ALABAMA ENVIRONMENTAL INVESTIGATION AND REMEDIATION GUIDANCE

A COMPREHENSIVE GUIDANCE DOCUMENT PREPARED FOR ALABAMA INDUSTRIES OR INDIVIDUALS INVOLVED IN ENVIRONMENTAL ASSESSMENT, INVESTIGATION, AND REMEDIATION PROJECTS BY THE ALABAMA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

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NOTICE

This document has been prepared to assist individuals in understanding the necessary elements of environmental investigations and remediation projects. It is not intended as a substitute for the regulations and should not be used as such. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ALABAMA ENVIRONMENTAL INVESTIGATION AND REMEDIATION GUIDANCE

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1.0 INTRODUCTION

This guidance document presents a comprehensive statement of the requirements for performing environmental investigations and remediation projects in Alabama. These requirements generally represent the Alabama Department of Environmental Management's (ADEM's) expectations necessary for complete investigations and remediation projects for programs that manage contamination from hazardous constituents, hazardous waste, petroleum products, and/or petroleum wastes. Various programs administered by ADEM, which require investigation, monitoring and/or remediation, may have areas in which different or more specific requirements apply. This guidance document is designed to be used strictly as an aid in the development of adequate environmental investigations and remediation projects by individuals with the appropriate technical expertise and skill. This guidance document is not intended to be used as a substitute for existing program regulations and should not be used as such. Certain submissions required by ADEM involve the practice of engineering and/or land surveying, as those terms are defined in Code of Alabama 1975, as amended, § 34-11-1 to 34-11-37; and/or the practice of geology, as that term is defined in Code of Alabama 1975, as amended, § 34-41-1 to 34-41-24. It is the responsibility of any person preparing or submitting such information to ensure compliance with these laws and any regulations promulgated there under, as may be required by the State Board of Registration for Professional Engineers and Land Surveyors and/or the Alabama Board of Licensure for Professional Geologists. All submissions, or parts thereof, which are required by State law to be prepared by a licensed engineer, land surveyor, or geologist, must include the engineer's, land surveyor's, and/or geologist's signature and/or seal, as required by the applicable licensure laws.

2.0 PRELIMINARY INVESTIGATION

2.1 Section Outline

2.2 Purpose of a Preliminary Investigation

A Preliminary Investigation is conducted to gain information about the site, confirm or deny that a release(s) of constituents of potential concern (COPCs) has occurred, and to determine what potential receptors exist in the area.

2.3 Elements of Preliminary Investigation Activities

A Preliminary Investigation Work Plan should be developed and, if required by a specific regulatory program, submitted to ADEM. The plan should include a detailed discussion of all applicable issues outlined in this section. The performance of the Preliminary Investigation should, at a minimum, include the following activities:

2.3.1 Surrounding Land Use - An accurate description of the surrounding land use should be made and should include, at a minimum, the following information:

(a) The type of surrounding population (rural vs. urban, residential vs. industrial vs. commercial, and population density),

(b) The location of the site [physical address, mailing address, latitude and longitude in decimal degrees with precision of six significant digits to the right of the decimal; and topographic map location (section, township and range)],

(c) A site map developed with information which includes, but is not limited to, all known:

i. Areas of concern (AOCs),

ii. Monitoring wells,
iii. Sampling sites,
iv. Drainage patterns,
v. Utilities,
vi. Buildings,
vii. Property Boundaries,
viii. North Arrow, and
ix. All Private & Public Supply Wells.

2.3.2 Well Inventory - A complete well inventory, both public and private, should be conducted within a 1 mile radius of the site using publicly available resources (*i.e.*, local water supply authorities, ADEM's Public Water Supply Branch, United States Geological Survey, Geological Survey of Alabama, etc.). Any pertinent information gleaned from a door-to-door survey of all residents within 500 feet of the property boundaries or as otherwise directed by the Department should also be included. Also, a determination should be made to identify if the site is located within a source water assessment area. Information on each identified well should include the following:

(a) The owner of well,
(b) The depth of well,
(c) The aquifer of production,
(d) The use of well,
(e) The screened interval, and
(f) The depth to groundwater.

2.3.3 Surface Water Intake Inventory - A complete inventory of surface water intakes including both the potable springs and the surface water intakes should be conducted within a 1 mile radius of the site using publicly available resources (*i.e.*, local water supply authorities, ADEM's Public Water Supply Branch, United States Geological Survey, Geological Survey of Alabama, etc.). Any pertinent information gleaned from a door-to-door survey of all residents within 500 feet of the property boundaries or as otherwise directed by the Department should also be included. Also, a determination should be made to identify if the site is located within a source water protection area.

2.3.4 Surface Water Locations - The locations of all surface water bodies that may potentially be impacted by the subject property should be determined with a review of topographic or other area maps. Use classification(s) of surface water stream(s) are listed in ADEM Division 6 Regulations.

2.3.5 Records Search - A thorough records search concerning the current and historical activities and processes used on site should be conducted. The search should include an inventory list of all chemicals stored and used onsite. The search should also include an inventory list of all types of wastes produced, managed, and/or disposed onsite. These inventory lists will be essential in the determination of constituents of potential concern (COPCs). The identification of COPCs is necessary in determining a sampling or analysis strategy. The inventory list of chemicals used and/or wastes produced onsite should be compared with constituents listed in program-specific regulations to determine which, if any, may be of potential concern.

