method include:

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate.
- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow.
- In-situ samples cannot be taken, unless the hole is cased.
- Casing must generally be used in unconsolidated materials.
- Air-rotary drill rigs are large and heavy.

A variation of the typical air-rotary drill bit is a down hole hammer which hammers the drill bit down as it drills. This makes drilling in hard rock faster. Air-rotary drills can also be adapted to use for rock coring although they are generally slower than other types of core drills. A major application of the air-rotary drilling method would be to drill holes in rock for well installation.

Fluid-Rotary drilling operates in a similar manner to air-rotary drilling except that a drilling fluid ("mud") or clean water is used in place of air to cool the drill bit and remove cuttings. There are a variety of fluids that can be used with this drilling method, including bentonite slurry and synthetic slurries. If a drilling fluid other than water/cuttings is used, it must be a natural clay (i.e., bentonite) and a "background" sample of the fluid should be taken for analysis of possible organic or inorganic contaminants.

Advantages to the fluid-rotary drilling method include:

- The ability to drill in many types of formations.
- Relatively quick and inexpensive.
- Split-barrel (split-spoon) or thin-wall (Shelby) tube samples can be obtained without removing drill rods if the appropriate size drill rods and bits (i.e., fish-tail or drag bit) are used.
- In some borings temporary casing may not be needed as the drilling fluids may keep the borehole open.
- Drill rigs are readily available in most areas.

Disadvantages to this method include:

- Formation logging is not as accurate as with hollow-stem auger method if split-barrel (split-spoon) samples are not taken (i.e., the depths of materials logged from cuttings delivered to the surface are approximate).
- Drilling fluids reduce permeability of the formation adjacent to the boring to some degree, and require more extensive well development than "dry" techniques (augering, air-rotary).
- No information on depth to water is obtainable while drilling.
- Fluids are needed for drilling, and there is some question about the effects of the drilling fluids on subsequent water samples obtained. For this reason as well, extensive well development may be required.
- In very porous materials (i.e., rubble fill, boulders, coarse gravel) drilling fluids may be continuously lost into the formation. This requires either constant replenishment of the drilling fluid, or the use of casing through this formation.
- Drill rigs are large and heavy, and must be supported with supplied water.
- Groundwater samples can be potentially diluted with drilling fluid.

The procedures for performing direct rotary soil investigations and sampling shall conform with the applicable ASTM standards: D2113-83, D1587-83, and D1586-84.

Soil samples shall be taken as specified by project plan documents, or more frequently, if requested by the project geologist. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool.

When field conditions prevent the advancement of the hole to the desired depth, a new boring may be drilled at the request of the Field Operations Leader. The original boring shall be backfilled using methods and materials appropriate for the given site and a new boring started a short distance away at a location determined by the project geologist.

5.2.4 Rotosonic Drilling

The Rotosonic drilling method employs a high frequency vibrational and low speed rotational motion coupled with down pressure to advance the cutting edge of a drill string. This produces a uniform borehole while providing a continuous, undisturbed core sample of both unconsolidated and most bedrock formations. Rotosonic drilling advances a 4-inch diameter to 12-inch diameter core barrel for sampling and can advance up to a 12-inch diameter outer casing for the construcito of standard and telescoped monitoring wells. During drilling, the core barrel is advanced ahead of the outer barrel in increments as determined by the site geologist and depending upon type of material, degree of subsurface contamination and sampling objectives.

The outer casing can be advanced at the same time as the inner drill string and core barrel, or advanced down over the inner drill rods and core barrel, or after the core barrel has moved ahead to collect the undisturbed sample and has been pulled out of the borehole. The outer casing can be advanced dry in most cases, or can be advanced with water or air depending upon the formations being drilled, the depth and diameter of the hole, or requirements of the project.

Advantages of this method include:

- Sampling and well installation are faster as compared to other drilling methods.
- Continuous sampling, with larger sample volume as compared to split-spoon sampling.
- The ability to drill through difficult formations such as cobbles or boulders, hard till and bedrock.
- Reduction of IDW by an average of 70 to 80 percent.
- Well installations are quick and controlled by elimination of potential bridging of annular materials during well installation, due to the ability to vibrate the outer casing during removal.

Disadvantages include:

- The cost for Rotosonic drilling as compared to other methods are generally higher. However, the net result can be a significant savings considering reduced IDW and shortened project duration.
- Rotosonic drill rigs are large and need ample room to drill, however, Rotosonic units can be placed on the ground or placed on an ATV.
- There are a limited number of Rotosonic drilling contractors at the present time.

5.2.5 Reverse Circulation Rotary Drilling

The common reverse-circulation rig is a water or mud-rotary rig with a large-diameter drill pipe which circulates the drilling water down the annulus and up the inside of the drill pipe (reverse flow direction from direct mud-rotary). This type of rig is used for the construction of large-capacity production water wells and is not suited for small, water quality sampling wells because of the use of drilling muds and the large-diameter hole which is created. A few special reverse-circulation rotary rigs are made with double-wall drill pipe. The drilling water or air is circulated down the annulus between the drill pipes and up inside the inner pipe.

Advantages of the latter method include:

- The formation water is not contaminated by the drilling water.
- Formation samples can be obtained, from known depths.
- When drilling with air, immediate information is available regarding the water-bearing properties of formations penetrated.
- Collapsing of the hole in unconsolidated formations is not as great a problem as when drilling with the normal air-rotary rig.

Disadvantages include:

- Double-wall, reverse-circulation drill rigs are very rare and expensive to operate.
- Placing cement grout around the outside of the well casing above a well screen often is difficult, especially when the screen and casing are placed down through the inner drill pipe before the drill pipe is pulled out.

5.2.6 Drill-through Casing Driver

The driven-casing method consists of alternately driving casing (fitted with a sharp, hardened casing shoe) into the ground using a hammer lifted and dropped by the drill rig (or an air-hammer) and cleaning out the casing using a rotary chopping bit and air or water to flush out the materials. The casing is driven down in stages (usually 5 feet per stage); a continuous record is kept of the blows per foot in driving the casing (see SOP GH-1.5). The casing is normally advanced by a 300-pound hammer falling freely through a height of 30 inches. Simultaneous washing and driving of the casing is not recommended. If this procedure is used, the elevations within which wash water is used and in which the casing is driven must be clearly recorded.

The driven casing method is used in unconsolidated formations only. When the boring is to be used for later well installation, the driven casing used should be at least 4 inches larger in diameter than the well casing to be installed. Advantages to this method of drilling include:

- Split-barrel (split-spoon) sampling can be conducted while drilling.
- Well installation is easily accomplished.
- Drill rigs used are relatively small and mobile.
- The use of casing minimizes flow into the hole from upper water-bearing layers; therefore, multiple aquifers can be penetrated and sampled for rough field determinations of some water quality parameters.

Some of the disadvantages include:

- This method can only be used in unconsolidated formations.
- The method is slower than other methods (average drilling progress is 30 to 50 feet per day).

- Maximum depth of the borehole varies with the size of the drill rig and casing diameter used, and the nature of the formations drilled.

- The cost per hour or per foot of drilling may be substantially higher than other drilling methods.

- It is difficult and time consuming to pull back the casing if it has been driven very deep (deeper than 50 feet in many formations).

5.2.7 Cable Tool Drilling

A cable tool rig uses a heavy, solid-steel, chisel-type drill bit ("tool") suspended on a steel cable, which when raised and dropped, chisels or pounds a hole through the soils and rock. Drilling progress may be expedited by the use of "slip-jars" which serve as a cable-activated down hole percussion device to hammer the bit ahead.

When drilling through the unsaturated zone, some water must be added to the hole. The cuttings are suspended in the water and then bailed out periodically. Below the water table, after sufficient ground water enters the borehole to replace the water removed by bailing, no further water needs to be added.

When soft caving formations are encountered, it is usually necessary to drive casing as the hole is advanced to prevent collapse of the hole. Often the drilling can be only a few feet below the bottom of the casing. Because the drill bit is lowered through the casing, the hole created by the bit is smaller than the casing. Therefore, the casing (with a sharp, hardened casing shoe on the bottom) must be driven into the hole (see Section 5.2.5 of this guideline).

Advantages of the cable-tool method include the following:

- Information regarding water-bearing zones is readily available during the drilling. Even relative permeabilities and rough water quality data from different zones penetrated can be obtained by skilled operators.

- The cable-tool rig can operate satisfactorily in all formations, but is best suited for caving, boulder, cable or coarse gravel type formations (e.g., glacial till) or formations with large cavities above the water table (such as limestones).

- When casing is used, the casing seals formation water out of the hole, preventing down hole contamination and allowing sampling of deeper aquifers for field-measurable water quality parameters.

- Split-barrel (split-spoon) or thin-wall (Shelby) tube samples can be collected through the casing.

Disadvantages include:

- Drilling is slow compared with rotary rigs.

- The necessity of driving the casing in unconsolidated formations requires that the casing be pulled back if exposure of selected water-bearing zones is desired. This process complicates the well completion process and often increases costs. There is also a chance that the casing may become stuck in the hole.

- The relatively large diameters required (minimum of 4-inch casing) plus the cost of steel casing result in higher costs compared to rotary drilling methods where casing is not required (e.g., such use of a hollow-stem auger).

- Cable-tool rigs have largely been replaced by rotary rigs. In some parts of the U.S., availability may be difficult.

5.2.8 Jet Drilling (Washing)

Jet drilling, which should be used only for piezometer or vadose zone sampler installation, consists of pumping water or drilling mud down through a small diameter (1/2- to 2-inch) standard pipe (steel or PVC). The pipe may be fitted with a chisel bit or a special jetting screen. Formation materials dislodged by the bit and jetting action of the water are brought to the surface through the annulus around the pipe. As the pipe is jetted deeper, additional lengths of pipe may be added at the surface.

Jet percussion is a variation of the jetting method, in which the casing is driven with a drive weight. Normally, this method is used to place 2-inch-diameter casing in shallow, unconsolidated sand formations, but this method has also been used to install 3- to 4-inch-diameter casings to a depth of 200 feet.

Jetting is acceptable in very soft formations, usually for shallow sampling, and when introduction of drilling water to the formation is acceptable. Such conditions would occur during rough stratigraphic investigation or installation of piezometers for water level measurement. Advantages of this method include:

- Jetting is fast and inexpensive.

- Because of the small amount of equipment required, jetting can be accomplished in locations where access by a normal drilling rig would be very difficult. For example, it would be possible to jet down a well point in the center of a lagoon at a fraction of the cost of using a drill rig.

- Jetting numerous well points just into a shallow water table is an inexpensive method for determining the water table contours, hence flow direction.

Disadvantages include the following:

- A large amount of foreign water or drilling mud is introduced above and into the formation to be sampled.

- Jetting is usually done in very soft formations which are subject to caving. Because of this caving, it is often not possible to place a grout seal above the screen to assure that water in the well is only from the screened interval.

- The diameter of the casing is usually limited to 2 inches; therefore, samples must be obtained by methods applicable to small diameter casings.

- Jetting is only possible in very soft formations that do not contain boulders or coarse gravel, and the depth limitation is shallow (about 30 feet without jet percussion equipment).

- Large quantities of water are often needed.

5.2.9 Drilling with a Hand Auger

This method is applicable wherever the formation, total depth of sampling, and the site and groundwater conditions are such as to allow hand auger drilling. Hand augering can also be considered at locations where drill rig access is not possible. All hand auger borings will be performed according to ASTM D1452-80.

Samples should be taken continuously unless otherwise specified by the project plan documents. Any required sampling is performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. Typical equipment used for sampling and advancing shallow "hand auger" holes are Iwan samplers (which are rotated) or post hole diggers (which are operated like tongs). These techniques are slow but effective where larger pieces of equipment do not have access, and where very shallow holes are desired (less than 15 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

5.2.10 Rock Drilling and Coring

When soil borings cannot be continued using augers or rotary methods due to the hardness of the soil or when rock or large boulders are encountered, drilling and sampling can be performed using a diamond bit corer in accordance with ASTM D2113.

Drilling is done by rotating and applying downward pressure to the drill rods and drill bit. The drill bit is a circular, hollow, diamond-studded bit attached to the outer core barrel in a double-tube core barrel. The use of single-tube core barrels is not recommended, as the rotation of the barrel erodes the sample and limits its use for detailed geological evaluation. Water or air is circulated down through the drill rods and annular space between the core barrel tubes to cool the bit and remove the cuttings. The bit cuts a core out of the rock which rises into an inner barrel mounted inside the outer barrel. The inner core barrel and rock core are removed by lowering a wire line with a coupling into the drill rods, latching onto the inner barrel and withdrawing the inner barrel. A less efficient variation of this method utilizes a core barrel that cannot be removed without pulling all of the drill rods. This variation is practical only if less than 50 feet of core is required.

Core borings are made through the casing used for the soil borings. The casing must be driven and sealed into the rock formation to prevent seepage from the overburden into the hole to be cored (see Section 5.3 of this guideline). A double-tube core barrel with a diamond bit and reaming shell or equivalent should be used to recover rock cores of a size specified in the project plans. The most common core barrel diameters are listed in Attachment A.

Soft or decomposed rock should be sampled with a driven split-barrel whenever possible or cored with a Denison or Pitcher sampler.

When coring rock, including shale and claystone, the speed of the drill and the drilling pressure, amount and pressure of water, and length of run can be varied to give the maximum recovery from the rock being drilled. Should any rock formation be so soft or broken that the pieces continually fall into the hole causing unsatisfactory coring, the hole should be reamed and a flush-joint casing installed to a point below the broken formation. The size of the flush-joint casing must permit securing the core size specified. When soft or broken rock is anticipated, the length of core runs should be reduced to less than 5 feet to avoid core loss and minimize core disturbance.

Advantages of core drilling include:

- Undisturbed rock cores can be recovered for examination and/or testing.
- In formations in which the cored hole will remain open without casing, water from the rock fractures may be recovered from the well without the installation of a well screen and gravel pack.
- Formation logging is extremely accurate.
- Drill rigs are relatively small and mobile.

Disadvantages include:

- Water or air is needed for drilling.
- Coring is slower than rotary drilling (and more expensive).
- Depth to water cannot accurately be determined if water is used for drilling.
- The size of the borehole is limited.

This drilling method is useful if accurate determinations of rock lithology are desired or if open wells are to be installed into bedrock. To install larger diameter wells in coreholes, the hole must be reamed out to the proper size after boring, using air or mud rotary drilling methods.

5.2.11 Drilling & Support Vehicles

In addition to the drilling method required to accomplish the objectives of the field program, the type of vehicle carrying the drill rig and/or support equipment and its suitability for the site terrain, will often be an additional deciding factor in planning the drilling program. The types of vehicles available are extensive, and depend upon the particular drilling subcontractor's fleet. Most large drilling subcontractors will have a wide variety of vehicle and drill types suited for most drilling assignments in their particular region, while smaller drilling subcontractors will usually have a fleet of much more limited diversity. The weight, size, and means of locomotion (tires, tracks, etc.) of the drill rig must be selected to be compatible with the site terrain to assure adequate mobility between borehole locations. Such considerations also apply to necessary support vehicles used to transport water and/or drilling materials to the drill rigs at the borehole locations. When the drill rigs or support vehicles do not have adequate mobility to easily traverse the site, provisions must be made for assisting equipment, such as bulldozers, winches, timber planking, etc., to maintain adequate progress during the drilling program.

Some of the typical vehicles which are usually available for drill rigs and support equipment are:

- Totally portable drilling/sampling equipment, where all necessary components (tripods, samplers, hammers, catheads, etc.) may be hand carried to the borehole site. Drilling/sampling methods used with such equipment include:
  - Hand augers and lightweight motorized augers.
  - Retractable plug samplers--driven by hand (hammer).

- Motorized cathead - a lightweight aluminum tripod with a small gas-engine cathead mounted on one leg, used to install small-diameter cased borings. This rig is sometimes called a "monkey on a stick."

- Skid-mounted drilling equipment containing a rotary drill or engine-driven cathead (to lift hammers and drill string), a pump, and a dismounted tripod. The skid is pushed, dragged, or winched (using the cathead drum) between boring locations.

- Small truck-mounted drilling equipment using a jeep, stake body or other light truck (4 to 6 wheels), upon which are mounted the drill and/or a cathead, a pump, and a tripod or small drilling derrick. On some rigs, the drill and/or a cathead are driven by a power take-off from the truck, instead of by a separate engine.

- Track-mounted drilling equipment is similar to truck-mounted rigs, except that the vehicle used has wide bulldozer tracks for traversing soft ground. Sometimes a continuous-track "all terrain vehicle" is also modified for this purpose. Some types of tracked drill rigs are called "bombardier" or "weasel" rigs.

- Heavy truck-mounted drilling equipment is mounted on tandem or dual tandem trucks to transport the drill, derrick, winches, and pumps or compressors. The drill may be provided with a separate engine or may use a power take-off from the truck engine. Large augers, hydraulic rotary and reverse circulation rotary drilling equipment are usually mounted on such heavy duty trucks. For soft-ground sites, the drilling equipment is sometimes mounted on and off the road vehicle having low pressure, very wide diameter tires and capable of floating; these vehicles are called "swamp buggy" rigs.

- Marine drilling equipment is mounted on various floating equipment for drilling borings in lakes, estuaries and other bodies of water. The floating equipment varies, and is often manufactured or customized by the drilling subcontractor to suit specific drilling requirements. Typically, the range of flotation vehicles include:

  - Barrel-float rigs - a drill rig mounted on a timber platform buoyed by empty 55-gallon drums or similar flotation units.

  - Barge-mounted drill rigs.

  - Jack-up platforms - drilling equipment mounted on a floating platform having retractable legs to support the unit on the sea or lake bed when the platform is jacked up out of the water.

  - Drill ships - for deep ocean drilling.

In addition to the mobility for the drilling equipment, similar consideration must be given for equipment to support the drilling operations. Such vehicles or floating equipment are needed to transport drill water, drilling supplies and equipment, samples, drilling personnel, etc. to and/or from various boring locations.

5.2.12 Equipment Sizes

In planning subsurface exploration programs, care must be taken in specifying the various drilling components, so that they will fit properly in the boring or well.

For drilling open boreholes using rotary drilling equipment, tri-cone drill bits are employed with air, water or drilling mud to remove cuttings and cool the bit. Tri-cone bits are slightly smaller than the holes they drill (i.e., 5-7/8-inch or 7-7/8-inch bits will nominally drill 6-inch and 8-inch holes, respectively).

For obtaining split-barrel samples of a formation, samplers are commonly manufactured in sizes ranging from 2 inches to 3-1/2 inches in outside diameter. However, the most commonly used size is the 2-inch O.D., 1-3/8-inch I.D. split-barrel sampler. When this sampler is used and driven by a 140-pound (± 2-pound) hammer dropping 30 inches (± 1 inch), the procedure is called a Standard Penetration Test, and the blows per foot required to advance the sampler into the formation can be correlated to the formation's density or strength.

In planning the drilling of boreholes using hollow-stem augers or casing, in which thin-wall tube samples or diamond core drilling will be performed, refer to the various sizes and clearances provided in Attachment A of this guideline. Sizes selected must be stated in the project plan documents.

5.2.13 Estimated Drilling Progress

To estimate the anticipated rates of drilling progress for a site, the following must be considered:

- The speed of the drilling method employed.
- Applicable site conditions (e.g., terrain, mobility between borings, difficult drilling conditions in bouldery soils, rubble fill or broken rock, etc.).
- Project-imposed restrictions (e.g., drilling while wearing personal protective equipment, decontamination of drilling equipment, etc.).

Based on recent experience in drilling average soil conditions (no boulders) and taking samples at 5-foot intervals, for moderate depth (30 feet to 50 feet) boreholes (not including installation or development of wells), the following daily rates of total drilling progress may be anticipated for the following drilling methods:

Drilling Method	Average Daily Progress (linear feet)
Hollow-stem augers	75'
Solid-stem augers	50'
Mud-Rotary Drilling	100' (cuttings samples)
Rotosonic Drilling	100'-160' (continuous core)
Reverse-Circulation Rotary	100' (cuttings samples)
Skid-Rig with driven casing	30'
Rotary with driven casing	50'
Cable Tool	30'
Hand Auger	Varies
Continuous Rock Coring	50'

5.3 Prevention of Cross-Contamination

A telescoping or multiple casing technique minimizes the potential for the migration of contaminated groundwater to lower strata below a confining layer. The telescoping technique consists of drilling to a confining layer utilizing a spun casing method with a diamond cutting or augering shoe (a method similar to the rock coring method described in Section 5.2.10, except that larger casing is used) or by using a driven-casing method (see Section 5.2.6 of this guideline) and installing a specified diameter steel well casing. The operation consists of three separate steps. Initially, a drilling casing (usually of 8-inch diameter) is installed followed by installation of the well casing (6-inch-diameter is common for 2-inch wells). This well casing is driven into the confining layer to ensure a tight seal at the bottom of the hole. The well casing is sealed at the bottom with a bentonite-cement slurry. The remaining depth of the boring is drilled utilizing a narrower diameter spun or driven casing technique within the outer well casing. A smaller diameter well casing with an appropriate length of slotted screen on the lower end, is installed to the surface.

Clean sand is placed in the annulus around and to a point of about 2 feet above the screen prior to withdrawal of the drilling casing. The annular space above the screen and to a point 2 feet above the bottom of the outer well casing is sealed with a tremied cement-bentonite slurry which is pressure-grouted or displacement-grouted into the hole. The remaining casing annulus is backfilled with clean material and grouted at the surface, or it is grouted all the way to the surface.

5.4 Cleanout of Casing Prior to Sampling

The boring hole must be completely cleaned of disturbed soil, segregated coarse material and clay adhering to the inside walls of the casing. The cleaning must extend to the bottom edge of the casing and, if possible, a short distance further (1 or 2 inches) to bypass disturbed soil resulting from the advancement of the casing. Loss of wash water during cleaning should be recorded.

For disturbed samples both above and below the water table and where introduction of relatively large volumes of wash water is permissible, the cleaning operation is usually performed by washing the material out of the casing with water; however, the cleaning should never be accomplished with a strong, downward-directed jet which will disturb the underlying soil. When clean out has reached the bottom of the casing or slightly below (as specified above), the string of tools should be lifted one foot off the bottom with the water still flowing, until the wash water coming out of the casing is clear of granular soil particles. In formations where the cuttings contain gravel and other larger particles, it is often useful to repeatedly raise and lower the drill rods and wash bit while washing out the hole, to surge these large particles upward out of the hole. As a time saver, the drilling contractor may be permitted to use a split-barrel (split-spoon) sampler with the ball check valve removed as the clean-out tool, provided the material below the spoon is not disturbed and the shoe of the spoon is not damaged. However, because the ball check valve has been removed, in some formations it may be necessary to install a flap valve or spring sample retainer in the split-spoon bit, to prevent the sample from falling out as the sampler is withdrawn from the hole. The use of jet-type chopping bits is discouraged except where large boulders and cobbles or hard-cemented soils are encountered. If water markedly softens the soils above the water table, clean out should be performed dry with an auger.

For undisturbed samples below the water table, or where wash water must be minimized, clean out is usually accomplished with an appropriate diameter clean out auger. This auger has cutting blades at the bottom to carry loose material up into the auger, and up-turned water jets just above the cutting blades to carry the removed soil to the surface. In this manner, there is a minimum of disturbance at the top of the material to be sampled. If any gravel material washes down into the casing and cannot be removed by the clean out auger, a split-barrel sample can be taken to remove it; bailers and

sandpumps should not be used. For undisturbed samples above the groundwater table, all operations must be performed in a dry manner.

If all of the cuttings created by drilling through the overlying formations are not cleaned from the borehole prior to sampling, some of the problems which may be encountered during sampling include:

- When sampling is attempted through the cuttings remaining in the borehole, all or part of the sampler may become filled with the cuttings. This limits the amount of sample from the underlying formation which can enter and be retained in the sampler, and also raises questions as to the validity of the sample.

- If the cuttings remaining in the borehole contain coarse gravel and/or other large particles, these may block the bit of the sampler and prevent any materials from the underlying formation from entering the sampler when the sampler is advanced.

- In cased borings, should sampling be attempted through cuttings which remain in the lower portion of the casing, these cuttings could cause the sampler to become bound into the casing, such that it becomes very difficult to either advance or retract the sampler.

- When sampler blow counts are used to estimate the density or strength of the formation being sampled, the presence of cuttings in the borehole will usually give erroneously high sample blow counts.

To confirm that all cuttings have been removed from the borehole prior to attempting sampling, it is important that the rig geologist measure the "stickup" of the drill string. This is accomplished by measuring the assembled length of all drill rods and bits or samplers (the drill string) as they are lowered to the bottom of the hole, below some convenient reference point of the drill string, then measuring the height of this reference point above the ground surface. The difference of these measurements is the depth of the drill string (lower end of the bit or sampler) below the ground surface, which must then be compared with the depth of sampling required (installed depth of casing or depth of borehole drilled). If the length of drill string below grade is more than the drilled or casing depth, the borehole has been cleaned too deeply, and this deeper depth of sampling must be recorded on the log. If the length of drill string below grade is less than the drilled or casing depth, the difference represents the thickness of cuttings which remain in the borehole. In most cases, an inch or two of cuttings may be left in the borehole with little or no problem. However, if more than a few inches of cuttings are encountered, the borehole must be recleaned prior to attempting sampling.

5.5 Materials of Construction

The effects of monitoring well construction materials on specific chemical analytical parameters are described and/or referenced in SOP GH-2.8. However, there are several materials used during drilling, particularly drilling fluids and lubricants, which must be used with care to avoid compromising the representativeness of soil and ground water samples.

The use of synthetic or organic polymer slurries is not permitted at any location where soil samples for chemical analysis are to be collected. These slurry materials could be used for installation of long-term monitoring wells, but the early time data in time series collection of ground water data may then be suspect. If synthetic or organic polymer muds are proposed for use at a given site, a complete written justification including methods and procedures for their use must be provided by the site geologist and approved by the Project Manager. The specific slurry composition and the concentration of suspected contaminants for each site must be known.

For many drilling operations, potable water is an adequate lubricant for drill stem and drilling tool connections. However, there are instances, such as drilling in tight clayey formations or in loose gravels, when threaded couplings must be lubricated to avoid binding. In these instances, to be determined in the field by the judgment of the site geologist and noted in the site logbook, and only after approval by the Project Manager, a vegetable oil or silicone-based lubricant should be used. Petroleum based greases, etc. will not be permitted. Samples of lubricants used must be provided and analyzed for chemical parameters appropriate to the given site.

5.6 Subsurface Soil Samples

Subsurface soil samples are used to characterize subsurface stratigraphy. This characterization can indicate the potential for migration of chemical contaminants in the subsurface. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of the soil samples. Where the remedial activities may include in-situ treatment or excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Engineering and physical properties of soil may also be of interest should site construction activities be planned. Soil types, grain size distribution, shear strength, compressibility, permeability, plasticity, unit weight, and moisture content are some of the physical characteristics that may be determined for soil samples.

Penetration tests are also described in this procedure. The tests can be used to estimate various physical and engineering parameters such as relative density, unconfined compressive strength, and consolidation characteristics of soils.

Surface protocols for various soil sampling techniques are discussed in SOP SA-1.3. Continuous-core soil sampling and rock coring are discussed below. The procedures described here are representative of a larger number of possible drilling and sampling techniques. The choice of techniques is based on a large number of variables such as cost, local geology, etc. The final choice of methods must be made with the assistance of drilling subcontractors familiar with the local geologic conditions. Alternative techniques must be based upon the underlying principles of quality assurance implicit in the following procedures.

The CME continuous sample tube system provides a method of sampling soil continuously during hollow-stem augering. The 5-foot sample barrel fits within the lead auger of a hollow-auger column. The sampling system can be used with a wide range of I.D. hollow-stem augers (from 3-1/4-inch to 8-1/4-inch I.D.). This method has been used to sample many different materials such as glacial drift, hard clays and shales, mine tailings, etc. This method is particularly used when SPT samples are not required and a large volume of material is needed. Also, this method is useful when a visual description of the subsurface lithology is required. Rotosonic drilling methods also provide a continuous soil sample.

5.7 Rock Sampling (Coring) (ASTM D2113-83)

Rock coring enables a detailed assessment of borehole conditions to be made, showing precisely all lithologic changes and characteristics. Because coring is an expensive drilling method, it is commonly used for shallow studies of 500 feet or less, or for specific intervals in the drill hole that require detailed logging and/or analyzing. Rock coring can, however, proceed for thousands of feet continuously, depending on the size of the drill rig, and yields better quality data than air-rotary drilling, although at a substantially reduced drilling rate. Rate of drilling varies widely, depending on the characteristics of lithologies encountered, drilling methods, depth of drilling, and condition of drilling equipment. Average

output in a 10-hour day ranges from 40 to over 200 feet. Down hole geophysical logging or television camera monitoring is sometimes used to complement the data generated by coring.

Borehole diameter can be drilled to various sizes, depending on the information needed. Standard sizes of core barrels (showing core diameter) and casing are shown in Figure 1.

Core drilling is used when formations are too hard to be sampled by soil sampling methods and a continuous solid sample is desired. Usually, soil samples are used for overburden, and coring begins in sound bedrock. Casing is set into bedrock before coring begins to prevent loose material from entering the borehole, to prevent loss of drilling fluid, and to prevent cross-contamination of aquifers.

Drilling through bedrock is initiated by using a diamond-tipped core bit threaded to a drill rod (outer core barrel) with a rate of drilling determined by the downward pressure, rotation speed of drill rods, drilling fluid pressure in the borehole, and the characteristics of the rock (mineralogy, cementation, weathering).

5.7.1 Diamond Core Drilling

A penetration of typically less than 6 inches per 50 blows using a 140-lb. hammer dropping 30 inches with a 2-inch split-barrel sampler shall be considered an indication that soil sampling methods may not be applicable and that coring may be necessary to obtain samples.

When formations are encountered that are too hard to be sampled by soil sampling methods, the following diamond core drilling procedure may be used:

- Firmly seat a casing into the bedrock or the hard material to prevent loose materials from entering the hole and to prevent the loss of drilling fluid return. Level the surface of the rock or hard material when necessary by the use of a fishtail or other bits. If the drill hole can be retained open without the casing and if cross-contamination of aquifers in the unconsolidated materials is unlikely, leveling may be omitted.

- Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10 feet (3 m), remove the core barrel from the hole and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately. In soft materials, a large starting size may be specified for the coring tools; where local experience indicates satisfactory core recovery or where hard, sound materials are anticipated, a smaller size or the single-tube type may be specified and longer runs may be drilled. NX/NW size coring equipment is the most commonly used size.

- When soft materials are encountered that produce less than 50 percent recovery, stop the core drilling. If soil samples are desired, secure such samples in accordance with the procedures described in ASTM Method D 1586 (Split-barrel Sampling) or in Method D 1587 (Thin-Walled Tube Sampling); sample soils per SOP SA-1.3. Resume diamond core drilling when refusal materials are again encountered.

- Since rock structures and the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: (1) cement the hole; (2) ream and case; or (3) case and advance with the next smaller size core barrel, as conditions warrant.

FIGURE 1

STANDARD SIZES OF CORE BARRELS AND CASING

Coring Bit Size	Nominal*		Set Size*	
	O.D.	I.D.	O.D.	I.D.
RWT	1 5/32	3/4	1.160	0.735
EWT	1 1/2	29/32	1.470	0.905
EX, EXL, EWG, EWM	1 1/2	13/16	1.470	0.845
AWT	1 7/8	1 9/32	1.875	1.281
AX, AXL, AWG, AWM	1 7/8	1 3/16	1.875	1.185
BWT	2 3/8	1 3/4	2.345	1.750
BX, BXL, BWG, BWM	2 3/8	1 5/8	2.345	1.655
NWT	3	2 5/16	2.965	2.313
NX, NXL, NWG, NWM	3	2 1/8	2.965	2.155
HWT	3 29/32	3 3/16	3.889	3.187
HWG	3 29/32	3	3.889	3.000
2 3/4 x 3 7/8	3 7/8	2 3/4	3.840	2.690
4 x 5 1/2	5 1/2	4	5.435	3.970
6 x 7 3/4	7 3/4	6	7.655	5.970
AX Wire line ___|___/	1 7/8	1	1.875	1.000
BX Wire line ___|___/	2 3/8	1 7/16	2.345	1.437
NX Wire line ___|___/	3	1 15/16	2.965	1.937

* All dimensions are in inches; to convert to millimeters, multiply by 254.

___|___/ Wire line dimensions and designations may vary according to manufacturer.

FIGURE 1
STANDARD SIZES OF CORE BARRELS AND CASING
PAGE TWO

Size Designations		Casing O.D., Inches	Casing Coupling		Casing bit O.D., Inches	Core barrel bit O.D., Inches*	Drill rod O.D., Inches	Approximate Core Diameter	
Casing; Casing coupling; Casing bits; Core barrel bits	Rod; rod couplings		O.D., Inches	I.D., Inches				Normal, Inches	Thinwall, Inches
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	---	0.735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	0.845	0.905
AX	A	2.250	2.250	1.906	2.345	1.875	1.625	1.185	1.281
BX	B	2.875	2.875	2.375	2.965	2.345	1.906	1.655	1.750
NX	N	3.500	3.500	3.000	3.615	2.965	2.375	2.155	2.313
HX	HW	4.500	4.500	3.938	4.625	3.890	3.500	3.000	3.187
RW	RW	1.437	Flush Joint	No Coupling	1.485	1.160	1.094	---	0.735
EW	EW	1.812			1.875	1.470	1.375	0.845	0.905
AW	AW	2.250			2.345	1.875	1.750	1.185	1.281
BW	BW	2.875			2.965	2.345	2.125	1.655	1.750
NW	NW	3.500			3.615	2.965	2.625	2.155	2.313
HW	HW	4.500			4.625	3.890	3.500	3.000	3.187
PW	---	5.500			5.650	---	---	---	---
SW	---	6.625			6.790	---	---	---	---
UW	---	7.625			7.800	---	---	---	---
ZW	---	8.625			8.810	---	---	---	---
---	AX __|__\	---	---	---	---	1.875	1.750	1.000	---
---	BX __|__\	---	---	---	---	2.345	2.250	1.437	---
---	NX __|__\	---	---	---	---	2.965	2.813	1.937	---

* All dimensions are in inches; to convert to millimeters, multiply by 254.
___|___/ Wire line dimensions and designations may vary according to manufacturer.

NOMINAL DIMENSIONS FOR DRILL CASINGS AND ACCESSORIES. (DIAMOND CORE DRILL MANUFACTURERS ASSOCIATION). 288-D-2889

- In soft, seamy, or otherwise unsound rock, where core recovery may be difficult, M-design core barrels may be used. In hard, sound rock where a high percentage of core recovery is anticipated, the single-tube core barrel may be employed.

5.7.2 Rock Sample Preparation and Documentation

Once the rock coring has been completed and the core recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core shall be described, classified, and logged using a uniform system as presented in SOP GH-1.5. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of clay formations) or oxidation of the core, the core shall be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number, and the footage represented in each sleeve shall be included, as well as designating the top and bottom of the core run.

After sampling, rock cores shall be placed in the sequence of recovery in well-constructed wooden boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box unless accepted by the Project Geologist. The core boxes shall be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each and shall be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened down. Wood partitions shall be placed at the end of each core run and between rows.

The depth from the surface of the boring to the top and bottom of the drill run and run number shall be marked on the wooden partitions with indelible ink. A wooden partition (wooden block) shall be placed at the end of each run with the depth of the bottom of the run written on the block. These blocks will serve to separate successive core runs and indicate depth intervals for each run. The order of placing cores shall be the same in all core boxes. Rock core shall be placed in the box so that, when the box is open, with the inside of the lid facing the observer, the top of the cored interval contained within the box is in the upper left corner of the box, and the bottom of the cored interval is in the lower right corner of the box. The top and bottom of each core obtained and its true depth shall be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, an empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.
The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data on the box's contents. At a minimum, the following information shall be included:

- Project name.
- Project number.
- Boring number.
- Run numbers.
- Footage (depths).
- Recovery.
- RQD (%).
- Box number and total number of boxes for that boring (Example: Box 5 of 7).

For easy retrieval when core boxes are stacked, the sides and ends of the box shall also be labeled and include project number, boring number, top and bottom depths of core and box number.

Prior to final closing of the core box, a photograph of the recovered core and the labeling on the inside cover shall be taken. If moisture content is not critical, the core shall be wetted and wiped clean for the photograph. (This will help to show true colors and bedding features in the cores).

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ATTACHMENT A

DRILLING EQUIPMENT SIZES

Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Hollow-stem augers (Ref. 7)	6 1/4	5	2 1/4	
	6 3/4	5 3/4	2 3/4	---
	7 1/4	6 1/4	3 1/4	---
	13 1/4	12	6	---
Thin Wall Tube Samplers (Ref. 7)	---	2	1 7/8	---
	---	2 1/2	2 3/8	---
	---	3	2 7/8	---
	---	3 1/2	3 3/8	---
	---	4 1/2	4 3/8	---
	---	5	4 3/4	---
Drill Rods (Ref. 7)	RW	1 3/32	23/32	13/32
	EW	1 3/8	15/16	7/16
	AW	1 3/4	1 1/4	5/8
	BW	2 1/8	1 3/4	3/4
	NW	2 5/8	2 1/4	1 3/8
	HW	3 1/2	3 1/16	2 3/8
	E	1 5/16	7/8	7/16
	A	1 5/8	1 1/8	9/16
	B	1 7/8	1 1/4	5/8
	N	2 3/8	2	1
				Wall Thickness (Inches)
Driven External Coupled Extra Strong Steel* Casing (Ref. 8)	2 1/2	2.875	2.323	0.276
	3	3.5	2.9	0.300
	3 1/2	4.0	3.364	0.318
	4	4.5	3.826	0.337
	5	5.63	4.813	0.375
	6	6.625	5.761	0.432
	8	8.625	7.625	0.500
	10	10.750	9.750	0.500
	12	12.750	11.750	0.500

* Add twice the casing wall thickness to casing O.D. to obtain the approximate O.D. of the external pipe couplings.

ATTACHMENT A
DRILLING EQUIPMENT SIZES
PAGE TWO

Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Flush Coupled Casing (Ref. 7)	RX	1 7/16	1 3/16	1 3/16
	EX	1 13/16	1 5/8	1 1/2
	AX	2 1/4	2	1 29/32
	BX	2 7/8	2 9/16	2 3/8
	NX	3 1/2	3 3/16	3
	HX	4 1/2	4 1/8	3 15/16
Flush Joint Casing (Ref. 7)	RW	1 7/16	1 3/16	
	EW	1 13/16	1 1/2	
	AW	2 1/4	1 29/32	
	BW	2 7/8	2 3/8	
	NW	3 1/2	3	
	HW	4 1/2	4	
	PW	5 1/2	5	
	SW	6 5/8	6	
	UW	7 5/8	7	
	ZW	8 5/8	8	
Diamond Core Barrels (Ref. 7)	EWM	1 1/2	7/8**	
	AWM	1 7/8	1 1/8**	
	BWM	2 3/8	1 5/8**	
	NWM	3	2 1/8	
	HWG	3 7/8	3	
	2 3/4 x 3 7/8	3 7/8	2 11/16	
	4 x 5 1/2	5 1/2	3 15/16	
	6 x 7 3/4	7 3/4	5 15/16	
	AQ (wireline)	1 57/64	1 1/16**	
	BQ (wireline)	2 23/64	1 7/16**	
	NQ (wireline)	2 63/64	1 7/8	
	HQ (wireline)	3 25/32	2 1/2	

** Because of the fragile nature of the core and the difficulty to identify rock details, use of small-diameter core (1 3/8") is not recommended.

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1.0 PURPOSE

The purpose of this document is to establish standard procedures and technical guidance on borehole and sample logging.

2.0 SCOPE

These procedures provide descriptions of the standard techniques for borehole and sample logging. These techniques shall be used for each boring logged to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Geologist. Responsible for supervising all boring activities and assuring that each borehole is completely logged. If more than one rig is being used on site, the Site Geologist must make sure that each field geologist is properly trained in logging procedures. A brief review or training session may be necessary prior to the start up of the field program and/or upon completion of the first boring.

5.0 PROCEDURES

The classification of soil and rocks is one of the most important jobs of the field geologist/engineer. To maintain a consistent flow of information, it is imperative that the field geologist/engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

5.1 Materials Needed

When logging soil and rock samples, the geologist or engineer may be equipped with the following:

- Rock hammer
- Knife
- Camera
- Dilute hydrochloric acid (HCl)
- Ruler (marked in tenths and hundredths of feet)
- Hand Lens

5.2 Classification of Soils

All data shall be written directly on the boring log (Figure 1) or in a field notebook if more space is needed. Details on filling out the boring log are discussed in Section 5.5.

5.2.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Figure 1 (Continued).

FIGURE 1

BORING LOG (EXAMPLE)

BORING LOG

Page ___ of ___

PROJECT NAME: _____ BORING NUMBER: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	MATERIAL DESCRIPTION: Color	MATERIAL DESCRIPTION: Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	PID/FID Reading (ppm): Sampler BZ	PID/FID Reading (ppm): Borehole**	PID/FID Reading (ppm): Driller BZ**

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.

Remarks: _____

Drilling Area Background (ppm): [ ]

Converted to Well: Yes _____ No _____ Well I.D. #: _____

FIGURE 1 (CONTINUED)

SOIL TERMS

UNIFIED SOIL CLASSIFICATION (USCS)

COARSE-GRAINED SOILS — More Than Half of Material is LARGER Than No. 200 Sieve Size

FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights			GROUP SYMBOL	TYPICAL NAMES
GRAVELS (50%(+)>1/4"Ø	CLEAN GRAVELS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
	GRAVELS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see ML)	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.
		Plastic fines (for identification procedures, see CL)	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
SANDS 50%(+)<1/4"Ø	CLEAN SANDS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	SW	Well graded sand, gravelly sands, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands, little or no fines.
	SANDS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see MCL)	SM	Silty sands, poorly graded sand silt mixtures.
		Plastic fines (for identification procedures, see CL)	SC	Clayey sands, poorly graded sand clay mixtures.

FINE-GRAINED SOILS — More Than Half of Material is SMALLER Than No. 200 Sieve Size

FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)	Identification Procedures on Fraction Smaller than No. 40 Sieve Size				GROUP SYMBOL	TYPICAL NAMES
		DAY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)		
SILTS AND CLAYS Liquid Limit <50		None to Slight	Quick to Slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
		Medium to High	None to Very Slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		Slight to Medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.
SILTS AND CLAYS Liquid Limit >50		Slight to Medium	Slow to None	Slight to Medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		High to Very High	None	High	CH	Inorganic clays of high plasticity, fat clays.
		Medium to High	None to Very Slow	Slight to Medium	OH	Organic clays of medium to high plasticity.
HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.				Pt	Peat and other organic soils

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example, GW GC, well graded gravel sand mixture with clay binder.
All sieve sizes on this chart are U.S. Standard.

DENSITY OF GRANULAR SOILS

DESIGNATION	STANDARD PENETRATION RESISTANCE BLOWS/FOOT
Very Loose	0-4
Loose	5-10
Medium Loose	11-30
Dense	31-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	UNC COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT	FIELD IDENTIFICATION METHODS
Very Soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb.
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb.
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail.

ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)			ROCK BROKENNESS		
Descriptive Terms	Screwdriver or Knife Effects	Hammer Effects	Descriptive Terms	Abbreviation	Spacing
Soft	Easily Gouged	Crushes when pressed with hammer	Very Broken	(V. Br.)	0-2"
Medium Soft	Can be Gouged	Breaks (one blow); crumbly edges	Broken	(Br.)	2"-1'
Medium Hard	Can be scratched	Breaks (one blow); sharp edges	Blocky	(Bl.)	1'-3"
Hard	Cannot be scratched	Breaks conchoidally (several blows); sharp edges	Massive	(M.)	3'-10'

LEGEND:

SOIL SAMPLES - TYPES

S-2" Split-Barrel Sample

ST-3" O.D. Undisturbed Sample

O - Other Samples, Specify in Remarks

ROCK SAMPLES - TYPES

X-NX (Conventional) Core (-2-1/8" O.D.)

Q-NQ (Wireline) Core (-1-7/8" O.D.)

Z - Other Core Sizes, Specify in Remarks

WATER LEVELS

12/18 ▼ 12.6' Initial Level w/Date & Depth

12/18 ▼ 12.6' Stabilized Level w/Date & Depth

This method of classification identifies soil types on the basis of grain size and cohesiveness.

Fine-grained soils, or fines, are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition. The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

Coarse-grained soils shall be divided into rock fragments, sand, or gravel. The terms sand and gravel not only refer to the size of the soil particles but also to their depositional history. To insure accuracy in description, the term rock fragments shall be used to indicate angular granular materials resulting from the breakup of rock. The sharp edges typically observed indicate little or no transport from their source area, and therefore the term provides additional information in reconstructing the depositional environment of the soils encountered. When the term "rock fragments" is used it shall be followed by a size designation such as "(1/4 inchΦ-1/2 inchΦ)" or "coarse-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

5.2.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors. Samplers tend to smear the sample surface creating color variations between the sample interior and exterior.

The term "mottled" shall be used to indicate soils irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.

Soil Color Charts shall not be used unless specified by the project manager.

5.2.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist is to first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer-grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

The density of noncohesive, granular soils is classified according to standard penetration resistances obtained from split-barrel sampling performed according to the methods detailed in Standard Operating Procedures GH-1.3 and SA-1.3. Those designations are:

Designation	Standard Penetration Resistance (Blows per Foot)
Very loose	0 to 4
Loose	5 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	Over 50

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12 inches into the material using a 140-pound hammer falling freely through 30 inches. The sampler is driven through an 18-inch sample interval, and the number of blows is recorded for each 6-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of each sample interval. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the log and referenced to the sample number. Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, or SC (see Figure 1).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Figure 2.

Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Figure 1).

The consistency of cohesive soils is determined either by blow counts, a pocket penetrometer (values listed in the table as Unconfined Compressive Strength), or by hand by determining the resistance to penetration by the thumb. The pocket penetrometer and thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample in the split-barrel sampler. The sample shall be broken in half and the thumb or penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency shall not be determined solely by blow counts. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are shown in Figure 2.

FIGURE 2

CONSISTENCY FOR COHESIVE SOILS

Consistency	Standard Penetration Resistance (Blows per Foot)	Unconfined Compressive Strength (Tons/Sq. Foot by pocket penetration)	Field Identification
Very soft	0 to 2	Less than 0.25	Easily penetrated several inches by fist
Soft	2 to 4	0.25 to 0.50	Easily penetrated several inches by thumb
Medium stiff	4 to 8	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort
Stiff	8 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 to 30	2.0 to 4.0	Readily indented by thumbnail
Hard	Over 30	More than 4.0	Indented with difficulty by thumbnail

5.2.4 Weight Percentages

In nature, soils are comprised of particles of varying size and shape, and are combinations of the various grain types. The following terms are useful in the description of soil:

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
Trace	0 - 10 percent
Some	11 - 30 percent
Adjective form of the soil type (e.g., "sandy")	31 - 50 percent

Examples:

- Silty fine sand: 50 to 69 percent fine sand, 31 to 50 percent silt.
- Medium to coarse sand, some silt: 70 to 80 percent medium to coarse sand, 11 to 30 percent silt.
- Fine sandy silt, trace clay: 50 to 68 percent silt, 31 to 49 percent fine sand, 1 to 10 percent clay.
- Clayey silt, some coarse sand: 70 to 89 percent clayey silt, 11 to 30 percent coarse sand.

5.2.5 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgment. A suggested parameter for this would be calling a soil wet if rolling it in the hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire drilling job.

Laboratory tests for water content shall be performed if the natural water content is important.

5.2.6 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil and rock is depending on grain size and composition. The classification to be used for stratification description is shown in Figure 3.

5.2.7 Texture/Fabric/Bedding

The texture/fabric/bedding of the soil shall be described. Texture is described as the relative angularity of the particles: rounded, subrounded, subangular, and angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation between particles (i.e., all the flat particles are parallel or there is some cementation). The bedding or structure shall also be noted (e.g., stratified, lensed, nonstratified, heterogeneous varved).

FIGURE 3

BEDDING THICKNESS CLASSIFICATION

Thickness (metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick Bedded
10 cm - 30 cm	4" - 1.0'	Medium Bedded
3 cm - 10 cm	1" - 4"	Thin Bedded
1 cm - 3 cm	2/5" - 1"	Very Thin Bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly Laminated
< 1 mm	<1/32"	Micro Laminated

(Weir, 1973 and Ingram, 1954)

5.2.8 Summary of Soil Classification

In summary, soils shall be classified in a similar manner by each geologist/engineer at a project site. The hierarchy of classification is as follows:

- Density and/or consistency
- Color
- Plasticity (Optional)
- Soil types
- Moisture content
- Stratification
- Texture, fabric, bedding
- Other distinguishing features

5.3 Classification of Rocks

Rocks are grouped into three main divisions: sedimentary, igneous and metamorphic. Sedimentary rocks are by far the predominant type exposed at the earth's surface. The following basic names are applied to the types of rocks found in sedimentary sequences:

- Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.

- Siltstone - Made up of granular materials less than 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.

- Claystone - Very fine-grained rock made up of clay and silt-size materials. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.

- Shale - A fissile very fine-grained rock. Fractures along bedding planes.

- Limestone - Rock made up predominantly of calcite ($CaCO_3$). Effervesces strongly upon the application of dilute hydrochloric acid.

- Coal - Rock consisting mainly of organic remains.

- Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record. The local abundance of any of these rock types is dependent upon the depositional history of the area. Conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

In classifying a sedimentary rock the following hierarchy shall be noted:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Weathering
- Other characteristics

5.3.1 Rock Type

As described above, there are numerous types of sedimentary rocks. In most cases, a rock will be a combination of several grain types, therefore, a modifier such as a sandy siltstone, or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, etc.

Grain size is the basis for the classification of clastic sedimentary rocks. Figure 4 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different than the USCS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse grained rocks. For example, the division between siltstone and claystone may not be measurable in the field. The boundary shall be determined by use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a claystone.

5.3.2 Color

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples shall be classified while wet, when possible, and air cored samples shall be scraped clean of cuttings prior to color classifications.

Rock color charts shall not be used unless specified by the Project Manager.

5.3.3 Bedding Thickness

The bedding thickness designations applied to soil classification (see Figure 3) will also be used for rock classification.

5.3.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

- Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).
- Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.
- Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.
- Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage here of the works "scratch" and "gouge." A scratch shall be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

FIGURE 4

GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4 - 64 mm
Granules	2 - 4 mm
Very Coarse Sand	1 - 2 mm
Coarse Sand	0.5 - 1 mm
Medium Sand	0.25 - 0.5 mm
Fine Sand	0.125 - 0.25 mm
Very Fine Sand	0.0625 - 0.125 mm
Silt	0.0039 - 0.0625 mm

After Wentworth, 1922

5.3.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is calculated and the fracturing is described by the following terms:

- Very broken (V. BR.) - Less than 2-inch spacing between fractures
- Broken (BR.) - 2-inch to 1-foot spacing between fractures
- Blocky (BL.) - 1- to 3-foot spacing between fractures
- Massive (M.) - 3 to 10-foot spacing between fractures

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run, to obtain a percentage.

Method of Calculating RQD
(After Deere, 1964)

$$RQD\ \% = r/l \times 100$$

r = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches length, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc.

l = Total length of the coring run.

5.3.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.

- Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration.

- Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.

- Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

5.3.7 Other Characteristics

The following items shall be included in the rock description:

- Description of contact between two rock units. These can be sharp or gradational.
- Stratification (parallel, cross stratified).

- Description of any filled cavities or vugs.
- Cementation (calcareous, siliceous, hematitic).
- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs shall be neat to the point where it can be reproduced on a copy machine for report presentation. The data shall be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

5.3.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

- Seam - Thin (12 inches or less), probably continuous layer.

- Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams."

- Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams."

- Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."

- Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

The preceding sections describe the classification of sedimentary rocks. The following are some basic names that are applied to igneous rocks:

- Basalt - A fine-grained extrusive rock composed primarily of calcic plagioclase and pyroxene.

- Rhyolite - A fine-grained volcanic rock containing abundant quartz and orthoclase. The fine-grained equivalent of a granite.

- Granite - A coarse-grained plutonic rock consisting essentially of alkali feldspar and quartz.

- Diorite - A coarse-grained plutonic rock consisting essentially of sodic plagioclase and hornblende.

- Gabbro - A coarse-grained plutonic rock consisting of calcic plagioclase and clinopyroxene. Loosely used for any coarse-grained dark igneous rock.

The following are some basic names that are applied to metamorphic rocks:

- Slate - A very fine-grained foliated rock possessing a well developed slaty cleavage. Contains predominantly chlorite, mica, quartz, and sericite.
- Phyllite - A fine-grained foliated rock that splits into thin flaky sheets with a silky sheen on cleavage surface.
- Schist - A medium to coarse-grained foliated rock with subparallel arrangement of the micaceous minerals which dominate its composition.
- Gneiss - A coarse-grained foliated rock with bands rich in granular and platy minerals.
- Quartzite - A fine- to coarse-grained nonfoliated rock breaking across grains, consisting essentially of quartz sand with silica cement.

5.4 Abbreviations

Abbreviations may be used in the description of a rock or soil. However, they shall be kept at a minimum. Following are some of the abbreviations that may be used:

C	-	Coarse	Lt	-	Light	Yl	-	Yellow
Med	-	Medium	BR	-	Broken	Or	-	Orange
F	-	Fine	BL	-	Blocky	SS	-	Sandstone
V	-	Very	M	-	Massive	Sh	-	Shale
Sl	-	Slight	Br	-	Brown	LS	-	Limestone
Occ	-	Occasional	Bl	-	Black	Fgr	-	Fine-grained
Tr	-	Trace						

5.5 Boring Logs and Documentation

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections shall be used to complete the logs. A sample boring log has been provided as Figure 5.

The field geologist/engineer shall use this example as a guide in completing each boring log. Each boring log shall be fully described by the geologist/engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided either on the back of the boring log or on a separate sheet, for field use.

FIGURE 5
COMPLETED BORING LOG (EXAMPLE)

BORING LOG

Page 1 of 1

PROJECT NAME: NSB - SITE
PROJECT NUMBER: 9594
DRILLING COMPANY: SOILTEST CO.
DRILLING RIG: CME-55

BORING NUMBER: SB/MW 1
DATE: 3/8/96
GEOLOGIST: SJ CONTI
DRILLER: R. ROCK

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS*	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
S-1	0.0	7/6	1.5/2.0		M DENSE	BRN	SILTY SAND - SOME	SM	MOIST SL. ORG.	5	0	0	0
@ 0800	2.0	9/10				TO BLK	ROCK FR: TR BRICKS		ODOR				
							(FILL)		FILL TO 4'±				
	4.0			4.0									
S-2 @		5/7	2.9/2.0		M DENSE	BRN	SILTY SAND - TR FINE	SM	MOIST - W ODOR	10	0	-	-
0810	6.0	3/8					GRAVEL		NAT. MATL. TOOK SAMPLE				
	•			7'± ▽					SB01-0406 FOR ANALYSIS				
	8.0			8.0									
S-3 @		6/8	1.9/2.0		DENSE	TAN BRN	FINE TO COARSE SAND	SW	WET	0	0	0	0
0820	10.0	17/16					TR. F. GRAVEL		HIT WATER: 7'±				
	12.0			12.0									
S-4 @		7/6	1.6/2.0		STIFF	GRAY	SILTY CLAY	CL	MOIST → WET	0	.5	-	-
0830	14.0	5/8											
	15.0			15.0					AUGER REF @ 15'				
				11 BLK 16	M HARD	BRN	SILTSTONE	VER	WEATHERED				
									LO ∡ JNTS @ 15.5				
9/5	①		4.0/5.0						WATER STAINS @ 16.5, 17.1, 17.5	0	0	0	0
				19'					LOSING SOME				
	20.0				HARD	GRAY	SANDSTONE - SOME	BR	DRILL H2O @ 17'±				
							SILTSTONE		SET TEMP 6" CAS TO 15.5				
4.9/5.0	②		5.0/5.0						SET 2" Φ PVC SCREEN 16-25	0	0	0	0
									SAND 14-25				
	25.0			25					PELLETS 12-14				

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.

• 1-20Z
1-80Z

Drilling Area Background (ppm): 0

Remarks: CME-55 R16, 4 1/4" ID HSA - 9" OD ±
2" SPLIT SPOONS - 140 LB HAMMER - 30" DROP
NX CORE IN BEDROCK RUN ① = 25 min, RUN ② = 15 min

Converted to Well: Yes ✓ No ____ Well I.D. #: MW-1

5.5.1 Soil Classification

- Identify site name, boring number, job number, etc. Elevations and water level data to be entered when surveyed data is available.

- Enter sample number (from SPT) under appropriate column. Enter depth sample was taken from (1 block = 1 foot). Fractional footages, i.e., change of lithology at 13.7 feet, shall be lined off at the proportional location between the 13- and 14-foot marks. Enter blow counts (Standard Penetration Resistance) diagonally (as shown). Standard penetration resistance is covered in Section 5.2.3.

- Determine sample recovery/sample length as shown. Measure the total length of sample recovered from the split-spoon sampler, including material in the drive shoe. Do not include cuttings or wash material that may be in the upper portion of the sample tube.

- Indicate any change in lithology by drawing a line at the appropriate depth. For example, if clayey silt was encountered from 0 to 5.5 feet and shale from 5.5 to 6.0 feet, a line shall be drawn at this increment. This information is helpful in the construction of cross-sections. As an alternative, symbols may be used to identify each change in lithology.

- The density of granular soils is obtained by adding the number of blows for the last two increments. Refer to Density of Granular Soils Chart on back of log sheet. For consistency of cohesive soils refer also to the back of log sheet - Consistency of Cohesive Soils. Enter this information under the appropriate column. Refer to Section 5.2.3.

- Enter color of the material in the appropriate column.

- Describe material using the USCS. Limit this column for sample description only. The predominate material is described last. If the primary soil is silt but has fines (clay) - use clayey silt. Limit soil descriptors to the following:

  - Trace: 0 - 10 percent
  - Some: 11 - 30 percent
  - And/Or: 31 - 50 percent

- Also indicate under Material Classification if the material is fill or natural soils. Indicate roots, organic material, etc.

- Enter USCS symbol - use chart on back of boring log as a guide. If the soils fall into one of two basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example ML/CL or SM/SP.

- The following information shall be entered under the "Remarks" column and shall include, but is not limited by, the following:

  - Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.

- Angularity - describe angularity of coarse grained particles using the terms angular, subangular, subrounded, or rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.
- Particle shape - flat, elongated, or flat and elongated.
- Maximum particle size or dimension.
- Water level observations.
- Reaction with HCl - none, weak, or strong.

- Additional comments:
  - Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.
  - Indicate odor and Photoionization Detector (PID) or Flame Ionization Detector (FID) reading if applicable.
  - Indicate any change in lithology by drawing a line through the lithology change column and indicate the depth. This will help when cross-sections are subsequently constructed.
  - At the bottom of the page indicate type of rig, drilling method, hammer size and drop, and any other useful information (i.e., borehole size, casing set, changes in drilling method).
  - Vertical lines shall be drawn (as shown in Figure 5) in columns 6 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.
  - Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.2 Rock Classification

- Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent, and core recovery under the appropriate columns.
- Indicate lithology change by drawing a line at the appropriate depth as explained in Section 5.5.1.
- Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.

- Enter color as determined while the core sample is wet; if the sample is cored by air, the core shall be scraped clean prior to describing color.

- Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.

- Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.

- The following information shall be entered under the remarks column. Items shall include but are not limited to the following:

  - Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.

  - Indicate calcareous zones, description of any cavities or vugs.

  - Indicate any loss or gain of drill water.

  - Indicate drop of drill tools or change in color of drill water.

- Remarks at the bottom of Boring Log shall include:

  - Type and size of core obtained.

  - Depth casing was set.

  - Type of rig used.

- As a final check the boring log shall include the following:

  - Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.

  - If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.3 Classification of Soil and Rock from Drill Cuttings

The previous sections describe procedures for classifying soil and rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that shall be followed when logging cuttings are:

- Obtain cutting samples at approximately 5-foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock"

bag for future reference, and label the jar or bag (i.e. hole number, depth, date, etc.). Cuttings shall be closely examined to determine general lithology.

- Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.
- Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.
- Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.
- Record this and any other useful information onto the boring log as provided in Figure 1.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split-barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

5.6 Review

Upon completion of the borings logs, copies shall be made and reviewed. Items to be reviewed include:

- Checking for consistency of all logs.
- Checking for conformance to the guideline.
- Checking to see that all information is entered in their respective columns and spaces.

6.0 REFERENCES

Unified Soil Classification System (USCS).

ASTM D2488, 1985.

Earth Manual, U.S. Department of the Interior, 1974.

7.0 RECORDS

Originals of the boring logs shall be retained in the project files.

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1.0 PURPOSE

This procedure is intended to describe methods for conducting packer (pressure) hydraulic conductivity testing in boreholes. The data obtained through packer testing is evaluated to provide information regarding the hydraulic conductivity (water transmitting capability) of the tested subsurface interval(s).

2.0 SCOPE

Packer testing is most commonly performed in consolidated rock formations, however, it can also be performed in unconsolidated formations under some circumstances. The testing can be performed on subsurface units either in the saturated or unsaturated zone. Packer testing may be useful in both hydrogeologic and geotechnical investigations.

3.0 GLOSSARY

Packer - A device used to isolate a section of a borehole which is to be hydraulically tested or sampled from upper and/or lower portions of the borehole. Pneumatic packers are typically constructed of rubber tubing slightly smaller in diameter than the borehole to be tested, and their length is several times their diameter in size. The packers are inflated with air or nitrogen (i.e., nonflammable gases) to seal off the desired test interval of the borehole. Mechanical packers also are typically made of rubber, however, sealing is achieved by shortening the length of the packer mechanically (causing an increase in diameter) rather than by inflation. Pneumatic packers are more common than mechanical packers. Packers are used either singly or in pairs to isolate portions of a borehole. Packer lengths should be at least five times as long as the borehole diameter.

Water Pressure Gauge - A gauge which measures the water pressure at the location in which the packer test is being performed. The pressure gauge measures pressure in pounds per square inch (psi) and should be capable of measuring to a resolution and accuracy of ± 2 psi. During the performance of a packer test, the water pressure gauge reading should remain constant at the desired pressure. For maximum accuracy, the pressure range of the gauge should be close to the maximum expected testing pressure. For example, if the tests are to be run at pressures up to 60 psi, a gauge with a range of 0 to 100 psi should be used, as opposed to a gauge with a range of 0 to 2,000 psi. For maximum accuracy, the water pressure gauge should be installed either on the elbow connected to the waterline coming out of the borehole, or on the waterline between the elbow and the packers.

Water Flow Meter - The water flow meter is used to measure the amount of flow into the formation during the performance of a packer test. Flow meters normally measure in gallons or cubic feet (ft^3), and measure the total amount of flow (not the rate of flow). Flow meters should have a resolution and accuracy of 0.1 gallons or 0.01 ft^3.

4.0 RESPONSIBILITIES

Site Geologist - The site geologist, in conjunction with the Project Manager and Senior Geologist, is responsible for determining packer test intervals, testing pressures and test times and duration. He/she must also check the test setup to ensure that the proper equipment is being used and is connected in the proper sequence. During the actual performance of the test, the site geologist is responsible for collecting time/water flow data and obtaining the necessary data regarding the packer test setup (static water level, depth to test interval, height of swivel above ground, packer test interval, packer pressures, water pressures, borehole size, etc.).

5.0 PROCEDURES

5.1 Testing Procedure

Once the need for packer testing has been established and the required equipment gathered, the site geologist should identify the interval(s) of the borehole to be packer tested. Typical packer testing zones can be fracture zones or unfractured intervals of a formation that are thought to be permeable. Packer tests can be used for identifying water yielding zones or intervals of suspected low permeability, or to identify possible confining layers. The site geologist should have the boring log present as a reference during packer testing operations, as well as any rock core obtained from the boring to be tested. When testing several discrete intervals within a borehole, a double packer assembly is generally used, with packers spaced 5 to 10 feet apart. The test length selected should be at least five times as long as the borehole diameter, except in special circumstances where one discrete fracture or thin water bearing zone is to be isolated and tested. If only one or two intervals near the bottom of the borehole are to be tested, a single packer assembly may be used. Prior to testing, the borehole should be flushed to remove cuttings/mud which may affect the test.

After the final design of the packer test has been decided upon, the equipment required should be assembled and installed. Exhibit A illustrates typical packer test setups. Along with the packers, water line, air line, and air tank/valves/gauges (for pneumatic packers), the required elements of the test apparatus include a pump (to pump water into the system under pressure), a bypass value (used to control the water pressure during the test), the water flow meter, and the water pressure gauge. A surge chamber may be required if the pump does not pump at a steady pressure, to compensate for cyclic variations in pumping pressures. The flow valve can be used to isolate the downhole portion of the packer test assembly from the remaining portion, in order to perform a holding test if desired. The bypass valve may also be used for this purpose.

Once the packer testing setup is assembled and installed to the initial interval to be tested, the packers should be inflated/expanded to isolate the testing interval. Pneumatic packers should not be overpressured, as this may cause a blow out. Generally, 80-140 psi inflation pressure is adequate for most testing applications. After packer inflation expansion, water is pumped through the system at the desired pressure. The selected water pressure(s) used vary with testing situations. The maximum testing pressure which may be used can be calculated by the formula Pmax = 10 psi + 1 psi/ft of depth to the top of the tested interval. A good rule of thumb to ensure that the formation tested is not overpressured (which could hydraulically fracture or jack the rock mass) is to not exceed 1 psi/ft of depth or 100 psi total, whichever is lower. It is generally advisable to perform 2-3 tests at each test interval, which can be done at different pressures (example: 20, 40, and 60 psi) or at the same pressure. The bypass valve is used to control water pressures in the system. As more water is routed out of the bypass line, pressure in the testing portion of the system is decreased, and vice versa.

After water pressure has stabilized at the desired testing pressure, the test should be started. The flow meter reading at the beginning of the testing period should be recorded, then flow meter readings should be taken at 15- to 30-second intervals for the duration of the test. A minimum of 5 minutes of readings should be taken for each test. All time/flow measurements should be recorded on the packer test report form (or equivalent) provided as Exhibit B, along with other pertinent data. If higher than expected water flow through the system occurs during the test, the test should be repeated using the same water pressure but increasing the packer air pressure, to check for leakage around the packers. If the flow rate decreases, then leakage occurred during the previous test. Also, if water levels rise in the borehole/borehole casing during the test, leakage around the packers may be occurring, thus invalidating the test results. If no measurable flow occurs within 5 to 10 minutes of testing, a holding test can be performed for several minutes as a check. To conduct the holding test, the flow or bypass value

is shut to completely isolate the system, then the water pressure gauge is checked for a drop in pressure over time. The water pressure should remain essentially unchanged during the period of isolation if the formation tested is not taking any water. Generally, if the formation does not take water at the initial test pressure, there is no need to repeat the test at a higher water pressure. After the completion of testing at one interval, the downhole packer assembly should be moved to the next interval to be tested, and the testing procedure repeated.

5.2 Data Evaluation

Formulas for evaluating pressure testing data are given in U.S. Department of Interior publication; Groundwater Manual (1981). The formulas have the best validity when stratum thickness is at least five times the length of the hole tested and are considered more accurate for tests in the saturated zone than unsaturated zone. For convenience, the formula for pressure testing can be written:

$$K\left(\frac{Ft}{Yr}\right) = C_p \frac{Q\ (gal/\min)}{H\ (feet)}$$

Where: H = head of water acting on the test length. In tests in the saturated zone, H is the distance from the water table to the swivel plus the applied pressure in units of feet of water. Where the test zone is above the water table in the unsaturated zone, H is the distance from the center of the length tested to the swivel plus the applied pressure in feet of water. For gravity tests, where water is added but no pressure is applied, measurements for H are made to the water level inside the casing. For highly permeable formations, head loss due to friction in the piping may significantly alter the testing results. If desired, the head loss due to friction can be considered by using the Tables provided in the Ground Water Manual. Alternatively, head loss curves can be determined more accurately by laying out and connecting the water pipe on the ground, attaching pressure gauges to both ends of the piping, then pumping water through the piping at varying pressures and generating head loss curves through the pressure gauge readings. The outflow end of the pipe must be constricted by use of a valve so that varying pressure build-ups within the piping can be created and maintained.

K = Hydraulic conductivity, ft/yr
Q = Rate of inflow, gallons per minute (gpm)
L = Length of test section, ft
Cp = Volume per linear foot (see following discussion)

Values of Cp for common borehole sizes are given in the following table:

Length of Test Section in Feet, L	Cp Values			
	Boring Sizes			
	EX (1.5")	AX (1.875")	BX (2.37")	NX (3.0")
1	31,000	28,500	25,800	23,300
2	19,400	18,100	16,800	15,500
3	14,400	13,600	12,700	11,800
4	11,600	11,000	10,300	9,700
5	9,800	9,300	8,800	8,200
6	8,500	8,100	7,600	7,200
7	7,500	7,200	6,800	6,400
8	6,800	6,500	6,100	5,800
9	6,200	5,900	5,600	5,300
10	5,700	5,400	5,200	4,900
15	4,100	3,900	3,700	3,600
20	3,200	3,100	3,000	2,800

When testing a borehole with a diameter other than those listed above, the appropriate Cp value can be calculated using the formula Cp = (1/2 π) ln (L/r) (70,315.5) where r = borehole radius in feet.

An example of pressure testing data evaluation is presented below:

Nx (tooling designation) casing set to a depth of 5 feet
Q = 2.2 gal/min
ln - natural log
L = 1 foot
h (gravity) = distance from groundwater level to gauge = 3.5 feet
h (pressure) = 5 psi x 2.31 (conversion factor) = 11.6 feet of water
H = h (gravity) + h (pressure) = 15.1 feet
From table Cp = 23,300

$$K = Cp\frac{Q}{H}$$

$$= \frac{(23{,}300)(2.2)}{15.1}$$

= 3,395 ft/yr : 3.3 x 10^{-3} cm/sec (after conversion factors applied)

This SOP presents guidelines for performing packer pressure testing to determine formation hydraulic conductivities. Packers can also be utilized to perform gravity tests (slug tests) or to perform groundwater sampling operations. Slug testing using packers can be performed by applying the methodologies described in SOP GH-2.4, in-situ Hydraulic Conductivity Testing. It should be noted that

the radius of the water pipe should be used in place of well casing radius in calculations for evaluating slug test data when packers are used. Sampling can be performed using packers, by installing a submersible pump in between the packers and modifying the design of the system appropriately.

5.3 Review, Revision, and Approval

All packer testing data and calculations should be reviewed by senior-level personnel to check for completeness and accuracy. The person reviewing the calculations should indicate approval of the data/calculations by initialing and dating the data/calculation sheets.

5.4 Distribution

A copy of the approved data and calculations should be retained by the responsible site geologist. Other copies should be distributed to project personnel as needed. The original data/calculation sheets must be placed in the project central file. Copies may also be included in project reports when appropriate.

6.0 REFERENCES

U.S. Department of the Interior, 1974. Earth Manual, Section Edition. U.S. Government Printing Office, Washington, D.C.

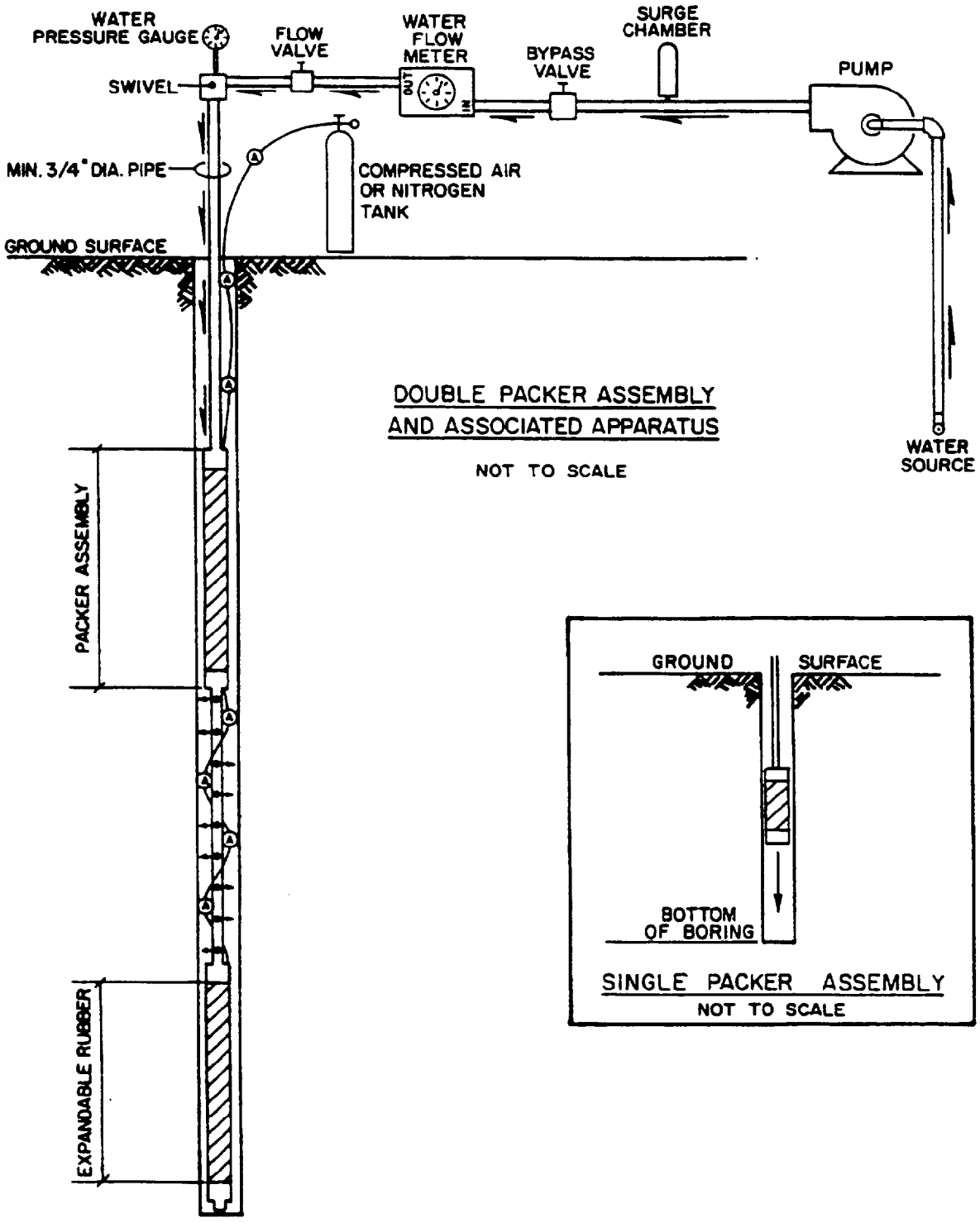
U.S. Department of the Interior, 1981. Ground Water Manual. U.S. Government Printing Office, Denver, Colorado.

7.0 RECORDS

The Packer Testing Report Form (Exhibit B) should be used to record testing data. Supplemental information, if required, should be recorded in the field logbook. The boring log should be available for use as a reference during packer testing and data analysis activities.

EXHIBIT A

TYPICAL PACKER TEST SETUPS



DOUBLE PACKER ASSEMBLY AND ASSOCIATED APPARATUS

NOT TO SCALE

SINGLE PACKER ASSEMBLY

NOT TO SCALE

EXHIBIT B

PACKER TEST REPORT

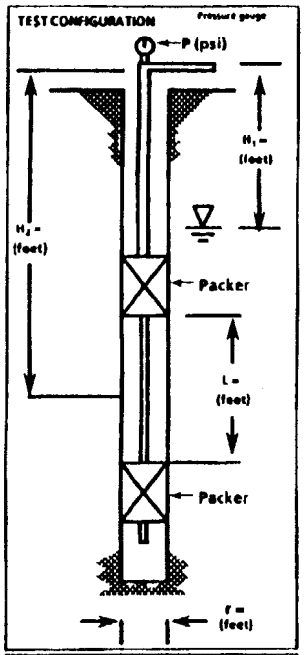
PROJECT: _____ PROJECT NO.: _____ TEST NO: _____ PAGE ____ OF ____

BORING NO.: _____ CASING DEPTH: _____ CONTRACTOR: _____ STATIC WATER LEVEL _____

TEST INTERVAL: _____ BY: _____ CHECKED: _____ PACKER PRESSURE _____

Flow Test					Calculated Results							
Pressure, p (psi)	Elapsed Time (min)	Flow Reading	Δ Flow, ΔQ (ft^3)	Δ Flow, ΔQ (gal)	Flow Rate Q (gal/min)	H_1* (ft)	Hp(ft) = 2.31 (psi)	H_2* (ft)	H = Hp + (H1 or H2)	Cp	K (ft/yr) = Cp Q/H	K (cm/sec) = 9.67 x 10^{-7} K (ft/yr)

TEST CONFIGURATION



Length of Test Section in feet, L	Cp Loading Bit Size			
	EX (1.5")	AX (1.875")	BX (2.375")	NX (3")
1	31,000	28,500	25,000	23,300
2	19,400	18,100	16,000	15,500
5	9,800	9,300	8,000	8,200
8	6,800	6,500	6,100	5,800
10	5,700	5,400	5,200	4,900
15	4,100	3,900	3,700	3,600
20	3,200	3,100	3,000	2,800

$CP = (1/(2 \pi L)) \ln(L/r)(70,315.5)$

7.48 Gallons = 1 Ft^3

1 psi = 2.31 ft head

* H_1 is used when the test length is below the water table.
H_2 is used when the test length is above the water table.

Remarks: _____

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Revision 0		Effective Date 03/01/96

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B PUMPING TEST DATA SHEET - OBSERVATION WELL 10

1.0 PURPOSE

The objective of this procedure is to provide general reference information and technical guidance on the performance and evaluation of pumping tests.

2.0 SCOPE

This procedure gives overall technical guidance for the performance and evaluation of pumping tests. The methodologies presented should be modified to meet the requirements/constraints of specific projects.

Pumping test data analysis is subject to much interpretation. Therefore, evaluation of the test results should be performed by an experienced hydrogeologist familiar with pumping test analytical techniques and interpretation. Due to the complexity of some of the evaluation methods and the wide variety of corrections which may be required to be factored into the data obtained, this guideline presents only a general overview of the pumping test evaluation process. The references provided in Section 6.0 should be consulted for detailed discussions regarding pumping test evaluation techniques.

3.0 GLOSSARY

Cone of Influence - The area around a discharging well where the hydraulic head in the aquifer has been resultingly lowered. Also called cone of depression.

Confined Aquifer - An aquifer that is overlain and underlain by strata of lower permeability. The potentiometric surface of a confined aquifer is higher than the base of the upper confining layer at any given point.

Discharge (Q) - Volume of water removed per unit time.

Drawdown (S) - Difference between the elevation of initial static water level and the water level position at a given time during pumping.

Hydraulic Conductivity (K) - A quantitative measure of the ability of porous material to transmit water. Volume of water that will flow through a unit cross sectional area of porous material per unit time under a head gradient. Hydraulic conductivity is dependent upon properties of the medium and fluid.

Pumping Test - A test made by pumping a well for a period of time and observing the resulting change in hydraulic head in the aquifer. A pumping test may be used to determine the hydraulic characteristics of the aquifer and the capacity of the pumped well.

Specific Capacity (SC) - Rate of yield per unit drawdown. Often expressed as gallons per minute per foot of drawdown.

Specific Storage - The amount of water released from or taken into storage per unit volume of aquifer per unit change in head.

Specific yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the total volume of the rock or soil.

Storage Coefficient (S) - Volume of water an aquifer releases from or takes into storage per unit volume of aquifer per unit change in head. The product of specific storage times saturated thickness. Also called storativity.

Transmissivity (T) - A quantitative measure of the ability of an aquifer to transmit water. The product of the hydraulic conductivity times saturated thickness.

4.0 RESPONSIBILITIES

Project Hydrogeologist - The Project Hydrogeologist, in conjunction with the Project Manager, has the responsibility of determining the need to perform a pumping test or tests for investigative purposes. Factors that should be taken into account when considering whether a pumping test should be performed or not include:

- Project objectives and the data required to meet these objectives.
- The amount and accuracy of hydrogeologic data currently available.
- Cost and schedule constraints.
- Physical site limitations (discharge of contaminated/uncontaminated water, aquifer water yielding capability, access, etc.)

Pumping tests (especially long-term tests) can be time-consuming, labor intensive, and costly. On the other hand, pumping tests generally yield the most accurate data regarding aquifer characteristics that can be obtained, when designed, performed, and evaluated properly. Specific uses for pumping tests include:

- Determination of aquifer hydraulic characteristics.
- Determination of the extent of influence of a pumped well.
- Design of groundwater withdrawal systems (for groundwater treatment or water supply).
- Determination of the interconnection between water bearing formations.
- Identification of aquifer boundaries (recharge/discharge boundaries).

Once the need to perform a pumping test has been established, the Project Hydrogeologist is responsible for the design and oversight of the pumping test, including identifying the wells to be used, designing and locating the pumping and observation wells as needed, specifying methodologies to be used, and determining the length of time of the test. The Project Hydrogeologist should ensure that all field personnel involved are familiar with the planned test and the field operations related to the performance of the test. During the startup of the pumping test, the Project Hydrogeologist may need to be onsite to ensure that proper field procedures are used. Data generated during the performance of the pumping test should be concurrently reviewed by the Project Hydrogeologist to identify any modifications to the planned procedure that may be required during the performance of the test. Data reduction/evaluation should be performed under the supervision of the Project Hydrogeologist.

Field Personnel - All field personnel should be familiar with the overall methodology of performing pumping tests, as well as being familiar with the specific requirements of each individual test that they will participate in. The field personnel should be familiar with the types and uses of the various field equipment required for the performance of a pumping test (surface or submersible pumps, generators, water level measuring devices, data sheets, support equipment). It is the responsibility of the field personnel to alert the Project Hydrogeologist to any unexpected conditions that may be encountered that would require modifications to the planned procedure. The field personnel are responsible for performing the test as described in the approved project plans and any approved modifications. Once

the pumping test has been completed, field personnel are to assist the Project Hydrogeologist in the process of data reduction/evaluation.

5.0 PROCEDURES

5.1 Planning for a Pumping Test

The need for and design of a pumping test is determined largely by the project goals and geologic/hydrogeologic conditions within the study area. The pumping test should be set up so that the results obtained will be representative of the area under study.

As much information as possible should be collected and evaluated before running a pumping test. This includes data regarding physical and hydraulic characteristics of the aquifer, groundwater flow direction, hydraulic gradients, velocity, regional water level trend, the existence of other pumping wells in the vicinity of the test area, and the expected quality/quantity of the discharge water.

The placement and design of the pumping well is critical to the success of the pumping test. Placement of the well is dependent on pumping test objectives and local geologic conditions. In general, the pumping well should fully penetrate the aquifer to be pumped, and be screened across the entire saturated interval of the aquifer. Due to project constraints, this is often not the case, and corrections must be factored into the data analysis.

If an existing well is to be used for a test, the well should closely conform to the requirements for aquifer testing. Boring logs, construction data, and performance characteristics of other wells in the area should be examined to develop a preliminary estimate of the aquifer characteristics. Transmissivities can be estimated from the boring logs and preliminary testing.

Any number of observation wells may be used. The number chosen depends on maintaining a balance between cost and need to obtain the maximum amount of accurate and reliable data. If three of four observation wells are to be installed in the pumped aquifer, all but one well should be installed along a radial line from the pumping well, with the remaining well placed along a line normal to the line of observation wells and passing through the pumping well, to detect any radial anisotropy within the aquifer. If two observation wells are to be installed, they should be placed in a straight line away from the pumping well. In a fracture controlled bedrock flow system; joint orientations should be considered when deciding where to place observation wells.

When a pumping well does not fully penetrate an unconfined aquifer (any well with an 85 percent or more open or screened hole in the saturated thickness may be considered as fully penetrating), the observation wells should be located at a minimum distance equal to 1-1/2 to 2 times the aquifer thickness from a partially penetrating pumping well. This minimizes the effect of flow field distortions resulting from pumping a partially penetrating well.

If the confined aquifer is not thick, the pumping well should be screened for the entire thickness of the aquifer. The nearest observation well should be located at least 25 feet from the pumping well and should penetrate and be screened in the middle portion of the aquifer.

Observation wells screened within the aquifer that is being pumped will provide information regarding aquifer characteristics. Wells screened in an overlying or underlying aquifer will provide information regarding the degree of interconnection between aquifers. If an observation well is screened in an overlying aquifer, it should be placed close to the pumping well so that the response of the overlying aquifer is monitored at a point where the difference in head between aquifers is relatively large.

The pumping and observation well configurations and locations described above are not requirements, but are suggested setups to maximize the accuracy of the data generated. In many instances, less than ideal conditions regarding screened intervals/depths and observation well numbers/locations will be encountered due to project constraints. Valid pumping tests can still be performed if the wells used do not conform to the ideal setup.

Single well pumping tests can be performed when project constraints do not allow for the installation of observation wells. The data obtained from these tests is less accurate than for tests performed using observation wells, and specific yield/specific storage cannot be determined. Drawdown measurements in a pumped well may not reflect the actual drawdown in the adjacent aquifer due to well inefficiency, so this factor must be considered when interpreting results.

5.2 Preparation for a Test

For a few days before starting a long-term pumping test, water levels in the pumping well and observation wells should be measured at about the same time each day to determine whether there is a measurable trend in groundwater levels. If such a trend is apparent, a graph of the change in water level versus time should be prepared and used to correct the water levels obtained during the test.

Pumping wells should undergo a preliminary pumping prior to the actual test to ensure that the well will function at it's maximum efficiency. This will enable fines to be flushed from the formation and a steady flow rate to be established. The preliminary pumping should determine the maximum drawdown in the well at a given pumping rate and establish the pumping rate for the later test. The aquifer should then be given adequate time to fully recover before the pumping test is begun.

Step-drawdown tests can be performed prior to the actual pumping test, to determine the optimum pumping rate for the test. A step-drawdown test consists of pumping a well at several successively higher rates, for a given time period (1/2-2 hours for each rate), and measuring the rate of drawdown for each pumping rate. If possible, the well should be allowed to recover between tests. The resulting data generated can be used to predict drawdown versus time over an extended period for various pumping rates.

Barometric changes may affect water levels in wells. An increase in barometric pressure may cause a decrease in the water level. The response of wells to changes in barometric pressure should be determined in order to correct the measurement of water levels during a long-term pumping test.

A record should be maintained of the pumping times and discharge rates of other pumping wells in the vicinity if their radius of influence intersects the cone of depression of the pumping test well.

In areas of severe winter climate, where the frostline may extend to depths of several feet, pumping tests should be avoided during the winter where the water table is near ground surface. Under some circumstances, the frozen soil acts as a confining bed, combining with leaky aquifer and delayed yield characteristics to make the results of the test unreliable.

5.3 Conducting a Test

Immediately before the pump is started, the water levels should be measured in the pumping well and all observation wells to determine the static water levels upon which drawdowns will be based. These data and the time of measurement should be recorded on a pumping test data sheet (see Attachment A for an example).

It may be useful to collect water samples from the pumping well (at least) before and after pumping. This data can give an indication of changes in groundwater quality due to pumpage.

Critical data that must be collected for each pumping test includes the time that pumping started and ended, water level measurements during the test, periodic measurements of the pumping rate, and the distances between the pumping well and the observation wells.

Pump selection depends on the expected pumping rate and the physical constraints of the test (e.g., depth to water, expected total drawdown, pumping well diameter). Pump size is related to the required discharge capacity and the well diameter. Submersible pumps or air-lift set-ups are required when the drawdown of the water level is expected to exceed 25 feet below ground surface. Suction pumps can be used if total drawdown plus well headspace is not expected to exceed 25 feet.

Once pumping is initiated, the flow rate should immediately be measured and adjusted as necessary to achieve a constant discharge at the desired rate. The discharge rate should be checked, adjusted, and recorded frequently during the performance of the test, especially during the early stages of the test. The initial pumping rate should not be the maximum rate that the pump is capable of, as progressive drawdown may decrease the pump's efficiency, thereby reducing the discharge rate. If the pump is initially operating at less than full capacity, the decrease in efficiency can be countered by increasing the pump speed or, if the discharge rate is controlled through a valve (as is more typical), opening the value further. Pumping rates can be monitored using a flowmeter or, for low volume pumping tests, a stopwatch and calibrated bucket can be used to measure discharge rates.

The tone or rhythm of an internal-combustion engine provides a check of performance. If there is sudden change in tone, the discharge should be checked immediately and proper adjustments made to the gate valve or to the engine speed if necessary.

At least 10 observations of drawdown within each log cycle of time should be measured in the pumping well and observation wells. Continuous water level recording for the observation wells nearest to the pumping well can be extremely useful. A suggested schedule for measurements is as follows:

- 0 to 10 minutes: 0.0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6.5, 8, and 10 minutes. It is important in the early part of the test to record with maximum accuracy the time at which readings are taken.
- 10 to 100 minutes: 10, 15, 20, 25, 30, 40, 50, 60, 80, and 100 minutes.
- 1- to 2-hour intervals: To the end of the first day.
- 500- to 1,000-minute intervals: After the first day.

Initially, there should be enough manpower available to station a minimum of one person at each well used in the pumping test, unless continuous water level recorders or pressure transducers and data loggers are used. After the first two hours of the pumping test, two people are usually sufficient to continue the test.

The total pumping time for a test depends on the type of aquifer and degree of accuracy desired, and can range from less than 2 hours to several days. Economizing on the period of pumping is not recommended. More reliable results are obtained if pumping continues until the cone of depression reaches a stabilized condition, however, this is not always practical or necessary. The cone of depression will continue to expand at a progressively slower rate until recharge of the aquifer equals the

pumping rate and a steady state condition is established. The time required to achieve steady state flow conditions may vary from less than an hour to beyond the practical limits of a pumping test. Under average conditions, it is good practice to run a large scale pumping test in a confined aquifer for at least 24 hours and in an unconfined aquifer, for a minimum of 72 hours. A longer period of pumping may reveal the presence of boundary conditions not previously known. Single well pumping tests or small scale tests may be run for shorter time periods. Preliminary field plotting of drawdown data should be conducted during the test to evaluate how the test is progressing and how much longer it should continue.

Water pumped from an unconfined aquifer during a pumping test should be disposed of in such a way so that the aquifer is not recharged by discharge water infiltration during the test, as recharge would influence the results obtained. Also, if contaminated water is pumped during the test, the water may have to be stored and treated or disposed of in an acceptable manner.

The method of disposal of discharge water from the pumping well should be planned. The discharge water could be routed to a storm sewer or surface water body if uncontaminated, or temporarily stored in tanks, drums or in a lined pit if collection is required. If necessary, contaminated discharge water should be transported and deposited into a designated secure area.

5.4 Recovery Test

When pumping is stopped after completing the drawdown portion of the pumping test, the cumulative drawdown and time at which pumping was discontinued are recorded. The rate of recovery of the water levels in the wells should then be measured.

The same procedure and time pattern are followed as at the beginning of a pumping test; that is, the depth-to-water is periodically measured during the recovery test in the pumping well and observation wells. Recovery data should follow the same general trend as drawdown data, and is considered in many cases to be more accurate and useful for pumping test analysis than drawdown data.

The recovery data should be recorded until the aquifer fully recovers, or as long as possible within project constraints.

5.5 Data Analysis

A constant rate pumping test can be run to determine transmissivity and hydraulic conductivity. If the effects of pumping the well can be measured in one or more observation wells at known distances from the pumping well, the specific yield or storage coefficient can also be determined. A good check of the transmissivity value can be made using recovery data from the pumped well and of transmissivity and storage coefficient from recovery rate measurements in observation wells.

An example data collection form for a pumping test is illustrated in Attachment A. The form can be used to record data for either the pumping well or an observation well. It should be noted that some different types of data are to be recorded for pumping versus observation wells.

The effects of all extraneous factors such as barometric pressure, tidal influence, injection interference, or other pumpage in the nearby area, can be adjusted for and corrected from the measured data by using applicable correlation techniques.

After correction of the raw data to eliminate or reduce the amount of extraneous interference, graphs are prepared showing resulting drawdowns versus time and/or distance; these are plotted on semi-log or

log-log paper. The graphs are used to determine aquifer characteristics by matching type curves or by straight line slope analysis processes. Analytical methods not requiring the use of a graph have also been developed. Selection of the most appropriate evaluation technique is dependent on the test setup and results.

5.6 Records

The Pumping Test Data Sheet exhibited on Attachment A should be used to record data from pumping wells and the Pumping Test Data Sheet exhibited on Attachment B should be used to record data from observation wells. A written log of the field setup and performance of the pumping test must also be kept in a bound site logbook or notebook. Descriptions of procedures used, daily activities, and any other pertinent observations made prior to, during, and following the test should also be recorded.

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ATTACHMENT A
EXAMPLE PUMPING TEST DATA SHEET, PUMPING WELL

PUMPING TEST DATA SHEET
PUMPING WELL

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
PUMPING TEST: [ ]
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DEPTH CORRECTION: _____

PUMPING WELL NUMBER: _____
DATE(s): _____
STEP DRAW DOWN TEST [ ]
MONITORING POINT: _____
ELEVATION OF MONITORING POINT: _____ MSL
PUMP SETTING (Ft. below monitoring point): _____

PUMPING TEST PERFORMED BY: _____
REMARKS: _____

TIME (Hour:Min.)	(t) ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	(s) DRAW DOWN OR RECOVERY (Ft.)	FLOW METER READING (Gals.)	(Q) PUMPING RATE (GPM)	REMARKS

SIGNATURES: _____

ATTACHMENT B
EXAMPLE PUMPING TEST DATA SHEET, OBSERVATION WELL

PUMPING TEST DATA SHEET
OBSERVATION WELL

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DEPTH CORRECTION: _____

OBSERVATION WELL NUMBER: _____
DATE(s): _____
MONITORING POINT: _____
ELEVATION OF MONITORING POINT: _____ MSL

CORRESPONDING PUMPING WELL NUMBER: _____
DISTANCE FROM PUMPING WELL (Ft.) (r): _____
REFERENCE POINT MEASUREMENTS BY: _____
REMARKS: _____

TIME (Hour:Min.)	(t) ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	(s) DRAW DOWN OR RECOVERY (Ft.)	REMARKS

SIGNATURES: _____

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ATTACHMENTS

A HYDRAULIC CONDUCTIVITY TESTING DATA SHEET 7

1.0 PURPOSE

This guideline is intended to describe procedures for performing in-situ hydraulic conductivity testing (slug testing) in boreholes and monitoring wells, and provide a short description of commonly used evaluation techniques for the data generated. Slug tests are used to provide data regarding the hydraulic properties of the formation tested. A variation of the slug test, called a constant-head test, is also briefly described.

2.0 SCOPE

Slug tests are short-term tests designed to provide approximate hydraulic conductivity values for the portion of a formation immediately surrounding the screened/open interval of a well or boring. These tests are less accurate than pumping tests, as a much more localized area is involved. Therefore, a number of slug tests are performed and averaged to determine a representative hydraulic conductivity value for the formation tested. Performance of slug tests may be preferable to pumping tests in situations where handling of large volumes of contaminated water is a concern or when time/budget constraints preclude the more expensive and time-consuming setup and performance of a pumping test.

Constant-head tests also are used to determine hydraulic conductivity values and are similar to slug tests with regard to the quality of data obtained and time/cost considerations. A disadvantage of constant-head tests is that a significant volume of water may be added to the formation, potentially affecting short-term water quality.

3.0 GLOSSARY

Hydraulic Conductivity (K) - A quantitative measure of the ability of porous material to transmit water. Volume of water that will flow through a unit cross-sectional area of porous material per unit time under a head gradient. Hydraulic conductivity is dependent upon properties of the medium and fluid. Common units of expression include centimeters per second (cm/sec), feet per day (ft/day), and gallons per day per foot^2 (gpd/ft^2).

Transmissivity (T) - A quantitative measure of the ability of an aquifer to transmit water. The product of the hydraulic conductivity times the saturated thickness.

Slug Test - A rising head or falling head test used to measure hydraulic conductivity. A slug test consists of instantaneously changing the water level within a well and measuring the rate of recovery of the water level to equilibrium conditions. Slug tests are performed by either withdrawing a slug of water (rising head test) or adding a slug of water (falling head test), then measuring recovery over time. A solid slug of known volume can be used to displace a volume of water, thereby simulating the addition or removal of water.

4.0 RESPONSIBILITIES

Project Hydrogeologist - The project hydrogeologist, in conjunction with the Project Manager, shall evaluate the type(s) and extent of hydraulic testing required for a given project during the planning process, and design the field program accordingly. The project hydrogeologist also shall ensure that field personnel have the necessary training and guidance to properly perform the tests, and shall oversee data reduction activities, including selecting the appropriate evaluation techniques and checking calculations for accuracy.

Field Geologist - The field geologist is responsible for performing the planned field tests as specified in the project planning documents, (or approved modifications thereto). The field geologist also generally assists in the data evaluation process. The field geologist shall be knowledgeable in the testing methodologies used and is responsible for obtaining the necessary support equipment required to perform the field tests. All applicable data regarding testing procedures, equipment used, well construction, and geologic/hydrogeologic conditions shall be recorded by the field geologist. The field geologist shall be familiar enough with testing procedures/requirements to be able to recommend changes in methodology, should unanticipated field conditions be encountered.

5.0 PROCEDURES

5.1 In-situ Hydraulic Conductivity Testing in Wells

Slug tests are commonly performed in completed wells. Prior to testing, the well shall be thoroughly developed and allowed to stabilize, in order to obtain accurate results. Once the water level within the well has stabilized, it shall be quickly raised or lowered and the rate of recovery measured.

One of the basic assumptions of slug testing is that the initial change in water level is instantaneous; therefore, an effort shall be made to minimize the time involved in raising or lowering the water level initially. Various methods can be used to induce instantaneous (or nearly instantaneous) changes in water level within the well. A rise in water levels can be induced by pouring water into the well. A solid slug of known volume, quickly lowered below the water level within the well, will displace an equivalent volume of water and raise the water level within the well. The slug can be left in place until the water level restabilizes at the static water level, then suddenly removed to create a drop in water level within the well. An advantage of using a solid cylinder of known volume (slug) to change the water level is that no water is removed or added to the monitoring well. This eliminates the need to dispose of contaminated water and/or add water to the system, which might raise doubts regarding the representativeness of future groundwater samples. A bailer or pump can be used to withdraw water from the well. If a pump is used, pumping shall not continue for more than several seconds so that a cone of depression is not created which would adversely impact testing results. The pump hose shall also be removed from the well during the recovery period, as data analysis techniques involve volume of recovery versus time. and leaving the hose within the well would distort the calculated testing results by altering the apparent volume of recovery. Falling head slug tests should only be performed in wells with fully submerged screens, while rising head slug tests can be performed in wells with either partially or fully submerged screens/open intervals.

Other methods that can be used to change water levels within a well include creating a vacuum or a high pressure environment within the well. The vacuum method will raise water levels within the well, while the pressure method will depress the water level in the well. These methods are particularly useful in highly permeable formations where other methods are ineffective in creating measurable changes in water levels. Both of these methods are limited to wells which have completely submerged screens.