2.3.6 Utilities Search - A thorough utilities survey should be conducted to identify and delineate all utilities that cross under the site or that are adjacent to the property. The utilities to be delineated should include sanitary sewers, storm sewers, water lines, electrical lines, gas lines, phone lines, or other utility lines. The delineation can be accomplished through use of "Line Locator" services, local utility personnel, personal communication with owner, ground penetrating radar, or other similar methods.

2.3.7 Sampling Strategy - A sampling strategy should be determined for each type of media to be sampled.

(a) The soil sampling strategy should include the following:

i. Soil sampling should be conducted in a manner expected to produce the maximum concentration of COPCs such as at the release point, within the visually observable area of contamination, and along potential migration pathways (*i.e.,* utilities).

ii. A minimum of 4 soil borings for the collection of surface soil samples and subsurface soil samples should be conducted. (See Appendix C)

iii. To establish background surface and subsurface soil conditions (i.e.: for inorganic contamination or if a potential source of COPCs are up gradient of the site)), a minimum of 4 soil borings should be collected in an area up gradient from and unaffected by facility operations. The arithmetic mean of the results of the soil samples should be used as the background soil concentration for the respective sampling interval.

iv. Soil borings should be extended to obtain samples that represent the zones most likely to have been impacted.

v. Soil borings should be extended to the top of the first continuous zone of saturation under the site or to bedrock if no groundwater is encountered. If it is determined that the water table or bedrock exists at significantly excessive depths, the Department should be notified for assistance.

vi. Soil samples should be collected in accordance with the methods outlined in Appendix C of this document. All soil samples should be analyzed in accordance with USEPA approved methods included in the EPA document Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846 (latest edition) or others.

vii. A minimum of 4 surface soil samples should be collected. All surface soil samples should be collected as grab samples and collected within the uppermost 12-inches of soil. All surface soil samples should be analyzed for the COPCs using Method Detection Limits (MDLs) that are less than or equal to ADEM's Preliminary Screening Values (PSVs) developed in accordance with Section 4.0 of this document.

viii. Subsurface soil samples should be taken at no more than 5-feet intervals from each boring. All subsurface soil samples should be field screened (*i.e.,* PID, HNU, XRF, and color-metric), and a minimum of 3 subsurface soil samples per boring (if possible) should be collected for laboratory analysis. The 3 subsurface soil samples should include, at a minimum, 2 samples exhibiting high field screening levels and 1 sample just above the water table. If soil borings are greater than 50 feet in depth, additional subsurface soil samples should be collected for laboratory analysis. All subsurface soil samples should be analyzed for COPCs using MDLs that are less than or equal to ADEM's PSVs selected in accordance with Section 4.0 of this document.

ix. All surface soil samples should be obtained by using appropriate equipment such as spoons, shovels, hand-augers, push tubes, and post-hole diggers. Surface soil samples may also be collected in conjunction with the collection of subsurface soil samples using mechanical drilling equipment and/or ADEM approved specialized sampling equipment (Appendix C).

x. All subsurface soil samples should be obtained using appropriate equipment such as Shelby Tubes, split spoon samplers or other specialized samplers (direct push technologies, EnCore™ Samplers, etc.) (Appendix C). The use of specialized samplers should be approved by ADEM prior to initiating all assessment activities. Auger cuttings are not appropriate.

xi. Quality Assurance/Quality Control procedures, and decontamination procedures outlined in Appendices D and E should be utilized to ensure sample quality.

xii. All Investigation-Derived Waste (IDW) should be collected, properly contained and stored, sampled and analyzed for a waste determination, and properly disposed of as outlined in Appendix D and in accordance with the ADEM Regulations.

xiii. All analysis collected should be compared to the Preliminary Screening Values identified in Section 4.0 of this document.

(b) Installation of Groundwater Monitoring Wells should meet the following criteria:

i. Groundwater flow direction should be determined after the installation of 3 piezometers or Type-I Temporary Monitoring Wells. All piezometers or Type-I Temporary Monitoring Wells should be installed in accordance with design, construction and installation criteria addressed in Appendix B of this document.

ii. Based on the groundwater elevation/potentiometric surface data collected from the piezometers or Type-I Temporary Monitoring Wells, a minimum of one permanent up gradient well located in an area that has not been impacted by the release or the site's activities should be installed.

iii. Typically a minimum of 3 permanent wells, located immediately down-gradient of the unit, structure, and/or at the release point, is appropriate.

iv. All permanent wells should be screened in the first saturated zone (or water-bearing zone) below the ground surface, or first saturated zone (or water bearing zone) below the unit or structure under investigation. All permanent wells should have a maximum screened interval of 10-feet, and should be placed at the appropriate interval to detect the COPCs. Nested well systems may be warranted and should be used if determined to be necessary.

v. All permanent monitoring wells should be installed, constructed and developed in accordance with the appropriate drilling and monitoring well installation techniques (See Appendix B).

(c) The collection of groundwater samples and of flow measurements should adhere to the following procedures:

i. Groundwater samples should be collected from all permanent monitoring wells installed and analyzed for the COPCs.

ii. Groundwater samples should be collected in accordance with the approved methods documented in Appendix C of this document.

iii. All groundwater samples should be analyzed using an USEPA approved methods included in the USEPA document Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846 (latest edition) with Method Detection Limits that are less than or equal to ADEM's Preliminary Screening Values selected in accordance with Section 4.0 of this document.

iv. Quality Assurance/Quality Control and decontamination procedures outlined in Appendices D and E of this document should be utilized to ensure sample quality.

v. All Investigation-Derived Waste (*i.e.,* groundwater and decontamination fluids) collected during the development and purging activities should be contained and disposed of as outlined in Appendix D and in accordance with the ADEM Regulations.

vi. A survey of the site should be conducted to establish well elevations, groundwater elevations, and ground elevations at each well, the locations of key structures, and the location of the release. The survey datum should be site-specific and based on a USGS established benchmark or interpolated from a topographic map. Survey datum established to 100 feet artificial benchmark is not appropriate.