Rate of recovery measurements shall be obtained from time zero (maximum change in water level) until water level recovery exceeds 90 percent of the initial change in water level. In low permeability formations, the test may be cut-off short of 90 percent recovery due to time constraints. Time intervals between water level readings will vary according to the rate of recovery of the well. For a moderately fast recovering well, water level readings at 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.75, 1.0, 1.25, 1.5, 2.0, 2.5, 3.0, 4.0, . . . minutes may be required. With practice, readings at down to 0.05-minute (3 seconds) time intervals can be obtained with reasonable accuracy, using a pressure transducer and hand held readout. For wells which recover very fast, a pressure transducer and data logger may be required to obtain representative data. Time intervals between measurements can be extended for slow recovering wells.

A typical schedule for measurements for a slow recovering well would be 0, 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0, 8.0, 10.0, 15.0, 20.0, 30.0, . . . minutes from the beginning the test. Measurements shall be taken from the top of the well casing.

Water level measurements can be obtained using an electric water level indicator, popper, or pressure transducer. Steel tape coated with chalk or water sensitive paste although very accurate, is a slower method of obtaining water levels and is generally not recommended for use due to the frequency at which water level measurements need to be obtained during the performance of a slug test.

The following data shall be recorded when performing slug tests in wells or borings:

- Well/boring ID number
- Total depth of well/boring
- Screened/open interval depth and length
- Gravel pack interval depth and length
- Well and boring radii
- Well stickup above ground surface
- Gravel pack radius
- Static water level
- Aquifer thickness
- Depth to confining layer
- Time/recovery data
- Gravel pack porosity

A variation of the slug test, called a constant-head test, is a test in which water is added to the well at a measured rate sufficient to maintain the water level in the well at a constant height above the static water level. Once a stable elevated water level has been achieved, discharge (pumping) rate measurements are recorded in place of time/recovery data for approximately 10 to 20 minutes. The hydraulic conductivity is then calculated from this information. The constant-head test is generally not recommended for monitoring wells as large volumes of water may be introduced into the screened formation, potentially impacting later sampling events.

5.2 In-situ Hydraulic Conductivity Testing in Borings

Slug tests can be performed in borings while the boring is being advanced. This permits testing of formations at different depths throughout the drilling process. Boreholes to be tested shall be drilled using casing, so that discrete depths may be investigated. Various tests and testing methods are described below. The most appropriate test and testing method to be used in a situation varies with drilling, geologic, and general site conditions and shall be selected after a careful evaluation of the above factors.

Rising head or falling head slug tests can be performed in saturated and unsaturated formations during drilling. There are two ways that the tests can be performed. One way entails setting the casing flush with the bottom of the boring when the desired testing depth has been reached. The hole is then cleaned out to remove loose materials, the drill bit and rods are carefully withdrawn from the boring, and a few feet of sand (of higher permeability than the surrounding formation) is added to the bottom of the boring. After the water level in the boring has stabilized (for saturated formations), the static water level is measured and recorded. The water level is then raised (falling head test) or lowered (rising head test) and the change in water level is measured at time intervals determined by the field hydrogeologist. Only falling head tests can be performed for depth intervals within the unsaturated (vadose) zone. As described for wells, time intervals for water level measurements will vary according to the formation's

hydraulic conductivity. The faster the rate of recovery expected, the shorter the time intervals between measurements shall be. A predetermined pattern of time intervals must be used during each test. The rate of change of water level will be used to calculate hydraulic conductivity. The test is to be conducted until the water level again stabilizes, or for a minimum of 20 minutes. In low permeability formations, it is not always practical to run the test until the water level stabilizes, as it may take a long time to do so. The top of the casing shall be used as the reference point for all water level measurements.

The second method for conducting a slug test during drilling consists of placing a temporary well with a short screen into the cleaned-out boring, pulling the drilling casing back to expose the screen, allowing the formation to collapse around the screen (or placing a sand/gravel pack around the screen), and performing the appropriate hydraulic conductivity test in the well, as described for the first method. Again, the test shall be conducted until the water level stabilizes or for a minimum of 20 minutes. This method allows for testing a larger section of the formation and results in more reliable hydraulic conductivity estimates.

Constant-head tests may also be performed in borings. As described for monitoring wells, once a stable elevated level has been achieved, the discharge rate into the boring is measured for a period of time, usually 10 to 20 minutes, and the hydraulic conductivity is calculated from this. This method is the most accurate method depicted in this section, and shall be given preference over others if the materials are available to perform the test and the addition of water to the boring does not adversely impact project objectives. Once the test is over, additional information can be gathered by measuring the rate of the drop in water level in the boring (for saturated formations). A limitation of the constant-head test is that foreign water is introduced into the formation which must be removed from the well area by natural or artificial means, before a representative groundwater sample can be obtained.

Detailed descriptions regarding the performance of borehole hydraulic conductivity tests and subsequent data analysis techniques are provided in Ground Water Manual (1981).

5.3 Data Analysis

There are a number of data analysis methods available to reduce and evaluate slug testing data. The determination of which method is most appropriate shall be made based on the testing conditions (including physical setup of the well/boring tested, hydrogeologic conditions, and testing methodology) and the limitations of each test analysis method. Well construction details, aquifer type (confined or unconfined), and screened/open interval (fully or partially penetrating the aquifer) shall be taken into account in selecting an analysis method. Cooper, et al. (1967), and Papadapulos, et al. (1973) have developed test interpretation procedures for fully penetrating wells in confined aquifers. Hvorslev (1951) developed a relatively simple analytical procedure for point piezometers in an infinite isotropic medium. In Cedergren (1967), Hvorslev presents a number of analytical procedures which cover a wide variety of hydrogeologic conditions, testing procedures, and well/boring/piezometer configurations. Bouwer and Rice (1976) developed an analytical technique applicable to both unconfined and confined conditions, which factors in partial/full penetration and discusses well screen gravel pack considerations. The Ground Water Manual (1981) presents a number of testing and test analysis procedures for wells and borings open above or below the water table, and for both falling head and constant-head tests. The methods described above do not represent a complete listing of test analysis methods available, but are some of the more commonly used and accepted methods. Other methods can be used, at the discretion of the project hydrogeologist and in concurrence with the Project Manager and client.

One consideration to be noted during data analysis is the determination of the screened/open interval of a tested well. If a well with a fully submerged screen is installed in a relatively low permeability formation, and a gravel pack which is significantly more permeable is installed around the screen, the

length of the gravel pack (if longer than the screened interval) may be used as the screened/open length, rather than the screen length itself. In situations where the formation permeability is judged to be comparable to the gravel pack permeability (within about an order of magnitude) this adjustment is not required.

All data analysis applications and calculations shall be reviewed by technical personnel thoroughly familiar with testing and test analysis procedures. Upon approval of the calculations and results, the calculation sheets shall be initialed and dated by the reviewer. Distribution copies shall be supplied to appropriate project personnel and the original copy stored in the project central file.

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7.0 RECORDS

Field data shall be recorded on the data sheet included as Attachment A (or equivalent).[1] Any notes regarding testing procedures, problems encountered, and general observations not included on the data sheet shall be noted in the bound site logbook or field notebook. The boring log and well construction diagrams for each well/boring tested shall be used as references during testing and data analysis activities. Original data sheets shall be placed in the project file, along with the logbook/notebook.

[1] If an automated data recorder is used, the data may be displayed using the printer output from the unit. Such printouts should be annoted to include the relevant data form, or attached to the form shown as Attachment A.

ATTACHMENT A
EXAMPLE HYDRAULIC CONDUCTIVITY TESTING DATA SHEET

HYDRAULIC CONDUCTIVITY TESTING DATA SHEET

PROJECT NAME: ..... WELL/BORING NO.: .....

PROJECT NO.: ..... GEOLOGIST: .....

WELL DIAMETER: ..... SCREEN LENGTH/DEPTH: ..... TEST NO.: .....

STATIC WATER LEVEL (Depth/Elevation): ..... DATE: .....

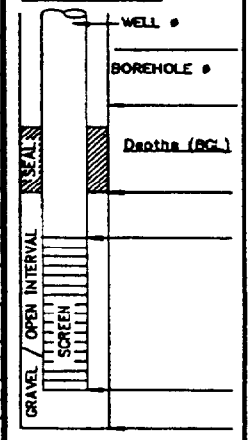
TEST TYPE (Rising/Falling/Constant Head): ..... CHECKED: .....

METHOD OF INDUCING WATER LEVEL CHANGE: ..... PAGE ..... OF .....

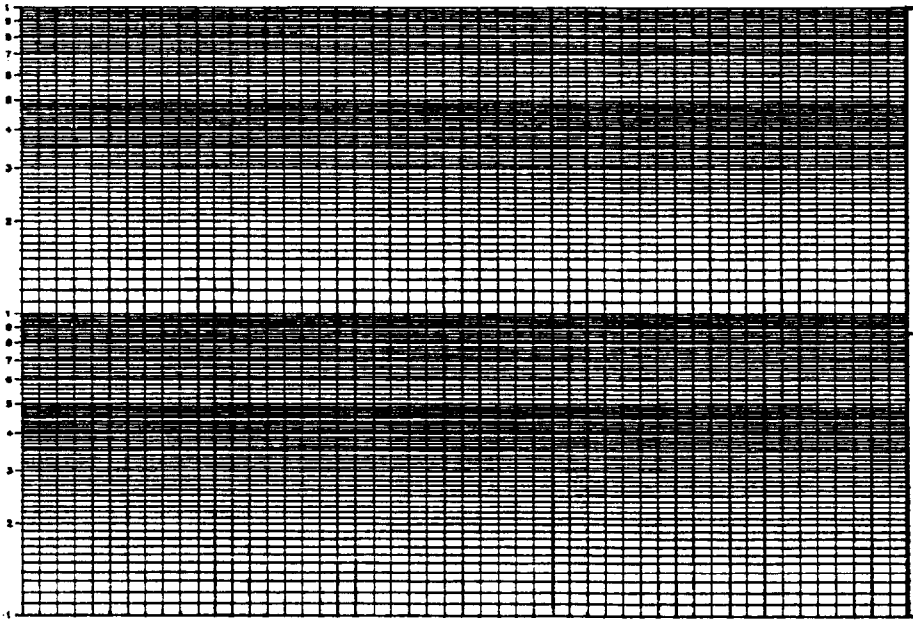
REFERENCE PT. FOR WL MEAS. (Top of Casing, Transducer, etc.): .....

ELAPSED TIME (min. or sec.)	MEASURED WATER LEVEL (feet)	DRAWDOWN OR HEAD (ΔH) (feet)	ELAPSED TIME (min. or sec.)	MEASURED WATER LEVEL (feet)	DRAWDOWN OR HEAD (ΔH) (feet)

WELL SCHEMATIC



Indicate SWL Depth on Drawing



REMARKS:

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CALCS,SKETCH MAPS, ETC.:

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1.0 PURPOSE

The purpose of this procedure is to provide a basic understanding of developing contour maps and the approaches used to identify and quantify the direction and rate of groundwater flow and contaminant plume movement.

2.0 SCOPE

This procedure provides only a general overview of the field techniques, mathematical and physical relationships and data handling procedures used for determining groundwater flow direction and rate. The references identified herein can provide a more complete explanation of particular methods cited, as well as a more comprehensive discussion on the interpretation of hydrogeologic data.

3.0 GLOSSARY

Aquifer - A geologic formation capable of transmitting usable quantities of groundwater to a well or other discharge point.

Aquitard - A geologic formation which retards the flow of groundwater due to its low permeability.

Confined Aquifer - An aquifer that is overlain and underlain by zones of lower permeability (aquitards). If the aquifer is "artesian," the potentiometric head of the aquifer at a given point is higher than the top of the zone comprising the aquifer at that point.

Equipotential Line - A line connecting points of equal elevation of the water table or potentiometric surface. Equipotential lines on the water table are also called water table contour lines.

Flow Line - A flow line indicates the direction of groundwater movement within the saturated zone. Flow lines are drawn perpendicular to equipotential lines.

Flow Net - A diagram of groundwater flow showing flow lines and equipotential lines.

Hydraulic Conductivity (K) - A parameter relating the volume of fluid flowing through a cross-sectional area of a saturated permeable medium to the driving force for the flow (hydraulic gradient). The hydraulic conductivity is a function both of the aquifer characteristics (porosity and interconnection of pores) and of the characteristics of the fluid (density and viscosity) passing through the aquifer. Thus, an aquifer will have a different hydraulic conductivity for water compared to pure-phase organic liquids.

Hydraulic Gradient (i) - The rate of change of hydraulic head per unit distance of flow at a given point and in the downgradient direction.

Hydraulic Head - The height to which water will rise inside a well casing, equal to the elevation head plus the pressure head. In a well screened across the water table, hydraulic head equals the elevation head, as the pressure head equals 0. In wells screened below the water table in an unconfined aquifer or screened at any interval within a confined aquifer, the head is the sum of the elevation of the aquifer (the elevation head) and the fluid pressure of the water confined in the aquifer (the pressure head).

Permeability - The capacity of a porous medium to transmit water. The degree of permeability depends on the size and shape of the pores, and the extent of their interconnections.

Porosity - Percentage of the total volume of a rock or soil which is occupied by voids (pore space).

Potentiometric (piezometric) Surface - A hypothetical surface that coincides with the static level of the water in aquifer (i.e., the maximum elevation to which water will rise in a well or piezometer penetrating the aquifer). The term "potentiometric surface" is usually applied to confined aquifers, although the water table is the potentiometric surface of an unconfined aquifer.

Unconfined Aquifer - An aquifer in which the water table forms the upper boundary.

Water Table - The surface in the groundwater system at which the fluid pressure is equal to atmospheric pressure (i.e., the net pressure head is zero) and below which all strata are saturated with water.

4.0 RESPONSIBILITIES

Project Hydrogeologist - The project hydrogeologist has overall responsibility for obtaining water level measurements and developing groundwater contour maps. The hydrogeologist (with the concurrence of the Project Manager) shall specify the reference point from which water levels are measured (usually a specific point on the upper edge of the inner well casing), the number of data points needed and which wells shall be used for a contour map, and how many complete sets of water levels are required to adequately define groundwater flow directions (e.g., if there are seasonal variations).

Field Personnel - All supporting field personnel must have a basic familiarity with the equipment and procedures involved in obtaining water levels, and must be aware of any project-specific requirements.

5.0 PROCEDURES

5.1 Potentiometric Surface Mapping

5.1.1 Selection of Wells

All wells used to prepare a flow net in a plan or map view should represent the same hydrogeologic unit, be it aquifer or aquitard. All water level measurements used shall be collected on the same day, preferably within 2-3 hours. This is especially important when working in an area where groundwater levels are tidally influenced or influenced by pumping.

Before mapping, review the recorded water levels and monitoring-well construction data, site geology and topographic setting must be reviewed to ascertain that the wells are completed in the same hydrogeologic unit and to determine if strong vertical hydraulic gradients may be present. Such conditions will be manifested by a pronounced correlation between well depth and water level, or by a difference in water level between two wells located near each other but set to different depths or having different screen lengths. Professional judgment of the hydrogeologist is important in this determination. If vertical gradients are significant, the data to be used must be limited vertically, and only wells finished in a chosen vertical zone of the hydrogeologic unit can be used.

At least three wells must be used to provide an estimation of the direction of groundwater flow; information from many more wells are needed to provide an accurate contour map. Generally, shallow systems require data from more wells than deep systems for accurate contour mapping.

5.1.2 Water Level Measurements

After selection of the wells to be used for mapping, the next step in determining the direction of groundwater flow is to obtain water level elevations from the selected points. In addition, any other

readily available wells/surface water bodies should also be measured to ensure that sufficient data are available for interpretation purposes.

Elevations are obtained from measurements of the depth to water in a monitoring well or piezometer taken from the top of the well casing (see SOP GH-1.2) and then referencing the elevation of the casing to a chosen and consistent datum point, usually mean sea level. Subtracting the depth to water from the casing elevation provides the elevation of the potentiometric surface. Elevations of points and areas of groundwater discharge or recharge such as springs, seeps, streams, rivers, and lakes also need to be determined, typically through staff gauge measurements. Comparison of these elevations, which represent hydraulic heads, will reveal the direction of flow because groundwater flows from areas of high head to areas of low head.

5.1.3 Construction of Equipotential Lines

Graphical methods available for depicting the flow of groundwater include the use of equipotential lines and flow lines to construct potentiometric surface maps and vertical flow nets. If the hydrogeologic system consists of a water table aquifer and one or more confined aquifers, separate contour maps should be prepared for each aquifer system. Water table maps should be developed using water level measurements obtained from monitoring wells screened at the unsaturated-saturated interface. Water level measurements collected from monitoring wells screened in the deeper portions of an unconfined aquifer should generally be contoured as a separate potentiometric surface map. Surface water discharge or recharge features are contoured in the water table system. Vertical flow nets should be constructed using a cross section aligned parallel to the direction of groundwater flow. All water level measurements along this cross section, both deep and shallow, are used in developing equipotential lines and flow lines for the flow net.

To construct equipotential lines, water elevations in the chosen wells are plotted on a site map. Other hydrogeologic features associated with the zone of interest -- such as seeps, wetlands, and surface-water bodies -- should also be plotted along with their elevations.

The data should then be contoured, using mathematically valid and generally accepted techniques. Linear interpolation is the most commonly used technique. However, quadratic interpolation or any technique of trend-surface analysis or data smoothing is acceptable. Computer-generated contour maps may be useful for large data sets. Contour lines shall be drawn as smooth, continuous lines which never cross one another.

Inspect the contour map, noting known features, such as pumping wells and site topography. The contour lines must be adjusted utilizing the professional judgment of the hydrogeologist in accordance with these features. Closed contours should be avoided unless a known sink exists. Groundwater mounding is common under landfills and lagoons; if the data imply this, the feature must be evident in the contour plot.

5.1.4 Determination of Groundwater-Flow Direction

Flow lines shall be drawn so that they are perpendicular to equipotential lines. Flow lines will begin at high head elevations and end at low head elevations. Closed highs will be the source of additional flow lines. Closed depressions (i.e., wells) will be the termination of some flow lines. Care must be used in areas with significant vertical gradients to avoid erroneous conclusions concerning gradients and flow directions.

5.2 Groundwater Flow Considerations

Groundwater movement is an integral part of the hydrologic cycle. Recharge to the shallow groundwater environment generally occurs by infiltration of precipitation through an upper unsaturated soil zone. Movement is downward under the force of gravity until the water reaches the saturated zone of the water table aquifer. Once water is part of the water table aquifer, movement is controlled by differences in hydraulic head with movement from areas of high head to areas of low head. Areas of low head include natural discharge areas such as springs, lakes, rivers, and, ultimately, the ocean. These features can be considered as outcrops of the water table. Points of low head also are created by pumping wells.

Local head differences and consequent vertical flow patterns within an aquifer can be detected by well clusters. A well cluster consists of several adjacent wells, generally installed within a few feet of each other, and screened at different depths. Variations in water levels in these closely spaced wells indicates the vertical component of groundwater flow within an aquifer, provided that the wells are all screened within the same aquifer.

The number, location, and extent of geologic units and their properties with regard to aquifer or aquitard characteristics must be understood to properly interpret water level data gathered from the monitoring system. This firm understanding of the hydrogeologic system must be developed through a program of soil borings and interpretation of subsurface geology. The adequacy of the positions and depths of borings used to define relevant subsurface hydrogeologic conditions must also be assessed. The location of surface water discharge or recharge points must be considered. Surface water features influence the system, as flow is most likely toward them (if they are discharge points) or away from them (if they are recharge points). Man-made discharge or recharge features such as pumping or injection wells, ditches, and trenches can also affect the flow of groundwater.

5.3 Determination of Flow Rate

Darcy's Law states that the quantity of water flowing through a geologic material is dependent upon the permeability of the material, the hydraulic gradient, and the cross sectional area through which the water flows. This relation is expressed in the equation:

$$Q = KiA$$

where:

Q = volume of water flowing through the cross sectional area of the formation (L^3/T).
K = hydraulic conductivity (L/T).
i = hydraulic gradient (L/L, i.e., dimensionless).
A = cross sectional area of formation being considered (L^2).

The relation is similar to one used in stream flow measurements where:

$$Q = VA$$

where:

Q = discharge from the cross sectional area of a stream or pipe (L^3/T).
V = average velocity of flowing water (L/T).
A = cross sectional area through which water flows (L^2).

The velocity of water movement in a geologic formation depends on the specific formation properties and the head differences across the formation. This relation is defined in the equation:

$$V = \frac{K_i}{n}$$

where:

V = average linear velocity of groundwater through the formation (L/T)
K = hydraulic conductivity (L/T)
i = hydraulic gradient (dimensionless)
n = porosity (expressed as a fraction).

Values of porosity for several geologic materials are given in Attachment A. More accurate and specific values of porosity can be obtained by laboratory analysis of a formation sample.

Hydraulic conductivity is related to the permeability of the formation and depends on the size and interconnection of the pore spaces. In isotropic and homogeneous formations, the hydraulic conductivity will be the same vertically and horizontally. However, in anisotropic formations, horizontal and vertical conductivity can be markedly different and the vertical hydraulic conductivity can be up to several orders of magnitude lower than the horizontal hydraulic conductivity. For example, an unfractured shale has a very high porosity, but because of its layered nature, the pore spaces are not connected vertically. Consequently, unfractured shale often has a moderate horizontal hydraulic conductivity but a very low vertical hydraulic conductivity.

Generally, hydraulic conductivity is high for sands, gravels, and limestone containing large solution cavities and low for clays and tightly fractured rock. Attachment A gives values of hydraulic conductivity for several geologic materials. More accurate values can be obtained during field testing of aquifers or from laboratory measurements on undisturbed cores. However, results from field testing usually indicate higher hydraulic conductivities than laboratory testing because full-scale field testing includes the effects of the formational macrostructure (i.e., secondary permeability due to jointing or fractures) which is not reflected in the testing of a small sample in the laboratory.

The hydraulic gradient, i, is determined from field measurements of hydraulic head obtained from water level measuring points. Do not measure gradient from well to well; measure across equipotential lines that are based on the well (and other) data. Once a potentiometric surface map has been generated using the hydraulic head data, the hydraulic gradient can be calculated using the following formula:

$$i = \frac{dh}{dl}$$

where:

dh = change in head (L)
dl = distance between equipotential lines (L)

The hydraulic gradient along any flow line can be calculated from a potentiometric surface map by dividing the contour interval by the length of the flow line between contour lines.

When chemical solutes are traveling in groundwater, as in cases of groundwater contamination, the calculated groundwater velocity may predict flow rates in excess of what is actually observed. This difference in chemical versus water velocities may be due to attenuation or biodegradation of the chemical species in the aquifer. Attenuation is most often caused by adsorption of the chemical contaminant onto the formation grains or matrix. The result is that the chemical does not appear at the downgradient sampling point as quickly as the velocity calculation predicts. An equation to correct for this attenuation is:

$$V_c = V_w/(1 + K_d P_b/n)$$

where:

V_c = velocity of the chemical solute flow (L/T)
V_w = velocity of groundwater flow (L/T)
P_b = formation mass bulk density (M/L^3)
n = formation porosity (expressed as a fraction)
K_d = distribution coefficient = (L^3/M)

The K_d is equal to the mass of solute per unit mass of solid phase divided by the concentration of solute in solution. The term in the denominator is known as the retardation factor.

Density differences between water and contaminants can also cause velocity determination errors. Light hydrocarbons such as gasoline are less dense than water and consequently float on the water table. These contaminants can migrate along the water table surface at rates faster or slower than the rate of groundwater movement, depending on specific conditions, and may also volatilize into unsaturated soil pore spaces. On the other hand, contaminants denser than water such as heavy hydrocarbons (e.g., coal tar) or chlorinated compounds (e.g., TCE, PCE) tend to sink to the bottom of an aquifer if present in concentrations exceeding their solubility limit. Here, the contamination may move at faster or slower rates than the overlying groundwater or may actually move in a direction opposite to that of the groundwater, depending on the geologic characteristics of the aquifer base and direction of dip of the underlying aquitard.

Other factors involving the physicochemical interaction between the chemical and the groundwater, such as dilution (mixing contaminated water or chemicals with additional quantities of groundwater) and dispersion (molecular diffusion of the chemical throughout the groundwater regime), can also affect the observed rates of travel of contaminants in groundwater. In addition to such physicochemical characteristics, all of the aquifer and aquitard properties and groundwater flow characteristics described above must be known so that adequate and accurate estimations of the extent and severity of groundwater contamination can be developed.

6.0 REFERENCES

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ATTACHMENT A

GENERALIZED POROSITY AND HYDRAULIC CONDUCTIVITY VALUES FOR GEOLOGIC MATERIALS

Material	Porosity Range (%)	Hydraulic Conductivity Range	
		cm/sec	ft/day
Gravel	30-40	10^{-1} to 10^{-2}	280 to 2.8×10^{5}
Coarse sand (clean)	30-40	10^{-1} to 1	280 to 2,800
Medium sand (clean)	35-45	10^{-2} to 10^{-1}	28 to 280
Fine sand (clean)	40-50	5×10^{-4} to 10^{-2}	1.4 to 28
Silty sand	25-40	10^{-5} to 10^{-2}	0.03 to 280
Glacial Till	Variable	10^{-10} to 10^{-4}	3×10^{-7} to 0.3
Unweathered Clay/Shale	45-55 (clay)	10^{-7} to 10^{-4}	3×10^{-4} to 0.3 (horizontal)
		10^{-10} to 10^{-6}	3×10^{-7} to 3×10^{-3} (vertical)
Karst Limestone	---	10^{-4} to 10^{-1}	0.3 to 2,800
Fractured Igneous/ Metamorphic Rocks	---	10^{-6} to 10^{-1}	3×10^{-3} to 280
Sandstone	5-30	10^{-8} to 10^{-4}	3×10^{-5} to 0.3

Source: References 1 and 2

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1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper monitoring well design, installation, and development.

2.0 SCOPE

This procedure is applicable to the construction of permanent monitoring wells. The methods described herein may be modified by project-specific requirements for monitoring well construction. In addition, many regulatory agencies have specific regulations pertaining to monitoring well construction and permitting. These requirements must be determined during the project planning phases of the investigation, and any required permits must be obtained before field work begins. Innovative monitoring well installation techniques, which typically are not used, will be discussed only generally in this procedure.

3.0 GLOSSARY

Monitoring Well - A well which is properly screened (if screening is necessary, e.g., open borehole), cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored.

Piezometer - A pipe or tube inserted into the water bearing zone, typically open to water flow at the bottom and to the atmosphere at the top, and used to measure water level elevations. Piezometers may range in size from 1/2-inch-diameter plastic tubes to well points or monitoring wells.

Potentiometric Surface - The surface representative of the level to which water will rise in a well cased to the screened aquifer.

Well Point (Drive Point) - A screened or perforated tube (Typically 1-1/4 or 2 inches in diameter) with a solid, conical, hardened point at one end, which is attached to a riser pipe and driven into the ground with a sledge hammer, drop weight, or mechanical vibrator. Well points may be used for groundwater injection and recovery, as piezometers (i.e., to measure water levels) or to provide groundwater samples for water quality data.

4.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing all phases of proper monitoring well installation and construction. The driller may also be responsible for obtaining, in advance, any required permits for monitoring well installation and construction.

Rig Geologist - The rig geologist supervises and documents well installation and construction performed by the driller, and insures that well construction is adequate to provide representative groundwater data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

5.0 PROCEDURES

5.1 Equipment/Items Needed

Below is a list of items that may be needed when installing a monitoring well:

- Health and safety equipment as required by the Site Safety Officer.
- Well drilling and installation equipment with associated materials (typically supplied by the driller).
- Hydrogeologic equipment (weighted engineer's tape, water level indicator, retractable engineers rule, electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).
- Drive point installations tools (sledge hammer, drop hammer, or mechanical vibrator; tripod, pipe wrenches, drive points, riser pipe, and end caps).

5.2 Well Design

The objectives for each monitoring well and its intended use must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, require different types of construction. During all phases of the well design, attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials to be used. The objectives for installing the monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for trace contaminants.
- Determining aquifer characteristics (e.g., hydraulic conductivity).

Siting of monitoring wells shall be performed after a preliminary estimation of the groundwater flow direction. In most cases, groundwater flow and potential well locations can be determined through the review of geologic data and the site terrain. In addition, data from production wells or other monitoring wells in the area may be used to determine the groundwater flow direction. If these methods cannot be used, piezometers, which are relatively inexpensive to install, may have to be installed in a preliminary investigative phase to determine groundwater flow direction.

5.2.1 Well Depth, Diameter, and Monitored Interval

The well depth, diameter, and monitored interval must be tailored to the specific monitoring needs of each investigation. Specification of these items generally depends on the purpose of the monitoring system and the characteristics of the hydrogeologic system being monitored. Wells of different depth, diameter, and monitored interval can be employed in the same groundwater monitoring system. For instance, varying the monitored interval in several wells, at the same location (cluster wells) can help to determine the vertical gradient and the levels at which contaminants are present. Conversely, a fully penetrating well is usually not used to quantify or vertically locate a contaminant plume, since groundwater samples collected in wells that are screened over the full thickness of the water-bearing zone will be representative of average conditions across the entire monitored interval. However, fully penetrating wells can be used to establish the existence of contamination in the water-bearing zone. The

well diameter desired depends upon the hydraulic characteristics of the water-bearing zone, sampling requirements, drilling method and cost.

The decision concerning the monitored interval and well depth is based on the following (and possibly other) information:

- The vertical location of the contaminant source in relation to the water-bearing zone.
- The depth, thickness and uniformity of the water-bearing zone.
- The anticipated depth, thickness, and characteristics (e.g., density relative to water) of the contaminant plume.
- Fluctuation in groundwater levels (due to pumping, tidal influences, or natural recharge/discharge events).
- The presence and location of contaminants encountered during drilling.
- Whether the purpose of the installation is for determining existence or non-existence of contamination or if a particular stratigraphic zone is being investigated.
- The analysis of borehole geophysical logs.

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (1 to 2 feet) are usually required where flow lines are not horizontal, (i.e., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

Many factors influence the diameter of a monitoring well. The diameter of the monitoring well depends on the application. In determining well diameter, the following needs must be considered:

- Adequate water volume for sampling.
- Drilling methodology.
- Type of sampling device to be used.
- Costs.

Standard monitoring well diameters are 2, 4, 6, or 8 inches. However, drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch-diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open-hole monitoring wells are required. In the smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced, however, the type of sampling devices that can be used are limited. In specifying well diameter, sampling requirements must be considered (up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples). The volume of water in the monitoring well available for sampling is dependent on the well diameter as follows:

Casing Inside Diameter (Inch)	Standing Water Depth to Obtain 1 Gallon Water (Feet)	Total Depth of Standing Water for 4 Gallons (Feet)
2	6.13	25
4	1.53	6
6	0.68	3

However, if a specific well recharges quickly after purging, then well diameter may not be an important factor regarding sample volume requirements.

Pumping tests for determining aquifer characteristics may require larger diameter wells; however, in small-diameter wells in-situ permeability tests can be performed during drilling or after well installation is completed.

5.2.2 Riser Pipe and Screen Materials

Well materials are specified by diameter, type of material, and thickness of pipe. Well screens require an additional specification of slot size. Thickness of pipe is referred to as "schedule" for polyvinyl chloride (PVC) casing and is usually Schedule 40 (thinner wall) or 80 (thicker wall). Steel pipe thickness is often referred to as "Strength" and Standard Strength is usually adequate for monitoring well purposes. With larger diameter pipe, the wall thickness must be greater to maintain adequate strength. The required thickness is also dependent on the method of installation; risers for drive points require greater strength than wells installed inside drilled borings.

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive presentation on this topic). The two most commonly used materials are PVC and stainless steel for wells in which screens are installed. Properties of these two materials are compared in Attachment B. Stainless steel is preferred where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, and ease of manipulation; however, there are also some questions about organic chemical sorption and leaching that are currently being researched (see Barcelona et al., 1983). Concern about the use of PVC can be minimized if PVC wells are used strictly for geohydrologic measurements and not for chemical sampling. The crushing strength of PVC may limit the depth of installation, but Schedule 80 materials normally used for wells greater than 50 feet deep may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps required for sampling or testing. Due to this problem, the minimum well pipe size recommended for Schedule 80 wells is 4-inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe, may corrode and release metal ions or chemically react with organic constituents, but this is considered by some to be less of a problem than the problem associated with PVC material. Galvanized steel is not

recommended where samples may be collected for metal analyses, as zinc and cadmium levels in groundwater samples may become elevated from leaching of the zinc coating.

Threaded, flush-joint casing is most often preferred for monitoring well applications. PVC, Teflon, and steel can all be obtained with threaded joints at slightly more costs. Welded-joint steel casing is also acceptable. Glued PVC may release organic contaminants into the well, and therefore, should not be used if the well is to be sampled for organic constituents.

When the water-bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary and the screened interval is artificially packed with a fine sand. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The rig geologist shall specify the combination of screen slot size and sand pack which will be compatible with the water-bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. For example, as a standard procedure, a Morie No. 1 or No. 10 to No. 20 U.S. Standard Sieve size filter pack is typically appropriate for a 0.020-inch slot screen; however, a No. 20 to No. 40 U.S. Standard Sieve size filter pack is typically appropriate for a 0.010-inch slot screen.

5.2.3 Annular Materials

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a fine- to medium-grained poorly graded, silica sand and should relate to the grain size of the aquifer sediments. The quantity of sand placed in the annular space is dependent upon the length of the screened interval, but should always extend at least 1 foot above the top of the screen. At least 1 to 3 feet of bentonite pellets or equivalent shall be placed above the sand pack. Cement-bentonite grout (or equivalent) is then placed to extent from the top of the bentonite pellets to the ground surface.

On occasion, and with the concurrence of the involved regulatory agencies, monitoring wells may be packed naturally (i.e., no artificial sand pack installed), and the natural formation material is allowed to collapse around the well screen after the well is installed. This method has been used where the formation material itself is a relatively uniform grain size, or when artificial sand packing is not possible due to borehole collapse.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets extending to the surface. The grout effectively seals the well and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom of the hole upward, to prevent bridging, and to provide a better seal. However, in shallow boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of two assemblages of material, (e.g., cement-bentonite). A cement-bentonite grout normally is a mixture of cement, bentonite, and water at a ratio of one 90-pound bag of Portland Type I cement, plus

3 to 5 pounds of granular or flake-type bentonite, and 6 gallons of water. A neat cement consists of one ninety-pound bag of Portland Type I cement and 6 gallons of water.

In certain cases, the borehole may be drilled to a depth greater than the anticipated well installation depth. For these cases, the well shall be backfilled to the desired depth with bentonite pellets or equivalent. A short (1- to 2-foot) section of capped riser pipe sump is sometimes installed immediately below the screen, as a silt reservoir, when significant post-development silting is anticipated. This will ensure that the entire screen surface remains unobstructed.

5.2.4 Protective Casing

When the well is completed and grouted to the surface, a protective steel casing is often placed over the top of the well. This casing generally has a hinged cap and can be locked to prevent vandalism. A vent hole shall be provided in the cap to allow venting of gases and maintain atmospheric pressure as water levels rise or fall in the well. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

A protective casing which is level with the ground surface is used in roadway or parking lot applications where the top of a monitoring well must be below the pavement. The top of the riser pipe is placed 4 to 5 inches below the pavement, and a locking protective casing is cemented in place to 3 inches below the pavement. A large diameter protective sleeve is set into the wet cement around the well with the top set level with the pavement. A manhole-type lid placed over the protective sleeve. The cement should be slightly mounded to direct pooled water away from the well head.

5.3 Monitoring Well Installation

Pertinent data regarding monitoring well installation shall be recorded on log sheets as depicted and discussed in SOP SA-6.3. Attachments to this referenced SOP illustrate terms and physical construction of various types of monitoring wells.

5.3.1 Monitoring Wells in Unconsolidated Sediments

After the borehole is drilled to the desired depth, well installation can begin. The procedure for well installation will partially be dictated by the stability of the formation in which the well is being placed. If the borehole collapses immediately after the drilling tools are withdrawn, then a temporary casing must be installed and well installation will proceed through the center of the temporary casing, and continue as the temporary casing is withdrawn from the borehole. In the case of hollow-stem auger drilling, the augers will act to stabilize the borehole during well installation.

Before the screen and riser pipe are lowered into the borehole, all pipe and screen sections should be measured with an engineer's rule to ensure proper placement. When measuring sections, the threads on one end of the pipe or screen must be excluded while measuring, since the pipe and screen sections are screwed flush together.

After the screen and riser pipe are lowered through the temporary casing, the sand pack can be installed. A weighted tape measure must be used during the installation procedure to carefully monitor installation progress. The sand is poured into the annulus between the riser pipe and temporary casing, as the casing is withdrawn. Sand should always be kept within the temporary casing during withdrawal in order to ensure an adequate sand pack. However, if too much sand is within the temporary casing (greater

than 1 foot above the bottom of the casing) bridging between the temporary casing and riser pipe may occur.

After the sand pack is installed to the desired depth (at least 1 foot above the top of the screen), then the bentonite pellet seal (or equivalent), can be installed in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack.

The cement-bentonite grout is then mixed and either poured or tremied into the annulus as the temporary casing or augers are withdrawn. Finally, the protective casing can be installed as detailed in Section 5.2.4.

In stable formations where borehole collapse does not occur, the well can be installed as discussed above, and the use of a temporary casing is not needed. However, centralizers may have to be installed, one above and one below the screen, to assure enough annular space for sand pack placement.

5.3.2 Confining Layer Monitoring Wells

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between the unconfined and confined aquifer. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large-diameter boring through the upper aquifer, 1 to 3 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting the outer casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for installation of the monitoring well as detailed for overburden monitoring wells (with the exception of not using a temporary casing during installation). Sufficient time (determined by the rig geologist), must be allowed for setting of the grout prior to drilling through the confined layer.

5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5 feet into the bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout has cured, a smaller diameter boring is continued through the bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. However, if a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be installed temporary until final well installation is completed.

5.3.4 Drive Points

Drive points can be installed with either a sledge hammer, drop hammer, or a mechanical vibrator. The screen is threaded and tightened onto the riser pipe with pipe wrenches. The drive point is simply pounded into the subsurface to the desired depth. If a heavy drop hammer is used, then a tripod and pulley setup is required to lift the hammer. Drive points typically cannot be driven to depths exceeding 10 feet.

5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only one or two small-diameter tubes extending to the surface.

Manufacturers of these types of samplers claim that four samplers can be installed in a 3-inch-diameter borehole. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross-contamination from sampling equipment. These samplers also perform well when the water table is within 25 feet of the surface (the typical range of suction pumps). Two manufacturers of these samplers are Timco Manufacturing Company, Inc., of Prairie du Sac, Wisconsin, and BARCAD Systems, Inc., of Concord, Massachusetts. Each manufacturer offers various construction materials.

Two additional types of multilevel sampling systems have been developed. Both employ individual screened openings through a small-diameter casing. One of these systems (marketed by Westbay Instruments Ltd. of Vancouver, British Columbia, Canada) uses a screened port and a sampling probe to obtain samples and head measurements or perform permeability tests. This system allows sampling ports at intervals as close as 5 feet, if desired, in boreholes from 3 to 4.8 inches in diameter.

The second system, developed at the University of Waterloo at Waterloo, Ontario, Canada, requires field assembly of the individual sampling ports and tubes that actuate a simple piston pump and force the samples to the surface. Where the depth to ground water is less than 25 feet, the piston pumps are not required. The assembly is made of easily obtained materials; however, the cost of labor to assemble these monitoring systems may not be cost-effective.

5.4 Well Development Methods

The purpose of well development is to stabilize and increase the permeability of the gravel pack around the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water is removed from the well. Sequential measurements of pH, conductivity and temperature taken during development may yield information (stabilized values) that sufficient development is reached. The selection of the well development method shall be made by the rig geologist and is based on the drilling methods, well construction and installation details, and the characteristics of the formation that the well is screened in. The primary methods of well development are summarized below. A more detailed discussion may be found in Driscoll (1986).

5.4.1 Overpumping and Backwashing

Wells may be developed by alternatively drawing the water level down at a high rate (by pumping or bailing) and then reversing the flow direction (backwashing) so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack serves to remove fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods, including pouring water into the well and then bailing, starting and stopping a pump intermittently to change water levels, or forcing water into the well under pressure through a water-tight fitting ("rawhiding"). Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen.

5.4.2 Surging with a Surge Plunger

A surge plunger (also called a surge block) is approximately the same diameter as the well casing and is used to agitate the water, causing it to move in and out of the screens. This movement of water pulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and valved surge plungers. In formations with low yields, a valved surge plunger may be preferred, as solid

plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.

5.4.3 Compressed Air

Compressed air can be used to develop a well by either of two methods: backwashing or surging. Backwashing is done by forcing water out through the screens, using increasing air pressure inside a sealed well, then releasing the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air suddenly into an open well below the water level to produce a strong surge by virtue of the resistance of water head, friction, and inertia. Pumping of the well is subsequently done using the air lift method.

5.4.4 High Velocity Jetting

In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire screened area. Jetting using a hose lowered into the well may also be effective. The fines washed into the screen during this process can then be bailed or pumped from the well.

6.0 REFERENCES

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7.0 RECORDS

A critical part of monitoring well installation is recording of significant details and events in the site logbook or field notebook. The geologist must record the exact depths of significant hydrogeological features screen placement, gravel pack placement, and bentonite placement.

A Monitoring Well Sheet (see Attachments to SOP SA-6.3) shall be completed thus ensuring the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information shall include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. Documentation is very important to prevent problems involving questionable sample validity. Somewhat different information

will need to be recorded.depending on whether the well is completed in overburden, in a confined layer, in bedrock with a cased well. or as an open hole in bedrock.

The quantities of sand, bentonite, and grout placed in the well are also important. The geologist shall calculate the annular space volume and have a general idea of the quantity of material needed to fill the annular space. Volumes of backfill significantly higher than the calculated volume may indicate a problem such as a large cavity, while a smaller backfill volume may indicate a cave-in. Any problems with rig operation or down-time shall be recorded and may affect the driller's final fee.

ATTACHMENT A

RELATIVE COMPATIBILITY OF RIGID WELL CASING MATERIAL (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material						
	PVC 1	Galvanized Steel	Carbon Steel	Lo-carbon Steel	Stainless Steel 304	Stainless Steel 316	Teflon*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Mineral Acid/ High Solids Content	100	48	57	60	80	82	100
Aqueous/Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

Preliminary Ranking of Rigid Materials:

1 Teflon®
2 Stainless Steel 316
3. Stainless Steel 304
4 PVC 1
5 Lo-Carbon Steel
6 Galvanized Steel
7 Carbon Steel

* Trademark of DuPont

RELATIVE COMPATIBILITY OF SEMI-RIGID OR ELASTOMERIC MATERIALS (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material								
	PVC Flexible	PP	PE Conv.	PE Linear	PMM	Viton®*	Silicone	Neoprene	Teflon®*
Buffered Weak Acid	97	97	100	97	90	92	87	85	100
Weak Acid	92	90	94	96	78	78	75	75	100
Mineral Acid/ High Solids Content	100	100	100	100	95	100	78	82	100
Aqueous/Organic Mixtures	62	71	40	60	49	78	49	44	100
Percent Overall Rating	88	90	84	88	78	87	72	72	100

Preliminary Ranking of Semi-Rigid or Elastomeric Materials:

1 Teflon®
2 Polypropylene (PP)
3. PVC Flexible/PE Linear
4 Viton®
5 PE Conventional
6 Plexiglas/Lucite (PMM)
7 Silicone/Neoprene

* Trademark of DuPont

Source: Barcelona et al., 1983

ATTACHMENT B

COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength are not critical.
Weight	Relatively heavier.	Light-weight; floats in water.
Cost	Relatively expensive.	Relatively inexpensive.
Corrosivity	Deteriorates more rapidly in corrosive water.	Non-corrosive -- may deteriorate in presence of ketones, aromatics, alkyl sulfides, or some chlorinated hydrocarbons.
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work with in the field.
Preparation for Use	Should be steam cleaned organics will be subsequently sampled.	Never use glue fittings -- pipes should be threaded or pressure fitted. Should be steam cleaned when used for monitoring wells.
Interaction with Contaminants*	May sorb organic or inorganic substances when oxidized.	May sorb or release organic substances.

* See also Attachment A.

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1.0 PURPOSE

The purpose of this guideline is to provide a general description of, and technical management guidance on, the use of Magnetic and Metal Detection Surveys for site investigations.

2.0 SCOPE

This guideline provides a description of the principles of operation, instrumentation, applicability and implementability of standard geophysical methods used during site investigations to determine site features related to magnetic anomalies and buried metal. The document is intended to be used by the site manager (SM), RI leader, field operations leader, or site geologist to develop an understanding of each method sufficient to permit work planning and scheduling, resource planning, subcontractor procurement and evaluation, and manipulation and use of the technical data during remedial investigations and feasibility studies. This guidance is not intended to provide a detailed description of methodology and operation. The highly specialized nature of the subject geophysical methods requires inclusion of project-specific, site-specific, and subcontractor-specific information prior to development of detailed operating procedures, during both planning and execution.

The description focuses on methods and equipment that are readily available and typically applied; it is not intended to provide a complete discussion of the state of the art.

3.0 GLOSSARY

Magnetic Susceptibility -- Property of a material corresponding to its ability to distort an applied magnetic field.

Magnetometer -- A device used for precise and sensitive measurements of magnetic fields.

Magnetic Survey -- A geophysical survey method that depends on detection of magnetic anomalies caused by the presence of buried ferromagnetic objects.

Metal detection -- A geophysical survey method that is based on electromagnetic coupling caused by underground conductive objects.

Magnetometry -- The science of measuring variations in the earth's magnetic field.

Vertical Gradiometer -- A magnetometer equipped with two sensors that are vertically separated a fixed distance apart. It is best suited to map near surface features and is less susceptible to deep geologic features.

4.0 RESPONSIBILITIES

Site Manager -- responsible for scoping the magnetic or metal detection surveys during development of the Work Plan with the help of the RI leader, site geologist, and site geophysicist.

Site Geophysicist -- central role in determining the technique used for providing necessary data. Field work for these surveys is supervised by the site geophysicist, with support from geophysical technical specialists and other personnel as needed. Data reduction and interpretation are performed by the site geophysicist or technical specialists.

5.0 PROCEDURES

5.1 Description of Methods

5.1.1 Theory and Principles of Operation

5.1.1.1 Magnetometry

Materials subject to a magnetic field will develop an induced magnetization, proportional to the applied magnetic field and the magnetic susceptibility of the material.

Induced magnetization in an object produces a local magnetic field which either reinforces (positive magnetic susceptibility) or reduces (negative susceptibility) the external applied field. The variations in an otherwise homogenous field caused by the presence of the object is called a magnetic anomaly, and observations of such anomalies can be used to infer the presence of magnetic objects.

Because there are numerous factors that affect magnetic fields there is no unique interpretation of a set of magnetometry data. Conversely, there is no unique magnetic anomaly produced by a particular kind of buried object. Factors that influence the response of a magnetometer to buried objects include the size, shape, depth, orientation, and magnetic susceptibility of the buried material, and permanent magnetometers such that many objects of interest at hazardous waste sites (particularly buried ferromagnetic materials such as drums, tanks, pipes and iron scrap) are detectable. While the location of ferromagnetic material can be detected to the precision of the survey, difficulties may be encountered in interpreting and attempting to identify the source of magnetic anomalies.

5.1.1.2 Metal Detection

When a radio frequency electromagnetic field generated by a transmitter coil encounters a highly conductive object such as metal (not necessarily ferromagnetic), alternating currents are induced in the object that, in turn, generate alternating secondary magnetic fields that are detected as alternating voltages by a receiver coil. The presence of the metal object effectively "couples" the transmitter and receiver coils, which otherwise are oriented so that little or no coupling exists. The principles of metal detector operation are very similar to those associated with electromagnetic induction instruments.

A number of factors influence the response of a metal detector. The receiver response increases with the size and surface area, and decreases with the depth of a buried object. Factors such as soil properties and object shape complicate detectability and interpretation. Certain shapes, such as elongated metal rods, are difficult to detect. Iron minerals and conductive fluids will affect the detector response in much the same manner as a target of interest. Generally, metal detectors show greater response to smaller nearby targets than to larger targets at greater depth, and the presence of widespread metallic debris at a site can interfere with attempts to detect buried drums and other objects.

5.1.2 General Applicability

5.1.2.1 Magnetic Surveys (Magnetometry)

Magnetometer and gradiometer surveys are useful in environmental and engineering projects that require a technique for mapping buried vertically oriented metallic pipe (e.g., locating a buried water well casing), or mapping stratigraphy or geologic structure in an igneous settings. Magnetometers are also a useful tool for mapping buried metallic debris, metallic utilities or metallic containers. However, electromagnetic (EM) equipment is generally better suited for mapping and delineating these targets.

Magnetic surveys can more readily detect metallic masses than identify or characterize targets. Calculations of the mass or size of detected objects generally yield only approximate results.

Magnetic surveys may be impractical in areas where metal pipes, fences, railroad tracks, metal buildings, and other ferrous metal artifacts are abundant. However, proper selection of equipment and survey techniques can often alleviate some of these problems.

5.1.2.2 Metal Detectors

Metal detectors (MDs) can be used for locating buried metallic containers of various sizes; defining the boundaries of trenches containing metallic containers; locating buried metallic storage tanks; locating buried metallic pipes; avoiding buried utilities when drilling or trenching; or locating utility trenches which may provide a permeable pathway for contaminants.

The detection range of a MD is relatively short. Its sensitive areas are focused directly above and below the coil providing good definition of object location. Quart-sized metal objects can be detected at a distance of about 1 meter; objects the size of a 55 gallon drum can be detected up to 3 meters; and massive piles of metals can be detected at depths of 3 to 6 meters. Deeper objects are difficult to detect with an MD. Although most MDs are operated on foot, some can be vehicle-mounted if desired.

5.1.3 Instrumentation

5.1.3.1 Magnetometers

Three types of magnetometers, the fluxgate, proton precession, and the cesium vapor magnetometers, are commonly used at hazardous waste sites. The fluxgate magnetometer uses an iron core of high magnetic susceptibility as a sensor. The amount of coiled electrical current necessary to induce magnetic saturation of the rod is directly dependent upon, and thus measures, the strength of the ambient magnetic field. In a proton precession magnetometer a strong magnetic field is applied to a sensor filled with proton-rich fluid (e.g., kerosene) that realigns the protons. The field is then turned off and the frequency of the signal generated by the protons as they realign themselves ("precess") to the earth's magnetic field is dependent upon and measures the strength of the field at that point. The third common type of magnetometer is the cesium vapor (alkali-vapor) magnetometer. The cesium vapor magnetometer is capable of obtaining an order of magnitude greater sensitivity than the proton precession magnetometer. The cesium vapor magnetometer operates via a beam of polarized light from a cesium vapor lamp that is passed through a cell of cesium vapor. The atoms of the vapor become excited as they absorb greater amounts of the polarized light. The vapor in the cell eventually reaches an energy state that can no longer absorb the light and renders the cell transparent. A radio-frequency magnetic field causes the atoms of the vapor to shift back to an energy state that allows the vapor to again absorb the polarized light. The frequency required to return the vapor to an energy state that allows the cell to absorb light is a function of the ambient magnetic field. Some magnetometers, such as the fluxgate, are extremely sensitive to orientation during measurement. In order to alleviate this problem, two sensors are connected by a rigid pole to form a "gradiometer" that measures only a certain directional component of the earth's magnetic field. These gradiometers are commonly used at hazardous waste sites.

The type of magnetometer best suited for a particular site investigation depends upon characteristics of that site and should be chosen by a person familiar with the different instruments available. Proton precession magnetometers, while very useful in many situations, will cease to function in an area with high magnetic gradients such as a junkyard or near a steel bridge.

Different instruments have different levels of sensitivity. Whereas in some cases, high sensitivity may be desired to detect deeply buried objects, in other instances, a low sensitivity instrument may be desired to reduce the effects of "noise" from nearby fences or cars. Furthermore, the size of the survey area and the resolution required will determine whether the magnetometer used is hand-held for stationary measurements or a vehicle-mounted continuous sensor model.

5.1.3.2 Metal Detectors (MDs)

Three general classes of metal detectors are commonly used in hazardous waste site studies: pipeline/cable locators, conventional "treasure hunter" detectors and specialized detectors. The pipeline/cable detectors are commonly used by EPA field investigation teams. They do not respond to small objects like soda cans. Although most of the "treasure hunter" type detectors are used for locating coin-sized objects, some can be fitted with larger sensor coils suitable for detection of larger objects at greater depths. Some of these models also can operate with adverse soil conditions such as high iron content. Specialized detectors are also available to operate to greater depths, over a wide sweep area, operate continuously, cope with special field problems, or operate while vehicle-mounted. These special MDs require an experienced operator and are not commonly available.

5.2 Data Acquisition

5.2.1 Field Procedures

5.2.1.1 Magnetics

Magnetic measurements are generally made in a cross-grid pattern, or if a continuous sensor is used, in a series of parallel lines across the survey area. The desired resolution (reconnaissance or high density) and the size and depth of the objects sought, determines the spacing of measurement stations or survey lines. Because of the phenomenon of temporal magnetic drift, a magnetic survey must include a base station where magnetic measurements are made at regular intervals. A separate base station magnetometer is used to monitor fluctuations in the earth's magnetic field. The base station magnetometer is time synchronized with the mobile magnetometer and placed in an area of the site believed to be free of metals or other anthropogenic features. The base station magnetometer is configured to record one data point at a set time interval (e.g., every 5 seconds). At the completion of the survey, the base station magnetometer is interfaced with the mobile magnetometer and the total field magnetic data are automatically corrected for any observed diurnal drift.

Special care must be taken with handling of the magnetometer during use. The operator must not take measurements with the sensor near ferromagnetic objects such as belt buckles or steel-toed boots. The orientation of the magnetometer and its height from the ground must also be carefully controlled during operation. Recorded data must be annotated with station locations to allow construction of a site magnetic map.

5.2.1.2 Metal Detector

Surveys with metal detectors are similar in planning to those with magnetometers. A grid pattern of evenly spaced parallel lines is used. Desired resolution and the size of objects determine spacing. In some cases, elevating the MD a few feet off the ground may help to eliminate noise from small surface objects. An experienced operator is recommended. Recorded data must be annotated with station locations to allow construction of a site metal detection map.

5.2.2 Data Format

5.2.2.1 Magnetics

Most magnetometers are equipped with a solid stated data logger that records the total field magnetic and/or the vertical gradient values, the survey line location, the survey station location and the time of the reading. The common units (SI) for total field magnetic data are Teslas (T). Magnetometers data record total field data in units of nanoTeslas (nT). However, older texts may also refer to magnetic values as gammas (one gamma equals one nanoTesla). Vertical gradient data are commonly recorded in units of nanoTeslas per meter (nT/M).

5.2.2.2 Metal Detection

The data provided by a metal detector is less quantitative than that of a magnetometer. The MD signal strength may vary (depending on the instrument) with object depth, size and shape, but this signal does not translate into a quantity such as field strength. It merely indicates the presence of a metal object. This on/off type of signal is useful because it can indicate the boundaries of a metal-bearing zone more clearly than some quantitative data such as magnetometer recordings.

5.3 Data Interpretation

5.3.1 Magnetics

5.3.1.1 Correction of Diurnal Variations

Diurnal drift is automatically corrected for by interfacing the mobile magnetometer with the base station magnetometer. However, all of the diurnal corrections should be checked to verify the values and insure against instrument malfunction.

5.3.1.2 Depth Estimates from Total Field

The width of a magnetic anomaly is proportional to the depth (or distance) of the source from the magnetometer sensor; the deeper the source, the broader the anomaly. This relationship is of primary importance in interpreting the results of a magnetic survey. The proportion between the width of an anomaly and the depth of the source is a function of the fall-off rate, or the variation of anomaly amplitude with distance(d). For a dipole, the total-field anomaly amplitude varies as $1/d^3$, and for a monopole as $1/d^2$. In actual practice, source orientation and other factors may result in fall-off rates from $1/d$ to $1/d^3$. The shape of the magnetic profile of an anomaly and knowledge of the source object help in selecting the proper fall-off rate for depth estimation. A range of depths determined from several fall-off rates may be the most appropriate way to present depth estimates.

In general the anomaly width is on the order of one to three times the depth of the source. Thus, for an anomaly with a width of 100 feet, the source probably lies between 30 and 100 feet deep (or distant). Several methods, including the half-width rule and the slope technique, can be used to estimate source depths from total field profiles.

5.3.1.3 Half-Width Rule

The half-width ($x_{1/2}$) of an anomaly on a total field profile is the horizontal distance between the principal maximum (or minimum) of the anomaly (assumed to be over the center of the source) and the point where the total field value is exactly one-half of the principal maximum (Figure 3.2-1). A profile that is used for

depth estimation by using the half-width rule should be oriented perpendicular to the long axis of the anomaly to give the narrowest profile. This rule is valid only for forms such as spheres, cylinders, and other simple shapes. For example, a single upright 55-gallon steel drum can be approximated as a vertical cylinder (monopole) and the depth (d) = 1.3 $x_{1/2}$. A buried trench filled with drums can be approximated by a horizontal cylinder, where d = 2 $x_{1/2}$.

5.3.1.4 Slope Techniques

Depth of the source can be estimated using the slope of the anomaly at the inflection points of the profile. The horizontal extent (X_z) of the "straight" portion of the slope is determined as shown in Figure 3.2-1. The depth is then estimated by the equation,

$$d = KX_z \text{ where } 0.5 < K < 1.5$$

5.3.2 Metal Detection

Very little interpretation is necessary for Metal Detection surveys performed to provide qualitative data on the presence of metallic objects in the survey area, as a precursor to more detailed subsequent geophysical surveys. For these cases, the positive audible responses or meter deflections are recorded on site grid maps and no further processing or interpretation is made. More detailed metal detection surveys using strip-chart or magnetic tape recording are possible. Typically, data is plotted on site grid maps following computer processing. Corrections for nonlinearities and smoothing of the data to eliminate small-target responses can be accomplished.

5.4 Applications Management

5.4.1 Prerequisites

As described in Section 5.1.2, appropriate planning of magnetic and metal detection surveys requires at least a basic understanding of general site features and geohydrologic characteristics, as well as the probable variability in conditions. The Work Plan should describe, in as much detail as possible, the known site conditions which may affect the measurements, and the objectives of proposed survey efforts. The type and degree of data interpretation and the desired format for data presentation should be specified if possible.

5.4.2 Work Planning and Scheduling

Magnetic and metal detection surveys may be performed concurrently with field geotechnical investigations, in which case on-site interpretation of data may provide real-time guidance for well drilling activities. Ideally, however, these geophysical surveys should be conducted in advance, allowing sufficient time for data interpretation and use of the results in planning other field exercises.

The time and effort required by these geophysical surveys vary greatly depending on the site-specific objectives and site conditions. Typically, 2 to 10 acres of metal detection can be performed by one person per day. Additionally, 2 to 3 linear miles of magnetometer data can be collected by 1 person per day. Data reduction and interpretation will require at least an equivalent amount of time to the field work. Weather conditions, terrain, and obstructive site features cause considerable variability in these estimates.

5.5 Calibration

5.5.1 Magnetic Survey

Magnetometer readings should be compared regularly to readings of a reference base station magnetometer; this procedure is necessary if corrections are to be made for changes in the earth's magnetic field over time.

5.5.1.1 Daily Quality Control

All data sets should be accompanied by quality control data that indicates the level of quality of each individual data point. Periodically, replicate measurements should be made so that measurement precision can be established. This procedure also requires corrections for variations in the earth's magnetic field with time. Each data set should be referenced to the most recent calibrations. All data obtained prior to a calibration requiring significant changes in instrument controls is suspect, and the measurements should be repeated or otherwise validated. Data should be preliminarily reduced and plotted during the field program to determine the overall quality of the data and whether the survey results are consistent with the site conceptualization. Data points representing discontinuities in the curves should be validated by repetition and, if necessary, a fine grid of measurements made to determine whether the anomaly represents a site feature of interest, a spurious reading, or an obstructive interference.

The earth's magnetic field varies constantly due, primarily, to solar activity. These natural fluctuations must be accounted for and removed from the survey data. A second magnetometer will be used as a base station to measure and record these fluctuations. These data will subsequently be used to drift correct the survey magnetometer data. In addition, the U.S. Space Environmental Agency should be contacted daily to obtain the latest solar activity forecasts. Data acquisition will cease in the event of a magnetic storm. The phone number for the U.S. Space environmental Agency is (303) 497-3171.

5.5.2 Metal Detection

5.5.2.1 Calibration

Metal detectors normally are not calibrated, and only relative response is of interest. Periodically, the sensitivity should be checked by nulling the instrument at a fixed location known to be free of metal, and adjusting the gain to provide a proper response over a known target.

5.5.2.2 Daily Quality Control

Metal detector data should be accompanied by sufficient quality control data to verify that the instrument was operating properly. Occasional repetitive measurements and a log of the sensitivity adjustments usually suffice for this purpose.

5.6 LIMITATIONS

Magnetometer data may be adversely affected by the presence of anthropogenic surface features such as buildings, fences, power lines, vehicles, and reinforced concrete. The magnetic response from these surface features can be much larger than that due to a single buried steel drum, and thus can mask the response of a drum. Magnetometer surveys should not be conducted in urban areas or areas where surface anthropogenic features are prevalent.

Data interpretation is not always straight forward with magnetic data. Metallic drums that are buried at the same depth but at different orientations can yield very dissimilar instrument responses. Data that are collected along survey lines oriented east-west can appear very different than data that are collected along survey lines oriented north-south (the preferred survey orientation).

6.0 REFERENCES

Good discussions of various geophysical survey techniques and applications are found in the following references:

Benson, R. C., R. A. Glaccum and M. R. Noel, 1982. Geophysical Techniques for Sensing Buried Wastes and Waste Migration, Technos, Inc., Miami, Florida, Contract No. 68-03-3050, U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

Costello, R. L., 1980. Identification and Description of Geophysical Techniques, Report No. DRXTH-TE-CR-80084, U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland; Defense Technical Information System Number ADA 123939.

McKown, G. L., G. A. Sandness and G. W. Dawson, 1980. Detection and Identification of Buried Waste and Munitions, Proceedings of the 11th American Defense Preparedness Association Environmental Systems Symposium, Arlington, Virginia, 1980.

Ward, Stanley, H. 1990. Geotechnical and Environmental Geophysics, Society of Exploration Geophysicists. Tulsa, Oklahoma.

7.0 RECORDS

None.

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1.0 PURPOSE

The purpose of this guideline is to provide a general description of, and technical management guidance on, the use of Ground-Penetrating Radar (GPR) Surveys in Remedial Investigations (RIs) and Feasibility Studies.

2.0 SCOPE

This guideline provides a description of the principles of operation, instrumentation, applicability and implementability of standard GPR methods used during site investigations, to determine subsurface stratigraphic and other interfaces discernable by GPR. The document is intended to be used by the Site Manager (SM), RI Leader, Field Operations Leader (FOL), or site geologist to develop an understanding of each method sufficient to permit work planning, scheduling, and resource planning. This guidance is not intended to provide a detailed description of methodology and operation. The highly specialized nature of GPR surveys requires inclusion of project-specific, site-specific, and subcontractor-specific information prior to development of detailed operating plans, during both planning and execution.

3.0 GLOSSARY

Dielectric Constant. Property of a medium that determines reflection, absorption, and transmission characteristics of a radar signal; a measure of the ability of a material to store charge when an electric field is applied. Also known as permittivity.

Depth of Investigation. The depth at which an object of interest can be detected in a GPR survey.

Radar Trace. A display of reflected signal strength on a graph of lateral distance along the ground versus the radar signal travel time (corresponding to vertical distance of penetration).

Two-Way Travel Time. The time required for a radar signal to travel from the antenna to a target and return to the antenna. Travel time is a function of the depth of an object and the dielectric constant (permittivity) of the medium (soil, rock, etc.).

4.0 RESPONSIBILITIES

Field Operations Leader - Responsible for overall management and coordination of the field work.

Site Manager - Responsible for scoping of the ground-penetrating radar surveys during development of the Work Plan, with input from the RI leader, site geologist, and site geophysicist.

Site Geophysicist - As a specialist in this field, the site geophysicist plays a central role in determining the appropriateness of this technique for providing necessary data. Field work for these surveys is supervised by the site geophysicist, with support from geophysical technical specialists and other personnel as needed. Data reduction and interpretation are performed by the site geophysicist or technical specialist.

5.0 PROCEDURES

5.1 Description of Methods

5.1.1 Theory and Principles of Operation

Commercially-available Ground-Penetrating Radars (GPR) operate on the principle of time-domain reflectometry, in which the difference in strength and the time delay between a transmitted electromagnetic pulse and its reflection from an object are measured. The time delay or two-way travel time, t, is directly related to the propagation velocity of the electromagnetic waves, v, and to the distance between the transmitter and the object, D, as follows:

$$t = \frac{2D}{v}$$

Because GPRs are normally used at or near the surface of the ground, the distance D corresponds to the depth of buried targets that reflect the radar signals.

The strength of a radar signal is a complex function of the distance traveled through the medium and the dielectric constant, the magnetic permeability and the electrical conductivity of the medium. Radar signals are attenuated rapidly in materials with high dielectric constant. This attenuation in subsurface media is a function of the mineralogy and the water content. Thus, materials such as dry sands and gravels are least absorptive of radar signals, whereas wet clays are highly absorptive. The absorptive properties of the medium limits the depth of investigation, e.g., the depth at which targets can be detected.

Radar antennas are available which operate at frequencies centered on 25-900 MHz. Whereas the higher frequencies are able to detect smaller targets, the penetration depth is roughly inversely proportional to frequency. Thus, any GPR survey requires an analysis of the trade-off between resolution and depth of penetration so that the optimal frequency can be selected.

The amplitude of a radar reflection is a function of the composition, size shape, and depth of the target and contrast between permittivity of target and permittivity of surrounding material. High amplitude are reflections are from objects exhibiting large differences in dielectric constant from the surrounding medium, and are large in size compared to the radar signal wave length.

5.1.2 General Applicability

GPR signals are reflected from any interface which corresponds to an abrupt change in dielectric constant. Therefore, both metallic and nonmetallic objects (including voids) as well as changes in geologic structure can be detected by this method. Because of the higher frequencies used, target resolution is considerably improved over seismic or resistivity sounding methods. However, the high frequencies also result in strong attenuation of the signals, particularly in clay materials with high moisture content. At 100 MHz, the depth of investigation in clay soil with 20 percent moisture content is 3 feet or less, whereas in dry clay, or a sand with 20 percent moisture, the penetration depth can extend to approximately 30 feet.

GPR can be a powerful method for locating and mapping buried drums, wooden objects, foundations, non-containerized wastes, underground utilities, and many other artifacts (including historical artifacts)

at a site. Depending on whether sufficient depth of investigation can be achieved, the method can also be used to map saturated zones and bedrock contours, and locate sinkholes or fracture systems.

A major limitation to applicability is the degree of subjective interpretation that is employed. The problem of noting a small signal disturbance in a sea of clutter can be overcome somewhat by simultaneous observation of a large number of parallel tracks.

5.1.3 Instrumentation

The standard array of GPR instrumentation consists of a transmitter/antenna unit which is pulled along the ground; a control unit, containing a power supply and signal processing circuitry which is connected to the antenna by a cable; and a laptop computer or analog tape recorder. The system can be vehicle-mounted, and the transmitter can be connected via radio link to the signal processing and recording equipment.

5.2 Data Acquisition

5.2.1 Field Procedures

GPR surveys are performed by establishing a grid of parallel survey lines across the site and moving the radar antenna along each of these lines. A suitable means must be provided for determining the location of the radar unit along each of the lines, and for documenting this information on the recording medium. Typical systems measure the time and velocity of antenna motion, or determine the position of the antenna by synchronization signals from the wheels or tracks of the vehicle used to tow the antenna.

To determine the depth of anomalies noted on radar traces, it is necessary to convert the travel time data that are actually recorded. The velocity of electromagnetic waves in the subsurface medium at the site is determined by excavation to observed targets and measuring their depths. The velocity should be determined at several points in the area of interest. Depths to targets can be estimated by using published values of dielectric constants for a range of different earthen materials and the following formula:

$$D = \frac{ct}{2\sqrt{e_r}} = \frac{V_m t}{2} \qquad V_m = \frac{c}{\sqrt{e_r}}$$

Where:

D = depth to target (feet)
t = two-way travel time (nanoseconds)
c = velocity of light (1 foot/nanosecond)
ϵ_r = dielectric constant (dimensionless)

Two-way travel times can also be calculated by collecting GPR data over targets of known depth (e.g., trenches, buried pipes/culverts).

Specific procedures for data acquisition are as follows:

1. The time scale of the GPR unit shall be checked regularly for accuracy. This can be done either on or off the site by placing the GPR unit at a known distance from the ground, a wall, etc., and measuring the two-way travel time to that reflecting surface in the air. The velocity of electromagnetic waves in air is 1 foot per nanosecond ($3x10^8$ m/sec.). The following equation shall be used:

$$t = 2d/c$$

where:

t = two-way travel time from antenna to the surface, (nanoseconds)
d = distance of antenna to the surface, (feet)
c = velocity of light in air, (1 foot/nanosecond)

2. Prior to conducting a survey, a GPR traverse should be conducted over a buried object of known depth (if available). From the two-way travel time and the measured burial depth of the object, the average electromagnetic wave velocity (V) in soil can be calculated from the following equation:

$$V = 2d/t$$

3. A short GPR traverse shall be repeated twice daily over a known feature prior to and after conducting daily operations. Technical judgment shall be exercised to ensure that variations between repeat readings are a result of changing soil conditions rather than the electronics.

5.2.2 Data Format

Reflected radar signals are electronically processed and displayed as an intensity-modulated time spectrum, where the time corresponds to target depth as described above. The series of signals corresponding to the reflected pulses as the antenna moves along a path forms a three-dimensional data set containing distance of traverse, depth, and intensity information.

Typically, the data are recorded on a computer's hard drive with distance displayed along the X-axis, time (depth) displayed along the Y-axis, and the intensity given by the degree of amplitude of the reflection. In a typical survey, a series of parallel tracks are traversed by the GPR, and the series of resulting oscillograph traces provides XYZ locational information and intensity of reflection from targets of interest.

Although much of the data obtained in a GPR survey is automatically recorded by the instrument, additional information to identify and interpret each trace should be recorded on standard data sheets. As a minimum the data sheet should contain the following information:

1. Project name, number and location.
2. Company or organization.
3. Date and time of day.
4. Operator's name.
5. Line and trace designation (also recorded directly on the signal recording medium).
6. Equipment serial numbers.
7. Antenna frequency.

8. Direction and speed of antenna movement.
9. Weather and temperature.
10. Site map coordinates at the beginning and end of the trace.
11. Notes, remarks or comments.
12. Electromagnetic velocity in the subsurface medium at the nearest calibration point.

5.3 Data Interpretation

Except for those systems which provide extensive data processing, interpretation of anomalies in GPR traces requires considerable subjective evaluation by a trained geophysicist. Extensive experience is essential to distinguish target reflections from inherent system noise and interferences. In many cases, the anomalies due to targets of interest are small compared to varying reflections from the antenna system, the ground surface, geologic perturbations, and other interferences. Similarly, an acceptable interpretation of target depth from travel time data requires a knowledge of geophysical characteristics across the site.

A radar antenna transmits a "cone," rather than a thin beam of electromagnetic energy, so that reflections are obtained from objects not directly below the antenna. As the antenna moves across the plane of an object, reflections are obtained for a considerable distance along the antenna path. The signal travel times will vary during this process, corresponding to the distance between the antenna and the object. A discrete spherical target would exhibit a hyperbolic reflection pattern on the radar trace, with the apex of the hyperbola corresponding to the location and depth of the object. Multiple or odd-shaped targets, or targets of considerable size (compared to the radar wavelength) will exhibit complex reflection patterns consisting of overlapping hyperbolas. Thus, a true "picture" of subsurface objects is not obtained, and experience is necessary to translate the complex tracings into information on target depth, size or shape.

5.4 Applications Management

5.4.1 Prerequisites

Appropriate planning of GPR surveys requires at least a basic understanding of the geophysical characteristics of the site. The type and structure of soils and geologic formations should be indicated. The description of the site should include the depth, size and shape, and type of potential targets to be detected, as well as obstructive site features such as rough or wet terrain and underground structures. The existence of, and depth to known buried objects should be listed and mapped. Other specifications include the degree of locational resolution desired, probable weather conditions during site activities, and the type and sophistication required for data interpretation and presentation.

5.4.2 Work Planning and Scheduling

If possible, GPR surveys should be performed concurrently with other geophysical surveys and in advance of excavation or drilling at a site. Radar data complements information from other geophysical methods such as seismic refraction, magnetometry, and resistivity in arriving at an interpretation of subsurface geohydrologic features and location of buried waste materials. This information is important in locating and selecting the appropriate type of monitoring wells.

The time and effort required to perform GPR surveys vary greatly depending on the sophistication of the available equipment and the complexity of the site. Assuming a 2-person team, simple hand-operated radar systems can cover from 1/4 to 1/2 acre per day for the survey, proper documentation and simple interpretation. Vehicle-mounted systems with automatic data recording and processing can cover from 2 to 5 acres per day. Sophisticated data processing, detailed interpretations, and high-quality displays

require considerable computer usage and approximately twice the time required for the actual field survey.

The specific objectives of the GPR survey should be defined in the Work Plan and should include the following elements:

1. Type of survey (level of detail) to be accomplished, and area to be covered.
2. Type, depth, size and composition, of targets of interest (if known).
3. Locational accuracy required.
4. Schedule limitations.
5. Degree of sophistication required for data presentation and interpretation.
6. Specific deliverables required.

5.5 Quality Control (QC)

5.5.1 General

Because of the specialized nature of the method and the highly subjective interpretations needed to process the data, GPR surveys are subject to misapplication, erroneous interpretation, and collection of inadequate or incomplete data. This susceptibility to misuse requires that an adequate quality control program be established. Quality control aspects include the following :

- Insistence on a defined scope of work, specifications, and data validation procedures.
- No data point should be rejected from a data set without appropriate justification; field data sheets should contain all observed data and the conditions that could impact data validation.
- All field data should be recorded in permanent ink in a bound logbook, and each page signed and dated by the operator. Original unaltered logbooks should be retained in the files.
- In general, the objectives of geophysical surveys can be met by relative measurements across an area or with depth. Absolute calibration is therefore of lesser importance than precision of measurements. However, a properly calibrated instrument provides an added measure of data validity and permits correlation and comparison of the associated data with site features and geohydrologic characteristics not evident at the time of the field effort.
- An evaluation should be made of noise, interferences and obstructions at a site and such measurements, interferences and explanations should be recorded in the field. These real-time quality control procedures aid field personnel in correction of noise sources over which they have control, in validating suspected external sources, and in early detection of problems that may jeopardize the survey objectives.

5.5.2 Daily Quality Control

All radar traces and interpreted data sets should be accompanied by quality control data that indicate the level of quality of the data. Periodic replicate measurements should be made so that measurement precision can be established. Time and/or depth calibrations should be performed on a daily basis.

A calibration that yields significant changes in instrument parameters or travel time may indicate the need for repetition of data or increased density of travel time calibrations in the area of interest. Graphical data should be reviewed during the field activities to determine that data quality is adequate, and whether the survey results appear to be consistent with geophysical concepts of the site.

5.6 Potential Problems

GPR surveys are subject to a wide variety of problems that may be encountered. Problems can be expected to arise in the following areas:

5.6.1 Planning and Execution

Rarely is a survey accomplished exactly according to the original plan. Site features not previously specified and other variations can occur that force changes in the details of the approach. However, the objectives of the survey, the general methodology, the amount and quality of data required and the degree of data interpretation requested should remain unchanged. Project work scopes should be written with some degree of latitude to allow a change in plans whenever justified.

5.6.2 Noise and Interferences

Measurements can be affected severely by natural and by man-made sources of interference. Source of system noise that degrade the quality of radar traces include improper spacing of antennas above ground, improper cable placement, location of antennas too close to other system components, and facility instrument operation. Because reflections are obtained from any objective with a dielectric constant differing from the surroundings, large masses or high density of buried or surface rocks, metal, debris, wet soil, or structures can mask targets of interest. Some antennas are not shielded on top, and similar interfering reflections will be obtained from overhead objects such as trees, power lines and buildings. The site personnel must recognize the limitations posed by these obstructions, and take steps to minimize the interferences.

Topographic and geologic features can also interfere with acquisition of high-quality target detection data. Small depressions in the ground surface, the presence of boulders, clay lenses and moist soil zones affect both the detectability of a target and determination of its depth from the travel time.

Sources of electromagnetic energy in the vicinity, such as radio or television transmitters, or navigational radar antennas can result in spurious signals in the radar traces. In some cases, these problems can be minimized by judicious selection of radar and/or data communications frequency, and by scheduling the surveys during periods of transmission inactivity.

5.6.3 Weather Conditions

Because water is a good absorber of radar signals, wet weather has a very serious effect on the ability to perform GPR surveys. Physical difficulties in executing a survey over wet terrain also may be expected. The field activities should be planned, if possible, during periods when dry weather can be expected. Schedules for surveys should account for the probability that moist soil conditions will exist.

5.6.4 Technical Difficulties

Preventable difficulties include equipment malfunction, or misapplication, poor operator training, and lack of applications experience. Other difficulties may arise because the geophysical character of the site is not as initially conceptualized. The effect of these problems can be minimized by early recognition, using

responsive and responsible technical management. Interim, real-time scrutiny of the data by the site geophysicist and management personnel is essential. The geophysical subcontractor must be responsive regarding equipment replacement, repair, or changes in personnel. The Site Manager and the Site Geologist should be cognizant of technical difficulties beyond the control of the field personnel, and should recognize the need to change plans, change performers, or cancel a survey, as appropriate.

6.0 REFERENCES

Good discussions of various geophysical survey techniques and applications are found in the following references:

1. Benson, Richard C., Robert A. Glaccum and Michael R. Noel, Geophysical Techniques for Sensing Buried Wastes and Waste Migration. U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

2. Costello, Robert L., 1980, Identification and Description Geophysical Techniques, Report No. DRXTH-TE-CR-80084, U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland; Defense Technical Information System Number ADA 123939.

3. McKown G. L., G. A. Sandness and G. W. Dawson, Detection and Identification of Buried Waste and Munitions, Proceedings of the 11th American Defense Preparedness Association Environmental Systems Symposium, Arlington, Virginia.

B.2 Addenda to Brown & Root Standard Operating Procedures

SOP NUMBER GH-2.8 (DATED 03/01/96)
GROUNDWATER MONITORING POINT INSTALLATION
REVISIONS/ADDITIONS/CLARIFICATIONS
MARINE CORPS RECRUIT DEPOT PARRIS ISLAND, SC

Section 4.0 Responsibilities; page 2: The drilling subcontractor will be licensed and certified in the State of South Carolina. Additionally, the driller will notify the regulatory agencies of upcoming activity within 72 hours of the event.

Section 5.2.2 Riser Pipe and Screen Materials; page 5: Borehole size as it relates to casing diameters will conform with Section E.5.1 of the Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), 1996, U.S. EPA, Region 4.

Screen slot size and filter pack design will conform with Section E.5.3 of the EISOPQAM, 1996, U.S. EPA, Region 4.

Section 5.3.1 Monitoring Wells in Unconsolidated Sediments: Well completion requirements regarding the addition of bentonite and grout will conform to Section E.3.4 of the EISOPQAM, 1996, U.S. EPA, Region 4.

SOP NUMBER SA-1.1 (DATED 03/01/96)
GROUNDWATER SAMPLE AQUISITION AND
ONSITE WATER QUALITY TESTING
REVISIONS/ADDITIONS/CLARIFICATIONS
MARINE CORPS RECRUIT DEPOT PARRIS ISLAND, SC

Section 5.5.6 Measurement of Turbidity: When collecting measurements for turbidity, efforts will be made to achieve a turbidity of 10 NTUs or less during purging. If a value of less than 10 NTUs cannot be achieved, attempts to stabilize the turbidity at a constant value will be made.

SOP NUMBER SA-7.1 (DATED 01/21/97)
DECONTAMINATION OF FIELD EQUIPMENT AND WASTE HANDLING
REVISIONS/ADDITIONS/CLARIFICATIONS
MARINE CORPS RECRUIT DEPOT PARRIS ISLAND, SC

Section 5.2 Sampling Equipment: Consideration will be given to using the decontamination procedures outlined in the Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), 1996, U.S. EPA, Region 4, as well as the Brown & Root Environmental SOPs.

Section 5.2.2 Sampling Pumps: The use of pumps for sampling will conform to Section 7.3 of the Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, 1996, U.S. EPA, Region 4.

Section 5.5.3 Drilling Muds and Well Development Fluids: The use of mud pits will not be permitted for drilling activities at the Marine Corp Recruit Depot Parris Island, SC.

Rev. 0
03/27/98

Master Quality Assurance Plan

Marine Corps Recruit Depot

Parris Island, South Carolina
U.S. EPA Identification Number
SC6 170 022 762

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888

Contract Task Order 0020

March 1998

Rev. 0
03/27/98

MASTER QUALITY ASSURANCE PLAN

MARINE CORPS RECRUIT DEPOT
PARRIS ISLAND, SOUTH CAROLINA
U.S. EPA IDENTIFICATION NUMBER
SC6 170 022 762

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, South Carolina 29406

Submitted by:
Brown & Root Environmental
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CONTRACT NUMBER N62467-94-D-0888
CONTRACT TASK ORDER 0020

MARCH 1998

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ACRONYMS/ABBREVIATIONS

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BAT	Best Available Technology
BNA	Base/Neutral/Acid
BOD	Biological Oxygen Demand
B&R Environmental	Brown & Root Environmental
CADD	Computer-Assisted Drafting and Design
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CIH	Certified Industrial Hygienist
CLEAN	Comprehensive Long-term Environmental Action Navy
CLP	Contract Laboratory Program
COC	Chain-of-Custody
COD	Chemical Oxygen Demand
CRDL	Contract-Required Detection Limit
CRQL	Contract-Required Quantitation Limit
CTO	Contract Task Order
DQOs	Data Quality Objectives
DRO	Diesel-Range Organics
FOL	Field Operations Leader
FTMR	Field Task Modification Request
GC/MS	Gas Chromatograph/Mass Spectrometer
GRO	Gasoline-Range Organics
HSM	Health and Safety Manager
ICP	Inductively Coupled Plasma
ICS	Interference Check Samples
IDL	Instrument Detection Limit
IDW	Investigative-Derived Waste
IR	Installation Restoration
LD	Laboratory Duplicate
LQAC	Laboratory Quality Assurance Coordinator
LQAP	Laboratory Quality Assurance Plan
Master FSP	Master Field Sampling Plan

Master HASP	Master Health & Safety Plan
Master PP	Master Project Plan
Master QAP	Master Quality Assurance Plan
MCRD	Marine Corps Recruit Depot
MDL	Method Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NAVFAC	Naval Facilities Engineering Command
NFESC	Naval Facilities Engineering Service Center
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
OSHA	Occupational Safety and Health Administration
PAH	Polynuclear Aromatic Hydrocarbons
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PCB	Polychlorinated biphenyl
PE	Professional Engineer
PM	Project Manager
ppb	parts per billion
PQL	Practical Quantitation Limit
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manager
QAP	Quality Assurance Plan
QAPP	Quality Assurance Project Plan
QNs	Quality Notices
RCRA	Resource Conservation and Recovery Act
RPD	Relative Percent Difference
RPM	Remedial Project Manager
SCDHEC	South Carolina Department of Health and Environmental Controls
SDG	Sample Delivery Group
SOP	Standard Operating Procedure
SOUTHDIV	Southern Division
SOW	Statement of Work
SSO	Site Safety Officer
SVOC	Semivolatile Organic Compound
TAL	Target Analyte List
TCLP	Toxicity Characteristic Leaching Procedure

TDS	Total Dissolved Solids
TEM	Transmission Electron Microscopy
TOC	Total Organic Carbon
TOMs	Task Order Managers
TOX	Total Organic Halides
TPH	Total Petroleum Hydrocarbons
TSS	Total Suspended Solids
U.S. EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WP	Work Plan
XRF	X-ray Fluorescence

1.0 INTRODUCTION

This Master Quality Assurance Plan (Master QAP) pertains to contract environmental field activities performed at Marine Corps Recruit Depot (MCRD) Parris Island, South Carolina. This Master QAP has been prepared by Brown & Root Environmental (B&R Environmental) for the Southern Division (SOUTHDIV) Naval Facilities Engineering Command (NAVFAC) under the Navy Comprehensive Long-term Environmental Action Navy (CLEAN) Program, Contract Number N62467-94-D-0888, Contract Task Order (CTO) 0020. This Master document applies to contract activities performed under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) requirements. Site-specific applicable regulatory criteria and professional technical standards will be defined in the Quality Assurance Project Plans (QAPPs), which will be written as addenda to this document.

Although project-specific details are not provided in this Master QAP, this document has been written to address all issues contained in the United States Environmental Protection Agency (U.S. EPA) guidance "Requirements for Quality Assurance Project Plans for Environmental Data Operations," (U.S. EPA, August 1994).

1.1 QA/QC SYSTEM OBJECTIVES

As described in the Naval Facilities Engineering Service Center (NFESC) guidance document entitled "Navy Installation Restoration Laboratory Quality Assurance Guide" (NFESC, February 1996), the Navy, in conjunction with its contractors under the CLEAN Program, has established quality assurance/quality control (QA/QC) measures and a program to ensure that these measures are applied to the collection and interpretation of all environmental data obtained. Procedures for field sampling, chain-of-custody, laboratory analysis, and data management have been established that will provide for the generation of environmental data of known and acceptable quality, so that applicable regulatory requirements and contract criteria can be effectively addressed. This Master QAP was prepared in accordance with the aforementioned NFESC guidance document.

1.2 MASTER PLAN DOCUMENTS

In conformance with QA/QC system objectives, all activities must be planned and conducted in accordance with accepted standards and practices. This ensures that the resultant data are verifiable, valid, and suitable for their intended use(s). The following Master Work Plan documents have been generated for MCRD Parris Island by B&R Environmental to address these issues:

Master Work Plan (three volumes)

Volume I

- Master Project Plan (Master PP)

Volume II

- Master Field Sampling Plan (Master FSP)
- Master Quality Assurance Plan (Master QAP)
- Project Health & Safety Plan (Project HASP)

Volume III

- Master Decision Document

The Master PP (Volume I) contains an overview of facility history and past operations as well as a summary of environmental investigations previously conducted at Parris Island. The Master PP also contains extensive background information describing regional geology, hydrogeology, and topography.

A comprehensive overview of potential environmental investigative techniques is provided in the Master FSP (Volume II). Additionally, the Master FSP details standard procedures to be used for sample collection, sample identification, equipment decontamination, field equipment calibration and preventive maintenance, sample and field documentation, waste handling, and surveying.

This Master QAP (Volume II) contains summary discussions of management schemes and Data Quality Objectives (DQOs), as well as detailing standard procedures for sample custody, sample preservation, packaging and shipping, laboratory analysis and preventive maintenance, internal and external quality control checks, data evaluation and management, audits, and identification and performance of corrective actions.

The Project HASP (Volume II) prescribes how considerations of worker health and safety are addressed in a manner that is compliant with Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) regulations.

The Master Decision Document (Volume III) contains the ecological and human health risk criteria and environmental sampling screening criteria established to support decisions made during the execution of environmental sample collection.

1.3 PROJECT PLAN DOCUMENTS

Corresponding addenda to the previously described Master Work Plan documents for MCRD Parris Island will be generated to address site-specific considerations. These addenda are collectively referred to as the "Site-Specific Documents" and consist of the following:

- Site-Specific Sampling and Analysis Plan composed of the:
  - Site-Specific WP
  - Site-Specific FSP
  - QAPP

- Site-Specific HASP

Site-specific scope and DQOs are defined in the Site-Specific WP. A field sampling summary, details pertaining to mobilization/demobilization, and other site-specific field considerations are presented in the Site-Specific FSP. The QAPP presents site-specific considerations of the key elements addressed by the Master QAP. Likewise, the Site-Specific HASP presents site-specific considerations of the key elements addressed by the Project HASP.

All site-specific documents for MCRD Parris Island will be written in compliance with U.S. Navy/Marine Corps Installation Restoration (IR) Manual requirements (Naval Facility Engineering Command, 1997).

2.0 MANAGEMENT ORGANIZATION AND RESPONSIBILITIES

The Navy, in conjunction with its contractors, is responsible for the overall management, implementation, and inspection of contract field activities at MCRD Parris Island. Personnel from the Navy will be actively involved with its contractor in a number of areas. The authorities and organizational relationship of key personnel are depicted in Figure 2-1. Responsibilities for program management, project management, field operations, and laboratory operations are discussed in the following sections.

2.1 PROGRAM MANAGEMENT AND PROJECT ORGANIZATION

The following sections outline the project organization for installation restoration activities at MCRD Parris Island.

2.1.1 Navy/Regulators

The Navy Remedial Project Manager (RPM), Art Sanford, has overall responsibility for all phases of the MCRD Parris Island investigation. In general, the Navy RPM acts as the focal representative for the Navy, providing management, technical direction, and oversight for all Parris Island Installation Restoration activities performed by contractors and their subcontractors. In matters such as facilitation of access, oversight, etc., the Navy RPM is assisted by the MCRD Parris Island Natural Resources and Environmental Affairs Office. Personnel from the U.S. EPA Region 4 and the South Carolina Department of Health and Environmental Controls (SCDHEC) represent Agency considerations and will provide input from this perspective, as well as lend general historical and technical assistance to the Parris Island field activities.

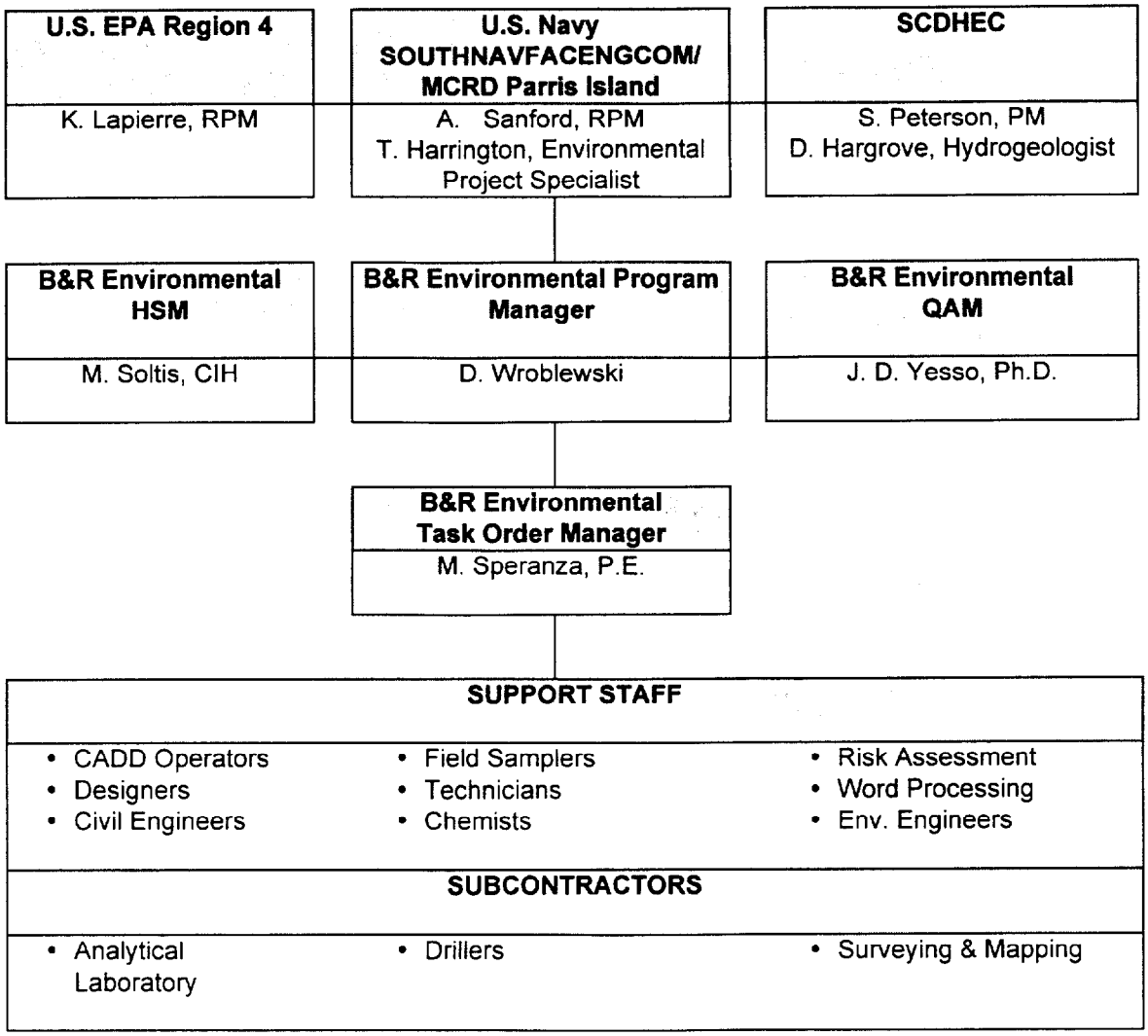
2.2.2 B&R Environmental

B&R Environmental, as the Navy CLEAN contractor, will be responsible for executing environmental investigation work at Parris Island. Duties of key personnel are described below:

Program Manager:

The B&R Environmental CLEAN Program Manager provides operations, technical, and administrative leadership, and oversees and supports quality assurance policies. The Program Manager assigns project Task Order Managers (TOMs) and oversees their performance. The Program Manager also ensures the availability of technical and clerical resources for program operations, and maintains consistency in procedures and product among CTO assignments.

FIGURE 2-1
PROJECT ORGANIZATION CHART
MCRD PARRIS ISLAND, SOUTH CAROLINA



CADD = Computer-Assisted Drafting and Design
CIH = Certified Industrial Hygienist
HSM = Health and Safety Manager
PE = Professional Engineer
PM = Project Manager
QAM = Quality Assurance Manager
RPM = Remedial Project Manager

Task Order Manager:

The B&R Environmental TOM, Mark Speranza, has the overall responsibility for project (i.e., scope, schedule, budget) and technical management and is responsible for identifying and ensuring the availability of qualified, onsite personnel. Additional responsibilities of the TOM are:

- Ensuring timely resolution of project-related technical, quality, safety, or waste management issues.
- Functioning as a primary interface with the RPM, field personnel, laboratory point-of-contact, and subcontractors.
- Monitoring and evaluating subcontractor performance.
- Coordinating and overseeing work performed by technical staff (including risk assessment and modeling).
- Coordinating and overseeing maintenance of all project records.
- Coordinating and overseeing review of project deliverables.
- Preparing and issuing final project deliverables to the Navy.

Quality Assurance Manager (QAM):

The B&R Environmental QAM has the responsibility for the following activities:

- Developing, maintaining, and monitoring quality assurance policies and procedures
- Providing training to B&R Environmental staff in QA/QC policy and procedures.
- Conducting systems and performance audits to monitor compliance with environmental regulations, contractual requirements, Project Plan requirements, and corporate policies and procedures.
- Conducting audits of project records.
- Ensuring external audits of subcontracted laboratories and monitoring subcontractor quality controls and records.

- Assisting in the development of corrective action plans; ensuring correction of nonconformances reported in internal or external audits.
- Overseeing the implementation of the Master QAP.
- Overseeing and reviewing the development and revision of site-specific QAPPs.
- Overseeing the responsibilities of the B&R Environmental Site QA/QC Officer.
- Preparing quality assurance reports for management.

Health and Safety Manager (HSM):

The B&R Environmental HSM, Matthew Soltis, is responsible for the following:

- Implementation of the Master HASP.
- Overseeing the development and review of the project HASP.
- Assigning the Site Safety Officer and supervising his/her performance.
- Conducting Health & Safety audits.
- Preparing Health & Safety reports to management.

2.2 FIELD OPERATIONS

The B&R Environmental field investigation team will be organized according to the activities planned. Field team members will be selected based on the type and extent of effort required. All team members will be appropriately skilled and trained for the tasks they are assigned to perform. The team will consist of a combination of the following personnel:

- Field Operations Leader (FOL)
- Site QA/QC Officer

- Site Safety Officer (SSO)
- Field hydrogeologist/geologist(s)

Identities and responsibilities of these project personnel will be provided in the site-specific QAPP prepared for MCRD Parris Island.

2.3 LABORATORY OPERATIONS

Generally, the attending field chemist and his/her immediate supervisor are responsible for QA/QC aspects of onsite mobile laboratory operations. The fixed-base laboratory subcontractor(s) competitively procured to conduct chemical and geotechnical analyses will perform analyses using qualified personnel. Selected laboratories shall comply with state certification and NFESC requirements. The designated Laboratory Quality Assurance Coordinator (LQAC) is responsible for the QA/QC oversight of all laboratory activities. The LQAC has the authority to stop work on projects if QA/QC problems arise which affect the quality of the data produced. Duties of the LQAC are detailed in the Laboratory Quality Assurance Plan (LQAP). Key elements addressed by LQAPs are summarized in Table 4-2 of this Master QAP.

3.0 DATA QUALITY REQUIREMENTS

The overall objectives of the QA/QC system were previously described in Section 1.1. The purpose of this section is to address the QA objectives in terms of the PARCC parameters (Precision, Accuracy, Representativeness, Comparability, and Completeness) and field-related (i.e., external) QA/QC checks. Internal laboratory QA/QC practices (i.e., use of spikes, method blanks, etc.) are discussed in Section 6.0 of this Master QAP.

3.1 DATA QUALITY OBJECTIVES

The DQO process outputs are qualitative and quantitative statements designed to (1) clarify the objectives of the investigation, (2) define the most appropriate type of data to gather, (3) determine applicable conditions for data collection, and (4) specify tolerable limits or decision errors to establish the quantity and quality of the data needed to support the decisions. A discussion of the DQO process is developed in detail in the Master Project Plan (Volume I). Quantitative limits for decision making are developed in the Master Decision Document (Volume III). Specific DQO outputs will be developed in the Site-Specific WPs for site-specific applications.

3.2 THE PARCC PARAMETERS

The PARCC parameters are qualitative and/or quantitative statements regarding the quality characteristics of the data used to support project objectives and, ultimately, environmental decisions. These parameters (i.e., key quality characteristics) are Precision, Accuracy, Representativeness, Comparability, and Completeness.

3.2.1 <u>Precision</u>

Precision characterizes the amount of variability and bias inherent in a data set. Precision describes the reproducibility of measurements of the same parameter for samples under similar conditions. Precision is expressed as a Relative Percent Difference (RPD), which is a relation of the range relative to the mean, expressed as a percent. RPDs are used to evaluate both field duplicate and/or split sample and laboratory duplicate precision, and are calculated as follows:

$$\text{Range} = [OR - DR]$$

$$\%RPD = [(OR - DR) / (OR + DR) / 2)] * 100$$

where:

OR = original sample result

DR = duplicate sample result

RPDs are calculated for each set of field duplicates or splits obtained. In general, field precision is assessed through the collection and measurement of field duplicates or splits at the rate of 1 duplicate/split per 10 analytical samples.

Field duplicate/split precision monitors the consistency with which environmental samples were obtained and analyzed. Field split results for solid matrix samples are considered to be precise if the RPD is less than 50 percent. Field duplicate results for aqueous matrix samples are considered to be precise if the RPD is less than 30 percent. Further detail regarding field duplicates/splits is provided in Sections 3.3.1 and 3.3.2.

Laboratory duplicates, including matrix spike duplicates for organic analysis, are analyzed with a minimum frequency of 5 percent (i.e., 1 laboratory duplicate is analyzed per 20 environmental samples of similar matrix). Laboratory duplicates measure the reproducibility with which laboratory results are generated. Results from laboratory duplicate analyses are evaluated against control limits specified by the U.S. EPA Contract Laboratory Program (CLP) (for CLP analyses) or against laboratory-derived statistical quality control limits (for non-CLP methods). Procedures for compiling statistical control limits are defined by the analytical methodology used and by the LQAP or applicable mobile laboratory Standard Operating Procedure (SOP). These limits are based on three times the standard deviation of a series of RPD or range values. Generally, laboratory duplicates for solid and aqueous matrices are considered to be precise if the RPD is less than 35 percent and 20 percent, respectively.

3.2.2 Accuracy

Accuracy is the comparison of a spiked sample result against a known or calculated value expressed as a percent recovery (%R). Percent recoveries are derived from the analysis of known amounts of compounds spiked into deionized water (i.e., blank spike analysis), or into actual samples (i.e., surrogate or matrix spike analysis). Blank spike analyses measure the accuracy of laboratory operations. Surrogate and matrix spike analyses measure the accuracy of laboratory operations as affected by matrix. Blank spike analyses and matrix spike analyses are performed with a minimum frequency of once per 20 associated samples of like matrix. Surrogate spike analysis is performed for each sample analyzed using

organic chromatographic analytical procedures (with the exception of dioxin/furan analysis). Percent recovery is calculated as follows:

$$\%R = \frac{SSR - SR}{SA} \times 100$$

where:

SSR = Spiked Sample Result
SR = Sample Result
SA = Spike Added

Blank spikes, surrogate spikes, and matrix spikes are further discussed in Section 6.0 (Internal QA/QC Checks). In general, spike recoveries are evaluated against acceptance limits statistically derived by the laboratory in accordance with established practices identified in the analytical method employed, and further defined in the LQAP (or mobile laboratory subcontractor SOP). Generally, upper and lower control limits for accuracy are set at the mean plus or minus three times the standard deviation of a series of %R values. Acceptable limits for spike recoveries vary greatly because of the difference in performance of various compounds based on their chemical nature. When statistically derived control limits cannot yet be determined or when CLP methods are being used, the recovery criteria identified in the appropriate analytical method is used to evaluate the recovery data.

3.2.3 Representativeness

Representativeness is an expression of the degree to which the data accurately and precisely depict the actual characteristics of a population or environmental condition existing at an individual sampling point. Carefully compiled Project Plans and use of standardized sampling, handling, analytical, and reporting procedures are designed so that the final data derived are accurate representations of actual site conditions.

3.2.4 Comparability

Comparability is defined as the confidence with which one data set can be compared to another (e.g., between sampling points; between sampling events). Comparability is achieved by using standardized sampling and analysis methods and data reporting formats (including use of consistent units of measure and reporting of solid matrix sample results on a dry-weight basis). Additionally, consideration is given to seasonal conditions and other environmental variations that could influence data results.

3.2.5 Completeness

Completeness is a measure of the amount of usable, valid, analytical data obtained, compared to the amount expected to be obtained. Completeness is typically expressed as a percentage and is determined using the following equation:

Completeness(%) = [number of valid datapoints/number of planned datapoints] X 100

The ideal objective for completeness is 100 percent (i.e., every sample planned to be collected is collected; every sample submitted for analysis yields valid data). Realistically, however, samples can be rendered unusable during shipping or preparation (e.g., bottles broken or extracts accidentally destroyed); errors can be introduced during analysis (e.g., loss of instrument sensitivity, introduction of ambient laboratory contamination); or strong matrix effects can become apparent (e.g., extremely low matrix spike recovery). These instances result in data that do not meet QC and utilization criteria. Based on these considerations, 90 percent is an acceptable expression of a project's data completeness objective.

If critical data points are lost to the above (or other) considerations, resampling and/or reanalysis may be required.

3.3 FIELD-RELATED QUALITY CONTROL SAMPLES

External QC measures (i.e., field quality control samples) consist of field duplicates, split samples, source water blanks, trip blanks, equipment rinsate blanks, field blanks, material blanks, and background samples. Information gained from these analyses further characterizes the level of data quality obtained to support project goals. Each of these types of field QC samples undergoes the same preservation, analysis, and reporting procedures as the related environmental samples. Each type of field QC sample is discussed below.

3.3.1 Field Duplicates

Field duplicates are two samples collected simultaneously into separate containers from the same source under identical conditions. Field duplicates (also discussed in Section 3.2.1) are collected and analyzed for chemical constituents to measure the precision of the sampling and analysis methods employed. Field duplicates will be collected for all aqueous samples at a frequency of 10 percent (i.e., one out of every 10 samples collected).

3.3.2 Split Samples

Split samples are samples that have been positioned into two or more containers from a single sample container or sample mixing container. Spilt samples will be collected for all solid matrices at a frequency of 10 percent (i.e., one per 10 samples collected). When volatile organic compounds (VOCs) are to be analyzed, the VOC sample aliquots will be containerized prior to mixing to avoid loss of constituents. Split samples, as previously addressed in Section 3.2.1, are analyzed for chemical constituents as a measure of the precision of field sampling procedures.

3.3.3 Source Water Blanks

Source water blanks consist of water used in decontamination and steam cleaning, and are obtained at the rate of 1 per source per sampling event. Source water blanks are analyzed for all organic and inorganic constituents under investigation, as a means of determining whether the source waters used in field procedures could potentially have introduced contaminants to the environmental samples collected. Source water blanks are evaluated in accordance with data validation protocol to determine whether false positive results may exist.

3.3.4 Trip Blanks

Trip blanks are used to assess potential VOC cross-contamination of samples caused by contaminant migration during sample shipment and storage. Trip blanks are generated by the fixed-base laboratory subcontractor(s) and consist of preserved aliquots of analyte-free water contained in sealed vials. These vials are shipped to the site with the empty sample containers and stored with the environmental samples as they are collected for VOC analysis. One set of trip blanks is returned to the laboratory with each shipment of samples collected for VOC analysis. Trip blanks are analyzed for VOCs only.

3.3.5 Equipment Rinsate Blanks

Equipment rinsate blanks are obtained under representative field conditions by collecting the rinse water generated by running analyte-free water through sample collection equipment after decontamination and prior to use. Current NFESC guidance recommends the collection of 1 rinsate blank per day per matrix. If pre-cleaned, dedicated, or disposable sampling equipment is used, one rinsate blank per lot or batch per type of equipment must be collected as a "batch blank". Rinsate blanks are analyzed for the same chemical constituents as the associated environmental samples.

3.3.6 Field Blanks

A field blank or ambient blank is a sample that is prepared in the field to evaluate the potential for contamination of investigative samples by site contaminants from a source not associated with the samples (for example, airborne dust or organic vapors which could contaminate a sample). Organic-free water is taken to the field in sealed containers or generated onsite. The water is poured into the appropriate sample containers at site sampling locations, as required. Field blanks should be collected in dusty environments and/or from areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled. Field blanks will be collected at the discretion of the FOL based on site conditions during sampling.

3.3.7 Material Blanks

Certified-clean materials will be used for all well construction activities. Contamination of these materials has not been a problem historically. However, QC blanks for grout, sand, and bentonite will be collected and held for analysis pending the analytical results of the field investigation. If it is suspected that contaminants have been introduced by well installation materials, the samples will be sent to the laboratory for analysis. For inorganics, holding times will not be exceeded because the holding time for inorganic analysis is considerably longer than the 3-week turn-around time anticipated for analytical results. For organics, material blank analysis is not anticipated because monitoring well purging and development activities should dissipate minor organic contamination if present.

3.3.8 Background Samples

Background samples are collected and analyzed as a basis for determining the nature and extent of constituents inherent to the site, and, in turn, the nature and extent of contamination that may be the result of impact by Depot processes. Information gained from the analysis of background samples is integral to the selection and development of potential remedial strategies if implementation of such strategies is warranted.

3.4 MATRIX SPIKE/DUPLICATE SAMPLE ALIQUOTS

Laboratory duplicates and matrix spike samples were introduced in the previous precision and accuracy discussions (Sections 3.2.1 and 3.2.2, respectively). These analyses are performed as internal QC checks and are therefore also discussed in Section 6.0. For organic analyses, the matrix spike (MS) is analyzed in duplicate (MSD). For inorganic analyses, an MS is analyzed as well as an (unspiked) laboratory duplicate (LD). To accommodate these laboratory QC analyses, the field crew must provide

extra aliquots of sample, as required. These extra sample aliquots are identified with the same sample location information as the selected environmental sample and are provided to the laboratory with a frequency of 1 set per 20 samples of similar matrix.

3.5 BOTTLEWARE REQUIREMENTS

The type of bottleware required to support a particular analysis is contingent upon the analytical method used and the matrix of the sample collected. General guidelines regarding bottleware requirements are contained in 40 CFR 136 (Guidelines for Establishing Test Procedures for the Analysis of Pollutants; September 1992).

The NFESC Interim Guidance Document, "Navy Installation Restoration Laboratory Quality Assurance Guide" (NFESC, February 1996), requires the use of specifically cleaned bottleware. If pre-cleaned bottleware is supplied by a commercial vendor, certification of bottleware cleanliness must be provided.

Soil classification jars and Shelby tubes (when applicable to contain samples for certain geotechnical analysis) are normally supplied by the drilling subcontractor.

3.6 OTHER CONSIDERATIONS

Use of standardized sampling procedures and observance of specified methods of sample containerization and preservation (detailed in Master FSP, Volume II), as well as stipulation of analytical detection limits and observance of maximum technical holding time allowances (detailed in Section 5.0 of this Master QAP) are also considered to be external quality control measures.

4.0 SAMPLE CUSTODY AND SHIPMENT

Sample custody procedures are designed to provide documentation of sample acquisition and integrity. Maintenance of sample custody is critically important to the subsequent legal defensibility of the data generated. In general, a sample is under custody if

- It is in the physical possession of an authorized person.
- It is in view of an authorized person after being in his/her possession.
- It is placed in a secure area by an authorized person after being in his/her possession.
- It is in a secure area, restricted to authorized personnel only.

The chain-of-custody (COC) report is a multi-part, standardized form used to summarize and document pertinent sample information, such as sample identification and type, matrix, date and time of collection, preservation, and requested analyses. Furthermore, through the sequential signatures of various sample custodians (e.g., sampler, airbill number, laboratory sample custodian), the COC report documents sample custody and tracking.

Custody procedures apply to all environmental and associated field QC samples obtained as part of the data collection system.

4.1 FIELD CUSTODY/DOCUMENTATION

The FOL (or designee) is responsible for the care and custody of the samples from the time of collection until they are relinquished to the analyzing laboratory or entrusted to a commercial overnight courier. COC reports are completed for each sample shipment. The reports are filled out in a legible manner, using waterproof ink, and are signed (and dated) by the sampler. Pertinent notes, such as whether the sample was field filtered or whether the sample is suspected to be high in contaminant concentration, are also to be indicated on the COC report. Information similar to that contained in the COC report is also provided on the sample label, which is securely attached to the sample bottle. COC report forms and sample labels are generally supplied by the laboratory subcontractor. In accordance with the NFESC Interim Guidance Document, entitled "Navy Installation Restoration Laboratory Quality Assurance Guide" (NFESC, February 1996), samples for chemical constituent analysis must be sent (for next-day receipt) to the laboratory within 24 hours of collection.

Full details regarding sample chain-of-custody (including use of custody seals and sample shipment protocols) are contained in B&R Environmental SOP SA-6.1, which is provided in Appendix B of the

Master FSP (also in Volume II of the Master Work Plan). B&R Environmental SOP SA-6.3, also provided in Appendix B of the Master FSP, discusses maintenance of site logbooks, site notebooks, and other field records. Additionally, each of the various sampling SOPs incorporated into the Master FSP contains a section that addresses relevant sample documentation (i.e., completion of sample logsheets, etc.). All sample records are eventually docketed into the B&R Environmental project central file.

4.2 SAMPLE PRESERVATION

Some samples require chemical preservation based on the type of matrix collected and constituents to be analyzed. Chemical preservatives, where applicable, are added as "fixatives" to preserve the composition of the sample collected and prevent degradation. Appropriate chemical preservatives are detailed in 40 CFR 136 (September 1992). A summary of this information is provided in Table 4-1. Samples designated for dissolved metals analysis are preserved after field-filtration.

In general, the laboratory subcontractor will provide all required preservatives and dispensing materials along with the bottleware shipments. All preservatives must be reagent grade or better.

In addition to chemical preservation, other sample-handling considerations (such as use of amber glass bottles when photo-degradation is a concern, and icing of samples to cool to 4°C) are considered to be methods of sample preservation. Samples to be cooled are iced upon acquisition and maintained on ice until the samples are received by the laboratory for analysis.

Sample preservation and integrity are also ensured through observation of maximum technical holding time allowances. These maximum technical holding time allowances are discussed in Section 5.0.

4.3 LABORATORY CUSTODY

Most mobile laboratory vendors develop and follow SOPs for sample custody and receipt similar to the fixed-base laboratory protocols described below.

When samples are received by the laboratory subcontractor(s), the laboratory's sample custodian examines each cooler's custody seals to verify that they are intact and that the integrity of the environmental samples has been maintained. The custodian then opens the cooler and measures its internal temperature. The temperature reading is noted on the accompanying COC report. The sample custodian then signs the COC report and examines the contents of the cooler. Sample container breakages or discrepancies between the COC report and sample label documentation are recorded. The

TABLE 4-1

PRESERVATION REQUIREMENTS
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Parameter	Preservation or Requirement
Volatile Organic Compounds (VOCs)	AQ: Add Na_2SO_3 if chlorinated water source; 1:1 HCl to pH < 2. Soil: Low concentration, sodium bisulfate to pH < 2, High concentration 5 ml of methanol. Both: Cool to 4°C.
Semivolatile Organic Compounds (SVOCs), Polynuclear Aromatic Hydrocarbons (PAHs), Phenols	AQ: Add Na_2SO_3 if chlorinated water source. Use amber glass. Both: Cool to 4°C.
Organochlorine, Organophosphorous Pesticides	AQ: Add Na_2SO_3 if chlorinated water source. Both: Cool to 4°C.
Carbamate Pesticides	AQ: Add Na_2SO_3 if chlorinated water source. Both: Cool to 4°C.
Polychlorinated Biphenyls (PCBs)	Both: Cool to 4°C.
Chlorinated Herbicides	AQ: Add Na_2SO_3 if chlorinated water source. 1:1 HCl to pH < 2. Both: Cool to 4°C.
Dioxins & Furans	AQ: Add Na_2SO_3 if chlorinated water source. Both: Cool to 4°C.
Explosives	AQ: Add Na_2SO_3 if chlorinated water source. Adjust to pH 7-10. Use amber glass. Both: Cool to 4°C.
Target Analyte List (TAL) Analytes	AQ: HNO_3 to pH < 2.
Hexavalent Chromium	Both: Cool to 4°C.
Total Cyanide	AQ: Add ascorbic acid if chlorinated water source. NaOH to pH > 12.
Gross Alpha, Beta	AQ: HNO_3 to pH < 2.
Radium - 226 & 228	AQ: HNO_3 to pH < 2.
Ignitability	None.
Corrosivity (towards steel)	None.
Reactive Cyanides/Sulfides	AQ: Use amber glass. Both: Cool to 4°C.
Toxicity Characteristic Leaching Procedure (TCLP) Organics & Inorganics	Preservation per fractional analysis.
Specific Conductance	Both: Cool to 4°C.
Hardness	AQ: HNO_3 to pH < 2.
Total Suspended Solids (TSS)	AQ: Cool to 4°C.
Total Dissolved Solids (TDS)	AQ: Cool to 4°C.
Settleable Solids	AQ: Cool to 4°C.
Total Volatile Solids/Ash Content	AQ: Cool to 4°C.
Turbidity	AQ: Cool to 4°C.
Acidity	AQ: Cool to 4°C.
Carbonate/Bicarbonate Alkalinity	AQ: Cool to 4°C.
Chloride	None.
Sulfate	AQ: Cool to 4°C.

TABLE 4-1

PRESERVATION REQUIREMENTS
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Parameter	Preservative
Sulfide	AQ: Add ZnAc as a biocide. NaOH to pH > 9.
Sulfite	None.
Total Phosphorus	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Ortho-phosphorus	AQ: Filter immediately. Both: Cool to 4°C.
Ammonia (as N) by distillation	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Kjeldahl Nitrogen/ Organic Nitrogen	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Nitrate Nitrogen	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Nitrate-Nitrite Nitrogen	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Nitrite Nitrogen	Both: Cool to 4°C.
Biological Oxygen Demand (BOD; 5-day)	Both: Cool to 4°C.
Chemical Oxygen Demand (COD)	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Total Petroleum Hydrocarbons (TPH) (Gasoline Range - GRO)	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Total Petroleum Hydrocarbons (TPH) (Diesel Range - DRO)	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Oil & Grease	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.
Total Organic Carbon (TOC)	AQ: HCl_2 or H_2SO_4 to pH < 2. Both: Cool to 4°C.
Total Organic Halides (TOX)	AQ: H_2SO_4 to pH < 2. Both: Cool to 4°C.

pH of chemically preserved samples is checked using Hydrion paper and recorded. All problems or discrepancies noted during this process are to be promptly reported to the B&R Environmental TOM.

Other pertinent issues relating to sample custody, such as the identity of the sample custodian, inter-laboratory chain-of-custody procedures, and specific procedures for sample handling, storage, disbursement for analysis, and remnant disposal, are addressed by the LQAP. All laboratory subcontractors are pre-qualified prior to participation in the competitive procurement process; award is based upon a technical evaluation of capabilities as well as cost. Only laboratories possessing NFESC approval and/or South Carolina state approval (as applicable) will be used to support MCRD Parris Island activities. For reference purposes, Table 4-2 highlights key elements, based on NFESC guidance, addressed in LQAPs.

TABLE 4-2

KEY LQAP ELEMENTS
MCRD PARRIS ISLAND, SOUTH CAROLINA

- Signature Page
- Table of Contents
- Laboratory Organization
- Document Control and Storage
- Data Quality Objectives
- Quality Control Checks
- Statistical Evaluation of Data
- Analytical Protocols and Method Detection Limits
- Sample Custody, Preservation, and Tracking
- Maintenance
- Materials and Subcontractors
- Data Recording, Reduction, Review, Reporting, and Validation
- Quality Assurance Audits
- Quality Assurance Reports to Management
- Corrective Action
- Security
- Software QA
- References

5.0 SAMPLE ANALYSES

In general, there are four basic technical approaches used to generate environmental analytical data:

- Use of portable in-field analytical instruments
- Use of immunoassay test kits
- Use of onsite mobile laboratories
- Use of fixed-base laboratories

The appropriateness of the technical approach(es) chosen to support a project is determined by the project's goals and the types of decisions to be made based on the data, and by other pertinent considerations such as applicability, schedule constraints, and cost. General discussions of the above-mentioned four basic analytical technical approaches follow. The technical approach used to generate environmental analytical data will be specified in the Site-Specific FSP and QAPP.

5.1 PORTABLE IN-FIELD ANALYTICAL INSTRUMENTS

Portable instruments, such as ambient temperature gas chromatographs (GCs) and X-ray Fluorescence (XRF) units, are available for the in-field analysis of selected organic and inorganic constituents, respectively. Generally these instruments are used only as screening tools. The results obtained from these instruments are considered to be qualitative because constituent identification is not definitive and the detection limits achieved do not support quantitation. In other words, these instruments generally yield "Yes/No" results.

Ambient temperature GCs are sometimes used to support soil-gas surveys to achieve a better delineation of a volatile contaminant plume and thus better focus traditional sampling and analysis efforts. Similarly, portable XRF units are sometimes used to better delineate site areas of significant metals contamination.

5.2 IMMUNOASSAY TEST KITS

Where feasible, use of immunoassay test kits can be an effective means of obtaining timely site characterization data. Immunoassay test kits may not be available or sensitive enough to test for all analytes of concern, and the expertise needed to use the kits varies with analysis type and commercial vendor. At best, immunoassay test kits provide semi-qualitative/semi-quantitative data (meaning, contaminant identification is not definitive and quantitation is estimated). Hence careful consideration

must be given to the use of immunoassay test kits to ensure that the data generated suits the intended use.

Where immunoassay test kits are employed, it is common practice to perform fixed-base laboratory split-sample analyses on 10 percent of the samples collected for confirmatory purposes. Sample splits sent to the fixed-base laboratory should include suspected "clean" (uncontaminated) samples as well as contaminated samples so that the possibility of both false negatives and false positives can be evaluated.

5.3 ONSITE LABORATORIES

Use of an onsite mobile laboratory may be an economical means of providing quick-turnaround data. Onsite laboratories can be used to accomplish various organic, inorganic, and wet-chemistry analyses. Contingent upon the methodologies used and the through-put demands made on the laboratory, the onsite mobile laboratory can provide fully quantitative data, or semi-quantitative data.

Mobilization/demobilization costs, utility hookups, waste disposal considerations, and per diem expenses, as well as other critical factors, must be considered when evaluating the value of using an onsite laboratory. If an onsite laboratory is used, care must be taken when procuring a subcontractor to ensure that the analysis techniques and associated quality assurance and reporting procedures required by the project are well-defined and sufficient to meet the intended data use. It is common practice to perform fixed-base laboratory split-sample analyses on 10 percent of the samples collected for confirmatory purposes. Sample splits sent to the fixed-base laboratory should include suspected "clean" (uncontaminated) samples as well as contaminated samples so that the possibility of both false negatives and false positives can be evaluated.

5.4 FIXED-BASE LABORATORIES

Chemical and geotechnical analyses by fixed-base laboratories will be conducted by pre-qualified laboratory subcontractors. The chemical laboratory will have prior NFESC approval and comply with State certification requirements. Analytical subcontractor activities will be monitored by the QAM. Various aspects of fixed-base laboratory analysis are discussed in the following subsections.

5.4.1 Analytical Methods

In accordance with regulatory and NFESC criteria, all analytical methods used in support of the MCRD Parris Island field activities will be U.S. EPA-approved. A general presentation of analytical and

geotechnical methods that may potentially be employed is shown in Table 5-1. Selection of analytical methodologies on a site-specific basis will be based on the analytes and matrices of interest.

Analyses to support investigative-derived waste (IDW) considerations will be required. Disposal of RCRA waste off site shall comply with the CERCLA Off-Site Rule. Refer to the Master FSP (Volume II), Section 2.11, for sampling and disposal of IDW. Various geotechnical analyses may also be required to support potential remedial design considerations

Site-specific FSPs for the Depot will define the number and matrices of samples to be collected and the specific analyses to be performed.

5.4.2 Maximum Technical Holding-Time Allowances

Maximum technical holding time allowances are established in 40 Code of Federal Regulations (CFR) 136 (September 1992) and vary with the matrix analyzed and method of analysis performed. Holding times are specified for both extraction (preparation), where applicable, and analysis. Where no holding times are specified for solid matrices, the aqueous matrix holding time stipulated is to be observed. Maximum technical holding times must be strictly observed so as not to diminish the sample's integrity through degradation or constituent loss.

A summary of maximum technical holding time allowances is provided in Table 5-2. For purposes of the Navy CLEAN program, holding times are measured in calendar days from date of sample collection. Additionally, 40 CFR 136 also stipulates the type of sample container required. Because sample volume requirements vary from laboratory to laboratory, specific container sizes and types are not addressed herein. These considerations are addressed in the Site-Specific FSP and QAPP.

TABLE 5-1

ANALYTICAL METHODS
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 7

AQUEOUS METHOD	PARAMETER	SOLID METHOD
VOC[1]		
CLP OLM03.2	TCL Compounds	CLP OLM03.2
SW-846/8260B (5030B)	Purgeable (GC/MS)	SW-846/8260B (5035)
CLP OLC02.0	Low-concentration VOCs	
SW-846/8260B (5030B)	Low-concentration VOCs	SW-846/8260B (5035)
SW-846/8021B (5030B)	Purgeable Halocarbons (GC)	SW-846/8021B (5035)
SW-846/8021B (5030B)	Purgeable Aromatics (GC)/BTEX	SW-846/8021B (5035)
SW-846/8260B (5030B)	Appendix IX Volatile Organics	SW-846/8260B (5035)
SVOC (EXTRACTABLES, BNAs)[1]		
CLP OLM03.2	TCL Compounds	CLP OLM03.2
CLP OLC02.0	Low-concentration SVOCs	CLP OLC02.0
SW-846/8270C (3510C/3520C)	GC/MS	SW-846/8270C (3540C/3550C)
SW-846/8270C (3510C/3520C)	Appendix IX Semivolatiles	SW-846/8270C (3540C/3550C)
SW-846/8041A (3510C/3535C)	Phenols	SW-846/8041 (3540C/3550C)
SW-846/8061A (3510C/3520C)	Phthalate Esters	SW-846/8061 (3540C/3550C)
SW-846/8100 (3510C/3520C)	Polynuclear Aromatic Hydrocarbons	SW-846/8100 (3540C/3550C)
SW-846/8310 (3510C/3520C)	Polynuclear Aromatic Hydrocarbons	SW-846/8310 (3540C/3550C)
PESTICIDE/PCB & HERBICIDES[1]		
CLP OLM03.2	TCL Compounds	CLP OLM03.2
SW-846/8081A	Organochlorine Pesticides (only)	SW-846/8081A (3540C/3550C)
SW-846/8082 (3510C/3520C)	Organochlorine PCBs (only)	SW-846/8082 (3540C/3550C)
SW-846/8081A & 8141A (3510C/3520C)	Appendix IX Pesticides/PCBs	SW-846/8081A & 8141A (3540C/3550C)
SW-846/8141A (3510C/3520C)	Organophosphorous Pesticides	SW-846/8141A (3540C)
SW-846/8318	Carbamate Pesticides	SW-846/8318
ASTM D4059-83	PCBs in transformer oil	
SW-846/8151A	Chlorinated Herbicides	SW-846/8151A

TABLE 5-1

ANALYTICAL METHODS
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 7

AQUEOUS METHOD	PARAMETER	SOLID METHOD
DIOXINS & FURANS[1]		
CLP DFLM01.0	Dioxins & Furans	CLP DFLM01.0
SW-846/8280A	Dioxins & Furans (Screen)	SW-846/8280A
SW-846/8290	Dioxins & Furans (High Resolution)	SW-846/8290
ENERGETICS		
SW-846/8330	Energetics	SW-846/8330
USATHAMA (mod)	Nitrocellulose	USATHAMA (mod)
USATHAMA (mod)	Nitroguanidine	USATHAMA (mod)
SW-846/8332	Nitroglycerin	SW-846/8332
	PETN as an add-on to SW-846/8330	
RADIOLOGICAL		
E 900 (modified)	Gross Alpha, Beta	SW-846/9310
E 901.1 (modified)	Gamma	HASL 300 or equiv.
E 907 (modified)	Thorium	NAS-NS-3004
E 903, 904 (modified)	Radium	SW-846/9315, 9319
E 906 (modified)	Tritium	EERF 4.01 or equiv.
ASBESTOS		
		EPA 600/R-93/116 Polarized Light Microscopy

TABLE 5-1

ANALYTICAL METHODS
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 3 OF 7

AQUEOUS METHOD	PARAMETER	SOLID METHOD
METALS[2]		
SW-846/6010B	Inductively Coupled Plasma (ICP) Screen	SW-846/6010B
SW-846/7060A, 6010B	Arsenic (GFAA)	SW-846/7060A, 6010B
SW-846/7131A, 6010B	Cadmium (GFAA)	SW-846/7131A, 6010B
SW-846/7196A	Hexavalent Chromium (Cr+6)	SW-846/7196A
SW-846/7421, 6010B	Lead (GFAA)	SW-846/7421, 6010B
SW-846/7470A	Mercury (Cold Vapor)	SW-846/7471A
SW-846/7740, 6010B	Selenium (GFAA)	SW-846/7740, 6010B
SW-846/7841, 6010B	Thallium (GFAA)	SW-846/7841, 6010B
CLP ILM04.0	TAL Metals	CLP ILM04.0
SW-846/6010B	RCRA 8 Metals	SW-846/6010B
PHYSICAL PROPERTIES/NON-METAL INORGANICS		
CLP ILM04.0	Cyanide	CLP ILM04.0
SW-846/9010B	Total & Amenable Cyanide	SW-846/9012A
E 120.1	Specific Conductance	SW-846/9050A
SW-846/9040B	Ph	SW-846/9045C
E 150.1	PH	
E 130.2	Hardness	E 130.2 (modified)
CALC	Hardness (metals ions calculation)	CALC
PHYSICAL PROPERTIES/NON-METAL INORGANICS		
E 160.1	Total Suspended Solids (TSS)	
E 160.2	Total Dissolved Solids (TDS)	
SM 209E or E 160.5	Settable Solids	
E 160.4	Total Volatile Solids/Ash Content	SM 209D or E 160.4
E 300.0	Inorganic Ions	SW-846/9056

TABLE 5-1

ANALYTICAL METHODS
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 4 OF 7

AQUEOUS METHOD	PARAMETER	SOLID METHOD
PHYSICAL PROPERTIES/NON-METAL INORGANICS		
E 325.2	Chloride	SW-846/9251
E 370.1	Silica, dissolved	
E 375.4	Sulfate	SW-846/9036,9038
E 376.2	Sulfide	SW-846/9030A
E 377.1	Sulfite	E 377.1 (modified)
E 365.4	Total Phosphorus	E 365.4 (modified)
E 365.2	Ortho-phosphorus	E 365.2 (modified)
E 420.1	Phenols (distillation, colorometric)	SW-846/9065
E 420.2	Total Phenols	SW-846/9066
E 350.2	Ammonia (as N; distillation)	E 350.2 (modified)
E 350.3	Ammonia (as N; specific-ion electrode)	E 350.3 (modified)
E 351.3	Kjeldahl Nitrogen	E 351.3 (modified)
E 352.1	Nitrate Nitrogen	E 352.1 (modified)
E 353.3	Nitrate-Nitrite Nitrogen	E 353.3 (modified)
E 354.1	Nitrite Nitrogen	E 354.1 (modified)
CALC	Organic Nitrogen	CALC
	Eh	ASTM D1498
	Cation Exchange Capacity (CEC)	SW-846/9080 or 9081
ASTM D3286 or D240-77	BTU	ASTM D3286 or D2015-77
E 425.1	Surfactants (MBAS)	
SM 93	Heterotrophic (Std) Plate Count	

TABLE 5-1

ANALYTICAL METHODS
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 5 OF 7

AQUEOUS METHOD	PARAMETER	SOLID METHOD
WET CHEMISTRY ORGANICS		
E 305.1	Acidity	E 305.1 (modified)
E 310.1	Alkalinity (Total)	E 310.1 (modified)
SM 403	Carbonate/Bicarbonate Alkalinity	SM 403
E 360.2	Dissolved Oxygen	
SM 5210B or E 405.1	Biological Oxygen Demand (BOD-5)	SM 5210B or E 405.1
E 410.1	Chemical Oxygen Demand (COD)	E 410.1 (modified)
E 418.1 or API Methods	Total Petroleum Hydrocarbons (TPH)	SW-846/9071A
SW-846/8015B	TPH	SW-846/8015B or API
SW-846/8100	TPH	SW-846/8100 or API
E 413.1	Oil & Grease	SW-846/9070
E 415.1	Total Organic Carbon (TOC)	Lloyd-Kahn
SW-846/9020B	Total Organic Halides (TOX)	SW-846/9020B
RCRA WASTE CHARACTERIZATION / TCLP		
SW-846/1010	(Liq.) Ignitability (Pensky-Martens)	
SW-846/1110	Corrosivity (towards steel)	SW-846/1110
SW-846/7.7.3	Reactive Cyanides/Sulfides (Reactivity)	SW-846/7.7.3
SW-846/1311/+	Organics & Inorganics (TCLP)	SW-846/1311/+

TABLE 5-1

ANALYTICAL METHODS
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 6 OF 7

AQUEOUS METHOD	PARAMETER	SOLID METHOD
AIR MATRIX ANALYSES		
TO-1	VOCs (GC/MS; Tenax)	
TO-2	VOCs (GC/MS; Carbon Molecular Sieve	
TO-14	VOCs (GC/MS; Suma Canister)	
TO-13	PAHs	
TO-8	Phenols, Methylphenols (cresols) (HPLC)	
TO-10	Organochlorine Pesticides/PCBs (GC; PUF)	
TO-9	Dioxins/Furans (GC/MS)	
40 CFR 50; Appendix B	Particulates (High Volume Sampling)	
Transmission Electron Microscopy (TEM) EPA Level 2	Asbestos	
EPA 102 or SW-846\6010	Metal Particulate Matter (ICP & XRF)	
GEOTECHNICAL PARAMETERS		
	ASTM D421/D422	Particle size preparation & analysis
	ASTM D854	Specific Gravity
	ASTM D2166	Unconfined Compressive Strength
	ASTM D2216	Water Content
	ASTM D4318	Liquid & Plastic Limits (Atterberg Limits)
	SW-846\9100	Saturated Hydraulic & Leachate Conductivity (Intrinsic Permeability)
	MSA	Bulk Density

1 Separate preparative extraction methods are required for certain SW-846 methods. The SW-846 method numbers for these methods are provided in parentheses, where applicable.

TABLE 5-1

ANALYTICAL METHODS
MCRD PARRIS ISLAND, SOUTH CAROLINA
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2 Separate preparative digestion procedures are required for certain SW-846 methods. (It should be noted that preserved groundwater samples which have been filtered for dissolved metals analysis do not require digestion.) Digestion procedures for SW-846 metals analyses are as follows:

For ICP (SW-846/6010B)

Aqueous: SW-846/3005A, 3010A, 3015
Solid: SW-846/3050B, 3051

For all SW-846 GFAA Methods

Aqueous: SW-846/3020A
Solid: SW-846/3050B, 3051

For Hexavalent Chromium (SW-846/7196A)

Aqueous: No preparation method required.
Solid: SW-846/3060A

TABLE 5-2

MAXIMUM TECHNICAL HOLDING-TIME ALLOWANCES
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

PARAMETER	HOLDING TIME
Volatile Organic Compounds (VOCs)	14 days; 7 days for aromatic compounds if aqueous sample is unpreserved. 48 hours to lab extraction of soils if EnCore™ sampler is used.
Semivolatile Organic Compounds (SVOCs), Polynuclear Aromatic Hydrocarbons (PAHs), Phenols	(Aqueous) 7 days to extraction; 40 days from extraction to analysis; (Solid) 14 days to extraction; 40 days from extraction to analysis.
Organochlorine, Organophosphorous Pesticides	(Aqueous) 7 days to extraction; 40 days from extraction to analysis; (Solid) 14 days to extraction; 40 days from extraction to analysis.
Carbamate Pesticides	7 days to extraction; 14 days from extraction to analysis.
Polychlorinated Biphenyls (PCBs)	(Aqueous) 7 days to extraction; 40 days from extraction to analysis; (Solid) 14 days to extraction; 40 days from extraction to analysis.
Chlorinated Herbicides	(Aqueous) 7 days to extraction; 40 days from extraction to analysis; (Solid) 14 days to extraction; 40 days from extraction to analysis.
Dioxins & Furans	30 days to extraction; 40 days from extraction to analysis.
Explosives	(Aqueous) 7 days to extraction; 40 days from extraction to analysis; (Solid) 14 days to extraction; 40 days from extraction to analysis.
Metals	6 months to analysis; exception of Mercury, 28 days.
Hexavalent Chromium	(Aqueous) 24 hrs. to analysis; (Solid) 7 days to extraction; 24 hours from extraction to analysis.
Total Cyanide	14 days to analysis.
Gross Alpha, Beta	6 months to analysis.
Radium - 226 & 228	6 months to analysis.
Ignitability	7 days to analysis.
Corrosivity (toward steel)	7 days to analysis.
Reactive Cyanides/Sulfides	7 days to analysis.
TCLP Organics & Inorganics	TCLP extraction: VOC and SVOC, 14 days; Hg, 28 days; metals, 180 days. Analysis holding-time per fractional analysis.
Specific Conductance	28 days to analysis.

TABLE 5-2

MAXIMUM TECHNICAL HOLDING-TIME ALLOWANCES
MCRD PARIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

PARAMETER	HOLDING TIME
Hardness	6 months to analysis.
Total Suspended Solids (TSS)	7 days to analysis.
Total Dissolved Solids (TDS)	7 days to analysis.
Settleable Solids	48 hrs. to analysis.
Total Volatile Solids/Ash Content	7 days to analysis.
Turbidity	48 hrs. to analysis.
Acidity	14 days to analysis.
Carbonate/Bicarbonate Alkalinity	14 days to analysis.
Chloride	28 days to analysis.
Sulfate	28 days to analysis.
Sulfide	7 days to analysis.
Sulfite	Analyze Immediately.
Total Phosphorus	28 days to analysis.
Ortho-phosphorus	48 hrs. to analysis.
Ammonia (as N) by distillation	28 days to analysis.
Kjeldahl Nitrogen/ Organic Nitrogen	28 days to analysis.
Nitrate Nitrogen	48 hrs. to analysis.
Nitrate-Nitrite Nitrogen	28 days to analysis.
Nitrite Nitrogen	48 hrs. to analysis.
Biological Oxygen Demand (BOD; 5-day)	48 hrs. to analysis.
Chemical Oxygen Demand (COD)	28 days to analysis.
Total Petroleum Hydrocarbons (TPH) (Gasoline Range - GRO)	28 days to analysis.
Total Petroleum Hydrocarbons (TPH) (Diesel Range - DRO)	28 days to analysis.
Oil & Grease	28 days to analysis.
Total Organic Carbon (TOC)	28 days to analysis.
Total Organic Halides (TOX)	7 days to analysis.

5.5 DETECTION AND QUANTITATION LIMITS

Data generated through use of CLP protocols will be reported to the Contract-Required Quantitation Limit (CRQL) for organics analysis, and the Contract-Required Detection Limit (CRDL) for inorganics analysis. All environmental data generated through use of non-CLP protocols (e.g., TPH data) will be reported to the analyte's Practical Quantitation Limit (PQL). A PQL is based on the method detection limit (MDL), for organics and applicable general chemistry parameters, or instrument detection limit (IDL), for metals, by adjusting the MDL/IDL to a higher level to ensure that the precision and accuracy requirements of a method can be attained. All solid matrix results should be reported on a dry-weight basis. Associated MDL and IDL information shall be provided in each analytical data package. It should be noted that MDLs are instrument and matrix specific and are calculated in accordance with the requirements in 40 CFR, Part 136, Appendix B. IDLs are instrument and method specific and are calculated in accordance with the CLP SOW ILM04.0.

As discussed previously, analytical methodologies appropriate to support a project are selected based upon regulatory and DQO requirements. Other factors, however, must also be considered. In some instances, the achievement of very low analyte detection limits is desirable, but may not be achievable due to limitations in Best Available Technology or budgetary constraints. Care must be exercised when considering the use of established low-concentration methodologies (e.g., CLP SOW OLCO2.0). Use of these low-concentration methodologies is appropriate only for uncontaminated samples, or for samples known to contain only small amounts of contamination. Low-concentration methodologies should not be employed for the analysis of samples containing contaminants at concentrations greater than 100 ppb (parts per billion).

The reason for this methodological constraint is that low-concentration methodologies, because they are focused at the lowest possible limits of detection, can perform only across a narrow linear range (approximately 1-20 ppb, dependent upon the analyte). Furthermore, these sensitive methods are very susceptible to matrix interference effects. Analysis of contaminant levels greater than 100 ppb may cause the analytical system to become contaminated and yield sample data results that are suspect because of possible system carryover. Dilution of the sample matrix to a contaminant level that can be accommodated by the analytical system nullifies the attempt at performing low-concentration analysis, since the reported analyte detection limits would be raised in proportion to the dilution factor used. The overriding concept to remember is that the decision to use low-concentration methodologies for analysis usually cannot be made on a project-wide basis, but must be made on a sample-by-sample basis where the historical concentrations of contaminants found at the particular sample location are known (and are conducive to low-concentration analysis).

5.6 ANALYTICAL SUBCONTRACTOR SELECTION AND MANAGEMENT

B&R Environmental maintains a database of analytical services vendors. This database contains pertinent information such as technical capabilities, certifications, and performance records. Appropriate vendors will be solicited to compete for Parris Island project support based on the technical needs of the project, required state certifications, acceptable performance records, and other considerations. The QAM provides input with regard to the list of laboratories participating in each solicitation and is responsible for the technical oversight of the laboratory subcontractor(s) selected. Because B&R Environmental views its subcontractors as team-partners, potential problems are generally resolved pro-actively through effective communication. When required, immediate corrective actions are performed. In severe cases, formal Cure Notices may be issued. Instances of poor performance may result in the negotiation of invoice reductions or in the loss of current and/or future work.

6.0 INTERNAL QC CHECKS

Field-related (i.e., external) QC checks were discussed in Section 3.0. This section further details internal QC checks (i.e., laboratory duplicate and spike analyses), which were also discussed in Section 3.0. Additionally, method blank analyses and other laboratory QA/QC considerations are also discussed. Each of the following laboratory quality control checks will be performed in accordance with the requirements of each different analytical method.

6.1 LABORATORY DUPLICATES

For organic fraction analyses, the matrix spike analysis is performed in duplicate as a measure of laboratory precision. For inorganic analyses, 1 laboratory duplicate analysis is likewise performed for every 20 environmental sample analyses of like matrix. With the exception of VOC MSD analyses, laboratory duplicates are prepared by thoroughly mixing and splitting a sample aliquot into two portions and analyzing each portion following the same analytical procedures that are used for the environmental sample analyses. For VOC MSD analyses, a second sample aliquot is used for analysis to avoid VOC constituent loss through the homogenization process. The field crew provides extra volumes of sample matrices designated for laboratory quality control analyses, as required. Control limits for laboratory duplicate analyses are established statistically by the laboratory in accordance with method-specific procedures and general protocols outlined in the LQAP (or mobile laboratory vendor SOPs). The LQAP (or onsite laboratory vendor SOPs) also define under what circumstances corrective actions are warranted and how they must be performed when required. Control limits for CLP analyses are specified in the appropriate CLP Statement of Work (SOW).

6.2 MATRIX SPIKE ANALYSES

Samples for matrix spike analysis are designated by the field crew with a frequency of 1 matrix spike sample per 20 samples of like matrix (i.e., at a rate of 5 percent). Extra volumes of these designated samples are supplied to the laboratory as required. As discussed previously in Section 3.0, matrix spikes consist of known amounts of representative target analytes spiked into a replicate sample aliquot from which measured compound concentrations are compared to theoretical yield values. Matrix spike analyses are performed for organic and inorganic methodologies and provide a means of measuring the effect of sample matrix on the measurability of target compounds. Control limits are specified in the CLP SOW (for CLP methods) or are developed statistically by the laboratory (non-CLP methods). Where laboratory-derived statistical control limits are not available, the guidance control limits published in the appropriate approved method are used for evaluation purposes.

6.3 SURROGATE SPIKES

Surrogates are organic compounds (typically brominated, fluorinated, or isotopically labeled), which are similar in nature to the compounds of concern, and which are not likely to be present in environmental media. Surrogates are spiked into each sample, standard, and method blank prior to analysis, and, with the exception of dioxin/furan analyses, are used in organic chromatographic analysis procedures as a check of method effectiveness. Surrogate recoveries are evaluated against limits specified in the CLP SOW (CLP methods) or against laboratory-derived statistical control limits (non-CLP methods). Where laboratory control limits are unavailable, surrogate recovery guidance ranges identified in the appropriate analytical method for organics analysis are used for evaluation purposes.

6.4 BLANK SPIKE AND CHECK SAMPLE ANALYSES

Blank spikes (or laboratory control samples) are known amounts of standards spiked into analyte-free water. One blank spike sample is analyzed per set of up to 20 samples per matrix. The purpose of blank spike sample analyses is to demonstrate laboratory control over the analytical method being employed. Since blank spike samples are free of matrix effects, blank spike sample results are often used in conjunction with matrix or surrogate spike results to substantiate the suspected matrix effects. Control limits for blank spike sample analyses vary contingent upon the analyte being measured, but are generally statistically-derived by the laboratory.

6.5 METHOD BLANKS

Laboratory method blanks are prepared and analyzed in accordance with the analytical method employed to determine whether contaminants originating from laboratory sources have been introduced and have affected environmental sample analyses. A method blank generally consists of an aliquot of analyte-free water that is subjected to the same preparation and analysis procedures as the environmental samples undergoing analysis. At a minimum, method blanks must be prepared/analyzed daily or at a frequency of 1 per 20 samples in the analytical batch. With the exception of recognized common laboratory contaminants (e.g., methylene chloride, acetone, 2-butanone, and phthalates), method blanks must not contain levels of target analytes above the reported detection limits (above 2 times the reported detection limit for recognized common contaminants). If method blank contamination is found to exist above allowable limits, corrective actions indicated in the LQAP must be followed. Under no circumstances are laboratory method blank contaminant values subtracted from environmental sample analysis results.

6.6 CALIBRATION AND PREVENTIVE MAINTENANCE OF LABORATORY INSTRUMENTS

Calibration is required to ensure that the analytical system is operating correctly and functioning at the proper sensitivity to meet the required detection limits. All instruments are to be calibrated in accordance with manufacturer specifications and in the manner (and in observation of the control limits) established by the method used for analysis. Where QC criteria are not met, corrective actions shall be taken in a timely manner in accordance with manufacturer specifications and the analytical method. All equipment and standards used to calibrate analytical instruments must be National Institute of Standards and Technology (NIST)-certified or calibrated periodically against standards having known and valid traceability to recognized standards.

Additionally, the laboratory subcontractor must observe a well-defined preventive maintenance program designed to prevent instrument failure and minimize downtime if failure does occur (i.e., maintenance of critical spare parts inventory). This preventive program must include the periodic inspection, lubrication, cleaning, and replacement of worn or malfunctioning equipment parts, as required. All preventive maintenance must be documented (auditable).

6.7 ICP INTERFERENCE CHECK SAMPLES

Inductively Coupled Plasma (ICP) Interference Check Samples (ICS) verify the laboratory's interelement and background correction factors for metals analyzed via CLP and SW-846 ICP methods. The ICSs consist of two solutions (solution A and solution AB) that must be run at the beginning and end of an analytical run or twice during every 8-hour work shift, whichever is more frequent. Results for the ICS analysis must be reported for all of the elements of the ICS solution AB, especially arsenic, barium, cadmium, lead, and selenium, which are most affected by high levels of calcium, iron, and aluminum. Results for the ICS solution AB analysis must fall within the control limits of ±20 percent of the true value.

6.8 ICP SERIAL DILUTION ANALYSIS

The serial dilution analysis determines, for metals analyzed via ICP, whether significant physical or chemical interferences exist due to sample matrix. An ICP serial dilution analysis must be performed on a sample from each group of samples of similar matrix (e.g., water, soil) for each Sample Delivery Group (SDG), whichever is more frequent. If an analyte concentration is sufficiently high (minimally, a factor of 50 above the IDL) the serial dilution (a five-fold dilution) must agree within 10 percent of the original determination after correction for dilution.

6.9 GRAPHITE FURANCE REQUIREMENTS

Although not required by SW-846 analytical methods, duplicate injections and post-digestion spike recoveries for SW-846 graphite furnace atomic absorption analyses must be performed for each MCRD Parris Island sample based on the specifications of the CLP SOW.

6.10 OTHER LABORATORY QC PROCEDURES

Other requirements that the laboratory subcontractor must meet to ensure that the analytical data generated are of sufficient quality include

- Proper handling and storage of samples.
- Use of qualified technicians.
- Independent confirmation of data computations and deliverables.

These issues are addressed in the LQAP.

7.0 PROJECT RECORDS

All documented information necessary to support the defensibility of the data collected is retained as project records. Records requirements (i.e., maintenance of site logbooks, completion of field forms, COC documentation, data evaluation reports, corrective action documentation, training records, etc.), are addressed throughout this Master QAP, throughout the MCRD Parris Island Master FSP, and throughout appended B&R Environmental SOPs. The purpose of this section is to summarize the basic requirements for maintaining these environmental record files. Key elements of B&R Environmental records management protocols are shown below:

- Each program must support a secure central file area for maintaining project files.

- The TOM shall develop a comprehensive project file index, which is consistent with the project's work scope. Records will be organized for retention in accordance with this project file index.

- A docket log shall be initiated and maintained for all project files; each record entered into the project file shall be marked with a serialized document number.

- Hardcopy laboratory data package originals shall be managed and maintained by the Data Validation Coordinator until the project's central file is formally closed out.

- If project records are needed for reference, it is recommended that a photocopy be made. If records must be removed, a completed outcard shall be placed in this project file.

The TOM, assisted by a project administrator, is directly responsible for the maintenance and periodic review the project's central file. Periodic file audits are conducted by the QAM.

Formal file close-outs and technical file transfers will be completed in accordance with B&R Environmental protocols and Navy direction.

8.0 DATA REDUCTION, VALIDATION, AND REPORTING

8.1 DATA REDUCTION

Raw data from field measurements are recorded directly in field notebooks or on sample logs. Reduction of field data entails the summarization and presentation of this data in tabular form. The reduction of laboratory data entails the manipulation of raw data instrument out-put into reportable results.

Field data are verified on a daily basis by the FOL. All tabular data summaries are checked against the original report forms using technically qualified personnel. Laboratory data are verified by the laboratory's Group Supervisor and, subsequently, by the laboratory's QC/documentation department.

8.2 DATA VALIDATION

Data validation consists of a stringent review of the chemical analytical data packages generated by the laboratory subcontractor(s), during which sample receipt and handling, observance of maximum holding time allowances, performance of the analytical method employed, accuracy of data reporting, and completeness of the deliverables generated are evaluated. Data validation also takes into consideration the impact of field-related QC checks. The overall purposes of data validation are (through independent review) to assess the validity of the data generated with respect to the pre-established criteria and to generate a report detailing noncompliances and thereby warn potential users of limitations in data utility.

As discussed previously in Section 3.0, the quality level of the data needed to be produced by the laboratory is determined by the project goals and intended use of the data. Correspondingly, data used to develop qualitative trends, for example, will not have the same data validation requirements as data used for litigation purposes.

For MCRD Parris Island projects, all geotechnical and onsite mobile laboratory data will be reviewed for completeness and accuracy. All fixed-base laboratory chemical data will be fully validated (as described below) unless otherwise stipulated in the Project Plan documents. The level of data quality (i.e., the methods used for analysis and the type of data deliverable needed) will be determined by the project goals and intended use of data. Data generated from certain sites at Parris Island may not require data validation. Therefore a CLP or CLP-like data package (i.e., all raw data and method specific quality control summary forms) may not be required. Hence, deliverable requirements will be addressed in project-specific planning documents.

Data generated through use of CLP protocol analyses will be validated in accordance with the most recent edition of the U.S. EPA National Functional Guidelines for Evaluating Organic (or Inorganic) Analyses. Data generated using other U.S. EPA-approved methodologies (such as SW-846) will be evaluated by qualified B&R Environmental chemists in accordance with NFESC guidelines against method-specific QC criteria, as well as the QC limits established in the LQAP. The National Functional Guidelines will be used to the extent practicable for non-CLP methods. Professional judgment will also be employed.

Data validation reports summarizing noncompliances will be generated, and qualifier flags will be applied to data, where warranted, to alert users of limitations in utility. These validation reports are directed to the Task Order Manager after internal senior review is completed by the B&R Environmental Data Validation Coordinator.

8.3 DATA ASSESSMENT

Data assessment processes are conducted either independently of or in conjunction with data validation processes, and consist of PARCC parameters evaluation. The purpose of PARCC parameters evaluation is to document and ensure that the data generated from project activities are appropriate to the intended data use, meet precision and accuracy requirements, and are representative of actual site conditions.

8.4 ELECTRONIC DATA/DATABASE PRESENTATION

In addition to hardcopy analytical data packages, the analytical laboratory subcontractor(s) must generate electronic database-file deliverables. Exact specifications for these electronic deliverables are included in the subcontract agreement. These electronic deliverables are directed to the B&R Environmental Data Validation Coordinator, whose staff checks the electronic database values against the hardcopy data package results. The database files are updated as required, based on the addition of data qualifier flags applied as a result of the data validation process. The database files are then merged into a project database. Iterations of the database may also be used for mapping, modeling, or risk assessment support purposes. All database manipulations will be performed by qualified computer systems personnel. Access to the project database is controlled. All data entries will be independently reviewed by appropriate technical staff for quality assurance purposes. Blank results will be presented in the manner qualified by the data validation process; alteration of sample results by subtraction of blank levels of contamination is not allowed. Field duplicate results will be averaged for presentation in the database.

The information included in the electronic database will be compiled in a format defined by the Navy. An electronic copy of the database will be submitted to the Navy as a project deliverable, where applicable. The TOM is responsible for maintaining an archival copy of the database.

8.5 DATA INTERPRETATION AND REPORTING

Site-specific data interpretation and reporting considerations are identified in the Site-Specific documents. Generally, all data collected will be summarized and presented in reports in a format defined by the Navy. The reports will also contain contextual and interpretive information, as well as a summary of any QA/QC problems noted and the associated corrective actions taken.

9.0 PERFORMANCE AND SYSTEM AUDITS

System audits will be performed periodically to ensure that work is being implemented in accordance with the approved Site-Specific documents and in an overall satisfactory manner. System audits will be performed by various personnel and will include evaluation of field, laboratory, data validation, and data reporting processes. Examples of pertinent system audits are discussed below:

- The FOL will supervise and check daily that the field measurements are made accurately, equipment is thoroughly decontaminated, samples are collected and handled properly, and fieldwork is documented accurately and neatly.

- System audits for the laboratory will be performed regularly, in accordance with the LQAP.

- Only Navy-approved laboratories will be used for Installation Restoration activities. The Navy's laboratory approval process includes a pre-screening which requires review of the LQAP, analysis of performance evaluation samples, generation of data deliverables for the performance evaluation samples, an onsite technical systems audit of the laboratory, and satisfactory resolution of all deficiencies and findings.

- The data validator will review (on a timely basis) the chemical analytical data packages submitted by the laboratory. The data validator will check that the data were obtained through use of the approved methodology, that the appropriate level of QC effort and reporting was conducted, and whether or not the results are in conformance with QC criteria. On the basis of these factors, the data validator will generate a report describing data limitations, which will be reviewed internally by the Data Validation Coordinator prior to submittal to the TOM.

- The TOM will maintain contact with the FOL and Data Validation Coordinator to ensure that management of the acquired data proceeds in an organized and expeditious manner. Similarly, the TOM will interface with the Risk Assessment and Modeling Coordinators, as applicable.

Additionally, an independent performance audit of field activities may be conducted by the B&R Environmental QAM (or designee). If a formal field audit is conducted, the QAM will check that sample collection, handling, and shipping protocols, as well as equipment decontamination and field documentation procedures, are being performed in accordance with the approved Site-Specific documents and SOPs. Following is a general summary of performance audit protocols:

- Prior to the audit, the auditor will prepare a detailed checklist to be used as an auditing guide.

- Upon arrival at the audit location, the auditor shall conduct a pre-audit meeting with the responsible management of the organization or project to be reviewed.

- Field audits will include a review of required project documentation (logbooks, sample log sheets, etc.) for completeness and agreement; and field operations (well installation, groundwater sampling, sample handling and preservation, etc.) to determine compliance with applicable SOPs.

- File audits will consist of reviewing required project records for completeness, organization and ease of retrieval, and compliance with applicable docketing protocols.

- The audit checklist will be used to record observations including any noted nonconformances.

- A formal post-audit debriefing will be conducted; potential immediate corrective actions will be discussed.

- The auditor will generate a formal audit report which will address corrective actions. This report will be provided by the auditor to the TOM.

- The auditor will manage corrective action verification and audit closure.

- The following audit records will be maintained by the QAM:

  - Original monitoring schedules and revisions
  - Audit checklists
  - Audit reports
  - Response evaluations
  - Verification of corrective actions
  - Follow-up checklists and audit reports

Performance audits of laboratories are coordinated through the NFESC and are conducted by NFESC's independent QA contractor. If so desired, SCDHEC and/or the U.S. EPA Region 4 may also conduct an independent laboratory audit.

10.0 CORRECTIVE ACTIONS

Under the B&R Environmental QA/QC program, it is required that any and all personnel noting conditions adverse to quality report these conditions immediately to the TOM and QAM. These parties, in turn, are charged with performing root-cause analyses and implementing appropriate corrective action in a timely manner. It is ultimately the responsibility of the QAM to document all findings and corrective actions taken and to monitor the effectiveness of the corrective measures performed.

10.1 FIELD ACTIVITIES

Nonconformances or conditions adverse to quality must be identified and corrected as quickly as possible so that work integrity or quality of product is not compromised. The need for corrective action may arise based on deviations from Site-Specific documents and procedures, adverse field conditions, unexpected laboratory performance issues, or other unforeseen circumstances. Corrective action needs may become apparent during the performance of daily work tasks or as a consequence of system or performance audits.

Corrective actions may include resampling and/or reanalyzing samples, or may involve amending previously approved Site-Specific project procedures. If warranted by the severity of the problem (e.g., if a change in the approved Site-Specific documents or SOPs is required), the Navy will be notified in writing via a Field Task Modification Request (FTMR), and Navy (in conjunction with U.S. EPA and SCDHEC, as appropriate) approvals will be obtained. The FOL is responsible for initiating FTMRs; a FTMR will be initiated for all deviations from the Site-Specific documents, as applicable. An example of a FTMR is provided as Figure 10-1. Copies of all FTMRs will be maintained with the onsite project documents and will be placed in the final project records file.

Minor modifications to field activities, such as a slight offset of a boring location, will be initiated at the discretion of the FOL, subject to onsite approval by MCRD Parris Island/Navy personnel and the onsite SCDHEC representative (as appropriate). Major modifications, such as elimination of a sampling point, must be obtained via a FTMR.

FIGURE 10-1

BROWN & ROOT ENVIRONMENTAL

FIELD TASK MODIFICATION REQUEST FORM

Client Identification Project Number FTMR Number

To_____ Location_____ Date_____

Description:

Reason for Change:

Recommended Disposition:

Field Operations Leader (Signature, if applicable) Date

Disposition:

Task Order Manager (Signature, if required) Date

Distribution:

Program Manager Others as required_____

Quality Assurance Officer

Project Manager

Field Operations Leader

10.2 LABORATORY ACTIVITIES

The laboratory maintains an internal, closed-loop corrective action system that operates under the direction of the LQAC. Elements and authorities of the laboratory corrective action program are contained in the LQAP. In general, laboratory corrective actions are warranted whenever an out-of-control event or potential out-of-control event is noted. The specific corrective action taken depends on the specific analysis and the nature of the event. Generally, the following occurrences alert laboratory personnel that corrective action may be necessary:

- QC data are outside established warning or control limits.
- Method blank analyses yield concentrations of target analytes above acceptable levels.
- Undesirable trends are detected in spike recoveries or in duplicate RPDs.
- There is an unexplained change in compound detection capability.
- Inquiries concerning data quality are received.
- Deficiencies are detected by laboratory QA staff audits or from performance evaluation sample test results.

10.3 DATA EVALUATION ACTIVITIES

As a means of oversight, the QAM may audit a percentage of the data evaluation deliverables generated. Oversight audits may also be conducted directly by Navy personnel or by an independent data validation firm under contract to the Navy.

The need for corrective action may become apparent during data interpretation or presentation activities, or problems may be identified as a result of oversight findings. The performance of rework, instituting a change in work procedures, or providing additional/refresher training are possible corrective actions relevant to data evaluation activities.

10.4 ADMINISTRATIVE ACTIVITIES

Findings identified by the conduct of file audits may also necessitate the performance of corrective actions. Corrective actions involving file management usually consist of correction of an isolated nonconformance or the performance of activities necessary to conform with clarified guidance.

11.0 TRAINING

All personnel are assigned for project support based on their technical experience and capabilities. Staff members are monitored and closely supervised as additional skills and responsibilities are acquired. A field orientation meeting is held prior to mobilization to ensure that project personnel are familiar with project-specific requirements. Health & Safety training is administered in accordance with the Project HASP (also in Volume II).

Documentation of all program-related training is maintained by the QAM. Training documentation pertinent to project task assignments is maintained by the TOM and is subsequently incorporated into the project's central file. Health & Safety records relevant to B&R Environmental personnel are maintained by the HSM. Documentation of Health & Safety training provided to subcontractors is incorporated into the project's central file; the HSM also retains a copy.

12.0 ADVANCE QUALITY PLANNING

Advance quality planning consists of pro-active (rather than reactive) management practices. Various individuals (i.e., Program Manager, QAM, TOM, etc.) are responsible for advance quality planning. Examples of advance quality planning include:

- Effective communications between B&R Environmental, the Navy, U.S. EPA Region 4, and SCDHEC.
- Conductance of regularly scheduled program management meetings.
- Conductance of regularly scheduled project reviews.
- Periodic performance of subcontractor reviews.
- Use of audit findings, corrective action reports, FTMRs, and internal and external comments to clarify, update, and improve SOPs and other work practices.

Periodic QA reports to management that discuss the activities described above may be used to formalize advance quality planning. It should be noted that NFESC no longer requires approved laboratories to submit monthly progress reports.

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Rev. 0
03/27/98

Project Health and Safety Plan

Marine Corps Recruit Depot

Parris Island, South Carolina
U.S. EPA Identification Number
SC6 170 022 762

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888
Contract Task Order 0020

March 1998

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PROJECT HEALTH AND SAFETY PLAN

MARINE CORPS RECRUIT DEPOT
PARRIS ISLAND, SOUTH CAROLINA
U.S. EPA IDENTIFICATION NUMBER
SC6 170 022 762

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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A HEALTH AND SAFETY GUIDANCE MANUAL

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ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
APR	Air Purifying Respirators
ASVE	Air Sparging Vapor Extraction
B&R	Brown & Root
CFR	Code of Federal Regulations
CNS	Central Nervous System
CQP	Construction Quality Plan
CZR	Contamination Reduction Zone
DHEC	Department of Health and Environmental Control
DOD	United States Department of Defense
DOT	Department of Transportation
DRI	Direct Reading Instruments
EAP	Emergency Action Plan
eV	electron Volts
FID	Flame Ionization Detector
FOL	Field Operations Leader
FTL	Field Team Leader
HAZWOPER	Hazardous Waste Operations and Emergency Response
HEPA	High Efficiency Particulate Air
HSM	Health and Safety Manager
IDLH	Immediately Dangerous to Life or Health
MSDS	Material Safety Data Sheet
N/A	Not Applicable
NIOSH	National Institute for Occupational Safety and Health
MCRD	Marine Corps Recruit Depot
OSHA	Occupational Safety and Health Administration (U.S. Department of Labor)
PCBs	Polychlorinated Biphenyls
PE	Polyethylene
PEL	Permissible Exposure Limit
PHSP	Project Health and Safety Plan
PID	Photoionization Detector
PPE	Personal Protective Equipment

ppm	Parts per million
psi	Pounds per square inch
PVC	Polyvinyl Chloride
ROICC	Resident Officer in Charge of Construction
SAP	Sampling and Analysis Plan
SCBA	Self-Contained Breathing Apparatus
SCDHEC	South Carolina Department of Health and Environmental Control
SOPs	Standard Operating Procedures
SSHP	Site-Specific Health and Safety Plan
SSO	Site Safety Officer
STEL	Short Term Exposure Limit
TBD	To Be Determined
TOM	Task Order Manager
TWA	Time-Weighted Average
USTs	Underground Storage Tanks
UV	Ultraviolet
WP	Work Plan

OVERVIEW

This Project Health and Safety Plan (Project HASP) Overview presents the process for developing and implementing a Site-specific Health and Safety Plan (Site-specific HASP) for environmental investigation and remediation site activities that will be performed at Marine Corps Recruit Depot, Parris Island, South Carolina. This Overview presents a systematic approach and format for standardizing the essential elements of a Site-specific HASP in accordance with current regulations, as well as internal and client requirements. By incorporating these critical elements into a Site-specific HASP, potential health and safety hazards will be recognized, evaluated, and effectively controlled or eliminated.

This Overview addresses each of the sections required for the Site-specific HASP, with emphasis on the key items needed to ensure compliance with the OSHA "Hazardous Waste Operations and Emergency Response" (HAZWOPER) regulations (predominantly, 29 CFR 1910.120) and other sections of the OSHA General Industry and Construction Industry standards. The Site-specific HASP will be designed to illustrate the specific procedures that will be enacted to protect Brown & Root Environmental (B&R Environmental) and subcontractor personnel during site activities.

The Site-specific HASP will be prepared in the planning stages of the project and will be completed prior to the initiation of any intrusive site activities. A review of the Site-specific HASP with site personnel will be an integral part of pre-entry briefings held prior to the initiation of any site activity, and at other times as necessary. The effectiveness of the Site-specific HASP will be determined and monitored through the performance of site inspections by the assigned site Health and Safety Officer.

The Site-specific HASP will be used in conjunction with the B&R Environmental Health and Safety Guidance Manual and other site-specific documents. The Health and Safety Guidance Manual provides further detailed information pertaining to Site-specific HASPs as well as Standard Operating Procedures (SOPs). This manual supplements the Site-specific HASPs by presenting detailed instructions and information on topics including air monitoring instrumentation, decontamination activities, emergency response, hazard assessments, site control measures, standard work practices, and training requirements. The Health and Safety Guidance Manual also addresses health and safety program requirements on topics such as hazard communication, hearing conservation, medical surveillance, personal protective equipment (PPE), and respiratory protection.

All Site-specific HASPs will include the following sections:

Section 1	Title Page/Introduction/Key Project Personnel and Organization
Section 2	Emergency Action Plan

Section 3	Site Background
Section 4	Scope of Work
Section 5	Tasks/Hazards/Controls Summarization
Section 6	Hazard Assessment
Section 7	Air Monitoring
Section 8	Training/Medical Surveillance Requirements
Section 9	Site Control
Section 10	Spill Containment Program
Section 11	Confined-space Entry
Section 12	Materials and Documents
Section 13	Document Status Report

A brief overview of the intended contents of each of these Site-specific HASP sections is provided in the following sections.

1.0 TITLE PAGE/INTRODUCTION/KEY PROJECT PERSONNEL AND ORGANIZATION

The first section of the Site-specific Health and Safety Plan (Site-specific HASP) will provide introductory discussion and introduce project and site personnel.

A title page will appear as the first page of the Site-specific HASP. This page will include project site name, project number, site location, the names and signatures of the individuals who have reviewed and approved the Site-specific HASP, the date (month and year) of preparation, and the revision number, if one has been assigned.

The Introduction/Key Project Personnel and Organization section will briefly describe the basic objectives and purpose of the plan and outline the information that will be found in the Site-specific HASP. This section will also establish the project-specific personnel organization for site activities. Field team members and their corresponding responsibilities during site activities will be identified, including the designation of the personnel and alternates who will be responsible for overall site safety and health of B&R Environmental and subcontractor employees. In addition, Section 1.0 of the Site-specific HASP will identify the task order manager, subcontractor personnel, applicable agency or client personnel, and any other persons involved with the project.

A Site Information and Personnel Assignments Form containing specific site information and identified personnel assignments will be completed prior to conducting on-site activities and will be included in the Site-specific HASP, an example of which is presented in the following text.

The Site-specific HASP is specifically written to provide general information concerning site activities that are to be conducted at the Marine Corps Recruit Depot (MCRD) Parris Island, South Carolina. In addition to the Site-specific HASP, a copy of the Brown & Root Environmental Health and Safety Guidance Manual (Appendix A) will be present at the site during the performance of site activities. This guidance manual provides detailed information pertaining to procedures referenced in the Site-specific HASP as well as Brown & Root Environmental (B&R Environmental) standard operating procedures (SOPs). Both documents must be present at the site to comply with the requirements stipulated in the Occupational Safety and Health Administration (OSHA) standard 29 CFR 1910.120.

The Site-specific HASP will be developed using the latest available information regarding known or suspected chemical contaminants and potential physical hazards associated with the proposed work and associated sites. The Site-specific HASP will be modified if new information becomes available. All changes to the Site-specific HASP will be made with the approval of the B&R Environmental CLEAN (Comprehensive Long-Term Environmental Action Navy) Health and Safety Manager (HSM). Requests for modifications to the Site-specific HASP will be directed to the Site Safety Officer (SSO), who will

determine and make the needed changes. The SSO will notify the Task Order Manager (TOM), who will notify all affected personnel of all changes. A Document Status Report (see Section 13.0) will document all changes to the plans.

The Site-specific HASP will be developed to meet the requirements established by OSHA 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response" (HAZWOPER), and sections of 29 CFR 1926, "Safety and Health Regulations for Construction." The information contained in this plan, as well as policies on conducting onsite operations, has been obtained from the B&R Environmental Health and Safety Program and Navy/Marine Corps policies and procedures.

1.1 KEY PROJECT PERSONNEL AND ORGANIZATION

This section defines responsibility for site safety and health for B&R Environmental and subcontractor employees engaged in onsite activities. Personnel assigned to these positions shall exercise the primary responsibility for all onsite health and safety. These persons will be the primary point of contact for any questions regarding the safety and health procedures and the selected control measures.

- The B&R Environmental TOM is responsible for the overall direction and implementation of health and safety for this project.

- The B&R Environmental Field Operations Leader (FOL) is responsible for implementation of this site Project HASP with the assistance of an appointed SSO. The FOL manages field activities, executes the work plan, and enforces safety procedures as applicable to the work plan.

- The SSO supports site activities by advising the FOL on all aspects of health and safety on site. These duties may include the following:

  - Coordinates all health and safety activities with the FOL.
  - Selects, inspects, implements, and maintains personal protective equipment.
  - Establishes work zones and control .
  - Directs and assists in the development of decontamination areas and procedures.
  - Implements air monitoring program for onsite activities.
  - Verifies training and medical status of onsite personnel in relation to site activities.
  - Implements hazard communication, respiratory protection, and other associated safety and health programs as necessary.
  - Coordinates emergency services.
  - Provides site-specific training for all onsite personnel.

- Compliance with these requirements is monitored by the SSO and coordinated through the Clean Health and Safety Manager (HSM).

1.2 SITE INFORMATION AND PERSONNEL ASSIGNMENTS

Site Name:	MCRD Parris Island	**Navy RPM:**	Art Sanford
Address:	Parris Island, South Carolina	**RPM Phone Number:**	(803) 820-7482
		MCRD Contact:	Timothy Harrington
		Phone Number:	(803) 525-2630

Purpose of Site Visit: This activity will be divided into a multi-task operation performed sequentially through the execution of the elements as defined in the scope of work.

PROPOSED DATES OF WORK:_____

Project Team:

Brown & Root Environmental Personnel:	**Discipline/Tasks Assigned:**
Debra M. Wroblewski	Program Manager
Mark P. Speranza, P.E.	Task Order Manager (TOM)
Matthew M. Soltis, CIH, CSP	Manager of Health and Safety (HSM)
TBD on Project Basis	Site Safety Officer (SSO)

Non-Brown & Root Environmental Personnel	**Affiliation/Discipline/Tasks Assigned**
TBD	Drilling Subcontractor
TBD	Direct-Push Subcontractor
TBD	Analytical Subcontractor
TBD	Survey Subcontractor
TBD	Other

PREPARED BY: _____

REVIEWED AND APPROVED BY (TOM): M. P. Speranza

REVIEWED AND APPROVED BY (HSM): For: MMS

TBD - To be determined

2.0 EMERGENCY ACTION PLAN

The site Emergency Action Plan (EAP) will be developed and presented as the second section of the Site-specific HASP. The EAP will be reviewed with site personnel and implemented before any onsite operations occur. Response of site personnel will be limited to the incidental events, such as incipient-stage fire response and responding to small spills (depending on the type and quantity of material involved). No further response by site personnel will occur, once the incident has progressed beyond an incipient or minor stage or is declared an emergency. At MCRD Parris Island, all personnel will evacuate the site in the event of an emergency. In accordance with the requirements stipulated in 29 CFR 1910.120(1)(a)(ii) and 1910.38(a), the EAP section will be prepared to include the following site-specific information:

- Emergency escape procedures and escape route assignments.
- Procedures for personnel who will remain on site to operate any critical operations before they evacuate.
- Rescue and medical duties for those employees who may perform them.
- Procedures for accounting for all personnel following an evacuation.
- Preferred means of reporting fires and other emergencies.
- Names or job titles of persons or departments who will be contacted, if additional information or assistance is needed.

Emergency reference information will be assembled and incorporated into the EAP, consisting of the names, capabilities, and telephone numbers of emergency contacts and response agencies. This information will be compiled into a table in the Site-specific HASP to allow for easy interpretation and use.

Section 2.0 may also provide information needed for:

- Emergency recognition and prevention of emergencies
- Emergency routes to the hospital
- Emergency personal protective equipment
- Emergency decontamination procedures
- Safe distances and places of refuge

Should an incident such as injury or exposure, property damage, or even a near-miss situation occur, an incident investigation will be conducted by the SSO or HSM, and a report will be completed.

An example of a typical Section 2.0 of an EAP is presented in the following text.

This section has been developed as part of a preplanning effort to direct and guide field personnel in the event of an onsite emergency.

2.1 INTRODUCTION

In the event of onsite emergencies at MCRD Parris Island, site personnel will be evacuated to a safe place of refuge. The appropriate emergency response agencies will be notified. Since a majority of potential foreseeable emergency situations will require assistance from outside emergency responders, B&R Environmental and subcontractor personnel will not provide emergency response support for significant emergency events beyond their capabilities. However, workers who become ill or who have suffered a nonserious injury may be transported by site personnel to nearby medical facilities, provided that such transport does not aggravate or further endanger the welfare of the injured/ill person. The emergency response agencies listed in this plan are capable of providing the most effective response, and as such, will be designated as the primary responders. These agencies are located within a reasonable distance from the area of operations, a factor which ensures adequate emergency response time. This emergency action plan conforms to the requirements of OSHA Standard 29 CFR 1910.38(a), as stipulated in OSHA 29 CFR 1910.120(l)(1)(ii).

B&R Environmental will, through necessary services, provide incidental response measures for incidents such as:

- Incipient fire-fighting support and prevention
- Incipient spill control and containment measures and prevention
- Removal of personnel from emergency situations
- Provision of initial medical support for injury/illness requiring only first-aid-level support
- Provision of site control and security measures as necessary

Differentiation between emergency response situations[1] and incipient response measures will be determined by the FOL or SSO.

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[1] In accordance with 29 CFR 1910.120(2)(3), "Emergency response" means a coordinated response effort by employees from outside the immediate release area or by outside responders (i.e., mutual aid groups, local fire departments, etc.) to an occurrence which results, or is likely to result, in an uncontrolled release of a hazardous substance. Responses to incidental releases that can be absorbed, neutralized, or otherwise controlled at the time of release by employees in the immediate release area are not considered emergency responses within the scope of this standard.

2.2 PRE-EMERGENCY PLANNING

An analysis of pre-emergency planning activities at MCRD Parris Island has determined injury or illness resulting from exposure to chemical or physical hazard or fire are the most probable emergencies that could be encountered. As a means of controlling these potential hazards, the FOL and the SSO are responsible for pre-emergency planning activities associated with this project including the following:

- Coordinating response actions with MCRD Parris Island Emergency Services personnel to ensure that B&R Environmental emergency action activities are compatible with existing facility emergency response procedures.

- Establishing and maintaining information at the project staging area (support zone) for easy access in the event of an emergency. It will be the responsibility of the B&R Environmental FOL to ensure that such information is available and present at the site. This information will include the following:

  - Chemical Inventory (used on site), with Material Safety Data Sheets.
  - Onsite personnel medical records (medical data sheets).
  - A logbook identifying personnel on site each day.
  - A copy of the Site-specific HASP and B&R Environmental Health and Safety Guidance Manual.

- Identifying a chain of command for emergency action.

- Educating site workers to the hazards and control measures associated with planned activities at the site, and providing early recognition and prevention, where possible.

- Conducting drills and practicing incidental response measures periodically.

2.3 EMERGENCY RECOGNITION AND PREVENTION

Hazard recognition and incident prevention play a major role in eliminating or reducing the harmful effects of hazardous incidents at the site.

2.3.1 Recognition

Potential emergency situations that may be encountered during site activities will generally be recognizable by visual observation. Visual observation will play a primary role in the identification of associated physical hazards. To a lesser degree, visual observation will also play a role in detecting chemical exposures. A clear knowledge of these signs and symptoms which may be evident in the event of overexposure to contaminants of concern may alert personnel of potential hazards concerning themselves or co-workers. These potential hazards, the activities with which they have been associated,

and the recommended control methods are discussed in detail in Sections 5.0 and 6.0 of this document. Additionally, early recognition will be supported by periodic site surveys to eliminate any situation predisposed to an emergency. The FOL and SSO and subcontractor representatives, as applicable, will constitute the site evaluation committee responsible for these periodic surveys of the operation areas.

The above actions will provide early recognition for potential emergency situations. B&R Environmental will provide incipient-stage support. Should an incident take place, B&R Environmental will take defensive and offensive measures to control these situations. However, if the FOL and the SSO determine that an incident has progressed to a serious emergency situation, B&R Environmental will withdraw and notify the appropriate response agency.

2.3.2 Prevention

B&R Environmental and subcontractor personnel will minimize the potential for emergencies by following the Corporate Health and Safety Guidance Manual and ensuring compliance with the site Site-specific HASP and applicable OSHA regulations, and through expedient response to any survey findings revealed during the periodic site surveys.

2.4 SAFE DISTANCES AND PLACES OF REFUGE

In the event that the site must be evacuated, all personnel will immediately stop activities and report to the telephone communications point for that area. Telephone communication points and safe places of refuge will be determined prior to the commencement of site activities and will be conveyed to personnel as part of the daily safety meeting conducted each morning. Upon reporting to the refuge location, personnel will remain there until directed otherwise by the B&R Environmental FOL. The FOL or the SSO will take a head count at this location to confirm the location of all site personnel. The site logbook will be used to take the head count.

2.5 EVACUATION ROUTES AND PROCEDURES

An evacuation will be initiated whenever any of the following situations occur: a fire or explosion occurs, readings on monitoring instrumentation indicate levels of contamination greater than instituted action levels, or personnel show signs or symptoms of overexposure to potential site contaminants. In the event of an evacuation, personnel will proceed immediately to the designated place of refuge as identified for that area on the Safe Work Permit, unless doing so would further jeopardize the welfare of workers. In such an event, personnel will proceed to a designated alternative location and remain there until further notification from the B&R Environmental FOL.

Evacuation procedures will be discussed prior to the initiation of any work at the site. Evacuation routes from the site are dependent upon the location at which work is being performed and the circumstances

under which an evacuation is required. As a result, assembly points will be selected and communicated to the workers relative to the site location where work is being performed.

2.6 DECONTAMINATION PROCEDURES/EMERGENCY MEDICAL TREATMENT

During a site evacuation, decontamination procedures will be performed by site personnel only if doing so does not further jeopardize the welfare of site workers. If it is determined that performing decontamination procedures would further endanger the lives of workers, decontamination will not be performed. However, it is unlikely that an evacuation would occur at this site which would require workers to evacuate the site without first performing decontamination procedures. At a minimum, at least two members of a field crew will be trained and will hold current certification for CPR, general first aid, and bloodborne pathogen training to enable emergency medical first-aid level support.

2.7 EMERGENCY ALERTING AND ACTION/RESPONSE PROCEDURES

Since B&R Environmental personnel will be working in proximity to each other, hand signals, voice commands, air horns, and two-way radios will be sufficient to alert site personnel of an emergency.

If an accident occurs at the site, the following procedures shall be initiated:

- Initiate an evacuation (if needed) by voice commands, hand signals, air horns, or two-way radio.
- Describe to the FOL (who will serve as the Incident Coordinator in charge of the incident) what has occurred and as many details as possible. Once all personnel are evacuated, incipient response procedures will be enacted to control the situation.

In the event that site personnel cannot control the incident through offensive and/or defensive measures, the FOL and SSO will enact the emergency notifications procedure to secure additional outside support in the following manner:

- Call 911 and report the emergency.
- Give the emergency operator the location of the emergency and a brief description of what occurred.
- Stay on the phone and follow the instructions given by the operator.

The appropriate agency will then be notified and dispatched.

If an accident occurs at the Depot which affects field personnel outside the designated operating area, the following procedures are to be initiated:

- Initiate an evacuation (if needed) by voice commands, hand signals, air horns, or two-way radio.
- Proceed to the designated assembly points as directed by the Depot.

2.8 PERSONAL PROTECTIVE EQUIPMENT (PPE) AND EMERGENCY EQUIPMENT

A first-aid kit, stretcher, fire extinguishers (strategically placed), and fire blanket will be maintained on site and shall be immediately available for use in the event of an emergency. The personal protective equipment (PPE) used in support of everyday activities will serve as the highest level of defense authorized in an emergency, above which will require evacuation. This PPE will be required at all sites and will be accessible to authorized personnel.

2.9 EMERGENCY CONTACTS

Prior to performing work at the site, all personnel will be thoroughly briefed on the emergency procedures to be followed in the event of an accident. A mobile phone shall also be available on site. Table 2-1 provides a list of emergency contacts and their corresponding telephone numbers. This table must be posted on site where it is readily available to all site personnel.

2.10 EMERGENCY ROUTE TO HOSPITAL

Hospital:
Beaufort Memorial Hospital
121 South Ribaut Road
Beaufort, South Carolina
(803) 552-5200

A map showing the route from the facility to the hospital is shown on Figure 2-1. Directions to the hospital are as follows:

- Leave the island by way of Malecon Drive, over Archers Creek and across the Causeway.
- Exit the main gate and proceed east over Battery Creek (Bell Memorial Bridge) onto Ribaut Road.
- Proceed approximately 3 miles north on Ribaut Road to the hospital.
- Follow signs to entrance of Beaufort Memorial Hospital.

TABLE 2-1

EMERGENCY REFERENCES
MCRD PARRIS ISLAND

AGENCY	TELEPHONE NO.
EMERGENCY (Fire, Police, and Ambulance)	911
Beaufort Memorial Hospital	(803) 522-5200
Provost Marshall's Office	(803) 525-2478
Facility Point of Contact Timothy Harrington, NREAO	(803) 525-2630
Chemtrec National Response Center	(800) 424-9300 (800) 424-8802
B&R Environmental, Pittsburgh Office	(412) 921-7090
Health & Safety Manager Matthew M. Soltis	(412) 921-8912
Project Health & Safety Officer TBD on Project Basis	TBD
Task Order Manager Mark Speranza	(412) 921-8916
Navy Remedial Project Manager Art Sanford	(803) 820-7482
Maintenance (Emergency) Maintenance Division, Utilities Branch	(803) 525-3145 (803) 525-3405

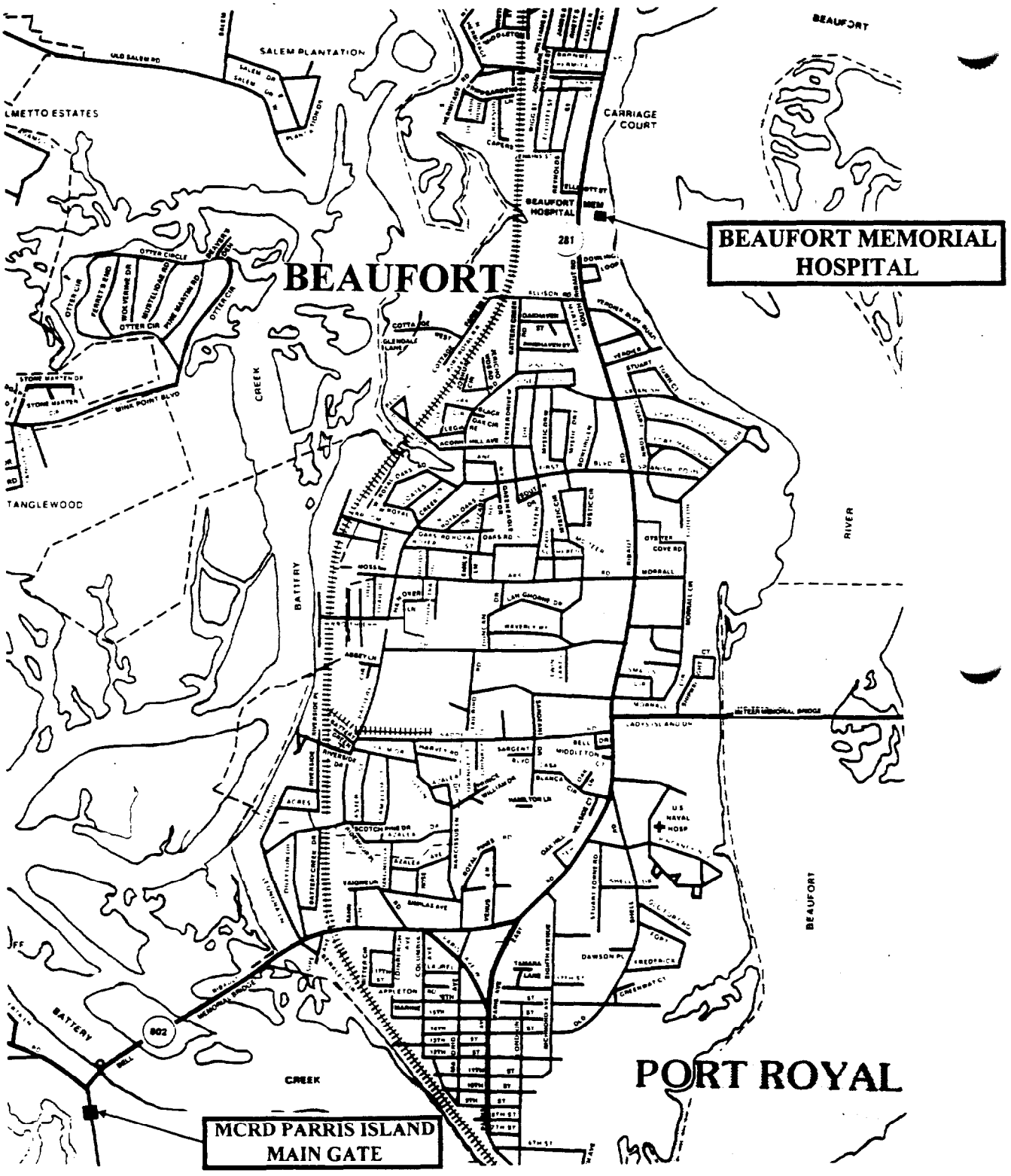

FIGURE 2-1

EMERGENCY ROUTE

MCRD PARRIS ISLAND

3.0 SITE BACKGROUND

The third section of the Site-specific HASP will provide background information about MCRD Parris Island, South Carolina, as a whole and will then focus on work-area-specific details where work will be performed. This background information will include the historic information, current status and activities, and physical features. The description of the facility and results of any available data on past monitoring will be addressed.

Recognizing that there will be multiple work areas involved in this project, an individual site breakdown will be included to present a specific description of the activities to be performed in each area. The site breakdown will include, at a minimum, the following information:

- Location and approximate size of the area
- Description and duration of the planned project activities/job tasks
- Site topography and accessibility

Past investigations and assessments of individual work areas, including any initial surveys, confirmation studies, or actual corrective measures, will be referenced and key findings will be documented. An example of this is presented in the following text.

The MCRD Parris Island is located approximately 3 miles south of the city of Beaufort, South Carolina. MCRD Parris Island was placed on the United States Environmental Protection Agency's (U.S. EPA's) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL) in January of 1995, primarily because of the presence of unlined landfills placed in direct contact with surrounding wetlands. The United States Department of the Navy is currently negotiating a Federal Facilities Agreement (FFA) with U.S. EPA Region IV and the South Carolina Department of Environmental Control (SCDHEC) regarding remediation of the site. Additional information regarding site background is contained in the Volume I Master Work Plan (Master Project Plan). The Site-specific HASP will provide additional information about individual sites or solid waste management units (SWMUs) associated with MCRD Parris Island.

3.1 CURRENT STATUS

MCRD Parris Island is an active facility. The mission of MCRD Parris Island is to provide for the reception and recruit training of enlisted male personnel east of the Mississippi River and all female personnel upon their first entry into the Marine Corps; provide field and combat skills training for recruits; and to provide schools to train enlisted Marines as Drill Instructors and Field Staff. Other elemens of the mission include

conducting rifle marksmanship training for Marine officers and enlisted personnel in the southeastern United States and conducting training for Marine reserves.

4.0 SCOPE OF WORK

The Scope of Work section of the Site-specific HASP will provide critical information about the tasks that will performed during proposed site activities at the MCRD Parris Island facility. This section will present a complete summary of all activities and the subsequent work tasks that will be involved in performing the project work. These tasks will correspond to those specified in the Project Work Plan. As information becomes available through completion of the scope of work, site-specific tasks may be added or removed to fill data gaps. An example of this is presented in the following text.

Section 4.0 of the Site-specific HASP addresses the potential site activities that may be conducted at MCRD Parris Island. If tasks other than those listed below are performed at the site, this section may require modification.

Site activities conducted at MCRD Parris Island may include the following:

- Installation of groundwater monitoring wells.
- Soil boring activities.
- Excavation of test pits.
- Geophysical and ecological surveying activities.
- Multimedia sampling, including air, water (ground and surface), soils, decontamination materials, and purge waters. Personal samples may also be collected on personnel representing "at-risk" job classifications during this action.
- Soil-gas studies.
- Demolition activities.

The above listing represents a summarization of the identified tasks as they apply to the scope and application of this Project HASP. For a more detailed description of the associated tasks, refer to the Master Quality Assurance Plan (MQAP) and/or the Master Field Sampling Plan (MFSP).

5.0 TASKS/HAZARDS/ASSOCIATED CONTROL MEASURES SUMMARIZATION

The Tasks/Hazards/Associated Control Measures Summarization section will provide the primary direction concerning safety, health, and hazard control measures within the Site-specific HASP. This section will address each specific task that will be performed at the individual work areas. For each task involved under the scope of work, the following information will be detailed:

- Anticipated chemical and physical hazards that may be associated with each task, and the area(s) in which the task is to be conducted. This information will identify the potential risks to site personnel in relation to the task(s) that they will perform.

- Recommended control measures. This information will identify the control measures that will be followed to minimize the recognized risk potentials to within a range of acceptability (i.e., proper selection and use of personal protective equipment, adherence to specified work area restrictions and procedures, and other administrative and engineering controls). Details of these control measures will be provided in other sections of the Site-specific HASP, but they will also be mentioned in this section to explain how these control measures relate to the identified risk potentials.

- Air monitoring requirements. This information will specify when air monitoring activities will take place, to include the following times:

  1. When work begins at a different work area.
  2. When contaminants not previously identified are encountered.
  3. When a different type of operation is initiated

  This information will further assist in the proper selection of engineering controls, safe work practices, and personal protective equipment.

- PPE requirements. This information will specify the level of personal protection required for each specific site task and operation, and special provisions that may become necessary if changes in the scope of work occur.

- Necessary decontamination procedures. Information will include the minimum decontamination procedures that will be used for personnel and equipment.

All of this information will be presented in a table format to facilitate easy access and use by site personnel of the pertinent information regarding potential hazards and the steps necessary to negate those hazards.

The section will be prepared so that each site task and operation will have corresponding potential risks and statements on how these potential risks will be recognized and controlled. As a general rule, a conservative approach will be used to ensure that employees are adequately protected from potential health or safety hazards. An example of this is presented in the following text.

The Site-specific HASP shall contain tables which provide specific hazards associated with the proposed tasks. The anticipated hazards, recommended control measures, air-monitoring recommendations, required PPE, and decontamination measures for each site task will be discussed in detail in the Site-specific HASP. Identified tasks, hazards, and the associated control measures shall be changed if the scope of work, contaminants of concern, or other conditions relating to a particular project change. From the information provided in the Site-specific HASP, the FOL can determine which hazards are associated with each task, what hazards are present at each site, and which associated control measures are necessary to minimize exposure to injuries related to those hazards. The information provided in the Site-specific HASP also assists the FOL in determining which PPE and decontamination procedures should be use based on proper air monitoring techniques and site-specific conditions.

As discussed earlier, the Project HASP and the Site-specific HASP are accompanied by a Health and Safety Guidance Manual. This manual is designed to further explain supporting elements for any site-specific operations as required by 29 CFR 1910.120. This Guidance Manual should be referenced for additional information regarding air monitoring instrumentation, decontamination activities, emergency response, hazard assessments, hazard communication and hearing conservation programs, medical surveillance, PPE, respiratory protection, site control measures, standard work practices, and training requirements. Many of B&R Environmental's SOPs are also provided in this Guidance Manual.

6.0 HAZARD ASSESSMENT

The Hazard Assessment section of the Site-specific HASP will provide information regarding the known or anticipated chemical hazards associated with site-specific activities. This section will cover the following items:

- Toxicological information
- Exposure limits
- Recognition qualities
- Health hazards

The chemical hazard information will be incorporated into a table specifying details about potential contaminants. This information will include:

- Name of chemical
- Chemical Abstract Service (CAS) number
- Air monitoring/sampling information
- Exposure limits
- Warning properties
- Physical properties
- Health hazard information

An example of this format is presented in the following text.

A variety of potential chemical hazards exist and are associated with activities that may be conducted at various sites throughout MCRD Parris Island. This Project HASP will provide general information related to the chemical hazards that may be present at various sites where field work may be performed. Specific physical and chemical hazards associated with site specific tasks will be discussed in the Site-specific HASP. Additionally, toxicological information, exposure limits, symptoms of exposure, physical properties, and air monitoring and sampling data will be presented in Table 6-1 of the Site-specific HASP. It should be noted that the contaminants of concern may vary between sites and that each site's contaminants should be verified through Table 6-1 in the Site-specific HASP.

6.1 CHEMICAL HAZARDS

General contaminants of concern at MCRD Parris Island include, but are not limited to, various metals, pesticides, PCBs, semivolatile organic compounds, and volatile organic compounds. As indicated earlier, a more detailed description of potential chemical hazards relating to site specific activities is provided in

Table 6-1 of the Site-specific HASP. In most instances the greatest potential for exposure to site contaminants is performance of intrusive activities, such as drilling and sampling. Several potential contaminants of concern can be evaluated using direct-reading instrumentation. Others, such as metals, PCBs, pesticides, and some semi-volatile compounds, are difficult to monitor, given their physical and chemical characteristics. Many contaminants of concern can be bound to or in the form of airborne particulates. Primary routes of exposure to site contaminants are through inhalation, ingestion, or contact with the skin. Specific information regarding contaminants of concern will be discussed in the Site-specific HASP.

7.0 AIR MONITORING

The Air Monitoring section of the Site-specific HASP will address the actions that will take place in the effort to identify and monitor potential chemical and physical health and safety hazards to onsite workers. Air monitoring will be performed as necessary, and in accordance with the requirements specified in paragraph (h) of 29 CFR 1910.120. This section will identify the equipment and procedures to be used for both personal and area monitoring procedures that will be used to detect and evaluate the presence of contaminants or other potentially harmful agents. Again, this topic will be addressed for each specific task and operation that is intended to be performed. This section will also address:

- Frequency and types of air monitoring, personal monitoring, and environmental sampling techniques and instrumentation that will be used.
- Any applicable "action levels" (e.g., analytical sampling results) that will result in a need to alter site operations procedures, alter PPE requirements, or other such changes.
- Methods of maintenance and calibration of monitoring equipment that will be used on site.
- Provisions for documenting equipment maintenance and calibration, as well as any instrument readings and/or analytical results obtained that will be used during site operations.

Furthermore, this section will address periodic instrument calibration requirements while in use at the project site. In such instances, the following information will be documented for each field calibration effort:

- Date(s) of calibration
- Instrument name, model, and B&R Environmental identification number.
- Name(s) of the individual performing the calibration.
- Any relevant instrument settings (before and after calibration).
- Instrument flow rates or other relevant performance parameters.
- Any relevant remarks or comments.

Records of these calibrations will be entered on a Documentation of Field Calibration Form, provided in the B&R Environmental Health and Safety Guidance Manual. A copy of this manual will be maintained on site at all times throughout the project.

An example of the Air Monitoring section of the Site-specific HASP is presented in the following text.

Monitoring devices such as Direct-Reading Instruments (DRIs), personal sampling pumps, noise dosimeters, etc., may be employed at the site to detect and evaluate the presence of site contaminants and other potentially harmful agents. The specific type of monitoring and the associated instruments, frequency of use, and applicable action levels are dependent upon the site-specific conditions and the contaminants of concern. As a result, specific air monitoring measures and requirements will be established and presented within Table 5-1 of the Site-specific HASP as they apply to the specific tasks to be conducted. Additionally, Section 1.0 of the B&R Environmental Health and Safety Manual contains detailed information regarding direct reading instrumentation and personal and area air sampling procedures, as well as general calibration procedures of various instruments.

8.0 TRAINING/MEDICAL SURVEILLANCE REQUIREMENTS

The Training and Medical Surveillance Requirements section of the Site-specific HASP will discuss the necessary level of training and medical surveillance required by 29 CFR 1910.120(e) and (f) for B&R Environmental and subcontractors to ensure that personnel are prepared and capable of performing their assigned duties in a safe and healthful manner while working at the MCRD Parris Island project site.

Although training requirements may vary between work activities because of the nature of work performed, regulatory requirements, and/or associated potential hazards (e.g., decontamination activities versus welding or cutting tasks), the following requirements will be applicable for all tasks unless specific exemptions are granted by the Health and Safety Manager or by the site Health and Safety Officer:

- Initial general site worker health and safety training for hazardous waste operations (40 hours in duration plus 3 days onsite supervision)
- Site supervision (for site managers and supervisors, 8 hours in duration)
- Annual refresher training (8 hours in duration)
- Site-specific training

Training must be documented for all personnel associated with onsite activities prior to their commencement. Documentation of the dates that each participant attended the training course will be included in Site-specific HASP, along with the method for documentation of that training. This documentation, such as training certificates or official letters, will be attached to the Site-specific HASP. A copy of the Site-Specific Training Documentation Form and an official OSHA training certification letter is provided in the Health and Safety Guidance Manual - Section 11.

All employees working at the MCRD Parris Island site will be required to attend an initial, site-specific training session prior to participating in any onsite activities. This training will be conducted by the assigned site Health and Safety Officer, who will review the Site-specific HASP with the trainees as the integral part of this training. This initial training will, at a minimum, thoroughly cover the following:

- The names of personnel and alternates responsible for site safety and health
- Safety, health, and other hazards that may be present at the site
- Use of PPE
- Work practices that site personnel are to observe to help minimize risks from site hazards
- Safe use of engineering controls (as applicable) and equipment on the site
- Medical surveillance requirements

Additional training requirements applicable to a specific task will also be addressed in this section. Other training required by the Occupational Safety and Health Administration (OSHA), such as for respiratory protection, powered industrial truck operation, asbestos-related work, confined-space entry, hot work, or for other unique or nonroutine jobs which require specific training, will be identified.

An example of the Training/Medical Surveillance Requirements section of the Site-specific HASP is presented in the following text.

8.1 INTRODUCTORY/REFRESHER/SUPERVISORY TRAINING

8.1.1 Requirements for B&R Environmental Personnel

All B&R Environmental personnel must complete 40 hours of introductory hazardous waste site training prior to performing work at MCRD Parris Island. Additionally, B&R Environmental personnel who have had introductory training more than 12 months prior to site work must have completed 8 hours of refresher training within the past 12 months before being cleared for site work. In addition, 8-hour supervisory training in accordance with 29 CFR 1910.120(e)(4) will be required for site supervisory personnel.

Documentation of B&R Environmental introductory, supervisory, and refresher training and a site-specific training will be maintained at the project. Copies of certificates or other official documentation will be used to fulfill this requirement.