(d) Surface water sampling should be conducted to collect representative sample(s) of the affected or potentially affected surface water(s) of interest. The sampling techniques and equipment should minimize effects on the integrity of the sample. The physical characteristics of the location of the person conducting the sampling should dictate the type of sampling equipment to be used in the sampling event. Surface samples can be taken by directly dipping of the sample container into the water body. This can be done from a boat, pier, bridge or wading [Wading is appropriate if the water body has a noticeable current and the sample is collected in such a manner as to prevent biasing by the re-suspension of bottom sediments]. Various types of primary sampling equipment such as peristaltic pumps, discreet depth samplers, bailers, buckets and supplemental equipment may be necessary as conditions dictate.

For flowing water situations, samples should be collected from a minimum of three locations. If possible, the first sample should be collected downstream of an area of actual or suspected release, the second sample collected at the point of the actual or suspected release, and the third sample should be collected upstream of the area of the actual or suspected release. The upstream sample should be used to determine background levels [If an upstream sample is unattainable, a nearby site that has not been affected by the release should be used]. Estuarine area samples are normally collected on successive slack tides. For water bodies that have a tendency to stratify and lack the mixing characteristics of flowing waters (*i.e.,* lakes, ponds, surface impoundments etc.), the number of samples will be dependent upon the scope of the investigation. The following factors should be considered when conducting a surface water sampling event:

i. Water use;
ii. Point source discharges;
iii. Nonpoint source;
iv. Tributary locations;
v. Changes in stream characteristics;
vi. Type of streambed;
vii. Depth of stream, pond, lake, etc.;
viii. Turbulence;
ix. Presence of structures (weirs, dams, etc.);
x. Accessibility; and
xi. Tidal effect (estuarine).

(e) Sediment sampling should be conducted to collect representative sample(s) from affected or potentially affected surface water bodies. The physical characteristics of the location of the person conducting the sampling should dictate the type of sampling equipment to be used in the sampling event. Wading is the preferred method for reaching shallow flowing water sampling locations. A number of sediment samples should be collected along a cross section of a water body in order to characterize the bed material.

The factors that should be considered when conducting a sediment sampling event are the same as used when conducting a surface water sampling event.

2.3.8 Emergency Response and Free Product Recovery - Procedures for emergency response and free product recovery include, but are not limited to, the following:

(a) If free product is encountered or an immediate threat to human health and the environment occurs, free product recovery and emergency response activities should be implemented immediately.

(b) Results of the free product recovery and emergency response activities should be reported to ADEM in accordance with the applicable regulatory program.

(c) All free product recovery and emergency response activities should be conducted until all free product has been completely recovered, to the maximum extent possible and/or technically feasible; and/or the immediate threat to human health and the environment has been eliminated. Affected programs (RCRA, CERCLA, UST, Industrial, UIC, etc.) should be referred for specific recovery, remediation, and/or discharge requirements.

(d) Recovery of contaminated runoff should be conducted to the maximum extent possible, and/or technically feasible; and/or the immediate threat to human health and the environment has been eliminated. Affected programs (RCRA, CERCLA, UST, Industrial, UIC, etc.) should be referred to for recovery, remediation, and/or discharge requirements.

2.3.9 Management of Investigation-Derived Waste (IDW) - The management of all investigation-derived waste (i.e.: soil cuttings, groundwater, decontamination fluids, etc.) generated during the Preliminary Investigation should include both the collection and the containment of such wastes. A waste determination should be performed in order to determine the proper handling and disposal procedures. All wastes should be disposed of as outlined in Appendix D and in accordance with the ADEM regulations.

2.4 Submission of a Preliminary Investigation Report

A **Preliminary Investigation Report** should be developed and submitted to ADEM for review at the conclusion of the preliminary investigation. The Preliminary Investigation Report should include a detailed description of all investigation activities and information recommended by this guidance.

3.0 COMPREHENSIVE INVESTIGATION

3.1 Section Outline

3.2 Purpose of a Comprehensive Investigation

A Comprehensive Investigation is conducted in order to determine the full horizontal and vertical extent of contamination (soil and groundwater) and/or free product plume in all media. A Comprehensive Investigation is necessary when the results of the Preliminary Investigation confirm that contamination is present in any environmental media.

3.3 Elements of a Comprehensive Investigation Work Plan

Prior to beginning a Comprehensive Investigation, a work plan should be developed. The plan should include detailed discussions of, at a minimum, all of the activities described below under soil investigation, groundwater investigation, and management of investigation-derived waste. Refer to the applicable regulatory requirements for the specifics on the submittal of this plan to the Department.

At the conclusion of the Comprehensive Investigation, a Comprehensive Investigation Report should be developed and submitted to ADEM in accordance with the applicable regulatory requirements. The Comprehensive Investigation Report should include a detailed description of all investigation activities conducted at the site outlined in the Site Investigation Report checklist (Figure 2). In addition to the copies of all original laboratory reports the Comprehensive Investigation Report should include electronic version of all analytical data (past and present) obtained from each monitoring well. This data should be compiled and reported to the Department in a spreadsheet format.