B&R Environmental will conduct a brief meeting daily to discuss operations planned for that day. At the end of the workday, a short meeting will be held to discuss the operations completed and any problems encountered. This activity will be supported through the use of a Safe Work Permit System (See Section 9.4).

8.1.2 Requirements for Subcontractors

All B&R Environmental subcontractor personnel must have completed introductory hazardous waste site training or equivalent work experience as defined in OSHA Standard 29 CFR 1910.120(e) and 8 hours of refresher training meeting the requirements of 29 CFR 1910.120(e)(8) prior to performing field work at MCRD Parris Island. B&R Environmental subcontractors must certify that each employee has had such training by sending B&R Environmental a letter, on company letterhead, containing the information in the example letter provided as Figure 8-1 and by providing copies of certificates for all subcontractor personnel participating in site activities.

FIGURE 8-1

TRAINING LETTER

The following statements must be typed on company letterhead and signed by an officer of the company and accompanied by copies of personnel training certificates:

LOGO
XYZ CORPORATION
555 E. 5th Street
Nowheresville, Kansas 55555

Month, day, year

Mr. Mark Speranza, P.E.
Task Order Manager
Brown & Root Environmental
Foster Plaza 7 661 Andersen Drive
Pittsburgh, Pennsylvania 15220

Subject: HAZWOPER Training for MCRD Parris Island, South Carolina

Dear Mr. Speranza:

As an officer of XYZ Corporation, I hereby state that I am aware of the potential hazardous nature of the subject project. I also understand that it is our responsibility to comply with all applicable occupational safety and health regulations including those stipulated in Title 29 of the Code of Federal Regulations (CFR), Parts 1900 through 1910 and Part 126.

I also understand that Title 29 CFR 1910.120 entitled "Hazardous Waste Operations and Emergency Response" requires an appropriate level of training for certain employees engaged in hazardous waste operations. In this regard, I hereby state that the following employees have had 40 hours of introductory hazardous waste site training or equivalent work experience as requested by 29 CFR 1910.120(e) and have had 8 hours of refresher training as required by 29 CFR 1910.120(e)(8), and those employees representing our company within the supervisory capacity have had training as required by 29 CFR 1910.120(e)(4). Please also find copies of the associated certificates for the employees identified below.

LIST FULL NAMES OF EMPLOYEES AND THEIR SOCIAL SECURITY NUMBERS HERE.

Should you have any questions, please contact me at (555) 555-5555.

Sincerely,

(Name and Title of Company Officer)

8.2 SITE-SPECIFIC TRAINING

B&R Environmental will provide site-specific training to all B&R Environmental employees and subcontractor personnel who will perform work on this project. Site-specific training will also be provided to all personnel (DOD, U.S. EPA, SCDHEC, etc.) who may enter the site to perform functions that may or may not be directly related to site operations. Site-specific training will consist of a detailed review of the Site-specific HASP, which will include:

- Names of designated personnel and alternates responsible for site safety and health
- Safety, health, and other hazards present on site
- Use of personal protective equipment
- Work practices to minimize risks from hazards
- Safe use of engineering controls and equipment
- Medical surveillance requirements
- Signs and symptoms of overexposure
- Contents of the Health and Safety Plan and addendum
- Emergency response procedures (evacuation and assembly points)
- Review of the contents of relevant Material Safety Data Sheets

Site-specific documentation will be established through the use of Figure 8-2. All site personnel and visitors must sign this document upon receiving site-specific training.

8.3 MEDICAL SURVEILLANCE

To provide adequate health monitoring of personnel, all B&R Environmental workers participating in field activities will receive physical examinations and be included in a medical surveillance program. The Medical Surveillance section will identify the details of the medical surveillance program and will provide documentation that workers have been physically examined and are capable of performing the scheduled onsite activities. Documentation of medical clearances will be maintained on site for all personnel.

All identified subcontractors will also provide verification that they are medically qualified to perform site work. Provisions for subcontractor's will be identified in this section and the proper documentation included in the Site-specific HASP. Documentation will consist of either Subcontractor Medical Approval Forms, which will be signed by a licensed physician, or by a letter from an appropriate officer or other authorized representative of the subcontracted firm. A copy of the Subcontractor Medical Approval Form and the Medical Surveillance Letter is included in the Health and Safety Guidance Manual - Section 7.

FIGURE 8-2

SITE-SPECIFIC TRAINING DOCUMENTATION

My signature below indicates that I am aware of the potential hazardous nature of performing investigation activities at MCRD Parris Island, South Carolina, and that I have received site-specific training which included the elements presented below:

- Names of designated personnel and alternates responsible for site safety and health
- Safety, health, and other hazards present on site
- Use of personal protective equipment
- Work practices to minimize risks from hazards
- Safe use of engineering controls and equipment
- Medical surveillance requirements
- Signs and symptoms of overexposure
- Contents of the Health and Safety Plan and addendum
- Completion and use of the Safe Work Permit
- Emergency response procedures (evacuation and assembly points)
- Review of contents of relevant Material Safety Data Sheets
- Associated hazards and restricted areas within MCRD

I further state that I have been given the opportunity to ask questions and that all of my questions have been answered to my satisfaction.

I further state, by the presence of my signature below, the date of my training (introductory, refresher, and supervisory, as applicable), and my medical surveillance requirements are accurate and correct to the best of my knowledge.

Name	40-Hour General Site Worker Training (Date)	8-Hour Refresher Training (Date)	8-Hour Supervisory Training (Date)	Date of Medical Surveillance	SIGNATURE

Medical Data Sheets will be collected for all site personnel and will specify the date of the employee's most recent physical examination and other pertinent information, such as known allergies, medical conditions, and physical restrictions or limitations. These limitations may include, but are not limited to:

- Heavy lifting restrictions
- Special hearing protection requirements
- Inability to perform work in certain types of PPE or respiratory protection devices
- Any special substance-exposure restrictions due to identified medical conditions

The Medical Data Sheets will also be included in the Site-specific HASP. A sample Medical Data Sheet is provided in the Health and Safety Guidance Manual - Section 7.

An example of the Medical Surveillance section of the Site-specific HASP is presented in the following text.

8.3.1 Medical Surveillance Requirements for B&R Environmental Personnel

All B&R Environmental personnel participating in project field activities will have had a physical examination meeting the requirements of B&R Environmental's medical surveillance program and will be medically qualified to perform hazardous waste site work using respiratory protection. Documentation for medical clearances will be maintained in the B&R Environmental Pittsburgh office and made available as necessary.

8.3.2 Medical Surveillance Requirements for Subcontractors

Subcontractors are required to obtain a certificate of their ability to perform hazardous waste site work and to wear respiratory protection. The "Subcontractor Medical Approval Form" provided in Figure 8-3 can be used to satisfy this requirement, providing it is properly completed and signed by a licensed physician.

Subcontractors who have a company medical surveillance program meeting the requirements of paragraph (f) of OSHA 29 CFR 1910.120 can substitute the "Subcontractor Medical Approval Form" with a letter, on company letterhead, containing all of the information in the example letter presented in Figure 8-4 of this Project HASP.

FIGURE 8-3

SUBCONTRACTOR MEDICAL APPROVAL FORM

For employees of _____

Company Name

Participant Name: _____ Date of Exam: _____

Part A

The above-named individual has:

1. **Undergone a physical examination in accordance with OSHA Standard 29 CFR 1910.120, paragraph (f), and was found to be medically -**

   ( ) qualified to perform work at the MCRD Parris Island work site
   ( ) not qualified to perform work at the MCRD Parris Island work site

and,

2. **Undergone a physical examination in accordance with OSHA 29 CFR 1910.134(b)(10) and was found to be medically -**

   ( ) qualified to wear respiratory protection
   ( ) not qualified to wear respiratory protection

My evaluation has been based on the following information, as provided to me by the employer.

( ) A copy of OSHA Standard 29 CFR 1910.120 and appendices.
( ) A description of the employee's duties as they relate to the employee's exposures.
( ) A list of known/suspected contaminants and their concentrations (if known).
( ) A description of any personal protective equipment used or to be used.
( ) Information from previous medical examinations of the employee that is not readily available to the examining physician.

Part B

I, _____, have examined _____
Physician's Name (print) Participant's Name (print)

and have determined the following information:

FIGURE 8-3
SUBCONTRACTOR MEDICAL APPROVAL FORM
PAGE TWO

1. Results of the medical examination and tests (excluding finding or diagnoses unrelated to occupational exposure):

_____
_____
_____

2. Any detected medical conditions which would place the employee at increased risk of material impairment of the employee's health:

_____
_____
_____

3. Recommended limitations upon the employee's assigned work:

_____
_____
_____

I have informed this participant of the results of this medical examination and any medical conditions which require further examination of treatment.

Based on the information provided to me, and in view of the activities and hazard potentials involved at the MCRD Parris Island work site, this participant

( ) may
( ) may not

perform his/her assigned task.

Physician's Signature _____

Address _____

Phone Number _____

NOTE: Copies of test results are maintained and available at:

_____
Address

FIGURE 8-4

MEDICAL SURVEILLANCE LETTER

The following statements must be typed on company letterhead and signed by an officer of the company:

LOGO
XYZ CORPORATION
555 E. 5th Street
Nowheresville, Kansas 55555

Month, day, year

Mr. Mark Speranza, P.E.
Task Order Manager
B&R Environmental Corp.
Foster Plaza 7, 661 Andersen Drive
Pittsburgh, Pennsylvania 15220

Subject: Medical Surveillance for MCRD Parris Island, South Carolina

Dear Mr. Speranza:

As an officer of XYZ Corporation, I hereby state that the persons listed below participate in a medical surveillance program meeting the requirements contained in paragraph (f) of Title 29 of the Code of Federal Regulations (CFR), Part 1910.120, entitled "Hazardous Waste Operations and Emergency Response." I further state that the persons listed below have had physical examinations under this program within the past 12 months and that they have been cleared, by a licensed physician, to perform hazardous waste site work and to wear positive- and negative-pressure respiratory protection. I also state that, to my knowledge, no person listed below has any medical restriction that would preclude him/her from working at the MCRD Parris Island, South Carolina site.

LIST FULL NAMES OF EMPLOYEES AND THEIR SOCIAL SECURITY NUMBERS HERE.

Should you have any questions, please contact me at (555) 555-5555.

Sincerely,

(Name and Title of Company Officer)

8.3.3 Requirements for All Field Personnel

Each field team member (including subcontractors) and visitors entering the exclusion zone(s) shall be required to complete and submit a copy of Medical Data Sheet. This shall be provided to the SSO, prior to participating in site activities. The purpose of this document is to provide site personnel and emergency responders with additional information that may be necessary to administer proper medical attention within an employee's particular restrictions.

8.4 SUBCONTRACTOR EXCEPTIONS

Subcontractors who will not enter the exclusion zone during operation, and whose activities involve no potential for exposure to site contaminants, will not be required to meet the requirements for training/medical surveillance other than site-specific training as stipulated in Section 8.2 of the Site-specific HASP.

9.0 SITE CONTROL

The Site Control section of the Site-specific HASP will identify the appropriate site control procedures for projects conducted at the MCRD Parris Island facility. Information supplied in this section will include, but not be limited to:

- Existing or defined site perimeter and/or zone controls, including specifications for delineating the needed zones
- Requirements for the use of the "buddy system"
- Criteria for continuing work at sites where nonroutine activities or particular sources are present
- Applicable site-specific standard operating procedures
- Maps of the site
- Material Safety Data Sheet (MSDS) procedures
- Site communication procedures, including alerting means for emergencies
- Site visitor access procedures
- Site security
- Safe work permits
- Procedures that will be used for inclement weather conditions (i.e., electrical storms, temperature extremes, etc.)

This section will also discuss the procedures that will be used for safety briefings for situations when:

- Routine or daily meetings are needed to explore safety problems
- New operations are conducted
- Site or environmental conditions change
- Safety practices are not being followed
- Deficiencies are identified from safety inspections

An example of a typical Site Control section is presented in the following text.

This section outlines the means by which B&R Environmental will delineate work zones and use these work zones in conjunction with decontamination procedures to prevent the spread of contaminants into previously unaffected areas of the site. It is anticipated that a three-zone approach, as later defined, will be used during work at a site: exclusion zone, contamination reduction zone, and support zone. It is also anticipated that this control measure will be used to control access to site work areas. Use of such controls will restrict the general public, minimize the potential for the spread of contaminants, and to protect individuals who are not cleared to enter the work areas.

9.1 EXCLUSION ZONE

The exclusion zone will be considered those areas of the site of known or suspected contamination or hazardous activities. It is not anticipated that significant amounts of surface contamination will be present in the proposed work areas of any site. It is anticipated that this will remain so until/unless contaminants are brought to the surface by intrusive activities such as drilling or through other means of excavation. Furthermore, once such activities have been completed and surface contamination has been removed, the potential for exposure is again diminished and the area can then be reclassified as part of the contamination reduction zone or support zone. Therefore, the exclusion zones for each task of a given project will be limited to those areas of the site where active work is being performed plus so many feet surrounding the point of operation as identified in Table 5-1 of the Site-specific HASP. All exclusion zones will be delineated using barrier tape, cones and/or drive poles, and postings to inform and direct facility personnel.

9.1.1 Exclusion Zone Clearance

For each project, prestartup site visit will be conducted by members of the identified field team in an effort to identify proposed subsurface investigation locations, obtain utility clearances, and provide upfront notices concerning scheduled activities within the facility that may affect field efforts. Access to the various areas within MCRD Parris Island where project field activities will take place will be coordinated through the Provost Marshal's Office. Utility clearances will incorporate the combined efforts of the Depot Maintenance Division and Public Works Engineering Department. The phone numbers for both of these services may be found in Table 2-1.

In all cases, no subsurface activities will proceed without utility clearance. In the event a utility is struck during a subsurface investigative activity, the appropriate authorities will be notified using the emergency numbers provided in Section 2.9, Table 2-1.

It is anticipated that most field work will be conducted during normal working hours. Field activities, on a project basis, will be coordinated with MCRD Parris Island personnel working in the proximity of activities to be conducted, to minimize the disruption of both the field investigation and ongoing Depot operations.

9.1.2 Site Restoration

To ensure base personnel, contractors, and the general public are not exposed to the contaminants in question, B&R Environmental will implement the following mechanisms as control measures:

- The top layers of sod (humus layer) will be removed as intact as possible and placed on plastic to be used as a top cover during site restoration. This humus layer will be placed over clean fill, which will replace the excavated materials, and will be choked in with topsoil or sand.

- Plastic will be laid down to catch any soil cuttings during drilling activities, and U.S. Department of Transportation (DOT) approved drums will be used to collect drill cuttings as they are generated. No loose excavated materials, resulting either from intrusive activities or sample acquisition, will be left on the surface.

- All concrete and/or asphalt removed to gain access to subsurface media will be replaced prior to releasing the area back to the Depot.

- All surface plots in and around well heads will be restored prior to releasing these areas back to the Depot.

9.2 CONTAMINATION REDUCTION ZONE

The contamination reduction zone (CRZ) will be a buffer area between the exclusion zone and any area of the site where contamination is not suspected. Personnel decontamination will take place in this area. Equipment decontamination will take place at a central location established for a given project. This area, instead, will serve as a focal point in supporting exclusion zone activities. This area will be delineated using barrier tape, cones and/or drive poles, and postings to inform and direct facility personnel.

9.3 SUPPORT ZONE

The support zone for a given project will include a staging area where site vehicles will be parked, equipment will be unloaded, and where food and drink containers will be maintained. In all cases, the support zones will be established at areas of the site where exposure to site contaminants would not be expected during normal working conditions or foreseeable emergencies.

9.4 SAFE WORK PERMITS

All exclusion zone work conducted in support of a given project will be performed using Safe Work Permits to guide and direct field crews on a task-by-task basis. An example of the Safe Work Permit to be used is illustrated in Figure 9-1. These work permits will be further supported by the daily meetings conducted during their generation. This effort will ensure all site-specific considerations and changing conditions are incorporated into the planning effort. All permits will require the signature of the FOL and the SSO. All personnel engaged in onsite activities will be aware of the elements indicating levels of protection and precautionary measures to be used.

FIGURE 9-1

SAFE WORK PERMIT

Permit No. _____ Date: _____ Time: From _____ to _____

SECTION I: General Job Scope (To be filled in by person performing work)

I. Work limited to the following (description, area, equipment used): Monitoring well repair to include demolition of existing concrete pads, the conversion of several stick-up type wells to flush mount vault boxes, replacing the pads with new concrete.

II. Names: _____

III. Onsite Inspection conducted ☒ Yes ☐ No Initials of Inspector _____
B&RE MCRD

SECTION II: General Safety Requirements (To be filled in by permit issuer)

IV. Protective equipment required

Level D ☒	Level B ☐	Full face APR	☐	Escape Pack	☐
Level C ☐	Level A ☐	Half face APR	☐	SCBA	☐
Detailed on Reverse		SKA-PAC SAR	☐	Bottle Trailer	☐
		Skid Rig	☐	None	☒

Respiratory equipment required

Modifications/Exceptions: Minimum Level D requirements as stipulated in Section II, Item IV.

V.

Chemicals of Concern	Action Level(s)	Response Measures
Total Dust	5 mg/m^3	Apply water to control dust
Respirable Dust	3 mg/m^3	Apply water to control dust

VI. Additional Safety Equipment/Procedures

Hardhat	☐ Yes	☒ No	Hearing Protection (Plugs/Muffs)	☒ Yes	☐ No
Safety Glasses	☒ Yes	☐ No	Safety belt/harness	☐ Yes	☒ No
Chemical/splash goggles	☐ Yes	☒ No	Radio	☐ Yes	☒ No
Splash Shield	☐ Yes	☒ No	Barricades	☐ Yes	☒ No
Splash suite/coveralls	☐ Yes	☒ No	Gloves (Type- Leather work)	☒ Yes	☐ No
Steel toe/shank Workboots	☒ Yes	☐ No	Work/rest regimen	☐ Yes	☒ No

Modifications/Exceptions: _____

VII. Procedure review with permit acceptors

	Yes	NA		Yes	NA
Safety shower/eyewash (Location & Use)	☐	☒	Emergency alarms	☒	☐
Procedure for safe job completion per HASP	☐	☒	Evacuation routes	☒	☐
Contractor tools/equipment inspected	☒	☐	Assembly points	☒	☐

VII. Equipment Preparation

	Yes	NA
Equipment drained/depressured	☐	☒
Equipment purged/cleaned	☐	☒
Isolation checklist completed	☐	☒
Electrical lockout required/field switch tested	☐	☒
Blinds/misalignments/blocks & bleeds in place	☐	☒
Hazardous materials on walls/behind liners considered	☐	☒

VIII. Additional Permits required (Hot work, Confined Space Entry, Excavation etc.). ☐ Yes ☒ No
If yes, contact the Health Sciences Department

IX. Special instructions, precautions: Associated hazards for this task include noise, pressurized system, flying projectiles, pinch & compression hazards, and whole-body vibration. The above selected PPE and safety control measures identified within this permit are intended to protect individuals associated with this task from those hazards.

Permit Issued by: _____ Permit Accepted by: _____
Job Completed by: _____ Date: _____

The use of these permits will establish and provide for reviewing protective measures and hazards associated with each operation. The Site-specific HASP will be used as the primary reference for selecting levels of protection and control measures for site-specific applications. The work permit will take precedence over the Site-specific HASP when more conservative measures are required based on specific site conditions.

9.5 SITE MAP

Once the areas of contamination, access routes, topography, and dispersion routes are determined, a site map will be generated and adjusted as site conditions change. These maps will be posted to illustrate up-to-date collection of contaminants and adjustment of zones and access points. A site map will be included in each Project HASP, representing site-specific conditions.

9.6 BUDDY SYSTEM

Personnel engaged in onsite activities will practice the "buddy system" to ensure the safety of all personnel involved in this operation.

9.7 MATERIALS SAFETY DATA SHEET (MSDS) REQUIREMENTS

B&R Environmental personnel will provide MSDSs for all chemicals brought on site. The contents of these documents will be reviewed by the SSO with the user(s) of the chemical substances prior to any actual use or application of the substances on site. The MSDSs will then be maintained in a central location (i.e., temporary office) and will be available for anyone to review upon request.

9.8 COMMUNICATION

Because personnel may not always be working in proximity to one another during field activities, a supported means of communication between field crews will be used as necessary. Two-way radio communication devices may be utilized while conducting field work at MCRD Parris Island. All two-way radio communications devices will be submitted for the approval by MCRD for use while at the facility.

External communication will be accomplished by using the telephones at predetermined and approved locations or through cellular phones. External communication will primarily be used for the purpose of resource and emergency resource communications. Prior to the commencement of activities at the station, the FOL will determine and arrange for telephone communicationsif it is determined a cellular means will not be used.

9.9 SITE VISITORS

Site visitors, for the purpose of this document, are identified representing the following groups of individuals:

- Personnel invited to observe or participate in operations by B&R Environmental.
- Regulatory personnel (i.e., DOD, EPA, OSHA, etc.)
- Southern Division/ROICC personnel
- Other authorized visitors

All non-DOD personnel who require site (areas of ongoing operations) access will be required to obtain permission from the FOL and the Base Contact. Upon gaining access to the site, all site visitors wishing to observe operations in progress will be required to meet the following minimum requirements:

- All site visitors will be routed to the FOL, who will sign them in to the field logbook. Information to be recorded in the logbook will include the individual's name (proper identification required), who they represent, and purpose for the visit.

- All site visitors will be required to produce the necessary information supporting clearance onto the site. This includes information attesting to applicable training (40-hours of HAZWOPER training required for all Southern Division Navy personnel) and to medical surveillance, as stipulated in Section 8.3 of this document. In addition, to enter the site's operational zones during planned activities, all visitors will be required to first go through site-specific training covering the topics stipulated in Section 8.2 of this document and the accompanying Site-specific HASP and associated Safe Work Permit.

Following this, the site visitor will be permitted to enter the site and applicable operational areas. All visitors are required to observe the protective equipment and site restrictions in effect at the area of their visit. Any and all visitors not meeting the requirements as stipulated in this plan for site clearance will not be permitted to enter the site operational zones during planned activities. Any incidence of unauthorized site visitation will cause all onsite activities to be terminated until that visitor can be removed. Removal of unauthorized visitors will be accomplished with support from the Base Contact, if necessary. At a minimum, the Base Contact will be notified of any unauthorized visitors.

All DOD oversight personnel who will perform functions in the contamination reduction area or the exclusion area will work within the provisions of this plan. All personnel assigned to field activities for the project must read this plan and sign the site-specific training documentation form (Figure 8-2) before the start of site activities. At a minimum, all provisions of the B&R Environmental site Project HASP will be followed. All B&R Environmental subcontractors, U.S. DOD oversight personnel, and B&R Environmental personnel will be responsible for operating in accordance with the most current OSHA directives.

9.10 SITE SECURITY

Site security will be accomplished using field personnel. This is a multiple-person operation, involving multiple operational zones. B&R Environmental personnel will retain complete control over active operational zones.

As this activity will take place at a Marine Corps facility, the first line of security will take place at the Main Gate controlling access by the general public. The second line of security will take place at the work site, where interested parties will be referred to the FOL and Base Contact. The Base Contact will serve as a focal point for base personnel and for interested parties and will serve as the final line of security and the primary enforcement contact.

10.0 SPILL CONTAINMENT PROGRAM

The Spill Containment section of the Site-specific HASP will describe the spill containment program along with the procedures and equipment required to contain, control, and isolate bulk materials (both in the solid and liquid form) that are anticipated to be generated, handled, and stored as a result of executing site activities at the MCRD Parris Island facility. An example of a spill containment program section is presented in the following text.

10.1 SCOPE AND APPLICATION

Depending on the specific project and associated site tasks, the potential exists for the handling of bulk hazardous materials (over 55-gallons) at the Depot. It is not anticipated that spillage of bulk hazardous materials would constitute a danger to human health or the environment, given the typical characteristics and quantities generated during most site activities. In most cases, as the job progresses, the potential for accumulating decontamination fluids in a central staging area exists. Once these fluids and materials are characterized, these fluids can be removed from this area and properly disposed of. Because these fluids and soils remained uncharacterized while in the staging area, a spill containment program will be developed and instituted as part of the Site-specific HASP.

10.2 POTENTIAL SPILL AREAS

Potential spill areas will be periodically monitored in an ongoing attempt to prevent and control further potential contamination of the environment. Currently, limited areas are vulnerable to this hazard. Areas that have the greatest spill potential include the area that will be used for central staging and decontamination activities. At this junction, it is anticipated all decontamination fluids generated, as a result of site-specific sampling activities, will be containerized, labeled, and staged to await further analyses. The results of this analysis will determine the method of disposal. Refer to Section 2.11 of the Master Field Sampling Plan for waste handling requirements and disposal procedures.

10.3 LEAK AND SPILL DETECTION

To establish an early detection of potential spills or leaks, a periodic walk-around by the personnel staging or disposing of drums will be conducted during working hours to visually determine that containers are not leaking. If a leak is detected, the drum contents will be transferred, using a hand pump, into a new container. The leak will be collected and contained using absorbents such as Oil-dry, vermiculite, or sand, which are stored at the staging area in a drum conspicuously marked. This used material, too, will be containerized for disposal pending analysis. All inspections will be documented in the project logbook.

10.4 PERSONNEL TRAINING AND SPILL PREVENTION

All personnel will be instructed in the procedures for spill prevention, containment, and collection of hazardous materials in the site-specific training. The FOL and the SSO will serve as the Spill Response Coordinator for this operation, should the need arise.

10.5 SPILL PREVENTION AND CONTAINMENT EQUIPMENT

The following represents the minimum equipment that will be maintained at the staging area at all times for the purpose of supporting this Spill Prevention/Containment Program.

- Sand, clean fill, vermiculite, or other noncombustible absorbent (Oil-dry).
- Drums (55-gallon U.S. DOT IA2).
- Shovels, rakes, and brooms.
- Hand-operated drum pump with hose.
- Container Labels.

10.6 SPILL CONTROL PLAN

This section describes the procedures the B&R Environmental field crew members will employ upon the detection of a spill or leak.

1. Notify the SSO or FOL immediately upon the detection of a leak or spill.

2. Employ the personnel protective equipment stored at the staging area. Take immediate actions to stop the leak or spill by plugging or patching the container or raising the leak to the highest point in the vessel. Spread the absorbent material in the area of the spill, covering it completely.

3. Transfer the material to a new container; collect and containerize the absorbent material. Label the new container appropriately. Await analyses for treatment or disposal options.

4. Recontainerize spills, including 2-inches of top cover impacted by the spill. Await test results for treatment or disposal options.

It is not anticipated that a spill will occur which the field crews cannot handle. Should this occur, notification of the Emergency Response Personnel will be carried out by the FOL or SSO in accordance with the procedures discussed in Section 2.0 of this Site-specific HASP.

11.0 CONFINED-SPACE ENTRY

The Confined-Space Entry section of the Site-specific HASP will define what constitutes a confined space and the procedures that will be followed if one is encountered. The B&R Environmental policy for all confined- space entry tasks is that all entries are regarded as permit-required.

An example of a Confined-Space Entry section in which entry will not be performed is presented in the following text.

Personnel under the provisions of this Site-specific HASP are not allowed, under any circumstances, to enter confined spaces. A confined space is defined as an area that has one or more of the following characteristics:

- Is large enough and so configured that an employee can bodily enter and perform assigned work.
- Has limited or restricted means for entry or exit (for example, tanks, manholes, sewers, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
- Is not designed for continuous employee occupancy.
- Contains or has a potential to contain a hazardous atmosphere.
- Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly caving walls or by a floor that slopes downward and tapers to a smaller cross-section.
- Contains any other recognized, serious, safety or health hazard.

For further information on confined space, consult the Manager, Health Sciences. Any confined-space entry operations will be addressed in the Site-specific HASP and will require in the immediate notification of the Project Health and Safety Officer. This determination shall be made by the FOL and SSO.

12.0 MATERIALS AND DOCUMENTATION

The Materials and Documents section of the Site-specific HASP will identify all documentation and materials that will be stored, used, or maintained at the MCRD Parris Island project site. An example of a typical Section 12.0 is presented in the following text.

The B&R Environmental Field Operations Leader (FOL) shall ensure the following materials/documents are taken to the project site and used when required.

- A complete copy of the Site-specific HASP
- Health and Safety Guidance Manual
- Incident Reports
- Medical Data Sheets
- Material Safety Data Sheets for all chemicals brought on site, including decon solutions, fuels, sample preservatives, calibration gases, etc.
- Follow-up Reports (to be completed by the FOL)
- A full-size OSHA Job Safety and Health Poster (posted in the site trailer)
- Training/Medical Surveillance Documentation Form (Blank)
- First-Aid Supply Usage Form
- Emergency Reference Form (Section 2.0, extra copy for posting)
- Safe Work Permits

12.1 MATERIALS TO BE POSTED AT THE SITE

The following documentation is to be posted at the site for quick reference purposes. In situations where posting of these documents is not feasible (such as no office trailer), these documents should be separated and immediately accessible.

Chemical Inventory Listing - This list represents all chemicals brought on site, including decontamination solutions, sample preservatives, fuel, etc. This list should be posted in a central area.

Material Safety Data Sheets (MSDSs) - The MSDSs should also be in a central area accessible to all site personnel. These documents should match all the listings on the chemical inventory list for all substances employed on site. It is acceptable to have these documents within a central folder and the chemical inventory as the table of contents.

The OSHA Job Safety & Health Protection Poster - This poster, as directed by 29 CFR 1903.2 (a)(1), should be conspicuously posted in places where notices to employees are normally posted. Each FOL shall ensure that this poster is not defaced, altered, or covered by other material.

Site Clearance Posting - This listed is found within the training section of the Site-specific HASP (See Figure 8-1). This list identifies all site personnel, dates of training (including site-specific training), and medical surveillance. This lists indicates not only clearance but also status. If personnel do not meet these requirements, they do not enter the site while site personnel are engaged in activities.

Emergency Phone Numbers and Directions to the Hospital(s) - This list of numbers and the directions will be maintained at all phone communications points and in each site vehicle.

Medical Data Sheets/Cards - Medical Data Sheets will be filled out by all onsite personnel and filed in a central location. The Medical Data Sheet will accompany any injury or illness requiring medical attention to the medical facility. A copy of this sheet or a wallet card will be given to all personnel to be carried on their person.

Hearing Conservation Standard (29 CFR 1910.95) - This standard will be posted anytime hearing protection or other noise abatement procedures are employed.

Personnel Monitoring - All results generated through personnel sampling (levels of airborne toxics, noise levels, etc.) will be posted to inform individuals of the results of that effort.

Placards and Labels - Where chemical inventories have been separated because of quantities and incompatibilities, these areas will be conspicuously marked using DOT placards and acceptable [Hazard Communication 29 CFR 1910.1200 (f)] labels.

The purpose, as stated above, is to allow site personnel quick access to this information. Variations concerning location and methods of presentation are acceptable, providing the objective is accomplished.

13.0 DOCUMENT STATUS REPORT

The final section of a typical Section 13.0 of the Site-specific HASP is the document status section employed to inform site personnel of changes made and the growth of the document.

Revision Requested:		
Revision Made:		
By Whom:	Approved by: TOM: HSM:	Date:

Revision Requested:		
Revision Made:		
By Whom:	Approved by: TOM: HSM:	Date:

Revision Requested:		
Revision Made:		
By Whom:	Approved by: TOM: HSM:	Date:

Revision Requested:		
Revision Made:		
By Whom:	Approved by: TOM: HSM:	Date:

APPENDIX A

HEALTH AND SAFETY GUIDANCE MANUAL

029514R1/P

BROWN & ROOT ENVIRONMENTAL

HEALTH & SAFETY

GUIDANCE MANUAL

Developed by:

Brown & Root Environmental
Health Sciences Group
Pittsburgh, Pennsylvania

029514R1/P

BROWN & ROOT ENVIRONMENTAL

HEALTH & SAFETY

GUIDANCE MANUAL

April 1996

Developed by:

Brown & Root Environmental
Health Sciences Group
Pittsburgh, Pennsylvania

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AIR MONITORING

1.0 PURPOSE

The purpose of this section is to provide procedures for air monitoring during site activities at hazardous waste operations. Information regarding instrument operation, principles of operation, limitations, advantages, maintenance, calibration, and trouble-shooting is also provided. **If the information in this document cannot answer a question concerning a specific instrument, refer to the manufacturer's instructions for further information.**

2.0 SCOPE

This section applies to all Brown & Root Environmental personnel conducting air monitoring activities during the performance of hazardous waste operation site activities.

3.0 GLOSSARY

Direct Reading Instruments (DRIs) - Instrumentation operating on flame ionization or photoionization principles, providing real time readings of ambient contaminants, usually in parts per million (ppm) in air.

Detector Tubes - Small, glass tubes filled with solid absorbent material such as silica gel, activated alumina, or inert granules, and impregnated with detecting chemicals, through which air is aspirated at a controlled rate. Also known as "colorimetric tubes" or "indicator tubes."

Alpha Radiation - Particles, consisting of two protons and two neutrons, equivalent to the nucleus of a helium atom. Tissue (skin) is almost opaque to alpha radiation.

Beta Radiation - Electrons emitted during the radioactive decay of certain nuclei. Depending upon electron energy, will penetrate tissue from 0.05 to 8 mm.

Gamma Radiation - Electromagnetic radiation produced in atomic nuclei. Highly penetrating, passing through the body and through long distances in air. Gamma radiation constitutes the most common type of external radiation exposure.

TLD Badge - A personal monitoring badge, worn by onsite personnel, which will detect cumulative exposure to ionizing radiation. Requires a readout device to indicate total badge ionizing radiation exposure in millirems.

4.0 RESPONSIBILITIES

Project Health and Safety Officer (PHSO) - The PHSO is responsible for determining air monitoring requirements and providing direction for activities in the HASP. In addition, the PHSO shall insure that the user has been appropriately trained and certified in the usage of applicable instrumentation.

Site Safety Officer (SSO) - The SSO shall ensure implementation of these air monitoring procedures during field site activities.

Instrument User - The user should be personally secure that he/she has been adequately trained and understands the operation and limitations of the instruments. He/she is further responsible to insure that the instrument has been calibrated and is working properly.

5.0 INTRODUCTION

Air monitoring is used to help establish criteria for worker safety, document potential exposures, determine protective measures, evaluate the environmental impact of the site, and support mitigation activities. To accomplish this monitoring requires the establishment of an effective air surveillance program, tailored to meet the conditions found at each work site.

During site operations, data are needed about air contaminants and any changes that may occur. Surveillance for vapors, gases, and particulates is done using DRIs and air sampling systems. The most accurate method for evaluating any air contaminant is to collect samples and analyze them at a reliable laboratory. Although accurate, this method has two disadvantages: (1) cost and (2) the time required to obtain results. Analyzing large numbers of samples in laboratories is very expensive, especially if results are wanted quickly. Onsite laboratories tend to reduce the turnaround time, but unless they can analyze other types of samples, they also are costly. In emergencies, time is often not available for laboratory analysis of samples either on site or off site.

To obtain air monitoring data rapidly at the site, instruments utilizing flame ionization detectors (FIDs), photoionization detectors (PIDs), and other similar instruments can be used. These may be used as survey instruments (total concentration mode) or operated as gas chromatographs (gas chromatograph mode),

if they have this function. As gas chromatographs, these instruments can provide real-time, qualitative/quantitative data when calibrated with standards of known air contaminants. Combined with selective laboratory analysis of samples, they provide a tool for evaluating airborne organic hazards on a real-time basis and at a lower cost than analyzing all samples in a laboratory.

6.0 DIRECT READING INSTRUMENTS (DRIs)

6.1 Photoionization Detectors - Principle of Operation

A photoionizer such as a HNu or Photovac 2020, detects the concentration of many organic gases as well as a few inorganic gases. The basis for detection is the ionization of gaseous species. The incoming gas molecules are subjected to ultraviolet (UV) radiation, which is energetic enough to ionize many gaseous compounds. The molecule is transformed into charged-ion pairs, creating a current between two electrodes. Each molecule has a characteristic ionization potential, which is the energy required to remove an electron from the molecule, yielding a positively-charged ion and the free electron. The instrument measures this energy level.

At the time that this document was prepared, Brown & Root Environmental is phasing out the HNu PI101 for site operations and instituting the Photovac PID 2020. As a result, the attachments provided with this section address both the HNu and Photovac Photoionization Detectors.

6.1.1 Instrument Configuration

There are three probes available on both the HNu and Photovac, each of which contain a different UV light source. Probe energies are 9.5, 10.2, and 11.7eV for the HNu, and 8.4, 10.6 and 11.8 for the Photovac. All three detect many aromatic and large-molecule hydrocarbons. Higher eV probes (10.2, 10.6, 11.7 and 11.8eV), in addition, detect some smaller organic molecules and some halogenated hydrocarbons. The mid-range probes (10.2eV and 10.6eV) are the most useful for hazardous waste operations, since they are more durable than the 11.7eV probe and they detect more compounds than the 9.5eV or 8.4eV probes.

6.1.2 Calibration of the HNu PI-101

The primary PID calibration gas is benzene (or isobutylene, a benzene equivalent). The span potentiometer knob is adjusted for benzene calibration. A knob setting of zero increases the sensitivity to benzene approximately ten-fold. The instrument's response can be adjusted to give more accurate readings for

specific gases and eliminate the necessity for calibration charts. Daily calibration is to be performed in accordance with Attachment G.

6.1.3 Specialized Uses

While PIDs are primarily used as qualitative instruments, they can also be used to detect certain contaminants or at least to narrow the range of possibilities. Noting instrument response to a contaminant source with different probes can eliminate some contaminants from consideration. For instance, a compound's ionizing potential may be such that the 9.5eV probe produces no response, but the 10.2 and 11.7eV probes do elicit a response. Also, PIDs do not detect methane or hydrogen cyanide.

6.1.4 Instrument Advantages

PIDs are easy to use in comparison to many other types of monitoring instrumentation. Their range detection limits are also in the low parts per million range. Response time is rapid. In the case of the HNu, the meter needle reaches 90 percent of the indicated concentration in 3 seconds for benzene. In addition, the HNU can be zeroed in a contaminated atmosphere.

6.1.5 Cautions

PIDs can monitor only certain vapors and gases in air. Nonvolatile liquids, toxic solids, particulates, and many other toxic gases and vapors cannot be detected. Because the types of compounds that a PID can detect is only a fraction of the chemicals possibly present at a field site, a zero reading does not necessarily signify the absence of air contaminants.

The instruments are nonspecific, and their response to different compounds is relative to the calibration setting. Instrument readings may be higher or lower then the true concentration. These discrepancies can be especially serious problems when monitoring for total contaminant concentrations, if several different compounds are being detected at once. In addition, the response of these instruments is not linear over the entire detection range. Care must, therefore, be taken when interpreting the data. All identifications should be reported as tentative until they can be confirmed by more precise analysis. Concentrations should be reported in terms of the calibration gas and span potentiometer of the gas-select-knob setting.

PIDs cannot be used as an indicator for combustible gases or oxygen deficiency.

6.1.6 HNu PI.101 Start-up and Shutdown Procedures

Start-up

1. Attach the probe to the readout unit. Match the alignment key, then twist the connector clockwise until a distinct locking is felt.

2. Turn the FUNCTION switch to the battery check position. Check to ensure that the indicator reads within or beyond the green battery arc on the scale plate. If the indicator is below the green arc, or if the red LED comes on, the battery must be charged prior to using.

3. To zero the instrument, turn the FUNCTION switch to the STANDBY position and rotate the ZERO POTENTIOMETER until the meter reads zero. Wait 15-20 seconds to ensure that the zero adjustment is stable. If not, then readjust.

4. Check to see that the SPAN POTENTIOMETER is set at the appropriate setting for the probe being used. Follow procedures in Section 6.1.12 pertaining to the performance of daily calibrations.

5. Set the FUNCTION switch to the desired ppm range.

6. Listen for the fan operation to verify fan function.

7. Check instrument with an organic point source (such as a magic marker) prior to usage to verify instrument function.

Shut Down

1. Turn FUNCTION switch to OFF.
2. Place the instrument on the charger.

6.1.7 Maintenance and Calibration Schedule

Function	Frequency
Routine Calibration	Prior to each use*
Factory Check-out and Calibration	Yearly or when malfunction
Wipe Down Read-Out Unit	After each use
Clean UV Light Source Window	Every month or as use and site conditions dictate
Clean the Ionization Chamber	Monthly
Recharge Battery	After each use

6.1.8 Calibration Procedure

Calibration Procedure 1

1. Run through start-up procedures as per Attachment 1.

2. Fill a sampling bag with HNU calibration gas of known contents.

3. Allow sample bag contents to be drawn into the probe and check response in ppm.

4. If the reading deviates ± 15 percent from the concentration of the calibration gas, the instrument requires maintenance.

5. Each office must develop a mechanism for the documentation of calibration results. This documentation includes:

   a. date inspected
   b. person who calibrated the instrument
   c. the instrument number (Serial number or Other ID number)
   d. the result of the calibration (ppm, probe ev, span pot setting)
   e. identification of the calibration gas (source, type, concentration)

Calibration Procedure 2 (for HNU Calibration Canisters Equipped with a Regulator)

1. Run through start up procedures as per Attachment 1.
2. Connect a sampling hose to the regulator outlet and the other end to the sampling probe of the HNU.
3. Crack the regulator valve.
4. Take reading after 5-10 seconds.
5. If the reading deviates ±15 percent from the concentration of the calibration gas, the instrument requires maintenance.
6. Calibration documentation should be as in No. 5 above.

6.1.9 Cleaning the UV Light Source Window

1. Turn the FUNCTION switch to the OFF position and disconnect the sensor/probe from the Read Out/Control unit.

2. Remove the exhaust screw located near the base of the probe. Grasp the end cap in one hand and the probe shell in the other. Separate the end cap and lamp housing from the shell.

3. Loosen the screws on the top of the end cap and separate the end cap and ion chamber from the lamp housing, taking care that the lamp does not fall out of this housing.

4. Tilt the lamp housing with one hand over the opening, so that the lamp slides out of the housing into your hand.

5. The lamp window may now be cleaned with any of the following compounds using lens paper:

   a. HNU Cleaning Compound-All lamps except the 11.7 eV
   b. Carbon tetrachloride-All lamps except the 11.7 eV
   c. Methanol-All lamps

6. Following cleaning, reassemble by first sliding the lamp back into the lamp housing. Place the ion chamber on top of the housing, making sure the contacts are properly aligned.

7. Place the end cap on top of the ion chamber and replace the two screws. Tighten the screws only enough to seal the O-ring. Do Not Overtighten.

8. Line up the pins on the base of the lamp housing with pins inside the probe shell and slide the housing assembly into the shell. It will only fit one way.

6.1.10 Cleaning the Ionization Chamber

1. Turn the FUNCTION switch to the OFF position and disconnect the sensor/probe from the Read Out/Control unit.

2. Remove the exhaust screw located near the base of the probe. Grasp the end cap in one hand and the probe shell in the other. Separate the end cap and lamp housing from the shell.

3. Loosen the screws on the top of the end cap and separate the end cap and ion chamber from the lamp housing, taking care that the lamp does not fall out of this housing.

4. The ion chamber may now be cleaned according to the following sequence:

   a. acetone rinse with agitation (10 min.), then dry (preferably with oven at 100°C).
   b. methanol rinse with agitation (10 min.), then dry (preferably with oven at 100°C).

5. Place the ion chamber on top of the housing, making sure the contacts are properly aligned.

6. Place the end cap on top of the ion chamber and replace the two screws. Tighten the screws only enough to seal the O-ring. Do Not Overtighten.

7. Line up the pins on the base of the lamp housing with pins inside the probe shell and slide the housing assembly into the shell. It will only fit one way.

6.1.11 Troubleshooting

To be performed by qualified technician only.

1. No meter response in any switch position (including BATT CHK).

   A. Broken meter movement.

(1) Tip instrument rapidly from side to side. Meter needle should move freely and return to zero.

B. Electrical connection to meter is broken.

(1) Check all wires leading to meter and clean the contacts of quick-disconnects.

C. Battery is completely dead.

(1) Disconnect battery and check voltage with a volt-ohm meter.

D. If none of the above solves the problem, consult the factory.

2. Meter responds in BATT CHK position, but reads zero or near zero for all others.

A. Power supply defective.

(1) Check power supply voltages per Figure 11 of the HNU owner's manual. If any voltage is out of specification, consult the factory.

B. Input transistor or amplifier has failed.

(1) Rotate zero control; meter should deflect up/down, as control is turned.
(2) Open probe. Both transistors should be fully seated in sockets.

C. Input signal connection broken in probe or readout.

(1) Check input connector on printed circuit board. The input connector should be firmly pressed down.

(2) Check components on back side of printed circuit board. All connections should be solid and no wires should touch any other object.

(3) Check all wires in readout for solid connections.

6.1.12 Daily Calibration

HNU PI-101 organic vapor meters are to be field calibrated at the beginning of each work day, prior to actual on site usage.

In order to accomplish this, HNUs assigned to jobs shall be accompanied with a calibration gas cylinder, an appropriate fitting, and a flexible connecting hose. The procedure for performing field calibration is as follows:

1. Connect the probe to the instrument and turn it on.
2. Attach the eight-inch extension to the probe.
3. Set the Span Potentiometer to the setting specified on the calibration cylinder.
4. Connect the cylinder fitting to the cylinder.
5. Connect the cylinder and the instrument together with the flexible tubing.
6. Open the cylinder valve and wait 15 seconds.
7. Instrument reading should coincide with the designed reading stated on the calibration cylinder label.
8. If item number 7 does not coincide, adjust the Span Potentiometer until the desired reading is achieved. Any such adjustments must be within the following limits:

Probe	Initial Span Pot. Setting	Maximum Acceptable Span Pot. Adjustment
9.5 eV	5.0	1.0
10.2 eV	9.8	8.5
11.7 eV	5.0	2.0

If these limits are exceeded, the sensitivity and accuracy of the instrument is hindered. At these points, the instruments are to be returned to the Brown & Root Environmental Equipment Manager for inspection, necessary cleaning and maintenance, and recalibration.

The manufacturer also recommends that the lamp inside of the probe be checked twice per week (16 hours of use) and cleaned at least weekly. This involves removing any noticeable obstructions or contamination from the lamp by wiping it off with a clean, soft cloth being careful not to scratch the circular window.

In using this instrument to protect Brown & Root Environmental employees and subcontractors, it is imperative that it is accurately responding to airborne substances present at the work site. By implementing these procedures, this end will be better achieved.

Additionally, all calibration activities must be documented in field log books, instrument calibration log sheets, or equivalent. This information must include the date inspected, the person calibrating the instrument, the instrument serial or identification number, the probe lamp eV (9.5 , 10.2, or 11.7), identification of calibration gas (gas source stated on the cylinder label), the initial and final Span Potentiometer settings, and the instrument resultant reading. This information must be submitted to the Site Safety officer at the completion of the job.

6.1.13 References

HNU Systems, Inc. Instruction Manual for Model PI 101 Photoionization Analyzer, 1975.

E. & E. FIT Operation and Field Manual: HNU Systems PI 101 Photoionization Detector and Century Systems (Foxboro) Model OVA-128 Organic Vapor Analyzer.

Personal Communication with Fran Connel, HNU Systems, Inc., January 4, 1984.

6.2 Overview of the Photovac 2020 PID

2020 measures the concentration of airborne photoionizable gases and vapors and automatically displays and records these concentrations. It does not distinguish between individual pollutants. The reading displayed represents the total concentration of all photoionizable chemicals present in the sample. 2020 is factory set to display concentration in units of ppm or mg/m^3.

2020 operates automatically. The meter display updates itself once per second. You can read concentrations directly from the meter display. If you are using the dilution probe (Photovac Part No. 35(X)13) you must multiply the displayed reading by the dilution factor.

2020 is always performing short term exposure limit (STEL), time weighted average (TWA) and PEAK calculations. You can view any of these results, but only one mode may be viewed at a time.

2020 has many datalogging options. You can select an averaging interval, or you can use manual operation. if you select an averaging interval, the minimum, maximum, and average concentrations measured in each period are automatically recorded in 2020's datalogging memory. 2020 can log up to 1 (XX) entries.

In manual operation, 2020 prompts you to locate a site and then to record a background and sample readings for the site. You can record up to 1(XX) manual entries. There is no averaging of data in manual operation.

Recorded data can be reviewed on the display, sent to a printer in either tabular or graphical format, or sent to a computer. Data are recorded by date and time.

2020 has 6 keys for alphanumeric entry and for accessing 2020's functions. The keys are used to set up and calibrate 2020. They allow you to manipulate the concentration data in various ways.

All information entered with the keys and stored in 2020's memory is retained when the instrument is switched off. The clock and calendar continue to operate and do not need to be set each time 2020 is turned on.

6.2.1 Displays

The 2020 has a meter display for reporting detected concentration, and a status display used to display status information and guide you through configuration options. All functions of the 2020 will be controlled or reported using one of these displays.

6.2.1.1 Meter Display

The meter display is a 4-digit display. It will always be used for reporting detected concentration. When the detector and pump are off, the meter display will be blank.

In order to accommodate the range of concentrations 2020 can detect, the meter reading will be reported using one of 2 resolutions. A resolution of 0.1 will be used for concentrations below 100 ppm, and a resolution of 1 will be used for concentrations above 100 ppm.

6.2.1.2 Status Display

The status display is a 2 line by 16 character display. The top line is used to display status information and prompts you for information. The bottom line is used for soft key names. Up to 3 names can be displayed for the 3 soft keys. If a name does not appear for a soft key, then the soft key has no associated function.

6.2.2 Keys

6.2.2.1 Fixed Keys

The three round keys below the soft keys each have a fixed function. The first key is the ON/OFF key, the middle key is the EXIT key and the last key is the ENTER key.

The ON/OF key is used to both turn power on to the 2020 as well as turn the power off. To turn on 2020, press the ON/OFF key. To turn the power off, press the ON/OFF key and hold it down for 2 seconds, and then release it. This is done to prevent accidental power off.

The EXIT key provides a way of returning to the default display. In the functional map, the soft keys allow you to advance and the EXIT key provides a way to go back. If you are at the root entry of the menu, EXIT will return you to the default display.

The ENTER key has a context sensitive function. When you are operating or navigating through the function map, the ENTER key is used to exit the functions and return you to the default display. When entering data such as a name, number, date or time, ENTER is used to confirm the entry.

6.2.2.2 Soft Keys

The three soft keys on 2020 are located directly below the status display. Each key has varying functions for configuring 2020, editing the datalogger, and controlling the display. Since only three soft keys are available, each function is broken down into a path.

6.2.2.3 Entering Text With the Soft Keys

For all information that you must enter, the left, center and right soft keys correspond to the up, down, and right arrow.

The up and down arrows are used to change the character highlighted by the cursor. The right arrow is used to advance the cursor to the next character on the right. When the cursor is advanced past the right most character, it wraps around to the first character again. To accept the changes, press the ENTER key. To ignore the change, press EXIT.

Formatting characters, such as the colon (:) in the time, the decimal (.) in a concentration, and the slash (/) in date are skipped when advancing the cursor.

All inputs are an 8 character input, which is displayed on the right side of the top line of the status display. The prompt, describing the input, occupies the left half of the top line. The soft keys are defined on the bottom line of the status display.

6.3 Beginning Operation

6.3.1 Turning 2020 On

1. Turn 2020 on by pressing the ON/OFF key.

2. 2020 will display the software version number. Wait for the 2020 to proceed to the default display.

3. Allow 10 minutes for the instrument to warm-up and stabilize.

6.3.2 Default Display

The meter display shows the detected concentration. The resolution of the display changes with the magnitude of the reading. A reading of 0 to 99.9 will be displayed with a resolution of 0.1 ppm or mg/m^3. A reading greater than 99.9 will be shown with a resolution of 1 ppm or mg/m^3. The meter will display concentrations up to 2000 ppm or 2(XX) mg/m^3.

The status display is used to display the instrument status, date, time, units and active soft keys.

The default display provides the following information: instrument status, current detected concentration, time, date and measurement units. The status display toggles between showing time and units and then the date.

When the display mode is MAX, the date and time correspond to the date and time the MAX concentration was recorded. In TWA mode, the time represents the number of hours and minutes during which the TWA has been accumulating. For PEAK and STEL monitoring, the date and time correspond to the current date and time.

6.4 Monitoring

6.4.1 Instrument Status

The instrument status is shown on the left of the first line of the status display and on the Table and Graph outputs. Each status has a priority assigned to it. If more than one status is in effect, then the status with the highest priority is displayed until the condition is corrected or until the option is turned off.

6.4.2 Alarms

While operating the instrument, any one of three alarm conditions can occur. To accurately identify the source of the alarm, each type of alarm has been given a unique status.

In addition to the status, 2020 also has an audio alarm and an alarm LED. To conserve power the 2020 alternates between the LED and audio. Different alarms are identified by the frequency at which the 2020 alternates between the audio and LED; Peak alarm 5 times per second. STEL alarm 2.5 times per second, and TWA alarm is 1.25 times per second.

The left soft key is used for acknowledging alarms, and is named "Ack". If no alarm exists, then the "Ack" key is not shown. To clear the alarm, press the "Ack" key. Once acknowledged, the alarm indicators are cleared. The alarm status will remain until the alarm condition clears.

2020 updates the peak concentration once every second. Following every update, the peak concentration is compared to the peak alarm level, and if exceeded, an alarm is triggered.

If 15 minute average exceeds the STEL, a STEL alarm is generated.

The TWA alarm is generated when the current average of concentration, since the TWA was last cleared, has exceeded the TWA exposure limit.

During calibration, all alarms are disabled. Once the calibration is complete the alarms are re-enabled.

6.5 STEL, TWA, MAX and PEAK Operation

The 2020's meter display can be configured to show one of 4 values: STEL, TWA, PEAK and MAX.

6.5.1 Short Term Exposure Limit (STEL) Mode

The Short Term Exposure Limit (STEL) mode displays the concentration as a 15 minute moving average. 2020 maintains 15 samples, each representing a one minute averaging interval.

Once every minute, the oldest of the 15 samples is replaced with a new one minute average. This moving average provides a 15 minute average of the last 15 minutes with a one minute update rate. Since the average is calculated using 15 one minute averages, the meter display will only update once every minute.

STEL is set to zero each time the instrument is turned on. Since STEL is a 15 minute moving average, there is no need to clear or reset the STEL.

STEL calculations are always being performed by 2020. You can display the results of the calculations by selecting STEL as the Display mode.

6.5.2 Time Weighted Average (TWA) Mode

The TWA accumulator sums concentrations every second until 8 hours of data have been combined. I this value exceeds the TWA alarm setting, a TWA alarm is generated. The TWA is not calculated using a moving average. Once 8 hours of data have been summed, the accumulation stops. In order to reset the TWA accumulator, press the "Clr" key.

This sum will only be complete after 8 hours, so the meter displays the current sum divided by 8 hours. While you are in TWA mode, the time on the status display will show the number of minutes and hours of data that TWA has accumulated. When this reaches 8:9X) or 8 hours 2020 stops accumulating data and the TWA is complete.

TWA calculations are always being performed by 2020. You can display the results of the calculations by selecting TWA as the Display mode.

6.5.3 MAX Mode

The MAX mode displays the maximum signal, with the date and time that it was recorded. 2020 continues to log data according to the selected averaging interval, but only the maximum detected concentration is displayed on the meter display.

The right soft key is used to clear the meter when displaying MAX. The "Clr" key only affects the reading that the meter is displaying. For example, if you display the MAX reading, and you press "Clr", only the MAX value is cleared. The TWA is still accumulating in the background.

6.5.4 PEAK Mode

The PEAK mode displays the current detected concentration. The reading is updated once a second. In the background, the 2020 datalogger is sampling the concentration and measuring minimum, maximum, and average concentrations for the selected averaging interval. At the end of every interval, one entry is placed in the datalogger until the datalogger is full.

6.6 Set Functions

Set functions are used to setup 2020. There are 3 functions which can be set on the 2020: Calibration, Pump and Clock.

6.6.1 Pump

The Pump function is used to control the pump. After selecting Set Pump, 2020 responds by displaying the new pump status.

The detector is also turned off when you turn the pump off. This prevents the detector from being damaged when there is no sample flowing through the detector.

When the pump and the detector are off, the meter display will be blank. Turn the pump and detector off when concentration measurements are not necessary, and 2020 will only be used for reviewing data or generating reports. By operating the instrument with the pump and detector off when you do not need them, you will conserve the battery and ultraviolet (UV) lamp.

1. Press the ENTER key. The top line of the status display changes to "Select?". The bottom lone displays 3 soft key names: "Set", "Log" and "Disp".

2. Press the soft key below "Set".

3. The names of the soft keys change to reflect the Set options. The display now shows 3 devices which can be set: "Clock", "Pump", and "Cal". Press the "Pump" key.

4. The 2020 turns the pump off. If the pump was off, pressing "Pump" will turn the pump on.

5. A message will be displayed to show you the status of the pump. 2020 reverts back to the previous menu after a few seconds.

6. To return to the default display, press the ENTER key.

6.6.2 Clock

The Clock function is used to set both the current date and time.

1. Press the ENTER key.

2. Press the "Set" key.

3. When the names of the soft keys change, press the "Clock" key.

   The up and down arrows are used to change the character underlined by the cursor. The right arrow is used to advance the cursor to the next character on the right. When the cursor is advanced past the right most character, it warps around to the first character again.

   Formatting characters, such as the colon (:) in the time and the slash (/) in the date are skipped when advancing the cursor.

4. Use the "arrow keys" to enter the correct time. The time is formatted as Hour:Minute:Second.

5. Press the ENTER key to confirm the time and move to the date option.

6. When setting the date, the 2020 prompts you for the current date formatted as Year/Month/Day. Use the "arrow keys" to enter the correct date.

7. Press the ENTER key to confirm the date and return to the Set options. You can wait for the display to timeout or press ENTER to return to the default display.

6.6.3 Cal

Cal allows you to setup and calibrate 2020. You have three options under the Cal function: "Zero", Span" and "Mem".

A calibration memory consists of a name, a response factor, and PEAK, TWA and STEL alarm levels.

The "Zero" and "Span" keys are covered in detail in the manufacturer's operations manual for the instrument.

To edit the calibration memory, select "Mem" and then "Chng". The 2020 prompts you with two new soft keys: "User" and "Lib".

6.6.4 Library

Library selections simplify Cal Memory programming, and provide standard response factors for approximately 70 applications. "Lib" allows you to select an entry from a pre-programmed Library. The name, response factor and three alarm levels are all set from the library. To select a library entry to program the selected Cal Memory:

1. Select "Set", "Cal", "Mem", "Chng" and "Lib".

2. Use the "Next" and "Prev" keys to scroll through the list. See the manufacturer's manual Appendix 8.7 for a list of the library entries.

6.7 Flame Ionization Detector

A flame ionization detector monitors total organic vapors. In this detector pure hydrogen is burned with air. The hydrogen flame ionized molecules of organic vapor present in the air and these ions are collected by an electrode. The current generated is proportional to the concentration of vapor int he air brought to the detector by a small diaphragm air pump. Different organic compounds ionize to different but repeatable extent in the flame. Therefore, the response of the FID for any given compound is expressed relative to a standard (benzene for the two services described). B&R Environmental currently uses three different types of FIDs which will be presented in this document:

- Foxboro Organic Vapor Analyzer (OVA)
- Photovac MicroFid
- Sensidyne Flame Ionization Detector

The Foxboro (OVA) is being phased out by B&R Environmental but at the time this manual is being written the OVA is still in use.

6.8 Organic Vapor Analyzer (OVA) - Principle of Operation

The OVA operates in two different modes. In the survey mode, it can determine the approximate concentration of all detectable species in air. With the gas chromatograph option, individual components can be detected and measured independently, with some detection limits as low as a few parts per billion.

6.8.1 Gas Chromatograph Function

In the Gas Chromatograph (GC) mode, a small sample of ambient air is injected into a chromatographic column and carried through the column by a stream of hydrogen gas. Contaminants with different chemical structures are retained on the column for different lengths of time (known as retention times) and, hence, are detected separately by the flame ionization detector. A strip chart recorder can be used to record the retention times, which are then compared to the retention times of a standard with known chemical constituents. The sample can be injected into the column either from the air-sampling hose or directly from a gas-tight syringe.

6.8.2 Calibration

The OVA is internally calibrated to methane by the manufacturer. When measuring methane, it indicates the true concentration. In response to all other detectable compounds, however, the instrument reading may be higher or lower than the true concentration. Relative response ratios for substances other than methane are available. To interpret the readout correctly, it is necessary either to make calibration charts relating the instrument readings to the true concentrations or to adjust the instrument, so that it reads correctly. This second procedure is done by turning the 10-turn, gas-select knob, which adjusts the response of the instrument. The knob is normally set at 300 when calibrated to methane. Secondary calibration to another gas is done by sampling a known concentration of the gas and adjusting the gas-select knob, until the instrument reading equals the true concentration.

6.8.3 Limitations

The OVA has an inherent limitation in that it can detect only organic molecules. Also, it should not be used at temperatures lower than about 40°F, because gases condense in the pump and column. It has no temperature control and, since retention times vary with ambient temperatures for a given column, absolute determinations of contaminants are difficult. Despite these limitations, the GC mode can often provide tentative information on the identity of contaminants in air without relying on costly, time-consuming laboratory analysis.

6.8.4 Cautions

The instrument can monitor only certain vapors and gases in air. Many nonvolatile liquids, toxic solids, particulates, and other toxic gases and vapors cannot be detected. Because the types of compounds that the OVA can potentially detect are only a fraction of the chemicals possibly present at an incident, a zero reading does not necessarily signify the absence of air contaminants.

The instrument is nonspecific, and its response to different compounds is relative to the calibration setting. Instrument readings may be higher or lower than the true concentrations. These discrepancies can be especially serious problems when monitoring for total contaminant concentrations, if several different compounds are being detected at once. In addition, the response of this instrument is not linear over the entire detection range. Care must, therefore, be taken when interpreting the data. All identifications should be reported as tentative until they can be confirmed by more precise analysis. Concentrations should be reported in terms of the calibration gas and span potentiometer or gas-select knob setting.

This instrument cannot be used as an indicator for combustible gases or oxygen deficiency.

6.8.5 Start-up and Shutdown Procedures

Start-up

1. Connect the probe/read out connectors to the side-pack assembly.

2. Check battery condition and hydrogen supply.

3. For measurement taken as methane equivalent, check that the GAS SELECT Dial is set at 300.

4. Turn the electronics on by moving the INSR switch to the ON position and allow five (5) minutes for warm-up.

5. Set CALIBRATE switch to X10, use CALIBRATE knob to set indicator at 0.

6. Open the H_2 tank valve and the H_2 supply valve all the way. Check that the hydrogen supply gauge reads between 8.0 and 12.0 psig.

7. Turn the PUMP switch ON and check the flow system, according to the manufacturer's procedures.

8. Check that the BACKFLUSH and INJECT valves are in the UP position.

9. To light the flame, depress the igniter switch until a meter deflection is observed. The igniter switch may be depressed for up to five (5) seconds. Do not depress for longer than five (5) seconds, since it may burn out the igniter coil. If the instrument does not light, allow it to run several minutes and repeat ignition attempt.

10. Confirm OVA operational state by sniffing an organic source, such as a magic marker.

11. Establish a background level in a clean area, by using the charcoal scrubber (depress the sample inject valve) and recording measurements referenced to background.

12. Set the alarm level, if desired.

<u>Shutdown</u>

1. Close H_2 supply valve and H_2 tank valve (<u>Do Not Overtighten Valves</u>).
2. Turn INSTR switch to OFF.
3. Wait until H_2 supply gauge indicates system is purged of H_2, then switch off pump.
4. Put instrument on electrical charger at completion of day's activities.

6.8.6 Maintenance and Calibration Schedule

- Check Particle Filters — Weekly or as-needed
- Check Quad Rings — Monthly or as-needed

• Clean Burner Chamber	Monthly or as-needed
• Secondary Calibration Check	Prior to project start-up
• Primary Calibration Check	Monthly or if secondary check is off by more than ± 10%
• Check Pumping System	Prior to project start-up
• Replace Charcoal	120 hours of use or when background readings are higher with the inject valve down than with the inject valve up, in a clean environment.
• Factory Service	At least annually

* Instruments which are not in service for extended periods of time need not meet the above schedule. However, they must be given a complete check-out prior to their first use addressing the above maintenance items.

6.8.7 Calibration Procedure

Primary Calibration

1. Remove instrument components from the instrument shell.

2. Turn on Electronics and Zero instrument on X10 scale. Gas select dial to 300.

3. Turn on Pump and Hydrogen. Ignite Flame. Go to Survey Mode.

4. Introduce a Methane Standard near 100 ppm.

5. Adjust R-32 Trimpot on Circuit Board to make meter read to standard.

6. Turn off hydrogen flame and adjust meter needle to read 40 ppm (calibrate @ X10) using the calibration adjust knobs.

7. Switch to X100 Scale. The meter should indicate 0.4 on the 1-10 meter markings (0.4 x 100 = 40 ppm). If the reading is off, adjust with R33 Trimpot.

8. Return to X10 Scale and adjust meter needle to 40 ppm with calibration adjust knob, if necessary.

9. At the X10 Scale, adjust meter to read 0.4 on the 1-10 meter markings using the calibration adjust. Switch to X1 scale. The meter should read 4 ppm. If the reading is off, adjust using the R-31 Trimpot.

Secondary Calibration

1. Fill an air sampling bag with 100 ppm (Certified) methane calibration gas.
2. Connect the outlet of the air sampling bag to the air sampling line of the OVA.
3. Record the reading obtained off the meter onto the calibration record.

Documentation

Each office shall develop a system, whereby the following calibration information is recorded.

a. Instrument calibrated (I.D. or Serial No.)
b. Date of calibration
c. Method of calibration
d. Results of the calibration
e. Identification of person who calibrated the instrument
f. Identification of the calibration gas (source, type, concentration, Lot No.)

6.8.8 Pump System Checkout

1. With pump on hold unit upright and observe flow gauge.
2. Ball level significantly below a reading of 2 is inadequate flow.
3. Check connections at the sample hose.
4. Clean or replace particle filters, if flow is impaired or it is time for scheduled service.
5. Reassemble and retest flow.
6. If flow still inadequate, replace pump diaphragm and valves.
7. If flow normal, plug air intake. Pump should slow and stop.
8. If no noticeable change in pump, tighten fittings and retest.
9. If still no change, replace pump diaphragm and valves.
10. Document this function in the maintenance records.

6.8.9 Burner Chamber Cleaning

1. Remove plastic exhaust port cover.

2. Unscrew exhaust port.
3. Use wire brush to clean burner tip and electrode. Use wood stick to clean Teflon.
4. Brush inside of exhaust port.
5. Blow out chamber with a gentle air flow.
6. Reassemble and test unit.
7. Document this function in the maintenance records.

6.8.10 Quad Ring Service

1. Remove OVA guts from protective shell.
2. Remove clip ring from bottom of valve.
3. Unscrew nut from top of valve.
4. Gently pull valve shaft upward and free of housing.
5. Observe rings for signs of damage - replace as necessary.
6. Lightly grease rings with silicone grease.
7. Reassemble valve - do not pinch rings during shaft insertion.
8. Document this function in the maintenance records.

6.8.11 Troubleshooting

Indication	Possible Causes
High Background Reading (More than 10 ppm)	1. Contaminated Hydrogen 2. Contaminated Sample Line
Continual Flameout	1. Hydrogen Leak 2. Dirty Burner Chamber 3. Dirty Air Filters
Low Air Flow	1. Dirty Air filter 2. Pump Malfunction 3. Line Obstruction
Flame Will Not Light	1. Low Battery 2. Ignitor Broken 3. Hydrogen Leak 4. Dirty Burner Chamber 5. Air Flow Restricted
No Power to Pump	1. Low Battery 2. Short Circuit
Hydrogen Leak (Instrument Not in Use)	1. Leak in Regulator 2. Leak in Valves

To be performed by qualified technician only.

1. No meter response in any switch position (including BATT CHK).

   A. Broken meter movement.

      (1) Tip instrument rapidly from side to side. Meter needle should move freely and return to zero.

   B. Electrical connection to meter is broken.

      (1) Check all wires leading to meter and clean the contacts of quick-disconnects.

   C. Battery is completely dead.

      (1) Disconnect battery and check voltage with a volt-ohm meter.

   D. If none of the above solves the problem, consult the factory.

2. Meter responds in BATT CHK position, but reads zero or near zero for all others.

   A. Power supply defective.

      (1) Check power supply voltages per Figure 11 of the HNU owner's manual. If any voltage is out of specification, consult the factory.

   B. Input transistor or amplifier has failed.

      (1) Check input connector on printed circuit board. The input connector should be firmly pressed down.

      (2) Check components on back side of printed circuit board. All connections should be solid and no wires should touch any other object.

      (3) Check all wires in readout for solid connections.

6.8.12 Shipping

Since the OVA-128 contains hydrogen, it is subject to shipping restrictions.

As Personal Luggage

The OVA-128 can be taken on a plane as luggage, since a permit has been issued from the Department of Transportation to the manufacturer (Foxboro).

Air Express

The following labels must be affixed to both sides of the OVA case when shipping OVA by Air Express.

- Danger - Peligro
- Flammable Gas
- Inside Container Complies with D.O.T. Regulations
- Hydrogen UN #1049
- Name and Address of Recipient

A hazardous air bill must be filled out. The following information is requested.

Proper Shipping Name	Hydrogen
Classification	Flammable Gas
I.D. No.	UN 1049
Net Quantity	75 Cubic Centimeters

In addition, the shipping's certification must be signed and marked CARGO AIRCRAFT ONLY.

6.8.13 Hydrogen Recharging

1. High grade hydrogen (99.999%) is required.

2. Connect the fill hose to the REFILL FITTING on the side Pack Assembly, with the FILL/BLEED valve in the OFF position.

3. Open H_2 supply bottle valve.

4. Place FILL/BLEED valve on fill hose in BLEED position momentarily to purge any air out of the system.

5. Crack the instrument TANK VALVE.

6. Open REFILL valve on instrument.

7. Place FILL/BLEED valve in FILL position until the instrument PRESSURE GAUGE equalizes with the H_2 SUPPLY BOTTLE PRESSURE GAUGE.

8. Shut REFILL valve, FILL/BLEED valve, and H_2 SUPPLY BOTTLE valve, in quick succession.

9. Turn FILL/BLEED valve to BLEED until hose pressure equalizes to atmospheric pressure.

10. Turn FILL/BLEED valve to FILL Position, then to BLEED position, then to OFF.

11. Close TANK on instrument.

12. Disconnect the FILL HOSE and replace protective nut on the REFILL FITTING.

6.8.14 Particle Filter Servicing

There are two points in the air sampling line of the OVA where filters have been placed to keep particulates from entering the instrument. The location of these filters are indicated on the figure in Attachment M. The first filter is located in the probe assembly and the second filter (primary filter) is located on the side pack assembly. Cleaning procedures are as follows:

1. Detach the probe assembly from the readout assembly.

2. Disassemble the probe (the components unscrew).

3. The particle filter located within the probe can be cleaned by blowing air through the filter.

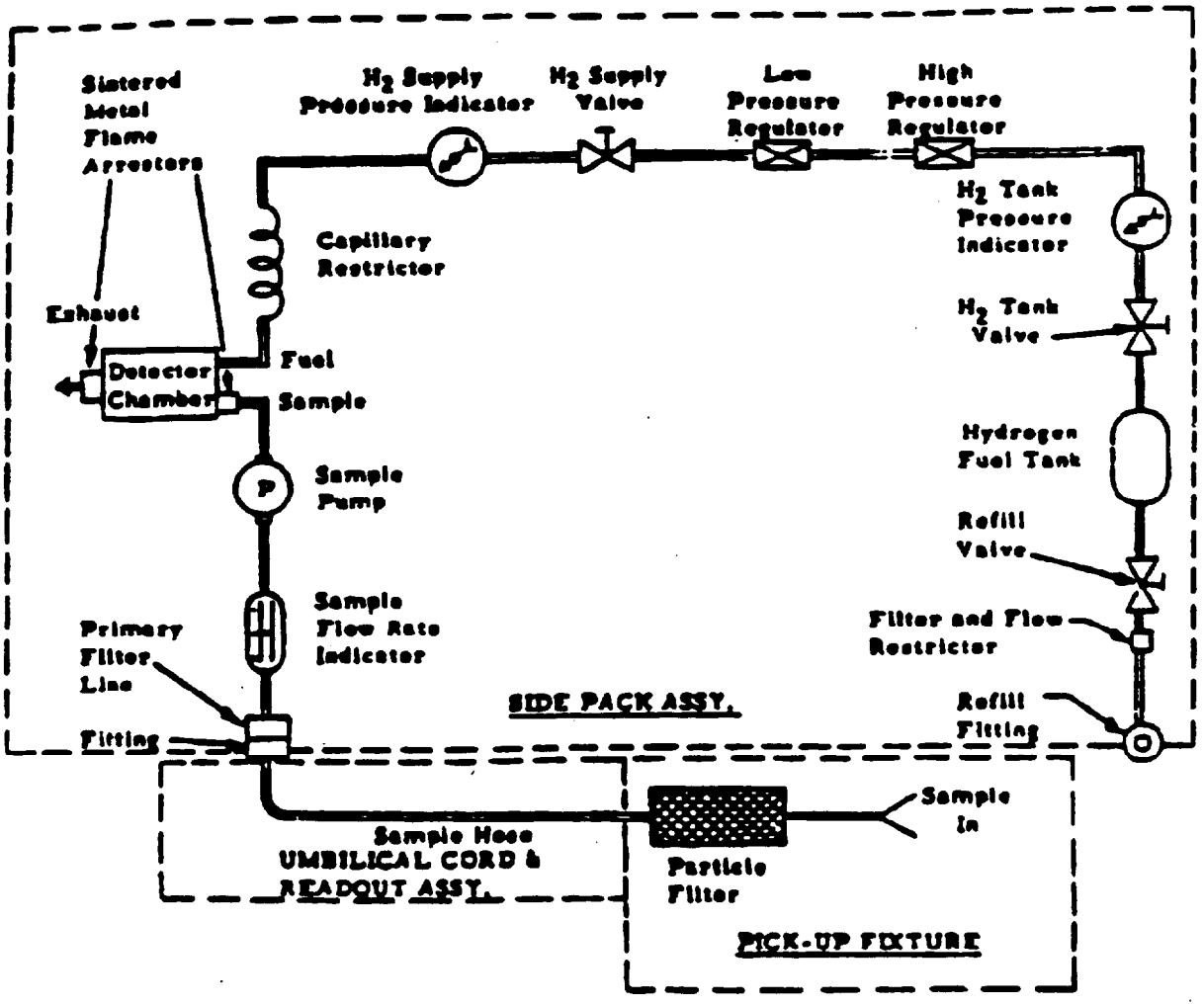
4. Reassemble the probe.

5. The primary filter, located behind the sample inlet connector on the side pack assembly, is accessed by removing the sample inlet connector with a thin-walled 7/16 inch socket wrench. Remove the filter and clean as above.

6. Reassemble the sample inlet fitting and filter to the side pack assembly.

7. Check sample flow rate.

6.8.15 Flow Diagram - Gas Handling System



6.8.16 References

Century Systems (Foxboro). Service Procedures: Organic Vapor Analyzer; 128GC.

6.9 MicroFID Hand Held Flame Ionization Detector

6.9.1 Beginning Operation

You can operate MicroFID without the flame to print or review logged data. In this way you can conserve the hydrogen.

If you choose to start the flame, MicroFID will attempt to ignite the flame once you have turned on the flow of hydrogen gas. If MicroFID has been unused for a while, it is possible that the gas supply lines are filled with air. If the flame cannot be started, MicroFID will begin a 30 second purge cycle. During the purge cycle it will flush the gas supply lines with hydrogen. After the purge cycle it will attempt to light the flame again. If it fails again, another purge cycle will be performed and MicroFID will try a third time to ignite the flame.

1. Turn the instrument on by pressing the front of the On/Off switch. When the instrument is powered up, the version number and creation date of the instrument software are displayed. Press ENTER.

2. You will be prompted to start the flame. If you do not want to start the flame, use the ARROW keys to select "No Flame Needed" and press ENTER. To start the flame use the ARROW keys to select Start Flame and press ENTER.

3. If you selected "Start Flame", MicroFID will prompt you to turn on the hydrogen. Turn the shut-off valve counterclockwise to start the flow of hydrogen and press ENTER. See Figure 1 for the location of the shut-off valve.

4. The pump will start and MicroFID will then ignite the flame. You will hear a small pop when the flame has been ignited. Once the flame has been started the message "Detector flame has been started OK" will be displayed followed by the default display.

The default display provides the following information: instrument status, current detected concentration, Event name (if the datalogger is on), time, and date. If an event name is longer than three characters, the bottom line of the display will scroll through the information.

The instrument status appears at the left of the upper line of the display and on the Print and Graph outputs. Each status has a priority assigned to it. If more than one status is in effect, then the status with the highest priority is displayed until the condition is corrected or until the option is turned off.

When the bar graph is selected, the instrument status is reduced to a one-letter code.

6.9.2 TUTOR Key

To assist you in learning the key functions, MicroFID has a built-in tutorial session that displays a two-line description of the function of each key. Pressing the TUTOR key begins a tutorial session and pressing the EXIT key after any other key, ends the session. While in the tutorial session, key presses have no effect on MicroFID's operation.

To begin a tutorial session:

1. Turn on MicroFID and select the "No Flame" option.

2. Press the TUTOR key and begin a tutorial session.

3. Press each key and read the display.

If a fault is encountered during normal operation, press the TUTOR key to display a description of the fault. If more than one fault is occurring at the same time, press the TUTOR key to see each of the faults in turn. When all the faults have been viewed, press EXIT to return to the normal display.

6.9.3 Key Functions

Press a key to execute a function. If there are no options to the key function, the key acts immediately. The BATT key is one example. If there are option,s the current option is displayed. You are prompted to display the other options by pressing the ARROW keys. Pressing ENTER confirms that the displayed value is correct and moves to the next option.

If the function requires numeric input, the current value is displayed. You can change the value using the numeric keys on the keypad. Pressing ENTER confirms that the displayed value is correct and moves to the next key option.

Some functions have multiple steps for options and/or numeric inputs. These are arranged so that the most frequently changed inputs are displayed first. Once the desired changes have been made you can bypass the rest of the steps by pressing EXIT.

Each key function is described in more detail in the following sections. Leave MicroFID on and try each key in turn.

6.9.4 BATT Key

Press the BATT key to open a window that displays the battery voltage. The voltage will be 9 volts when the instrument is fully charged. When the voltage drops below 7.2 volts, a "LoBatt" status will be displayed and the battery pack must be recharged.

Note: Do not remove or recharge the battery pack in a hazardous location.

An audio signal will be generated when "LoBatt" occurs. The signal will not clear until you connect the battery pack to an AC supply or replace the battery pack with a fully charged one.

Note: Do not leave the battery pack uncharged for an extended period of time. This will result in damage to the battery pack.

6.9.5 DISPLAY Key

If a numerical display is shown, pressing DISPLAY will change it to a bar graph. If the bar graph is shown, pressing DISPLAY changes it to a numerical display. The top line of the bar graph display shows the instrument status and the concentration range. The bar graph range is selected with the SETUP key.

In the bar graph display, the instrument status becomes a one letter code. See Table 1 for a description of the instrument status codes. The bottom line of the display remains unchanged in bar graph mode and will continue to scroll and display data.

6.9.6 LIGHT Key

Press the LIGHT key to display the flame status. If the flame has been ignited and is burning, the status will be Detector flame is lit. If you are not analyzing, the flame status will be "Detector Flame is not lit".

6.9.7 EXIT Key

The EXIT key terminates all MicroFID functions. When you press the EXIT key the display reverts to the default display. Most functions exit automatically if no key is pressed for 15 seconds.

When EXIT is pressed during printing, MicroFID stops sending information to the printer. The printer will continue to print until its buffer is empty.

6.9.8 CLEAR Key

CLEAR erases the last entry. If a value is entered in error, press CLEAR to erase the entry and then re-enter the correct number.

CLEAR used in conjunction with the MAX key clears the Max register.

6.9.10 MAX Key

Press the MAX Key. The maximum concentration, the event during which it was encountered and the time and date of the occurrence will be displayed. Max is shown for 15 seconds and then the display reverts to the default display.

Press MAX then press CLEAR twice to resent the Max register. "Max Cleared" will be displayed with the current date and time. After 15 seconds the display reverts to the default display.

6.9.11 AUDIO Key

If an "Alarm" status, "LoBatt" status or a flame out fault occurs, an audio signal will be generated. Under these conditions you will hear the audio signal even if a headset is not connected.

If you have a "LoBatt" status, the audio signal will not clear until you connect the battery pack to an AC supply or replace the battery pack with a fully charged one.

If a flame out fault has occurred, the audio signal will not stop until the flame has been restarted or you turn MicroFID off.

In the case of an alarm condition, an audio signal will be generated when an alarm is encountered. You can turn off the audio signal on alarm:

1. Press the AUDIO key.

2. Select "Audio Off" with the ARROW keys and press ENTER.

6.9.12 ALARM Key

Press the ALARM key to display the current alarm level or to enter a new alarm level. The displayed alarm level is specific to the current Cal Memory. When the Cal Memory is changed, the alarm level associated with the newly loaded Cal Memory will be displayed and used during sampling.

1. Press CAL and select the desired Cal Memory. Press ENTER and then press EXIT. You do not want to calibrate MicroFID at this point.

2. Press ALARM to display the current alarm level. If this value is correct, press EXIT to return to the normal display.

3. If a new value is to be set, enter the new value, and press ENTER. This alarm level is specific to the current Cal Memory.

When an alarm condition is detected, the instrument status changes to "Alarm" and an audio signal is generated. The "Alarm" status will not clear until the detected concentration falls below the set alarm level.

6.9.13 PLAY Key

The PLAY key plays back previously recorded data.

1. Press PLAY. Tow options are available. Pressing ENTER begins playback where it was last stopped. Press the SETUP (*) key to set the playback options.

2. Select the start Event, MicroFID will display a list of available events. Use the ARROW keys to scroll through the list. When the start event you want is displayed, press ENTER.

Note: An event name may not be available if it has been deleted.

3. If data has been averaged over an interval, select which value is to be displayed, either the Minimum, the Average, or the Maximum, and press ENTER. If you are playing back Method 21 data, select Background, Sample or Difference to be displayed.

4. The data can be played back in either numerical or bar graph display. press the DISPLAY key to select the desired option.

5. Press the ARROW keys to play back the data. You can move forward or backward through the datalogger.

6. Press EXIT at any time to return to normal operation.

If the flame is on, MicroFID is measuring and recording real time concentrations when the instrument status is "Play". If, during playback, an instrument status with a priority higher than that of "Play" is encountered in real time, it will be displayed. MicroFID will however, continue to play back recorded data.

The PLAY function provides a speed search to review data or to find the desired start and stop event names for printing or graphing.

6.9.14 SETUP Key

The setup key is used to enter analysis information. Press SETUP and step through the options. Press ENTER to accept the displayed data or enter a numerical value using the keypad and then press ENTER. If no values are entered, the display reverts to the default display after 15 seconds.

1. The first option is for the detector. If you have been using the instrument with no flame and you now need to start the flame, use this option. You can also use this option to start the flame after a flame out fault. If you do not want to change the status of the detector, use the ARROW keys to select "No Change". Press ENTER to move to the next option.

2. The next option is Repair. Use Repair to record the state of repair. You must define the repair codes and ensure all users are aware of the codes. This option is most useful for Method 21 monitoring.

   For example, a code of 0 may represent no repair underway, 1 may represent first attempt at repair with 5 days, 2 may represent final repair attempt within 15 days, 3 may indicate irreparable damage, and a 4 may represent a state in which a repair cannot be attempted until the next scheduled shut down.

3. Next, select the operating range. This option sets the full scale range for the bar graph display, the graph output. Use the ARROW keys to select a Range of 20, 200, 2000, 10000, 50000 ppm. This does not affect MicroFID's numerical display and datalogging.

4. Select the Interval next. You can average data over intervals of 1 second (s) 5 s, 10 s, 15 s, 30 s, 1 minute (m), 2 m, or 5 m. You may also select Method 21 mode.

   If you select Method 21, the datalogger will be cleared. If you do not want to lose your previously recorded data, press EXIT. Then print or save the data to disk before changing the interval to Method 21. See Sections 2.15, 2.16 and 4.2 for more information on printing and saving logged data.

Note: The datalogger will be cleared when you change from Interval mode to Method 21.

Method 21 mode first prompts you to locate a specific sampling site and then allows you to record both a background and sample entry int he datalogger. Method 21 mode will be covered in more detail in Section 3.3.

5. The date option is next. Enter the current day, month and year. Press ENTER to confirm the entry. The date is retained when the instrument is turned off. You do not need to enter this information every time you use MicroFID.

6. Next enter the correct time. press ENTER.

6.9.15 EVENT Key

Events may be used to identify a particular sample or sampling location in memory. An event name is issued in Method 21 operation to identify a sampling location. Recorded data are played, printed and removed from the datalogger by specifying a start and stop event name.

The EVENT key controls MicroFID's datalogger. Press the EVENT key to see the event options.

1. Press the ARROW keys until the "Insert" option is displayed.

2. To insert an event, press ENTER. You will be prompted to enter an event name. You can enter a numerical name directly from the MicroFID keypad or you can connect MicroFID to a computer and enter the event name using the STAR 21 Software (Photovac Part No. 396027). An event name may be up to 16 characters long. Refer to the User's Manual for the STAR 21 software for details of using the software with MicroFID.

3. Press the ARROW keys to move to the next option.

4. You can delete the current event, all recorded events or a range of events. Press ENTER then use the ARROW keys to select the desired option.

   If you want to delete a range of events, you must select a start and stop event. Use the ARROW keys to scroll through the list of events to select the start event and then to select the stop event.

Note: Deleted information cannot be recovered. You should play back and print or download the contents of the datalogger before deleting any information.

5. You can turn the datalogger off by selecting Stop. MicroFID will continue to analyze, but no data will be stored. To turn the datalogger on again press the EVENT key and use the ARROW keys to select Start. MicroFID will begin logging data again.

6. You can find a specific event in the datalogger using the "Find" option. Use the ARROW keys to scroll through the list of events to select the desired event. When you press ENTER, the selected event will be displayed. Use this option in Method 21 operation to find an event for monitoring or remonitoring.

7. The next option is "Scan". You can use a bar code reader (Photovac Part No. 396025) to scan a bar coded event name. See Section 4.8 for details of connecting the bar code reader to MicroFID.

8. To activate the bar code reader, use the ARROW keys to select "Scan". press ENTER to activate the bar code reader. it will remain activated until you scan a code. If no bar code is scanned within 15 seconds, the bar code reader will be deactivated. This is done to conserve battery life. "Scan", when used with the bar code reader has the same function as the "Insert" option.

MicroFID can record continuously until the datalogger is full. When the datalogger is full the instrument status will change to "Endlog". The datalogger will stop logging data when it is full.

If it is necessary to retain a copy of recorded data, the data should be printed or stored in a computer when "Endlog" is displayed. This will prevent loss of information.

6.9.16 CAL Key

The CAL key is used to calibrate MicroFID. Calibration has been automated for ease of operation. Before beginning calibration ensure you have a reliable source of zero air and calibration gas. A brief description of the functions under the CAL key will be provided here.

When you press the CAL key you will first be prompted to select a Cal Memory. Each Cal Memory stores a unique zero point, sensitivity setting, response factor and alarm level.

You will then be prompted to enter a response factor. Refer to Appendix 8.5 for a list of response factors. If the compound is not in Appendix 8.5 or you are measuring gas mixtures, enter a value of 1.00. The concentration detected by MicroFID will be multiplied by the response factor before it is displayed and logged.

Next select Low Range or High Range operation. Use Low Range if you are sampling concentrations between 0.5 and 2000 ppm (methane equivalents). Use High Range if you are sampling concentrations between 10 and 50,000 ppm (methane equivalents).

You will now be prompted to connect a supply of zero air. You can use ambient air, a charcoal filter (Photovac part No. 396021, 396022) to clean ambient air or, for best results, use a clean sampling bag filled with zero grade air.

After MicroFID has set its zero point, you then enter the concentration of the calibration gas and then connect the calibration gas. MicroFID sets its sensitivity for the specified Cal Memory. You must have a supply of calibration gas ready before calibrating MicroFID.

When calibrating MicroFID, ensure the instrument is level. If MicroFID is tilted from side to side, gravity will affect the flame height and cause erroneous readings.

6.9.17 PRINT Key

MicroFID has been designed for use with a serial printer. The printer must have a print width of at least 65 characters and a proportionally spaced font. If you are using a parallel printer, you will also need the serial to parallel converter (Photovac Part No. 380145).

See Section 4.1 for instructions on connecting and configuring a printer for use with MicroFID. See Section 4.6 for instructions on connecting the serial to parallel converter to MicroFID and to the printer.

When MicroFID is printing data it is still measuring real time concentrations.

Note: MicroFID is not classified for use in hazardous locations with a printer.

To print data:

1. Turn MicroFID off.

2. Use the MicroFID printer cable (Photovac Part No. 395006) to connect the MicroFID I/O connector to the printer.

3. Turn MicroFID on and press the PRINT key and then the SETUP (*) key to select the desired setup options.

4. MicroFID will ask for the start and stop Events. Use the ARROW keys to scroll through the list of events to select the start event and then to select the stop event.

5. Enter an ID number if desired. Any number up to 16 digits long may be entered as an ID number.

   The ID number can be used, for example, to differentiate between users or instruments. If more than one person is using a single instrument, each person can use an individual number for printed reports. If more than one MicroFID is being used, each instrument can have its own ID number on printed reports.

   If an ID number is not required, leave this option blank and move tot he next option by pressing ENTER.

6. Enter the baud rate. This value is specific to the printer being used and must be set correctly. Refer to the printer user's manual to determine the correct baud rate.

7. Enter the parity. The parity is specific to the printer being used and must be set correctly. Most printers will have parity set to none.

8. When the setup is correct, ensure the printer is on-line and press ENTER.

MicroFID stores one set of readings (Min, Avg and Max) each interval. In each averaging interval the printed minimum is the minimum of all the stored readings in that interval. The printed Avg is the average of all the recorded average readings and the Max is the maximum of all the recorded maximum readings. In Method 21 operation, the background, sample and the difference are stored.

When you are using interval mode, the date and time are printed along with the event name, repair code and the minimum, average and maximum concentration of each interval. The date, time, event name,a nd repair code are only printed when they change.

When you are using Method 21 mode, the date and time are printed along with the event name, repair code and the background, difference and sample concentration of each interval. The date, time, event name, and repair code are only printed when they change.

While the information is being printed, the display shows that printing is in progress. The keypad will not accept commands until they present print job has been completed.

Pressing EXIT during printing stops the job. The printer will continue to print until its buffer is empty.

6.9.18 GRAPH Key

Pressing the GRAPH key prints the recorded data in graphical format. When MicroFID is graphing recorded data it is also measuring real time concentrations. To graph logged data:

Note: MicroFID is not classified for use in hazardous locations with a printer.

1. Turn MicroFID off.

2. Use the MicroFID printer cable (Photovac Part No. 395006) to connect the MicroFID I/O connector to the printer.

3. Turn MicroFID on and press the SETUP key to set the range for the graph. Use the ARROW keys to select the 20, 200, 2000, 10,000 or 50,000 ppm range.

4. Press the GRAPH key and then the SETUP (*) key to select the desired setup options.

5. MicroFID will ask for the start and stop events. Enter the desired event and press ENTER. Use the ARROW keys to scroll through the list of events to select the start event and then to select the stop event.

6. Enter an ID number if desired. Any number up to 16 digits long may be entered as an ID number.

The ID number can be used, for example, to differentiate between users or instruments. If more than one person is using a single instrument, each person can use an individual number for printed reports. If more than one MicroFID is being used, each instrument can have its own ID number on printed reports.

If an ID number is not required, leave this option blank and move onto the next option by pressing ENTER.

7. Enter the baud rate. This value is specific to the printer being used and must be set correctly. Refer to the printer user's manual to determine the correct baud rate.

8. Enter the parity. The parity is specific to the printer being used and must be set correctly. Most printers will have parity set to none.

9. When the setup is correct, ensure the printer is on-line and press ENTER.

MicroFID stores one set of readings (Min, Avg and Max) for each averaging interval. In each averaging interval the graphed minimum is the minimum of all the stored readings in that interval. The graphed Avg is the average of all the recorded average readings and the Max is the maximum of all the recorded maximum readings. In Method 21 operation, the background, sample and the difference are stored.

In Interval mode the date and time are printed along with the event name and the repair code. The date, time, event name, and repair code are only printed when they change.

A minus sign is used to draw the graph from the minimum to the average. Plus signs are used to graph the area between average and maximum.

In Method 21 mode the date and time are printed along with the event name and the repair code. The date, time, event name,a nd repair code are only printed when they change.

A minus sign is used to draw the graph from the background to the difference. Plus signs are used to graph the area between difference and sample. Difference is calculated by subtracting the background from the sample.

While the information is being printed, the display shows that printing is in progress. The keypad will not accept commands until the present print job has been completed.

Pressing EXIT during printing stops the job. The printer will continue to print until its buffer is empty.

6.10 Detailed Operation

6.10.1 Calibration

MicroFID must be calibrated in order to display concentration in ppm units equivalent to the calibration gas. First a supply of zero air, which contains no ionizable gases or vapors, is used to set MicroFID's zero point. Then, calibration gas, containing a known concentration of an ionizable gas or vapor, is used to set the sensitivity.

Occasionally clean ambient air will be suitable as zero air. Due to MicroFID's sensitivity, outdoor air is unsuitable for calibration. A charcoal filter (Photovac Part No. 396021, 396022) may be connected to the instrument to produce clean air from otherwise unsuitable ambient air. For best results, use a commercial source of zero grade air and a second sampling bag. Zero air should have not more than 0.1 ppm total hydrocarbons (THC).

Methane in air is recommended as span gas. The concentration of the calibration gas will depend on your application. When ordering calibration gas(es), specify methane in hydrocarbon free air. Balance air should have not more than 0.1 ppm total hydrocarbons (THC).

Method 21 protocol requires that commercial cylinders of calibration gas be analyzed and certified to be within ±2% accuracy and that a shelf life must be specified ont he cylinder. At the end of the shelf life, the cylinder must be replaced or reanalyzed.

6.10.2 Preparing the Calibration Gas Bag and the Zero Air Bag

Use the calibration kit (Photovac Part No. 396011) as follows:

Warning: Observe proper handling techniques for all gases!

1. Connect the regulator to the calibration gas cylinder.

   If you are using a portable tank of calibration gas, connect the regulator supplied with the calibration kit.

If you are using a large cylinder of calibration gas, you must obtain a high purity regulator. Methane in air is usually supplied with a standard CGA 590 cylinder valve outlet. Obtain a regulator with the matching fitting. Connect the regulator to the tank of calibration gas.

Note: Do not force the connection.

Do not use Teflon tape with CGA fittings. In general, these fittings are designed for metal to metal sealing.

Do not use adapters to connect one CGA fitting to another type of CGA fitting. if the regulator does not match the outlet on your calibration tank, contact your specialty gas supplier.

2. Tighten the regulator onto the tank with a wrench. Do not overtighten.

3. Attach the knurled nut ont he gas bag adapter to the regulator. Finger-tighten the fitting.

4. Loosen the knurled nut on the reducing union of the gas bag adapter.

Note: Do not remove the nut from the union as the Teflon ferrules contained inside the nut my be lost.

5. Insert the tube stub from the gas bag into the knurled nut. Tighten the knurled nut and ensure the tube stub is secure. if the gas bag is not secure, ensure you have inserted the tube stub far enough into the knurled nut. Do not over tighten the fitting.

Note: Over-tightening the Teflon ferrules will result in damage to the ferrules!

6. The union should be connected to the gas bag adapter. If it is not, then tighten the nut on the adapter tube to the union.

7. Open the gas bag valve. Turn the knurled plastic knob counterclockwise to loosen it, then use the knurled collar on the valve tube to gently push the valve tube toward the bag.

8. Turn the regulator knob counterclockwise about half a turn to start the flow of gas. Fill the gas bag about half full and then close the regulator.

9. Disconnect the gas bag from the gas bag adapter and empty the gab. Flush the bag a few times with the calibration gas and then fill it.

10. Close the gas bag valve. Gently pull the valve tube away from the bag, then turn the knurled plastic knob clockwise to tighten it against the valve tube.

11. Remove the knurled nut on the adapter tube from the regulator.

12. Repeat this procedure, if necessary, to prepare a bag of zero air.

Note: Do not use the same gas bag or gas bag adapter for the bag of zero air. You will contaminate the bag of zero air.

6.10.3 Calibrating MicroFID

1. Press CAL and select the desired Cal Memory. MicroFID has 10 Cal Memories and can be calibrated with 10 different span gases or response factors if desired. Only one Cal Memory can be used at a time. Each Cal Memory stores a different response factor, zero point, sensitivity, and alarm level.

2. Enter the desired response factor and press ENTER. Refer to Appendix 8.5 of the manufacturer's manual for a list of Response Factors. If the compound is not in Appendix 8.5 or you are measuring gas mixtures, then enter a value of 1.00. The concentration detected by MicroFID will be multiplied by the response factor before it is displayed and logged.

3. Select Low Range or High Range and press ENTER. Use Low Range if you are sampling concentrations between 0.5 and 2000 ppm (methane equivalents). Use High Range if you are sampling concentrations between 10 and 50,000 ppm (methane equivalents).

4. Connect the supply of zero air. If you are using room air, press ENTER.

5. If you are using a charcoal filter, connect the filter as outlined in Section 4.5. Press ENTER and MicroFID will set its zero point.

Note: The charcoal filter does not filter methane or ethane. If these compounds are present, use a gas bag with a supply of commercial zero air.

6. If you are using a gas bag with zero air, connect the gas bag adapter to the inlet. Open the bag and press ENTER. MicroFID sets its zero point.

7. MicroFID then asks for the span gas concentration. Enter the known span gas concentration and then connect the gas bag adapter to the inlet. Open the bag.

8. Press ENTER and MicroFID sets its sensitivity.

Note: Readings may fluctuate slightly as the gas bag empties. Do not allow the MicroFID to evacuate the bag completely.

9. When MicroFID's display reverts to normal, it is calibrated and ready for use. Remove the span gas bag from the inlet.

10. Press the ALARM key and enter the alarm level for the selected Cal Memory.

6.10.4 Programming the Cal Memories

MicroFID has 10 Cal Memories and can be calibrated with 10 different span gases or response factors if desired. To program the Cal Memories:

1. Prepare the bags of calibration gas as outlined in Section 3.1.2. Use a different gas bag and gas bag adapter for each concentration and for each type of calibration gas.

2. Press CAL and select the desired Cal Memory (1 to 10) with the ARROW keys.

3. Enter the desired response factor and press ENTER. See manufacturer's manual Appendix 8.5.

Note: It does not matter which Cal Memory is selected or which response factor is entered. MicroFID's response is not specific to any one compound. The reading displayed represents the total concentration of all ionizable compounds in the sample.

4. Select the Low Range or High Range and press ENTER. The range will depend on the concentration of the calibration gas. Use Low range if you are sampling concentrations between 0.5 and 2000 ppm (methane equivalents). Use High Range if you are sampling concentrations between 10 and 50,000 ppm (methane equivalents).

5. You will not be prompted to connect a supply of zero air. You can use ambient air, a charcoal filter (Photovac Part No. 396021, 396022) to clean ambient air or, for best results, use a clean sampling bag filled with zero grade air.

6. After MicroFID has set its zero point, you then enter the concentration of the calibration gas and then connect the calibration gas. MicroFID sets its sensitivity for the specified Cal Memory. The span gas concentration, response factor and alarm level entered here are specific to the selected Cal Memory only.

When the calibration is completed it is automatically stored in the selected Cal Memory.

7. Press the ALARM key and enter the alarm level for the selected Cal Memory.

8. Repeat this procedure for each Cal Memory you need.

When calibrating MicroFID, ensure the instrument is level. If MicroFID is tilted side to side, gravity will affect the flame height and cause erroneous readings.

Whenever the instrument is calibrated, MicroFID updates the selected Cal Memory only. Each Cal Memory must be calibrated at least once a day. Frequency of calibration will depend on ambient conditions and instrument response. If ambient conditions change or the response has drifted, a calibration must be performed for each Cal Memory to ensure reliable operation.

6.11 Sensidyne Flame Ionization Detector

The Sensidyne Flame Ionization Detectors are designed for use in non-explosive, non-flammable areas only. The instruments are not designed to be explosion proof and are not certified intrinsically safe.

The detection and measurement of organic gases and vapors is based on the principle of flame ionization. The carrier gas, hydrogen, and the sample are continuously supplied to the flame ionization detector chamber by the constant flow pump. As organic gases and vapors burn, a high voltage electrode inside the chamber produces an electrostatic field that collects the carbon-containing ions.

If the hydrogen carrier is the only substance present in the chamber, the current is small and a baseline response is produced. As organic gases and vapors combine with the carrier gas, the current increases

proportionally due to the intensified production of electrons and carbon-containing ions. The resultant current is a measurement of the sample concentration.

Every FID is factory aligned using methane. The measurement that is observed when the FID responds to an unknown substance is the substance's sensitivity to methane. If it is required that the concentration of a specific substance be read directly, the relationship between the instrument's response to methane and its response to the substance must be determined.

Table 6.3 demonstrates the FID's sensitivity to some organic substances.

The standard FID measurement range is 0-1000 ppm and 0-10000 ppm methane. Measurement is possible at concentrations as low as 0.1 ppm to 1 ppm. The x10 sensitivity FID measurement range is 0-100 ppm. The x10 sensitivity FID measurement range is 0-100 ppm and 0-1000 ppm methane. Therefore, methane concentrations greater than 1.0% by volume (^{0}/oV) (10000 ppm or 1000 ppm, dependent on the specific version) will cause the instrument to over range. Please note that it is dangerous to sample areas having more than 3.5 ^{0}/oV (or 70% LEL).

Measurement is displayed on a semi-logarithmic, analog meter. The meter scale is subdivided linearly in the lower decade and logarithmically in the two subsequent decades. The measurement is also interpretable at the recorder output (linear only) and as an audible frequency modulated (FM) tone.

6.2 Options and Accessories

The following sections describe accessories of specific interest. Ordering information may be found in Section Five-Parts List of the manufacturer's operation manual.

- Data Logger Kit

The FID Datalogger Kit facilities field sampling of multiple locations and allows descriptions and notes to be added to each logging record. The kit comes with a hand-held computer, datalogger module, communication cabling for the FID and a computer, metal bracket & logger sleeve, software and manuals.

- Range Extender

An optional Range Extender (PN^{Q}7012184) is available for use with either the FID or x10 Sensitivity FID. The Range Extender enables a 10:1 dilution of the sample, which is collected via a length of 2-3 mm tubing while the instrument remains in clean, stable air. Use of the Range Extender minutely lengthens the FID's response time.

- Earphones

Optional earphones available for use with the FID are useful for monitoring in noisy environments or when the audible tone may be distracting to other personnel working in the area.

- Probes

A telescoping probe is included with the unit. Certain situations, however, may warrant the use of the additional (optional) probes.

Tee Probe & Sids
This probe provides a survey width of 5.9" for most walking surveys.

Probe Cup
The optional probe cup seals an opening less than 1.5 inches in diameter to allow sampling without drawing in ambient air.

- Calibration Kit

Sensidyne offers a calibration kit for use with the FID. Verification of factory alignment and calibration is possible with this kit that consists of a compressed gas cylinder containing 200 ppm methane in air, flow regulator, tubing, and calibration labels.

- Activated Charcoal Filter

The optional activated charcoal filter attaches to the end of the probe. The filter is filled with activated charcoal which acts as an absorbent and effectively discriminates between methane and higher hydrocarbons. Typically, the user sweeps the sampling area without the activated charcoal filter ir

place. When a high reading occurs, the charcoal filter is installed and a second reading is performed. The difference between the two readings is an indication of higher hydrocarbons.

6.13 Start up

The following sections describe the start up procedures for the FID. There are certain special instructions for the start up of the x10 sensitivity FID. Be certain to observe the following cautions:

CAUTION

Do not draw water into the unit. Do not submerge the probe in any liquid detectable by the FID. It will damage the instrument. Always inspect and drain the water trap in the handle frequently.

1) Lightly grease the o-ring on the fuel cylinder with silicone grease. Place the o-ring into the fuel cylinder fitting.

2) Carefully slide the gas cylinder onto the carriage below the housing.

3) Align the threads of the fuel cylinder valve with the threads of the fuel cylinder fitting. The threads of the fuel cylinder fitting are right-handed. Carefully *hand tighten* the connection (DO Not Use Tools!)

CAUTION

Overtightening the connections may damage the threads and cause hazardous conditions.

4) Disconnect the earphone, if applicable.

5) Turn the volume adjust fully clockwise. Turn the range switch to either Range 1 (RI) or Range 2 (R2), whichever is desired. The intermittent beep will sound, indicating a flame-out condition.

6) Verify that the battery level indicator is in the green sector. If the indicator is in the red sector, do not proceed. The battery requires charging (see Section Four-Maintenance, page 21).

7) Check the flowmeter. The float in the flowmeter will rise and the pump will make an audible sound.

CAUTION

Do not continue with Start Up unless pump is operational. Contact Sensidyne if pump is not running.

8) If necessary, turn the flow adjust until the float is centered on the middle line of the flowmeter. The float should remain centered on this line while the FID is operational.

IMPORTANT

Check the flow rate at regularly. Adjust flow if flowrate changes or a different probe is used. Changes in flow affect FID response.

9) Slowly open fuel cylinder valve by turning the valve 1/4 to 1/2 turn counter clockwise.

10) Verify that there are no leaks around the connection of the fuel cylinder valve and the fuel cylinder fitting. Use of Snoop® is recommended with this system (see Appendix A-Parts List, page 32, for ordering information).

WARNING

DO NOT CONTINUE WITH START UP IF A HYDROGEN LEAK IS DETECTED. IMMEDIATELY CLOSE FUEL CYLINDER VALVE AND SHUT DOWN UNIT. FIX LEAK BEFORE CONTINUING.

11) Read the pressure gauge and verify the hydrogen pressure is equal to or greater than 190 psi to sustain proper operation of the FID for 1 hours. Fuel pressure should never be allowed to fall below 130 psi. If the indicated pressure is below 130 psi, the fuel cylinder must be refilled or replaced.

NOTE

Fuel pressure decreases about 58 psi per hour of operation. The FID can operate about 29 hours with a fully charged (1700 psi) cylinder.

12) Allow 30 to 60 seconds to elapse before pressing the ignitor button. Ignition is indicated by a deflection of the meter and a change from intermittent beeping (flame-out) to a solid tone.

NOTE

Several attempts may be needed to obtain ignition.

13) Turn the zero adjust until the analog meter indicates 0 ppm. The user will no longer hear a tone but a low pitched tick.

14) If it is not possible to obtain an indication of 0 ppm, there may be extraneous detectable substances in the environment. Remove the unit to clean air or supply clean air from another source to make the zero adjustment.

15) The unit is now ready for measurement.

6.14 Shut Down

Follow these instructions for safe equipment shut down.

1) Turn the fuel cylinder valve clockwise to stop fuel flow to the FID. Wait until the intermittent beep is heard and the indication on the pressure gauge decreases slowly to zero. It will take 10-15 minutes for the pressure to discharge fully.

2) Turn the range switch to the "off" position.

3) Remove the fuel cylinder if the instrument is not used on a daily to weekly basis. Removal and safe storage of the fuel cylinder is recommended when there will be a long interval before next use, or when the instrument must be forwarded to or returned from a test location.

CAUTION

Do not loosen the fitting and remove the fuel cylinder until the pressure gauge reads zero.

4) Remove the fuel cylinder as follows:

   a) Loosen the connection between the fuel cylinder valve and the fuel cylinder fitting by hand. Do not use tools!

b) Slide the cylinder out of the carriage below the housing.

c) Safely store the fuel cylinder until next use.

d) The o-ring may fall out of the fitting. Remove the o-ring from the fuel cylinder fitting and inspect if for wear. If no wear is evident, retain the o-ring. Replace the o-ring if it is badly worn.

6.15 General

It is recommended that alignment and calibration of the FID be checked using the Sensidyne FID Calibration Kit. The kit consists of:

- A compressed gas cylinder containing 200 ppm methane in air;
- A flow regulator to deliver 2 LPM;
- A tubing assembly to fit the telescoping probe end;
- Calibration labels (card of nine).

Please refer to Appendix A-Parts List (page 32) for ordering information.

It is recommended that the calibration procedure be performed every 3 months.

6.15.1 Calibration Verification

1) Start up the unit using instructions in Section 2.3 (page 15) of the manufacturer's manual.

2) Assemble calibration kit. Turn the flow regulator valve fully clockwise to ensure that it is closed.

3) Screw the flow regulator onto the compressed gas cylinder of methane in air. Attach the tubing assembly to the flow regulator.

4) Open the flow regulator valve.

5) Insert the probe into the tubing assembly.

6) Observe the meter and wait for a stable indication. If the meter indication is not 200 ± 50 ppm, re-calibration is required. If re-calibration is not required, proceed to Step 7.

a) Remove the label covering the calibration adjust.

b) Using a small, slotted screwdriver, turn the calibration adjust until the meter indicates exactly 200 ppm.

c) Replace the label covering the calibration adjust with a new label showing the current date.

7) Remove the probe from the tubing assembly and close the flow regulator valve.

8) Disassemble the calibration kit. Disconnect the tubing assembly from the flow regulator.

9) Unscrew the flow regulator from the compressed gas cylinder of methane in air.

10) Safely store the calibration kit until next use.

6.12 Oxygen Meter

6.12.1 Introduction

The oxygen content, in a confined space, is of prime concern to anyone about to enter that space. Removal of oxygen by combustion, reduction reactions, or displacement by gases or vapors is a hazard potential which response personnel must address. To accomplish this task, remote measurements must be made before anyone enters a confined space.

Portable oxygen indicators are invaluable when working in hazardous atmospheres. Terrain variations in the land and unventilated rooms or areas may contain insufficient oxygen to support life. When used properly, the portable oxygen indicator will read the percent oxygen in the immediate atmosphere. The normal ambient oxygen concentration is 20.8 percent.

Most meters have indicators which display the oxygen content from 0-25 percent. There are also oxygen meters available which measure concentration from 0-10 percent and 0-100 percent. The most useful range for response and hazardous waste operations is the 0-25 percent oxygen content readout, since decisions involving air-supplying respirators and the use of combustible gas indicators fall into this range.

6.12.2 Principle of Operation

The oxygen indicator has three principle components for operation. These three components include the air flow system, the oxygen sensing device, and the microamp meter. Air is drawn to the oxygen detector with an aspirator bulb or pump. The oxygen detector uses an electrochemical sensor to determine the oxygen concentration in air. The sensor consists of: two electrodes, a sensing and a counting electrode; a housing containing a basic electrolytic solution; and a semipermeable Teflon membrane.

Oxygen molecules (O_2) diffuse through the membrane into the solution. Reactions between the oxygen and the electrodes produce a minute electric current, which is directly proportional to the sensor's oxygen content. This current passes through the electronic circuit. The resulting signal is shown as a needle deflection on a meter, which is usually calibrated to read 0-10 percent, 0-25 percent, or 0-100 percent oxygen.

6.12.3 Limitations

The operation of oxygen meters depends on the absolute atmospheric pressure. The concentration of natural oxygen (to differentiate it from manufactured or generated oxygen) is a function of the atmospheric pressure at a given altitude.

At sea level, where the weight of the atmosphere above is greatest, more O_2 molecules are compressed into a given volume than at higher elevations. As elevation increases, this compression decreases, resulting in fewer O_2 molecules being "squeezed" into a given volume. Consequently, an O_2 indicator, calibrated at sea level and operated at an altitude of several thousand feet, will falsely indicate an oxygen-deficient atmosphere (less than 19.5 percent).

High concentrations of carbon dioxide (CO_2) shorten the useful life of the oxygen detector cell. Therefore, the unit can be used in atmospheres greater than 0.5 percent CO_2 only with frequent replacement or rejuvenation of the oxygen detector cell.

Although several instruments can measure an oxygen-enriched atmosphere (O_2 greater than 21 percent), no testing or other work should ever be performed under such conditions, because a spark, arc, or flame could lead to fire or explosion. Oxygen measurements are most informative when paired with combustible gas measurements. Together, they provide quick and reliable hazard data.

6.13 Combustible Gas Meter

6.13.1 Introduction

The combustible gas indicator (CGI) is a type of flammable gas detector which is one of the first instruments to be used to survey a site. It measures the concentration of flammable vapor or gas in air, indicating the results as a percentage of the lower explosive limit (LEL) of the calibration gas.

The LEL of a combustible gas or vapor is the lowest concentration (by volume) in air which will explode, ignite, or burn when there is an ignition source. The upper explosive limit (UEL) is the maximum concentration of a gas or vapor which will ignite. Above the UEL, there is insufficient oxygen for the fuel level to support combustion. Below the LEL, there is insufficient fuel to support ignition.

6.13.2 Principle of Operation

Most combustible gas indicators operate on the "hot wire" principle. In the combustion chamber is a platinum filament that is heated. The platinum filament is an integral part of a balanced resistor circuit called a Wheatstone Bridge. The hot filament burns the combustible gas(es) on the immediate surface of the element, thus raising the temperature of the filament. Obviously, any single combustible gas or mixture of combustible gases will cause the meter to react. The effect of this trait must be understood by the CGI operator.

As the temperature of the filament increases so does its resistance. This change in resistance clauses an imbalance in the Wheatstone Bridge. This imbalance is measured as the ratio of combustible vapor present compared to the total required to reach the LEL of the combustible gas used to calibrate the CGI. For example, if the meter reads 0.5, this reading means that 50 percent of the concentration necessary to create a combustible situation is present. If the LEL for the gas is 5 percent, then the meter indicates that a 2.5 percent concentration is present.

If a concentration greater than the LEL and lower than the UEL is present, then the meter needle will stay beyond the 1.0 (100 percent) level on the meter. This indicates that the ambient atmosphere is readily combustible. When the atmosphere has a gas concentration above the UEL, the meter needle will rise above the 1.0 (100 percent) mark and then return to zero. This needle behavior occurs because the gas mixture in the combustion cell is too rich to burn. This condition permits the filament to conduct a current, just as if the atmosphere contained no combustibles at all. For this reason, it is very important to always

watch the meter because this rapid deflection may be missed. This is a dangerous condition as expressed in Item 4 of Section 5.4.

6.13.3 Operating Procedures

The following seven steps refer specifically to the MSA Explosimeter. CGIs sold by other manufacturers are similar, but the manufacturer's instructions must be consulted for changes.

Steps 1-4 shall be done in an uncontaminated atmosphere, as follows:

1. Attach sampling line and probe to the instrument.

2. Lift the rheostat on/off bar and turn the bar 1/4 turn clockwise. The meter pointer should move rapidly upscale and then return to zero or less.

3. Flush fresh air through the instrument by squeezing the aspirator bulb 5 times. Other instruments may have an internal-powered pump.

4. Adjust the rheostat knob until the meter pointer rests at zero. Taping the knob in the zeroed position will help to prevent its being jarred off zero while in use.

Steps 5-7 are done on site, as follows:

5. Place the end of the sampling line or probe at the point where sampling is to occur.

6. Aspirate the sample through the instrument until the highest reading is obtained. Five squeezes of the bulb are usually enough to give maximum deflection. Two additional squeezes are required for each added length of sampling line.

7. Do not turn the instrument off until you have left the atmosphere being tested and you have flushed the instrument with fresh air.

6.13.4 Limitations and Applications

The following shall apply:

1. The CGI shall be used in conjunction with an oxygen meter.

2. The instrument shall not be used in an oxygen-deficient atmosphere. In this situation, the atmosphere does not contain enough O_2 to support combustion; however a slight increase in O_2 may make the atmosphere extremely combustible.

3. The instrument shall not be used in an O_2-enriched environment because of the explosive nature of oxygen. This includes mixtures of oxygen with hydrogen or acetylene.

4. Be sure to watch the meter continuously while aspirating a sample. If the needle pegs and then returns to zero, the indication is that the atmosphere is either O_2-deficient or that combustible vapors exceed the UEL, creating a very explosive situation. In the second case, the danger is that an O_2 increase can create an explosive mixture.

5. When measuring, take readings with the probe held at ground, waist, and overhead positions to ensure detection of vapors, whose densities are greater or lesser than that of air. When inside a building or confined space, take special care to measure high, low, and middle positions and particularly check out room corners and other restricted areas, where explosive vapors could become trapped.

6. Do not use in atmospheres other than air. It is not capable of measuring the percentage of vapors in steam or other gaseous atmospheres.

7. The CGI will not indicate the presence of explosive or combustible mists or sprays, such as lubrication oil or explosive dusts, like grain or coal dusts.

8. Do not draw liquids into this unit. Be careful when sampling over drums, pools, etc.

9. The following substances may "poison" the detection filament: fuming acids, leaded gasoline, silanes, silicones, silicates and other silicon-containing components. Even minute quantities of these substances will cause inaccurate responses. When it is suspected that these substances have been aspirated, the instrument shall be checked with a calibration kit.

10. The relative humidity must be in the range of 10-90%. Weather information can be obtained from the Weather Service, a local airport, or the radio.

11. Do not switch the instrument on/off unless in a known combustible-free atmosphere.

12. When the batteries begin to become drained, the instrument will give sluggish responses.

13. In very cold temperatures, the batteries will drain much faster because more energy is required to heat the platinum filament.

14. In very warm temperatures, in excess of 125°F, condensation may cause erroneous readings.

15. The explosive limits for most gases and vapors are well above the TLVs for those substances.

16. High-boiling-point combustible solvents, which are tested at normal ambient temperatures, will show a relatively low vapor concentration. If the temperature of the solvent is increased, the increased concentration of vapors may become combustible.

17. High-boiling-point combustible solvents, which are sampled in areas warmer than the instrument, may be expected to form some condensation in the sampling line and flow systems; as a consequence the concentration may read lower than it actually is in the sampling environment.

18. The CGI meter reads only from 0 to 100% of the calibration gas (often either methane or propane) LEL. Therefore, when another combustible gas is detected, the exact meter reading is not correct or reliable. To provide an additional safety factor, field crews shall not work where combustible gas is measured above 25% of the LEL for a methane- or propane-calibrated CGI.

6.14 PhD Plus and Ultra

The pHD Plus and Ultra are personal, portable, microprocessor controlled datalogging gas detector that can monitor up to four atmospheric hazards simultaneously. The PhD measures oxygen, combustible gas, and up to two additional toxic gases. The PhD uses a top-mounted, back-lit, "Supertwist" LCD (liquid crystal display) to simultaneously show readings of the gases being measured. A loud audible alarm and individual alarm lights for each gas being monitored warn users of hazards.

The PhD offers a choice of three modes of operation, providing the right amount of information for users with different skill levels. The PhD microprocessor software allows true one-button operation. All procedures necessary for day to day operation, including automatic calibration adjustment, are controlled through the single on/off "mode" button. Biosystems EEPROM equipped "Smart Sensors" automatically let the instrument know which sensors are currently installed, assign the appropriate alarm settings, and let the instrument know if any changes have been made to the sensors since the last time the instrument was turned on. Two types of interchangeable battery packs (NiCad and disposable alkaline) provide up to 12 hours of continuous use.

The PhD is Classified by Underwriters Laboratories, Inc. as to Intrinsic Safety for use in Hazardous Locations Class I, Division 1, Groups A, B, C, and D.

Classification for intrinsic safety is based on tests conducted in explosive gas/air (21% oxygen) mixtures only. The PhD Ultra should not be used for combustible gas monitoring in atmospheres where oxygen concentrations exceed 23.5% oxygen.

WARNING: SUBSTITUTION OF COMPONENTS MAY IMPAIR INTRINSIC SAFETY.

6.14.1 Overview of PhD Ultra Operation

The PhD offers a choice of three modes of operation, "Text Only," "Basic," and "Technician." Which mode is selected is a function of how much information is required, the skill level of the user, and the nature of the job.

6.14.2 Turning the PhD Ultra on

The large black push-button on the top of the PhD Ultra case is called the "mode" button. It is used to turn the PhD Ultra on and off, as well as to control most other operations of the instrument. Pushing the mode button once turns the PhD Ultra on.

6.14.3 Start-up Sequence

After the detector has been turned on, it will automatically go through an electronic self test and start up sequence that takes approximately twenty seconds. During the self-test sequence, the meter display back-light will momentarily turn on, the visual LED alarm lights will flash, and the audible alarm will sound. The

PhD Ultra will also determine which "Smart Sensors" are currently installed, and whether there have been any changes since the last time the instrument was used.

During start-up the LCD display will display several messages or "screens" in sequence. The first screen displays the software version number.

Biosystems Inc. PhD Ultra V. 1.1

During the start-up and self-test procedure the PhD automatically evaluates itself to determine its electronic fitness for use.

Several screens will be shown as the instrument loads and evaluates information from the "Smart Sensors" which are currently installed.

Loading Instrument Data

↓

Loading 02 Sensor Data

↓

Loading LEL Sensor Data

↓

etc.

The next screen shows that the PhD is conducting an electronic self-test.

PERFORMING SELF TEST

During the self-test the audible alarm will sound and each LED alarm light will be briefly activated.

The next screen shows the kind of battery pack installed, the current battery pack voltage, and temperature in both Centigrade and Fahrenheit.

```
NiCad Bat. 3.6V
Temp. 25 C 77 F
```

The temperature displayed is not necessarily the temperature of the ambient air which surrounds the instrument. The temperature shown is actually a reading taken on the inside of the instrument case in the area where the sensors are located. This information is used by the PhD Ultra microprocessor to properly adjust the sensor output when the instrument is used in changing temperatures.

The next sequence of screens show the alarm setpoints of the sensors currently installed.

```
CURRENT ALARM
SETTINGS
        ↓
02 19.5%-23.5%
LEL      10%
        ↓
CO (Ceiling)
35 ppm
        ↓
CO  (STEL)  100 ppm
    (TWA)    35 ppm
```

NOTE: PhD gas reading alarms are user adjustable and may be set anywhere within the range of the sensor channel. In many cases it is possible to comply with OSHA guidelines while using higher alarm points than the "default" factory alarm settings. Factory default settings may be easily restored at any time. The procedure for changing or restoring default alarm settings is discussed in Chapter 4 of the manufacturer's manual.

The final screen in the self-test and start-up sequence is the current gas level screen. This screen shows the kind of sensors currently installed and the current readings.

When the instrument is operated in either the "Basic" or "Technician" mode, numerical readings are shown.

02	LEL	CO	H2S
20.9	0	0	0

If the instrument is operated in the "Text Only" mode an "OK" message will be displayed as long as conditions are safe. If readings exceed a pre-set alarm level, the message changes from "OK" to a numerical reading, the LED alarm light flashes, and the audible alarm sounds.

02	LEL	CO	H2S
OK	OK	OK	OK

6.14.4 Other Start-up Screens

Several additional screens may be shown under some circumstances. Usually the screen message is self explanatory.

6.14.4.1 "Self-Adjusting" or "Correcting"

In some cases the PhD may detect an electronic fault or need for adjustment when first turned on. A screen will indicate the nature of the error or fault. If the instrument is capable of correctly adjusting itself, a screen will indicate "Self-Adjusting" or "Correcting." When the correction has been successfully completed the instrument will continue the self-test and start-up sequence.

6.14.4.2 "Non-Standard Alarms"

If the instrument determines that dangerously non-standard or custom oxygen or LEL combustible gas alarms have been selected, the LCD will display the message "Non-Standard Alarms" at start-up. The LCD will display the alarm settings for the affected sensors.

WARNING: Alarms
Non-Standard

↓

02 Low = 0.0
MODE = Acknowledge

Press the mode button to use the non-standard settings.

Note: Factory default settings may be easily restored at any time. The procedure for restoring factory default alarm settings is discussed in Chapter 4 of the manufacturer's manual.

6.14.4.3 "Needs Cal"

Biosystems EEPROM equipped "smart" sensors automatically identify themselves to the PhD in which they are installed. The PhD is aware any time sensors are added, deleted, changed or replaced. Any time a change is made to the sensors installed, the PhD will display the message "Needs Cal" followed by a list of the affected sensors. This is an indication that the accuracy of the affected sensors should be verified by exposure to known concentration test gas before further use.

Caution: The PhD should not be put back into service or used until the accuracy of any affected sensor has been verified by exposure to the appropriate known concentration test gas.

The "Needs Cal" warning message may be acknowledged (and silenced) by pressing the mode button.

6.14.4.4 "Service Due"

PhD Datalink software may be used to assign an optional "service required" date for each sensor. This information is stored directly with the sensor EEPROM. Any interval between 1 and 365 days from the current date may be specified. If a service required date has been assigned, a "Service Due" message will be displayed whenever the instrument is first turned on any time after the date has passed.

```
02 Service Due!
Mode=Acknowledge
```

This screen will toggle between others which show all other sensors currently due for service.

```
LEL Service Due!
Mode=Acknowledge
```

Pressing the mode button acknowledges the message and allows normal operation. The message will continue to be displayed each time the instrument is turned on until a new service due date is assigned.

6.14.5 Turning the PhD Off

Holding the mode button down for three seconds turns the instrument off. In order to prevent accidental shut downs, the mode button must be depressed for a full three seconds in order to turn the instrument off.

After three seconds (marked by three beeps of the audible alarm) the LCD display will display the message "Release button."

Release Button

If the button is released prior to the "Release button" message being displayed, the instrument will not turn off.

After the button is released the LCD display the message, "Begin SHUT DOWN Please wait."

Begin SHUT DOWN Please Wait

The shut-down sequence is complete when the meter display blanks out in about ten seconds.

6.15 Operating Modes

The PhD plus and Ultra offers a choice of three modes of operation, "Text Only," "Basic," and "Technician." Which mode is selected is a function of how much information is required, the skill level of the user, and the nature of the job.

No matter which mode is selected, anytime the PhD is on it is remembering the peak readings of all gases measured, and is calculating both Time Weighted Averages and Short Term Exposure levels for any toxic gas sensors installed. No matter what mode of operation is selected the PhD will go into alarm whenever any alarm set-point is exceeded.

6.15.1 Text Only Mode

The simplest mode of operation is the "Text Only" mode. In this mode, during normal operation, the LCD screen does not display numerical readings, only the indication "OK."

02	LEL	CO	H2S
OK	OK	OK	OK

If an alarm condition occurs, that is, when one of the sensor readings exceeds a pre-set alarm level, the indication changes from "OK" to the numerical value, the LED alarm light flashes, and the audible alarm sounds.

02	LEL	CO	H2S
19.1	OK	OK	OK

PhD alarms are normally self-resetting. When readings drop back below the pre-set alarm levels, the screen reverts back to the "OK" indication, and visual and audible alarms cease.

In the Text Only mode, only one push-button is used to turn the instrument on and off, and to switch screens. Pressing the large black "mode" button allows the user to toggle between available meter display "screens." Two screens are available to the user in the "Text Only" mode. The first screen is the gas level display discussed above. Pressing the mode button displays the second screen, which shows battery voltage, running time for the instrument since last turned on (in hours and minutes), and temperature (in both Fahrenheit and Centigrade).

Run Time=00:25
Bat=3.7V 73F 23C

Pressing the mode button again toggles the display back to the first screen showing current gas levels.

Note: It is not possible to make calibration adjustments while the PhD is operated in the Text Only mode. The PhD must be operated in either the Basic or the Technician mode in order to initiate the "Auto-Calibration" sequence.

6.15.2 Basic Mode

The "Basic" mode of operation is designed for users with a higher level of understanding, and a need for numerical readings, but who are not experts in gas detection.

In the Basic mode, as in the Text Only mode, the user has access to only two "screens" of information. In both the Text Only and Basic modes, only one push-button (the mode button) is used to turn the instrument on and off, and to switch screens. The major difference between the two modes is that in the Basic mode numerical gas level readings are provided, whereas in the Text Only mode only an indication that conditions

are "OK" is provided during normal operation. Another important difference is that it is possible to enter the "Auto-Calibration" mode in order to make zero and span calibration adjustments while in the Basic mode. This feature is not enabled when the instrument is operated in the Text Only mode. (Calibration procedures are discussed in detail in Chapter 3 of the manufacturer's manual.)

Basic mode current gas level screen:

02	LEL	CO	H2S
20.9	0	0	0

If an alarm condition occurs, that is, when one of the sensor readings exceeds a pre-set alarm level, the numerical reading changes to reflect the new value, the LED alarm light flashes, and the audible alarm sounds.

02	LEL	CO	H2S
19.1	0	0	0

PhD alarms are normally self-resetting. When readings drop back below the pre-set alarm levels, visual and audible alarms cease, and normal operation of the instrument resumes.

Pressing the large black mode button allows the user to toggle between available meter display screens.

Two screens are available to the user in the Basic mode. The first screen is the gas level display discussed above. Pressing the mode button displays the second screen, which shows battery voltage, running time for the instrument since last turned on (in hours and minutes), and temperature (in both Fahrenheit and Centigrade).

Run Time=00:25
Bat=3.7V 73F 23C

Pressing the mode button again toggles the display back to the first screen showing current gas levels.

6.15.3 Technician Mode

The "Technician Mode" provides access to all advanced functions and displays, including Auto-Calibration.

Calibration procedures are discussed in detail in Chapter 3 of the manufacturer's manual.

After the completion of the start-up and self-test sequence, the meter display will show numerical readings of the gases being measured.

02	LEL	CO	H2S
20.9	0	0	0

If an alarm condition occurs, that is, when one of the sensor readings exceeds a pre-set alarm level, the numerical reading changes to reflect the new value, the LED alarm light flashes, and the audible alarm sounds.

02	LEL	CO	H2S
19.1	0	0	0

PhD alarms are normally self-resetting. When readings drop back below the pre-set alarm levels, visual and audible alarms cease, and normal operation of the instrument resumes.

pressing the large black mode button allows the user to toggle between available meter display screens. Several additional screens are available to the user in the Technician mode.

The first screen is the gas level display discussed above.

6.15.3.1 Peak Readings

Pressing the mode button once displays the "Peak" readings for the gases being measured. These readings represent the highest (or in the case of oxygen highest and lowest) values registered by the instrument during any period of operation. Peak readings are updated on a second by second basis.

The instrument will automatically cycle between two peak reading screens, one for oxygen, and one for the other gases being measured. The oxygen peak reading screen shows both the high (HI) and low (LO) readings.

PEAK	LO	HI
20	20.6	20.9

↓↑

PEAK	LEL	CO	H2S
	0	0	0

6.15.3.2 STEL Readings

Pressing the mode button again displays "STEL" readings for any toxic sensors currently installed.

STEL	CO	H2S
	0	0

The STEL (Short Term Exposure Limit) for a particular toxic gas is the maximum average concentration to which an unprotected worker may be exposed in any 15 minute interval during the day. The STEL value displayed by the PhD Ultra is the average concentration for the most recently completed 15 minutes of operation.

Note: For the first 15 minutes after the PhD is initially turned on the STEL reading is a projected value. The PhD will begin projecting a STEL value after the first 30 seconds of operation. For the first 30 seconds the STEL screen will show an "X" where the reading should be.

STEL	CO	H2S
	X	X

The STEL reading is constantly updated. Audible and visual gas alarms will be activated immediately any time the most recent 15 minute average exceeds the STEL alarm set-point.

Appendix A of the manufacturer's manual discusses Permissible Exposure Limit alarm calculations in greater detail.

6.15.3.3 TWA Readings

pressing the mode button again displays TWA (Time Weighted Average) exposure levels.

TWA	CO	H2S
1 HR	X	X

TWA values are calculated by projecting exposures over an eight hour period. It is not possible to compute a toxic gas TWA until the PhD has between monitoring for at least 15 minutes. Until the minimum monitoring time has elapsed, the TWA screen will show an "X" where the reading should be.

Note: After 30 minutes the screen will also begin to indicate how long the instrument has been on. This "run time" indication will be given in hours and completed 15 minute intervals.

6.15.3.4 Instrument Status Screen

Pressing the mode button again displays the instrument status screen, which shows clock time, number of data points saved, battery voltage, running time for the instrument since last turned on (in hours and minutes), and temperature (in both Fahrenheit and Centigrade).

12:35 0019 3.9V
00:19:56 72F 22C

Pressing the mode button again toggles the display back to the first screen showing current gas levels.

16.15.4 Changing Operating Modes

It is easily possible to shaft from one operating mode to another while the instrument is in use without the loss of data. It is not necessary to turn the instrument off before switching. Simply slide the belt clip located on the back of the PhD case downward to expose the four push-buttons on the instrument keypad. Push the "+" and "-" buttons at the same time to change operating modes. Each time the operating mode is changed the display screen will briefly indicate which operating mode has been selected.

Note: Shifting modes or otherwise reprogramming the instrument should only be done by employees who are authorized to do so.

6.16 Batteries

PhD batteries are housed in a removable battery pack. Two types of battery packs (rechargeable NiCad and disposable alkaline) are available for use. All battery packs are interchangeable. Battery packs are designed to be easily changed or replaced while the instrument is in the field. It is not necessary to open the instrument case to replace or change the type of battery pack currently installed.

Battery packs are clearly labeled as containing either NiCad or disposable alkaline batteries. The gasketed battery packs are held firmly in place by a spring loaded catch. The PhD should be turned off before changing or replacing battery packs.

6.17 Detector Tubes

6.17.1 Introduction

Detector tubes are not one of the most frequently used measuring methods for contaminants in work areas. When measurements of gases which do not absorb or react readily are made, a color change occurs uniformly throughout the entire length of the impregnated tube column. The intensity of the color change is taken as an index of the contaminant concentration. In the case of gases which are easily and quantitatively absorbed, the length of the stain is taken as the measure of concentration.
The advantage of detector tubes, as compared to methods requiring laboratory analysis, is that:

- The measurement can be carried out easily and yields a measurement result within minutes.
- No other simple system is currently able to cover such a wide range of gases and vapors quantitatively.
- The system is light-weight , compact, and economical.

The accuracy of detector tubes is commonly within 25 percent of the true concentration of the contaminant being sampled.

6.17.2 Type of Detector Tubes

The following types of detector tubes are in current use:

1. Scale tubes: Detector tubes with one or two scales printed on them and with a single indicating layer
2. Detector tubes consisting of one or several prelayers and one indicating layer.

3. Detector tubes with a phial (solid, liquid, vaporous) and an indicating layer.

6.17.3 Calibration

It is very important to use the same flow rate during both calibration and measurement. The collection efficiency varies considerably with the flow rate and a number of indicating tubes are therefore very sensitive to this rate. Rubber squeeze bulbs, frequently used for aspirating the air through the tubes, may deteriorate due to the aging of rubber and valves may get partially clogged; thus changing the flow rate through the tube. The flow shall therefore be checked at intervals; either by timing the period of the bulb expansion or by drawing the air (by means of the squeeze bulb) through a rotameter (or soap-bulb flowmeter) and the tube connected in series.

It is also important to check whether the instrument is leakproof, in order to avoid drawing (through the tube) a volume of air different from that drawn during calibration. This check is done by inserting an unopened tube into the holder, squeezing the bulb, and measuring the time of the bulb's expansion or the beginning of its expansion. There shall be no evidence of expansion at the end of a 2-minute period (or at any other time given in the manufacturer's instructions). In the case of calibrated piston pumps, the handle shall be pulled out completely, held in this position for 2 minutes, and then released. If more than 5 percent of the piston remains out of its original position, there are leaks. To avoid them, replacing valves, tube connections, or the rubber bulb, or greasing the piston is indicated.

Mistakes are also made in the use of the instrument. It is important that the total volume of air shall be drawn through the tube and, for this reason, enough time must be allowed for each stroke of the pump. The fact must be taken into account that, even upon a full expansion of the pump, the tube may still be under a vacuum and the air still be slowly drawn through it.

6.17.4 Use of Detector Tubes

The tubes shall be checked and used as follows:

1. Each batch of new tubes shall be carefully checked. A number of tubes shall be randomly selected and checked against a known concentration of a gas or vapor. For maximum reliability, the tubes shall be checked about every 6 months.

2. Tubes showing a discoloration shall not be used. This could mean a leak in the tube or a breakdown of the indicating chemicals.

3. The tubes shall be of uniform cross-section.

4. The tubes shall not be overly exposed to light, since some indicating chemicals are sensitive to light.

5. The tubes shall be stored in a refrigerator.

6. The tubes shall not be used beyond the indicated expiration date.

7. The sealed tube ends shall be properly broken. Openings smaller than normal could decrease the flow rate.

8. With some tubes, the air must flow in one direction. This is usually indicated by an arrow or a dot. This type of tube may contain a drying agent or a precleaning layer, ahead of the indicating chemical, to remove interfering gases or vapors. Or it may contain an oxidizing layer that releases a certain part of the vapor test molecule which, in turn, reacts with the indicating chemical. If this tube is not properly inserted into the pump, the test is useless.

9. The color or stain produced shall be evaluated immediately. Many colors fade rapidly.

10. If no color develops, the tube shall not be reused.

11. Indicator tubes shall be used within the specified temperature range. If a temperature correction factor is given, this shall be used. Hot gases and vapors shall be cooled before testing. However, cooling can condense vapors. Some tubes require pressure (altitude) corrections.

12. The tubes shall be used at the recommended detection levels.

13. The effect of interfering gases and vapors shall be understood. These interfere by reacting with the indicating chemical or by blanking the color produced by the contaminant being sought. The presence of multiple contaminants may lead to erroneous results. Care must be taken to rule out interferences from mixtures of chemicals in the air.

14. If interference is a problem or if the values obtained are doubtful, then the atmosphere shall be evaluated by using instrumental or chemical analysis techniques.

6.17.5 References

"Principles of the Chemistry of Gas Measuring Techniques," Henry, Manfred, Industrial Hygiene News, December 1985.

Industrial Hygiene Measurements (550), NIOSH, May 1974.

Encyclopedia of Occupational Health and Safety, I.L.O., 1971.

6.18 Radiation Survey Meters

6.18.1 Introduction

None of the ionizing radiations is detectable by any of man's five senses. Therefore, all indications of their presence and intensity must be obtained by instruments. Radiation detection devices, like other measuring instruments, operate because of some effect the phenomenon being measured has on matter. In the case of radiation, this effect is ionization. Survey meters are similar to other radiation detection instruments in their operational characteristics. A good survey meter should be portable, rugged, sensitive, simple in construction, and reliable. Portability implies lightness and compaction with a suitable handle or strap for carrying. Ruggedness requires that an instrument be capable of withstanding mild shock without damage. Sensitivity demands an instrument which will respond to the type and energy of radiation being measured. Rarely does one find an instrument capable of measuring all types and energies of radiation that are encountered in practice. "Simplicity in construction" necessitates convenient arrangement of components and "simple circuitry" is comprised of parts which may be replaced easily. "Reliability" is that attribute which implies ability to duplicate response under similar circumstances. All these conditions are not met in any one instrument, but they are approached in many. In any monitoring operation, one must select the proper instrument, use it intelligently, and then be able to interpret the results of the meter readings.

6.18.2 Types of Radiation Survey Meters

6.18.2.1 Ionization Chambers

Ionization chambers are instruments in which the ionization, initially produced within the chamber by radiation, is measured without further gas-amplification. Primary ions formed in the chamber are attracted to their respective electrodes and the current pulses are amplified externally to a measurable current. The gas-amplification factor is, thus, one.

Ionization chambers are usually about 30 to 50 cubic inches in volume and are filled with air at atmospheric pressure. The chamber wall design and type of material used in its construction determine its characteristics and, thus, the radiation energy to which it is sensitive. The larger the chamber, the more sensitive the instrument will become. Also, greater voltage will be required for proper operation of the larger chambers. In ionization chamber instruments with movable shields, it is possible to discriminate between types of radiation. In general, ionization chamber survey meters are used to measure relatively high level intensities. Their low sensitivity enhances their capacity to measure radiation at higher dosages or exposure rates.

Most ionization chamber survey instruments have a selector switch marked "off," "wait," and X1, X10, X100. When the switch is off, the batteries are disconnected and the meter is short-circuited, making the instrument inoperative. With the switch in the wait position, the batteries are connected, permitting the circuit to warm up and the instrument to be zeroed, after a warmup period of from 1 to 5 minutes. The meter is connected while the ionization chamber is disconnected, making it possible to adjust the meter accurately to zero, even in the presence of radiation.

No aural indication is typically used in ionization chamber instruments. Thus, the operator must constantly watch the meter to ascertain the field intensity. There is a lag between the instant radiation enters the chamber and the time when the meter reaches its maximum reading. Therefore, one must allow time for the meter to reach its maximum before taking a reading. This interval is usually just a few seconds.

Perhaps the most widely used and one of the most versatile ionization chamber instruments available for radiological survey work is the "Cutie Pie." These instruments are available with maximum scale readings up to 50 roentgens/hour.

6.18.2.2 Geiger-Mueller Instruments

Essentially, the theory of ion collection in the Geiger-Mueller type detector is the same as for the ionization chamber instrument, except that there is the formation of secondary electrons. In this process, primary ions, formed by the incident radiations, are accelerated (given energy) by the high voltage potential. This added energy enables them to produce secondary ion-pairs. For control of the amplification, a quenching gas is introduced. An ionization avalanche, caused by radiation entering the Geiger-Mueller tube, sends a pulse to the indicating unit of the survey instrument. The quenching gas functions to stop the avalanche and makes the Geiger-Mueller ready for another ionization event. The amplification, inherent in the detector tube, allows a single beta particle or gamma proton to be detected.

Most Geiger-Mueller tube walls are designed so that all but the weakest beta particles may enter. Allowing for the errors due to simultaneous entry, each and every beta particle entering the tube will be counted. Gamma ray counting is not nearly so efficient.

Since one measures each beta particle and each gamma ray that produces ionization within the sensitive tube volume, the instrument is extremely sensitive to radiation. On the most sensitive scales, background levels can be read.

A discriminating shield is usually provided for the Geiger-Mueller tube or probe which, when open, admits both beta and gamma particles. With the shield closed, only gamma is admitted.

To count efficiently, Geiger-Mueller tubes must have adequate means for quenching the ionization avalanche started by a particle entering the tube. In survey Geiger-Mueller counters, the tubes are invariably self-quenching. That is, the gas within the tube contains from 10 to 25 percent vapor of a substance, such as ethylene or iso-butane. Quenching gas is decomposed by radiation. Hence, a self-quenching tube has a limited lifetime. Therefore, a Geiger-Mueller counter should not be left turned on when not in use, especially near a source of radiation.

The indicating mechanism on most Geiger-Mueller counters is usually two-fold; that is, earphones for aural indication and a meter for visual indication. The meters are in reality microammeters that indicate radiation intensity by a pointer on a scale. The pointer or needle will waver slightly and an average reading should be used. In general, the dial is calibrated either in counts/minute or in milliroentgens (mr)/hour, or both. Also, the instrument has a switch for selecting different ranges of sensitivity. For the mr/hr scale, the sensitivities are usually indexed, indicating full scale values at a particular switch position. The counts/minute scale is usually marked by X1, X10, x100, or X1000 of full scale, as read on the face of the dial.

Equipment failure is generally due to batteries (some instruments have a battery check in the "on" position), loose connections, or faulty Geiger-Mueller tube.

The operation of the Geiger-Mueller Survey Instrument is essentially the same as that of the ionization chamber survey instrument. The warmup period is much less critical, and usually 5 to 10 seconds is ample. Care should be taken not to exceed the maximum capacity of the instrument. Such excessive exposure will likely damage the Geiger-Mueller detecting tube. The Geiger-Mueller tube is in operation when it is in the "on" position and no zero adjustment is possible. It is important to remember that Geiger-Mueller survey meters are sensitive instruments and, in general, do not read high levels of radiation intensity.

6.18.2.3 Other Radiation Survey Instruments

Other radiation survey instruments which operate under different physical principles are available, but are not usually used in waste site survey activity. These are: (1) proportional survey instruments utilized primarily in specialized alpha surveys and, (2) scintillation survey instruments, which are extremely sensitive, but radiation type-selective, depending upon the scintillating phosphor or crystal used.

6.18.3 Calibration

Instruments are designed by manufacturers to read directly in radiation intensity units, generally mr/hr or r/hr; however, there is considerable error in a direct reading, since the characteristics of individual components causes variations in instrument response. Each instrument must be calibrated for accurate interpretation. Instrument response (intended by the manufacturer) is related to one type of radiation, usually of a definite energy range. If radiation of a different energy or type is measured, the results will be incorrect. Thus the instrument must be recalibrated with radiation of the same type and energy that is to be measured.

Gamma ray calibration instruments can be checked by placing them in a known field of radiation. Radium and Co_{60} are the most frequently-used sources for gamma calibration. A plot of scale readings versus true radiation intensity is made, by comparing scale readings at known distances from the source against the true intensities at these distances, employing the formula given below.

$$I = \frac{\textit{milligrams of Ra}}{D^2}, \textit{ or } I = \frac{1.59 \textit{ x millicuries of } Co^{60}}{D^2}$$

where: I = Intensity, mr/hr

D = Distance from source to detector, yards

Five to ten equally-spaced scale readings shall be taken. A graph of these values versus the calculated intensities at the corresponding points is plotted on linear graph paper. A typical calibration curve plots meter readings on the ordinate and corresponding "true" intensities on the abscissa.

When calibrating an instrument, the reference point of the instrument is generally considered as the center of the sensitive volume. It should be pointed out that the ionization chamber-type survey instrument, when properly calibrated, will give a good measurement of x-ray or gamma radiation intensity. However, for alpha and beta radiation, only qualitative measurements can be made.

In calibrating Geiger-Mueller instruments, a less intense radiation source shall be used, since the sensitivity is much greater than that of the ionization chamber-type instrument.

7.0 AREA AIR SAMPLING

For more complete information about air contaminants, measurements obtained with DRIs must be supplemented by collecting and analyzing air samples. To assess air contaminants more thoroughly, air sampling devices equipped with appropriate collection media are placed at various locations throughout the area. These samples provide air quality information for the period of time they are taken, and can indicate contaminant types and concentrations over the lifetime of site operations. As data are obtained (from the analysis of samples, DRIs, knowledge about materials involved, site operations, and potential for airborne toxic hazards), adjustments are made in the types of samples, number of samples collected, frequency of sampling, and analysis required. In addition to air samplers, area sampling stations may also include DRIs equipped with recorders and operated as continuous air monitors.

Air sampling stations may be located as required by project and site needs in various places including:

- Upwind - Because many hazardous incidents occur near industries or highways that generate air pollutants, samples may be taken upwind of the site to establish background levels of air contaminants.

- Support Zone (SZ) - Samples may be taken near the command post or other support facilities to ensure that they are, in fact, located in a noncontaminated area and that the area remains clean throughout operations at the site.

- Contamination Reduction Zone (CRZ) - Air samples may be collected along the decontamination line to ensure that decontamination workers are properly protected and that onsite workers are not removing their respiratory protective gear in a contaminated area.

- Exclusion Zone (EZ) - The Exclusion Zone presents the greatest risk of release/generation of contaminants and requires the highest concern for air sampling. The location of sampling stations shall be based upon factors such as hot-spots detected by DRIs, types of substances present, and potential for airborne contaminants. The data from these stations, in conjunction with intermittent walk-around surveys with DRIs, are used to verify the selection of proper levels of worker protection and EZ boundaries as well as to provide a continual record of air contaminants.

- Downwind - One or more sampling stations may be located downwind from the site to indicate if any air contaminants are leaving the site. If there are indications of airborne hazards in populated areas, appropriate response action must be taken and additional samplers should be placed downwind.

7.1 Media for Collecting Air Samples

Hazardous waste operations can involve thousands of potentially dangerous substances, such as gases, vapors, and aerosols that could become airborne. A variety of media -- liquids and solids -- are used to collect these substances. Sampling systems typically include a calibrated air sampling pump, which draws air into selected collection media. Some of the most common types of samples and the collection media used for them are described below.

7.1.1 Organic Vapors

Activated carbon is an excellent adsorbent for most organic vapors. However, other solid adsorbents (such as Tenax, silica gel, and Florisil) are routinely used to sample specific organic compounds or classes of compounds that do not adsorb or desorb well on activated carbon. To avoid stocking a large number of sorbents for all substances anticipated, a smaller number chosen for collecting the widest range of materials or for substances known to be present generally are used. The vapors are collected using an industrial hygiene personal sampling pump with either one sampling port or a manifold capable of simultaneously collecting samples on several sorbent tubes; for example, a manifold with four sorbent tubes (or as individual pumps with varying flow rates). The tubes might contain:

- Activated carbon to collect vapors of materials with a boiling point above zero degrees Centigrade. These materials include most odorous organic substances, such as solvent vapors.

- A porous polymer, such as Tenax or Chromosorb, to collect substances (such as high-molecular-weight hydrocarbons, organophosphorous compounds, and the vapors of certain pesticides) that adsorb poorly onto activated carbon. Some of these porous polymers also adsorb organic materials at low ambient temperatures more efficiently than carbon.

- A polar sorbent, such as silica gel, to collect organic vapors (aromatic amines, for example) that exhibit a relatively high dipole moment.

- Another specialty adsorbent selected for the specific site. For example, a Florisil tube could be used if polychlorinated biphenyls are expected.

7.1.2 Inorganic Gases

The inorganic gases present at a hazardous waste site would primarily be polar compounds such as the haloacid gases. They can be adsorbed onto silica gel tubes and analyzed by ion chromatography. Impingers filled with selected liquid reagents can also be used.

7.1.3 Aerosols

Aerosols (solid or liquid particulates) that may be encountered at an incident include contaminated and noncontaminated soil particles, heavy-metal particulates, pesticide dusts, and droplets of organic or inorganic liquids. An effective method for sampling these materials is to collect them on a particulate filter, such as a glass fiber or membrane type. A backup impinger filled with a selected absorbing solution may also be necessary.

7.1.4 Other Methods

Colorimetric detector tubes can also be used with a sampling pump when monitoring for some specific compounds. Passive organic vapor monitors can be substituted for the active system described if they are available for the types of materials suspected to be present at a given site.

7.1.5 Information Resources

The National Institute for Occupational Safety and Health's (NIOSH) Manual of Analytical Methods, Volumes 1-7, contains acceptable methods for collecting and analyzing air samples for a variety of chemical substances. Consult these volumes for specific procedures.

7.2 Collection and Analysis

Samples are analyzed to determine types and quantities of substances present.

The following paragraphs provide additional guidance on sample collection analysis.

7.2.1 Aerosols

Samples for aerosols shall be taken at a relatively high flow rate (generally about 2 liters/minute) using a standard industrial hygiene pump and filter assembly. To collect particulates, a membrane filter having a 0.8 micrometer pore size is commonly used. The sample can be weighed to determine total particulates, then analyzed destructively or nondestructively for metals. If the metals analysis is done nondestructively or if the filter is sectioned, additional analysis (for example, organics, inorganics, and optical particle sizing) can be performed.

7.2.2 Sorbent Samples

The sorbent material chosen, the amount used, and the sample volume will vary according to the types and concentrations of substances anticipated at a particular site. Polar sorbent material (such as silica gel) will collect polar substances, which are not adsorbed well onto activated carbon and some of the porous polymers. The silica gel sample can be split and analyzed for the haloacid gases and aromatic amines.

Activated carbon and porous polymers will collect a wide range of compounds. Exhaustive analysis to identify and quantify all the collected species is prohibitively expensive at any laboratory and is technically difficult for a field laboratory. Therefore, samples should be analyzed for principal hazardous constituents (PHCs). The selection of PHCs shall be based upon the types of materials anticipated at a given site, from generator's records, and from information collected during the initial site survey. To aid in the selection of PHCs, a sample could be collected on activated carbon or porous polymer during the initial site survey and exhaustively analyzed off site to identify the major peaks within selected categories. This one thorough analysis, with what is already known about a particular site, could provide enough information to select PHCs. Standards of PHCs could then be prepared and used to calibrate instruments used for field analysis of samples. Subsequently, routine offsite analysis could be limited to scanning for only PHCs, saving time and money. Special adsorbents and sampling conditions can be used for specific PHCs if desired, while continued multimedia sampling will provide a base for analysis of additional PHCs that may be identified during the course of cleanup operations.

Other sample techniques involve the extraction or desorption of various solid sorbents. While many NIOSH analytical methods are available for a wide variety of individual compounds, the most useful methods in hazardous materials investigation involve some form of Gas Chromatography, coupled with Mass Spectrophotometry identification (GC/MS). The main advantages to GC/MS is the relatively high qualitativ accuracy, when looking for specific compounds. In addition, unexpected compounds can be identified by

comparing sample mass chromatograms to National Bureau of Standards standard mass chromatograms. While this method is not infallible, it is very useful in identifying organic vapors at hazardous waste sites.

In addition, when using sorbent tubes, it is wise to check a certain number of traps to assure that they are not channeled or plugged, which would affect collection efficiency. These safeguards are accomplished by checking the pressure drop across each trap being used.

7.2.3 Passive Dosimeters

A less traditional method of sampling is the use of passive dosimeters. The few passive dosimeters now available are only for gases and vapors. Passive dosimeters are used primarily to monitor personal exposure, but they can be used to monitor areas. Passive monitors are divided into two groups:

- Diffusion samplers, in which molecules move across a concentration gradient. This method is usually achieved within a stagnant layer of air between the contaminated atmosphere and the indicator material.

- Permeation devices, which rely on the natural permeation of a contaminant through a membrane. A suitable membrane is selected that is easily permeated by the contaminant of interest and is impermeable to all others. Permeation dosimeters are, therefore, useful in picking out a single contaminant from a mixture of possible interfering contaminants.

7.3 Personnel Monitoring

In addition to area atmospheric sampling, personnel monitoring -- both active and passive -- can be used to sample for air contaminants. Representative workers are equipped with personal samplers to indicate contaminants at specific locations or for specific work being done. Placed on workers, generally within 1 foot of their mouths and noses, the monitors indicate the potential for workers to inhale the contaminant(s).

7.4 Calibration

As a rule, the total air sampling system shall be calibrated, instead of just the pump. Proper calibration is essential for correct operation and for accurate interpretation of resultant data. At a minimum, the system shall be calibrated prior to and after use. The overall frequency of calibration will depend upon the general

handling and use of a given sampling system. Pump mechanisms shall be recalibrated after repair, when newly purchased, and following suspected abuse.

7.5 Meteorological Considerations

Meteorological information is an integral part of an air surveillance program. Data concerning wind speed and direction, temperature, barometric pressure, and humidity (singularly or in combination) are needed for:

- Selecting air sampling locations.
- Calculating air dispersion.
- Calibrating instruments.
- Determining population at risk or environmental exposure from airborne contaminants.

Knowledge of wind speed and direction is necessary to effectively place air samplers. In source-oriented ambient air sampling, samplers need to be located downwind (at different distances) of the source and others need to be placed to collect background samples. Shifts in wind direction must be known. Consequently, the samplers must be relocated or corrections must be made for the shifts. In addition, atmospheric simulation models for predicting contaminant dispersion and concentration need windspeed and direction as inputs for predictive calculations. Information may be needed concerning the frequency and intensity with which winds blow from certain directions (windrose data). Consequently, the wind direction must be continually monitored when use of this type of data is contemplated.

Air sampling systems need to be calibrated before use and corrections in the calibration curves need to be made for temperature and pressure. After sampling, sampled air volumes are also corrected for temperature and pressure variations. These corrections require knowing air temperature and pressure.

Air sampling is sometimes designed to assess population exposure (and frequently potential worker exposure). Air samplers are generally located in population centers, irrespective of wind direction. Even in these instances, however, meteorological data is needed for air dispersion modeling. Models are then used to predict or verify population-oriented sampling results.

Proper data are collected by having meteorological stations on site or by obtaining the information from one or more of several government or private organizations, which routinely collect such data. The choice of how information is obtained depends on the availability of reliable data at the location desired, resources needed to obtain meteorological equipment, accuracy of information needed, and use of information.

7.6 References

Standard Operating Safety Guides, EPA, November 1984.

NIOSH Manual of Analytical Methods, Volumes 1-7, April 1977-August 1981.

8.0 PROCEDURES - AIR SAMPLING PUMPS

8.1 Introduction

Accurate measurement of the concentration of air contaminants, to which a worker may be exposed, is a fundamental step in the health hazard assessment process. Air sampling also is essential in determining if the respiratory protection being used is in compliance with OSHA Act requirements. Air sampling results are also used to evaluate public health risks via air contamination. Therefore, data adequacy and accuracy are vital.

The accuracy and precision of taking an air sample is only as good as the sampling and analytical error (SAE) that the method allows. A great portion of the sampling error can be due to the flow rate of air through the sampling pump and, ultimately, the estimation of the total volume of air that passes through a sampling device. Therefore, it is essential that the HSO is knowledgeable about characteristics of the sampling pump and has it properly calibrated.

8.2 Pump Selection

The choice of a personal air sampling pump is determined most importantly by the air sampling flow rate required by the sampling method. Commercially available pumps are typically classified into three categories:

- High flow pumps, (from approximately one to about 4,000 ml/minute)
- Low flow pumps (from one to about 200 ml/minute).
- Multi-flow pumps or wide-flow range pumps (5 ml/minute to 4,000 ml/minute).

For each containment to be sampled, a standard governmental technique or a professional association recommendation shall be used (if available) to dictate an optional sampling flow rate and a minimum volume of air to be sampled. These factors in turn, suggest the appropriate sampling pump. For those cases where a standard method is not found, a method must be developed, peer-reviewed, and approved by the DHST.

Some other considerations for specific pump manufacturer selection are:

- Flow rate stability;
- Flow rate versatility;
- Cost, including the cost of the charger;
- Portability;
- Ruggedness;
- Battery capacity;
- Amount of maintenance required; and
- Adaptability for filling air-bags.

8.3 Calibration Procedure

Calibration may be accurately performed by use of the Buck Calibrator, soap bubble meter, or an inverted burette (in which the time required for a soap bubble to pass between two volume markings is used to indicate the volume displacement of the pump per unit time). A 1000 ml burette is used to calibrate high-flow pumps and a 100 ml burette is used for low-flow pumps. Alternate calibration methods may be used, if sufficiently accurate. Whenever possible, calibration efforts shall utilize the Buck Calibrator, since it is the most accurate, simplest, and most timely method.

Inverted burette calibration is performed as follows:

- The soap solution is poured into the burette very carefully to avoid raising foam. It is then emptied a the beaker in such a manner that the inside walls of the burette are coated with a thin film of the soapy solution.

- The burette is connected in sequence to the sampling device, which is followed by the personal sampler pump. In this way, the burette will be at atmospheric pressure and reflect actual conditions of pump use. Connections between units are made with the same type of tubing used for the personal sampling unit. To calibrate the pump with in-line sampling media, an air-tight container may be incorporated into the calibration apparatus (see Attachment A). The filter on the inside of the container is connected to the personal sampling pump and the bubble burette is attached to a tube leading into the sealed container.

Care must be exercised in the assembly procedure to assure adequate seals at the joints and to assure that the length of connecting tubing is kept at a minimum.

- Select four or five easily-reproducible points on the rotometer scale to be calibrated. Turn on the pump and adjust the pump rotometer, in turn, to the points to be calibrated.

- The open end of the burette is placed momentarily in contact with the surface of the soapy solution; when withdrawn, soap film adheres to the mouth of the burette and the bubble moves toward the source of suction.

- With a stopwatch, measure the time it takes for the bubbler to move up the burette from one calibration mark to another (zero to 1,000).

- Calculate the flow rate by dividing the volume between the preselected marks by the time required for the soap bubble to traverse the distance. This is a simplified air-flow calculation. For situations where more accurate information is needed, use the equation:

$$Qa = (V/E) \times ((P-PV)/760) \times ((298.16)/273 + T))$$

Where:

Qa	=	flow rate
V	=	volume of meter in cc
E	=	time of bubble traverse in min
P	=	corrected station pressure in mmHg
PV	=	saturation vapor pressure in mmHg
T	=	temperature of air in °C

If the flow rate is within the range desired, then repeat steps four and five until you have three consecutive readings within 0.5 seconds of each other. Average the results. If the flow rate is not within the desired range, adjust the rotometer and repeat steps four, five, and six.

- In this same manner, calibrate each selected rotometer point in flow units per minute.

8.4 Sampling With the Pump

- For employee sampling, select the employee to be sampled and discuss the purpose of the sampling. Advise the employee not to remove or tamper with the sampling equipment. Inform the employee when and where the equipment will be removed.

  For area sampling, select the appropriate sampling location and place the pump and sample media where a representation sample can be taken. Typically, a stake is used to place the sample media above the effects of placement on the ground.

- Instruct the employee to notify the Field Team Leader or the HSO if the sampler should require temporary removal.

- If collecting a personal sample, place the sampling equipment on the employee so that it does not interfere with work performance.

- If collecting a personal sample, attach the collection device (filter cassette, charcoal tube, etc.) to the shirt collar or within the employee's breathing zone. The inlet orifice should generally be in a downward vertical position to avoid contamination. Position the excess tubing so that it does not interfere with the work of the employee.

- Turn on the pump and record the starting time.

- Observe the pump operation for a short time to check the flow rate.

- Record the sampling information.

- At a minimum, check the pump flow after approximately the first 1/2 and, thereafter, every 2 hours. Ensure that the sampler is still assembled properly and that the hose has not become pinched or detached from the cassette or the pump.

- In order to determine if the desired flow rate is being maintained during sampling, observe and note the pump rotometer reading. On subsequent checks, if the pump rotometer has changed, it shall be adjusted back to the initial position. Flow volumes shall be calculated based upon these recordings, then averaged for each flow period.

- Periodically monitor the employees or area location throughout the workday to ensure that sample integrity is maintained, and cyclical activities and work practices are identified.

- Take detailed notes concerning visible airborne contaminants and other conditions.

- Prepare a blank or blanks during the sample period.

- Before removing the pump at the end of the sample period, check the flow rate to ensure that the rotometer float is still at the calibrated mark. If the float is no longer at the mark, record the pump reading.

- Turn off the pump and record the ending time.

8.5 Additional Considerations

Calibrate the pump at essentially the same atmospheric conditions at which you intend to sample (i.e., temperature, pressure, sampler in line.)

Where calibration cannot be done at actual use temperatures (which varies during the day at field sites anyway), calibration curves at several temperatures can be made and then interpolation to the temperature of use can be performed. Usually plots at 0°C, 15°C, and 30°C will suffice. Although not infallible, this limits the inaccuracy due to temperature variation.

Make certain that all seals in the sampling train are tight, and do not leak.

Check the voltage of the pump's battery pack prior to use, to ensure that it is at its rate capacity. (Attachment B).

Protect the pump in sampling (i.e., when using impingers, use a blank solution trap impinger). An empty cassette, in line just before the pump, will also lend sampling protection. Also, the cassette can be packed with a scrubber to protect the pump from acid or caustic vapor from an impinger solution.
Make certain that the sampler inlet is not obstructed during sampling (i.e., filter cassette inlet resting against a worker's lapel).

8.6 References

Air Sampling Pumps and their Calibration; Beaulieu, H.J., National Safety News, October, 1980.

Industrial Hygiene Technical Manual - OSHA 2058.

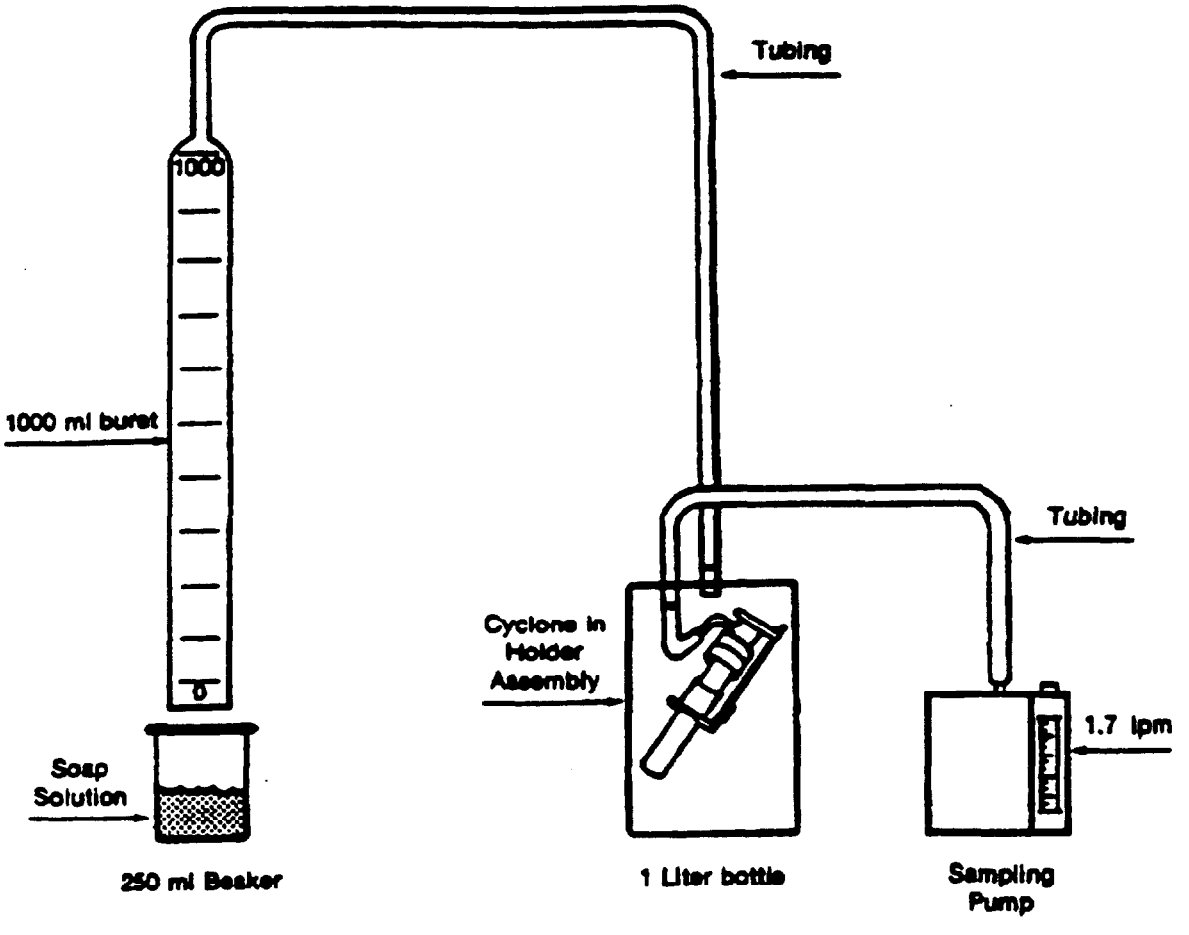
8.7 Attachments

Attachment A - Calibration Using a Bubble Meter

Attachment B - Battery Characteristics of Some Personal Sampling Pumps

ATTACHMENT A

CALIBRATION USING A BUBBLE METER



ATTACHMENT B

BATTERY CHARACTERISTICS OF SOME PERSONAL SAMPLING PUMPS

Sampling Pump	Voltage
MSA, Model G, S	6.25v
SKC	2.50v
Dupont, Model P-125	5.2v
Sipin	4.0v
	(Black to White)
	2.7v
	(Black to Grey)

9.0 THERMOILLUMINESCENT BADGES (TLD)

9.1 Badge Distribution

The OHSS or his designate will quarterly receive TLD badges and assign and distribute one to each individual assigned to Brown & Root Environmental site work by his company. A control badge shall be maintained in an area secure from ionizing radiation.

9.2 Badge Wear

Brown & Root Environmental personnel shall wear their issued TLD badges externally on their mid-torso to ensure that the TLD measures whole body ionizing radiation exposure. Carrying the badge in a back pocket or on a keychain is not acceptable.

9.3 Air Transportation

Personnel who are assigned TLD badges must wear the badge on their person if air transportation to the work site is necessary. (Badges packed in luggage may be exposed to ionizing radiation during airport inspection procedures.)

9.4 Badge Retrieval

At the end of each quarter, the OHSS or his designate will retrieve company TLD badges for readout. The control badge will be read at the same time as the badges used by personnel.

9.5 Investigation of Overexposure

Badge readouts in excess of 50 millirems for the quarter will require investigation regarding the source of ionizing radiation. Personal interviews of the wearers by the OHSS shall be conducted and reviews of field notebooks may be required. A narrative report of excessive exposure and the ensuing investigation shall be sent to the HSM.

9.6 Badge Record Retention

Reports of badge readouts shall be permanently maintained in the OHSS' H&S records. These reports will be subject to audit by the HSM.

10.0 GENERAL CALIBRATION REQUIREMENTS

Measuring and test equipment and instruments under the control of the Pittsburgh Warehouse shall be listed in the Warehouse Inventory file and properly stored.

M&TE and instruments that are being used or are intended to be used, shall be identified in an active status and entered into the program for controlled issuance, maintenance, calibration, and adjustment before issuance.

Active M&TE and instruments that require periodic calibration shall be identified on an active master list. This list shall contain the following information:

- Equipment identification number assigned to the M&TE or instrument.
- Date when the M&TE or instrument was added to the active status.
- Frequency of required calibration in terms of months, annually, prior to use, etc.

The above active master list shall be maintained by the Central Division, Equipment Manager.

The frequency established for calibration shall be determined by the Central Division Equipment Manager based upon manufacturer's recommendations and standard operating procedures developed by B&RE.

A record of issuance shall be maintained by the Pittsburgh warehouse identifying the M&TE or instrument, date of issuance, identification of the responsible Materials and Equipment Coordinator and calibration status.

Once issued to the Materials and Equipment Coordinator it shall be the responsibility of the Coordinator to maintain a record of use and to be responsible for ensuring that equipment is returned for calibration, as required by the Equipment Manager.

Equipment (other than equipment that requires field calibration or adjustment), that is found to be out of calibration shall be tagged "Out of Calibration," and immediately returned to the Equipment Manager.

Any equipment received in a damaged condition or damaged during field use shall be tagged, "Defective" and immediately returned to the Equipment Manager.

All equipment designated as "Out of Calibration" or "Defective" shall be stored in a manner to prevent inadvertent use.

10.1 Calibration

Measuring and test equipment or instruments requiring calibration shall be calibrated in accordance to their respective manufacturer's instructions or approved B&RE Standard Operating Procedures.

Individuals performing calibrations shall be authorized and technically knowledgeable to perform the required calibration adjustment.

Gases used for calibration such as methane, propane, isobutylene, etc., shall be certified by the supplier.

Primary standards used for calibration shall be traceable to NBS (National Bureau of Standards) or other recognized industry standards. Outside calibration laboratories shall be required to provide a certificate of calibration with identity of standards used.

Calibrations performed by Brown & Root Environmental shall be documented using the "Equipment Calibration Report" (Attachment A) which shall reflect the following:

- Equipment identification number.
- Date of calibration.
- Job number, when applicable.
- Identification of the individual performing the calibration.
- Description of calibration results.
- Identification of the procedure used.

Note: When recording the calibrations performed by outside calibration laboratories, the date of calibration, technician, and laboratory shall be recorded.

10.2 Maintenance

Maintenance activities performed by Brown & Root Environmental shall be performed only by authorized personnel.

For other than minor adjustments (i.e., loose screws or standard replacement items) maintenance shall be performed in accordance with manufacturer's instructions or standard operating procedures.

Maintenance records (Attachment B) shall reflect the following minimum information:

- Equipment identification number.
- Date the maintenance was performed.
- Notation of applicable warranty.
- Cost.
- Description of maintenance performed, including instruction or procedure used.

10.3 Equipment Recall and Return

10.3.1 Recall

No measuring and test equipment or instruments shall be used with an expired calibration date.

It shall be the responsibility of each Material and Equipment Coordinator to ensure that equipment requiring outside calibration, is promptly returned to the Equipment Manager for re-calibration.

10.3.2 Return

Upon job completion all issued measuring and test equipment and instruments shall be returned to the Equipment Manager.

Care shall be exercised in shipping to preclude damage.

10.4 Storage

Care shall be exercised in all cases to preserve equipment integrity and to prevent damage or deterioration. Where provided, M&TE and instruments shall be stored in the original cases provided by the manufacturer and secured in a manner that prevents shock or damage caused by temperature or humidity.

Methods of storage shall be as recommended by the equipment manufacturer, or as determined by the Equipment Manager.

10.5 Records

In order to document use of monitoring equipment and its effectiveness each field team is required to document:

- Type of instrument used
- Date and frequency of calibration
- Areas where readings were obtained

The following forms 10-1, 10-2 will facilitate and document the use of monitoring equipment. Each FOL is required to maintain these records for all onsite use of monitoring equipment.

Active master list

Record of issue

TABLE 10-1

DOCUMENTATION OF FIELD CALIBRATION

SITE NAME: _____ PROJECT NO.: _____

Date of Calibration	Instrument Name and Model	B & R Environmental Instrument I.D. Number	Person Performing Calibration	Instrument Settings		Instrument Readings		Calibration Standard (Lot Number)	Remarks/ Comments
				Pre-Calibration	Post-Calibration	Pre-Calibration	Post-Calibration		

TABLE 10-2

DIRECT-READING INSTRUMENT RESPONSE DATA

SITE NAME: _____ PROJECT NO.: _____

PAGE _____ OF _____

Date and Time(s)	Instrument Operator Name	Instrument Used	Instrument Reading and Duration	Location (e.g., borehole vs breathing zone)	Operation(s) Being Performed	Personnel in Vicinity at Time of Readings and Level of PPE Worn

DECONTAMINATION
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DECONTAMINATION

1.0 PURPOSE

To establish general decontamination procedures and guidelines for developing site and activity specific decontamination procedures.

2.0 SCOPE

Applies to all Hazardous waste activities where exposure to hazardous materials may occur.

3.0 RESPONSIBILITIES

Project Health and Safety Officer (PHSO) - The PHSO shall ensure that decontamination measures are adequately addressed in the Site Specific Health and Safety Plan.

Site Safety Officer (SSO) - The SSO is responsible for establishing a decontamination area. The SSO also ensures that adequate decontamination procedures are followed to prevent contamination of individuals or the environment beyond the exclusion zone.

Project Manager (PM) - The PM will ensure that sufficient information has been provided to the PHSO to prepare adequate decontamination procedures for inclusion in the site-specific Health and Safety Plan (HASP) .

4.0 PROCEDURES

4.1 Introduction

Personnel performing activities at hazardous waste sites may become contaminated during the course of their work on a site. Protective clothing and respirators help prevent the wearer from becoming contaminated or inhaling contaminants, while good work practices help to reduce the contamination of protective clothing, instruments, and equipment.

Contamination may still occur. In removing contaminated clothing, personnel may come in direct contact with and/or inhale the contaminants. To prevent such occurrences, contamination reduction and decontamination procedures have been developed and implemented. Such procedures must be in place before anyone enters a hazardous area and they must continue (modified as necessary) throughout the period of operation.

Decontamination involves physically removing contaminants and/or converting them chemically into harmless substances. How extensive decontamination will be depends on a number of factors, the most important being the types of contaminants involved. The more harmful the contaminant, the more extensive and thorough decontamination must be. Decontamination, proper PPE donning procedures, and safety zones minimize the chance of cross-contamination from protective clothing to wearer, equipment to personnel, and one area to another. Only general guidance can be given on methods and techniques for decontamination. The exact procedure is determined by evaluating factors specific to the site.

The SSO will determine how the Decontamination Line will be organized and what materials will be used. Factors that are considered include: (1) the extent and type of hazard expected, (2) explosive potential, (3) meteorological conditions, (4) topography, (5) levels of protection selected, and (6) availability of equipment and supplies.

4.2 PRELIMINARY CONCERNS

4.2.1 Initial Planning

The initial decontamination plan is based on the assumption that all personnel and equipment leaving the Exclusion Zone (area of potential contamination) are grossly contaminated. The plan will include a system for washing, rinsing, removal, and, disposal of clothing and equipment. The washing and rinsing are done sequentially removing the heaviest contaminated equipment and clothing first and the least contaminated clothing last. Each piece of clothing or operation requires a separate decontamination station. These individual stations are to be spaced at 3-foot intervals.

4.2.2 Contamination Avoidance

Avoiding contamination is the first and best method for preventing the transfer of contamination to personnel or to uncontaminated areas. When planning site operations, develop methods to prevent the contamination of personnel and equipment. Each person involved in site operations must regularly practice the methods listed below, for contamination reduction.

- Know the limitations of all protective equipment being used.

- Do not enter a contaminated area unless it is necessary to carry out a specific objective or job task.

- When in a contaminated area, avoid contaminated surfaces.

- Avoid pools of liquids, discolored areas, or any area that shows evidence of possible contamination.

- Stay upwind of contamination, if possible.

- Do not sit or lean against anything in a contaminated area. In cases where you have to kneel (e.g., to take samples) place a plastic sheet on the ground first.

- Before sampling any hazardous waste, read the label and manifest (if available) for the containers. This may give an indication as to the identity of the substance and the potential contamination hazard. Be cautious - the label may not accurately reflect the contents.

- Waste containers should be checked for incompatible materials. Contact between incompatible materials, and water or alkali metals may produce violent polymerization, or the dissolving of toxic substances. This may result in a fire or explosion.

- Do not set sampling equipment directly on contaminated areas. Place equipment on a protective cover such as a ground cloth.

- Use the proper tools to safely conduct the job. Never use tools not designed for the job function.

A Decontamination Plan specifying decon methods and ways to reduce the potential for contamination transfer will be prepared in advance. Examples of decon methods are: using remote sampling techniques, opening containers by non-manual means, bagging monitoring instruments, using drum grapplers, watering down dusty areas, and avoiding areas of contamination. All of these examples will reduce the possibility of contamination and prevent the spread of contamination.

4.2.3 Site Organization

The Decontamination Line is within the Contamination Reduction (Warm) Zone (see Attachment 6.1). Access Control Points limits access to the Exclusion (Hot) Zone and establishes an area for personnel decontamination activities. The size of the line depends on the wind direction (up or side wind), number of stations, the overall dimension of work control zones, and the amount of space available at the site. A corridor of 75 feet by 15 feet should be adequate for the most extensive decontamination.

The Decontamination line boundaries will be conspicuously marked, with entry and exit restricted. The far end is the hotline -- the boundary between the Exclusion Zone and the Contamination Reduction (Warm) Zone. Personnel exiting the Exclusion Zone must go through the Decontamination line. Anyone in the Decontamination area must be wearing the appropriate protection designated for the decontamination crew. Another corridor may be required for the entrance and exit of heavy equipment needing decontamination. Within the decontamination line, distinct areas are set aside for the decontamination of personnel, portable field equipment, clothing, etc. These areas will be marked and restricted to those personnel wearing the appropriate protection. All activities within the decontamination area are confined to decontamination. The level of decontamination must be spelled out in the Site Health and Safety Plan (HASP).

Protective clothing, respirators, monitoring equipment, sampling supplies, and other equipment are all maintained outside of the decontamination area. Personnel don protective equipment away from the decontamination line and enter the Exclusion Zone through the established access control point at the hotline.

5.0 DECONTAMINATION GUIDANCE

The PPE selected and worn in the Exclusion Zone determine the layout of the decontamination line. Different levels of protection require different decontamination procedures. Attachments 6.1.1, 6.1.2 and 6.1.3 outline the decontamination line organization for Levels A, B, and C.

The time required for personnel decontamination will be determined and incorporated in the scheduling of site activities. The extent of decontamination will be affected by the reason someone is leaving the Exclusion Zone. A worker leaving the Exclusion Zone to pick up or drop off equipment and immediately returning may not require full decontamination. A worker requiring a new air cylinder or changing a respirator would require some degree of decontamination. Personnel wearing self-contained breathing apparatus must leave work areas with sufficient air to go complete decontamination. Individuals at breaktime, lunchtime, or the end of the day must be thoroughly decontaminated.

The type of decontamination equipment, materials, and supplies are generally selected on the basis of availability, ease of equipment decontamination, and the use of disposable equipment is also considered. Soft-bristle scrub brushes with long-handles are used to remove contaminants. Buckets of water or garden sprayers can be used for rinsing. Large galvanized wash tubs, stock tanks, or children's wading pools can be used as containers for wash and rinse solutions. Large plastic garbage cans or similar containers lined with plastic bags are used for the storage of contaminated clothing and equipment. Use metal or plastic cans or drums for the temporary storage of contaminated liquids. Other supplies include paper or cloth towels for drying protective clothing and equipment. Heavy equipment such as bulldozers, trucks, backhoes, and drilling equipment are difficult to decontaminate. The methodology generally employed involves washing the equipment on a sloped concrete or plastic covered pad with a soapy water solution followed by a thorough water rinse. The wash and rinse solutions are applied through the use of a high pressure spray unit. Particular attention should be given to the tires, the scoop, and other components which directly contact the contaminated areas. Wipe test can be used to determine the effectiveness of decontamination. The wash and rinse water will be collected for proper disposal.

Protective equipment, sampling tools, and other equipment are usually decontaminated by scrubbing with detergent water using a soft-bristle brush followed by rinse with copious amounts of water. While this process may not be fully effective in removing some contaminants (in some cases, the contaminants may react with water). The site contaminant must be identified before a decontamination solution is selected for use. A decontamination solution will be selected with the approval of an experienced chemist. Some suggested decontamination solutions are outlined in Attachment 6.2.

Once decontamination procedures have been established, all personnel requiring decontamination will be given precise instructions and be acquainted with the procedure for moving through the decontamination line. Progress through the decontamination line will be deliberate, organized, to minimize hazard contamination for personal.

Decontamination station detail for various protection levels are outlined in Attachment 6.3.

5.1 Closure of the Decontamination Line

When the decontamination line is no longer needed, it will be closed down by site personnel. All disposable items used and generated during the operation will be double-bagged and contained on site, or removed to an approved off-site disposal facility. Decontamination and rinse solutions may be discarded on site if approved by regulatory agencies. If not, they will be removed to an approved disposal facility. Reusable rubber clothing should be dried and prepared for future use. If gross contamination had occurred, additional

decontamination or disposal of these items may be required. Cloth items must be bagged and removed from the site for final cleaning or disposal. All wash tubs, pails, containers, etc., must be thoroughly washed rinsed, and dried before removal from the site.

6.0 ATTACHMENTS

6.1 Contamination Reduction Zone Layout

6.1.1 Decontamination Layout - Level A Protection

6.1.2 Decontamination Layout - Level B Protection

6.1.3 Decontamination Layout - Level C Protection

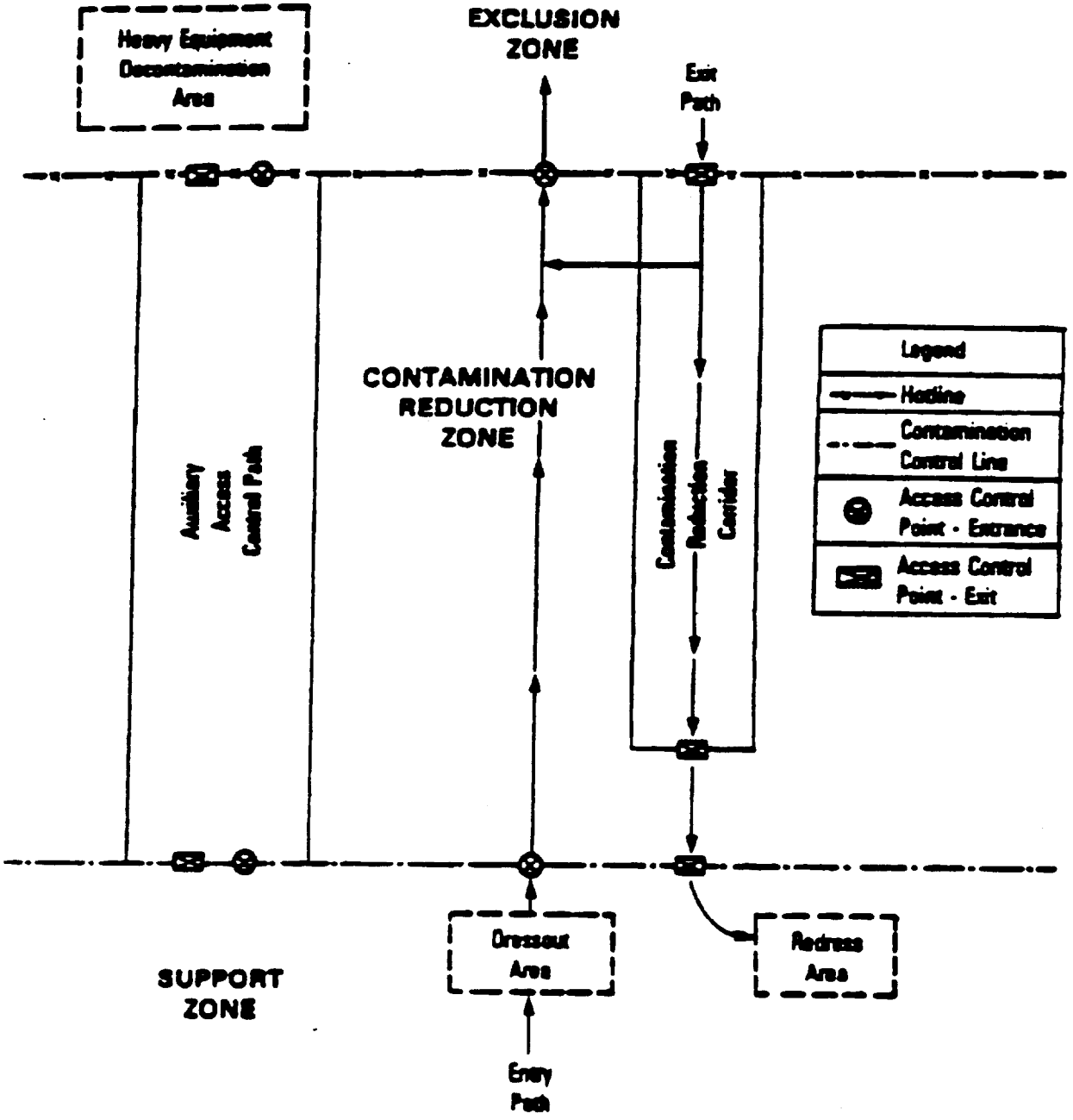
6.2 Suggested Decontaminating Solutions

6.3 Decontamination Station Detail (18 Sheets)

6.4 Questionnaire

ATTACHMENT 6.1

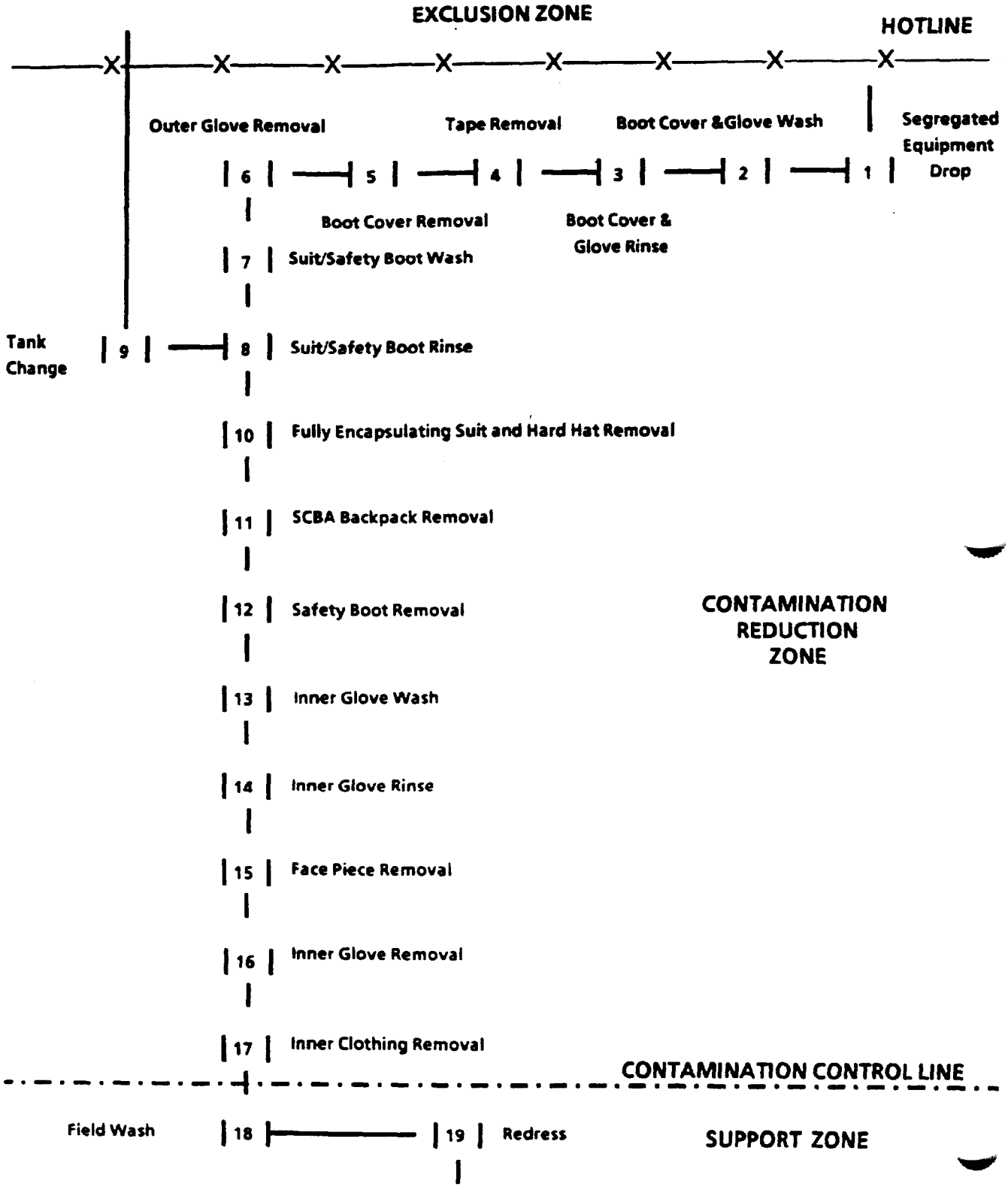
CONTAMINATION REDUCTION ZONE LAYOUT



Contamination Reduction Zone Layout

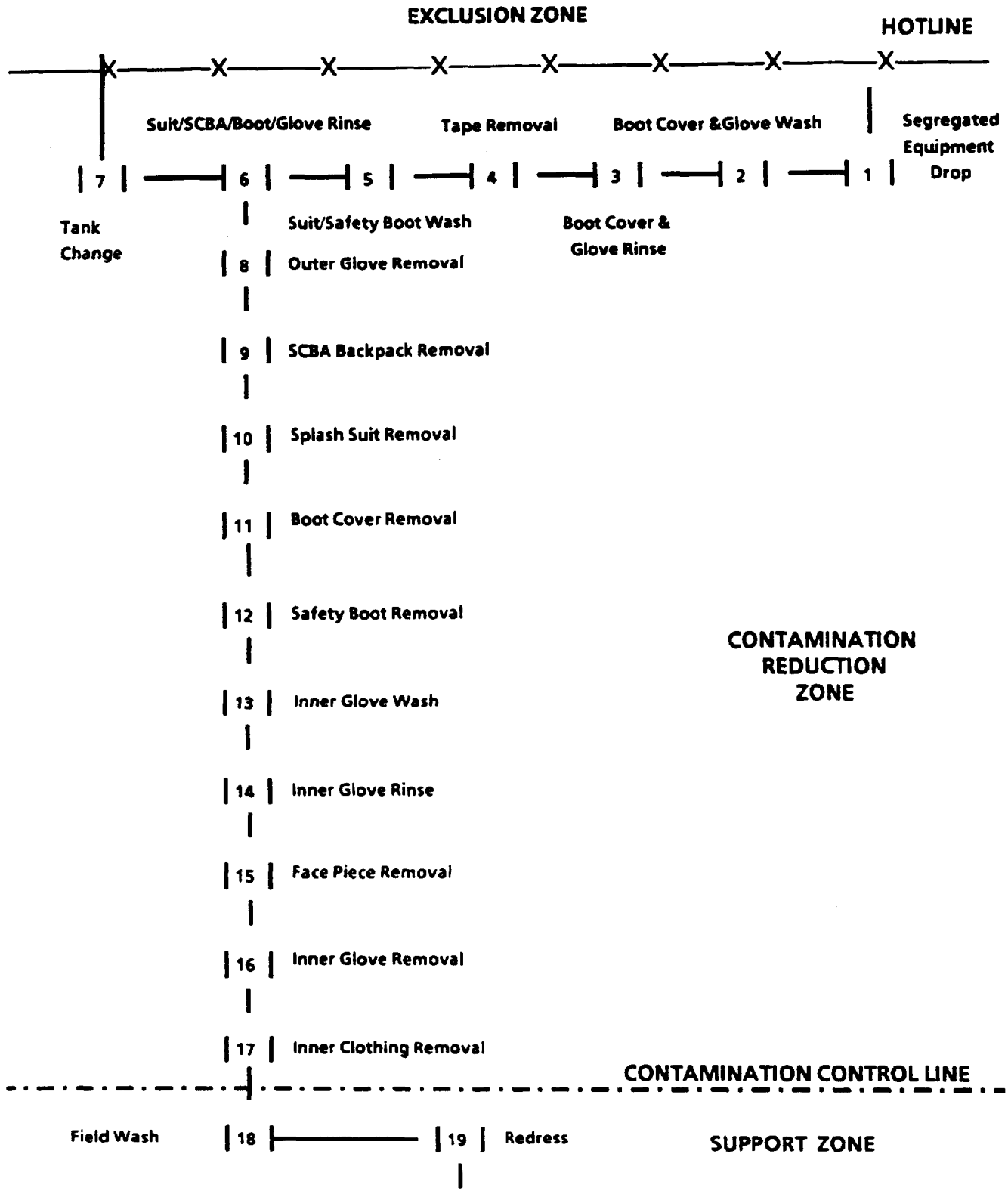
ATTACHMENT 6.1.1

DECONTAMINATION LAYOUT, LEVEL A PROTECTION - EXCLUSION ZONE



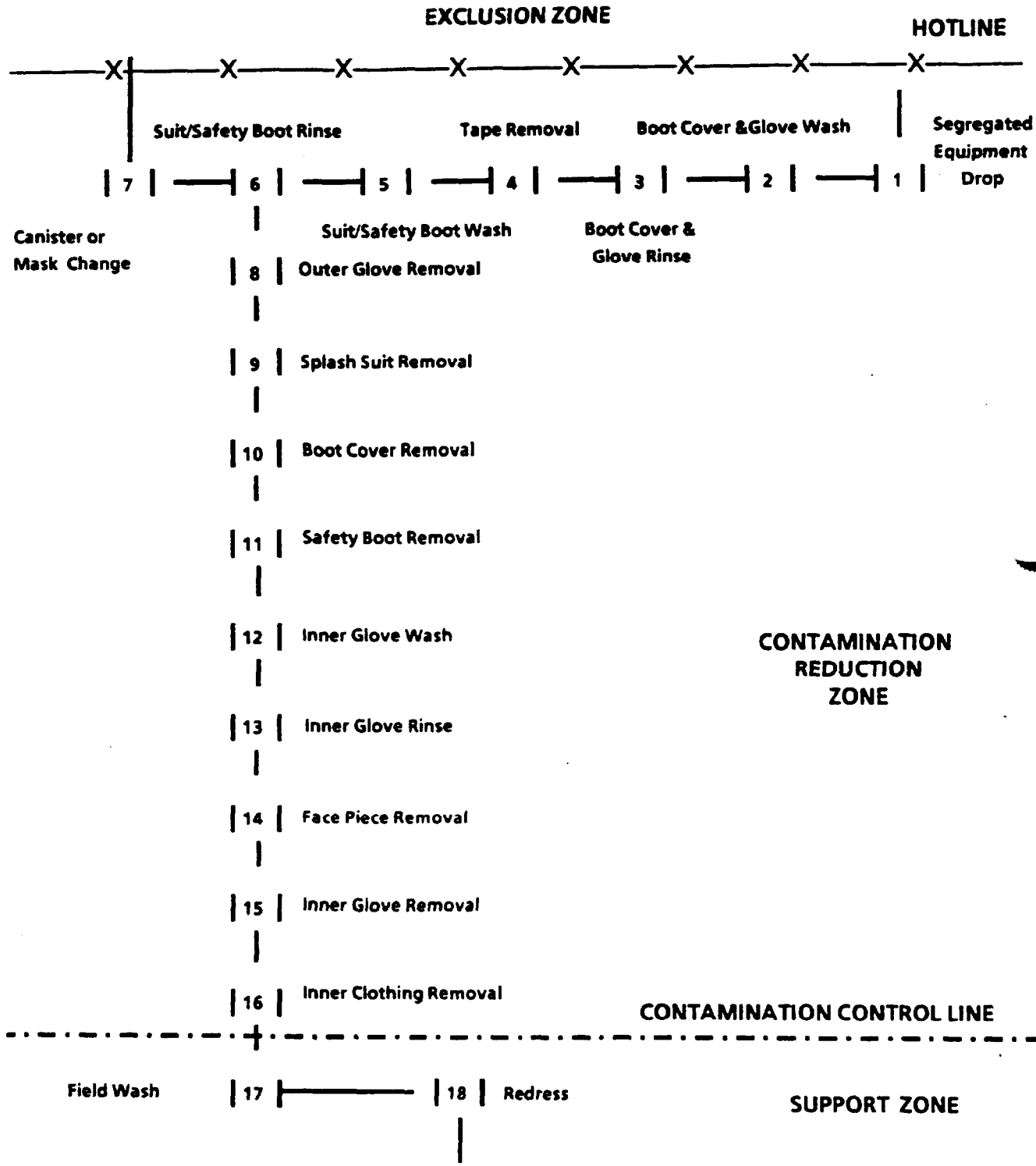
ATTACHMENT 6.1.2

DECONTAMINATION LAYOUT, LEVEL B PROTECTION - EXCLUSION ZONE



ATTACHMENT 6.1.3

DECONTAMINATION LAYOUT, LEVEL C PROTECTION - EXCLUSION ZONE



ATTACHMENT 6.2

SUGGESTED DECONTAMINATION SOLUTIONS

Decon Solution	Mixing Solutions	Uses/Remarks
A. An aqueous solution containing a low-sudsing detergent.	Follow the mixing instructions written on the particular product label.	Generally has the widest range of use. Best choice on sites where contaminants are unknown or a wide range of contaminants exists.
B. An aqueous solution containing 5% sodium carbonate (NA_2CO_3) washing soda.	To 10 gallons of water, add 4 pounds of sodium carbonate.	Decon solution of choice for base labile compounds such as the organophosphate pesticides. Effective in neutralizing inorganic acids. Since sodium carbonate is a water softening agent, this characteristic is an aid in physical removal of contaminants.
C. An aqueous solution containing 5% sodium bicarbonate ($NaHCO_3$) baking soda.	To 10 gallons of water, add 4 pounds of sodium bicarbonate.	Sodium bicarbonate can be used to neutralize either base or acid contaminants. Good decon for base labile compounds.
D. An aqueous solution containing 2% trisodium phosphate (Na_3PO_4) TSP.	To 10 gallons of water, add 2 pounds of trisodium phosphate.	See uses/remarks for Decon Solution B above.
E. An aqueous solution containing 10% calcium hypochlorite ($CaCl_2O_2$) HTH.	To 10 gallons of water, add 8 pounds of calcium hypochlorite.	Cyanide salts.
F. Ethylenediaminetetra-acetic acid (EDTA, versene, sesquesterene)	Commercial product, follow product label.	EDTA is a chelating agent and is decon of choice for heavy metal contaminants.
G. An aqueous solution containing 3 to 5% citric, tartaric, oxalic acids, of their respective sodium salts.	To 10 gallons of water, add 4 pounds citric, tartaric or oxalic acid.	These compounds are chelating agents and are a decon of choice for heavy metal contaminants.