If a previous Preliminary Investigation Report was not submitted to ADEM prior to initiation of any comprehensive investigation activities, the Comprehensive Investigation Report should also include a summary of all investigation activities conducted, with all respective soil boring logs, monitoring well diagrams, analytical data, and laboratory reports with copies of completed chain-of-custody forms.

3.4 Elements of a Comprehensive Investigation

A Comprehensive Investigation should include, at a minimum, the following elements:

3.4.1 Soil Sampling - A systematically designed soil sampling investigation should be conducted in order to define the horizontal and vertical extent of contamination in soils. All soil borings should be extended to obtain samples that represent the zones most likely to have been impacted. Consequently, all soil borings should be extended to the water table or to bedrock if no water is encountered. If it is determined that the water table or bedrock exists at significantly excessive depths, an alternative soil sampling plan should be developed and submitted to ADEM for review and approval.

All soil samples should be collected in accordance with the appropriate soil sampling methods outlined in Appendix C of this document. All soil samples should be analyzed in accordance with the USEPA approved methods included in the EPA document Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846 (latest edition) or other methods approved by the Department.

Surface soil samples should be obtained from all borings drilled and should be collected from between the surface and 12-inches below ground surface. All surface soil samples should be collected as grab samples and should be analyzed for the COPCs.

Surface soil samples may be obtained by using spoons, shovels, hand-augers, push tubes, or post-hole diggers. Surface soil samples may also be collected in conjunction with the collection of subsurface soil samples using heavy mechanical drilling equipment and/or ADEM approved specialized sampling equipment (Appendix C).

Subsurface soil samples should be taken from each boring at no more than five-foot intervals and should be field screened (PID, HNU, XRF, and color-metric). A minimum of three subsurface soil samples per boring (if possible) should be collected for laboratory analysis. The three subsurface soil samples should include, at a minimum, two samples exhibiting high field screening levels and one sample just above the water table. If soil borings are greater than 50 feet in depth, additional subsurface soil samples should be collected for laboratory analysis. All subsurface soil samples should be analyzed for the COPCs.

In order to expedite the assessment process, specialized sampling methods can be used to obtain subsurface soil samples. Specialized sampling methods and tools, which can be utilized, include immunoassay analyses, soil vapor survey, and field gas chromatographs. Appendix C of this guidance document includes detailed discussions of various field screening methods. The use of specialized samplers should be approved by ADEM prior to initiating all assessment activities.

Quality Assurance/Quality Control procedures (Appendix D), and EPA required decontamination procedures (Appendix E) should be utilized to ensure sample quality.

3.4.2 Groundwater Sampling - A systematically designed groundwater investigation should be conducted in order to define the horizontal and vertical extent of contamination. Site-specific hydrogeologic conditions should be determined at the sites or area of concern. Potential interconnection of an overlying aquifer or saturated zone with the next deeper aquifer or saturated zone should be established. The hydrogeologic conditions and interconnection potential should be established by all previous and proposed soil borings, all previous and proposed monitoring wells, hydraulic tests (slug and pump tests), geophysical survey investigations, and/or dye trace studies. If hydrogeologic conditions justify the need for a dye trace study (karst and highly fractured environments) and/or there is a potential risk to a public supply well or a significant spring, which is utilized as a public water supply, a dye trace study should be conducted to establish if a migration pathway from the area of contamination and the public supply well or spring does exist.

Installation of a sufficient number of permanent monitoring wells down-gradient is necessary to determine the horizontal extent of contamination. All permanent monitoring wells should be screened in the same saturated zone, water bearing zone, or stratigraphic interval currently being monitored in the previous monitoring wells installed during the Preliminary Investigation.

At a minimum, one permanent monitoring well should be located within the source release area. It should be screened in an interval beneath the shallower contamination plume and show no evidence of contamination. Due to site-specific hydrogeologic and groundwater quality conditions encountered during the Preliminary Investigation, additional deep permanent monitoring wells or well nests may be necessary to verify that the vertical extent of the contamination plume has been adequately investigated down-gradient of the contamination source area.

Field screening methods, such as direct push technologies, can be used to locate monitoring wells more effectively, and to significantly expedite the assessment process. However, these methods are only to be used as field screening tools with the results verified by the advancement of soil borings and the installation of permanent monitoring wells that meets the monitoring well design requirements discussed in this guidance document. Appendix C of this guidance document includes detailed discussions of various field screening methods.

A sufficient number of permanent monitoring wells should be installed to define the horizontal and vertical extent of any free product plume (LNAPL and DNAPL). A sufficient amount of monitoring wells should be installed within the free product plume to monitor the effectiveness of any free product recovery efforts. All permanent wells should be installed and screened to adequately establish the thickness of the free product plume.

All permanent monitoring wells should be installed, constructed, and developed in accordance with the acceptable procedures described in Appendix B of this guidance document.

Groundwater samples should be collected from all permanent groundwater monitoring wells installed and in accordance with the procedures outlined in Appendix C of this document. All samples should be analyzed for Constituents of Potential Concern

(COPCs) using the analytical methods included in the EPA document Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846 (latest edition). Any analytical method utilized should be capable of using MDLs that are less than or equal to the Preliminary Screening Values developed in accordance with Section 4 of this document. Quality Assurance/Quality Control procedures identified in Appendix D should be utilized to ensure sample quality.