ATTACHMENT 6.3

DECONTAMINATION STATION DETAIL

6.3.1 Level A Decontamination

Equipment Worn

The full decontamination procedure outlined is for workers wearing Level A protection (with taped joints between gloves, boots, and suit). Such protection consist of

1. Fully encapsulating suit with integral boots and gloves
2. Self-contained breathing apparatus (SCBA)
3. Hard hat (optional)
4. Chemical-resistant boots with steel toe and shank
5. Boot covers
6. Inner and outer gloves

Procedure for Full Decontamination

Station 1: Segregated Equipment Drop

Deposit equipment used on the site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each drop area shall be designated for items suspected of being contaminated to different degrees. Segregation at the drop reduces the probability of contamination.

Equipment necessary is

1. Containers of various sizes
2. Plastic liners
3. Plastic drop cloths

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/water solution.

Equipment necessary is

1. Container (20 to 30 gal)
2. Decon solution
3. Detergent/water solution
4. Two or three long-handled, soft-bristle scrub brushes

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE TWO

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment necessary is

1. Container (30 to 50 gal)
2. High-pressure spray unit
3. Water
4. Two or three long-handled, soft-bristle scrub brushes

Station 4: Tape Removal

Remove tape abound boots and gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

Station 5: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners
3. Bench or stool

Station 6: Outer -Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE THREE

Station 7: Suit/Safety Boot Wash

Thoroughly wash fully encapsulating suit and boots. Scrub suit and boots with long-handled, soft-bristle scrub brush and copious amounts of decon solution or detergent/water solution. Repeat as many times as necessary.

Equipment necessary is

1. Container (30 to 50 gal)
2. Decon solution
3. Detergent/water solution
4. Two or three long-handled, soft-bristle scrub brushes

Station 8: Suit/Safety Boot Rinse

Rinse off decon solution or detergent/water solution using copious amounts of water. Repeat as many times as necessary.

Equipment necessary is

1. Container (30 to 50 gal)
2. High-pressure spray unit
3. Water
4. Two or three long-handled, soft-bristle scrub brushes

Section 9: Tank Change

If worker leaves Exclusion Zone to change air tank, this is the last step in the decontamination procedure. Worker's air tank is exchanged, new outer gloves and boot covers donned, and joints taped. Worker then returns to duty.

Equipment necessary is

1. Air tanks
2. Tape
3. Boot covers
4. Gloves

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE FOUR

Station 10: Fully Encapsulating Suit and Hard Hat Removal

With assistance of helper, remove fully encapsulating suit and hard hat. Hang suits on rack or lay out on drop cloths.

Equipment necessary is

1. Rack
2. Drop cloths
3. Bench or stool

Station 11: SCBA Backpack Removal

While still wearing facepiece, remove backpack and place on table. Disconnect hose from regulator valve and proceed to next station.

Equipment necessary is a table.

Station 12: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners
3. Bench or stool
4. Boot jack

Station 13: Inner-Glove Wash

Wash with decon solution or detergent/water solution that will not harm skin.
Repeat as many times as necessary.

Equipment necessary is

1. Basin or bucket
2. Decon solution
3. Detergent/water solution
4. Small table

Station 14: Inner-Glove Rinse

Rinse with water. Repeat as many times as necessary.

Equipment necessary is

1. Water
2. Basin or bucket
3. Small table

Station 15: Facepiece Removal

Remove facepiece. Deposit in container with plastic liner. Avoid touching face with fingers.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners

Station 16: Inner-Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

Station 17: Inner-Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Do not wear inner clothing off the site, since there is a possibility that small amounts of contaminants have been transferred in removing fully encapsulating suit.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE SIX

Station 18: Field Wash

Shower if highly toxic, skin-corrosive, or skin-absorbable materials are known or suspected to be present. Wash hands and face if shoer is not available.

Equipment necessary is

1. Water
2. Soap
3. Small table
4. Basin or bucket
5. Field Showers
6. Towels

Station 19: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment necessary is

1. Tables
2. Chairs
3. Lockers
4. Clothes

Full Decontamination (Situation 1) and Three Modifications

The preceding description outlines each station that is included in a complete worst-case decontamination protocol. It is obvious that different sites will present different hazard levels and thus that site-specific modifications of this protocol will be required. The following table illustrates the modifications that can be made in response to a variety of conditions.

SIT*	STATION NUMBER																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X										
3	X						X	X		X	X	X		X	X	X	X	X	
4	X						X	X	X										

*SIT - Situation Number

Situation 1: The individual entering the Contamination Reduction Corridor (CRC) is observed to be grossly contaminated, or extremely toxic substances are known or suspected to be present.

Situation 2: Some as Situation 1 except that individual needs new air tank and will return to Exclusion Zone

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely toxic or skin-corrosive materials are not present. No outer gloves or boot covers are worn. Inner gloves re not contaminated.

Situation 4: Same as situation 3 except that individual needs new air tank and will return to Exclusion Zone.

6.3.2 Level B Decontamination

Equipment Worn

The full decontamination procedure outlined is for workers wearing Level B protection (with taped joints between gloves, boot, and suit). Such protection consists of

1. One-piece, hooded, chemical-resistant splash suit
2. Self-contained breathing apparatus
3. Hard hat
4. Chemical-resistant boots with steel toe and shank
5. Boot covers
6. Inner and outer gloves

Procedure for Full Decontamination

Station 1: Segregated Equipment Drop

Deposit equipment used on the site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment necessary is

1. Containers of various sizes
2. Plastic liners
3. Plastic drop cloths

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE EIGHT

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/water solution.

Equipment necessary is

1. Container (20 to 30 gal)
2. Decon solution
3. Detergent/water solution
4. Two or three long-handled, soft-bristle scrub brushes

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment necessary is

1. Container (30 to 50 gal)
2. High-pressure spray unit
3. Water
4. Two or three long-handled, soft-bristle scrub brushes

Station 4: Tape Removal

Remove tape around boots and gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

Station 5: Suit/Safety Boot Wash

Thoroughly wash chemical-resistant splash suit, SCBA, gloves, and safety boots. Scrub with long-handled, soft bristle scrub brush and copious amounts of decon solution or detergent/water solution.

Equipment necessary is

1. Container (30 to 50 gal)
2. Decon solution
3. Detergent/water solution
4. Two or three long-handled, soft-bristle scrub brushes
5. Small buckets
6. Sponges or cloths

Station 6: Suit/SCBA/Boot/Glove Rinse

Rinse off decon solution or detergent/water solution using copious amounts of water. Repeat as many times as necessary.

Equipment necessary is

1. Container (30 to 50 gal)
2. High-pressure spray unit
3. Water
4. Small buckets
5. Two or three long-handled, soft-bristle scrub brushes
6. Sponges or cloths

Station 7: Tank Change

If worker leaves Exclusion Zone to change air tank, this is the last step in the decontamination procedure. Worker's air tank is exchanged, new outer glove and boot covers donned, and joints taped. Worker returns to duty.

Equipment necessary is

1. Air tanks
2. Tape
3. Boot covers
4. Gloves

Station 8: Outer-Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

Station 9: SCBA Backpack Removal

While still wearing facepiece, remove backpack and place on table. Disconnect hose from regulator valve and proceed to next station.

Equipment necessary is a table.

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE TEN

Station 10: Splash Suit Removal

With assistance of helper, remove splash suit. Deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners
3. Bench or stool

Station 11: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners
3. Bench or stool

Station 12: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners
3. Bench or stool
4. Boot jack

Station 13: Inner-Glove Wash

Wash inner gloves with decon solution or detergent/water solution that will not harm skin. Repeat as many times as necessary.

Equipment necessary is

1. Decon solution
2. Detergent/water solution
3. Basin or bucket
4. Small table

Station 14: Inner-Glove Rinse

Rinse inner gloves with water. Repeat as many times as necessary.

Equipment necessary is

1. Water
2. Basin or bucket
3. Small table

Station 15: Facepiece Removal

Remove facepiece. Avoid touching face with gloves. Deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners

Station 16: Inner-Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

Station 17: Inner-Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Do not wear inner clothing off the site since there is a possibility that small amounts of contaminants have been transferred in removing fully encapsulating suit.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE TWELVE

Station 18: Field Wash

Shower if highly toxic, skin-corrosive, or skin-absorbable materials are known or suspected to be present. Wash hands and face if shower is not available.

Equipment necessary is

1. Water
2. Soap
3. Small tables
4. Basins or buckets
5. Field showers

Station 19: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment necessary is

1. Tables
2. Chairs
3. Lockers
4. Clothes

Full Decontamination (Situation 1) and Three Modifications

The preceding description outlines each station that is included in a complete worst-case decontamination protocol. It is obvious that different sites will present different hazard levels and thus that site-specific modifications of this protocol will be required. The following table illustrates the modifications that can be made in response to a variety of conditions.

SIT*	STATION NUMBER																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X										
3	X						X	X		X	X	X		X	X	X	X	X	
4	X						X	X	X										

*SIT - Situation Number

Situation 1: The individual entering the CRC is observed to be grossly contaminated, or extremely toxic substances are known or suspected to be present.

Situation 2: Some as Situation 1 except that individual needs new air tank and will return to Exclusion Zone

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely toxic or skin-corrosive materials are not present. No outer gloves or boot covers are worn. Inner gloves are not contaminated.

Situation 4: Same as situation 3 except that individual needs new air tank and will return to Exclusion Zone.

6.3.3 Level C Decontamination

Equipment Worn

The full decontamination procedure outlined is for workers wearing Level C protection (with taped joints between gloves, boot, and suit). Such protection consists of

1. One-piece, hooded, chemical-resistant splash suit
2. Canister-equipped full-face mask
3. Hard hat
4. Chemical-resistant boots with steel toe and shank
5. Boot covers
6. Inner and outer gloves

Procedure for Full Decontamination

Station 1: Segregated Equipment Drop

Deposit equipment used on the site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment necessary is

1. Containers of various sizes
2. Plastic liners
3. Plastic drop cloths

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE FOURTEEN

Station 2: Boot Cover and Glove Wash

Scrub outer boot covers and gloves with decon solution or detergent/water solution.

Equipment necessary is

1. Container (20 to 30 gal)
2. Decon solution
3. Detergent/water solution
4. Two or three long-handled, soft-bristle scrub brushes

Station 3: Boot Cover and Glove Rinse

Rinse off decon solution from Station 2 using copious amounts of water. Repeat as many times as necessary.

Equipment necessary is

1. Container (30 to 50 gal)
2. High-pressure spray unit
3. Water
4. Two or three long-handled, soft-bristle scrub brushes

Station 4: Tape Removal

Remove tape around boots and gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

Station 5: Suit/Safety Boot Wash

Thoroughly wash splash suit and safety boots. Scrub with long-handled, soft bristle scrub brush and copious amounts of decon solution or detergent/water solution. Repeat as many times as necessary.

Equipment necessary is

1. Container (30 to 50 gal)
2. Decon solution
3. Detergent/water solution
4. Two or three long-handled, soft-bristle scrub brushes

Station 6: Suit/SCBA/Boot/Glove Rinse

Rinse off decon solution or detergent/water solution using copious amounts of water. Repeat as many times as necessary.

Equipment necessary is

1. Container (30 to 50 gal)
2. High-pressure spray unit
3. Water
4. Two or three long-handled, soft-bristle scrub brushes

Station 7: Canister or Mask Change

If worker leaves Exclusion Zone to change canister (or mask), this is the last step in the decontamination procedure. Worker's canister is exchanged, new outer glove and boot covers donned, and joints taped. Worker returns to duty.

Equipment necessary is

1. Canister (or mask)
2. Tape
3. Boot covers
4. Gloves

Station 8: Outer-Glove Removal

Remove outer gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

Station 9: Splash Suit Removal

With assistance of helper, remove splash suit. Deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Bench or stool
3. Plastic liner

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE SIXTEEN

Station 10: Boot Cover Removal

Remove boot covers and deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners
3. Bench or stool

Station 11: Safety Boot Removal

Remove safety boots and deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners
3. Bench or stool
4. Boot jack

Station 12: Inner-Glove Wash

Wash inner gloves with decon solution or detergent/water solution that will not harm skin. Repeat as many times as necessary.

Equipment necessary is

1. Decon solution
2. Detergent/water solution
3. Basin or bucket

Station 13: Inner-Glove Rinse

Rinse inner gloves with water. Repeat as many times as necessary.

Equipment necessary is

1. Water
2. Basin or bucket
3. Small table

Station 14: Facepiece Removal

Remove facepiece. Avoid touching face with gloves. Deposit in container with plastic liner.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners

Station 15: Inner-Glove Removal

Remove inner gloves and deposit in container with plastic liner.

Equipment necessary is

1. Container (20 to 30 gal)
2. Plastic liners

Station 16: Inner-Clothing Removal

Remove clothing soaked with perspiration. Place in container with plastic liner. Do not wear inner clothing off th since there is a possibility that small amounts of contaminants have been transferred in removing fully encapsu suit.

Equipment necessary is

1. Container (30 to 50 gal)
2. Plastic liners

Station 17: Field Wash

Shower if highly toxic, skin-corrosive, or skin-absorbable materials are known or suspected to be present. Wash hands and face if shower is not available.

Equipment necessary is

1. Water
2. Soap
3. Tables
4. Wash basins or buckets
5. Field showers

ATTACHMENT 6.3
DECONTAMINATION STATION DETAIL
PAGE EIGHTEEN

Station 18: Redress

Put on clean clothes. A dressing trailer is needed in inclement weather.

Equipment necessary is

1. Tables
2. Chairs
3. Lockers
4. Clothes

Full Decontamination (Situation 1) and Three Modifications

The preceding description outlines each station that is included in a complete worst-case decontamination protocol. It is obvious that different sites will present different hazard levels and thus that site-specific modifications of this protocol will be required. The following table illustrates the modifications that can be made in response to a variety of conditions.

SIT*	STATION NUMBER																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X										
3	X						X	X		X	X	X		X	X	X	X	X	
4	X						X	X	X										

*SIT - Situation Number

Situation 1: The individual entering the CRC is observed to be grossly contaminated, or extremely toxic substances are known or suspected to be present.

Situation 2: Some as Situation 1 except that individual needs new air tank and will return to Exclusion Zone.

Situation 3: Individual entering the CRC is expected to be minimally contaminated. Extremely toxic or skin-corrosive materials are not present. No outer gloves or boot covers are worn. Inner gloves are not contaminated.
Situation 4: Same as situation 3 except that individual needs new air tank and will return to Exclusion Zone.

ATTACHMENT 6.4

QUESTIONNAIRE

1. Decontamination Checklist (List the information needed to establish a site specific decon line)

Site Contaminants	Chemical Incompatibilities	Decon Solution	Level of Protection

2. Decontamination Equipment (List the equipment needed for the site specific decontamination line.)

_____

_____

_____

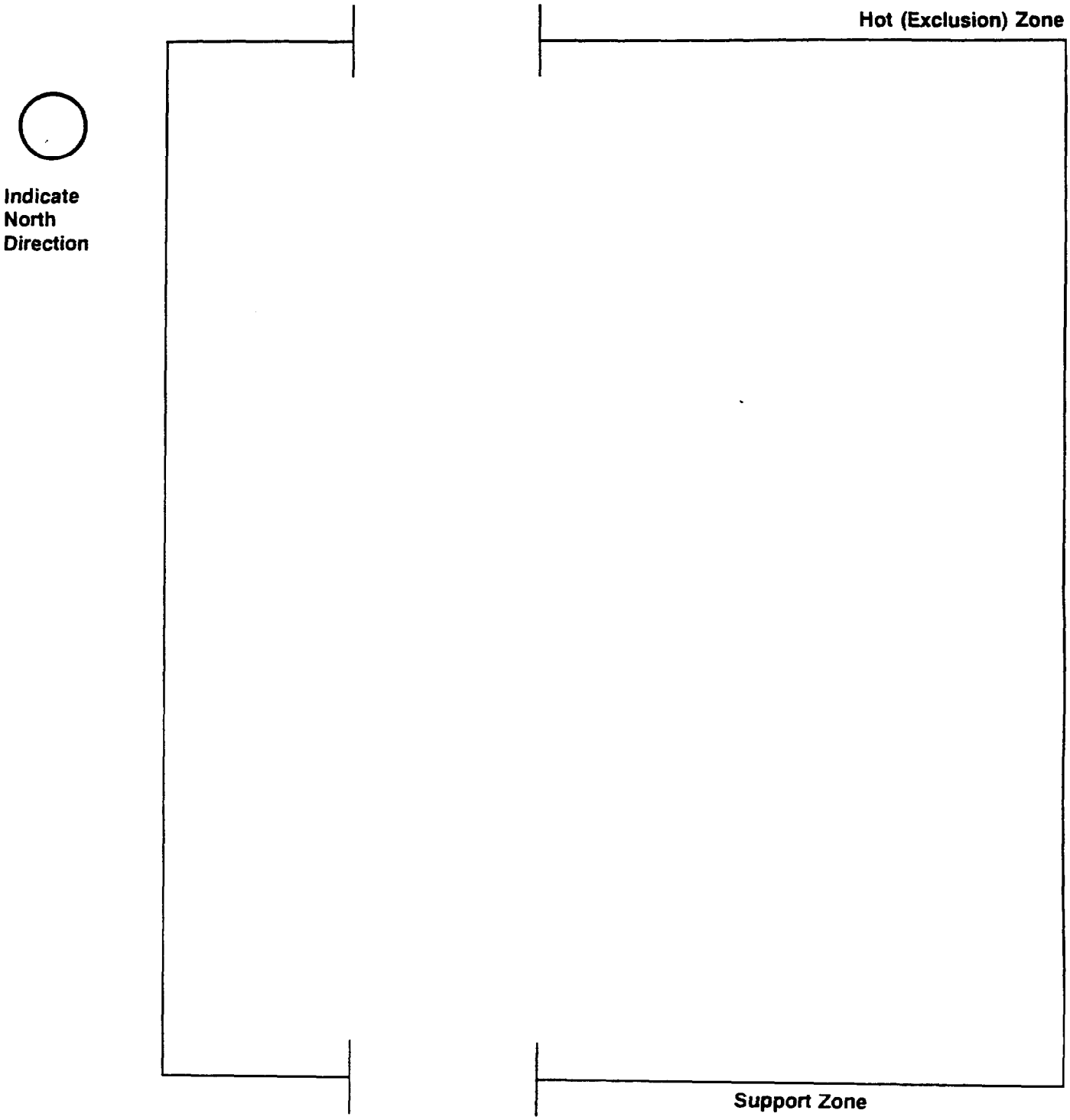
_____

_____

_____

ATTACHMENT 6.4
QUESTIONNAIRE
PAGE TWO

3. Decontamination Line Layout (Design the decontamination line on the form below)



ATTACHMENT 6.4
QUESTIONNAIRE
PAGE THREE

4. Describe a procedure for Emergency Decontamination.

_____

_____

_____

_____

5. List the site personnel responsible for decontamination.

_____

_____

_____

_____

EMERGENCY RESPONSE PLAN
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EMERGENCY RESPONSE PLAN

1.0 PURPOSE

This section has been developed to establish emergency response procedures for Brown & Root Environmental and subcontractor personnel engaged in hazardous waste operations.

2.0 SCOPE

This section applies to all Brown & Root Environmental and subcontractor personnel as well as any visitors who are present at hazardous waste operations.

3.0 GLOSSARY

Incident - Any Brown & Root Environmental work or site-related occurrence which results in (or could potentially result in) the need for medical care, or in property damage. Such incidents shall include lost time accidents or illness, medical treatment cases, exposures to toxic materials, or any other significant occurrence resulting in property damage or in "near-misses."

Lost-Time Accident - Illness or accident caused or related to Brown & Root Environmental site activity which prevented (or would prevent) the injured individual from reporting for and performing full, regular work activity on the day following the accident.

Medical Treatment - Illness or accident caused or related to Brown & Root Environmental site activity, which required professional medical treatment other than first aid.

Near-Miss - An incident which, if occurring at a different time or in a different personnel or equipment configuration, would have resulted in a reportable incident.

4.0 RESPONSIBILITIES

All Brown & Root Environmental Employees - It shall be the responsibility of all Brown & Root Environmental employees to report all incidents as soon as possible to the SSO, regardless of the severity.

Site Safety Officer (SSO) - It is the responsibility of the SSO to investigate and prepare an appropriate report of all accidents, illnesses, and incidents occurring on or related to site activities. The SSO shall complete Attachment B within 24 hours of the incident occurrence.

Project Health and Safety Officer (PHSO) - It is the responsibility of the PHSO to investigate and prepare an appropriate report of all lost-time injuries and illnesses as well as significant incidents occurring on or related to a Brown & Root Environmental site.

Field Operations Leader (FOL) - It shall be the FOL's responsibility to promptly correct any deficiencies that were determined to cause or contribute to the incident investigated.

5.0 EVACUATION PLAN

In the event of any onsite emergencies, site personnel will be immediately evacuated to a safe place of refuge and the appropriate offsite response agencies will be notified. Designated areas of safe refuge will be determined prior to the initiation of site activities since these areas may change depending on site conditions and activities. Brown & Root Environmental and subcontractor personnel will not provide emergency response support except for providing necessary first-aid to persons with injuries and/or illnesses resulting from physical hazards. This approach has been selected based on the types of emergencies most likely to be encountered during performance of site work and the fact that offsite emergency response organizations will provide the most effective response to these emergencies. Specifically, personal injury/illness resulting from physical hazards and fire/explosion resulting from the mishandling of petroleum products are the emergencies that are most likely to be encountered. Generally local of base fire departments and ambulance services are best suited for handling these emergencies and are usually located within a reasonable distance from the site to ensure adequate response time. In light of this approach, this emergency response plan has been prepared to conform to the requirements of OSHA Standard 29 CFR 1910.38(a), as permitted by OSHA 29 CFR 1910.120(l)(1)(ii).

It should be noted that the potential for emergencies involving overexposure to hazardous chemicals varies greatly from site to site. The potential for overexposure is dependent upon the activities being performed, the type, concentration, and physical properties of the contaminants, the PPE measures employed, and meteorological conditions. As a result, additional emergency response measures may be required which will be addressed in the site specific HASP. Additionally, emergency contacts (individuals, emergency services, hospitals and their representative telephone numbers) and directions and identity of a local/base hospital will be provided in the site specific HASP.

5.1 Pre-planning

Upon initial arrival at the site, the Brown & Root Environmental FOL/SSO will meet with the local or base Fire Department and Emergency Services to notify coordinators of the activities to be undertaken an where. All site personnel will be required to follow site emergency procedures and will rely on local/base services to handle emergency situations if encountered.

5.2 Emergency Escape Procedures and Assignments

In the event of an emergency (i.e. fire/explosion), personnel will proceed directly to personnel decontamination area and await further instruction. If the decontamination area cannot be reached as a result of the incident eliciting the escape, personnel will proceed directly to a pre-designated alternate location.

5.3 Maintenance of Critical Operations

If emergency evacuation is necessary, all personnel at the worksite are to immediately report to the designated safe place of refuge. At no time will personnel remain at their worksite to maintain any critical operations.

5.4 Personnel Accounting

Following site evacuation, the site safety officer (SSO) will conduct a roll call (using the site log book) to account for all personnel and to ensure that a total worksite evacuation has taken place. Any missing persons will be identified and communicated to outside emergency resources upon their arrival.

5.5 Rescue and Medical Duties

Persons in the immediate vicinity of a fire, explosion or other emergency will provide assistance to injured personnel as part of the evacuation process but will not attempt a rescue involving the potential for contact with heat, flames, or smoke. Such rescues, if needed, will be performed by the local or base fire department. Medical services will also be provided by the local of base ambulance services and, subsequently, by local hospital facilities. Specific ambulance, fire and hospital facilities are referenced as part of the site specific HASP are not authorized to perform emergency medical or first aid duties.

5.6 Emergency Reporting

Emergencies will be reported immediately to the Brown & Root Environmental FOL who, in turn, will telephone **911** or other appropriate telephone numbers (provided by the site specific HASP) to arrange for emergency ambulance, fire, and/or rescue service.

In the event of an emergency the Brown & Root Environmental Health Science Department should also be immediately notified at 1-800-245-2730 or 412-921-8678.

5.7 Site Emergency Alarm System

Many sites are small enough so that all personnel will be within visible and audible range of each other and, therefore, special alarm systems are not normally needed. However, three long blasts of an air horn or vehicle horn may be used to signal a site evacuation at larger sites. Where satellite operations are being performed, the use of 2-way radios may be used to communicate site evacuations.

5.8 Training (Site Personnel and Visitors)

All site personnel will be trained in the provisions of this Emergency Response Plan as part of the initial site-specific health and safety training. All site visitors will be informed of restricted areas, emergency communication signals, refuge locations, and other safety requirements. Site visitors will be escorted by Brown & Root Environmental or other site personnel at all times. Any visitors will also be entered in the site log book so that they can be accounted for in the event of any evacuations.

5.9 Plan Availability

This Emergency Response Plan will be maintained on site through the duration of all field activities, at a location readily-accessible by all site personnel. All site personnel will become aware of that location as part of the initial training process.

6.0 INCIDENT INVESTIGATION

On receiving a report of incident (or near-incident) occurrence from an Brown & Root Environmental employee, the SSO shall immediately investigate the circumstances and shall make appropriate recommendation(s) to prevent recurrence. The PHSO shall also participate in the investigation of more serious accidents and incidents. The Manger of the Health Sciences Department, shall also be immediately

notified by telephone about the occurrence of a serious accident or incident. At his discretion, he may also participate in the investigation. Attachment A may be used to assist the investigation.

6.1 Incident Report

Details of the incident shall be documented in the Incident Report (Attachment 7.2) within 24 hours of the incident and shall be distributed to the FOL, the PHSO, and the Health Sciences Department Manager. A copy of this report shall also be sent to the Brown & Root Environmental Medical Consultant and to the appropriate administrative contact for inclusion into the OSHA Form 101 and 200 Log.

6.2 Incident Follow-up Report

The Incident Follow-Up Report (Attachment 7.3) shall be distributed with the Incident Report within one week of the incident. Delay in filing this report shall be explained in a brief memorandum.

7.0 ATTACHMENTS

7.1 More Effective Accident Control

7.2 Incident Report (7 Sheets)

7.3 Incident Follow-Up Report

ATTACHMENT 7.1

MORE EFFECTIVE ACCIDENT CONTROL

THROUGH GOOD

INVESTIGATION AND **REMEDIAL ACTION**

BY APPLYING THESE OBJECTIVES

1. To determine all contributing causal factors.
2. To determine the fundamental or basic reason for the existence of each contributing factor.

1. To eliminate or control each contributing cause.
2. To eliminate or control the reason for the existence of each contributing cause.

AND FOLLOWING THESE GUIDEPOSTS

- In case of injury, make sure worker is properly cared for before doing anything else
- When practical, have scene kept as undisturbed as possible
- Investigate as promptly as possible
- Whenever possible, go to scene of accident for initial investigation
- As applicable, have someone else get photographs; make drawings or measurements
- Interview all witnesses, one at a time and separately
- Reassure each witness of investigations real purpose
- Get witnesses initial version with minimal interruption; ask for complete version step by step; have him describe and point without doing
- Apply empathy in interviews; make no attempt to fix blame or find fault
- Be objective; don't have fixed opinion in advance
- When witness finishes initial explanation, ask questions to fill in gaps
- Avoid questions that lead witness or imply answers wanted or unwanted
- Summarize your understanding with witness after interview
- Express sincere appreciation to anyone who helped in the investigation
- Record data accurately

(Select appropriate actions)

- Institute formal training program
- Give personal reinstruction
- Institute Proper Job Instruction Program
- Temporarily or permanently reassign person/s
- Institute a job analysis program
- Order job analysis on specific job/s
- Revise existing job analysis
- Institute a job observation program
- Order job observation on specific job/s
- Institute new or improve existing inspection program
- Institute pre-use checkout of equipment
- Establish or revise indoctrination for new or transferred employees
- Repair or replace equipment
- Improve design of equipment
- Establish design requirements for new equipment
- Improve basic design or establish design standards
- Improve identification or color code for safety
- Install or improve safeguards
- Eliminate unnecessary material in area
- Institute program of order or improve clean-up
- Institute mandatory protective equipment program or improve existing coverage or design
- Use safer material
- Establish purchasing standard/s or controls
- Institute incident recall program
- Create safety incentive program
- Improve physical examination program

WILL REDUCE

INJURIES & DAMAGE REJECTS & REWORK	DEFECTS & DELAYS MISTAKES & WASTE

. . . . Adequate time spent today on proper investigation and effective remedial action is cost reduction effort on tomorrows losses.

ATTACHMENT 7.2

INCIDENT REPORT

Date of Report: _____

Site: _____

Site Location: _____

Report Prepared by: _____
Name (Printed) Title

INCIDENT CATEGORY (check all that apply)

_____ Injury	_____ Illness	_____ Property Damage
_____ Near-Miss	_____ Fire	_____ Chemical Exposure
_____ Motor Vehicle	_____ Onsite Equipment	_____ Electrical
_____ Mechanical	_____ Other	

DATE AND TIME OF INCIDENT: _____

Narrative Report of incident:

(Provide sufficient detail so that the reader may fully understand the actions leading to or contributing to the incident, the incident occurrence, and actions following the incident. Append additional sheets of paper, if necessary.)

_____

_____

_____

_____

_____

_____

_____

_____

ATTACHMENT 7.2
INCIDENT REPORT
PAGE TWO

WITNESSES TO INCIDENT:

1. Name _____ Company _____

   Address _____

   Telephone No. _____

2. Name _____ Company _____

   Address _____

   Telephone No. _____

INJURIES:

FIRST INJURED PERSON:

Name and Address of Injured: _____

_____

SSN: _____ Age: _____ Sex: _____

Years of Service: _____ Time on Present Job: _____

Title/Classification: _____

Severity of Injury or Illness:

_____ Disabling _____ Nondisabling

_____ Fatality _____ Medical Treatment

Estimated Number of Days Away From Job: _____

Nature of Injury or Illness: _____

_____

ATTACHMENT 7.2
INCIDENT REPORT
PAGE THREE

Classification of Injury:

_____ Fractures	_____ Heat Burns	_____ Cold Exposure
_____ Dislocations	_____ Chemical Burns	_____ Frostbite
_____ Sprains	_____ Radiation Burns	_____ Heat Stroke
_____ Abrasions	_____ Bruises	_____ Heat Exhaustion
_____ Lacerations	_____ Blisters	_____ Concussion
_____ Punctures	_____ Toxic Respiratory Exposure	_____ Bites
_____ Faint/Dizziness		_____ Toxic Ingestion
_____ Respiratory Allergy		_____ Dermal Allergy

Part of Body Affected: _____

Degree of Disability: _____

Date Medical Care was Received: _____

Where Medical Care was Received: _____

Address (if off site): _____

If Hospitalized:

Name, Address, and Telephone No. of Hospital: _____

_____

Name, Address, and Telephone No. of Physician: _____

_____

SECOND INJURED PERSON:

Name and Address of Injured: _____

_____

SSN: _____ Age: _____ Sex: _____

Years of Service: _____ Time on Present Job: _____

Title/Classification: _____

ATTACHMENT 7.2
INCIDENT REPORT
PAGE FOUR

Severity of Injury or Illness:

_____ Disabling _____ Nondisabling

_____ Fatality _____ Medical Treatment

Estimated Number of Days Away From Job: _____

Nature of Injury or Illness: _____

_____

Classification of Injury:

_____ Fractures
_____ Dislocations
_____ Sprains
_____ Abrasions
_____ Lacerations
_____ Punctures
_____ Faint/Dizziness
_____ Respiratory Allergy

_____ Heat Burns
_____ Chemical Burns
_____ Radiation Burns
_____ Bruises
_____ Blisters
_____ Toxic Respiratory Exposure

_____ Cold Exposure
_____ Frostbite
_____ Heat Stroke
_____ Heat Exhaustion
_____ Concussion
_____ Bites
_____ Toxic Ingestion
_____ Dermal Allergy

Part of Body Affected: _____

Degree of Disability: _____

Date Medical Care was Received: _____

Where Medical Care was Received: _____

Address (if off site): _____

If Hospitalized:

Name, Address, and Telephone No. of Hospital: _____

_____

Name, Address, and Telephone No. of Physician: _____

_____

ATTACHMENT 7.2
INCIDENT REPORT
PAGE FIVE

PROPERTY DAMAGE:

Brief Description of Property Damaged

_____

_____

_____

_____

Estimate of Damage: $_____

INCIDENT LOCATION:

_____

_____

_____

INCIDENT ANALYSIS:

Causative agent most directly related to accident (object, substance, material, machinery, equipment, conditions):

_____

_____

_____

Was weather a factor? _____

Unsafe mechanical/physical/environmental condition at time of incident (Be specific):

_____

_____

_____

Unsafe act by injured and/or others contributing to the incident (Be specific, must be answered):

_____

_____

Personal factors (improper attitude, lack of knowledge or skill, slow reaction, fatigue):

_____

_____

Onsite Incidents:

Level of personal protection equipment required in Site Safety Plan:

_____

_____

Modifications: _____

_____

_____

Was injured using required equipment? _____

_____

_____

If not, how did actual equipment use differ from plan? _____

_____

_____

ATTACHMENT 7.2
INCIDENT REPORT
PAGE SEVEN

ACTION TAKEN TO PREVENT RECURRENCE:

(Be very specific. What has or will be done? When will it be done? Who is the responsible party to insure that the correction is made?)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

INCIDENT REPORT COMPLETED BY:

_____ _____
HSO Name Printed HSO Signature

OTHERS PARTICIPATING IN INVESTIGATION:

_____ _____
Name (Printed) Signature Title

_____ _____
Name (Printed) Signature Title

_____ _____
Name (Printed) Signature Title

ATTACHMENT 7.3

INCIDENT FOLLOW-UP REPORT

Date of Incident: _____

Site: _____

Brief Description of Incident: _____

_____

_____

_____

Outcome of Incident: _____

_____

_____

_____

_____

_____

Physician's Recommendations: _____

_____

_____

_____

_____

Date the Injured Returned to Work: _____

ATTACH ANY ADDITIONAL INFORMATION TO THIS FORM

ATTACHMENT 7.4

SITE EMERGENCY PROCEDURES

(FOL shall insure that all items are addressed. This list will be posted with the site OSHA Poster.)

1. Site evacuation meeting place -

   A. _____ Onsite Place of Refuge

   B. _____ Offsite Employee Assembly Point

2. Emergency notification (FOL will collect and document all emergency numbers)

Agency	Contact	Phone Number

3. Location where emergency response plan can be found on site.

_____

_____

_____

_____

HAZARD ASSESSMENT
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HAZARD ASSESSMENT

1.0 PURPOSE

This section addresses the chemical and physical hazards that are associated either directly or indirectly with tasks and operations performed during hazardous waste operations. Chemical and physical hazards vary from site to site and are dependent upon numerous factors associated with each site. Given this variation, the site-specific Health and Safety Plan will identify the chemical and physical hazards associated with the individual site and the planned activities that are to be performed at these sites.

2.0 SCOPE

This section applies to all Brown & Root Environmental personnel and subcontractors involved in hazardous waste operations. Site visitors such as client personnel representatives of regulatory agencies (EPA, OSHA) and occasional site visitors such as delivery personnel, truck drivers, and sanitation services are also covered under the provisions of the site HASP.

3.0 CHEMICAL HAZARDS

Chemical hazards associated with hazardous waste operations vary from site to site. The site specific HASP provides detailed information as to the chemicals of concern, potential routes of exposure, toxicological information regarding these chemicals, exposure limit information, symptoms of exposure, air monitoring protocols, and physical characteristics of the chemicals. Generally, this information is provided in a table format that can be easily referenced and used by site personnel.

This information contained in the HASP is generally compiled available information from previous site investigations, historical data pertaining to site operations, and preliminary analytical results. If any additional information regarding site contaminants becomes available, the HASP will be modified accordingly.

4.0 PHYSICAL HAZARDS

Particular emphasis is placed on the physical hazards associated with hazardous waste operations. Often more attention is place on the chemical hazards of a work site since chemical exposures are generally thought of when referring to hazardous waste work. However, physical hazards are often the more

predominant hazard which they result in far more injuries and fatalities than chemical exposure to site contaminants.

Physical hazards which may be involved in the execution of hazardous waste activities include the following items:

- Uneven or unstable terrain (Slip, trip, and fall hazards)
- The potential for a worker to be struck by or entangled in heavy machinery
- Lifting heavy objects
- Pinch/Compression points
- Inclement weather
- Contact with energized sources
- Ambient temperature extremes
- Noise in excess of 85 dBA
- Water hazards
- Open excavations
- Natural hazards (e.g. snakes, ticks, mosquitos, poisonous plants, etc.)
- Hazards associated with work performed at active sites (vehicular traffic, facility hazards such as flying projectiles, overhead hazards, etc.)

Control measures to protect site personnel from these physical hazards shall include the use of proper equipment maintenance, guarding, and operation. Additionally, adherence to proper standard work practices and standard operating procedures will aid in the elimination of these hazards. Each of the above mentioned items are further detailed below.

4.1 Uneven/Unstable Terrain (Slips, Trips, and Falls)

Planned activities associated with hazardous waste operations may bring field personnel into areas where this potential hazard exists (dilapidated buildings, river banks, test pits, loose and shifting ground cover of landfill areas, etc.). Additionally, it is possible that steep terrain may be encountered during the course of hazardous waste operations, particularly during sampling exercises. This hazard may exist in various locations. It is the responsibility of the Field Operations Leader (in accordance with Standard Operating Procedures and Safe Work Practices) to inspect and document the areas prior to placing heavy equipment or personnel at risk. As the operation moves from one area to another the hazards associated with that area will be discussed as part of the safety briefing prior to the commencement of activities in that area.

The use of personal protective equipment (safety shoes, hard hats, and safety glasses) will be implemented to protect personnel who may encounter this type of hazard. Additional equipment such as rope ladders, safety lines, harnesses, etc., may also be employed as conditions dictate. Personnel must be aware of their limitations and shall not attempt any exercise that will endanger their health and welfare.

4.2 Heavy Machinery

Activities such as soil borings with drill rigs, soil excavation and disposal operations have the potential to place site personnel at risk. The most predominant physical hazard associated with work around drill rigs is entanglement of safety equipment or clothing into the rotating augers. To address this hazard, a thorough inspection of all equipment will be performed to remove potential snag points. Also, ensure that emergency stop devices operate properly and all members of the field team know the location and operation of these devices. Persons working in close proximity to the drill rig will be required to secure all loose clothing or protective equipment to avoid possible entanglement. The use of a long-handled shovel or the equivalent will be used to remove drill cuttings away from the hole and from rotating tools. In addition, pins that protrude from augers shall not be permitted.

Test pitting operations and other soil excavation activities are accomplished through use of heavy equipment such as backhoes, bulldozers, excavators, and front-end loaders. Workers have the potential to be struck by moving attachments or other equipment during excavation operations. To address this hazard, workers will remain a safe distance (a distance greater than that at which the boom can extend) and will maintain two-way visual contact with the operator. In addition, no sampling activities of the test pits will be permitted while excavating activities are being performed. High visibility visits shall be used if work activities are performed in areas of heavy vehicular traffic.

All mechanized equipment brought on site will be inspected prior to the commencement of onsite activities and then periodically thereafter. These inspections will be performed by the SSO and will include that the following:

- All safety guards are in place.
- All safety-restraints (i.e. seatbelts) are in place and functioning properly as required by federal regulations.
- All vehicles have a backup alarms and emergency stop devices.

- All drivers will be required to have their Commercial Drivers License. All operators must be qualified.

- Traffic Control Measure Routes and regulations will be established and adherence required.

- All maintenance performed on the equipment will employ manufacturers recommended parts, and be inspected prior to returning to services by the SSO.

In addition to the requirements established by these guidelines, all heavy equipment and/or the movement of may also be bound to meet local or site-specific regulations. Control measures for these hazards are presented the "Standard Work Practices" section of this document.

4.3 Lifting Heavy Objects

The potential exists for workers to be injured while lifting or maneuvering heavy objects during the performance of various tasks. During soil boring activities workers have the potential to over-exert themselves while maneuvering the angering device and during sample extraction. In addition, various tasks may require lifting heavy pieces of equipment. If objects are improperly lifted, debilitating back strain and/or other injuries can result. Workers should obtain help from others, employ proper lifting techniques, and use machinery, where possible, to assist them when handling heavy objects.

4.4 Pinch/Compression Points

Pinch and Compression Points associated with drilling, sampling, and other equipment associated with hazardous waste operations may result in injury to site personnel. All equipment must be maintained in proper working order, with machine guarding devices in place. Any equipment found to be lacking in these areas shall be removed from service.

4.5 Inclement Weather

Most work activities related to hazardous waste operations are conducted outdoors. As a result, inclement weather may be encountered. As conditions may vary, it will be at the discretion of the Field Operations Leader and the Site Safety Officer representative to temporarily suspend or terminate activities as conditions dictate. All site activities will be terminated in the advent of electrical storms, tornadoes, and other hazardous weather conditions.

4.6 Contact With Energized Sources

One of the hazards associated with intrusive activities associated with hazardous waste work is the potential for encountering energized sources (pressurized lines, water lines, telephone lines, buried utility lines, high power lines, etc.), primarily while engaged in drilling and/or excavation activities. Due to the obvious ramifications associated with this hazard, extreme caution and strict adherence to procedures to detect, identify, and take evasive action shall be followed during the completion of site activities. Efforts will be made through local contacts, as built drawings (where available) along with geophysical surveys to identify potential locations. Positive readings will require the relocation of a soil boring point and/or test pit excavation. To further avoid hazards of this type, no drilling mast, boom, or any other such projecting items shall be permitted within a 20-foot radius of any energized source. Also, any areas targeted for subsurface activities shall first be investigated to determine the presence of underground utilities. Any such utilities identified shall be physically marked and avoided.

4.7 Ambient Temperature Extremes

Ambient temperature extremes (hot or cold working environments) may occur during performance of hazardous waste work depending on the project schedule. Work performed when ambient air temperatures are below 50°F may result in varying levels of cold stress (frost nip, frost bite, and/or hypothermia) depending on environmental factors such as temperature, wind speed, and humidity; physiological factors such as metabolic rate and moisture content of the skin; and other factors such as work load and the protective clothing being worn. Work performed when ambient temperatures exceed 70°F may result in varying levels of heat stress (heat rash, heat cramps, heat exhaustion, and/or heat stroke) depending on factors similar to those presented above for cold stress.

In either case, these conditions can be debilitating and, when extreme, they can be fatal. An understanding of the importance in preventing heat/cold stress, coupled with the worker's awareness of the signs and symptoms of overexposure, can significantly reduce the potential for adverse health effects. This awareness is typically a part of each employees' 40-hour hazardous waste operations training. If this hazard is present during site operations, each worker will be provided with information necessary to protect themselves and site management will be instructed to permit frequent breaks in mild temperature rest areas having hot/cold fluids available for consumption. In extreme cases, biological monitoring may be performed and data compared to the most recent recommendations of the American Conference of Governmental Industrial Hygienists (ACGIH). Additional information regarding heat/cold stress is provided at the end of this section (Attachment A).

4.8 Noise In Excess Of 85 dba

Noise exposures exceeding the OSHA Permissible Exposure Limit could be encountered during certain phases of drilling or excavation operations. Personnel who are repeatedly overexposed could experience a permanent reduction in their ability to hear normal conversation. Appropriate hearing protectors will be worn when in close proximity to drilling and excavating operations, as determined by the SSO. It shall also be the responsibility of the SSO to ensure the application, use, and maintenance of occupational noise protective measures in accordance with 29 CFR 1910.95.

4.9 Water Hazards

Hazardous waste operations (particularly sampling activities) occasionally take place near waters edge or from boats. To avoid potential hazards associated with working on or over water (drowning) the field team shall employ lifelines, safety harnesses, and U.S. Coast Guard approved personal flotation devices when working within four feet of the waters edge. Due to the obvious hazards associated with working on or near waters edge during inclement weather, all field activities may be temporarily suspended or terminated at the discretion and direction of the Field Operations Leader, or Site Safety Officer representative.

4.10 Open Excavations

During the performance hazardous waste operations, the potential exists for open excavations (test pits, trenches, USTs, etc.) to be created. Under no circumstances will workers be permitted to enter excavations with depths greater than 4 feet. In addition to cave-in concerns, the potential exists for oxygen deficient and/or toxic atmospheres to be present within open excavations. It should be noted that vapor concentrations from potential site contaminants may be heavier than air which may result in vapors accumulating in low lying areas such as open excavations. As a result, sufficient air monitoring must be implemented prior to sampling activities near excavations. The use of remote sampling techniques (i.e., core stems, excavating machinery) will be employed to obtain soil samples from excavations with depths greater than 4 feet. Precautions must be taken, however, to eliminate the potential for soil, equipment, and/or personnel around the excavation from collapsing into the excavation. A minimum distance of 3 feet should be maintained between equipment and personnel from the edge of any excavation. All excavations will be performed in compliance with Subpart P of the OSHA Construction Industry Safety and Health Standards 29 CFR 1926.

At some hazardous waste sites, the potential exists for personnel to encounter buried unidentified drums during the performance of excavation activities. All drum handling activities will be performed in strict

accordance with OSHA Standard 29 CFR 1910.120 (j). All unlabelled drums and containers shall be considered to contain hazardous substances and shall be handled accordingly until the contents are positively identified and labeled. As a result, any work involving unearthing of unidentified drums, overpacking of unidentified drums, or spill control activities for unidentified substances will be performed in Level B Protection (air supplied respirators). Buried drums may be corroded, ruptured or leaking. If drums or other containers are anticipated to be encountered at specific areas of the site, (based on the site's history), a ground-penetrating system or other type of detection system or device will be used to estimate their location and depth. To the maximum extent possible, any drums encountered during excavation activities will be left undisturbed and in place. Markers (flags) will be placed near undisturbed drums to identify the location of unearthed drums. As stated earlier, it should be noted that the potential exists for drums to be damaged as a result of excavating operations. All soil and covering material shall be removed with caution to prevent drum or container rupture. If product from uncovered drums is leaking, spill control measures will be initiated to minimize contamination of nearby areas. Such procedures will include the use of U.S. Department of Transportation specified salvage drums or containers and suitable quantities of proper absorbent material. Drums or containers under pressure, as evidenced by bulging or swelling, shall not be moved until such time as the cause for excess pressure is determined and appropriate containment procedures have been implemented to protect employees from the explosive relief of the drum. If drums are to be moved, material handling equipment used to transfer drums and containers shall be selected, positioned and operated to minimize sources of ignition related to the equipment from igniting vapors released from ruptured drums or containers. Additional information regarding drum handling practices can be found in the drum and container management section of this document.

Continuous air monitoring should be performed during all excavation activities. Detailed records relating to air monitoring readings and task operations should be recorded during all excavation activities, particularly during excavations in which buried drums are discovered.

4.11 Natural Hazards

Natural hazards such as poisonous plants, stings and bites from poisonous or disease carrying animals or insects (e.g. snakes, ticks, mosquitos) cannot be avoided in typical hazardous waste site environments. However, in an effort to offset the impact of this hazard, field personnel will have access to commercially available snake bite kits and insect repellents. Potential nesting areas in and about work areas shall be avoided to the greatest extent possible. Lastly, within recent years a marked increase in Lyme's Disease has been reported. Ticks have been shown to be the primary vector in the transmission of this disease. In an effort to control this hazard, close attention will be given during operations and decontamination with regard to personal hygiene to detect and remove any ticks from personnel. The information provided in

Section 6.0 of this module will be reviewed with site personnel to aid in the recognition and control of this threat and other hazards.

Additionally, site personnel who also are allergic to stinging insects such as bees, wasps, and hornets must be particularly cautious since severe illness or death may result in event of an allergic reaction. Site workers should convey such allergies to the SSO and FOL as part of the medical data sheet. The OSC of commercially available "anti-venom" kits are strongly encouraged for people who believe they are allergic to such insects.

5.0 HEAT/COLD STRESS

5.1 Heat Stress

The SSO shall visually monitor personnel to note for signs of heat stress. Field personnel will also be instructed to observe for symptoms of heat stress and methods on how to control it. One or more of the following control measures can be used to help control heat stress:

- Provide adequate liquids to replace lost body fluids. Personnel must replace water and salt lost from sweating. Personnel must be encouraged to drink more than the amount required to satisfy thirst. Thirst satisfaction is not an accurate indicator of adequate salt and fluid replacement. Replacement fluids can be commercial mixes such as Gatorade®.

- Establish a work regime that will provide adequate rest periods for cooling down. This may require additional shifts of workers. Breaks are to be taken in a cool rest area (77°F is best). Personnel shall not be assigned other tasks during rest periods. Personnel shall be informed of the importance of adequate rest, acclimation, and proper diet in the prevention of heat stress.

- Cooling devices such as vortex tubes or cooling vests can be worn beneath protective garments.

- Personnel shall remove impermeable protective garments during rest periods.

The heat stress of personnel on-site may be monitored utilizing biological monitoring or the Wet Bulb Globe Temperature Index (WBGT) technique when workers are not wearing protective coveralls (such as Tyvek). This method will require the use of a heat stress monitoring device.

One of the following biological monitoring procedures shall be followed when the workplace temperature is 70°F or above.

- Heart rate (HR) shall be measured through the pulse for 30 seconds as early as possible in the resting period. The HR at the beginning of the rest period should not exceed 110 beats/minute. If the HR is higher, the next work period should be shortened by 10 minutes (or 33 percent), while the length of rest period stays the same. If the pulse rate is 100 beats/minute at the beginning of the next rest period, the following work cycle should again be shortened by 33 percent. The length of the initial work period will be determined by using the table below.

PERMISSIBLE HEAT EXPOSURE THRESHOLD LIMIT VALUES

	Work Load		
Work-Rest Regimen	Light	Moderate	Heavy
Continuous	80.0°F	80.0°F	77.0°F
75% Work - 25% Rest, Each Hour	87.0°F	82.4°F	78.6°F
50% Work - 50% Rest, Each Hour	88.5°F	85.0°F	82.2°F
25% Work - 75% Rest, Each Hour	90.0°F	88.0°F	86.0°F

- Body temperature shall be measured orally with a clinical thermometer as early as possible in the resting period. Oral temperature at the beginning of the rest period should not exceed 99°F. If it does, the next work period should be shortened by 10 minutes (or 33 percent), while the length of the rest period stays the same. However, if the oral temperature exceeds 99.7°F at the beginning of the next rest period, the following work cycle shall be further shortened by 33 percent. OT should be measured at the end of the rest period to make sure that it has dropped below 99°F. At no time shall work begin with the oral temperature above 99°F.

NOTE: External temperatures in excess of those stated above shall be regarded as inclement weather. Work continuation, termination, or alteration of the work schedule will be at the discretion of the FTL and on site health and safety representative. The heat and cold stress related sections of this are applicable to the season when work will be completed.

5.2 Cold Stress

The cold stress TLVs are intended to protect workers from the severest effects of cold stress (hypothermia) and cold injury and to describe exposures to cold working conditions under which it is believed that nearly all workers can be repeatedly exposed without adverse health effects. The TLV objective is to prevent the deep body temperature from falling below 36°C (96.8°F) and to prevent cold injury to body extremities (deep body temperature is the core temperature of the body determined by conventional methods for rectal temperature measurements). For a single, occasional exposure to a cold environment, a drop in core temperature to no lower that 35°C (95°F) should be permitted. In addition to provisions for total body protection, the TLV objective is to protect all parts of the body with emphasis on hands, feet, and head from cold injury.

Fatal exposures to cold among workers have almost always resulted from accidental exposures involving failure to escape from low environmental air temperatures or from immersion in low temperature water. The single most important aspect of life-threatening hypothermia is the fall in the deep core temperature of the body. The clinical presentations of victims of hypothermia are shown in Table 1. Workers should be protected from exposure to cold so that the deep core temperature does not fall below 36°C (96.8°F); lower body temperatures will very likely result in reduced mental alertness, reduction in rational decision making, or loss of consciousness with the threat of fatal consequences.

Pain in the extremities may be the first early warning of danger to cold stress. During exposure to cold, maximum severe shivering occurs when the body temperature has fallen to 35°C (95°F). This must be taken as a sign of danger and exposure to cold should be immediately terminated when severe shivering becomes evident. Useful physical or mental work is limited when severe shivering occurs.

Since prolonged exposure to cold air, or to immersion in cold water, at temperatures well above freezing can lead to dangerous hypothermia. Whole body protection must be provided.

1. Adequate insulating dry clothing to maintain core temperatures above 36°C (96.8°F) must be provided to workers if work is performed in air temperatures below 4°C (40°F). Wind chill cooling rate and the cooling power of air are critical factors. [Wind chill cooling rate is defined as heat loss from a body expressed in watts per meter squared which is a function of the air temperature and wind velocity upon the exposed body.] The higher the wind speed and the lower the temperature in the work area, the greater the insulation value of the protective clothing required. An equivalent chill temperature chart relating the actual dry bulb air temperature and the wind velocity is presented in Table 2. The equivalent chill temperature should be used when estimating the combined cooling effect of wind and

TABLE 1

PROGRESSIVE CLINICAL PRESENTATIONS OF HYPOTHERMIA*

Core Temperature		Clinical Signs
°C	°F	
37.6	99.6	"Normal" rectal temperature
37	98.6	"Normal" oral temperature
36	96.8	Metabolic rate increases in an attempt to compensate for heat loss
35	95.0	Maximum shivering
34	93.2	Victim conscious and responsive, with normal blood pressure
33	91.4	Severe hypothermia below this temperature
32	86.0	Consciousness clouded; blood pressure becomes difficult to obtain; pupils dilated but react to light; shivering ceases
31	87.8	
30	86.0	Progressive loss of consciousness; muscular rigidity increases; pulse and blood pressure difficult to obtain; respiratory rate decreases
29	84.2	
28	82.4	Ventricular fibrillation possible with myocardial irritability
27	80.6	Voluntary motion ceases; pupils nonreactive to light; deep tendon and superficial reflexes absent
26	78.8	Victim seldom conscious
25	77.0	Ventricular fibrillation may occur spontaneously
24	75.2	Pulmonary edema
22	71.6	Maximum risk of ventricular fibrillation
21	69.8	
20	68.0	Cardiac standstill
18	64.4	Lowest accidental hypothermia victim to recover
17	62.6	Isoelectric electroencephalogram
9	48.2	Lowest artificially cooled hypothermia patient to recover

* Presentations approximately related to core temperature. Reprinted from the January 1982 issue of American Family Physician, published by the American Academy of Family Physicians.

TABLE 2

COOLING POWER OF WIND ON EXPOSED FLESH EXPRESSED AS EQUIVALENT TEMPERATURE
(under calm conditions)*

Estimated Wind Speed (in mph)	Actual Temperature Reading (°F)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	Equivalent Temperature (°F).											
Calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-24	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-32	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-121
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-51	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148

(Wind speeds greater than 40 mph have little additional effect)	**LITTLE DANGER** In < hr with dry skin. Maximum danger of false sense of security	**INCREASING DANGER** Danger from freezing of exposed flesh within one minute.	**GREAT DANGER** Flesh may freeze within 30 seconds.
	Trenchfoot and immersion foot may occur at any point on this chart.		

* Developed by U.S. Army Research Institute of Environmental Medicine, Natick, Massachusetts.

low air temperatures on exposed skin or when determining clothing insulation requirements to maintain the deep body core temperature.

2. Unless there are unusual or extenuating circumstances, cold injury to other than hands, feet, and head is not likely to occur without the development of the initial signs of hypothermia. Older workers or workers with circulatory problems require special precautionary protection against cold injury. The use of extra insulating clothing and/or a reduction in the duration of the exposure period are among the special precautions which should be considered. The precautionary actions to be taken will depend upon the physical condition of the worker and should be determined with the advice of a physician with knowledge of the cold stress factors and the medical condition of the worker.

5.2.1 Evaluation and Control

For exposed skin, continuous exposure should not be permitted when the air speed and temperature results in an equivalent chill temperature of -32°C(-25.6°F). Superficial or deep local tissue freezing will occur only at temperatures below -1°C (30.2°F) regardless of wind speed.

At air temperatures of 2°C (35.6°F) or less, it is imperative that workers who become immersed in water or whose clothing becomes wet be immediately provided a change of clothing and be treated for hypothermia.

TLVs recommended for properly clothed workers for periods of work at temperatures below freezing are shown in Table 3.

Special protection of the hands is required to maintain manual dexterity for the prevention of accidents:

1. If fine work is to be performed with bare hands for more than 10-20 minutes in an environment below 16°C (60.8°F), special provisions should be established for keeping the workers' hands warm. For this purpose, warm air jets, radiant heaters (fuel burner or electric radiator), or contact warm plates may be utilized. Metal handles of tools and control bars should be covered by thermal insulating material at temperatures below -1°C (30.2°F).

2. If the air temperature falls below 16°C (60.8°F) for sedentary, 4°C (39.2°F) for light, -7°C (19.4°F) for moderate work and fine manual dexterity is not required, then gloves should be used by the workers.

To prevent contact frostbite, the workers should wear anti-contact gloves.

TABLE 3

THRESHOLD LIMIT VALUES WORK/WARM-UP SCHEDULE FOR FOUR-HOUR SHIFT*

Air Temperature - Sunny Sky		No Noticeable Wind		5 mph Wind		10 mph Wind		15 mph Wind		20 mph Wind	
°C (approx)	°F (approx)	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks
-26° to -28°	-15° to -19°	(Norm Breaks)	1	(Norm Breaks)	1	75 min	2	55 min	3	40 min	4
-29° to -31°	-20° to -24°	(Norm Breaks	1	75 min	2	55 min	3	40 min	4	30 min	5
-32° to -34°	-25° to -29°	75 min	2	55 min	3	40 min	4	30 min	5	Non-emergency work should cease	
-35° to -37°	-30° to -34°	55 min	3	40 min	2	30 min	5	Non-emergency work should cease		Non-emergency work should cease	
-38° to -39°	-35° to -39°	40 min	4	30 min	1	Non-emergency work should cease		Non-emergency work should cease		Non-emergency work should cease	
-40° to -42°	-40° to -44°	30 min	5	Non-emergency work should cease		Non-emergency work should cease		Non-emergency work should cease		Non-emergency work should cease	
-43° & below	-45° & below	Non-emergency work should cease		Non-emergency work should cease		Non-emergency work should cease		Non-emergency work should cease		Non-emergency work should cease	

NOTES:

1. Schedule applies to moderate to heavy work activity with warm-up breaks of ten (10) minutes in a warm location. For Light-to-Moderate Work (limited physical movement): apply the schedule one step lower. For example, at -35°C (-30°F) with no noticeable wind (Step 4), a worker at a job with little physical movement should have a maximum work period of 40 minutes with 4 breaks in a 4-hour period (Step 5).
2. The following is suggested as a guide for estimating wind velocity if accurate information is not available: 5 mph: light flag moves; 10 mph: light flag fully extended; 15 mph: raises newspaper sheet; 20 mph: blowing and drifting snow.
3. If only the wind chill cooling rate is available, a rough rule of thumb for applying it rather than the temperature and wind velocity factors given above would be: (1) special warm-up breaks should be initiated at a wind chill cooling rate of about 1750 W/M^2; (2) all non-emergency work should have ceased at or before a wind chill of 2250 W/m^2. In general, the warm-up schedule provided above slightly under-compensates for the wind at the warmer temperatures, assuming acclimatization and clothing appropriate for winter work. On the other hand, the chart slightly over-compensates for the actual temperatures in the colder ranges, since windy conditions rarely prevail at extremely low temperatures.
4. TLVs apply only for workers in dry clothing.

* Adapted from Occupational Health & Safety Division, Saskatchewan Department of Labor.

1. When cold surfaces below -7°C (19.4°F) are within reach, a warning should be given to each worker by the supervisor to prevent inadvertent contact by bare skin.

2. If the air temperature is -17.5°C (0°F) or less, the hands should be protected by mittens. Machine controls and tools for use in cold conditions should be designed so that they can be handled without removing the mittens.

Provisions for additional total body protection are required if work is performed in an environment at or below 4°C (39.2°F). The workers should wear cold protective clothing appropriate for the level of cold and physical activity:

1. If the air velocity at the job site is increased by wind, draft, or artificial ventilating equipment, the cooling effect of the wind should be reduced by shielding the work area or by wearing an easily removable windbreak garment.

2. If only light work is involved and if the clothing on the worker may become wet on the job site, the outer layer of the clothing in use may be of a type impermeable to water. With more severe work under such conditions, the outer layer should be water repellent, and the outerwear should be changed as it becomes wetted. The outer garments should include provisions for easy ventilation in order to prevent wetting of inner layers of sweat. If work is done at normal temperatures or in a hot environment before entering the cold area, the employee should make sure that clothing is not wet as a consequence of sweating. If clothing is wet, the employee should change into dry clothes before entering the cold area. The workers should change socks and any removable felt insoles at regular daily intervals or use vapor barrier boots. The optimal frequency of change should be determined empirically and will vary individually and according to the type of shoe worn and how much the individual's feet sweat.

3. If exposed areas of the body cannot be protected sufficiently to prevent sensation of excessive cold or frostbite, protective items should be supplied in auxiliary heated versions.

4. If the available clothing does not give adequate protection to prevent hypothermia or frostbite, work should be modified or suspended until adequate clothing is made available or until weather conditions improve.

5. Workers handling evaporative liquid (gasoline, alcohol, or cleaning fluids) at air temperatures below 4°C (39.2°F) should take special precautions to avoid soaking of clothing or gloves with the liquids

because of the added danger of cold injury due to evaporative cooling. Special note should be taken of the particularly acute effects of splashes of "cryogenic fluids" or those liquids with a boiling point that is just above ambient temperature.

5.2.1.1 Work - Warming Regimen

If work is performed continuously in the cold at an equivalent chill temperature (ECT) or below -7°C (19.4°F), heated warming shelters (tents, cabins, rest rooms, etc.) should be made available nearby. The workers should be encouraged to use these shelters at regular intervals, the frequency depending on the severity of the environmental exposure. The onset of heavy shivering, frostnip, the feeling of excessive fatigue, drowsiness, irritability, or euphoria are indications for immediate return to the shelter. When entering the heated shelter, the outer layer of clothing should be removed and the remainder of the clothing loosened to permit sweat evaporation or a change of dry work clothing provided. A change of dry work clothing should be provided as necessary to prevent workers from returning to work with wet clothing. Dehydration, or the loss of body fluids, occurs insidiously in the cold environment and may increase the susceptibility of the worker to cold injury due to a significant change in blood flow to the extremities. Warm sweet drinks and soups should be provided at the work site to provide caloric intake and fluid volume. The intake of coffee should be limited because of the diuretic and circulatory effects.

For work practices at or below -12°C (10.4°F) ECT, the following should apply:

1. The worker should be under constant protective observation (buddy system or supervision).

2. The work rate should not be so high as to cause heavy sweating that will result in wet clothing; if heavy work must be done, rest periods should be taken in heated shelters and opportunity for changing into dry clothing should be provided.

3. New employees should not be required to work full time in the cold during the first days of employment until they become accustomed to the working conditions and required protective clothing.

4. The weight and bulkiness of clothing should be included in estimating the required work performance and weights to be lifted by the worker.

5. The work should be arranged in such a way that sitting still or standing still for long periods is minimized. Unprotected metal chair seats should not be used. The worker should be protected from drafts to the greatest extent possible.

6. The workers should be instructed in safety and health procedures. The training program should include as a minimum instruction in:

   a. Proper rewarming procedures and appropriate first aid treatment.
   b. Proper clothing practices.
   c. Proper eating and drinking habits.
   d. Recognition of impending frostbite.
   e. Recognition of signs and symptoms of impending hypothermia or excessive cooling of the body even when shivering does not occur.
   f. Safe work practices.

5.2.1.2 Special Workplace Recommendations

Special design requirements for refrigerator rooms include:

1. In refrigerator rooms, the air velocity should be minimized as much as possible and should not exceed 1 meter/sec (200 fpm) at the job site. This can be achieved by properly designed air distribution systems.

2. Special wind protective clothing should be provided based upon existing air velocities to which workers are exposed.

Special caution should be exercised when working with toxic substances and when workers are exposed to vibration. Cold exposure may require reduced exposure limits.

Eye protection for workers employed out-of-doors in a snow and/or ice-covered terrain should be supplied. Special safety goggles to protect against ultraviolet light and glare (which can produce temporary conjunctivitis and/or temperature loss of vision) and blowing ice crystals should be required when there is an expanse of snow coverage causing a potential eye exposure hazard.

Workplace monitoring is required as follows:

1. Suitable thermometry should be arranged at any workplace where the environmental temperature is below 16°C (60.8°F) so that overall compliance with the requirements of the TLV can be maintained.

2. Whenever the air temperature at a workplace falls below -1°C (30.2°F), the dry bulb temperature should be measured and recorded at least every 4 hours.

3. In indoor workplaces, the wind speed should also be recorded at least every 4 hours whenever the rate of air movement exceeds 2 meters per second (5 mph).

4. In outdoor work situations, the wind speed should be measured and recorded together with the air temperature whenever the air temperature is below -1°C (30.2°F)

5. The equivalent chill temperature should be obtained from Table 2 in all cases where air movement measurements are required; it should be recorded with the other data whenever the equivalent chill temperature is below -7°C (19.4°F).

Employees should be excluded from work in cold at -1°C (30.2°F) or below if they are suffering from diseases or taking medication which interferes with normal body temperature regulation or reduces tolerance to work in cold environments. Workers who are routinely exposed to temperatures below -24°C (-11.2°F) with wind speeds less than five miles per hour, or air temperatures below -18°C (0°F) with wind speeds above five miles per hour, should be medically certified as suitable for such exposures.

Trauma sustained in freezing or subzero conditions requires special attention because an injured worker is predisposed to cold injury. Special provisions should be made to prevent hypothermia and freezing of damaged tissues in addition to providing for first aid treatment.

Note: This information has been adopted from the **1992-1993 "Threshold Limit Values** for Chemical Substances and Physical Agents and **Biological Indices"** by the American Conference of Governmental Industrial Hygienists (ACGIH).

6.0 TICK CONTROL AND LYME DISEASE

The occurrence of Lyme disease has become a worldwide problem since its identification in 1976. This disease is characteristically recognized as being transmitted by ticks, which may be encountered by field

personnel while working at this site. As a result, this discussion has been included with this Health and Safety Plan to provide for adequate recognition, evaluation, and control efforts to minimize the occurrence and effects of this potential hazard.

The discovery of Lyme disease is credited to Dr. Allen Steere of Yale University Medical School, and is named after the community where it was (reportedly) first encountered, Lyme, Connecticut. This disease can be transmitted to man through the bite of ticks that are infected with a cork screw-shaped microbe (spirochete). The spread of this disease has been so rapid that in 1984 it surpassed Rocky Mountain Spotted fever as the most common tick-borne disease in the United States. In this country, most of the incidents of this disease have been recorded in the Northeast, and the tick species most commonly attributed with its spread is the deer tick.

6.1 Recognition

This hazard potential exists primarily in the spring and summer months, as these are the seasons that tick populations and activity flourish. In fact, 90 percent of the reported cases have occurred from early June through September. Also, this concern exists primarily in heavily vegetated areas. Therefore, recognition of these factors can aid in the awareness and control of this threat.

To aid in the recognition and identification of these insects, an example illustration of the tick species common to the region where this site is located has been included with this discussion. This species (the American Dog tick) is common in the eastern half of the United States, and typically exists in areas covered with grass or underbrush. These insects will attach themselves to animals (including man) that pass through the area and rub against them. After finding a host, the tick inserts its mouthparts and sucks blood until it is fully engorged. This requires a time period of three to twelve days, then the tick will drop off. In addition to Lyme disease concerns, this tick has also been identified as a transmitter of Rocky Mountain Spotted Fever, and the organisms of tularemia and possibly relapsing fever. The wounds left by tick bites can be painful, and can also have a paralyzing effect commonly referred to as tick paralysis.

The earliest symptom of the onset of this disease is the occurrence of an unusual red skin rash. This is commonly the first indication since it has been evidenced that many persons who have contracted this disease were, in fact, unaware that they had been bitten. This rash can appear at the site of the bite anywhere from several days to a few weeks after the bite. It typically starts as a small red spot, and then expands as the spirochetes expand from the bite location. Rash sizes can vary, but have been most commonly associated in a 2 to 3 inch diameter size range. This rash will fade (with or without treatment) after a few weeks. Close inspection is necessary to detect this symptom as the rashes are easy to miss

because they're often very faint. Body sites where rashes frequently occur include the thigh areas, groin, and armpits. Also, it is not uncommon for a rash to develop in more than one place.

Other early symptoms include profound fatigue, a stiff neck, and flu-like symptoms such as headache, chills, fever, and muscle aches. Recognition of the onset of any of these symptoms is important since tick bites do not always produce a rash. If left untreated, the disease will progress to its second stage within weeks or months after the infection. This stage involves affects to the heart and nervous system. A common second stage symptom is a paralysis on one or both sides of the face. Others include severe headache, encephalitis, or meningitis. The third and final stage involves the development of chronic inflammatory arthritis, which can occur up to a year or more after the bite.

6.2 Evaluation

Evaluation of this hazard potential principally involves field personnel performing close self-inspections for the presence of ticks each time they leave the site. This should involve careful examination, especially of the individuals' heads. Personnel should be aware that when a tick attaches itself to its host, it inserts its entire head under the surface of the skin.

6.3 Control

Control of this threat involves several components. First, field personnel must be aware of the climate and area conditions which are commonly associated with being conducive to tick infestation. Second, when working in or walking through potential infested areas, personnel must ensure that they do not have exposed body parts (i.e. at least long sleeved shirts and long pants, particularly when protective coveralls are not worn). In heavily vegetated areas where infestation is likely, Tyvek coveralls will be required to minimize this hazard potential. Also, several commercial products have been demonstrated as being effective in repelling ticks. Examples include Permanone, Off!, and Cutter. These types of repellents will be used at the direction and discretion of the Brown & Root Environmental Health and Safety Officer, and only in accordance and observation of manufacturer's recommendations. In most instances, however, such repellents are typically applied to the outside surfaces of clothing (and not directly onto the skin), and should be applied also to shoe tops, socks, pants cuffs, and other areas most susceptible to ticks.

6.4 Tick Removal

In the event that a tick is discovered to be attached to a member of the field team, timely removal of the insect is critical to reducing the potential for contracting the disease. According to available information and

research, there is apparently a grace period of at least a few hours from the time of the bite before the tick transmits the microbe (the spirochetes are not present in the mouth parts of the tick). However, the incident of a tick bite is frequently unnoticed, and the discovery of the tick may not occur until after this suspected grace period has already elapsed. Therefore, timely removal is very important. The preferred method of tick removal is to pull it out using tweezers or small forceps. In this method, the tick should be grasped as close to the mouth as possible, and then pulled steadily upward. Care must be exercised so as not to pull in a jerking motion as this can result in the head becoming detached. After the tick has been removed, disinfect the bite with rubbing alcohol or povidone iodine (Betadine). The tick must not be handled as the microbes can enter the body through any breaks in intact skin. The bite should be checked occasionally for at least a two-week period to see if a rash forms. If it does, medical attention must be promptly sought.

In order to provide for proper and timely response to the occurrence of a tick bite, the Health and Safety Officer will ensure that the site First Aid kit is properly equipped with medical forceps and rubbing alcohol, in addition to the standard kit contents. Also, an adequate supply of commercial insect (tick) repellents will be maintained on site, and all personnel will be trained in its proper application and will be required to use it, at the direction of the Health and Safety Officer.

HAZARD COMMUNICATION PROGRAM
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HAZARD COMMUNICATION PROGRAM

1.0 PURPOSE

To establish general Hazard Communication Program and guidelines for developing site and activity specific Hazard Communication procedures.

2.0 SCOPE

Applies to all onsite activities where exposure to hazardous materials brought to that site may occur.

3.0 RESPONSIBILITIES

Project Health and Safety Officer (PHSO) - The PHSO shall ensure that the hazard communication program is adequately addressed in the Site Specific Health and Safety Plan.

Site Safety Officer (SSO) - The SSO is responsible for enforcing elements of the hazard communication program. The SSO also ensures that adequate hazardous communication procedures are followed to prevent exposure of individuals or contamination to the environment.

Project Manager (PM) - The PM will ensure that sufficient information has been provided to the PHSO to prepare adequate hazard communications procedures for inclusion in the site-specific activity for the Health & Safety Guidance Manual.

4.0 PROCEDURES

4.1 Introduction

Every worker has the right to know what types of chemical hazards are located in the work area. OSHA has established a standard known as 29 CFR 1910.1200, Hazard Communication Standard (HAZCOM), to meet this requirement. This standard affects:

- Manufacturers of hazardous chemicals.
- Nonmanufacturers whose employees can be exposed to hazardous chemicals, through process, handling, transport, disposal, or incidental exposure.

5.0 REQUIREMENTS

5.1 Written Hazard Communication Plan

A Hazard Communication Plan is required of all employers. The employer must develop, place in writing, and implement the plan. The plan must reveal how each of the following requirements will be met.

5.2 Plan Components

1. Chemical Inventory
2. Material Safety Data Sheets
3. Labeling/Product Identification
4. Employee Training
5. Informing Contractors
6. Information Availability

5.2.1 Chemical Inventory

Employers must maintain an up-to-date inventory of all hazardous products/chemicals at the onsite location. The inventory may be compiled for the entire facility or for individual work areas. The chemical inventory must be kept with the Material Safety Data Sheets so employees may access it during work hours. The FOL and the SSO will be responsible for generating and compiling this list utilizing Figure 1.

The purpose of the chemical inventory list is to provide a tool for documenting which products/chemicals are present within a facility. The inventory is required by law under the Federal Hazard Communication Standard. The chemical inventory shall:

- Identify all hazardous products/chemicals within the facility by the name of the product/chemical, address of manufacturer, and should include additional information (e.g., quantity of product/chemical).

- Identify which products/chemicals require an MSDS.

FIGURE 1

CHEMICAL INVENTORY

Job Title
Job No.

Chemical/Product Name/Synonym	Quantity	Location	Hazards	MSDS Location

Responsible Party _____
Signature

_____
Position

- Maintain an up-to-date inventory list and keep it with the MSDS so employees can access it during work hours. This will be accomplished by filling out the pull out inventory list to be placed in the Hazard Communication section.

- Cross-reference the product/chemical name with the name recognized by employees so that employees can find the MSDS.

5.2.2 Material Safety Data Sheets

A Material Safety Data Sheet (MSDS) must be maintained for each hazardous chemical located in a work area and on the chemical inventory list. All MSDS must be in a place accessible to employees during every work shift. MSDS are discussed in greater detail later in the module. The FOL will request for all chemical substances brought onsite that a MSDS sheet will accompany that delivery. For all purchased items once onsite the FOL or SSO will request copies from office support locations.

5.2.3 Labeling/Product Identification

OSHA requires that each container in the workplace must be labeled, tagged, or marked with specific information. This information is covered in detail following this section.

5.2.4 Employee Training

Training must be conducted for existing employees, for all new employees, and whenever new products/chemicals are brought into the workplace. Training must be documented and kept on file. The training must include the following:

- Basic requirements of the Hazard Communication Standard or applicable state regulations.
- Work tasks that expose employees to hazardous chemicals.
- Location and availability of this written hazard communication program, the chemical inventory, and the MSDS.
- Methods for detecting hazardous chemicals, such as by odor and by sight.
- Physical and health hazards of chemicals in the work area.
- Ways for employees to reduce or eliminate exposures.
- How to use the MSDS.

- How employees will be informed of the hazards of nonroutine tasks.
- The location of training materials.

5.2.5 Informing Contractors

The FOL and/or the SSO will inform all contractors and subcontractors of the hazardous products/ chemicals at a facility, necessary precautions, and location and use of the chemical inventory list and MSDS while working at the facility. This will be accomplished as part of the site-specific training.

5.2.6 Employee Information Availability

The written Hazard Communication Plan must inform employees of any operations in the work area where hazardous chemicals are present, and the location and availability of documentation (inventory and MSDS, see Figure 2) under that plan.

FIGURE 2

MSDS LOCATIONS

List all areas at the site where MSDS can be accessed. This may include client locations. This list must be posted along with the OSHA Poster in a conspicuous location.

Location
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

HEARING CONSERVATION
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HEARING CONSERVATION

1.0 PURPOSE

To establish general and site-specific hearing conservation procedures and guidelines.

2.0 SCOPE

Applies to all hazardous waste and other field activities where exposure to high levels of noise may occur. This program is designed to comply with OSHA General Industry Standard 29 CFR 1910.95.

3.0 RESPONSIBILITIES

Project Health and Safety Officer (PHSO) - The PHSO shall ensure that hearing conservation measures are adequately addressed in the Site Specific Health and Safety Plan.

Site Safety Officer (SSO) - The SSO is responsible for establishing and implementing a hearing conservation program. The SSO also ensures that adequate procedures are followed to prevent excessive exposure of individuals to high levels of noise.

Project Manager (PM) - The PM will ensure that sufficient information has been provided to the PHSO to prepare adequate procedures for inclusion in the site-specific Health and Safety Plan (HASP). The PM is also ultimately responsible for the effective compliance with these requirements.

4.0 MONITORING AND ESTABLISHING HIGH-NOISE AREAS

4.1 The SSO, as necessary, will perform and initial noise survey on Brown & Root Environmental and Subcontractors operations and work areas by the use of a sound meter and/or dosimetry. All monitoring will be done in accordance with 29 CFR 1910.95. Areas and operations which are expected to reach or exceed 85 decibels (dBA) will be required to adhere to the requirements for this program.

4.2 The HASP will set policy on mandatory use of hearing protection in affected areas, and while performing certain operations. The FOL and/or SSO will notify all Brown & Root Environmental and Subcontractor personnel of high noise areas and operations prior to work initiation.

The FOL and/or the SSO will be responsible for implementation and enforcement of the site-specific Hearing Conservation elements.

4.3 The FOL and/or the SSO will post or otherwise identify areas of operations which exceed 85 dBA. If significant changes in noise levels occur (such as a shutdown in an operating unit, change in procedures), the noise levels shall be re-evaluated by the SSO to determine if hearing protection will be worn.

5.0 HEARING PROTECTION

Each employee will have the opportunity to choose from a variety of hearing protection devices. Hearing protectors shall be replaced as necessary. The SSO will evaluate the attenuation factors of hearing protection devices and will select appropriate types based on sound level monitoring or personal dosimetry.

6.0 TRAINING PROGRAM

The Health Sciences Department will institute and maintain an initial training program for new employees and provide an annual training program for employees who may be exposed to noise sources 85 dBA or greater. The annual training will be incorporated with the refresher health and safety training curricula. All affected employees will be involved in the program and their participation documented.

6.1 The training program shall include the effects of noise on hearing. It will also include the purpose of hearing protectors; the advantages, disadvantages, and attenuation factors of the various types. Instruction shall be given on issue points, selection, fitting, use and care of hearing protectors.

6.2 A copy of the OSHA Noise Standard and applicable informational and training material will be available to all employees.

7.0 RECORDKEEPING

Exposure measurements, related records will be kept at the site. Record retention will be done in accordance with the time periods stated in 29 CFR 1910.95 and 1910.20.

8.0 ATTACHMENTS

8.1 29 CFR 1910.95 Occupational Noise Exposure

8.1.1 Code of Federal Regulations, Subsection 1910.95

ATTACHMENT 8.1

29 CFR 1910.95 OCCUPATIONAL NOISE EXPOSURE

Site:		Type of Audio Monitoring Equipment:		Date:
Employee Name	**Operation**	**Hearing Protection Type Attenuation Factor**	**Noise Levels Measured**	**Duration of Use**

Forward completed table (with backup noise monitoring data) to the Manager, Health Sciences.

ATTACHMENT 8.1.1

CODE OF FEDERAL REGULATIONS, SUBSECTION 1910.95

FR 5322, Feb. 10, 1984; 55 FR 32015, Aug. 6, 1990; 58 FR 35308, June 30, 1993]

§ 1910.95 Occupational noise exposure.

(a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table G-16 when measured on the A scale of a standard sound level meter at slow response. When noise levels are determined by octave band analysis, the equivalent A-weighted sound level may be determined as follows:

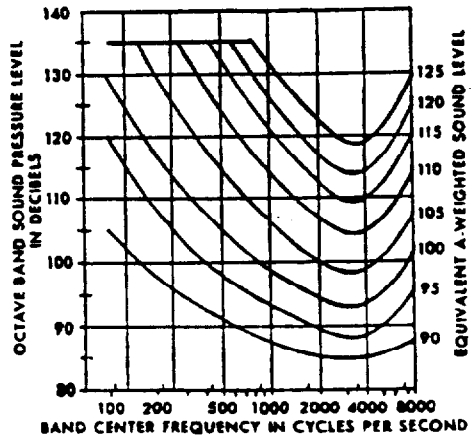

FIGURE G-9

Equivalent sound level contours. Octave band sound pressure levels may be converted to the equivalent A-weighted sound level by plotting them on this graph and noting the A-weighted sound level corresponding to the point of highest penetration into the sound level contours. This equivalent A-weighted sound level, which may differ from the actual A-weighted sound level of the noise, is used to determine exposure limits from Table 1.G-16.

(b)(1) When employees are subjected to sound exceeding those listed in Table G-16, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of Table G-16, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table.

(2) If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

TABLE G-16—PERMISSIBLE NOISE EXPOSURES [1]

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

[1] When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1+C_2/T_2$ C_n/T_n exceeds unity, then, the mixed exposure should be considered to exceed the limit value. *Cn* indicates the total time of exposure at a specified noise level, and *Tn* indicates the total time of exposure permitted at that level.

Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

(c) *Hearing conservation program.* (1) The employer shall administer a continuing, effective hearing conservation program, as described in paragraphs (c) through (o) of this section, whenever employee noise exposures equal or exceed an 8-hour time-weighted average sound level (TWA) of 85 decibels measured on the A scale (slow response) or, equivalently, a dose of fifty percent. For purposes of the hearing conservation program, employee noise exposures shall be computed in accordance with appendix A and Table G-16a, and without regard to any attenuation provided by the use of personal protective equipment.

(2) For purposes of paragraphs (c) through (n) of this section, an 8-hour time-weighted average of 85 decibels or a dose of fifty percent shall also be referred to as the action level.

(d) *Monitoring.* (1) When information indicates that any employee's exposure may equal or exceed an 8-hour time-weighted average of 85 decibels, the employer shall develop and implement a monitoring program.

(i) The sampling strategy shall be designed to identify employees for inclusion in the hearing conservation program and to enable the proper selection of hearing protectors.

(ii) Where circumstances such as high worker mobility, significant variations in sound level, or a significant

component of impulse noise make area monitoring generally inappropriate, the employer shall use representative personal sampling to comply with the monitoring requirements of this paragraph unless the employer can show that area sampling produces equivalent results.

(2)(i) All continuous, intermittent and impulsive sound levels from 80 decibels to 130 decibels shall be integrated into the noise measurements.

(ii) Instruments used to measure employee noise exposure shall be calibrated to ensure measurement accuracy.

(3) Monitoring shall be repeated whenever a change in production, process, equipment or controls increases noise exposures to the extent that:

(i) Additional employees may be exposed at or above the action level; or

(ii) The attenuation provided by hearing protectors being used by employees may be rendered inadequate to meet the requirements of paragraph (j) of this section.

(e) *Employee notification.* The employer shall notify each employee exposed at or above an 8-hour time-weighted average of 85 decibels of the results of the monitoring.

(f) *Observation of monitoring.* The employer shall provide affected employees or their representatives with an opportunity to observe any noise measurements conducted pursuant to this section.

(g) *Audiometric testing program.* (1) The employer shall establish and maintain an audiometric testing program as provided in this paragraph by making audiometric testing available to all employees whose exposures equal or exceed an 8-hour time-weighted average of 85 decibels.

(2) The program shall be provided at no cost to employees.

(3) Audiometric tests shall be performed by a licensed or certified audiologist, otolaryngologist, or other physician, or by a technician who is certified by the Council of Accreditation in Occupational Hearing Conservation, or who has satisfactorily demonstrated competence in administering audiometric examinations, obtaining valid audiograms, and properly using, maintaining and checking calibration and proper functioning of the audiometers being used. A technician who operates microprocessor audiometers does not need to be certified. A technician who performs audiometric tests must be responsible to an audiologist, otolaryngologist or physician.

(4) All audiograms obtained pursuant to this section shall meet the requirements of Appendix C: *Audiometric Measuring Instruments.*

(5) *Baseline audiogram.* (i) Within 6 months of an employee's first exposure at or above the action level, the employer shall establish a valid baseline audiogram against which subsequent audiograms can be compared.

(ii) *Mobile test van exception.* Where mobile test vans are used to meet the audiometric testing obligation, the employer shall obtain a valid baseline audiogram within 1 year of an employee's first exposure at or above the action level. Where baseline audiograms are obtained more than 6 months after the employee's first exposure at or above the action level, employees shall wearing hearing protectors for any period exceeding six months after first exposure until the baseline audiogram is obtained.

(iii) Testing to establish a baseline audiogram shall be preceded by at least 14 hours without exposure to workplace noise. Hearing protectors may be used as a substitute for the requirement that baseline audiograms be preceded by 14 hours without exposure to workplace noise.

(iv) The employer shall notify employees of the need to avoid high levels of non-occupational noise exposure during the 14-hour period immediately preceding the audiometric examination.

(6) *Annual audiogram.* At least annually after obtaining the baseline audiogram, the employer shall obtain a new audiogram for each employee exposed at or above an 8-hour time-weighted average of 85 decibels.

(7) *Evaluation of audiogram.* (i) Each employee's annual audiogram shall be compared to that employee's baseline audiogram to determine if the audiogram is valid and if a standard threshold shift as defined in paragraph (g)(10) of this section has oc-

curred. This comparison may be done by a technician.

(ii) If the annual audiogram shows that an employee has suffered a standard threshold shift, the employer may obtain a retest within 30 days and consider the results of the retest as the annual audiogram.

(iii) The audiologist, otolaryngologist, or physician shall review problem audiograms and shall determine whether there is a need for further evaluation. The employer shall provide to the person performing this evaluation the following information:

(A) A copy of the requirements for hearing conservation as set forth in paragraphs (c) through (n) of this section;

(B) The baseline audiogram and most recent audiogram of the employee to be evaluated;

(C) Measurements of background sound pressure levels in the audiometric test room as required in Appendix D: Audiometric Test Rooms.

(D) Records of audiometer calibrations required by paragraph (h)(5) of this section.

(8) *Follow-up procedures.* (i) If a comparison of the annual audiogram to the baseline audiogram indicates a standard threshold shift as defined in paragraph (g)(10) of this section has occurred, the employee shall be informed of this fact in writing, within 21 days of the determination.

(ii) Unless a physician determines that the standard threshold shift is not work related or aggravated by occupational noise exposure, the employer shall ensure that the following steps are taken when a standard threshold shift occurs:

(A) Employees not using hearing protectors shall be fitted with hearing protectors, trained in their use and care, and required to use them.

(B) Employees already using hearing protectors shall be refitted and retrained in the use of hearing protectors and provided with hearing protectors offering greater attenuation if necessary.

(C) The employee shall be referred for a clinical audiological evaluation or an otological examination, as appropriate, if additional testing is necessary or if the employer suspects that a medical pathology of the ear is caused or aggravated by the wearing of hearing protectors.

(D) The employee is informed of the need for an otological examination if a medical pathology of the ear that is unrelated to the use of hearing protectors is suspected.

(iii) If subsequent audiometric testing of an employee whose exposure to noise is less than an 8-hour TWA of 90 decibels indicates that a standard threshold shift is not persistent, the employer:

(A) Shall inform the employee of the new audiometric interpretation; and

(B) May discontinue the required use of hearing protectors for that employee.

(9) *Revised baseline.* An annual audiogram may be substituted for the baseline audiogram when, in the judgment of the audiologist, otolaryngologist or physician who is evaluating the audiogram:

(i) The standard threshold shift revealed by the audiogram is persistent; or

(ii) The hearing threshold shown in the annual audiogram indicates significant improvement over the baseline audiogram.

(10) *Standard threshold shift.* (i) As used in this section, a standard threshold shift is a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear.

(ii) In determining whether a standard threshold shift has occurred, allowance may be made for the contribution of aging (presbycusis) to the change in hearing level by correcting the annual audiogram according to the procedure described in Appendix F: *Calculation and Application of Age Correction to Audiograms.*

(h) *Audiometric test requirements.* (1) Audiometric tests shall be pure tone, air conduction, hearing threshold examinations, with test frequencies including as a minimum 500, 1000, 2000, 3000, 4000, and 6000 Hz. Tests at each frequency shall be taken separately for each ear.

(2) Audiometric tests shall be conducted with audiometers (including microprocessor audiometers) that

meet the specifications of, and are maintained and used in accordance with, American National Standard Specification for Audiometers, S3.6-1969.

(3) Pulsed-tone and self-recording audiometers, if used, shall meet the requirements specified in Appendix C: *Audiometric Measuring Instruments.*

(4) Audiometric examinations shall be administered in a room meeting the requirements listed in Appendix D: *Audiometric Test Rooms.*

(5) *Audiometer calibration.* (i) The functional operation of the audiometer shall be checked before each day's use by testing a person with known, stable hearing thresholds, and by listening to the audiometer's output to make sure that the output is free from distorted or unwanted sounds. Deviations of 10 decibels or greater require an acoustic calibration.

(ii) Audiometer calibration shall be checked acoustically at least annually in accordance with Appendix E: *Acoustic Calibration of Audiometers.* Test frequencies below 500 Hz and above 6000 Hz may be omitted from this check. Deviations of 15 decibels or greater require an exhaustive calibration.

(iii) An exhaustive calibration shall be performed at least every two years in accordance with sections 4.1.2; 4.1.3.; 4.1.4.3; 4.2; 4.4.1; 4.4.2; 4.4.3; and 4.5 of the American National Standard Specification for Audiometers, S3.6-1969. Test frequencies below 500 Hz and above 6000 Hz may be omitted from this calibration.

(i) *Hearing protectors.* (1) Employers shall make hearing protectors available to all employees exposed to an 8-hour time-weighted average of 85 decibels or greater at no cost to the employees. Hearing protectors shall be replaced as necessary.

(2) Employers shall ensure that hearing protectors are worn:

(i) By an employee who is required by paragraph (b)(1) of this section to wear personal protective equipment; and

(ii) By any employee who is exposed to an 8-hour time-weighted average of 85 decibels or greater, and who:

(A) Has not yet had a baseline audiogram established pursuant to paragraph (g)(5)(ii); or

(B) Has experienced a standard threshold shift.

(3) Employees shall be given the opportunity to select their hearing protectors from a variety of suitable hearing protectors provided by the employer.

(4) The employer shall provide training in the use and care of all hearing protectors provided to employees.

(5) The employer shall ensure proper initial fitting and supervise the correct use of all hearing protectors.

(j) *Hearing protector attenuation.* (1) The employer shall evaluate hearing protector attenuation for the specific noise environments in which the protector will be used. The employer shall use one of the evaluation methods described in Appendix B: *Methods for Estimating the Adequacy of Hearing Protection Attenuation.*

(2) Hearing protectors must attenuate employee exposure at least to an 8-hour time-weighted average of 90 decibels as required by paragraph (b) of this section.

(3) For employees who have experienced a standard threshold shift, hearing protectors must attenuate employee exposure to an 8-hour time-weighted average of 85 decibels or below.

(4) The adequacy of hearing protector attenuation shall be re-evaluated whenever employee noise exposures increase to the extent that the hearing protectors provided may no longer provide adequate attenuation. The employer shall provide more effective hearing protectors where necessary.

(k) *Training program.* (1) The employer shall institute a training program for all employees who are exposed to noise at or above an 8-hour time-weighted average of 85 decibels, and shall ensure employee participation in such program.

(2) The training program shall be repeated annually for each employee included in the hearing conservation program. Information provided in the training program shall be updated to be consistent with changes in protective equipment and work processes.

(3) The employer shall ensure that each employee is informed of the following:

(i) The effects of noise on hearing;

(ii) The purpose of hearing protectors, the advantages, disadvantages, and attenuation of various types, and instructions on selection, fitting, use, and care; and

(iii) The purpose of audiometric testing, and an explanation of the test procedures.

(l) *Access to information and training materials.* (1) The employer shall make available to affected employees or their representatives copies of this standard and shall also post a copy in the workplace.

(2) The employer shall provide to affected employees any informational materials pertaining to the standard that are supplied to the employer by the Assistant Secretary.

(3) The employer shall provide, upon request, all materials related to the employer's training and education program pertaining to this standard to the Assistant Secretary and the Director.

(m) *Recordkeeping*—(1) *Exposure measurements.* The employer shall maintain an accurate record of all employee exposure measurements required by paragraph (d) of this section.

(2) *Audiometric tests.* (i) The employer shall retain all employee audiometric test records obtained pursuant to paragraph (g) of this section:

(ii) This record shall include:

(A) Name and job classification of the employee;

(B) Date of the audiogram;

(C) The examiner's name;

(D) Date of the last acoustic or exhaustive calibration of the audiometer; and

(E) Employee's most recent noise exposure assessment.

(F) The employer shall maintain accurate records of the measurements of the background sound pressure levels in audiometric test rooms.

(3) *Record retention.* The employer shall retain records required in this paragraph (m) for at least the following periods.

(i) Noise exposure measurement records shall be retained for two years.

(ii) Audiometric test records shall be retained for the duration of the affected employee's employment.

(4) *Access to records.* All records required by this section shall be provided upon request to employees, former employees, representatives designated by the individual employee, and the Assistant Secretary. The provisions of 29 CFR 1910.20 (a)-(e) and (g)-(i) apply to access to records under this section.

(5) *Transfer of records.* If the employer ceases to do business, the employer shall transfer to the successor employer all records required to be maintained by this section, and the successor employer shall retain them for the remainder of the period prescribed in paragraph (m) (3) of this section.

(n) *Appendices.* (1) Appendices A, B, C, D, and E to this section are incorporated as part of this section and the contents of these appendices are mandatory.

(2) Appendices F and G to this section are informational and are not intended to create any additional obligations not otherwise imposed or to detract from any existing obligations.

(o) *Exemptions.* Paragraphs (c) through (n) of this section shall not apply to employers engaged in oil and gas well drilling and servicing operations.

(p) *Startup date.* Baseline audiograms required by paragraph (g) of this section shall be completed by March 1, 1984.

(Approved by the Office of Management and Budget under control number 1218-0048)

APPENDIX A TO § 1910.95—NOISE EXPOSURE COMPUTATION

This Appendix is Mandatory

I. Computation of Employee Noise Exposure

(1) Noise dose is computed using Table G-16a as follows:

(i) When the sound level, L, is constant over the entire work shift, the noise dose, D, in percent, is given by: $D = 100\ C/T$ where C is the total length of the work day, in hours, and T is the reference duration corresponding to the measured sound level, L, as given in Table G-16a or by the formula shown as a footnote to that table.

(ii) When the workshift noise exposure is composed of two or more periods of noise at different levels, the total noise dose over the work day is given by:

$$D = 100\,(C_1/T_1 + C_2/T_2 + \ldots + C_n/T_n),$$

where C_n indicates the total time of exposure at a specific noise level, and T_n indicates the reference duration for that level as given by Table G-16a.

(2) The eight-hour time-weighted average sound level (TWA), in decibels, may be computed from the dose, in percent, by means of the formula: $TWA = 16.61 \log_{10} (D/100) + 90$. For an eight-hour workshift with the noise level constant over the entire shift, the TWA is equal to the measured sound level.

(3) A table relating dose and TWA is given in Section II.

TABLE G-16a

A-weighted sound level, L (decibel)	Reference duration, T (hour)
80	32
81	27.9
82	24.3
83	21.1
84	18.4
85	16
86	13.9
87	12.1
88	10.6
89	9.2
90	8
91	7.0
92	6.1
93	5.3
94	4.6
95	4
96	3.5
97	3.0
98	2.6
99	2.3
100	2
101	1.7
102	1.5
103	1.3
104	1.1
105	1
106	0.87
107	0.76
108	0.66
109	0.57
110	0.5
111	0.44
112	0.38
113	0.33
114	0.29
115	0.25
116	0.22
117	0.19
118	0.16
119	0.14
120	0.125
121	0.11
122	0.095
123	0.082

TABLE G-16a—Continued

A-weighted sound level, L (decibel)	Reference duration, T (hour)
124	0.072
125	0.063
126	0.054
127	0.047
128	0.041
129	0.036
130	0.031

In the above table the reference duration, T, is computed by

$$T = \frac{8}{2^{(L-90)/5}}$$

where L is the measured A-weighted sound level.

II. Conversion Between "Dose" and "8-Hour Time-Weighted Average" Sound Level

Compliance with paragraphs (c)-(r) of this regulation is determined by the amount of exposure to noise in the workplace. The amount of such exposure is usually measured with an audiodosimeter which gives a readout in terms of "dose." In order to better understand the requirements of the amendment, dosimeter readings can be converted to an "8-hour time-weighted average sound level." (TWA).

In order to convert the reading of a dosimeter into TWA, see Table A-1, below. This table applies to dosimeters that are set by the manufacturer to calculate dose or percent exposure according to the relationships in Table G-16a. So, for example, a dose of 91 percent over an eight hour day results in a TWA of 89.3 dB, and, a dose of 50 percent corresponds to a TWA of 85 dB.

If the dose as read on the dosimeter is less than or greater than the values found in Table A-1, the TWA may be calculated by using the formula: $TWA = 16.61 \log_{10} (D/100) + 90$ where TWA = 8-hour time-weighted average sound level and D = accumulated dose in percent exposure.