All monitoring wells installed during the Comprehensive Investigation should be surveyed to establish top of casing elevations, ground elevations and latitude and longitude. All surveys should be conducted to an established datum that is site-specific and based on a USGS established benchmark or interpolated from a topographic map. Survey datum established to a 100-feet artificial benchmark is not appropriate. Monitoring wells may be located utilizing GPS technology.

A determination of the groundwater flow direction and rate should be made. A sufficient number of slug tests (slug in and slug out) or an aquifer pump test should be conducted to establish the hydraulic characteristics of the uppermost aquifer (transmissivity, storativity, porosity, leakage, hydraulic gradient, hydraulic conductivity, and flow rate).

A groundwater monitoring schedule should be designed in accordance with regulatory requirements. During the first year of groundwater monitoring, Groundwater Monitoring Reports should be developed and submitted to ADEM. The Groundwater Monitoring Reports should include:

(a) Description of all sampling activities conducted,

(b) Conclusions and interpretations drawn from the sampling event and analytical results,

(c) A site map illustrating the location of all monitoring wells on site and off site,

(d) A potentiometric map of the site illustrating the groundwater elevations at each well and the groundwater flow direction,

(e) A site map illustrating the contamination plume and analytical results for the COPCs,

(f) A table documenting all water levels and total depth of all wells measured, top of casing elevations, and groundwater elevations,

(g) The original laboratory reports obtained from the contracted laboratory,

(h) A table of current and historical groundwater analytical data obtained, and

(i) All completed chain-of-custody forms.

3.4.3 Surface Water Sampling - A surface water investigation should be conducted If it is determined that a surface water body (rivers, streams, creeks, lakes, ponds, impoundment, wetlands and estuaries) is threatened or has been impacted by a release, a complete investigation of that surface water body should be conducted. The investigation should include, at a minimum, the following information:

(a) Water use;

(b) Point source discharges;

(c) Nonpoint source discharges (springs, seeps, storm-water runoff points, etc.);

(d) Tributary locations;

(e) Changes in stream characteristics;

(f) Type of streambed;

(g) Turbulence;

(h) Presence of structures (weirs, dams, etc.);

(i) Tidal effect (estuarine);

(j) The width and depth;

(k) The flow velocity;

(l) Surface water sampling upstream, downstream and at intermediate stations along the length of the potentially effected area of a stream, and when major changes occur in a stream reach;

(m) Surface water sampling from any pond, lake, and impoundment potentially impacted;

(n) Surface water sampling from estuarine or wetland areas potentially impacted;

(o) If the site or sites is located within a complex hydrogeologic setting (*i.e.,* karst and fractured flow environments), a dye trace study should be conducted to identify all direct migratory pathways from the site to all potential surface water bodies in the area.

All surface water samples should be collected in accordance with the procedures outlined in Appendix C of this document. All samples should be analyzed for the COPCs using the analytical methods included in the EPA document Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846 (latest edition) or other ADEM approved methods. Quality Assurance/Quality Control procedures identified in Appendix D of this document should be utilized to ensure sample quality.

3.4.4 Sediment Sampling - A sediment investigation should be conducted if the determination is made that a release to a surface water body may have occurred. Sediment samples should be collected during the time of all surface water sampling activities, and at all surface water sample locations (if possible).

All sediment samples should be collected in accordance with the procedures outlined in Appendix C of this document. All samples should be analyzed for the COPCs using the analytical methods included in the EPA document Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW-846 (latest edition) or other ADEM approved methods. Quality Assurance/Quality Control procedures identified in Appendix D of this document should be utilized to ensure sample quality.

3.4.5 Management of Investigation-Derived Waste (IDW) - The management of all IDW (i.e.: soil cuttings, groundwater, and decontamination fluids) generated during the Comprehensive Investigation should include both the collection and the containment of such wastes. A waste determination should be performed in order to determine the proper handling and disposal procedures. All wastes should be disposed of as outlined in Appendix D and in accordance with the ADEM regulations.

3.5 Submission of a Comprehensive Investigation Report

A **Comprehensive Investigation Report** should be developed and submitted to ADEM for review at the conclusion of the comprehensive investigation. The Comprehensive Investigation Report should include a detailed description of all investigation activities and information collected under this section or, if applicable, in accordance with specific ADEM program requirements.

4.0 RISK ASSESSMENT

4.1 Section Outline

4.2 Purpose

At the completion of the Comprehensive Investigation, a sufficient amount of data should be available to support an assessment of baseline risks to human and ecological receptors. The risk assessment is intended to provide regulatory and site managers with information to:

1. Determine risk-based target levels (RBTL's) (i.e.: remediation levels) of contaminants of concern that can remain on-site and still be protective of human health and the environment;

2. Provide data to evaluate remedial alternatives for potential impacts to human health and the environment;

3. Effectively document and communicate to the public risks associated with contaminated properties.

4.3 Preliminary Screening Values

It is common for environmental risk assessments to begin with a comparison of site-specific contaminant concentrations to Preliminary Screening Values (PSVs). PSVs are conservative health-based concentrations of hazardous constituents determined to be indicators for the protection of human health or the environment. The detection of a contaminant(s) at a concentration greater than a PSV does not necessarily trigger a requirement to perform remediation. Conversely, the absence of chemical concentrations greater than PSVs does not necessarily mean that no further investigative or remedial action is warranted. These decisions should be made on a case-by-case basis. PSVs simply provide a general and rapid measure of the overall risk to human health and the environment associated with a contaminated site. PSVs can, in most cases, be utilized as default remediation levels because they are based on highly conservative exposure assumptions. PSVs should be developed for all effected media in accordance with the following:

4.3.1 Groundwater - PSVs for constituents in groundwater are equivalent to the Maximum Contaminant Levels (MCLs) as listed in ADEM Admin. Code R. 335-7-2 (Primary

Drinking Water Standards) and as listed by the USEPA (http://www.epa.gov/waterscience/drinking/standards/dwstandards.pdf). For constituents where there is not an MCL, PSVs should be consistent with the most current version of the USEPA Region IX Preliminary Remediation Goals (PRGs) for Tap Water (http://www.epa.gov/region09/waste/sfund/prg/index.htm). As a caveat, it should be noted that the Department recommends the use the of a hazard quotient (HQ) of 0.1. The Region IX PRGs utilize a HQ of 1.0. In order to use the ADEM recommend value(s), all constituents listed on the Region IX PRG table that were calculated based on their non-carcinogenic effects should be divided by a factor of 10 in order to properly reflect a HQ of 0.1. Table 2-2 located with the current version of the Alabama Risk-Based Corrective Action (ARBCA) document reflects the appropriate HQ and may be used to minimize any errors made when utilizing the groundwater PSVs.

4.3.2 Surface Water – PSVs for surface water should be consistent with the Alabama Water Quality Criteria (ADEM Admin. Code R. 335-6-10). For constituents where there are no Water Quality Criteria values, PSVs should be consistent with those for groundwater.

4.3.3 Ambient Air - PSVs for ambient air should be consistent with USEPA Region IX PRGs.

4.3.4 Soils - PSVs for soil must address several specific exposure routes that must be evaluated individually: (1) ingestion, (2) inhalation, (3) dermal contact and (4) the protection of groundwater (leachability). PSVs to address ingestion, inhalation and dermal contact should be consistent with the USEPA Region IX PRGs for the appropriate exposure scenarios. It is also appropriate to utilize the value that combines the direct exposure pathways (ingestion, inhalation, and dermal contact) for the appropriate use scenario (residential vs. industrial). As a caveat, it should be noted that the Department recommends the use the of a hazard quotient (HQ) of 0.1. The Region IX PRGs utilize a HQ of 1.0. In order to use the ADEM recommend value(s), all constituents listed on the Region IX PRG table that were calculated based on their non-carcinogenic effects should be divided by a factor of 10 in order to properly reflect a HQ of 0.1. Table 2-2 located in the current version of the Alabama Risk-Based Corrective Action (ARBCA) document reflects the appropriate HQ and may be used to minimize any errors made when utilizing the soil PSVs.

4.3.5 Sediment - PSVs for constituents in sediment shall be based on whether human health or ecological health is the major concern. If ecological concerns are deemed to predominate, see section 4.3.6. If human health is the prevailing concern, then the human health PSVs for sediment shall be consistent with those for soils.

4.3.6 Ecological – Surface water and sediment data collected should be compared to the USEPA Region 4 Ecological Screening Values with respect to ecological receptors. Additionally, sediment that is not saturated year round should be evaluated as surficial soil. In the absence of a Region 4 Ecological Screening Value for surface water, the surface water concentrations should be compared to the Water Quality Criteria located in ADEM Admin. Code 335-6-10 (the "Consumption Fish/Water" pathway should be used). If the surface water is a "water of the state" as defined in ADEM Admin. Code R. 335-6-10-.02(10), the surface water concentrations should be compared to the Water Quality Criteria regardless of whether a Region 4 Value exists, and the ADEM Water Division should be contacted. In the absence of a USEPA Region 4 Ecological Screening Value or an ADEM Water Quality Criteria Value, surface water should be compared to a groundwater value (see Section 4.3) and the sediment should be compared to a soil value (see Table 2-2).

4.4 Evaluation of Background Conditions

While PSVs provide a general and rapid assessment of risk, many PSVs, particularly for inorganic constituents, may be substantially less than concentrations that are found in environmental media under ambient conditions. Site managers should consider background conditions during site characterization.

To determine if a natural background is present in the soils, a minimum of four background samples should be obtained in an area which is reasonably expected to be unaffected by current or historical processes, but within depositional environments similar to those in impacted areas. Two times the arithmetic mean of the background sample's concentrations should be screened against the on-site maximum detected concentration. If the contaminant of potential concern is less than 2 times the background level, then the contaminant should be eliminated as a concern.

For groundwater, up-gradient monitoring wells should be installed in order to provide a measure of ambient groundwater quality, and an indication of up-gradient sources of contamination. The statistical procedures used to evaluate the groundwater samples are site-specific due to the variability of groundwater flow parameters throughout the state.

In some cases, it may be necessary to evaluate an anthropogenic background source. Anthropogenic substances are natural and human-made substances present in the environment as a result of human activities (not specifically related to the site in question). Some chemicals may be present in background as a result of both natural and man-made conditions (such as naturally occurring arsenic and arsenic from pesticide applications or smelting operations).

Generally, the type of background substance (natural or anthropogenic) does not influence the statistical or technical method used to characterize background concentrations. For this reason, the anthropogenic background concentration should be determined in the same manner as described above for the natural occurring background concentrations.

For other media or additional information concerning the determination of a background concentration, please contact the Department.

4.5 Comprehensive Risk Evaluation

If maximum detected site concentrations exceed background conditions and PSVs, a more comprehensive evaluation of risks to human health or the environment may be needed. The most recent edition of the ARBCA guidance document should be utilized when a more comprehensive evaluation is determined necessary.