TABLE A-1—CONVERSION FROM "PERCENT NOISE EXPOSURE" OR "DOSE" TO "8-HOUR TIME-WEIGHTED AVERAGE SOUND LEVEL" (TWA)

Dose or percent noise exposure	TWA
10	73.4
15	76.3
20	78.4
25	80.0
30	81.3
35	82.4
40	83.4
45	84.2
50	85.0
55	85.7
60	86.3
65	86.9
70	87.4
75	87.9
80	88.4
81	88.5
82	88.6
83	88.7
84	88.7
85	88.8
86	88.9
87	89.0
88	89.1
89	89.2
90	89.2
91	89.3
92	89.4
93	89.5
94	89.6
95	89.6
96	89.7
97	89.8
98	89.9
99	89.9
100	90.0
101	90.1
102	90.1
103	90.2
104	90.3
105	90.4
106	90.4
107	90.5
108	90.6
109	90.6
110	90.7
111	90.8
112	90.8
113	90.9
114	90.9
115	91.1
116	91.1
117	91.1
118	91.2
119	91.3
120	91.3
125	91.6
130	91.9
135	92.2
140	92.4
145	92.7
150	92.9
155	93.2
160	93.4
165	93.6
170	93.8
175	94.0

TABLE A-1—CONVERSION FROM "PERCENT NOISE EXPOSURE" OR "DOSE" TO "8-HOUR TIME-WEIGHTED AVERAGE SOUND LEVEL" (TWA)—Continued

Dose or percent noise exposure	TWA
180	94.2
185	94.4
190	94.6
195	94.8
200	95.0
210	95.4
220	95.7
230	96.0
240	96.3
250	96.6
260	96.9
270	97.2
280	97.4
290	97.7
300	97.9
310	98.2
320	98.4
330	98.6
340	98.8
350	99.0
360	99.2
370	99.4
380	99.6
390	99.8
400	100.0
410	100.2
420	100.4
430	100.5
440	100.7
450	100.8
460	101.0
470	101.2
480	101.3
490	101.5
500	101.6
510	101.8
520	101.9
530	102.0
540	102.2
550	102.3
560	102.4
570	102.6
580	102.7
590	102.8
600	102.9
610	103.0
620	103.2
630	103.3
640	103.4
650	103.5
660	103.6
670	103.7
680	103.8
690	103.9
700	104.0
710	104.1
720	104.2
730	104.3
740	104.4
750	104.5
760	104.6
770	104.7
780	104.8
790	104.9
800	105.0
810	105.1

TABLE A-1—CONVERSION FROM "PERCENT NOISE EXPOSURE" OR "DOSE" TO "8-HOUR TIME-WEIGHTED AVERAGE SOUND LEVEL" (TWA)—Continued

Dose or percent noise exposure	TWA
820	105.2
830	105.3
840	105.4
850	105.4
860	105.5
870	105.6
880	105.7
890	105.8
900	105.8
910	105.9
920	106.0
930	106.1
940	106.2
950	106.2
960	106.3
970	106.4
980	106.5
990	106.5
999	106.6

APPENDIX B TO § 1910.95—METHODS FOR ESTIMATING THE ADEQUACY OF HEARING PROTECTOR ATTENUATION

This Appendix is Mandatory

For employees who have experienced a significant threshold shift, hearing protector attenuation must be sufficient to reduce employee exposure to a TWA of 85 dB. Employers must select one of the following methods by which to estimate the adequacy of hearing protector attenuation.

The most convenient method is the Noise Reduction Rating (NRR) developed by the Environmental Protection Agency (EPA). According to EPA regulation, the NRR must be shown on the hearing protector package. The NRR is then related to an individual worker's noise environment in order to assess the adequacy of the attenuation of a given hearing protector. This appendix describes four methods of using the NRR to determine whether a particular hearing protector provides adequate protection within a given exposure environment. Selection among the four procedures is dependent upon the employer's noise measuring instruments.

Instead of using the NRR, employers may evaluate the adequacy of hearing protector attenuation by using one of the three methods developed by the National Institute for Occupational Safety and Health (NIOSH), which are described in the "List of Personal Hearing Protectors and Attenuation Data," HEW Publication No. 76-120, 1975, pages 21-37. These methods are known as NIOSH methods #1, #2 and #3. The NRR described below is a simplification of NIOSH method #2. The most complex method is NIOSH method #1, which is probably the most accurate method since it uses the largest amount of spectral information from the individual employee's noise environment. As in the case of the NRR method described below, if one of the NIOSH methods is used, the selected method must be applied to an individual's noise environment to assess the adequacy of the attenuation. Employers should be careful to take a sufficient number of measurements in order to achieve a representative sample for each time segment.

NOTE: The employer must remember that calculated attenuation values reflect realistic values only to the extent that the protectors are properly fitted and worn.

When using the NRR to assess hearing protector adequacy, one of the following methods must be used:

(i) When using a dosimeter that is capable of C-weighted measurements:

(A) Obtain the employee's C-weighted dose for the entire workshift, and convert to TWA (see appendix A, II).

(B) Subtract the NRR from the C-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(ii) When using a dosimeter that is not capable of C-weighted measurements, the following method may be used:

(A) Convert the A-weigh ed dose to TWA (see appendix A).

(B) Subtract 7 dB from the NRR.

(C) Subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(iii) When using a sound level meter set to the A-weighting network:

(A) Obtain the employee's A-weighted TWA.

(B) Subtract 7 dB from the NRR, and subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(iv) When using a sound level meter set on the C-weighting network:

(A) Obtain a representative sample of the C-weighted sound levels in the employee's environment.

(B) Subtract the NRR from the C-weighted average sound level to obtain the estimated A-weighted TWA under the ear protector.

(v) When using area monitoring procedures and a sound level meter set to the A-weighing network.

(A) Obtain a representative sound level for the area in question.

(B) Subtract 7 dB from the NRR and subtract the remainder from the A-weighted sound level for that area.

(vi) When using area monitoring procedures and a sound level meter set to the C-weighting network:

(A) Obtain a representative sound level for the area in question.

(B) Subtract the NRR from the C-weighted sound level for that area.

APPENDIX C TO § 1910.95—AUDIOMETRIC MEASURING INSTRUMENTS

This Appendix is Mandatory

1. In the event that pulsed-tone audiometers are used, they shall have a tone on-time of at least 200 milliseconds.

2. Self-recording audiometers shall comply with the following requirements:

(A) The chart upon which the audiogram is traced shall have lines at positions corresponding to all multiples of 10 dB hearing level within the intensity range spanned by the audiometer. The lines shall be equally spaced and shall be separated by at least ⅛ inch. Additional increments are optional. The audiogram pen tracings shall not exceed 2 dB in width.

(B) It shall be possible to set the stylus manually at the 10-dB increment lines for calibration purposes.

(C) The slewing rate for the audiometer attenuator shall not be more than 6 dB/sec except that an initial slewing rate greater than 6 dB/sec is permitted at the beginning of each new test frequency, but only until the second subject response.

(D) The audiometer shall remain at each required test frequency for 30 seconds (± 3 seconds). The audiogram shall be clearly marked at each change of frequency and the actual frequency change of the audiometer shall not deviate from the frequency boundaries marked on the audiogram by more than ± 3 seconds.

(E) It must be possible at each test frequency to place a horizontal line segment parallel to the time axis on the audiogram, such that the audiometric tracing crosses the line segment at least six times at that test frequency. At each test frequency the threshold shall be the average of the midpoints of the tracing excursions.

APPENDIX D TO § 1910.95—AUDIOMETRIC TEST ROOMS

This Appendix is Mandatory

Rooms used for audiometric testing shall not have background sound pressure levels exceeding those in Table D-1 when measured by equipment conforming at least to the Type 2 requirements of American National Standard Specification for Sound Level Meters, S1.4-1971 (R1976), and to the Class II requirements of American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.11-1971 (R1976).

TABLE D-1—MAXIMUM ALLOWABLE OCTAVE-BAND SOUND PRESSURE LEVELS FOR AUDIOMETRIC TEST ROOMS

Octave-band center frequency (Hz)	500	1000	2000	4000	8000
Sound pressure level (dB)	40	40	47	57	62

APPENDIX E TO § 1910.95—ACOUSTIC CALIBRATION OF AUDIOMETERS

This Appendix is Mandatory

Audiometer calibration shall be checked acoustically, at least annually, according to the procedures described in this appendix. The equipment necessary to perform these measurements is a sound level meter, octave-band filter set, and a National Bureau of Standards 9A coupler. In making these measurements, the accuracy of the calibrating equipment shall be sufficient to determine that the audiometer is within the tolerances permitted by American Standard Specification for Audiometers, S3.6-1969.

(1) Sound Pressure Output Check

A. Place the earphone coupler over the microphone of the sound level meter and place the earphone on the coupler.

B. Set the audiometer's hearing threshold level (HTL) dial to 70 dB.

C. Measure the sound pressure level of the tones at each test frequency from 500 Hz through 6000 Hz for each earphone.

D. At each frequency the readout on the sound level meter should correspond to the levels in Table E-1 or Table E-2, as appropriate, for the type of earphone, in the column entitled "sound level meter reading."

(2) Linearity Check

A. With the earphone in place, set the frequency to 1000 Hz and the HTL dial on the audiometer to 70 dB.

B. Measure the sound levels in the coupler at each 10-dB decrement from 70 dB to 10 dB, noting the sound level meter reading at each setting.

C. For each 10-dB decrement on the audiometer the sound level meter should indicate a corresponding 10 dB decrease.

D. This measurement may be made electrically with a voltmeter connected to the earphone terminals.

(3) Tolerances

When any of the measured sound levels deviate from the levels in Table E-1 or Table E-2 by ± 3 dB at any test frequency between 500 and 3000 Hz, 4 dB at 4000 Hz, or 5 dB at 6000 Hz, an exhaustive calibra-

tion is advised. An exhaustive calibration is required if the deviations are greater than 15 dB or greater at any test frequency.

TABLE E-1—REFERENCE THRESHOLD LEVELS FOR TELEPHONICS—TDH-39 EARPHONES

Frequency, Hz	Reference threshold level for TDH-39 earphones, dB	Sound level meter reading, dB
500	11.5	81.5
1000	7	77
2000	9	79
3000	10	80
4000	9.5	79.5
6000	15.5	85.5

TABLE E-2—REFERENCE THRESHOLD LEVELS FOR TELEPHONICS—TDH-49 EARPHONES

Frequency, Hz	Reference threshold level for TDH-49 earphones, dB	Sound level meter reading, dB
500	13.5	83.5
1000	7.5	77.5
2000	11	81.0
3000	9.5	79.5
4000	10.5	80.5
6000	13.5	83.5

APPENDIX F TO § 1910.95—CALCULATIONS AND APPLICATION OF AGE CORRECTIONS TO AUDIOGRAMS

This Appendix Is Non-Mandatory

In determining whether a standard threshold shift has occurred, allowance may be made for the contribution of aging to the change in hearing level by adjusting the most recent audiogram. If the employer chooses to adjust the audiogram, the employer shall follow the procedure described below. This procedure and the age correction tables were developed by the National Institute for Occupational Safety and Health in the criteria document entitled "Criteria for a Recommended Standard . . . Occupational Exposure to Noise," ((HSM)-11001).

For each audiometric test frequency;

(i) Determine from Tables F-1 or F-2 the age correction values for the employee by:

(A) Finding the age at which the most recent audiogram was taken and recording the corresponding values of age corrections at 1000 Hz through 6000 Hz;

(B) Finding the age at which the baseline audiogram was taken and recording the corresponding values of age corrections at 1000 Hz through 6000 Hz.

(ii) Subtract the values found in step (i)(B) from the value found in step (i)(A).

(iii) The differences calculated in step (ii) represented that portion of the change in hearing that may be due to aging.

EXAMPLE: Employee is a 32-year-old male. The audiometric history for his right ear is shown in decibels below.

Employee's age	Audiometric test frequency (Hz)				
	1000	2000	3000	4000	6000
26	10	5	5	10	5
*27	0	0	0	5	5
28	0	0	0	10	5
29	5	0	5	15	5
30	0	5	10	20	10
31	5	10	20	15	15
*32	5	10	10	25	20

The audiogram at age 27 is considered the baseline since it shows the best hearing threshold levels. Asterisks have been used to identify the baseline and most recent audiogram. A threshold shift of 20 dB exists at 4000 Hz between the audiograms taken at ages 27 and 32.

(The threshold shift is computed by subtracting the hearing threshold at age 27, which was 5, from the hearing threshold at age 32, which is 25). A retest audiogram has confirmed this shift. The contribution of aging to this change in hearing may be estimated in the following manner:

Go to Table F-1 and find the age correction values (in dB) for 4000 Hz at age 27 and age 32.

	Frequency (Hz)				
	1000	2000	3000	4000	6000
Age 32	6	5	7	10	14
Age 27	5	4	6	7	11
Difference	1	1	1	3	3

The difference represents the amount of hearing loss that may be attributed to aging in the time period between the baseline audiogram and the most recent audiogram. In this example, the difference at 4000 Hz is 3 dB. This value is subtracted from the hearing level at 4000 Hz, which in the most recent audiogram is 25, yielding 22 after adjustment. Then the hearing threshold in the baseline audiogram at 4000 Hz (5) is subtracted from the adjusted annual audio-

gram hearing threshold at 4000 Hz (22). Thus the age-corrected threshold shift would be 17 dB (as opposed to a threshold shift of 20 dB without age correction).

TABLE F-1—AGE CORRECTION VALUES IN DECIBELS FOR MALES

Years	Audiometric Test Frequencies (Hz)				
	1000	2000	3000	4000	6000
20 or younger	5	3	4	5	8
21	5	3	4	5	8
22	5	3	4	5	8
23	5	3	4	6	9
24	5	3	5	6	9
25	5	3	5	7	10
26	5	4	5	7	10
27	5	4	6	7	11
28	6	4	6	8	11
29	6	4	6	8	12
30	6	4	6	9	12
31	6	4	7	9	13
32	6	5	7	10	14
33	6	5	7	10	14
34	6	5	8	11	15
35	7	5	8	11	15
36	7	5	9	12	16
37	7	6	9	12	17
38	7	6	9	13	17
39	7	6	10	14	18
40	7	6	10	14	19
41	7	6	10	14	20
42	8	7	11	16	20
43	8	7	12	16	21
44	8	7	12	17	22
45	8	7	13	18	23
46	8	8	13	19	24
47	8	8	14	19	24
48	9	8	14	20	25
49	9	9	15	21	26
50	9	9	16	22	27
51	9	9	16	23	28
52	9	10	17	24	29
53	9	10	18	25	30
54	10	10	18	26	31
55	10	11	19	27	32
56	10	11	20	28	34
57	10	11	21	29	35
58	10	12	22	31	36
59	11	12	22	32	37
60 or older	11	13	23	33	38

TABLE F-2—AGE CORRECTION VALUES IN DECIBELS FOR FEMALES

Years	Audiometric Test Frequencies (Hz)				
	1000	2000	3000	4000	6000
20 or younger	7	4	3	3	6
21	7	4	4	3	6
22	7	4	4	4	6
23	7	5	4	4	7
24	7	5	4	4	7
25	8	5	4	4	7
26	8	5	5	4	8
27	8	5	5	5	8
28	8	5	5	5	8
29	8	5	5	5	9

TABLE F-2—AGE CORRECTION VALUES IN DECIBELS FOR FEMALES—Continued

Years	Audiometric Test Frequencies (Hz)				
	1000	2000	3000	4000	6000
30	8	6	5	5	9
31	8	6	6	5	9
32	9	6	6	6	10
33	9	6	6	6	10
34	9	6	6	6	10
35	9	6	7	7	11
36	9	7	7	7	11
37	9	7	7	7	12
38	10	7	7	7	12
39	10	7	8	8	12
40	10	7	8	8	13
41	10	8	8	8	13
42	10	8	9	9	13
43	11	8	9	9	14
44	11	8	9	9	14
45	11	8	10	10	15
46	11	9	10	10	15
47	11	9	10	11	16
48	12	9	11	11	16
49	12	9	11	11	16
50	12	10	11	12	17
51	12	10	12	12	17
52	12	10	12	13	18
53	13	10	13	13	18
54	13	11	13	14	19
55	13	11	14	14	19
56	13	11	14	15	20
57	13	11	15	15	20
58	14	12	15	16	21
59	14	12	16	16	21
60 or older	14	12	16	17	22

APPENDIX G TO § 1910.95—MONITORING NOISE LEVELS NON-MANDATORY INFORMATIONAL APPENDIX

This appendix provides information to help employers comply with the noise monitoring obligations that are part of the hearing conservation amendment.

WHAT IS THE PURPOSE OF NOISE MONITORING?

This revised amendment requires that employees be placed in a hearing conservation program if they are exposed to average noise levels of 85 dB or greater during an 8 hour workday. In order to determine if exposures are at or above this level, it may be necessary to measure or monitor the actual noise levels in the workplace and to estimate the noise exposure or "dose" received by employees during the workday.

WHEN IS IT NECESSARY TO IMPLEMENT A NOISE MONITORING PROGRAM?

It is not necessary for every employer to measure workplace noise. Noise monitoring or measuring must be conducted only when exposures are at or above 85 dB. Factors which suggest that noise exposures in the workplace may be at this level include employee complaints about the loudness of noise, indications that employees are losing

their hearing, or noisy conditions which make normal conversation difficult. The employer should also consider any information available regarding noise emitted from specific machines. In addition, actual workplace noise measurements can suggest whether or not a monitoring program should be initiated.

HOW IS NOISE MEASURED?

Basically, there are two different instruments to measure noise exposures: the sound level meter and the dosimeter. A sound level meter is a device that measures the intensity of sound at a given moment. Since sound level meters provide a measure of sound intensity at only one point in time, it is generally necessary to take a number of measurements at different times during the day to estimate noise exposure over a workday. If noise levels fluctuate, the amount of time noise remains at each of the various measured levels must be determined.

To estimate employee noise exposures with a sound level meter it is also generally necessary to take several measurements at different locations within the workplace. After appropriate sound level meter readings are obtained, people sometimes draw "maps" of the sound levels within different areas of the workplace. By using a sound level "map" and information on employee locations throughout the day, estimates of individual exposure levels can be developed. This measurement method is generally referred to as *area* noise monitoring.

A dosimeter is like a sound level meter except that it stores sound level measurements and integrates these measurements over time, providing an average noise exposure reading for a given period of time, such as an 8-hour workday. With a dosimeter, a microphone is attached to the employee's clothing and the exposure measurement is simply read at the end of the desired time period. A reader may be used to read-out the dosimeter's measurements. Since the dosimeter is worn by the employee, it measures noise levels in those locations in which the employee travels. A sound level meter can also be positioned within the immediate vicinity of the exposed worker to obtain an individual exposure estimate. Such procedures are generally referred to as *personal* noise monitoring.

Area monitoring can be used to estimate noise exposure when the noise levels are relatively constant and employees are not mobile. In workplaces where employees move about in different areas or where the noise intensity tends to fluctuate over time, noise exposure is generally more accurately estimated by the personal monitoring approach.

In situations where personal monitoring is appropriate, proper positioning of the microphone is necessary to obtain accurate measurements. With a dosimeter, the microphone is generally located on the shoulder and remains in that position for the entire workday. With a sound level meter, the microphone is stationed near the employee's head, and the instrument is usually held by an individual who follows the employee as he or she moves about.

Manufacturer's instructions, contained in dosimeter and sound level meter operating manuals, should be followed for calibration and maintenance. To ensure accurate results, it is considered good professional practice to calibrate instruments before and after each use.

HOW OFTEN IS IT NECESSARY TO MONITOR NOISE LEVELS?

The amendment requires that when there are significant changes in machinery or production processes that may result in increased noise levels, remonitoring must be conducted to determine whether additional employees need to be included in the hearing conservation program. Many companies choose to remonitor periodically (once every year or two) to ensure that all exposed employees are included in their hearing conservation programs.

WHERE CAN EQUIPMENT AND TECHNICAL ADVICE BE OBTAINED?

Noise monitoring equipment may be either purchased or rented. Sound level meters cost about $500 to $1,000, while dosimeters range in price from about $750 to $1,500. Smaller companies may find it more economical to rent equipment rather than to purchase it. Names of equipment suppliers may be found in the telephone book (Yellow Pages) under headings such as: "Safety Equipment," "Industrial Hygiene," or "Engineers-Acoustical." In addition to providing information on obtaining noise monitoring equipment, many companies and individuals included under such listings can provide professional advice on how to conduct a valid noise monitoring program. Some audiological testing firms and industrial hygiene firms also provide noise monitoring services. Universities with audiology, industrial hygiene, or acoustical engineering departments may also provide information or may be able to help employers meet their obligations under this amendment.

Free, on-site assistance may be obtained from OSHA-supported state and private consultation organizations. These safety and health consultative entities generally give priority to the needs of small businesses. See the attached directory for a listing of organizations to contact for aid.

OSHA ONSITE CONSULTATION PROJECT DIRECTORY

State	Office and address	Contact
Alabama	Alabama Consultation Program, P.O. Box 8005, University, Alabama 35486.	(205) 348-7136, Mr. William Weems, Director.
Alaska	State of Alaska, Department of Labor, Occupational Safety & Health, 3301 Eagle St., Pouch 7-022, Anchorage, Alaska 99510.	(907) 276-5013, Mr. Stan Godsoe, Project Manager (Air Mail).
American Samoa	Service not yet available.	
Arizona	Consultation and Training, Arizona Division of Occupational Safety and Health, P.O. Box 19070, 1624 W. Adams, Phoenix, AZ 85005.	(602) 255-5795, Mr. Thomas Ramsey, Manager.
Arkansas	OSHA Consultation, Arkansas Department of Labor, 1022 High St., Little Rock, Ark. 72202.	(501) 371-2992, Mr. George Smith, Project Director.
California	CAL/OSHA Consultation Service, 2nd Floor, 525 Golden Gate Avenue, San Francisco, CA 94102.	(415) 557-2870, Mr. Emmett Jones, Chief.
Colorado	Occupational Safety & Health Section, Colorado State University, Institute of Rural Environmental Health, 110 Veterinary Science Building, Fort Collins, CO 80523.	(303) 491-6151, Dr. Roy M. Buchan, Project Director.
Connecticut	Division of Occupational Safety & Health, Connecticut Department of Labor, 200 Folly Brook Boulevard, Wethersfield, Conn. 06109.	(203) 566-4550, Mr. Leo Alex, Director.
Delaware	Delaware Department of Labor, Division of Industrial Affairs, 820 North French Street, 6th Floor, Wilmington, DE 19801.	(302) 571-3908, Mr. Bruno Salvadon, Director.
District of Columbia	Occupational Safety & Health Division, District of Columbia, Department Employment Services, Office of Labor Standards, 2900 Newton Street NE., Washington, DC 20018.	(202) 832-1230, Mr. Lorenzo M. White, Acting Associate Director.
Florida	Department of Labor & Employment Security, Bureau of Industrial Safety and Health, LaFayette Building, Room 204, 2551 Executive Center Circle West, Tallahassee, FL 32301.	(904) 488-3044, Mr. John C. Glenn, Administrator.
Georgia	Economic Development Division, Technology and Development Laboratory, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, GA 30332.	(404) 894-3806, Mr. William C. Howard, Assistant to Director, Mr. James Burson, Project Manager.
Guam	Department of Labor, Government of Guam, 23548 Guam Main Facility, Agana, Guam 96921.	(671) 772-6291, Joe R. San Agustin, Director.
Hawaii	Education and Information Branch, Division of Occupational Safety and Health, Suite 910, 677 Ala Moana, Honolulu, HI 96813.	(808) 548-2511, Mr. Don Alper, Manager (Air Mail).
Idaho	OSHA Onsite Consultation Program, Boise State University, Community and Environmental Health, 1910 University Drive, Boise, ID 83725.	(208) 385-3929, Dr. Eldon Edmundson, Director.
Illinois	Division of Industrial Services, Dept. of Commerce and Community Affairs, 310 S. Michigan Avenue, 10 Floor, Chicago, IL 60601.	(800) 972-4140/4216 (Toll-free in State), (312) 793-3270, Mr. Stan Czwenku, Assistant Director.
Iowa	Bureau of Labor, 307 E. Seventh Street, Des Moines, IA 50319.	(515) 281-3606, Mr. Allen J. Meier, Commissioner.
Indiana	Bureau of Safety, Education and Training, Indiana Division of Labor, 1013 State Office Building, Indianapolis, IN 46204.	(317) 633-5845, Mr. Harold Mills, Director.
Kansas	Kansas Dept. of Human Resources, 401 Topeka Ave., Topeka, KS 66603.	(913) 296-4086, Mr. Jerry Abbott, Secretary.
Kentucky	Education and Training, Occupational Safety and Health, Kentucky Department of Labor, 127 Building, 127 South, Frankfort, KY 40601.	(502) 564-6895, Mr. Larry Potter, Director.
Louisiana	No services available as yet (Pending FY 83).	
Maine	Division of Industrial Safety, Maine Dept. of Labor, Labor Station 45, State Office Building, Augusta, ME 04333.	(207) 289-3331, Mr. Lester Wood, Director.
Maryland	Consultation Services, Division of Labor & Industry, 501 St. Paul Place, Baltimore, Maryland 21202.	(301) 659-4210, Ms. Ileana O'Brien, Project Manager, 7(c)(1) Agreement.
Massachusetts	Division of Industrial Safety, Massachusetts Department of Labor and Industries, 100 Cambridge Street, Boston, MA 02202.	(617) 727-3567, Mr. Edward Noseworthy, Project Director.

OSHA ONSITE CONSULTATION PROJECT DIRECTORY—Continued

State	Office and address	Contact
Michigan (Health)	Special Programs Section, Division of Occupational Health, Michigan Dept. of Public Health, 3500 N. Logan, Lansing, MI 48909.	(517) 373-1410, Mr. Irving Davis, Chief.
Michigan (Safety)	Safety Education & Training Division Bureau of Safety and Regulation, Michigan Department of Labor, 7150 Harris Drive, Box 30015, Lansing, Michigan 48909.	(517) 322-1809, Mr. Alan Harvie, Chief.
Minnesota	Training and Education Unit, Department of Labor and Industry, 5th Floor, 444 Lafayette Road, St. Paul, MN 55101.	(612) 296-2973, Mr. Timothy Tierney, Project Manager.
Mississippi	Division of Occupational Safety and Health, Mississippi State Board of Health, P.O. Box 1700, Jackson, MS 39205.	(601) 982-6315, Mr. Henry L. Laird, Director.
Missouri	Missouri Department of Labor and Industrial Relations, 722 Jefferson Street, Jefferson City, MO 65101.	1-(800) 392-0208, (314) 751-3403, Ms. Paula Smith, Mr. Jim Brake.
Montana	Montana Bureau of Safety & Health, Division of Workers Compensation, 815 Front Street, Helena, MT 59601.	(406) 449-3402, Mr. Ed Gatzemeier, Chief.
Nebraska	Nebraska Department of Labor, State House Station, State Capitol, P.O. Box 94600, Lincoln, NB 68509.	475-6451 Ext. 258, Mr. Joseph Carroll, Commissioner.
Nevada	Department of Occupational Safety and Health, Nevada Industrial Commission, 515 E. Musser Street, Carson City, NV 89714.	(702) 885-5240, Mr. Allen Traenkner, Director.
New Hampshire	For information contact	Office of Consultation Programs, Room N3472 200 Constitution Avenue, NW. Washington, DC 20210, Phone: (202) 523-8985.
New Jersey	New Jersey Department of Labor and Industry Division of Work Place Standards, CN-054, Trenton, NJ 08625.	(609) 292-2313, FTS-8-477-2313, Mr. William Clark, Assistant Commissioner.
New Mexico	OSHA Consultation, Health and Environment Department, Environmental Improvement Division, Occupational Health & Safety Section, 4215 Montgomery Boulevard, NE., Albuquerque, NM 87109.	(505) 842-3387, Mr. Albert M. Stevens, Project Manager.
New York	Division of Safety and Health, New York State Department of Labor, 2 World Trade Center, Room 8995, New York, NY 10047.	(212) 488-7746/7, Mr. Joseph Alleva, Project Manager, DOSH.
North Carolina	Consultation Services, North Carolina Department of Labor, 4 West Edenton Street, Raleigh, NC 27601.	(919) 733-4885, Mr. David Pierce, Director.
North Dakota	Division of Environmental Research, Department of Health, Missouri Office Building, 1200 Missouri Avenue, Bismarck, ND 58505.	(701) 224-2348, Mr. Jay Crawford, Director.
Ohio	Department of Industrial Relations, Division of Onsite Consultation, P.O. Box 825, 2323 5th Avenue, Columbus, OH 43216.	(800) 282-1425 (Toll-free in State), (614) 466-7485, Mr. Andrew Doehrel, Project Manager.
Oklahoma	OSHA Division, Oklahoma Department of Labor, State Capitol, Suite 118, Oklahoma City, OK 73105.	(405) 521-2461, Mr. Charles W. McGlon, Director.
Oregon	Consultative Section, Department of Workers' Compensation, Accident Prevention Division, Room 102, Building 1, 2110 Front Street NE., Salem, OR 97310.	(503) 378-2890, Mr. Jack Buckland, Supervisor.
Pennsylvania	For information contact	Office of Consultation Programs, Room N3472, 200 Constitution Avenue NW., Washington, DC 20210, Phone: (202) 523-8985.
Puerto Rico	Occupational Safety & Health, Puerto Rico Department of Labor and Human Resources, 505 Munoz Rivera Ave., 21st Floor, Hato Rey, Puerto Rico 00919.	(809) 754-2134, Mr. John Cinque, Assistant Secretary, (Air Mail).
Rhode Island	Division of Occupational Health, Rhode Island Department of Health, The Cannon Building, 206 Health Department Building, Providence, RI 02903.	(401) 277-2438, Mr. James E. Hickey, Chief.

OSHA ONSITE CONSULTATION PROJECT DIRECTORY—Continued

State	Office and address	Contact
South Carolina	Consultation and Monitoring, South Carolina Department of Labor, P.O. Box 11329, Columbia, SC 29211.	(803) 758-8921, Mr. Robert Peck, Director, 7(c)(1), Project.
South Dakota	South Dakota Consultation Program, South Dakota State University, S.T.A.T.E.-Engineering Extension, 201 Pugsley Center-SDSO, Brookings, SD 57007.	(605) 688-4101, Mr. James Ceglian, Director.
Tennessee	OSHA Consultative Services, Tennessee Department of Labor, 2nd Floor, 501 Union Building, Nashville, TN 37219.	(615) 741-2793, Mr. L. H. Craig Director.
Texas	Division of Occupational Safety and State Safety Engineer, Texas Department of Health and Resources, 1100 West 49th Street, Austin, TX 78756.	(512) 458-7287, Mr. Walter G. Martin, P.E. Director.
Trust Territories	Service not yet available.	
Utah	Utah Job Safety and Health Consultation Service, Suite 4004, Crane Building, 307 West 200 South, Salt Lake City, UT 84101.	(801) 533-7927/8/9, Mr. H. M. Bergeson, Project Director.
Vermont	Division of Occupational Safety and Health, Vermont Department of Labor and Industry, 118 State Street, Montpelier, VT 05602.	(802) 828-2765, Mr. Robert Mcleod, Project Director.
Virginia	Department of Labor and Industry, P.O. Box 12064, 205 N. 4th Street, Richmond, Va. 23241.	(804) 786-5875, Mr. Robert Beard, Commissioner.
Virgin Islands	Division of Occupational Safety and Health, Virgin Islands Department of Labor, Lagoon Street, Room 207, Frederiksted, Virgin Islands 00840.	(809) 772-1315, Mr. Louis Llanos, Deputy Director-DOSH.
Washington	Department of Labor and Industry, P.O. Box 207, Olympia, WA 98504.	(206) 753-6500, Mr. James Sullivan, Assistant Director.
West Virginia	West Virginia Department of Labor, Room 451B, State Capitol, 1900 Washington Street, Charleston, WV 25305.	FTS 8-885-7890, Mr. Lawrence Barker, Commissioner.
Wisconsin (Health)	Section of Occupational Health, Department of Health and Social Services, P.O. Box 309, Madison, WI 53701.	(608) 266-0417, Ms. Patricia Natzke, Acting Chief.
Wisconsin (Safety)	Division of Safety and Buildings, Department of Industry, Labor and Human Relations, 1570 E. Moreland Blvd., Waukesha, WI 53186.	(414) 544-8686, Mr. Richard Michalski, Supervisor.
Wyoming	Wyoming Occupational Health and Safety Department, 200 East 8th Avenue, Cheyenne, Wyo. 82002.	(307) 777-7786, Mr. Donald Owsley, Health and Safety Administrator.

APPENDIX H TO § 1910.95—AVAILABILITY OF REFERENCED DOCUMENTS

Paragraphs (c) through (o) of 29 CFR 1910.95 and the accompanying appendices contain provisions which incorporate publications by reference. Generally, the publications provide criteria for instruments to be used in monitoring and audiometric testing. These criteria are intended to be mandatory when so indicated in the applicable paragraphs of § 1910.95 and appendices.

It should be noted that OSHA does not require that employers purchase a copy of the referenced publications. Employers, however, may desire to obtain a copy of the referenced publications for their own information.

The designation of the paragraph of the standard in which the referenced publications appear, the titles of the publications, and the availability of the publications are as follows:

Paragraph designation	Referenced publication	Available from—
Appendix B	"List of Personal Hearing Protectors and Attenuation Data," HEW Pub. No. 76-120, 1975. NTIS-PB267461.	National Technical Information Service, Port Royal Road, Springfield, VA 22161.
Appendix D	"Specification for Sound Level Meters," S1.4-1971 (R1976).	American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.
§ 1910.95(k)(2), appendix E	"Specifications for Audiometers," S3.6-1969.	American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

MEDICAL SURVEILLANCE
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MEDICAL SURVEILLANCE

1.0 PURPOSE

To establish medical surveillance requirements for both Brown & Root Environmental personnel and subcontractors performing site activities at hazardous waste sites. All Brown & Root medical procedures will be in compliance with the Brown & Root Medical Management Procedures.

2.0 REQUIREMENTS FOR BROWN & ROOT ENVIRONMENTAL PERSONNEL

All Brown & Root Environmental personnel participating in project field activities will have had a physical examination meeting the requirements of the Brown & Root Environmental medical surveillance program and will be medically qualified to perform hazardous waste site work using respiratory protection. All field personnel will be required to submit the Brown & Root Medical Questionnaire.

Documentation for medical clearances will be maintained in the Brown & Root Environmental Pittsburgh office and made available as necessary. The HSO will be responsible for determining any site-specific requirements in cooperation with the Brown & Root Medical Consulting Physician.

3.0 REQUIREMENTS FOR SUBCONTRACTORS

Subcontractors are required to obtain a certificate of their ability to perform hazardous waste site work and to wear respiratory protection. The "Subcontractor Medical Approval Form" (Attachment 5.1) can be used to satisfy this requirement providing it is properly completed and signed by a licensed physician.

Subcontractors who have a company medical surveillance program meeting the requirements of paragraph (f) of OSHA 29 CFR 1910.120 can substitute a letter, on company letterhead, containing all of the information in the example letter presented in Attachment 5.2. The OSHA Training Certification letter and Medical Surveillance letter may be combined into one letter.

4.0 REQUIREMENTS FOR ALL FIELD PERSONNEL

Each field team member (including subcontractors) shall be required to complete and submit a copy of Medical Data Sheet. These will be handed out and collected as part of the site-specific training. This shall

be provided to the FOL prior to participating in site activities. It will be the responsibility of the FOL to assure that all site personnel comply with the requirements of the medical surveillance procedures.

Medical surveillance letters may need to be prepared in some instances. This document is contract-specific, such as for Navy CLEAN (Northern and Southern Divisions). For these contracts, a clearance letter must be prepared by the contract HSM, and submitted to the Navy, prior to site mobilization. The purpose of the clearance letter is to certify to the Navy that all Brown & Root Environmental site personnel satisfy appropriate medical surveillance requirements.

5.0 ATTACHMENTS

5.1 Subcontractor Medical Approval Form

5.2 Medical Surveillance Letter

5.3 Medical Data Sheet and Field Team Review

5.4 Health Sciences Clearance Letter

5.5 Medical Questionnaire

ATTACHMENT 5.1

SUBCONTRACTOR MEDICAL APPROVAL FORM

For employees of _____
Company Name

Participant Name: _____ Date of Exam: _____

Part A

The above-named individual has:

1. Undergone a physical examination in accordance with OSHA Standard 29 CFR 1910.120, paragraph (f) and found to be medically -

   ( ) qualified to perform work at the __(identify specific hazardous waste site)__ work site
   ( ) not qualified to perform work at the __(identify specific hazardous waste site)__ work site

   and,

2. Undergone a physical examination as per OSHA 29 CFR 1910.134(b)(10) and found to be medically -

   ( ) qualified to wear respiratory protection
   ( ) not qualified to wear respiratory protection

My evaluation has been based on the following information, as provided to me by the employer.

( ) A copy of OSHA Standard 29 CFR 1910.120 and appendices.
( ) A description of the employee's duties as they relate to the employee's exposures.
( ) A list of known/suspected contaminants and their concentrations (if known).
( ) A description of any personal protective equipment used or to be used.
( ) Information from previous medical examinations of the employee which is not readily available to the examining physician.

Part B

I, _____, have examined _____
Physician's Name (print) Participant's Name (print)
and have determined the following information:

ATTACHMENT 5.1
SUBCONTRACTOR MEDICAL APPROVAL FORM
PAGE TWO

1. Results of the medical examination and tests (excluding finding or diagnoses unrelated to occupational exposure):

_____

_____

_____

2. Any detected medical conditions which would place the employee at increased risk of material impairment of the employee's health:

_____

_____

_____

3. Recommended limitations upon the employee's assigned work:

_____

_____

_____

_____

I have informed this participant of the results of this medical examination and any medical conditions which require further examination of treatment.

Based on the information provided to me, and in view of the activities and hazard potentials involved at the (indicate specific hazardous waste site) work site, this participant

( ) may
( ) may not

perform his/her assigned task.

Physician's Signature _____

Address _____

Phone Number _____

NOTE: Copies of test results are maintained and available at:

_____
Address

ATTACHMENT 5.2

MEDICAL SURVEILLANCE LETTER

The following statements must be typed on company letterhead and signed by an officer of he company:

LOGO
XYZ CORPORATION
555 E. 5th Street
Nowheresville, Kansas 55555

Month, day, year

Mr./Ms. _____
Project Manager
Brown & Root Environmental
Foster Plaza VII 661 Andersen Drive
Pittsburgh, Pennsylvania 15220

Subject: Medical Surveillance - (indicate specific hazardous waste site)

Dear Mr..Ms. _____,

As an officer of XYZ Corporation, I hereby state that the persons listed below participate in a medical surveillance program meeting the requirements contained in paragraph (f) of Title 29 of the Code of Federal Regulations (CFR), Part 1910.120 entitled "Hazardous Waste Operations and Emergency Response: Final Rule." I further state that the persons listed below have had physical examinations under this program within the past 12 months and that they have been cleared, by a licensed physician, to perform hazardous waste site work and to wear positive and negative pressure respiratory protection. I also state that, to my knowledge, no person listed below has any medical restriction that would preclude him/her from working at (indicate specific hazardous waste site).

LIST FULL NAMES OF EMPLOYEES AND THEIR SOCIAL SECURITY NUMBERS HERE

Should you have any questions, please contact me at (555) 555-5555.

Sincerely,

(Name of Company Officer)

ATTACHMENT 5.3

MEDICAL DATA SHEET AND FIELD TEAM REVIEW

This brief Medical Data Sheet will be completed by all onsite personnel and will be kept in the command post during the conduct of site operations. This data sheet will accompany any personnel when medical assistance is needed or if transport to hospital facilities is required.

Project _____

NameHome Telephone _____

Address _____

Age _____ Height_____ Weight_____

Name of Next of Kin _____

Drug or other Allergies _____

Particular Sensitivities _____

Do You Wear Contacts? _____

Provide a Checklist of Previous Illnesses or Exposure to Hazardous Chemicals. _____

_____

_____

_____

What medications are you presently using? _____

_____

_____

Do you have any medical restrictions? _____

_____

_____

Name, Address, and Phone Number of Personal Physician: _____

_____

_____

_____

_____

I am the individual described above. I have read and understand this HASP.

_____

Signature Date

ATTACHMENT 5.4

HEALTH SCIENCES CLEARANCE LETTER

C-49-3-6-203

Date

Project No. _____

Mr. _____
COTR/Lead Engineer in Charge
c/o Commanding Officer
Northern Division (Code 1432/RB)
Naval Facilities Engineering Command
10 Industrial Highway, MS #82
Lester, Pennsylvania 19113

Reference: CLEAN Contract No. N62472-90-D-1298
Contract Task Order No. ___

Subject: Personnel Clearance for Site Visit

Dear Mr. _____:

The purpose of this letter is to inform you of upcoming site activities to be performed by Brown & Root Environmental personnel under the CLEAN contract, and to attest that the personnel identified herein are in compliance with applicable OSHA regulations. This information is being submitted as specified in Section H.8 and H.9 of the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract N62472-90-D-1298. The specific OSHA regulations involved for this project pertain to employee health and safety training and medical surveillance requirements, as identified in OSHA 29 CFR 1910.120, and 1910.134.

The subject project and planned activities involve _____ at _____ site, located in _____. This is scheduled to begin on _____. The individuals that will perform these tasks are employees of Brown & Root Environmental. These individuals are as follows:

(List of people doing field work)

If you have any questions, concerns, or if I can be of further assistance, please do not hesitate to contact me.

Very truly yours,

Matthew M. Soltis, CIH, CSP
CLEAN Health and Safety Manager

MMS:lld

c: J. Trepanowski

ATTACHMENT 5.5

MEDICAL QUESTIONNAIRE

BROWN & ROOT *and Associated Companies*
MEDICAL QUESTIONNAIRE

• SHADED AREAS FOR OFFICE USE ONLY •

Exam Type: ☐ Pre-Placement ☐ Annual
☐ Site Specific ☐ Exit/Conclusion

OSHA Type of Medical Exam: _____

Authorization for Medical Exam:

PO _____ Ac _____ Received _____ Sent _____

Exam Location: _____

Manager Requested Exam: _____

Job Title _____ Job Number _____

SECTION A: DEMOGRAPHIC DATA

Date _____ Sex M F Age _____

Name _____
(Last) (First) (Middle)

SS# _____ - _____ - _____

Race ☐ Asian ☐ American Indian ☐ Black
☐ Caucasian ☐ Hispanic ☐ Other _____

Date of Birth ____ /____ /____ Telephone (____) _____

Home Address

_____

_____

City _____ State _____ Zip _____

With how many persons do you share living quarters? _____

Please list their occupations: _____ _____

_____ _____

Family Physician _____ Phone# _____

Address _____

_____

INSTRUCTIONS: PLEASE ANSWER THE FOLLOWING QUESTIONS AS COMPLETELY AND ACCURATELY AS YOU CAN.

SECTION B:

1. Have you ever worked for Brown & Root and Associated Companies before? ☐ YES ☐ NO

2. In the past 12 months or since you last filled out this form, have you had surgery, medical care by a doctor, or any change in your health? ☐ YES ☐ NO If YES, indicate that information here:

_____

SECTION C:

1. MEDICAL HISTORY (please check conditions you have had)

☐ Cancer - Please explain _____
☐ Diabetes ☐ Hepatitis (liver disease) ☐ Mental Illness
☐ Drug/Alcohol abuse ☐ High Blood Pressure ☐ Rheumatic Fever
☐ Epilepsy / Seizures ☐ Kidney Disease ☐ Stroke
None of above ☐

Do you consider yourself to be healthy? ____ If no, please explain: _____

_____

What medications do you take regularly? _____

List any hospitalizations, major illness or injuries, (include year) _____

_____

Date of last chest X-Ray _____ Where was it conducted? _____

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2. FAMILY HISTORY (please check any condition your family members have had)

☐ Anemia (low blood) ☐ Cancer ☐ High Blood Pressure
☐ Bleeding disorders ☐ Diabetes ☐ Leukemia
☐ Blood transfusions ☐ Heart trouble ☐ Sickle Cell Disease
None of above ☐

3. RESPIRATORY SYSTEM (please check conditions you have had)

☐ Allergies ☐ Coughing up phlegm ☐ Pneumonia
☐ Asthma ☐ Frequent Colds ☐ Severe sore throat
☐ Broken ribs ☐ Hay Fever ☐ Shortness of breath
☐ Bronchitis ☐ Heart Disease ☐ Spitting up blood
☐ Chronic cough ☐ Night Sweats ☐ Wheezing
None of above ☐

4. CHEST COLDS (please check all that apply)

☐ I had chest illnesses in the past year that kept me off work or in bed.
☐ If I get a cold, it usually goes to my chest.
☐ I produced phlegm with some of these chest illnesses.

5. BLOOD DISORDERS (please check if you have ever had)

☐ Anemia (low blood) ☐ Blood in stools
☐ Bleeding of gums ☐ Bruising (easier than normal)
☐ Blood transfusions (Why?) _____
☐ Hard to stop bleeding ☐ Sickle Cell Disease
☐ Leukemia ☐ Vomiting up blood
None of above ☐

6. CENTRAL NERVOUS SYSTEM (please check if you have ever had)

☐ Epilepsy / seizures / convulsions ☐ Frequent nervousness or irritability
☐ Excessive depression ☐ Head injury or unconsciousness
☐ Frequent dizziness ☐ Muscle weakness or paralysis
☐ Frequent headaches ☐ Numbness in arms / legs
None of above ☐

7. STOMACH / INTESTINAL TRACT (please check if you have ever had)

☐ Stomach pain ☐ Excess gas / bloating
☐ Black stools ☐ Stomach ulcer
☐ Blood in stools ☐ Rupture of hernia
☐ *Change in bowel habits* ☐ *Unexplained weight loss / gain*
☐ Chronic indigestion ☐ Vomiting / nausea
None of above ☐

8. KIDNEY / BLADDER (please check if you have ever had)

☐ Blood in urine ☐ Difficulty starting urination
☐ Hernia surgery ☐ Kidney / Bladder infections
☐ Kidney stones ☐ Pain with urination
None of above ☐

9. LIVER (please check if you have ever had)

☐ Cirrhosis ☐ Hepatitis ☐ Yellow jaundice ☐ Other liver diseases
My daily consumption of alcohol ___ oz beer ___ oz wine ___ oz liquor

10. HEART & CIRCULATORY (please check if you have ever had)

☐ Abnormal EKG ☐ Heart murmur
☐ Abnormal vein condition ☐ High blood pressure
☐ Chest pains ☐ Irregular or rapid heartbeat
☐ Enlarged heart ☐ Low blood sugar
☐ Heart attack / disease ☐ Stroke
☐ Heart / chest surgery ☐ Swelling of ankles
None of above ☐

11. MUSCULO-SKELETAL (please check if you have ever had)

☐ Arthritis / gout / rheumatism ☐ Joint swelling
☐ Back injury ☐ Knee problems
☐ Back pain ☐ Neck pain / whiplash
☐ Back Surgery ☐ Broken Bones
Where? When? _____
None of above ☐

12. SKIN (please check if you have ever had)

☐ Cracking / bleeding ☐ Skin allergies
☐ Itching / peeling ☐ Skin discolorations
☐ Mole / growth on skin ☐ Skin rashes
☐ Seen skin doctor? Explain: _____
None of above ☐

13. VISION / EYES (please check if you have ever had)

☐ Abnormal night vision ☐ Difficulty w/ depth perception
☐ Blurred vision ☐ Eye allergies or infections
☐ Burning / tearing / redness of eyes ☐ Eye Surgery
☐ Cataracts ☐ Glaucoma
☐ Worn glasses / contacts ☐ Color Blindness
☐ for reading? ☐ for distant vision?
None of above ☐

14. ALLERGIES

List any known allergies and type of reaction you develop _____

_____

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MEDICAL QUESTIONNAIRE
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15. TOBACCO SMOKING (Check all that apply)

☐ I smoke a pipe or cigar. How much?_____

☐ I smoke cigarettes. *(Regular smoker up to 1 month ago)*

☐ I smoke_____ cigarettes per day

☐ I smoked_____ years. (or did smoke if ex-smoker) _____

☐ I am an ex-cigarette smoker. (Record "yes" if ever smoked as much as 1 cigarette a day or 1 oz. of tobacco for as long as a year.)

If an ex-smoker, how long since you stopped?_____

I never smoked ☐

16. IMMUNIZATIONS / VACCINATIONS

Check if you have received any of the following with approximate dates.

☐ Polio ☐ Diphtheria ☐ Hepatitis

☐ Rubella (German Measles) ☐ Other_____ (Date)_____

☐ Tetanus (Date)_____ If uncertain of date of last tetanus vaccination, check if you had a booster shot within the last 10 years.

17. OCCUPATIONAL HISTORY

Current job title?_____

☐ In the past year, I worked at least 30 hours per week for 6 months or more.

☐ In the past year, I worked in a dusty job.

☐ In the past year, I was exposed to gas or chemical fumes in my work.

Please name them _____

In the past year, my job / occupation was _____

18. EXPOSURE HISTORY (please check "yes" if you have ever worked around or been exposed to)

YES	YES
☐ Chemical plant	☐ Mine
☐ Chemistry labs	☐ Nuclear industry
☐ Coke oven	☐ Paper mill
☐ Construction	☐ Pharmaceutical
☐ Cotton, flax or hemp mill	☐ Plastic production
☐ Electronics plant	☐ Pottery mill
☐ Farm	☐ Refinery
☐ Foundry	☐ Rubber processing plant
☐ Hazardous waste	☐ Sand pit / quarry
☐ Hospital	☐ Service station
☐ Lumber mill	☐ Ship yard
☐ Metal production	☐ Smelter

How may days have you worked with a respirator in actual field settings in the last year?_____

19. CHEMICAL EXPOSURE (please check if you have ever worked around or been exposed to)

☐ Acrylonitrile	☐ Lead
☐ Arsenic	☐ Loud / continuous noise
☐ Asbestos	☐ Mercury
☐ Benzene	☐ PCBs
☐ Cadmium	☐ Pesticides or herbicides
☐ DDT	☐ Phenols
☐ Dust, coal	☐ Phosgene
☐ Ethylene oxide	☐ Radioactive materials
☐ Extreme heat / cold	☐ Silica
☐ Formaldehyde	☐ Spray painting
☐ Other_____	☐ Vinyl chloride

20. HEARING / EARS (please check conditions that apply to you)

Hearing Loss in Family:

☐ Mother ☐ Sister(s) ☐ Daughter(s)

☐ Father ☐ Brother(s) ☐ Son(s) ☐ Yourself

None ☐

Diseases or Infections:

☐ Measles ☐ Mumps ☐ Scarlet Fever

☐ Diabetes ☐ Allergies ☐ High Blood Pressure

None ☐

Ear Problems and Symptoms:

☐ Draining Ears ☐ Ear Surgery ☐ Hearing Difficulty

☐ Ears Ringing ☐ Dizziness ☐ Ear Aches

None ☐

Injury to Head or Ears:

☐ Severe blow to head ☐ Skull Fracture ☐ Knocked Out

☐ Eardrum puncture ☐ Explosion or blast ☐ Auto Accident

☐ Flying or skydiving ☐ Diving Accident ☐ Other_____

None of above ☐

Non-Occupational Activity:

☐ Active Military Duty ☐ Private Flying

☐ Hunting / Shooting ☐ Loud music

☐ Home power tools ☐ Home tractor/lawn mower/machinery

☐ Power boat(s) ☐ Hair dryers

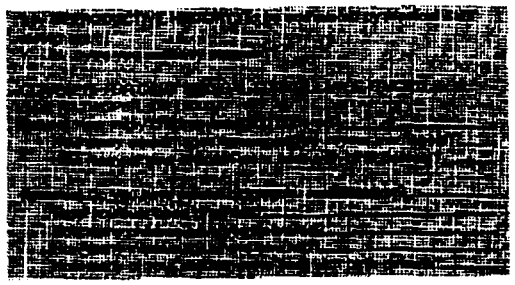
Current Symptoms - (Within the last 24 hours, I have:)

☐ Had ringing in my ears ☐ Had a cold, flu, or sinus condition

☐ Had an earache ☐ Been exposed to loud noise without hearing protection

☐ Taken any medications

None of above ☐



SECTION D:

I certify that the foregoing statements are true to the best of my knowledge. I understand that leaving out or misrepresenting the facts called for in this questionnaire may be the cause for refusal of employment or termination from the company. I hereby authorize the company to investigate the facts claimed by me on this questionnaire.

I hereby grant permission to the examining medical personnel and/or physician to disclose any information herein and hereinafter furnished by me, to authorized company personnel for purposes related to my employment at Brown & Root, Inc., and Associated Companies, and to legal entities requiring such information.

I understand that the pre-placement physical examination given to me is only intended to obtain information for employment purposes of Brown & Root, Inc., and Associated Companies. It is not a physical examination of the type given by a physician to assess the state of my health and it may not be relied upon by me for that purpose. I must look to my personal physician for such an assessment.

I understand that the medical surveillance test given to me is intended to identify specific instances of illness or health trends suggesting an adverse effect of workplace exposures.

I understand that the examining physician / medical staff and the Brown & Root Medical Surveillance Department will disclose, in writing, to me and appropriate Brown & Root, Inc. safety and health personnel any findings which, in the physician's opinion, indicate any adverse effect of occupational exposure or pre-existing physical condition which precludes exposure to specific toxic materials or physical hazards.

_____
Signature

_____
Date

PERSONAL PROTECTIVE EQUIPMENT (PPE)
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PERSONAL PROTECTIVE EQUIPMENT (PPE)

1.0 PURPOSE

This section presents requirements for the use of personal protective equipment for each of the activities being conducted as part of hazardous waste operations. This section includes the types and levels of personal protective equipment, the criteria used for selecting various levels of protection, and criteria for modifying levels of protection based on monitoring instrument readings and personal observations.

2.0 SCOPE

This section applies to all Brown & Root Environmental personnel and subcontractors participating in hazardous waste operations.

3.0 PERSONAL PROTECTIVE EQUIPMENT (PPE) OBJECTIVES

Hazardous waste operations require the use of personal protective equipment to adequately protect personnel from exposure to site contaminants that cannot be controlled through engineering or administrative controls. Many of the physical hazards associated with hazardous waste operations can be controlled or minimized with the use of PPE. Most hazardous waste operations in which Brown & Root Environmental is involved requires the use of level B, C, and D protection. Levels of protection are defined in Appendix B of OSHA Standard 29 CFR 1910.120 - "Hazardous Waste Operations and Emergency Response." and are provided in this document. The site specific HASP addresses specific PPE requirements for each task associated with the scope of work. In addition, criteria for upgrading and downgrading levels of protection based on air monitoring results are discussed in the site specific HASP.

3.1 Levels of Protection

The type and amount of protection required are usually expressed in levels. These levels are based on the hazard present, and the chemical concentration encountered on site. The four levels of protection, as defined by OSHA, range from Level A, the highest level to Level D, the lowest.

This information is presented as a guide to choosing personal protective equipment. The selection of PPE is a complicated process which should take into consideration a variety of factors. These factors are:

- Identification of the hazards
- Potential route(s) of exposure (inhalation and/or dermal)
- Performances
- Work requirements
- Durability of PPE material
- Physical and heat stress
- Knowledge of the hazard

In some circumstances, equipment from the various levels may be combined to provide the most appropriate protection against the hazards encountered.

3.1.1 Level D

This level is normal work attire and provides only minimal protection. Level D is not sufficient if chemical hazards are present.

- Coveralls or work clothes
- Steel-toed/shank boots
- Safety glasses with side shields or goggles
- Hard hat
- Work gloves
- Escape respirator[1]

3.1.2 Level C

Can be worn when the type(s) of airborne substance(s) is known, the concentration(s) is measured, and other criteria for using air-purifying respirators are met. Level C equipment includes:

- Full-face, air-purifying respirator such as our chin canister (MSHA/NIOSH approved).

- Chemical-resistant clothing (one-piece coverall; hooded, two-piece; chemical splash suit; chemical-resistant hood and apron, disposable, chemical-resistant coveralls).

- Boots, steel toe and shank, chemical resistant.

---

[1]Optional

- Boots, outer, chemical resistant (disposable).*
- Gloves, outer, chemical resistant.
- Gloves, inner, chemical resistant.
- Hard hat.
- Cloth coveralls (inside chemical protective clothing).[1]
- Depending on the job, there may be a need for two-way radio communications (intrinsically safe).[1]
- Escape respirator.[1]

Level C protection should only be used when the following criteria are met:

- Oxygen concentration is greater than 19.5 percent.
- Contaminants have adequate warning properties such as odor (alerting wearer to the presence of the contaminant).
- Canisters are available to remove the contaminants.
- The IDLH (immediately dangerous to life or health) concentrations are not exceeded.
- Contaminant and concentration are identified.
- No excessive fire/explosion hazard exists.

3.1.3 Level B

Can be worn when the highest level of respiratory protection is needed, but a lesser level of skin protection is required. OSHA requires that the minimum level for entry into an unknown situation is Level B protection. Level B protection is the minimum level required on initial site entries until the hazards have been further defined by onsite studies. The Incident Commander may then downgrade or upgrade the level of protection, depending upon the results. Level B PPE equipment includes:

---

[1]Optional

- Positive-pressure (pressure demand), self contained breathing apparatus (MSHA/NIOSH approved), or airline-supplied respirator with an escape SCBA.

- Chemical-resistant clothing, coveralls; hooded, two-piece, chemical splash suit; disposable chemical-resistant coveralls).

- Coveralls (under chemical resistant clothing).[1]

- Gloves, outer, chemical resistant.

- Gloves, inner, chemical resistant.

- Boots, chemical resistant, steel-toed and shank.

- Boot covers disposable.[1]

- Hard hat.

Level B protection should only be selected when the following criteria are met:

- The environment identified presents a higher respiratory hazard (above the IDLH or the oxygen concentration is below 19.5 percent) but not a severe skin hazard.

- A fire/explosion hazard exists or is possible.

- The airborne contaminant concentrations or conditions exceed the criteria for wearing an air-purifying respirator (APR).

- The contaminant is incompletely identified.

- OSHA-recommended minimum level for entry into an unknown situation.

---

[1]Optional

3.1.4 Level A

Must be worn when the highest level of respiratory, skin, and eye protection is needed. This includes the following:

- Positive-pressure (pressure demand), self contained breathing apparatus (MSHA/NIOSH approved).
- Fully encapsulating, chemical-resistant suit.
- Gloves, inner, chemical resistant.
- Gloves, outer, chemical resistant.
- Boots, chemical resistant, steel toe and shank; (depending on suit boot construction, worn over or under suit boot).
- Underwear, cotton, long-john type.[1]
- Hard hat (under suit).[1]
- Cooling unit.
- Coveralls (under suit).[1]
- Disposal boot cover.
- Two-way radio communications (intrinsically safe).

Level A protection will be used when:

- The hazardous substance has been identified and requires the highest level of protection.
- There are confined areas with poor ventilation which also present dermal exposure potentials.
- Existence or potential for high atmospheric concentration of gases, vapors, or particulates.

---

[1]Optional

- The work function requires it.
- There is an unidentified, suspicious risk requiring Level A protection.

In addition to specifying the level of protection, OSHA 29 CFR 1910.120 also addresses the testing procedure that totally encapsulating suits must pass before being used. The type of material used is also important, since there are no universal materials resistant against all chemicals. Protective clothing must be chosen using compatibility charts supplied by the manufacturer.

Note: Optional equipment may be required based on the hazard founds and the site characterization.

3.2 Styles of Protective Clothing

Three types of protective clothing are used to protect the skin surface from hazardous materials.

3.2.1 Fully Encapsulating Suit

- One-piece garment.
- Completely encloses the wearer.
- Vapor-proof (sealed so as to preclude the admission of harmful vapors or liquids into the suit).
- SCBA or airline respirator is used.
- Air must maintain a positive pressure within the suit.

3.2.2 Nonencapsulating Suit

- Two types:
  - One-piece coverall.
  - Two-piece pants and coat.
- Optional hood and other accessories.
- No face shield (does not encapsulate).
- Used when dermal threat is less hazardous.

3.2.3 Single-Use Garment

- Disposable.
- Decontamination is made easier (garment is disposed).

- Garment will withstand the demands of rigorous use.
- Use is dependent on type of contaminant and the concentration.

3.3 Protective Clothing Materials

In addition to the types of suits available, protective clothing is made of various materials. These materials are classified as either elastomers or nonelastomers.

3.3.1 Elastomers

Are defined as materials with the ability to be stretched to twice their original length and to retract (rapidly) to their original length. Examples include the following:

- Natural Rubber - Polyisoprene obtained from rubber plants. A highly flexible and conforming material used principally for gloves. High elasticity. Used for bases, alcohols, dilute acids. Poor for hydrocarbons.

- Butyl Rubber - Copolymer of isobutylene and a small amount of isoprene. Material has good resistance to weathering and a wide variety of chemicals. Both supported and unsupported forms of butyl rubber are used as protective clothing. Poor for halogenated hydrocarbons.

- Polyethylene - A fairly chemically resistant material that is used as a freestanding film (e.g., apron) or a fabric coating. Low-density polyethylene is the most common form used in protective clothing. Good for acids and bases. Poor for organic solvents, halogenated chemicals, hydrocarbons.

- Polyvinyl Chloride - A staff polymer that is made suitable for protective clothing applications by the addition of plasticizers. Used as a freestanding material for gloves, aprons, etc., as well as coatings for fabrics. Clear forms are also available as flexible face shields. Good for acids, bases, and some organics.

- Neoprene - Polychloroprene. A synthetic rubber having chemical and wear-resistance properties that are generally superior to those of natural rubber.

- Viton - A proprietary fluoroelastomer. Highly chemically resistant, but expensive synthetic elastomer. Good for crude oil, gasoline.

- Nitrile - Available in a wide range of acrylonitrile concentrations. Good for petroleum products and many acids.

- Polyvinyl Alcohol - A water-soluble polymer that, as long as it is dry, exhibits exceptional resistance to many organic solvents that rapidly permeate most rubbers. The material is somewhat stiff; thus dexterity is limited. PVA will break down when it contacts water (H_2O).

- Blends/Mixtures - Many materials are blended or mixed together. This blending increases the clothing's ability to resist the chemical. Check specific clothing available at your site to determine whether it is a blend, and which chemicals it resists.

- Laminated/Multilayer - Offers a wider range of protection to different contaminants. Some gloves are constructed of multiple layers of different materials. This gives them resistance to a wider variety of chemical classes. There is no "universal" material good for all compounds, but this type of PPE comes the closest.

3.3.2 Nonelastomers

Defined as materials without the ability to stretch and retract to their original shape. Examples include the following:

- Leather - Used for firefighting; cannot be cleaned and is readily penetrated.

- Nomex - Used for firefighting and as a filler for chemical-resistant suits. It is readily penetrated and is flame retardant.

- Gortex - A Teflon material which allows air and moisture to move through material but not water. (This reduces heat buildup.)

- Tyvek - A Du Pont product which is an excellent barrier to many dry particulates. This fabric is inexpensive, durable, and disposable; but offers poor protection against liquid chemicals. Coated Tyveks offers protection for a wide range of chemicals such as acids, and other liquid chemicals.

- Saranex - Is also a Du Pont product. It is a saran-coated Tyvek (as in Saran Wrap) and offers good protection for many substances.

There are many brands and types of protective clothing for the specific chemical that will be encountered.

3.4 Performance Requirements for Chemical Protective Clothing (CPC)

3.4.1 Primary Performance Requirements

When choosing chemical protective clothing, check the material's chemical resistance which will determine the garment's integrity.

Chemical Resistance

Chemical Resistance is defined as: "The ability of a material to withstand chemical and physical change to a chemical and block exposure caused by penetration, degradation, and permeation." A material's chemical resistance is the most important performance requirement. The suit must maintain its structural integrity and protective qualities upon contact with a hazardous substance. Chemical resistance is determined by the following factors:

- Penetration

  - Process of chemical transport through openings in a garment.
  - May be due to design or garment imperfections.
  - May be due to rips, tears, punctures, or abrasions to the garment.

- Degradation

  - Chemical action involving molecular breakdown of the material due to chemical contact.
  - Causes physical changes to the material.

- Permeation

  Permeation of a liquid or vapor through a rubber or plastic material is a three-step process involving:

  (1) The sorption of the chemical at the outside surface of the Chemical Protective Clothing (CPC).

(2) The diffusion of the chemical through the CPC material.

(3) The desorption of the chemical from the inside surface (i.e., toward the wearer) of the CPC.

- Permeation Occurrence

  -- Permeation rate

  Permeation rate is expressed in terms of the amount of a chemical which passes through a given area of clothing per unit of time. (Common units are micrograms per square centimeter per minute.) Thus, obviously, the total amount of chemical permeating an article of clothing increases as the area exposed to the chemical is increased and also as the duration of exposure is lengthened. For a given chemical/material pair, the permeation rate decreases as the material's thickness is increased.

  -- Permeation influences

  Permeation is influenced by:

  --- Construction of the material.
  --- Thickness of the material.
  --- Chemical substance the garment is exposed to.
  --- Concentration of chemical.
  --- Temperature.
  --- Contact time.

Included at the end of this section is a permeation chart to show you how PPE is selected.

- Work Function

The choice of protective clothing will be greatly influenced by the type of work that is being performed.

3.4.2 Additional Performance Requirements for Chemical Protective Clothing

Durability

The ability to withstand wear; the ability to resist punctures, abrasions, and tears; the material's inherent strength.

Flexibility

The ease to move and work in protective clothing. This has a direct impact on the worker's mobility and agility.

Temperature Resistance

The ability of a material to maintain its chemical resistance during temperature extremes and to remain flexible in cold weather.

Service Life

The ability of a material to resist aging and deterioration.

Cleanability

The ability of a material to be effectively decontaminated.

Design

The way the suit is constructed.

Size

The physical dimensions or proportions of clothing, which are directly related to comfort and which influence the number of unnecessary accidents.

Color

Brightly colored suit materials make it easier to maintain visual contact between personnel.

3.4.3 Physical Limitations

Wearing chemical protective clothing can cause severe problems. These involve heat stress, accidents, and physical exertion. Physical limitations can include:

- Heat stress - Caused by protective clothing interfering with the body's ability to cool itself. Clothing that provides a barrier against chemicals contacting the skin, unfortunately, also prevents the efficient dissipation of body heat. Evaporation, the body's primary cooling mechanism, is reduced, since ambient air is not in contact with the skin's surface.

- Accidents - Increases when wearing chemical-protective clothing. Suits are heavy, cumbersome, decrease mobility and dexterity, lessen visual and audio keenness, and increase physical exertion. The severity of the problems depends on the style of clothing worn. These negative qualities increase the risk of common accidental injury; for example, slips, falls, or being struck.

- Physical exertion - Working in protective clothing can in itself cause problems. Worker performance may decrease due to increased fatigue levels. Other more serious illnesses, such as stroke or heart attack, could occur.

5th Edition

Important "Right-To-Know" Information
Use this Guide to select gloves and protective clothing and prepare MSDS in accordance with OSHA's Hazard Communication Standard.

Ansell Edmont Chemical Resistance Guide

With new Permeation Information & Degradation Data

In November 1980, Edmont published the first version of *A Preliminary Guide to Permeation Resistance* for its products, which was the first such document available from any manufacturer. In the ten years since then, the *Guide* has been repeatedly expanded, updated and revised. The edition you're now holding is the first to come from the merged Ansell Edmont organization, and is still the best and most complete document of its kind available from any manufacturer. Data on natural rubber gloves has been revised in this edition to reflect the merger of Ansell and Edmont, and data on PVA™ gloves has been revised to reflect recent improvements in the materials used to make these gloves.

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Ansell Edmont
Industrial
One Company. One Source.
One Commitment to Quality and Performance.

When selecting gloves and clothing to help protect workers from the harmful effects of toxic, corrosive or other hazardous liquid chemicals, there are several performance factors to consider. One of those is *permeation* resistance, and Ansell Edmont has long been a driving force in the development of permeation data. As a result of increased demand for this data, an official American Society for Testing and Materials (ASTM) permeation test standard has been established. Ansell Edmont was the *first* glove and protective clothing manufacturer to work with ASTM, and to conduct tests on its own line over a broad range of chemicals using the ASTM standards.

Not only is Ansell Edmont the industry leader in developing and communicating permeation data, but also the innovative leader in the design and manufacture of high quality safety apparel, including the broadest line of chemical-resistant gloves in the industry. Ansell Edmont products such as SOL-VEX®, Supported PVA™ and neoprene help provide excellent resistance to hazardous chemicals, especially many of the aromatic, chlorinated and petroleum solvents and strong oxidizing acids.

Keep in mind that permeation tests are conducted under laboratory conditions, and that actual workplace conditions usually dictate a *combination* of performance capabilities. A product's resistance to cuts, snags, abrasion, punctures or tears must also be taken into consideration as a critical usage factor. A glove or article of clothing with excellent permeation resistance can be worthless if it tears or punctures easily. ONCE THE PROTECTIVE FILM HAS BEEN DAMAGED, YOU ARE DEALING WITH *PENETRATION* AND ARE NO LONGER CONCERNED WITH THE ISSUE OF PERMEATION, AND YOU SHOULD NOT USE THE DAMAGED GLOVE WITH HAZARDOUS CHEMICALS.

Ansell Edmont's complete line of gloves and protective clothing is manufactured in a broad range of special compounds and materials to help provide protection from hazardous chemicals, as well as cuts, abrasion, snags and punctures.

The results of Ansell Edmont ASTM standard permeation tests are provided on the following pages to complement current Ansell Edmont degradation data, and serve as an aid in determining the general suitability of various Ansell Edmont products for use with specific chemicals. HOWEVER, YOU MUST CONDUCT YOUR OWN EVALUATIONS TO DETERMINE THE CRITICAL COMBINATION OF PERMEATION AND DEGRADATION RESISTANCE IN YOUR PARTICULAR APPLICATIONS AND CONDITIONS.

PVC
Polyvinyl Chloride

Neoprene Unsupported

Natural Rubber

Neox®
Neoprene Supported

Sol-Vex®

PVA™

What are the differences in effects hazardous chemicals have on protective gloves and clothing?

First of all, the effects are categorized as penetration, degradation and permeation.

Penetration is the flow of a chemical through zippers, stitched seams, pores or imperfections in the material. In selecting chemical-resistant clothing, it is important to choose styles that are designed to resist penetration in these critical areas. Gloves and clothing which can be penetrated are designed only to prevent cuts, abrasions, thermal burns and other similar hazards, and are not suitable for use with hazardous chemicals.

Degradation is a reduction in one or more physical properties of a glove or protective clothing material due to contact with a chemical. Exposed products may get harder, stiffer and brittle, or they may get softer, weaker and swell to several times their original size. Although degradation resistance testing alone is not enough, it is essential to worker safety.

Permeation is a process by which a chemical can pass through a protective film without going through pinholes, pores or other visible openings. Individual molecules of the chemical enter the film, figuratively squirm through by passing between the film molecules, and leave the film on the other side. In some cases, the permeated material appears unchanged to the human eye.

Chemical permeation can be described in simple terms by comparing it to what happens to the air in an inflated balloon after several hours. Although there are no holes or defects and the balloon is tightly sealed, the air gradually goes through (permeates) its walls and escapes. In this simple example we are using gas permeation, but the principle is the same with liquids, passing through some type of film or coating by liquid permeation.

Why is Permeation testing important?

It provides an extra measure of safety information for hazardous chemical applications. For many years, the selection of protective gloves and clothing for those applications was commonly based on degradation data alone, but some chemicals will permeate rapidly through certain materials which have acceptable degradation resistance. This means that workers may be exposed even when they believe they are adequately protected.

Degradation data is also essential.

Current Ansell Edmont degradation data on specific products tested has also been included in these charts for comparison. The Degradation Guide for Ansell Edmont products also appears in our current catalog. Any samples rated "Poor" or "Not Recommended" in degradation testing were not tested for permeation resistance. It should be noted that permeation and degradation do not always correlate.

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How to Read the Charts

Three categories of data are represented for each Ansell Edmont product and corresponding chemical: (1) overall degradation resistance rating; (2) permeation breakthrough time, and (3) permeation rate.

The breakthrough times indicated are the shortest times observed from the start of the test to first detection of the chemical on the other side of the sample. They represent how long an article of clothing or a glove can be expected to provide the most effective resistance against a hazardous event.

The permeation rates for our data table were the highest flow rates recorded for the permeating chemicals through the protective films during a six-hour test. These qualitative ratings are comparisons of permeation rates to each other.

Standards for Color Coding in the Fifth Edition of the Guide

A glove-solvent combination ranks **GREEN** if: The degradation rating is Excellent or Good; the permeation breakthrough is 30 minutes or longer, and; the permeation rate is Excellent, Very Good or Good.

Where the necessary data is available, all three of these conditions must be fulfilled to assign a **GREEN** rating. However, if data required to test for all three conditions is not available, as for example, in testing acids and bases, professional judgment was used to determine the rating.

A glove-solvent combination rates **RED** if: the degradation rating is Poor or Not Recommended...regardless of the permeation rating.

All other glove-solvent combinations rate **YELLOW.** In other words, any glove-solvent combination that does not meet all three of the conditions required for a **GREEN** rating or does not have a degradation rating of Poor or Not Recommended for a **RED** rating, will receive a **YELLOW** rating.

Key to Permeation Rate	Simply Stated Drops Per Hour Through A Glove (Eyedropper size drop)
ND—None Detected during a six-hour test (Equivalent to Excellent)	None
E—Excellent; permeation rate of less than 0.9 $\mu g/cm^2/min$.	0 to 1/2 drop
VG—Very Good; permeation rate of less than 9 $\mu g/cm^2/min$.	1 to 5 drops
G—Good; permeation rate of less than 90 $\mu g/cm^2/min$.	6 to 50 drops
F—Fair; permeation rate of less than 900 $\mu g/cm^2/min$.	51 to 500 drops
P—Poor; permeation rate of less than 9000 $\mu g/cm^2/min$.	501 to 5000 drops
NR—Not Recommended; permeation rate greater than 9000 $\mu g/cm^2/min$.	5001 drops up

Note: The current revision to the ASTM standard permeation test calls for permeation to be reported in micrograms of chemical permeated per square centimeter of garment exposed per minute of exposure, "$\mu g/cm^2/min$."

Key to Permeation Breakthrough

>Greater than (time) <Less than (time)

Key to Degradation Ratings:

E—Excellent; fluid has very little degrading effect.
G—Good; fluid has minor degrading effect.
F—Fair; fluid has moderate degrading effect.
P—Poor; fluid has pronounced degrading effect.
NR—Fluid is *not recommended* with this material.

NOTE: ANY TEST SAMPLES RATED P (POOR) OR NR (NOT RECOMMENDED) IN DEGRADATION TESTING WERE NOT TESTED FOR PERMEATION RESISTANCE. A DASH (—) APPEARS IN THOSE CASES.

Specific gloves used for testing:	Degradation	Permeation
Nitrile NBR	Sol-Vex® 37-145 (11 mil/0.28 mm)	Sol-Vex® 37-165 (22 mil/0.54 mm)
Neoprene Unsupported	29-840 (15 mil/0.38 mm)	29-840 (15 mil/0.38 mm)
Neoprene Supported	Neox®	Neox®
PVA™ Supported	PVA™	PVA™
PVC	Snorkel® and Ever-Flex™	Monkey Grip™
Natural Rubber	392 (19 mil/0.48 mm)	392 (19 mil/0.48 mm)

Single palm thickness is listed in both mil and metric millimeter (mm) for Unsupported Gloves. Supported Gloves are specified by glove weight, *not* thickness.

Ansell Edmont Chemical Resistant Gloves

Natural Rubber**	•FL200/FL400
Natural Rubber	•Orange Heavyweight
Natural Rubber	•OMNI®
Natural Rubber	•Chemi-Pro®
Natural Rubber	•PVL®
Natural Rubber	•Natural Blue
Natural Rubber	•Canners and Handlers
Natural Rubber	•Technicians
Natural Rubber	•Tan Rubber
Natural Rubber	•Grab-It® (Chemical Resistant Style)
Natural Rubber	•Surgical Gloves
Natural Rubber	•Premium White Rubber
Natural Rubber	•Conform®
Neoprene	•Neoprene
Neoprene	•Scorpio®
Neoprene	•Neox®
Neoprene	•Redmont™
PVC	•Grappler® (Chemical Resistant Style)
PVC	•Snorkel®
PVC	•Ever-Flex™
PVC	•Ever-Flex Fireball™
PVC	•Monkey Grip™
PVC	•Winter Monkey Grip™ (Up to Knitwrist)
PVC	•Winter Fireball™ (Up to Knitwrist)
PVA™	•PVA™ (Caution: Coating is water sensitive)
NBR	•Sol-Vex® Nitrile

**"Rubber" here refers to Natural Rubber Latex

In general, thicker chemical resistant gloves may help provide greater protection than thinner gloves.

Why is a product with a shorter breakthrough time sometimes given a better rating than one with a longer breakthrough time?

One glove has a breakthrough time of just 4 minutes. It is rated "very good" while another with a breakthrough time of 30 minutes is rated only "fair." Why? Because in some cases, the rate is more significant than the time. In principle it's similar to liquids flowing through two different faucets. In one the liquid gets to the valve fast but the valve is only open a fraction of a turn, allowing only a trickle to flow through. In the other, the liquid gets to the valve slowly but the valve is closed so the liquid backs up. Suddenly, the valve is opened and the liquid gushes out. Although the former starts earlier, the latter emits more liquid once it starts. Which is better? It all depends on the chemical, the application, and how the glove or clothing is used.

The first square in each column for each glove type is color coded. This is an easy-to-read indication of how we rate this type of glove in relation to its applicability for each chemical listed. The color represents an overall rating for both degradation and permeation. The letter in each square is for Degradation alone...

GREEN: The glove is very well suited for application with that chemical.

YELLOW: The glove is suitable for that application under careful control of its use.

RED: Avoid use of the glove with this chemical.

Permeation/Degradation Resistance Guide for Ansell Edmont Gloves

	SOL-VEX® NITRILE NBR			NEOPRENE UNSUPPORTED			NEOX® SUPPORTED NEOPRENE			PVA™ SUPPORTED POLYVINYL ALCOHOL			POLYVINYL CHLORIDE PVC			NATURAL RUBBER		
	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate
1. Acetaldehyde	P	—	—	E	10min.	P	E	17min.	P	NR	—	—	NR	—	—	E	7min.	F
2. Acetic Acid, Glacial	G	4½hr.	—	E	7hr.	—	E	>6hr.	—	NR	—	—	F	3hr.	—	E	1⅙hr.	—
3. Acetone	NR	—	—	G	5min.	F	G	10min.	F	P	—	—	NR	—	—	E	10min.	F
4. Acetonitrile	F	30min.	F	E	30min.	VG	E	1½hr.	E	—	2½hr	G	NR	—	—	E	4min.	VG
5. Acrylic Acid	G	2hr.	—	G	1⅙hr.	—	F	ND	E	NR	—	—	NR	—	—	E	1⅓hr.	—
6. Ammonium Fluoride, 40%	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	ND	—	E	ND	—
7. Ammonium Hydroxide, Conc.	E	ND	—	E	>6hr.	—	E	>6hr.	—	NR	—	—	E	4hr.	—	E	1½hr.	—
8. Amyl Acetate	E	60min.	G	NR	—	—	NR	—	—	G	ND	E	P	—	—	NR	—	—
9. Amyl Alcohol	E	30min.	E	E	>6hr.	E	E	ND	E	G	3hr.	G	G	12min.	E	E	25min.	VG
10. Aniline	NR	—	—	G	35min.	VG	G	3hr.	VG	F	ND	E	F	3hr.	VG	E	25min.	VG
11. Aqua Regia	F	ND	—	G	45min.	—	G	ND	—	NR	—	—	G	2hr.	—	NR	—	—
12. Benzaldehyde	NR	—	—	NR	—	—	NR	—	—	G	ND	E	NR	—	—	G	10min.	VG
13. Benzene, Benzol	P	—	—	NR	—	—	NR	—	—	E	ND	E	NR	—	—	NR	—	—
14. Bromopropionic Acid	F	2hr.	—	G	3hr.	—	G	4hr.	—	NR	—	—	G	3hr.	—	E	3⅛hr.	—
15. Butyl Acetate	F	1¼hr.	F	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
16. Butyl Alcohol	E	ND	E	E	4hr.	VG	E	>8hr.	E	F	1¼hr.	G	G	3hr.	VG	E	20min.	VG
17. Butyl Cellosolve®	E	1½hr.	VG	E	1½hr.	VG	E	ND	E	—	2hr.	G	P	—	—	E	45min.	G
18. γ-Butyrolactone	NR	—	—	E	10min.	VG	G	—	—	E	2hr.	VG	NR	—	—	E	60min.	G
19. Carbon Disulfide	G	30min.	F	NR	—	—	NR	—	—	E	ND	E	NR	—	—	NR	—	—
20. Carbon Tetrachloride	G	2½hr.	G	NR	—	—	NR	—	—	E	ND	E	F	25min.	F	NR	—	—
21. Cellosolve® Acetate	F	1½hr.	G	F	25min.	G	G	1¼hr.	VG	—	ND	E	NR	—	—	E	10min.	G
22. Cellosolve® Solvent	G	3½hr.	G	E	45min.	E	E	4hr.	E	—	1¼hr.	G	P	—	—	E	25min.	VG
23. Chlorobenzene	NR	—	—	NR	—	—	NR	—	—	E	ND	E	NR	—	—	NR	—	—
24. Chloroform	NR	—	—	NR	—	—	NR	—	—	E	ND	E	NR	—	—	NR	—	—
25. Chloronaphthalene	P	—	—	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
26. Chlorothene® VG	F	1½hr.	P	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
27. Chromic Acid, 50%	F	4hr.	—	NR	—	—	NR	—	—	NR	—	—	G	ND	—	NR	—	—
28. Citric Acid, 10%	E	ND	—	E	ND	—	E	ND	—	F	50min.	—	E	ND	—	E	ND	—
29. Cyclohexanol	E	ND	E	E	2½hr.	VG	E	3hr.	E	G	ND	E	E	6hr.	E	E	10min.	G
30. Diacetone Alcohol	G	4hr.	E	E	5hr.	E	E	ND	E	—	2½hr.	G	NR	—	—	E	15min.	VG
31. Dibutyl Phthalate	G	ND	E	F	2hr.	E	F	5hr.	VG	E	ND	E	NR	—	—	E	20min.	—
32. Diethylamine	F	45min.	F	P	—	—	P	—	—	NR	—	—	NR	—	—	NR	—	—
33. Di-Isobutyl Ketone, DIBK	E	2hr.	F	P	—	—	P	—	—	G	ND	E	P	—	—	P	—	—
34. Dimethyl Acetamide, DMAC	NR	—	—	NR	—	—	NR	—	—	NR	—	—	NR	—	—	E	15min.	G
35. Dimethyl Formamide, DMF	NR	—	—	G	10min.	G	G	1hr.	G	NR	—	—	NR	—	—	E	25min.	VG
36. Dimethyl Sulfoxide, DMSO	E	>4hr.	VG	E	ND	E	E	>3hr.	G	NR	—	—	NR	—	—	E	3hr.	E
37. Dioctyl Phthalate, DOP	G	>6hr.	E	G	>6hr.	E	G	2hr.	E	E	30min.	F	NR	—	—	P	—	—
38. Dioxane	NR	—	—	NR	—	—	NR	—	—	P	—	—	NR	—	—	F	5min.	F
39. Electroless Copper (MacDermid® 9048)	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	ND	—	E	ND	—
40. Electroless Nickel (MacDermid® J60/61)	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	ND	—	E	ND	—
41. Epichlorohydrin	NR	—	—	P	—	—	F	10min.	F	E	5hr.	E	NR	—	—	E	5min.	F
42. Ethyl Acetate	NR	—	—	F	15min.	G	F	20min.	G	F	ND	E	NR	—	—	G	5min.	F

Cellosolve® is a registered trademark of Union Carbide Corp.
Chlorothene® is a registered trademark of Dow Chemical Co.

THIS INFORMATION APPLIES ONLY TO ANSELL EDMONT BRAND GLOVES	SOL-VEX® NITRILE NBR			NEOPRENE UNSUPPORTED			NEOX® SUPPORTED NEOPRENE			PVA™ SUPPORTED POLYVINYL ALCOHOL			POLYVINYL CHLORIDE PVC			NATURAL RUBBER		
	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate
43. Ethyl Alcohol	E	4hr.	VG	E	1½hr.	VG	E	3hr.	VG	NR	—	—	G	1hr.	VG	E	15min.	VG
44. Ethylene Dichloride	NR	—	—	NR	—	—	NR	—	—	E	ND	E	NR	—	—	P	—	—
45. Ethylene Glycol	E	ND	E	E	ND	E	E	ND	E	F	2hr.	VG	E	ND	E	E	ND	E
46. Ethyl Ether	E	2hr.	G	E	10min.	G	E	10min.	G	G	ND	E	NR	—	—	NR	—	—
47. Ethyl Glycol Ether	G	3½hr.	G	E	45min.	E	E	4hr.	E	—	1¼hr.	G	P	—	—	E	25min.	VG
48. Formaldehyde	E	ND	E	E	2hr.	E	E	2hr.	VG	P	—	—	E	1⅓hr.	VG	E	10min.	G
49. Formic Acid 90%	F	4hr.	—	E	ND	—	E	ND	—	NR	—	—	E	>6hr.	—	E	2½hr.	—
50. Freon® TMC	NR	—	—	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
51. Freon® TF	E	ND	E	E	4hr.	E	E	2hr.	VG	G	ND	E	NR	—	—	NR	—	—
52. Furfural	NR	—	—	G	20min.	G	G	2hr.	G	F	ND	E	NR	—	—	E	15min.	VG
53. Gasoline (White)	E	ND	E	NR	—	—	NR	—	—	G	ND	E	P	—	—	NR	—	—
54. Hexamethyldisilazane	E	ND	—	E	50min.	—	E	60min.	—	G	ND	—	P	—	—	F	15min.	F
55. Hexane	E	ND	E	E	45min.	F	E	1½hr.	G	G	ND	E	NR	—	—	NR	—	—
56. Hydrazine 65%	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	ND	—	E	2½hr.	VG
57. Hydrochloric Acid, Conc.	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	>5hr.	—	E	4⅚hr.	—
58. Hydrochloric Acid, 10%	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	ND	—	E	ND	—
59. Hydrofluoric Acid, 48%	E	2hr.	—	E	1hr.	—	E	1¼hr.	—	NR	—	—	G	40min.	—	E	3⅙hr.	—
60. Hydrogen Peroxide, 30%	E	ND	—	E	5min.	—	E	7min.	—	NR	—	—	E	ND	—	E	ND	—
61. Hydroquinone, Saturated	E	ND	E	E	ND	E	E	ND	E	NR	—	—	E	ND	E	G	ND	E
62. Isobutyl Alcohol	E	ND	E	E	10min.	E	E	ND	E	P	—	—	F	10min.	VG	E	15min.	VG
63. Iso-Octane	E	6hr.	E	E	1hr.	G	E	6hr.	E	E	ND	E	P	—	—	NR	—	—
64. Isopropyl Alcohol	E	ND	E	E	ND	E	E	ND	E	NR	—	—	G	2½hr.	E	E	20min.	VG
65. Kerosene	E	ND	E	E	>6hr.	E	E	ND	E	G	ND	E	F	>6hr.	E	NR	—	—
66. Lactic Acid, 85%	E	ND	E	E	ND	E	E	ND	E	F	ND	E	E	ND	E	E	ND	—
67. Lauric Acid, 36%/EtOH	E	ND	—	E	ND	—	E	ND	—	NR	—	—	F	15min.	—	E	ND	—
68. Maleic Acid, Saturated	E	ND	—	E	ND	—	E	ND	—	NR	—	—	G	ND	—	E	ND	—
69. Methyl Alcohol	E	11min.	F	E	1hr.	E	E	15min.	E	NR	—	—	G	45min.	G	E	20min.	VG
70. Methylamine	E	ND	E	G	4½hr.	G	G	6hr.	E	NR	—	—	E	2¼hr.	VG	E	55min.	VG
71. Methyl Cellosolve®	F	11min.	G	E	25min.	G	E	70min.	VG	G	30min.	G	P	—	—	E	20min.	VG
72. Methylene Bromide	NR	—	—	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
73. Methylene Chloride	NR	—	—	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
74. Methyl Ethyl Ketone, MEK	NR	—	—	P	—	—	P	—	—	F	1½hr.	VG	NR	—	—	F	5min.	F
75. Methyl Glycol Ether	F	11min.	G	E	25min.	G	E	70min.	VG	G	30min.	G	P	—	—	E	20min.	VG
76. Methyl Iodide	NR	—	—	NR	—	—	NR	—	—	F	ND	E	NR	—	—	NR	—	—
77. Methyl Isobutyl Ketone, MIBK	P	—	—	NR	—	—	NR	—	—	F	ND	E	NR	—	—	P	—	—
78. Methyl Methacrylate	P	—	—	NR	—	—	NR	—	—	G	ND	E	NR	—	—	P	—	—
79. N-Methyl-2-Pyrrolidone, NMP	NR	—	—	NR	—	—	NR	—	—	NR	—	—	NR	—	—	E	1¼hr.	VG
80. Methyl t-Butyl Ether, MTBE	E	ND	E	P	—	—	P	—	—	G	ND	E	NR	—	—	NR	—	—
81. Mineral Spirits, Rule 66	E	ND	E	G	1½hr.	VG	G	ND	E	E	ND	E	F	2½hr.	VG	NR	—	—
82. Monoethanolamine	E	ND	E	E	ND	E	E	ND	E	F	ND	E	E	ND	E	E	50min.	E
83. Morpholine	NR	—	—	P	—	—	P	—	—	G	1½hr.	G	NR	—	—	G	20min.	G
84. Muriatic Acid	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	>5hr.	—	E	4⅚hr.	—
85. Naphtha VM&P	E	ND	E	G	15min.	F	G	ND	E	E	>7hr.	E	F	2hr.	VG	NR	—	—

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SPECIAL NOTE:

The chemicals in this guide highlighted in BLUE are experimental carcinogens, according to the seventh edition of Sax' *Dangerous Properties of Industrial Materials*. Chemicals highlighted in GRAY are listed as suspected carcinogens, experimental carcinogens at extremely high dosages, and other materials which pose a lesser risk of cancer.

THIS INFORMATION APPLIES ONLY TO ANSELL EDMONT BRAND GLOVES	SOL-VEX® NITRILE NBR			NEOPRENE UNSUPPORTED			NEOX® SUPPORTED NEOPRENE			PVA™ SUPPORTED POLYVINYL ALCOHOL			POLYVINYL CHLORIDE PVC			NATURAL RUBBER		
	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate
86. Nitric Acid, 10%	E	ND	—	E	ND	—	E	ND	—	NR	—	—	G	ND	—	G	ND	—
87. Nitric Acid, 70%	NR	—	—	G	2⅓hr.	—	G	ND	—	NR	—	—	F	5¾hr.	—	NR	—	—
88. Nitric Acid, Red Fuming	NR	—	—	NR	—	—	NR	—	—	NR	—	—	P	—	—	P	—	—
89. Nitrobenzene	NR	—	—	NR	—	—	NR	—	—	G	ND	E	NR	—	—	F	15min.	G
90. Nitromethane 95.5%	F	30min.	F	E	1hr.	VG	E	1½hr.	E	G	ND	E	P	—	—	E	10min.	G
91. Nitropropane 95.5%	NR	—	—	G	5min.	F	G	1hr.	G	E	>6hr.	E	NR	—	—	E	5min.	G
92. Octyl Alcohol	E	ND	E	E	7hr.	E	E	>7hr.	E	G	ND	E	F	>6hr.	E	E	30min.	VG
93. Oleic Acid	E	ND	E	E	1hr.	VG	E	2½hr.	E	G	1hr.	E	F	1½hr.	VG	F	ND	—
94. Oxalic Acid, Saturated	E	ND	—	E	ND	—	E	ND	—	P	—	—	E	ND	—	E	ND	—
95. Palmitic Acid, Saturated	G	30min.	—	E	ND	—	E	ND	—	P	—	—	G	1¼hr.	—	G	5min.	—
96. Pentane	E	ND	E	E	30min.	F	E	45min.	VG	G	ND	E	NR	—	—	P	—	—
97. Pentachlorophenol	E	ND	E	E	6min.	E	E	6min.	E	E	5min.	F	F	3hr.	E	NR	—	—
98. Perchloric Acid, 60%	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	ND	—	F	ND	—
99. Perchloroethylene	G	5hr.	VG	NR	—	—	NR	—	—	E	ND	E	NR	—	—	NR	—	—
100. Phenol	NR	—	—	E	3hr.	G	E	>6½hr.	E	F	ND	E	G	1¼hr.	VG	E	1½hr.	—
101. Phosphoric Acid, Conc.	E	ND	—	E	ND	—	E	ND	—	NR	—	—	G	ND	—	F	ND	—
102. Picric Acid, Sat./EtOH	E	2⅔hr.	VG	E	2½hr.	VG	E	3hr.	VG	NR	—	—	E	40min.	VG	—	—	—
103. Potassium Hydroxide, KOH, 50%	E	ND	—	E	ND	—	E	ND	—	NR	—	—	E	ND	—	E	ND	—
104. Propyl Acetate	F	20min.	G	P	—	—	P	—	—	G	2hr.	VG	NR	—	—	P	—	—
105. Propyl Alcohol	E	ND	E	E	2½hr.	E	E	ND	E	P	—	—	F	1½hr.	VG	E	20min.	VG
106. Propylene Oxide	NR	—	—	NR	—	—	NR	—	—	G	35min.	G	NR	—	—	P	—	—
107. Pyridine	NR	—	—	NR	—	—	P	—	—	G	10min.	F	NR	—	—	F	10min.	F
108. Rubber Solvent	E	ND	E	G	30min.	G	G	1hr.	G	E	ND	E	NR	—	—	NR	—	—
109. Silicon Etch	NR	—	—	G	ND	—	G	ND	—	NR	—	—	F	2½hr.	—	NR	—	—
110. Skydrol® hydraulic fluid	NR	—	—	NR	—	—	NR	—	—	F	—	—	NR	—	—	NR	—	—
111. Sodium Hydroxide NaOH, 50%	E	ND	—	E	ND	—	E	ND	—	NR	—	—	G	ND	—	E	ND	—
112. Stoddard Solvent	E	ND	E	E	3hr.	VG	E	ND	E	E	ND	E	F	6hr.	E	NR	—	—
113. Styrene	NR	—	—	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
114. Sulfuric Acid, 95%	NR	—	—	F	3hr.	—	F	>6hr.	—	NR	—	—	*G	3⅔hr.	—	NR	—	—
115. Sulfuric 47% battery acid	E	ND	—	E	ND	—	E	ND	—	NR	—	—	G	ND	—	E	ND	—
116. Tannic Acid, 65%	E	ND	E	E	ND	E	E	ND	E	P	—	—	E	ND	E	E	ND	—
117. Tetrachloroethene	G	5hr.	VG	NR	—	—	NR	—	—	E	ND	E	NR	—	—	NR	—	—
118. Tetrahydrofuran, THF	NR	—	—	NR	—	—	NR	—	—	P	1½hr.	G	NR	—	—	NR	—	—
119. Toluene, Toluol	F	10min.	F	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
120. Toluene Di-Isocyanate, TDI	NR	—	—	NR	—	—	NR	—	—	G	ND	E	P	—	—	G	7min.	G
121. 1,1,1-Trichloroethane	F	1½hr.	P	NR	—	—	NR	—	—	G	ND	E	NR	—	—	NR	—	—
122. Trichloroethylene, TCE	NR	—	—	NR	—	—	NR	—	—	E	ND	E	NR	—	—	NR	—	—
123. Tricresyl Phosphate, TCP	E	ND	E	F	ND	E	F	ND	E	G	ND	E	F	ND	E	E	45min.	E
124. Triethanolamine 85%, TEA	E	ND	E	E	ND	E	E	ND	E	G	ND	E	E	ND	E	G	ND	E
125. Turpentine	E	30min.	E	NR	—	—	NR	—	—	G	ND	E	P	—	—	NR	—	—
126. Xylene, Xylol	G	1¼hr.	F	NR	—	—	NR	—	—	E	ND	E	NR	—	—	NR	—	—

*For hot sulfuric acid or fuming oleum, PVC is Not Recommended. Skydrol® is a registered trademark of Monsanto.

Ansell Edmont Industrial

Permeation/Degradation Resistance Guide for Ansell Edmont Clothing

THIS INFORMATION APPLIES ONLY TO ANSELL EDMONT BRAND CLOTHING	WET-WEAR® 550, LINED VINYL			WET-WEAR® 600, VINYL			WET-WEAR® 700, VINYL BLEND		
	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate	Degradation Rating	Permeation: Breakthrough	Permeation: Rate
1. Acetaldehyde	P	—	—	F	5min.	P	F	3min.	P
2. Acetic Acid, Glacial	G	30min.	—	F	6min.	—	F	16min.	—
3. Acetone	NR	—	—	NR	—	—	NR	—	—
4. Ammonium Hydroxide, Conc.	E	ND	—	E	18min.	—	E	11min.	—
5. Aniline	F	12min.	VG	F	30min.	VG	F	10min.	VG
6. Butyl Acetate	NR	—	—	NR	—	—	NR	—	—
7. Butyl Alcohol	G	8min.	G	G	40min.	G	E	35min.	VG
8. Chromic Acid, 50%	G	ND	—	G	ND	—	G	ND	—
9. Cyclohexanol	E	20min.	E	E	ND	E	E	15min.	VG
10. Dibutyl Phthalate	NR	—	—	F	ND	—	F	ND	—
11. Diethylamine	NR	—	—	NR	—	—	P	—	—
12. Dimethyl Formamide, DMF	P	—	—	NR	—	—	NR	—	—
13. Dioctyl Phthalate, DOP	F	11min.	—	G	ND	E	G	25min.	—
14. Ethyl Acetate	NR	—	—	NR	—	—	NR	—	—
15. Ethylene Glycol	E	20min.	—	E	ND	E	E	ND	E
16. Ethyl Ether	P	—	—	P	—	—	P	—	—
17. Formaldehyde	E	5min.	VG	E	6hr.	G	E	30min.	VG
18. Freon® TF	G	6min.	F	F	60min.	G	F	15min.	F
19. Formic Acid, 90%	E	25min.	—	E	1¼hr.	—	E	30min.	—
20. Gasoline (White)	F	6min.	G	F	5min.	F	F	5min.	F
21. Hydrazine, 65%	E	—	—	E	ND	—	E	ND	—
22. Hydrochloric Acid, 38%	G	ND	—	F	5hr.	—	F	55min.	—
23. Hydrofluoric Acid, 48%	G	1¼hr.	—	F	1½hr.	—	F	5min.	—
24. Isobutyl Alcohol	G	20min.	VG	G	2hr.	VG	E	7min.	VG
25. Kerosene	G	10min.	VG	G	3hr.	G	E	1¼hr.	G
26. Maleic Acid, Sat.	E	ND	—	E	ND	—	E	ND	—
27. Methyl Alcohol	G	5min.	G	G	30min.	G	E	20min.	VG
28. Methyl Acetate	P	—	—	NR	—	—	P	—	—
29. Methylamine, 40%	E	5min.	E	E	60min.	VG	E	30min.	G
30. Methylene Chloride	NR	—	—	NR	—	—	NR	—	—
31. Methyl Isobutyl Ketone, MIBK	NR	—	—	NR	—	—	NR	—	—
32. Methyl Methacrylate	NR	—	—	NR	—	—	NR	—	—
33. Monethanolamine	E	ND	—	E	ND	—	E	ND	—
34. Naphtha, VM&P	F	6min.	VG	F	20min.	G	F	9min.	G
35. Nitric Acid, 70%	F	45min.	—	F	2⅔hr.	—	F	6min.	—
36. Nitric Acid, 10%	E	ND	—	E	4¾hr.	—	E	ND	—
37. Nitropropane	NR	—	—	NR	—	—	F	<5min.	G
38. Octyl Alcohol	G	45min.	E	E	9min.	E	E	ND	E
39. Pentane	F	4min.	G	P	—	—	F	11min.	G
40. Perchloroethylene	F	4min.	G	P	—	—	F	5min.	F
41. Phenol 90%	F	35min.	VG	F	1½hr.	VG	F	50min.	VG
42. Phosphoric Acid, Conc.	G	ND	—	F	ND	—	F	ND	—
43. Potassium Hydroxide KOH, 50%	E	ND	—	E	ND	—	E	ND	—
44. Propylene Glycol	E	ND	E	E	ND	—	E	ND	—
45. Sodium Hydroxide NaOH, 50%	E	ND	—	E	ND	—	E	ND	—
46. Sulfuric Acid, 10%	E	1hr.	—	E	2⅓hr.	—	E	2hr.	—
47. Sulfuric Acid, 95%	F	5min.	—	F	1hr.	—	F	37min.	—
48. 1,1,1-Trichloroethane	F	4min.	G	F	2min.	F	F	6min.	P
49. Tricresyl Phosphate, TCP	F	20min.	—	E	ND	—	E	ND	—
50. Turpentine	F	10min.	VG	F	6min.	G	F	16min.	G
51. Xylene	P	—	—	P	—	—	F	>3min.	G

These permeation ratings are based on laboratory evaluations, and they reflect the best judgment of Ansell Edmont in the light of data available to us at the time of their preparation and in accordance with the current revision of ASTM F 739. They are intended to guide and inform Industrial Hygienists, Safety Specialists and other qualified professionals engaged in assuring safety in the workplace. Because the conditions of ultimate use are beyond our control, and because we cannot run permeation tests in all possible work environments and across all combinations or chemical solutions, these guides are advisory only. The suitability of the product for a specific job must be determined by testing by the purchaser.