4.6 Risk Management Evaluation

In order to maximize the conservation of our precious State resources, ADEM encourages sites to develop PSVs and remediation levels based on an unrestricted land use (residential) scenario. PSVs and remediation levels based on an alternate land use scenario (e.g.: industrial) may be appropriate if the site owner/operator is willing to establish an appropriate combination of engineering and land-use controls to ensure against inappropriate uses of the property. Such controls may require some form of enforceable document issued by the State (e.g.: a permit, or a consent agreement) to ensure long-term maintenance of these controls, if necessary, and depending on the specific regulatory program involved.

5.0 REMEDIATION

5.1 Section Outline

5.2 Purpose

The purpose of this section is to outline specific activities that are necessary for sites that have been determined to be a threat to human health and the environment, and/or where elevated plumes and/or areas of contamination exceeding regulatory limits have been determined.

5.3 Necessary Elements

5.3.1 Remediation Levels – A summary of the remediation goals should be provided that includes acceptable risk-based target levels that apply to the site (see Section 4 of this document).

5.3.2 Plans/Designs - A remediation plan should be submitted to the Department for review prior to implementation in accordance with applicable requirements. Cleanup/remediation plans should include, but not be limited to, the following:

(a) A description of the cleanup objectives with discussions of the remediation technology (or technologies) to be applied at the site for the contaminants of concern in all affected media.

(b) If free phase product is present, and extraction is the method for remediation, a description of the technique and placement of the extraction point(s) or a description of existing extraction is appropriate when applicable.

(c) Detailed plans and an engineering report with a description of the proposed cleanup method to remediate soils, sediments, and groundwater, and to mitigate potential hazardous discharges into a surface water source.

(d) A detailed description of the proposed groundwater remediation system including plans describing sampling points, monitoring well locations, analytical methods, and any other procedures or systems used for evaluating the effectiveness of the remediation plan, if applicable.

(e) A detailed description of how all treated wastewater or soils removed will be handled.

(f) The institutional requirements such as State or local permit requirements, or other environmental or public health requirements that may substantially affect implementation of the remediation system.

(g) An itemized schedule for implementation of the cleanup plan.

(h) A site plan map showing:

   i. A North directional arrow,

   ii. A horizontal scale,

   iii. Culture relevant to the site (buildings, structures, etc.)

   iv. The location of the point source of the contaminant release,

   v. All sumps, above ground storage tanks, pipelines, etc.,

   vi. The horizontal and vertical extent of free-product and/or dissolved phase contaminants in groundwater to above the regulatory levels,

   vii. The horizontal and vertical extent of the soils and/or sediments that are contaminated at levels in exceedance of the PSVs.

   viii. The location of the groundwater monitoring well system, which defines the horizontal and vertical extent of contamination,

   ix. The location of the proposed remediation system extraction/injection wells or points, and

   x. The proposed locations of an adequate number of wells to monitor the effectiveness of the remediation system.

(i) A potentiometric surface map contoured to equal mean sea level elevations of the static water level taken during the same measuring event in all groundwater monitoring wells and/or piezometers at the site. The potentiometric surface map should include:

   i. A North directional arrow,

   ii. A horizontal scale,

iii. The direction of groundwater flow indicated by arrows pointing down-gradient and perpendicular to the contours of equal groundwater elevation.

iv. Groundwater elevations for the event in each well.

(j) The format of the remediation plan effectiveness report will vary depending on the type of remediation technology utilized and the program under which the site is operating. The report should be prepared in accordance with applicable program requirements. The general report format should include, at a minimum, the following:

i. A detailed description of all remediation and/or groundwater sampling activities,

ii. A detailed description including summary tables of all analysis collected and conclusions developed,

iii. A site map showing the location of the groundwater monitoring system (if groundwater is being remediated),

iv. Potentiometric surface maps for all applicable aquifers or separate saturated zones being monitored (if groundwater is being remediated),

v. Time vs. Concentration graphs of selected wells and parameters to demonstrate the effectiveness of the groundwater remediation system (if groundwater is being remediated),

vi. Capture zone modeling results indicating the area of influence, and

vii. Recommendations for upgrade, modification of the system, or any additional remediation activities.

5.3.3 Decontamination - Prior to utilization of sampling equipment, all equipment should be properly decontaminated in accordance with Appendix E. All personnel should wear clean disposable sampling gloves when obtaining or handling samples. Gloves should be changed between each sampling event.

5.3.4 Case Studies on New Technologies - For new remediation technologies that are not currently discussed in Appendix F of this document, or have not been previously utilized in the State of Alabama, an effectiveness report or case study report developed from other sites utilizing the proposed remediation system should be submitted. The report should demonstrate the effectiveness of the proposed remediation system and comparable environmental conditions.

5.3.5 Management of Remediation Waste (All Media)

Remediation of sites under various corrective action programs may involve the management of large amounts of waste such as contaminated soils, recovered groundwater, debris, and sludges. All remediation wastes generated during site activities should be managed as IDW and in accordance with Appendix D and the ADEM regulations. There may be special management options for on site generated remediation wastes. Site managers should consult ADEM for the appropriate requirements.

5.3.6 Regulatory Requirements (SID, NPDES, UIC, Air, UST, etc.)

Many remediation technologies may be subject to special regulatory and/or permitting requirements, including, but not limited to:

(a) National Pollutant Discharge Elimination System (NPDES) permitting (ADEM Water & Field Operations Divisions);

(b) State Indirect Discharge (SID) permitting (ADEM Water & Field Operations Divisions);

(c) Underground Injection Control (UIC) permitting (ADEM Water Division);

(d) Source Water Assessment Program (ADEM Water Division); and

(e) Air Emissions (Air Division).