Ansell Edmont believes this information is the best currently available. It is subject to revision as additional knowledge and experience are gained. Test data herein reflects laboratory performance of partial gloves and not necessarily the complete unit. Anyone intending to use suggestions contained in this publication should first verify that the glove selected is suitable for the intended use and meets all appropriate health standards.

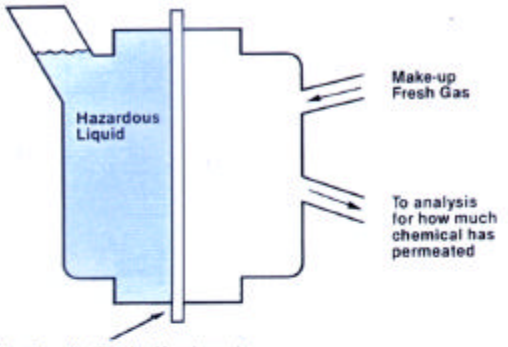
NEITHER THIS GUIDE NOR ANY OTHER STATEMENT MADE HEREIN BY OR ON BEHALF OF ANSELL EDMONT SHOULD BE CONSTRUED AS A WARRANTY OF MERCHANTABILITY OR THAT ANY ANSELL EDMONT PRODUCT IS FIT FOR A PARTICULAR PURPOSE. ANSELL EDMONT ASSUMES NO RESPONSIBILITY FOR THE SUITABILITY OR ADEQUACY OF AN END USER'S SELECTION OF GLOVES OR CLOTHING FOR A SPECIFIC APPLICATION.

Upon written request, Ansell Edmont will provide a sample of material to aid you in making your own selection under your own individual safety requirements.

How does Ansell Edmont conduct permeation tests?

As the leader in permeation testing among Safety Wearing Apparel Manufacturers, Ansell Edmont has, for a number of years, invested a substantial amount of time, effort and capital resources in testing Ansell Edmont products, and has participated in the work of ASTM Committee F-23 on Protective Clothing, playing an active role in the development of standard test methods.

PERMEATION TEST CELL



Glove/Clothing Sample (Barrier Membrane)

In accord with the standard established under ASTM Method F 739, this is how Ansell Edmont permeation tests are conducted: A specimen cut from the protective glove or clothing is clamped into a test cell as a barrier membrane. The "exterior" side of the specimen is exposed to the hazardous chemical. Then, at timed intervals the "interior" side of the test cell is checked to determine the presence of the permeated chemical and the extent to which it has permeated the material.

The standard allows a variety of options in analytical technique and collecting mediums. At Ansell Edmont, gas chromatography with FID detection is used as the analytical technique and dry nitrogen as the collecting medium. When testing inorganic acids and bases that are not amenable to FID detection, a simpler colorimetric method based on a British and proposed ISO standard is used. The collecting medium is water and detection is by change in color of a pH indicator.

How does Ansell Edmont conduct degradation tests?

Films of the test material are made. These films are weighed and measured and then completely immersed in the test chemical for 30 minutes. The percentage of change in size is determined and then films are dried to calculate the percentage of weight change. Observed physical changes are also recorded. Ratings are based on the combined data.

Testing for material in this guide has been conducted by Ansell Edmont Research and Development Department, in accordance with ASTM Standard, Method F 739.

Ansell Edmont Industrial

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3.5 Communications in Chemical Protective Clothing

Communications may be difficult when wearing PPE. In certain instances, radio, voice, or written communications cannot be used. Such instances may require the use of hand signals to solicit needed help or equipment. The following hand signals are universally recognized.

Signal	Meaning
Hand gripping throat:	Out of air, can't breathe.
Grip partner's wrist or place both hands around your waist:	Leave area immediately, no debate!
Both hands on top of head:	Need assistance.
Thumbs up:	Okay, I'm all right, I understand.
Thumbs down:	No, negative.
Forefinger and middle finger:	Need a wrench.

3.6 Conclusion

Wearing chemical protective clothing will protect us from the effects of hazardous materials. Certain items must be considered in the selection and use of protective clothing. They are:

- Type of contaminant and concentration
- Physical stress on wearer
- Work function of wearer

PERSONAL PROTECTIVE CLOTHING CHECKLIST

1. Site Contaminants: _____

   _____

   _____

2. Protective Equipment Employed*:

Type	Limitations
Dermal	
Gloves	
Boots	

*Respiratory Protection is addressed in a separate topic.

3. Materials resistance to Heat

4. Materials resistance to Cold

5. Color of dermal protection

RESPIRATORY PROTECTION PROGRAM

Air-Purifying Respirator Inspection and Maintenance

Air-Purifying Respirator Training

Air-Purifying Respirator Qualitative FIT Testing

Respiratory Protection Selection

Pressure-Demand SCBA Inspection and Maintenance

Self-Contained Breathing Apparatus (SCBA) Training

AIR-PURIFYING RESPIRATOR INSPECTION AND MAINTENANCE
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ATTACHMENTS

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AIR-PURIFYING RESPIRATOR INSPECTION AND MAINTENANCE

1.0 PURPOSE

To establish procedures for routine inspection, cleaning, and care of air-purifying respirators users.

2.0 SCOPE

Applies to all Brown & Root Environmental air-purifying respirator users.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

It shall be the responsibility of the air-purifying respirator user to correctly perform the inspection prescribed in these guidelines before and after each use of an air-purifying respirator.

5.0 PROCEDURES

5.1 Inspection Procedure

5.1.1 Facepiece

Examine the facepiece for:

- Excessive dirt.
- Cracks, tears, holes, or distortions from improper storage.
- Inflexibility (stretch and massage to restore flexibility).
- Cracked or badly-scratched lenses in full facepieces.
- Incorrectly-mounted full facepiece lens, broken, or missing mounting clips.
- Cracked or broken air-purifying element holder(s), badly worn threads, or missing gasket(s) (if required).

5.1.2 Harness

Examine the headstraps or head harness for:

- Breaks.
- Loss of elasticity.
  - Broken or malfunctioning buckles and attachments.
  - (Full facepieces only) Excessively-worn serrations on the head harness which might permit slippage.

5.1.3 Exhalation Valve

Examine the exhalation valve for the following, after removing its cover:

- Foreign material, such as detergent residue, dust particles, or human hair under the valve seat.
- Cracks, tears, or distortion in the valve material.
- Improper insertion of the valve body in the facepiece.
- Cracks, breaks, or chips in the valve body, particularly in the sealing surface.
- Missing or defective valve cover.
- Improper installation of the valve in the valve body.

5.1.4 Breathing Tube

If the device has a corrugated breathing tube, examine it for:

- Broken or missing end connectors.
- Missing or loose hose clamps.
- Deterioration, determined by stretching the tube and looking for cracks.

5.1.5 Air-Purifying Elements

Examine the air-purifying elements for:

- Incorrect cartridge, canister, or filter for the hazard.

- Incorrect installation, loose connections, missing or worn gaskets, or cross-threading in holder.
- Expired shelf-life date on cartridge or canister.
- Cracks or dents in outside case of filter, cartridge, or canister.
- Evidence of prior use of surbent cartridge or canister, indicated by absence of sealing material, tape, foil, etc., over inlet.

5.2 Cleaning

The air-purifying respirator shall be cleaned after each day's use. Air-purifyig respirators are cleaned according to the following procedures:

- Remove both cartridge and cartridge receptacle gaskets.
- Unscrew cartridge receptacles from inhalation valve seats; damage them to prevent reuse; and discard.
- Remove inhalation valves and inhalation valve seats from face mask.
- Remove exhalation valve cover and exhalation flapper valve.
- Remove nosecup, unscrew retainer ring, and remove speaking diaphragm and speaking diaphragm gasket.
- Wash the entire mask and all parts, except for the speaking diaphragm, in cleaner/sanitizer powder mixed with warm water, preferably at 120°F. Let soak for 3-5 minutes. Clean the speaking diaphragm by rinsing it quickly in clean water and dry it immediately, using a warm air source (such as a hair dryer).
- Remove all parts from wash water and rinse twice in clean warm water.
- Air-dry parts in a designated clean area.
- Reassemble the entire unit when parts are dry.
- Make sure the unit is working properly before using.

5.3 Storage

Follow manufacturers' storage instructions, which are always furnished with new respirators or affixed to the lid of the carrying case. In addition, these general instructions may be helpful:

- After respirators have been inspected, cleaned, and repaired, store them to protect against dust, excessive moisture, damaging chemicals, extreme temperatures, and direct sunlight.

- Do not store respirators in clothes lockers, bench drawers, or tool boxes. Place them in wall compartments at work stations or in a work area designated for emergency equipment. Store them in the original carton or carrying case.

- Draw clean respirators from storage for each use. Each unit can be sealed in a plastic bag, placed in a separate box, and tagged for immediate use.

5.4 Repairs

Only a trained person with proper tools and replacement parts should work on respirators. No one should ever attempt to replace components or to make adjustments or repairs beyond the manufacturer's recommendations.

6.0 REFERENCES

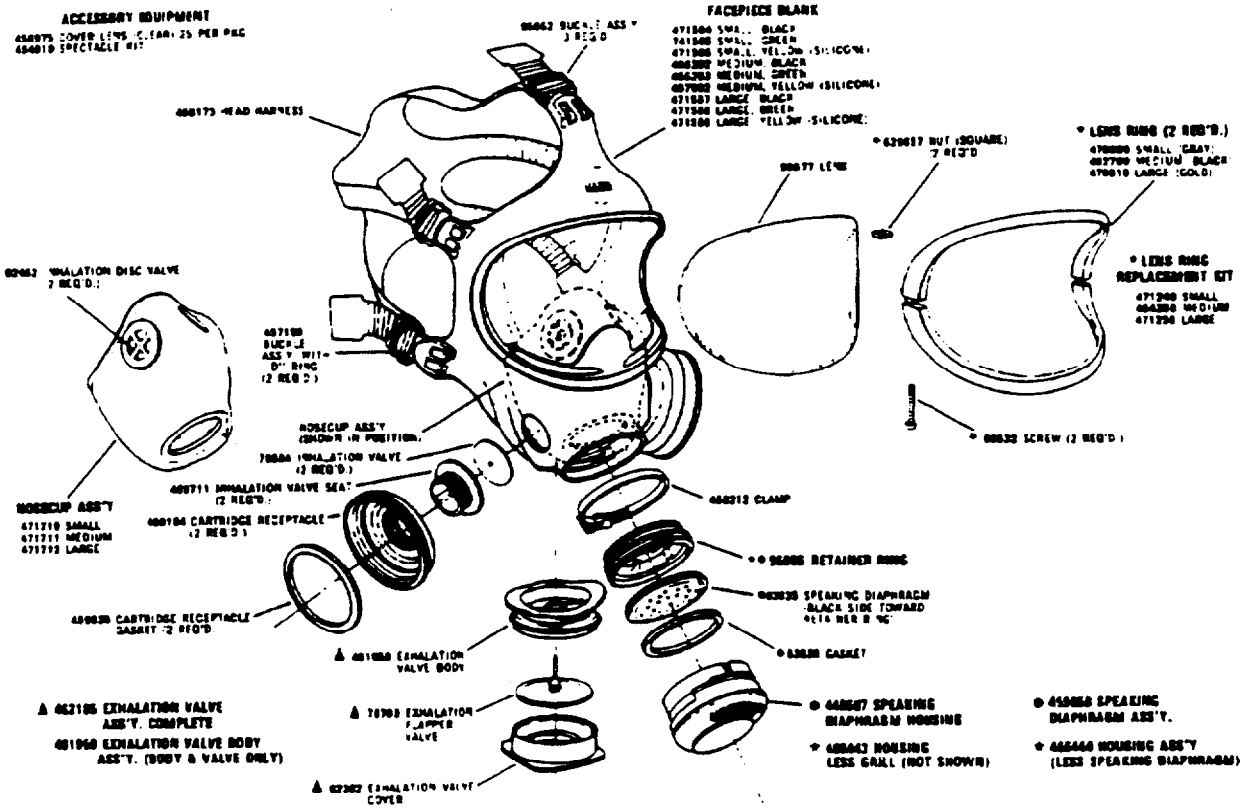
None.

7.0 ATTACHMENTS

Attachment A - MSA Ultra-Twin Respirator Components
Attachment B - MSA Dual Purpose Breathing Apparatus

ATTACHMENT A

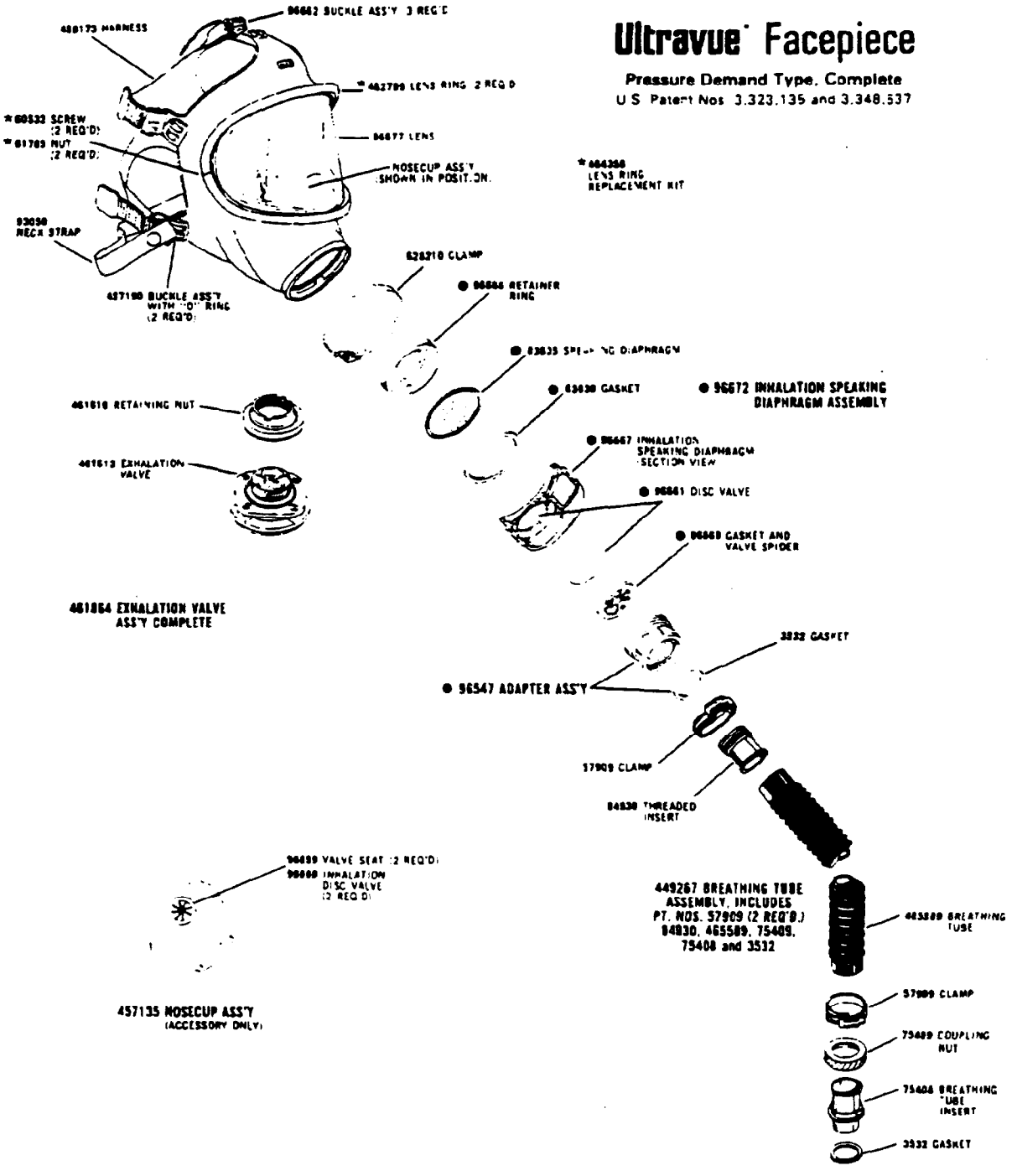
ULTRA-TWIN RESPIRATOR COMPONENTS



ATTACHMENT B

MSA DUAL PURPOSE BREATHING APPARATUS (FACEPIECE AND PARTS)

461614 PRESSURE DEMAND FACEPIECE COMPLETE.
NOTE: BREATHING TUBE ASS'Y AND NOSECUP MUST BE ORDERED SEPARATELY



AIR-PURIFYING RESPIRATOR TRAINING
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AIR-PURIFYING RESPIRATOR TRAINING

1.0 PURPOSE

To provide a format for Air-Purifying Respirator training and to ensure the proper and safe use of air-purifying respirators.

2.0 SCOPE

Applies to all Brown & Root Environmental personnel who may use air-purifying respirators in their work activity.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Office Health and Safety Supervisor (OHSS) - It shall be the responsibility of the OHSS to insure that all Brown & Root Environmental employees in his/her company, who may be required to wear air-purifying respirators, have received appropriate basic and refresher air-purifying respirator training, as required.

5.0 PROCEDURES

5.1 REQUIREMENTS

Prior to using an air-purifying respirator in the field, Brown & Root Environmental personnel must complete training and demonstrate proficiency in its use.

5.2 TRAINING TO BE PRESENTED

Training regarding respiratory protection will, at a minimum, incorporate the following:

1. Reasons why respiratory protection is being used (which may be covered in the pre-activity meeting for each site) and criteria for selection of the respirator.

2. Capabilities and limitations of the respirators used.

3. Procedures for inspecting, donning, fit checks, and wearing of the respirators.

4. Procedures for maintenance and storage of the respirator.

5. Procedures for identifying and dealing with respiratory emergencies.

6. Regulations concerning respirator use.

5.3 PROFICIENCY DEMONSTRATION

Following air-purifying respirator training, personnel must demonstrate:

1. An understanding of an air-purifying respirator.
2. Limitations of an air-purifying respirator.
3. Competency in donning, wearing, and removing the respirator.
4. Ability to disassemble an air-purifying respirator.
5. Ability to check-out and inspect the respirator for defects.
6. Knowledge of maintenance and storage procedures.

5.4 REFRESHER TRAINING

Refresher training in respiratory use will be required when a respirator has not been used during the previous six months.

5.5 RECORD KEEPING

The OHSS shall maintain an appropriate record of Brown & Root Environmental air purifying respirator training. The records shall be subject to annual audit by the HSM.

6.0 REFERENCES

None.

7.0 ATTACHMENTS

None.

AIR-PURIFYING RESPIRATOR QUALITATIVE FIT TESTING
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ATTACHMENT

A	AIR-PURIFYING RESPIRATOR QUALITATIVE FIT TEST	5

AIR-PURIFYING RESPIRATOR QUALITATIVE FIT TESTING

1.0 PURPOSE

To establish procedures for the qualitative fit testing of air-purifying respirators.

2.0 SCOPE

Applies to all personnel who will be required to wear air-purifying respirators in Brown & Root Environmental employment.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Office Health and Safety Supervisor (OHSS) - The OHSS is responsible to assure that all personnel in his company who may wear air-purifying respirators in Brown & Root Environmental employment have been fit-tested in compliance with these guidelines.

5.0 PROCEDURES

5.1 Essential FIT Considerations

The following shall be adhered to in the fitting and use of air-purifying respirators.

1. A fit test, utilizing an odorous and an irritant agent, is required prior to use of a new air-purifying pressure respirator for the first time.

2. A person may only use the specific make(s) and model(s) of full-face, air-purifying respirators for which he or she has obtained a satisfactory fit via the qualitative fit-testing procedures. Under no circumstances shall a person be allowed to use any make or model respirator not previously fit-tested or after having failed a fit test.

3. Due to possible changes in facial configuration, the odorous and irritant agent test shall be repeated at least annually.

4. If it is found that a person cannot obtain a good respirator-to-face seal because of facial or medical characteristics, he or she should not use and/or enter an atmosphere that will require the use of a respirator.

5. Facial hair such as beards, sideburns, or certain mustaches which may interfere with the fit test, are not permitted.

6. Persons requiring corrective lenses shall be provided with specially-mounted lenses inside the full-face mask. Under no circumstances will contact lenses and/or glasses be worn while using full-face respirators.

7. Negative and positive pressure self-fit tests shall be performed each time a respirator is donned.

5.2 User Self-FIT Tests

Prior to each use of the respirator, the user shall conduct a negative pressure and positive pressure sealing test according to the procedures given below.

5.2.1 Negative Pressure Sealing Test

1. With the cartridges in place, cover the porous area of the cartridge with your hand.

2. Inhale, attempting to achieve a negative pressure in the facepiece.

3. Inability to achieve or maintain a negative seal for 10 seconds indicates poor respirator fit or malfunction.

4. Recheck integrity of the respirator and reposition respirator for a better seal.

5. Repeat 1 and 2.

6. Do not use respirator if unable to achieve a negative pressure fit.

7. This is not considered a qualitative fit test, but rather a quick-check of respirator integrity and seal.

5.2.2 Positive Pressure Sealing Test

1. Remove the protective covering of the exhalation valve and seal the exhalation port with your hand.

2. Exhale slightly.

3. Inability to maintain a slight positive pressure for 10 seconds or longer, without indications of leakage, may be indicative of poor respirator fit or malfunction.

4. Recheck integrity of the respirator and reposition respirator for a better seal.

5. Repeat 1 and 2.

6. Do not use respirator if unable to achieve a positive pressure fit.

7. This is not considered a qualitative fit test, but rather a quick-check of respirator integrity and seal.

5.3 Odorous and Irritant Agent Test

1. Be sure that the air-purifying respirator to be tested is equipped with a combination organic vapor-high efficiency particulate cartridge designed for the respirator.

2. Have the subject don the respirator and perform negative and positive pressure self-fit tests.

3. Saturate a piece of cotton with isoamyl acetate. (The currently-established TLV for this compound is 100 ppm, but it is detectable by most subjects as "banana oil" at substantially lower concentrations.)

4. Bring the isoamyl acetate-saturated cotton close to the respirator while the subject moves his head. If no odor of banana oil is detected, proceed to step 5.

5. Break the ends off a stannic chloride tube, taking care not to get any of the material on your skin.

6. Attach the squeeze bulb to one end of the tube. Squeeze the bulb to ensure that a satisfactory stream of stannic chloride can be generated for the fit test.

7. In a closed space (a large trash bag is satisfactory), with the stannic chloride tube approximately 2 feet from the respirator, begin exposing the subject to the irritant agent.

8. Watch the subject closely for signs of irritation. If no penetration of the irritant agent is detected, move the stannic chloride closer to within 6 inches of the respirator and direct smoke to potential leak areas.

9. If no penetration of smoke is detected at this stage, have the subject rotate the head from side to side, up and down, and undertake deep breathing exercises.

10. If the respirator-wearer does not detect the penetration of smoke into the respirator, the subject is deemed to have achieved a satisfactory fit.

5.4 Record Keeping

Records of air-purifying respirator qualitative fit tests (excluding negative/positive pressure seal checks) shall be maintained on the attached form, or the equivalent, by the OHSS. This record will be subject to audit by the DHST.

6.0 REFERENCES

A guide to Industrial Respiratory Protection USHEW Publication No. (NIOSH) 76- 189.

7.0 ATTACHMENTS

Attachment A - Air-Purifying Respirator Qualitative Fit Test

ATTACHMENT A

AIR-PURIFYING RESPIRATOR QUALITATIVE FIT TEST

Person Tested	Make and Model of Respirator Tested	Date of Test	Test Results (Pass/Fail)	Test Conducted by (Name)	Due Date Next Test This Respirator

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RESPIRATORY PROTECTION SELECTION

1.0 PURPOSE

To establish guidelines for selection of respiratory protective equipment for use within Brown & Root Environmental.

2.0 SCOPE

This guideline applies to all respiratory selection decisions to be made in implementation of the Health and Safety Program.

3.0 GLOSSARY

Health and Safety Officer (HSO) - A qualified health and safety professional responsible for site-specific health and safety matters. The HSO must be knowledgeable about the types of respirators, use limitations, cartridge types and limitations, field work, and the physiologic as well as psychologic effects of respirator use.

4.0 RESPONSIBILITIES

Health and Safety Officer (HSO) - These guidelines must be carefully considered and followed by the HSO in development of each site-specific Health and Safety Plan (HASP).

Office Health and Safety Supervisor (OHSS) - The OHSS reviews and approves the site-specific HASP and assists the HSO in determining adequate protective measures for site activities.

5.0 PROCEDURES

5.1 INTRODUCTION

Field work often presents the workers with a variety of environmental conditions, some of which are better defined than others. It is not intended for this document to provide concisely defined decision logic encompassing every environmental situation with which one may be faced, since each situation will be

unique. This document recognizes that many respiratory protection decisions will be based on subjective risk assessments. The purpose of this guideline is to ensure that all relevant data are considered in the process of the conduction of respiratory risk assessment; resulting in the selection of specific items of respiratory equipment for protection against potential respiratory hazards.

5.2 PROCEDURAL STEPS

5.2.1 Information Gathering

Assimilate all available information pertaining to the hazard including: past activities, suspected materials, historical data, land use, analytical data, nature of current activities, etc.

5.2.2 Timeliness of Information

Evaluate the timeliness and relevancy of the data in determining protective levels for the task at hand:

1. Is the analytical data recent?

2. Was sampling or monitoring conducted during seasons similar to the anticipated activities? If not, what implications might this hold?

3. Was sampling or monitoring from a medium, which is pertinent to evaluating hazards associated with the activities specified in the task work plan?

5.2.3 Contaminant Identification

Identify substances known or suspected of being present at the work area.

5.2.4 Contaminant Evaluation

Evaluate each contaminant considering the following subject areas:

1. Threshold Limit Values (TLV), Permissible Exposure Limit (PEL).

2. Warning properties (see page 4, decision logic criteria).

3. Eye irritation potential for the substance (page 6, decision logic criteria).

4. Lower Flammability Limit (LFL) for the substance (page 8, decision logic criteria).

5. Immediately Dangerous to Life and Health levels (IDLH) for the substance (page 6, decision logic criteria).

6. Sorbent efficiency (page 5, decision logic criteria).

7. Possibility of systemic injury or death resulting from adsorbance of the substance (as a gas or vapor) through the skin (see below, decision logic criteria).

8. Possibility of severe skin irritation resulting from contact of the skin with corrosive gases, vapor, or particulates (see below, decision logic criteria).

9. The vapor pressure of the substance.

10. Possibility of high heat of reaction and/or shock sensitivity with sorbent material in cartridge or canister.

11. Possible effects of contaminants on respirator integrity.

12. Warning properties (if the substance is a gas or vapor).

13. Physical state(s) of the substance to be encountered.

5.2.5 Physical State of Substance

Determine the physical state(s) of the substance as it is likely to be encountered in the occupational environment. It will be either (1) gas or vapor; (2) particulate (dust, fume or mist); or (3) combination of (1) and (2).

5.2.6 Oxygen-Deficient Atmosphere

Air purifying respirators shall not be worn in environments deficient in oxygen (less than 19.5 percent by volume or partial pressure of oxygen less than 100mm of mercury). See 29 CFR 1910.

5.2.7 Evaluation Factors

1. Poor Warning Properties

It is important to realize the 30 CFR 11 approvals for air-purifying (organic vapor) devices prohibit use against organic vapors with poor warning properties. Specifically, 30 CFR 11.140 (note 7) covers chemical cartridge respirators. The approvals in 30 CFR 11, thus, are only for those organic vapors with adequate warning properties.

Warning properties include odor, eye irritation, and respiratory irritation. Warning properties relying upon human senses are not foolproof. However, they provide some indication, to the wearer, of possible sorbent exhaustion, poor facepiece fit, or other respirator malfunction.

Adequate warning properties can be assumed when the substance odor, taste, or irritation effects are detectable and persistent at concentrations at or below the permissible exposure limit. If the odor or irritation threshold of a substance is more than three times greater than the PEL or TLV, this substance should be considered to have poor warning properties. If the substance odor or irritation threshold is somewhat above the permissible exposure limit (not in excess of three times the limit), and there is no ceiling limit, consideration is given to whether undetected exposure in this concentration range could cause serious or irreversible health effects. If not, the substance is considered to have adequate warning properties. Some substances have extremely low thresholds of odor and irritation in relation to the permissible exposure limit. Because of these properties, these substances can be detected by a worker within the facepiece of the respirator, even when the respirator is functioning properly. These substances are, therefore, considered to have poor warning properties.

Though 30 CFR 11 does not specifically eliminate air-purifying respirators for pesticides with poor warning properties, prudent practice dictates that such a respirator should not be used. Positive pressure, self-contained breathing apparatus should be worn under these circumstances.

2. Sorbents

There are certain limitations involved with the use of sorbents in cartridge/canister cartridges. When the following conditions occur, a sorbent cartridge is not recommended:

- Where supporting evidence exists of immediate (less than 3 minutes) breakthrough time at the IDLH concentration (and below) for a cartridge or canister sorbent, air-purifying devices shall not be allowed for any use, escape, or other action.

- Where there is reason to suspect that commonly used sorbents (e.g., activated charcoal) do not provide adequate sorption efficiency against a specific contaminant, use of such sorbents shall not be allowed. However, where another sorbent material has been demonstrated to be effective against a specific contaminant, approved respirators using the effective sorbent material shall be allowed.

- Where there is reason to suspect that a sorbent has a high heat of reaction with a substance, use of that sorbent is not allowed.

- Where there is reason to suspect that a substance sorbed onto the surface of a cartridge or canister is shock-sensitive, use of air-purifying respirators is disallowed.

3. Eye Irritation

In addition to respiratory protection, it is quite important to consider a chemical's potential for producing eye irritation or damage. The following guidelines deal with eye protection:

- For routine work operations, any perceptible eye irritation is considered unacceptable. Therefore, only full facepiece respirators are permissible in contaminant concentrations that produce eye irritation. For escape, some eye irritation is permissible, if it is determined that such irritation would not inhibit escape and such irritation is reversible.

  Half-facepiece respirators are allowed where quantitative eye irritation data cannot be found in literature references and theoretical considerations indicate that substance should not be an eye irritant.

  Where a review of the literature indicates that a substance causes eye irritation but no eye irritation threshold is specified, the data will be evaluated to determine whether quarter- or half-facepiece respirators can be used.

4. IDLH

The definition of IDLH provided in 30 CFR 11.3(t) is as follows:

> "Immediately Dangerous to Life or Health" means conditions that pose an immediate threat to life or health, or conditions that pose an immediate threat of severe exposure to contaminants (such as radioactive materials) which are likely to have adverse cumulative or delayed effects on health.

The purpose of establishing an IDLH exposure concentration is to ensure that the worker can escape, without injury or irreversible health effects, from an IDLH concentration in the event of failure of the respiratory protective equipment. The IDLH is considered a maximum concentration, above which only a highly reliable breathing apparatus providing maximum worker protection is permitted. Since IDLH values are conservatively set, any approved respirator may be utilized to its maximum use concentration below the IDLH.

In establishing the IDLH concentration, the following factors are considered:

- Escape without loss of life or irreversible health effects. Thirty minutes is considered the maximum permissible exposure time for escape.

- Severe eye irritation, respiratory irritation, or other reactions that would prevent escape without injury.

IDLH should be determined from the following sources:

- Specific IDLH information provided in the literature, such as the AIHA Hygienic Guides.
- Human exposure data.
- Acute animal exposure data.

Where such data are lacking, acute toxicological data from analogous substances may be considered.

The following guidelines should be used to interpret toxicological data reported in the literature for animal species:

- Where acute animal exposure data are available (30-minute to 4-hour exposure), the lowest exposure concentration causing death or irreversible health effects in any species is determined to be the IDLH concentration.

- Chronic exposure data may have no relevance to the acute effects and should be used in determining the IDLH concentration, only upon competent toxicologic judgment.

- Where there is no toxicologic evidence of an IDLH concentration, 500 times the permissible exposure limit shall determine the upper limit--above which only a highly reliable breathing apparatus providing maximum worker protection is used.

5. Lower Flammable Limit (LFL) and Firefighting

In addition to toxic chemicals and irritants, it is necessary to consider flammable substances. In any atmosphere where there is a likelihood of a chemical fire, there is the risk of creating toxic vapors in the fire or of experiencing asphyxiation, caused by reduction of the oxygen content by the process of combustion.

Contaminant concentrations in excess of the LFL are considered to be IDLH. At or above the LFL, the use of respirators is limited to those devices that provide the maximum protection (i.e., positive pressure self-contained breathing apparatus [SCBA] and the combination of positive pressure supplied-air respirators with auxiliary positive pressure SCBA).

6. Protection Factors

The protection factors of a respiratory protection device are useful numerical tools to assist in the choice of a protective system. Protection factors are a measure of the overall effectiveness of a respirator. Filtering efficiency is part of the protection factors and becomes a significant consideration for less efficient air-purifying respirators.

The protection factor of a given respirator, for a specific user, multiplied by the PEL (or TLV) for a given substance is the maximum allowable concentration for that substance where the respirator may be used. For example, say the protection factor for a full-face mask respirator is 100. For substance X with a PEL (or TLV) of 100 ppm, the full-face mask respirator will provide protection up to 10,000 ppm. Note that there is a difference between "quantitative" protection factors and "qualitative"

protection factors. The current protection factor must be used in determining the maximum allowable concentration (see ANSI Z88.2-1969 for reference).

7. **Variations with 30 CFR 11**

The Type A supplied-air respirator is allowed in 30 CFR 11 for use in IDLH atmospheres. However, the air flow requirement of 50 liters/min is insufficient to maintain a positive pressure in the facepiece under all working conditions. Therefore, this device should have the same protection factor, as applied to other air-purifying and atmosphere-supplying respirators having a negative pressure in the facepiece (see Appendix I or 30 CFR 11).

Protection factor requirements are not contained in 30 CFR 11. Protection factors are used in the decision logic. In addition, 30 CFR 11 does not permit the use of an escape gas mask against acid gases or organic vapors with poor warning properties.

8. **Escape Protection**

Brown & Root Environmental will provide and ensure that the site personnel carry an escape respirator where the air is currently safe, but exposure may occur to extremely toxic substances or where the potential exists for an increase above the safe level for air contaminants. (An extremely toxic substance is defined as a gas or vapor having a rate LC_{50} of less than 10 ppm).

5.3 AIR-PURIFYING RESPIRATORS

The following basic facts are important for the use of the air-purifying respirator:

1. Air-purifying respirators employ filtering of air by the use of mechanical filters and/or sorbents.

2. Air-purifying respirators must not be used in atmospheres that are oxygen-deficient.

3. Air-purifying respirators must not be used in atmospheres that are IDLH.

4. The specific contaminant must be identified, both qualitatively and quantitatively. A tabulation of specific atmospheric contaminants and the colors assigned to cartridges and gas mask canisters, used to protect against such contaminants, is presented next.

Table 1 lists the common color-costing system for air purifying cartridges and canisters.

TABLE 1

COLOR-CODING CARTRIDGES AND CANISTERS

Atmospheric Contaminants to be Protected Against	Color Assigned
Acid gases	White
Organic vapors	Black
Ammonia gas	Green
Carbon monoxide gas	Blue
Acid gases and organic vapors	Yellow
Acid gases, ammonia, and organic vapors	Brown
Acid gases, ammonia, carbon monoxide, and organic vapors	Red
Other vapors and gases not listed above	Olive
Radioactive materials (except tritium and noble gases)	Purple
Dust, fumes, and mists (other than radioactive materials)	Orange

Notes:

1. A purple stripe shall be used to identify radioactive materials in combination with any vapor or gas.

2. An orange stripe shall be used to identify dusts, fumes, and mists in combination with any vapor or gas.

3. Where labels only are colored to conform to this table, the canister or cartridge body shall be gray; or a metal container or cartridge body may be left in its natural metallic color.

4. The user shall refer to the wording on the label to determine the type and degree of protection the canister or cartridge will afford.

5. Monitoring of the atmosphere must be performed, while an air-purifying respirator is used.

6. A respirator fit test must be performed and passed before the specific respirator can be used. The fit of the respirator changes with the growth of facial hair, weight loss/ gain, dental work, etc. The biggest cause of leakage is facial hair.

7. Protection factors must be used to determine if a specific respirator can be utilized in a given atmosphere.

There are many different types of air-purifying respirators for use in various circumstances:

1. Disposable dust respirators are only for use with dusts.

2. Mouth-bit respirators
   a. Only used as an escape device.
   b. Not useful for hazardous waste work.

3. Quarter-mask respirators
   a. Not for use with hazardous chemicals.
   b. High degree of leakage.

4. Half-mask respirators
   a. Can be used in restricted conditions with hazardous chemicals.
   b. High degree of leakage.
   c. Only 50 percent of population can get satisfactory fit.

5. Full-face-mask respirators
   a. Cover entire face from under the chin to above the eyes, thus providing eye protection as well as respiratory protection.
   b. Provide much better respirator protection than previously-mentioned respirators, since full-face respirators give a better fit.
   c. Are usually made of butyl rubber, neoprene or silicone rubber.

6. Powered air-purifying respirators are more effective than standard air-purifying respirators.

7. Gas masks are more effective than chin-cartridge, air-purifying respirators, due to their large sorbent capacity.

5.4 SUPPLIED-AIR RESPIRATORS

The supplied-air breathing apparatus is the most effective of the protective breathing devices. Supplied-air respirators are used, if the nature of the respiratory hazard is unknown or if the concentration of toxic pollutants is too high to allow the use of air-purifying respirators. There are two types of supplied-air respirators--open-circuit and closed-circuit.

1. Closed-circuit is a rebreathing system that adds fresh oxygen.
2. Open-circuit has a supply of breathing air; exhaled air is returned to the ambient atmosphere.

The supplied-air respirator has two modes of operation: demand and pressure-demand.

1. Demand. Negative-pressure is created inside the facepiece and breathing tubes, upon inhalation.

2. Pressure-Demand. Positive pressure is maintained inside the facepiece and breathing tubes at all times. This type of supplied-air respirator is to be used on waste site work or in IDLH-confined spaces.

Only pressure-demand units are approved for use in IDHL atmospheres.

Supplied-air respirators come in several forms:

1. Air Mask and Blower

   a. Limited by capacity of the hand or motor-driven blower.
   b. Blower must intake clean air.
   c. Unit operates open-circuit, demand

2. Air Mask and Airline

   a. Depending on type of mask, may operate either as demand or pressure-demand.
   b. Can be used in IDHL atmospheres, if an escape canister is attached to a pressure-demand unit.
   c. Useful for long periods of work, as large-capacity air tanks are available.

3. Self-Contained Breathing Apparatus (SCBA)

   a. SCBA carries the air-supply within the unit and may be a rebreather, oxygen resupply, or breathing air supply.
   b. SCBAs may be either demand or pressure-demand.

c. SCBAs are typically rated at up to 4 hours for rebreathers and from 30 to 60 minutes for the other configurations.

Maintenance of air regulators must be performed by personnel trained and certified by the manufacturer. Because the use of supplied-air respirators places physiological and psychological burdens on the user, personnel must be medically fit and extensively trained.

5.5 SELECTION OF EQUIPMENT

Equipment selection is based on "Joint NIOSH/OSHA Standards Completion Program Respirator Decision Logic" found in Reference 1. The purpose of the respirator decision logic is to ensure technical accuracy and uniformity in the selection of respirators and provide necessary criteria to support this selection. The decision logic is a step-by-step elimination of inappropriate respirators until only those that are acceptable remain. Judgment by persons knowledgeable about inhalation hazards and respiratory protection equipment is essential to ensure appropriate selection of respirators.

The primary technical criteria for what constitutes a permissible respirator are based on the technical requirements of 30 CFR 11. Safety standards and REM III policy will allow only respirators approved under 30 CFR 11. Classes of respirators are only included when at least one device has been approved.

Protection factors are criteria used in determining what limiting concentrations are to be permitted for each respirator type that will afford adequate protection to the wearer. The referenced subparts of 30 CFR 11 give technical descriptions concerning each type or class of respirator referenced in the decision logic. Hence, 30 CFR 11 should be used with the decision logic in order to properly understand the criteria for the specification of allowable respirators.

Throughout this text, reference is made to Permissible Exposure Limits (PELs). Prudent, accepted practice dictates the use of current ACGIH TLVs, which are updated each year, as well as the PEL which are only periodically updated.

The following material, used in concert with the decision logic charts (Attachment A, B, and C), provides a formalized selection guide for respiratory protection.

Step 1 - Assemble Information on Substance

Assemble necessary toxicological, safety, and research information for the particular contaminant. The following are required:

a. Permissible exposure limits specified in 29 CFR 1910.1000 (Tables Z-1, Z-2, and Z-3).

b. Warning properties, if the substance is a gas or a vapor.

c. Eye irritation potential of the substance.

d. LFL for the substance.

e. IDLH concentrations for the substance.

f. Any possibility of poor sorbent efficiency at IDLH concentration and below.

g. Any possibility of systemic injury or death resulting from absorbance of the substance (as a gas or vapor) through the skin.

h. Any possibility of severe skin irritation resulting from contact of the skin with corrosive gases, vapors, or particulates.

i. The vapor pressure of the substance (and equivalent ppm for saturated air).

j. Any possibility of high heat or reaction with the sorbent material in a cartridge or canister.

k. Any possibility of shock sensitivity of a substance sorbed on the sorbent of a cartridge or canister.

Step 2 - Determine Physical State of Substance

Determine the physical state(s) of the substance as it is likely to be encountered in the occupational environment. It will be either a gas or vapor; a particulate (dust, fume, or mist); or a combination of these forms.

Step 3 - Assemble a Table of Permissible Respiratory Protection for the Substance

This task is done using the material from Step 1, the appropriate specific decision logic chart in the attachments, and respiratory protection factors. Classes of respirators are only included in the attachments, where at least one device has been approved.

6.0 REFERENCES

A Guide to Industrial Respiratory Protection, HEW Publication (NIOSH) 76-189.

7.0 ATTACHMENTS

Attachment A - Format for Determining Respiratory Protection

Attachment B - Selection of Respiratory Equipment

Attachment C - ANSI Z88.2 Proposal Respirator Maximum Use Limits

ATTACHMENT A
FORMAT FOR DETERMINING RESPIRATORY PROTECTION
QUESTIONNAIRE
GAS MASK AND RESPIRATOR RECOMMENDATION

Name and address of company seeking recommendation: _____

Name of Individual: _____
His phone number: _____

1. Material–
   a. Chemical Name: _____
   b. Trade Name: _____
   c. Formula: _____
   d. TLV or TWA OSHA 1910.1000 _____ Current AGIH _____

2. Form in which it will be used–
   a. Liquid? _____ b. Solids? _____ c. Gaseous? _____
   d. If gaseous, is it an organic vapor? _____ or acid gas? _____

3. Maximum expected concentration–
   a. _____ parts per million, or
   b. _____ milligrams per cubic meter

4. Will material be heated? _____
   a. If so, to what temperature? _____ °F

5. What is the odor threshold of the material? _____

6. At what concentration is the material considered to be immediately dangerous to life or health? _____

7. Can the substance be absorbed through the skin? _____

8. Irritant to eyes? _____ Respiratory tract? _____ Skin? _____

9. At what concentration is it an irritant? _____

10. If the substance is known to be flammable, what are the lower and upper flammable limits, in percent by volume? _____

11. What is the vapor pressure of the material? _____

12. Will material be mixed with other chemicals? _____ If so, give details _____

13. Any possibility of oxygen deficiency? _____

14. Can good ventilation of the area be maintained? _____

15. Will exposure be continuous? _____ or intermittent? _____

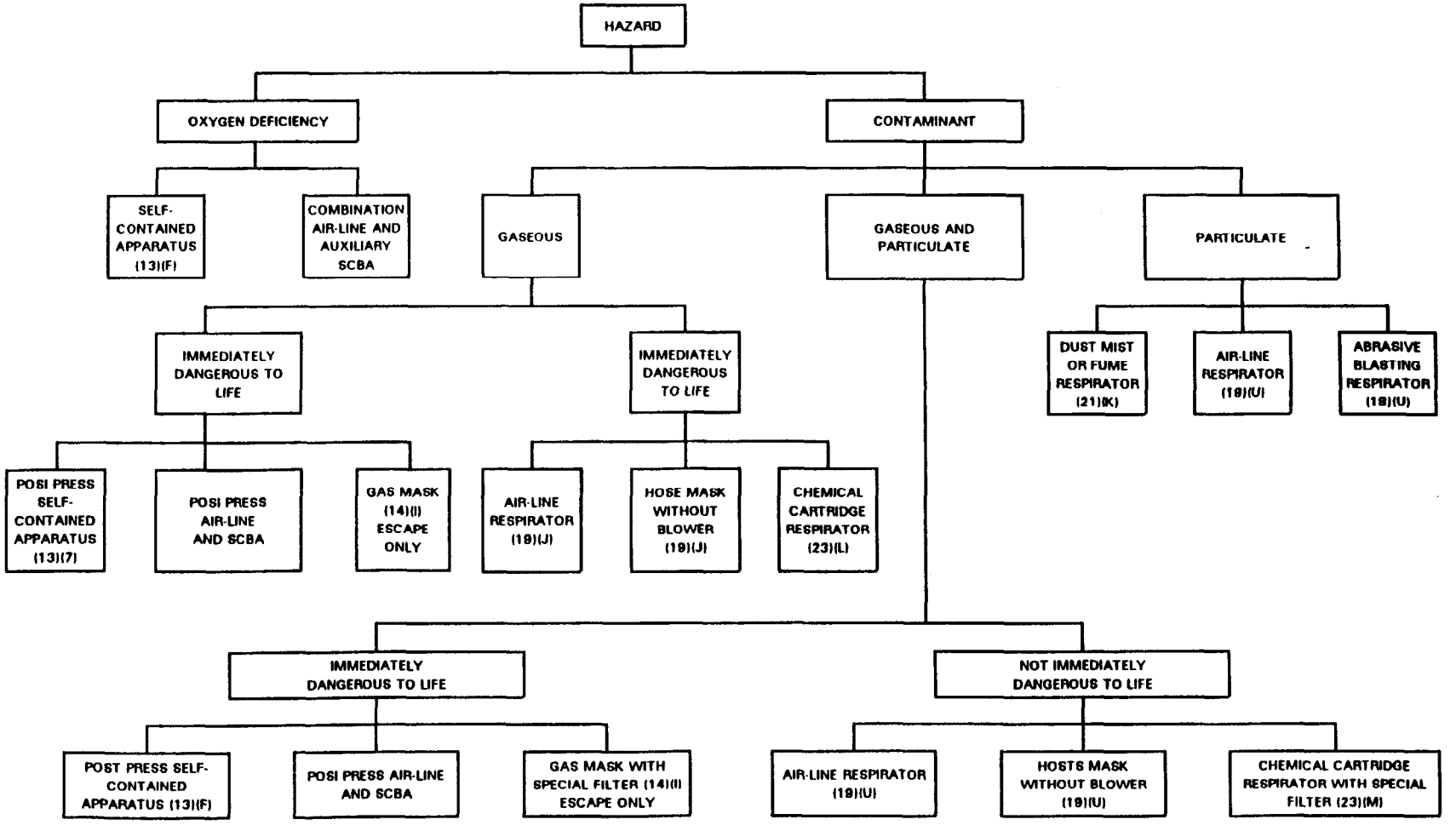
16. Will the respiratory device be used for routine exposures, or will it be used as an escape device? _____

17. Provide as much detail as possible concerning exposure conditions.

FORMAT FOR DETERMINING RESPIRATORY PROTECTION

ATTACHMENT B
SELECTION OF RESPIRATORY EQUIPMENT (LUNDIN, A., 1979)

OUTLINE FOR SELECTING RESPIRATORY PROTECTIVE DEVICES



ATTACHMENT C
ANSI Z88.2 PROPOSAL
RESPIRATOR MAXIMUM USE LIMITS

Respirator	Permitted for Use in Atmospheres		MUL Respirator Fit Index According to Fitting Method Used		
	O2 Def.	IDHL	Quantitative	Semi-Quantitative	Quantitative
1. 1/4 or 1/2 facepiece Particulate Filter*	No	No	10	200	As Measured on Each Person or MUL-C
2. 1/4 or 1/2 Facepiece Vapor Gas	No	No	Lower of 10 or MUL-C	Lower of 1,000 or MUL-C	
3. Full Facepiece Particulate Filter*	No	No	100	1,000	
4. Full Facepiece Vapor Gas	No	No			
5. Powered Air-Purifying (Any Respiratory Inlet Cover)*	No	No	MUL-C	MUL-C	
6. Air-Line (Demand) 1/4 or 1/2 Facepiece	No	No	10	200	As Measured on Each Person
7. Air-Line (Demand) Full Facepiece	No	No	100	1,000	
8. Air-Line (Demand) Full Facepiece with Escape Provision	Yes**	Yes	100	1,000	
9. Hose Mask Full Facepiece	No	No	100	1,000	
10. Air-Line (Pressure-Demand or Constant Flow)	No	No	N/A	N/A	N/A
11. Air-Line (Pressure-Demand with Escape Provision)	Yes**	Yes	N/A	N/A	N/A
12. Air-Line (Constant Flow with Escape Provision)	Yes**	Yes	N/A	N/A	N/A
13. Demand SCBA (Open or Closed Circuit) Full Facepiece or Mouthpiece	Yes	Yes	100	1,000	As Measured on Each Person
14. Pressure-Demand SCBA Half or Full Facepiece	Yes	Yes	N/A	N/A	N/A
15. Combination Devices Not Listed	Use Lowest MUL Listed				

* Use high-efficiency filters for particulates with TLV less than 0.05 mg/m^3.

** Escape provision must be an auxiliary self-contained air supply.

MUL-C MUL of cartridge or canister used.

PRESSURE-DEMAND SCBA INSPECTION AND MAINTENANCE
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PRESSURE-DEMAND SCBA INSPECTION AND MAINTENANCE

1.0 PURPOSE

To provide an inspection routine for pressure demand, self-contained breathing apparatus (SCBA). To keep SCBA equipment clean and working properly and to comply with Federal regulations (CFR Title 29, 1910.134) governing the maintenance of SCBAs.

2.0 SCOPE

Applies to all Brown & Root Environmental MSA SCBA users. Brown & Root Environmental shall only use MSA SCBAs.

3.0 GLOSSARY

Certified Repair Person - Individual(s) certified by the manufacturer to provide repairs.

Licensed Hydrotester - Individual(s) authorized by the U.S. Department of Transportation to hydrotest gas cylinders.

4.0 RESPONSIBILITIES

User - It is the responsibility of the user to correctly perform the check-out procedures described in the SCBA manufacturer's literature and in this operating guideline prior to donning the SCBA.

Certified Repair Person - The certified repair person is responsible for ensuring that the monthly check, regulation checks, and cylinder hydrotests are conducted according to schedule.

5.0 PROCEDURES

5.1 User Pre-wear Inspection

The following list of items must be addressed by the user immediately prior to the donning of SCBAs. Any malfunction found shall be reason to set the unit aside until it can be repaired by a certified repair person.

1. Preliminary Inspection

   Check to ensure that:

   a. O-ring gasket in high pressure line fitting is intact and in place.
   b. High pressure hose connector is tight on cylinder fitting.
   c. Bypass valve is closed.
   d. Mainline valve is closed.
   e. Dust cover is not covering regulator outlet.
   f. Pressure in the tank is at least 1,800 psi.

2. Backpack and Harness Assembly

   a. Straps

      (1.) Visually inspect for complete set.
      (2.) Visually inspect for frayed or damaged straps that may break during use.

   b. Buckles

      (1.) Visually inspect for mating ends.
      (2.) Check locking function.

   c. Backplate and cylinder lock

      (1.) Visually inspect backplate for cracks and for missing rivets or screws.
      (2.) Visually inspect cylinder hold-down strap and physically check strap tightener and lock arrangement to ensure that it is fully engaged.

3. Cylinder and Cylinder Valve Assembly

a. Cylinder

(1.) Physically check cylinder to ensure that it is tightly fastened to backplate.

b. Head and valve assembly

(1.) Visually inspect cylinder valve lock for presence.

(2.) Visually inspect cylinder gauge for condition of face, needle, and lens.

(3.) Open cylinder valve and listen or feel for leakage around packing. (If leaking is noted, do not use SCBA until repaired.) Note function of valve lock.

4. Regulator and Low-Pressure Alarm

a. High-pressure hose and connector.

Listen or feel for leakage in hose or at hose-to-cylinder connector. (A bubble in outer hose covering may be caused by seepage of air through the hose, when stored under pressure. This occurrence does not necessarily mean a faulty hose.)

b. Regulator and low-pressure alarm

(1.) Cover outlet of regulator with palm of hand. Open mainline valve and read regulatory gauge. (It must read at least 1,800 psi and not more than rated cylinder pressure).

(2.) Close cylinder valve and slowly move hand from regulator outlet to allow slow flow of air. Gauge should begin to show immediate loss of pressure, as air flows. Low-pressure alarm should sound between 650 and 550 psi. Remove hand completely from outlet and close mainline valve.

5. Facepiece and Corrugated Breathing Tube

a. Facepiece

(1.) Stretch breathing tube and visually inspect for deterioration and holes.

(2.) Visually inspect connector to ensure good condition of threads and for presence and proper condition of "O" ring or rubber gasket seal.

(3.) Negative pressure test of facepiece

(a.) Don backpack and facepiece.

(b.) With facepiece held tightly to face or facepiece properly donned, stretch breathing tube to open corrugations and place thumb or hand over end of connector.

(c.) Inhale. Negative pressure should be created inside mask, causing it to pull tightly to face. This negative pressure should be maintained for 5 to 10 seconds. If negative pressure cannot be maintained, the facepiece assembly is not adequate and should not be worn.

6. Storage of Units

Check to ensure that:

a. Unit is cleaned and inspected

b. Cylinder is fully charged after each use. Cylinders should not be stored partially charged for two reasons:

(1.) The life of the apparatus is reduced.
(2.) The safety relief device is only designed to protect a fully charged cylinder from the effects of a fire.

c. Pressure is bled off the high pressure hose.

d. High pressure hose is attached to cylinder.

e. Mainline valve is closed.

f. Bypass valve is closed.

g. All straps are completely loosened.

h. Facepiece is properly stored to protect against dust, sunlight, heat, extreme cold, excess moisture, and damaging chemicals.

5.2 Periodic Inspections

SCBAs shall be inspected within 30 days prior to use by a certified repair person to insure that they are working properly. These inspections involve the following:

1. The routine check-out procedure used by personnel, before every use of an SCBA, must be repeated by a certified repair person.
2. A complete physical examination must be made of all external working parts on a monthly basis.
3. Gaskets, seals, and rubber parts are examined for pliability and signs of deterioration.
4. A physical examination of the diaphragm, diaphragm spring, and lever assembly must be made.

5.3 Semiannual Regulatory Inspections

SCBAs must be checked within 6 months prior to use on a portable regulatory tester, to ensure that the regulator is mechanically sound. Checks on the regulatory tester must include the following:

1. Static pressure check.
2. Air flow performance test.
3. A test for excess aspiration of the regulator.

5.4 Cylinder Hydrostatic Tests

Air tanks must also be hydrostatically tested to insure soundness. Aluminum cylinders wound in fiberglass must be tested every 3 years; steel cylinders need only be tested every 5 years. All test dates must be recorded in the maintenance log book.

Air tanks should be almost empty when being shipped. However, several hundred psi of air should be left in the tanks to keep out moisture and contaminated air.

6.0 REFERENCES

None.

7.0 ATTACHMENTS

Attachment A - SCBA Maintenance and Inspection Schedule

ATTACHMENT A
SCBA MAINTENANCE AND INSPECTION SCHEDULE

Maintenance Function	Frequency	Responsibility
Routine check-out	Before each use	User
Complete check-out	Within 30 days prior to use	Certified repair person
Regulatory check	Within 6 months prior to use	Certified repair person
Hydrostatic tank test	Every 3 years (Aluminum/Fiberglass)	Licensed hydrotester
	Every 5 years (Steel)	Licensed hydrotester
Cleaning of SCBA	After each use	User

ATTACHMENT B

RESPIRATORY PROTECTION CHECKLIST

1. List site personnel using respiratory protection in the table below.

Name	FIT Test Date	Type of Respirator	Type of Cartridge

ATTACHMENT C

RESPIRATORY EQUIPMENT MAINTENANCE CHECKLIST

1. List person responsible for cleaning and maintaining respiratory equipment.

   _____

2. Location of area where equipment will be cleaned and maintained.

   _____

3. Describe cleaning procedure and solution used for onsite cleaning of respiratory equipment.

   _____
   _____
   _____
   _____

4. List address and phone numbers of nearest factory authorized equipment repair center.

   _____
   _____
   _____
   _____

5. Describe procedure for refilling SCBA cylinders.

   _____
   _____
   _____
   _____

6. List vendor used to refill SCBA cylinders and phone numbers.

   _____ _____
   _____ _____
   _____ _____
   _____ _____

SELF-CONTAINED BREATHING APPARATUS (SCBA) TRAINING
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SELF-CONTAINED BREATHING APPARATUS (SCBA) TRAINING

1.0 PURPOSE

To provide a format for self-contained breathing apparatus (SCBA) training and to ensure the proper and safe use of SCBAs.

2.0 SCOPE

Applies to all Brown & Root Environmental personnel who may use SCBAs in their work activity.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Office Health and Safety Supervisor (OHSS) - It shall be the responsibility of the OHSS to insure that all Brown & Root Environmental employees who may be required to wear SCBAs, have received appropriate basic and refresher SCBA training, as required.

5.0 PROCEDURES

5.1 Requirements

Prior to using an SCBA in the field, Brown & Root Environmental personnel must complete training and demonstrate proficiency in the use of the SCBA.

5.2 Training to be Presented

Training regarding respiratory protection will, at a minimum, incorporate the following:

1. Reasons why respiratory protection is being used (which may be covered in the pre-activity meeting for each site) and criteria for respirator selection.

2. Capabilities and limitations of the SCBA used.
3. Procedures for inspecting, donning, and wearing of the SCBA.
4. Procedures for maintenance and storage of the SCBA.
5. Procedures for identifying and dealing with respiratory emergencies.
6. Regulations concerning SCBA use.

5.3 Proficiency Demonstration

Following SCBA training, personnel must demonstrate:

1. An understanding of how an SCBA works.
2. Limitations of an SCBA.
3. Competency in donning, wearing, activating, and removing the SCBA. Ability to disassemble and clean an SCBA facepiece and hose.
4. Ability to check-out and inspect the SCBA for defects.
5. Knowledge of maintenance and storage procedures.

5.4 Refresher Training

Brown & Root Environmental site personnel who have not used an SCBA in the field during the preceding 6 months will be required to repeat 5.3 before assignment to field use of an SCBA. A repetition of training specified in 5.2 may be required to successfully complete the continuing proficiency demonstration.

5.5 Record Keeping

The OHSS shall maintain an appropriate record of Brown & Root Environmental SCBA training and proficiency demonstration(s). These records will be subject to annual audit by the Program Manager of Health Sciences.

6.0 REFERENCES

None.

7.0 ATTACHMENTS

None.

SITE CONTROL
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SITE CONTROL

1.0 PURPOSE

To provide general reference information on the control of contaminated materials typically generated during field investigations.

2.0 SCOPE

These procedures are applicable for conducting field investigations. However, site-specific needs may require different or additional precautions than those described here. These must be identified during the development of the Site Operation Plan or equivalent document.

3.0 RESPONSIBILITIES

Project Manager (PM) - Responsible for ensuring that project-specific plans are in compliance with these procedures.

Field Operations Leader (FOL) - Responsible for the correct implementation of these measures in the field.

4.0 PROCEDURES

Field investigation activities often result in the production or movement of contaminated materials that must be properly managed to protect the public and the environment, as well as to meet legal requirements. These guidelines address the proper management of these materials.

4.1 Overview

For the purposes of these procedures, contaminated materials are defined as "any by-products of a field investigation that are suspected or known to be contaminated with hazardous substances." These by-products include such materials as decontamination solutions, disposable equipment and clothing, drilling muds, well-development fluids, and spill-contaminated materials. However, it should be noted that contaminated materials are different from hazardous waste and the disposal requirements which apply to hazardous waste may not necessarily apply to contaminated materials.

In some instances, if proper waste handling or containerizing practices are employed, waste materials resulting from site activities can be left on site. This procedure shall be done whenever permitted by the client or the governing agency. However, there are instances discussed in Section 4.3 in which Brown & Root Environmental staff must consider removal of waste to a permitted hazardous waste facility.

The Site Operations Plan (or equivalent document) for a site investigation must include a description of control procedures for contaminated materials. This planning strategy would assess the type of contamination, estimate the amounts that would be produced, describe containment equipment and procedures, and delineate storage or disposal methods. As a general policy, it is wise to select investigation methods that minimize the generation of contaminated spills. Until sample analysis is complete, it is assumed that all produced materials suspected of contamination from hazardous chemicals will always require containment, unless expressly waived by the client or the governing agency.

4.2 Work Zones

4.2.1 Introduction

The activities required during responses to environmental incidents involving hazardous substances may contribute to the movement of materials (contaminants) from the site to unaffected areas. Response personnel who are working and equipment being used around the substances may become contaminated and carry the material into clean areas. Material may become airborne because of its volatility. Or the disturbance of contaminated soil may cause it to become wind-blown. To minimize the transfer of hazardous substance(s) from the site, due to site activities, contamination control procedures are needed. Two general methods are used: establishing site work zones and removing contaminants from people and equipment.

4.2.2 Control at the Site

A site must be controlled to reduce the possibility of: (1) exposure to any contaminants present and (2) their transport by personnel or equipment from the site. The possibility of exposure or translocation of substances can be reduced or eliminated in a number of ways, including:

1. Setting up security and physical barriers to exclude unnecessary personnel from the general area.
2. Minimizing the number of personnel and equipment at the site consistent with effective operations.
3. Establishing work zones within the site.

4. Establishing control points to regulate access to work zones.

5. Conducting operations in a manner to reduce the exposure of personnel and equipment and to eliminate the potential for airborne dispersion.

6. Implementing appropriate decontamination procedures.

Site security during work hours is controlled first at the support zone (SZ) and secondly, at the access control points of the contamination reduction zone (CRZ). If the site is not fenced or surrounded by a barrier or prohibitive terrain, site security presents a more difficult problem. On small area sites, if personnel are available, patrolling the site boundary may be feasible as long as line-of-sight is maintained. On larger area sites, posting signs around the perimeter may have some effect. In this case, the team should be alert to unauthorized personnel who may approach from a direction away from the SZ. When working on an active facility or property which is inhabited, it is not always feasible to prevent unauthorized personnel from entering the exclusion zone. Evacuation of the area by team members may be necessary if the unauthorized personnel create a danger to the health and safety of the work parties. An explanation of the work being performed and a request to avoid the area will hopefully invite the cooperation of property owners, facility employees, or local citizens. If the site presents a significant risk to the health and safety of the local populace, local police support should be requested for additional site security.

Site security during off-hours can be handled in two primary ways. First, a fence or barrier around the site would prevent unauthorized personnel from entering the site. In addition, equipment must be locked within the fence or trailer, or removed from the site each day. The other alternative is to employ a security guard to watch the area during off-hours or have the local police patrol the area. With this alternative, the equipment must still be locked up or removed from the site to prevent theft or tampering.

4.2.3 Delineation of Work Zones

One method, for minimizing the potential for the migration of contamination, is to delineate zones on the site where prescribed operations are to occur. Movement of personnel and equipment between zones and onto the site itself would be limited by access control points. By these means, contamination would be expected to be limited to certain relatively small areas on the site. Three contiguous zones (Section 5.1) are recommended:

Zone 1: Exclusion Zone (EZ)

Zone 2: Contamination Reduction Zone (CRZ)

Zone 3: Support Zone (SZ)

4.2.3.1 Zone 1: Exclusion Zone

The EZ, or the innermost of three concentric areas, is the zone where contamination does or could occur. All people entering the EZ must wear prescribed levels of protective gear. An entry and exit checkpoint must be established at the periphery of the EZ to regulate the flow of personnel and equipment into and out of the zone and to verify that the procedures established to enter and exit are followed.

The outer boundary of the EZ, the Hotline, is initially established by visually surveying the immediate environs of the incident and determining where the hazardous substances involved are located, i.e., where any drainage, leachate, or spilled material is found and whether any discolorations are visible. Guidance in determining the boundaries is also provided by data from the initial site survey, indicating the presence of organic or inorganic vapors/gases or particulates in the air; combustible gases, and radiation; or the results of air, water, and soil sampling.

Additional factors that shall be considered include the distances needed to prevent a fire or an explosion from affecting personnel outside the zone, the physical area necessary to conduct site operations, and the potential for contaminants to be blown from the area. Once the Hotline has been determined, it shall be physically marked, fenced, or well-defined by landmarks. During subsequent site operations, the boundary may be modified and adjusted as more information becomes available.

All personnel within the EZ must wear the required level of protective gear. Personnel protective equipment is designated on the basis of site-specific conditions, including the type of work to be done and the hazards that might be encountered. Frequently, within the EZ, different levels of protection are justified. Subareas are specified and conspicuously marked (Section 5.2). The level of protection within subareas is determined by the measured concentration of substances in the air, the potential for contamination, and the known or suspected presence of highly toxic substances.

Different levels of protection in the EZ might also be designated by job assignment. For example, collecting samples from open containers might require Level B protection; while, for a walk-through, Level C using air monitoring might be sufficient. The assignment (where appropriate) of different levels of protection within the EZ generally makes for a more flexible, effective, and less costly operation, while still maintaining a high degree of safety.

4.2.3.2 Zone 2: Contamination Reduction Zone (CRZ)

Between the EZ and the SZ is the CRZ. The CRZ serves as a buffer to further reduce the probability of the clean zone becoming contaminated or being affected by other existing hazards. It provides additional assurance that the physical transfer of contaminating substances on people, equipment, or in the air is limited through a combination of decontamination, distance between the EZ and SZ, air dilution, zone restriction, and work functions.

Initially, the CRZ is considered to be a noncontaminated area. At the boundary between the Exclusion and Contamination Reduction Zones, decontamination stations are established: one for personnel and one for heavy equipment. Depending on the size of the operation, more than two stations may be necessary. Exit from the EZ must be through a decontamination station.

As operations proceed, the area around the decontamination station may become contaminated, but to a much lesser degree than the EZ. On a relative basis, the amount of contaminants should decrease from the Hotline to the SZ, due to the distance involved and the decontamination procedures used.

The boundary between the SZ and the CRZ, called the Contamination Control Line, separates the possibly low contamination area from the clean SZ. Access to the CRZ from the SZ is through a control point. Personnel entering there would wear the prescribed personal protective equipment (PPE) for working in the CRZ. Entering the SZ requires removal of any protective equipment worn in the CRZ.

4.2.3.3 Zone 3: Support Zone (SZ)

The SZ, or the outermost part of the site, is considered to be a noncontaminated or clean area. Support equipment (command post, equipment trailer, etc) is located in this zone, and traffic is restricted to authorized response personnel only. Since normal work clothes are appropriate within this zone, potentially contaminated personnel clothing, equipment, and samples are not permitted; but are left in the CRZ until they are decontaminated.

The location of the command post and other support facilities in the SZ depends on a number of factors, including:

1. Accessibility - The topography, available open space, and the locations of highways and railroad tracks are major considerations.

2. Wind Direction - The support facilities shall be located upwind of the EZ. However, shifts in wind direction and other conditions may be such that an ideal location, determined on the basis of wind direction alone, does not exist.

3. Resources - There should be adequate roads, power lines, water, and shelter.

4.3 Sources of Contaminated Materials and Containment Methods

4.3.1 Decontamination Solutions

All decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site unless there are analytical or other kinds of data to the contrary. The solution volumes could vary from a few gallons to several hundred gallons, in cases where large equipment requires cleaning.

Decontamination solutions for disposal are generated from:

- Personnel decontamination activities
- Sampling equipment decontamination activities
- Large equipment decontamination

Fluids from personnel and sampling equipment decontamination activities shall be contained as required by the client or the governing agency.

Typically, large equipment decontamination is performed at a lined steam cleaning area. Collected fluids should be transferred to 55-gallon drums or to a storage tank for eventual treatment and/or disposal.

4.3.2 Disposable Equipment and Clothing

Disposable equipment that could be contaminated during a site investigation typically includes protective suits, gloves, boots, broken sample containers, paper towels, and spent respirator cartridges. These items can be temporarily stored in plastic bags with daily transfer to 55-gallon drums (with lids) at the end of the day. These containers shall be secured at the end of each workday.

4.3.3 Drilling Fluids and Well Development Fluids

Drilling, well development, and well evacuation fluids (prior to sampling) are materials either utilized during, or generated as a result of, groundwater monitoring, well installation, and sampling activities. The potential that these fluids are contaminated requires that they be contained and/or controlled. Often, monitoring wells are placed off the site to determine if hazardous chemicals have migrated below ground. These offsite wells require especially careful management of waste fluids, since they threaten contamination of offsite property.

The volumes of drilling, well development, and well evacuation fluids depend on well diameter and depth, groundwater characteristics, geologic formations, and the drilling methods being utilized. There are no simple mathematical formulas available for accurately predicting these volumes. It is best to rely on the experience of reputable well drillers familiar with local conditions and the well installation techniques selected. These individuals should be able to estimate the sizes of containment structures required. Since guesswork is involved, a conservative estimate should be prepared.

Drilling fluid (mud) is mixed and stored in a container commonly referred to as a mud pit (tub). This mud pit consists of a suction section from which drilling fluid is withdrawn and pumped through hoses, down the drill pipe, and back up the hole to a settling section. In the settling section, the fluid velocity is reduced by a screen and several flow-restriction devices, thereby allowing the well cuttings to settle out of the fluid. If water is used as the drilling fluid or if the mud pit is lined to prevent leaks, a mud pit can also be used to contain possibly contaminated drilling fluids. Spent drilling fluids can then be properly disposal of directly from the mud pit.

As the well is drilled, the sediments that accumulate in the settling section must be removed. This removal is best done by carefully shoveling them into drums or other similar containers. When the drilling is complete, the contents of the aboveground tank are likewise shoveled or pumped into drums. Then the tank is cleaned and available for reuse.

If ground pits are used, they shall not extend into the natural water table. They should also be lined with a bentonite-cement mixture, followed by a layer of flexible impermeable material such as plastic sheeting. Of course, to maintain its impermeable seal, the material used would have to be nonreactive with the wastes. An advantage of the inground pit is that well cuttings do not necessarily have to be removed periodically during drilling because the pit can be made deep enough to contain them. Depending on site conditions, the inground pit may have to be totally excavated and refilled with uncontaminated natural soils, when the drilling operation is complete.

When the aboveground tank or the inground pit is used, a reserve tank or pit should be located at the site as a backup system for leaks, spills, and overflows. In either case, surface drainage shall be such that any excess fluid will be controlled within the immediate area of the drill site.

The containment procedure for well development fluids is similar to that for drilling fluids. The volume of contaminated fluid will be determined by the method of development. When a new well is developed by bailing, usually less volume of fluid results than when backwashing is performed by high-velocity jetting. When bailing, the removed fluids can be directly placed in drums. For the latter, a Tee section can be fitted on the well casing (in order to direct overflow fluid to the drums).

4.3.4 Soil Cuttings

Contaminated soil, consisting of soil cuttings from borings and test pit excavations as well as discarded soils from soil sampling activities, can be generated during field investigations. As discussed in Section 4.2.3, these soils should be placed into drums, or otherwise controlled as directed by the client or governing agency.

4.3.5 Spill-Contaminated Materials

A spill is always possible when a site investigation involves opening and moving containers of liquids. Contaminated sorbents and soils resulting from spills will have to be contained for disposal. Small quantities of spill-contaminated materials are usually best contained in drums, while larger quantities can be placed in lined pits or in other impermeable structures. In some cases, onsite containment may not be feasible and immediate transport to an approved disposal site will be required.

4.4 Disposal of Contaminated Materials

Actual disposal techniques for contaminated materials are the same as those for any hazardous substance: incineration, landfilling, treatment, etc. The responsibility for disposal must be determined and agreed upon by all involved parties before the field work starts. If the site owner or manager was involved in activities that precipitated the investigation, it seems reasonable to encourage his/her acceptance of the disposal obligation. Whenever it is necessary to containerize and remove wastes resulting from investigative activities, all RCRA requirements must be met. The contractor is responsible for subcontracting with reputable waste transporters and for assuring compliance with RCRA requirements. The contractor must, therefore, provide for the disposal of wastes resulting from field activities. Consequently, the client must initiate and sign the appropriate manifest documents for transportation and disposal.

Another consideration in selecting disposal methods for contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable onsite disposal structure is expected, contaminated materials generated during the investigation shall be stored at the site for disposal with other site materials. In this case, the initial containment structures shall be evaluated for use as long-term storage structures. Also, other site conditions such as drainage control, security, and soil type must be considered, so that proper storage is provided. If onsite disposal is expected, then the limited containment structures shall be designed for that purpose.

4.5 Other Considerations

4.5.1 Modifications

The use of a three-zone system, access control points, and exacting decontamination procedures provide a reasonable assurance against the translocation of contaminating substances. This site control system is based on a "worst-case" situation. Less stringent site control and decontamination procedures may be used if more definitive information is available on the types of substances involved and the hazards they present. This information can be obtained through air monitoring, instrument survey and sampling, and technical data review of the characteristics and behavior of the material present.

4.5.2 Area Dimensions

The distance between the Hotline, Contamination Control Zones, the command post, and the size and shape of each zone have to be based on conditions specific to each site. Considerable judgment is needed to ensure that the distances between zone boundaries are large enough to allow room for the necessary operations, to provide adequate distances to prevent the spread of contaminants, and to eliminate the possibility of injury due to explosion or fire. Long-term operations should involve developing reasonable methods to determine if material is being transferred between zones and to assist in modifying site boundaries.

The following example criteria shall be considered in establishing area dimensions and boundary distances:

1. Physical and topographical features of the site.
2. Weather conditions.
3. Field/laboratory measurements of air contaminants and environmental samples.
4. Air dispersion calculations.
5. Potential for explosion and flying debris.
6. Physical, chemical, toxicological, and other characteristics of the substances present.

7. Cleanup activities required.
8. Potential for fire.
9. Area needed to conduct operations.
10. Decontamination procedures.
11. Dimensions of contaminated area.
12. Potential for exposure.

4.5.3 Monitoring and Sampling

To verify that site control procedures are preventing the spread of contamination, a monitoring and sampling program shall be established. The SZ shall be periodically monitored for air contaminants using direct-reading instruments and/or collecting air samples for particulate, gas, or vapor analysis. Analysis of soil samples collected in the most heavily-used area would indicate contaminants being carried from the EZ by personnel, equipment, or wind. Occasional swipe tests shall be taken in trailers and other areas by personnel.

These same types of samples shall be collected and air-monitored in the CRZ. Increased concentrations in air or other environmental media may indicate a breakdown in control over the Contamination Reduction Corridor, ineffective decontamination procedure, or failure to restrict site access.

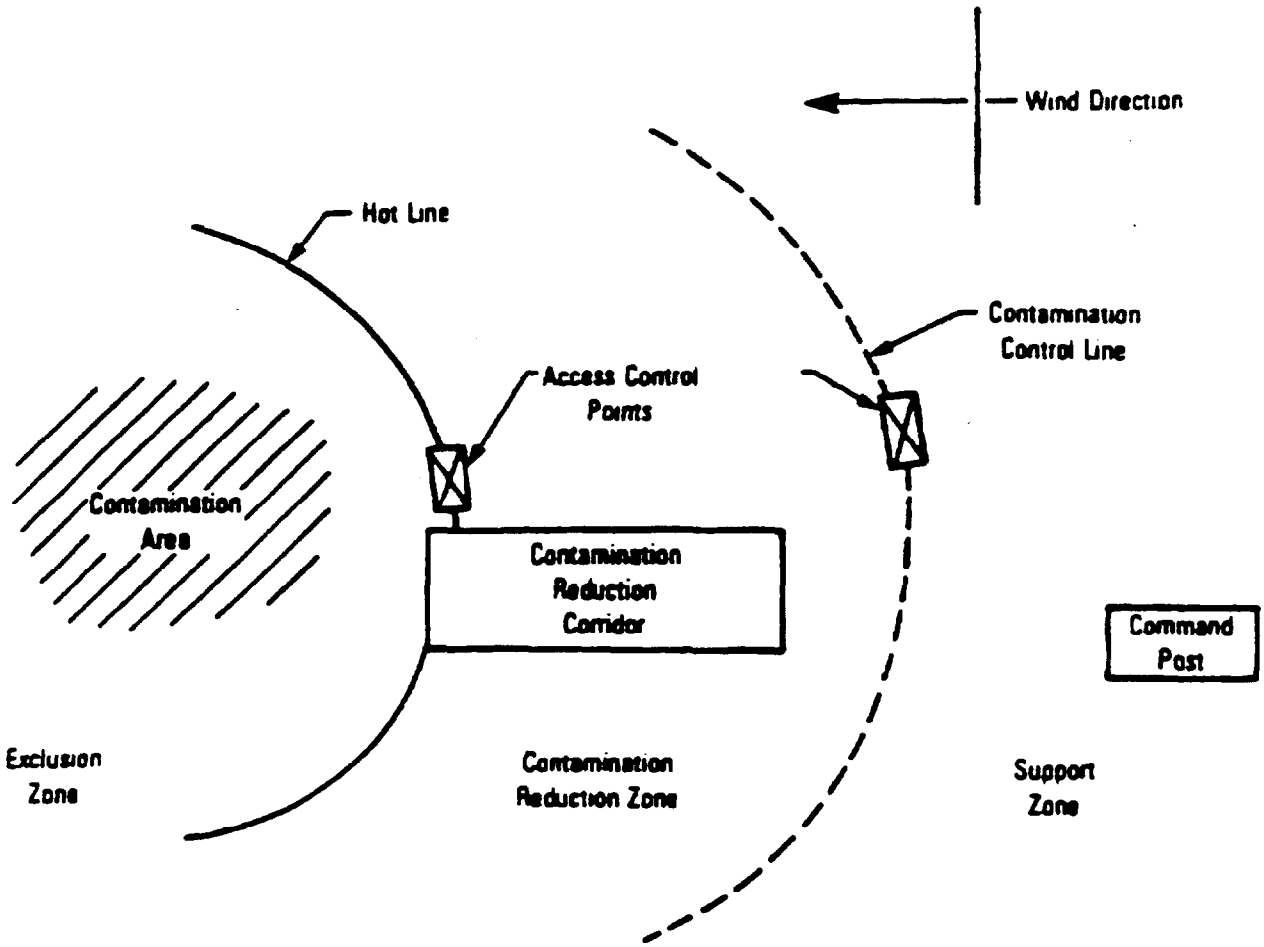
5.0 ATTACHMENTS

5.1 - Diagram of Site Work Zones

5.2 - Waste Site Subzones

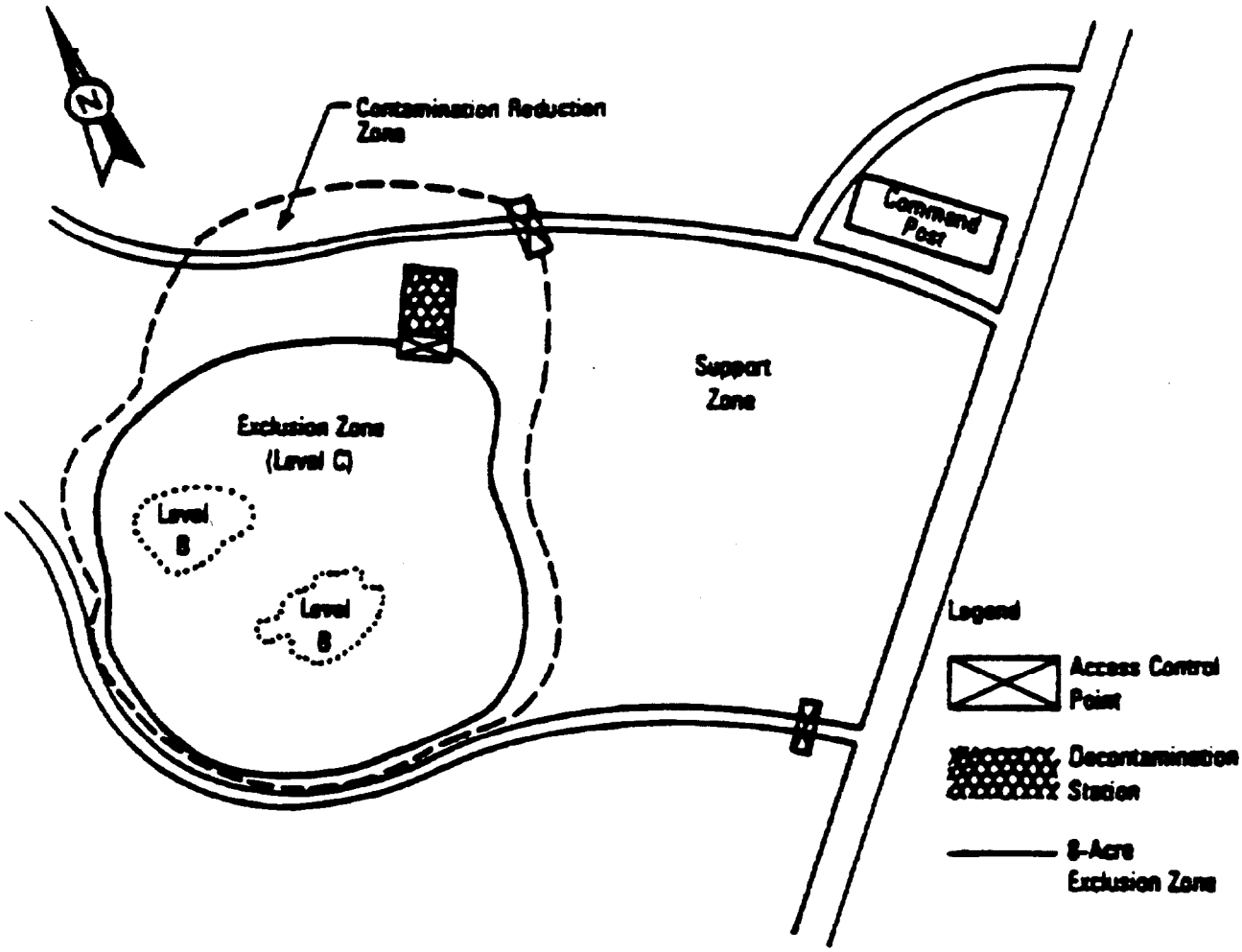
5.1

DIAGRAM OF SITE WORK ZONES



5.2

WASTE SITE SUBZONES



STANDARD WORK PRACTICES
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STANDARD WORK PRACTICES

1.0 PURPOSE

To establish standard work practices which are to be followed at all hazardous waste operation field activities. These standard work practices have been established to minimize the potential for exposure and injury to site personnel engaged in hazardous waste operations.

2.0 SCOPE

This section applies to all Brown & Root Environmental personnel and subcontractors involved in hazardous waste operations.

3.0 STANDARD WORK PRACTICES

The Standard Work Practices specified in this section are to be implemented and enforced, as applicable, for all site activities. Other standard work practices may be developed and implemented if appropriate for a specific activity such as welding, . . .

3.1 General Standard Work Practices

3.1.2 Eating, drinking, chewing gum or tobacco, taking medication, and smoking are prohibited in the exclusion or decontamination zones, or any location where there is a possibility for contact with site contaminants exists.

3.1.3 Upon leaving the exclusion zone, hands and face must be thoroughly washed with soap and potable water. Any protective outer clothing is to be decontaminated and removed as specified in this HASP, and left at a designated area prior to entering the clean area.

3.1.4 Contact with potentially-contaminated substances must be avoided. Contact with the ground or with contaminated equipment must also be avoided.

3.1.5 Facial hair interfering with a satisfactory fit of the respirator mask-to-face seal is prohibited.

3.1.6 All personnel must satisfy all training requirements (40-hr Introductory, 8-hr Refresher, Site-specific training, Emergency response training, and Supervisory as applicable) prior to commencing site activities.

3.1.7 All personnel must have a working knowledge of this HASP. Including being aware of the action levels for upgrading/downgrading levels of protective equipment, and emergency procedures.

3.1.8 All personnel must satisfy medical monitoring procedures.

3.1.9 All personnel must complete a medical data sheet, to be maintained on site.

3.1.10 All personnel working on-site must utilize the buddy system.

3.1.11 When lifting or moving equipment or material, use proper lifting techniques, the proper number of personnel, or equipment to move heavy loads.

3.1.12 All work areas must be kept free of ground clutter.

3.1.13 No flames or open fires will be permitted on site.

3.1.14 Site personnel must immediately notify Brown & Root Environmental Health Sciences of all incidents for OSHA recordkeeping purposes.

3.1.15 If personnel note any warning properties of chemicals (irritation, odors, symptoms, etc.) or even remotely suspect the occurrence of exposure, they must immediately notify the SSO for further direction.

3.1.16 Special permission with strict guidelines must be granted by the Health & Safety Manager to undertake any activity which would be considered a confined-space entry.

3.1.17 A full-sized copy of the OSHA poster included as part of this HASP shall be conspicuously posted on site.

3.1.18 Any new information relative to potential hazards or exposures must be promptly conveyed to the Project SSO and the Field Operations Leader.

3.1.19 All compressed gas cylinders used (empty or full) must be stored, secured, and used properly to protect from damage.

3.1.20 All field team members shall employ the use of lifelines, safety harnesses, and U.S. Coast Guard approved personal floatation devices when working within four feet of the water edge.

3.1.21 All field activities, particularly those associated with working on or near waters edge, will be suspended (at the discretion and direction of the Field Operations Leader, or Site Safety Officer) in the event of inclement weather.

3.2 Drilling Operations

3.2.1 Drilling or other operations with drill masts or other projecting devices must be further than 20 feet in any direction from overhead power lines. Prior to any subsurface investigations by the FOL shall ensure, the locations of all underground utilities will be identified and marked prior to initiating any subsurface activity.

3.2.2 Hand signals with the driller will be established prior to the commencement of drilling activities.

3.2.3 All drill rigs and other machinery with exposed moving parts must be equipped with an operational emergency stop device. All personnel working in a close proximity must be aware of the location of this emergency stop device and its operation. This device will be tested initially (and then periodically) to insure its operational status. The driller and the helper shall only handle moving augers or flights when there is a standby person able to activate the emergency stop device.

3.2.4 The driller may leave the controls only when tools are stopped or when all personnel are clear of the rotating equipment.

3.2.5 A long handled shovel or the equivalent shall be used to clear away drill cuttings from the hole and rotating equipment. Never use hands or feet for this purpose.

3.2.6 A remote sampling device must be used to sample drill cuttings near rotating tools. The driller shall shut down operations if the sampler must go near the tools to obtain samples.

3.2.7 All personnel working in the vicinity of the drill rig while its operating shall secure all loose clothing.

3.2.8 Only manufacturer-approved equipment may be used in conjunction with site equipment (i.e. pins for auger flights etc.). Pins or other protruding items from rotating equipment shall not be permitted.

3.2.9 Climbing a drill mast while equipment is rotating is prohibited.

3.2.10 Climbing a drill mast without use of ANSI approved fall protection (i.e. belts, lanyards and a fall protection slide rail) or portable ladders which meet OSHA's requirements is prohibited.

3.3 Excavation/Trenching Operations

3.3.1 No person, under any circumstance, will be permitted to enter an excavation. Personnel must use remote sampling techniques to collect samples from excavations or collect the samples from the backhoe bucket.

3.3.2 Personnel must not lean over excavations.

3.3.3 Personnel and the backhoe/operator must be positioned upwind from excavations at all times. Personnel must stand away from the reach of the backhoe, tires, and outriggers.

3.3.4 Personnel must stand a minimum of 3 feet from the edge of any excavation. Unstable excavations must be sloped at the sides to prevent cave-in.

3.3.5 Personnel must develop hand signals with the operator.

3.3.6 All open excavations must properly be barricaded unless attended.

3.3.7 The backhoe operator must never undermine the excavation.

3.3.8 All personnel, with the exception of the backhoe operator, shall be at least 25 feet from a test pit during excavation activities.

3.4 Heavy Equipment Maintenance and Operation

3.4.1 Heavy equipment must be operated in accordance with 29 CFR 1926 Subpart O.

3.4.2 Heavy equipment will be operated in a safe manner so that the equipment will be kept from rolling over or sliding into an excavation.

3.4.3 Dump vehicles will be level before the bed is raised. Dump beds will be smooth to prevent loads sticking at the front (top) of the bed. Stand away from either side of the dump vehicle while the bed is being raised or lowered as there is always a possibility that the vehicle will roll on its side.

3.4.4 A safety tire rack, cage, or equivalent protection must be used when inflating, mounting, or dismounting tires on split rims, or rims equipped with locking rings or other similar device.

3.4.5 All cab glass will be kept clean and will not impair the safe operation of the equipment.

3.4.6 All equipment will be operated at least 20 feet from overhead power lines and other electrical equipment unless otherwise permitted by 29 CFR 1926.550 (a)(15).

3.4.7 Equipment which has an obstructed view to the rear must be equipped with an audible reverse (backup) alarm.

3.4.8 Haulage vehicles with cabs will be equipped with a cab shield or canopy to protect the operator from falling and shifting loads.

3.4.9 All equipment must be equipped with seat belts except those which do not have roll-over protective structures. When seat belts are provided, they must be used.

3.4.10 All mechanized equipment on the job site will be inspected at the beginning of each shift in accordance with 29 CFR 1926.601(b)(14). This inspection will include checking the following parts, equipment and accessories to ensure they are in safe operating condition and free of apparent damage that could cause failure while in use: service brakes, including trailer brake connections; parking system (hand brake); emergency stopping system (brakes); tires; horn; steering mechanism; coupling devices; seat belts; operating controls; and safety devices. All defects shall be corrected before the vehicle is placed in service.

3.4.11 Equipment operators will wear hearing protection unless the owner of the equipment can demonstrate that noise exposures will not exceed the OSHA Permissible Exposure Limit.

3.5 Petroleum Storage Tank Operations

3.5.1 The removal and disposal of used petroleum storage tanks will conform to the most current recommendations of the American Petroleum Institute (API). API Publication 1604 has been attached.

3.5.2 Smoking will be prohibited in the vicinity of tank removal operations and all other ignition sources will be eliminated. Fire extinguishers of adequate size will be maintained at each tank removal operation.

3.5.3 Prior to the initiation of tank operations, all services to the tank (electrical, piping, etc.) will be removed/isolated. In addition, the boundaries of underground storage tanks will be positively identified and marked before excavation is initiated. Excavation will be performed so as not to puncture or damage the tank as this may create an ignition source.

3.5.4 Prior to moving the tank, product/material remaining in the tank will be removed by explosion-proof or air-driven pumps. Pump motors and suction hoses will be bonded to the tank or otherwise grounded to prevent electrostatic ignition hazards. If a vacuum truck is used, the area of operation for the vacuum truck will be vapor-free. The truck will be located upwind from the tank and outside the path of probable vapor travel. The vacuum pump exhaust gasses will be discharged through a hose of adequate size and length downwind of the truck and tank area.

3.5.5 Materials handling equipment used to lift storage tanks will be of adequate design and rated for the intended load. Such equipment will be properly inspected prior to use and operated by an experienced operator. Rigging will be performed by persons knowledgeable in various rigging techniques preferably using any lifting (rigging) lugs that exist on many tanks. Material being lifted will be controlled using multiple tag lines of sufficient length to keep ground personnel at a safe distance from the suspended load. Standing between a suspended load and a stationary object or structure is prohibited.

3.5.6 After product/material has been removed, the tank must be purged of flammable vapors using one or more of the methods described in API 1604 while observing all safety precautions described therein. A combustible gas indicator must be used to verify that flammable vapors

are less than 1% LEL at which time the tank can be cut open (as needed) to facilitate cleaning of the tanks interior walls. Equipment used to open up the tank will not create an ignition source regardless of purging activities (i.e. no torches). Personnel are prohibited from entering the tank (including head only entry) for cleaning without first obtaining the proper confined space entry training and permits.

3.5.7 Following initial cleaning and dismantling, the tank parts will be allowed to dry and air out after which combustible gas readings will be taken again to confirm adequate removal of flammable vapor hazards.

3.6 Electrical Installations/Repairs

3.6.1 All electrical work will be performed by persons who are familiar with the construction and operation of the equipment and the safety hazards involved with the work to be performed.

3.6.2 All installations and repairs will conform to the requirements of 29 CFR 1910 Subpart S and applicable National Electric Codes.

3.6.3 Temporary wiring will be adequately protected from physical damage.

3.6.4 Flexible cords (extension cords) will be of the three-prong double insulated type with ends that prevent stress from being applied to wire connections. Flexible cords will be affixed to a receptacle that is properly grounded and that is preferably equipped with a ground-fault circuit interrupter (GFI). Where the use of a GFI is not possible, an assured equipment grounding program will be available and implemented. Flexible cords will be in good condition and free of splices and loose end connections.

3.7 Truck/Container/Rail-Car Loading Operations

3.7.1 Persons handling potentially-contaminated soils/debris will be required to satisfy all medical and training requirements of this plan.

3.7.2 While trucks, containers, and/or rail-cars are being loaded with potentially-contaminates soils/debris, the persons who are responsible for the equipment being loaded will stand in the support zone away from the loading operation at all times, unless they satisfy the training and

medical requirements of this plan. Loading operations will not begin until such persons are positioned a safe distance away.

3.7.3 Truck beds, containers, and/or rail-cars used to haul potentially-contaminated soils/debris will be loaded in a manner that minimizes and controls spillage. Once loaded, the containers will be adequately covered to prevent dust emissions during transport. Containers used shall comply with DOT regulations for bulk packaging of PCB solids and will conform to the specifications of the disposal facility who will ultimately accept the material. Containers will be properly placarded and manifested.

TRAINING REQUIREMENTS
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TRAINING REQUIREMENTS

1.0 PURPOSE

This section describes the minimum requirements for initial, refresher, and site-specific training for Brown & Root Environmental and subcontractor personnel engaged in hazardous waste operations.

2.0 INTRODUCTORY AND REFRESHER TRAINING

2.1 Requirements For Brown & Root Environmental Personnel

All Brown & Root Environmental personnel must complete 40 hours of introductory hazardous waste site training prior to performing work at any hazardous waste site. Additionally, Brown & Root Environmental personnel who have had introductory training more than 12 months prior to site work must have completed 8 hours of refresher training within the past 12 months before being cleared for site work.

All Brown & Root Environmental personnel functioning in the supervisory capacity will have had Management and Supervisory training as required by 29 CFR 1910.120 (e)(4). No field personnel will function independently from a supervisor, unless they also satisfy this requirement.

Documentation of Brown & Root Environmental introductory, supervisory, and refresher training will be maintained at the project. Copies of certificates or other official documentation will be used to fulfill this requirement.

2.2 Requirements For Subcontractors

All Brown & Root Environmental subcontractor personnel must have completed introductory hazardous waste site training or equivalent work experience as defined in OSHA Standard 29 CFR 1910.120(e) and 8 hours of refresher training meeting the requirements of 29 CFR 1910.120(e)(8) prior to performing field work at the sites. All subcontractor personnel serving in the supervisory capacity will have had Management and Supervisory training as required by 29 CFR 1910.120 (e) (4). Brown & Root Environmental subcontractors must certify that each employee has had such training by sending Brown & Root Environmental a letter, on company letterhead, containing the information in the example letter provided as Figure 1.0 of this section. Accompanying that letter (or submitted separately prior to the initiation of any onsite activities), copies of

training certificates will be provided for all subcontractor personnel. The OSHA Training Certification letter and the Medical Surveillance letter may be combined into one letter.

2.3 Subcontractor Exceptions

Subcontractors such as surveying teams who will not perform any activities in the exclusion zone during sampling tasks or where there is no potential for exposure, will be excluded from the requirements stipulated in Section 2.2.

3.0 SITE-SPECIFIC TRAINING

Brown & Root Environmental will provide site-specific training to all Brown & Root Environmental employees and subcontractor personnel who will perform work on this project. Site-specific training will include:

- Names of personnel and alternates responsible for site safety and health
- Safety, health and other hazards present on site
- Use of personal protective equipment
- Work practices to minimize risks from hazards
- Safe use of engineering controls and equipment
- Medical surveillance requirements
- Signs and symptoms of overexposure
- The contents of the health and safety plan and addendum
- Emergency response procedures (evacuation and assembly points)
- Review the contents of relevant Material Safety Data Sheets

3.1 Site-specific Training Documentation

Brown & Root Environmental and subcontractor personnel will be required to sign a statement indicating receipt of site-specific training and understanding of site hazards and control measures. Figure 2.0 is used to document site-specific training.

FIGURE 1

OSHA TRAINING CERTIFICATION

The following statements must be typed on company letterhead and signed by an officer of the company:

LOGO
XYZ CORPORATION
555 E. 5th Street
Nowheresville, Kansas 55555

Month, day, year

Mr./Ms. _____
Project Manager
Brown & Root Environmental
Foster Plaza VII 661 Andersen Drive
Pittsburgh, Pennsylvania 15220

Subject: Hazardous Waste Site Training - (indicate specific site name)

Dear Mr./Ms. _____,

The employees listed below have had introductory hazardous waste site training or equivalent work experience as required by 29 CFR 1910.120(e). In addition, those employees listed below who have received their introductory training more than 12 months ago have also received 8 hours of refresher training in accordance with 29 CFR 1910.120 (e)(8) within the past 12 months.

LIST FULL NAMES OF EMPLOYEES AND THEIR SOCIAL SECURITY NUMBERS HERE

Should you have any questions, please contact me at (555) 555-5555.

Sincerely,

(Name of Company Officer)

FIGURE 2

SITE-SPECIFIC TRAINING DOCUMENTATION

My signature below indicates that I am aware of the potential hazardous nature of performing site activities at (state specific hazardous waste site), and that I have received site-specific training which included the elements presented below:

- Names of personnel and alternates responsible for site safety and health
- Safety, health and other hazards present on site
- Use of personal protective equipment
- Work practices to minimize risks from hazards
- Safe use of engineering controls and equipment
- Medical surveillance requirements
- Signs and symptoms of overexposure
- The contents of the health and safety plan
- Emergency response procedures (evacuation and assembly points)
- Review contents of relevant Material Safety Data Sheets

I further state that I have been given the opportunity to ask questions and that all of my questions have been answered to my satisfaction.

Name	Signature	Date