Site managers should consult with ADEM for any specific regulatory requirements associated with the proposed remediation technology.

5.4 Remedy Selection

5.4.1 Source Control - Source control measures should be evaluated as part of the remedy decision process at all sites particularly where MNA is under consideration as the remedy or as a remedy component. Source control measures include removal, treatment, or containment, or a combination of these approaches.

Contaminant sources that are not adequately addressed complicate the long-term cleanup effort. For example, following free product recovery, residual contamination from a petroleum fuel release may continue to leach significant quantities of contaminants into the groundwater posing unacceptable risks to humans and/or the environment. Such a lingering source often extends the time necessary to reach remediation objectives. This leaching can occur even while contaminants are being naturally attenuated in other parts of the plume. If the rate of attenuation is lower than the rate of replenishment of contaminants to the groundwater, the plume can continue to expand thus contaminating additional groundwater and potentially posing a threat to down-gradient receptors.

Control of source materials is the most effective means of ensuring the timely attainment of remediation objectives. The Department, therefore, expects that source control measures will be taken at most sites where practicable. At many sites it will be appropriate to implement source control measures during the initial stages of site remediation (“phased remedial approach”), while collecting additional data to determine the most appropriate remedy. See Appendix F for more information on possible remedial technologies.

5.5 Land-Use Controls

5.5.1 During the initial phase of cleanup, the site manager should:

(a) Establish clear objectives (what are you trying to accomplish through the use of land-use controls (LUCs)?);

(b) Discuss future land use plans with the community and local government to assist in analyzing the appropriate LUCs and other remedial alternatives;

(c) Evaluate LUCs using the appropriate threshold, balancing, and modifying criteria; and,

(d) Coordinate with regional attorneys on legal matters and the State as appropriate.

5.5.2 During remedy selection, the site manager should:

(a) Present information that aids the public to understand the impacts of the specific LUCs and their relationship with the overall remedy;

(b) Clearly describe the objectives to be attained by LUCs;

(c) Specify performance standards (e.g.: prevent exposure to contaminated groundwater by prohibiting well drilling);

(c) Consider layering LUCs to enhance their overall effectiveness;

(e) Discussions with entities (e.g.: local/state governments) involved in implementing LUCs;

(f) Discuss the kinds of controls envisioned and include enough information to show that effective implementation of the LUCs can reasonably be expected;

(g) Discuss plans for monitoring land use and other aspects of the remedy that depend on LUCs;

(h) Discuss the enforcement mechanisms that are anticipated to ensure the long-term reliability of the LUCs (e.g.: notice to the deed to the property); and,

(i) Continue coordination with attorneys.

5.5.3 During remedy implementation, the site manager should ensure that appropriate measures are taken to implement the LUCs (e.g.: arrange discussions between PRPs, other property owners, and local government or state officials);

5.5.4 During Post-Remediation activities (e.g.: a CERCLA 5-year review), the site manager should:

(a) Evaluate both the administrative/legal components as well as the physical evidence to ensure that LUCs are both implemented and fully effective;

(b) Ensure that any LUCs are available for inspection by any person performing a standard title search on the property and that the objectives of the LUCs are clearly presented; and

(c) Ensure that the site is listed on the Alabama Contaminated Properties Inventory List.

Appendix A

Glossary

APPENDIX A GLOSSARY

ADEM - The Alabama Department of Environmental Management as established by Code of Alabama 1975, § 22-22A-4.

Administrator - The Administrator of the United States Environmental Protection Agency.

ADPH - The Alabama Department of Public Health.

AHWMMA - The Alabama Hazardous Wastes Management and Minimization Act of 1978, as amended, Code of Alabama 1975, §§ 22-30-1 et seq.

ASTM - American Society for Testing and Materials. A technical society with headquarters located at 1916 Race Street, Philadelphia, Pennsylvania, 19103, which publishes national standards for the testing and quality assurance of materials.

CERCLA - The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended.

Certification - A statement of professional opinion based upon knowledge and belief.

CFR - Code of Federal Regulations.

Commission - The Alabama Environmental Management Commission as established by Code of Alabama 1975, § 22-22A-6.

Contaminant - "Contaminant" means any man-made or man-induced alteration of the chemical, physical or biological integrity of soils, sediments, air, surface water or groundwater including, but not limited to, such alterations caused by any:

1. Hazardous substance (as defined in the Comprehensive Environmental Response, Compensation and Liability Act, 42 USC § 9601(14));
2. Hazardous waste (as defined in ADEM Administrative Code 335-14);
3. Hazardous constituent (as defined in ADEM Administrative Code 335-14-2-Appendix VIII and/or ADEM Administrative Code 335-14-5-Appendix IX);
4. Solid waste (as defined in ADEM Administrative Code 335-13); or,
5. Petroleum product.

COPC – Constituent of Potential Concern

Director - The Director of ADEM, appointed pursuant to Code of Alabama 1975, § 22-22A-4, or his designee.

Disposal - The discharge, deposit, injection, dumping, spilling, leaking, or placing of any hazardous waste into or on any land or water so that such hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters including groundwater.

Endangered or Threatened Species – Any species listed as such pursuant to Section 4 of the Endangered Species Act.

Engineer - A person registered as a professional engineer with the State of Alabama Board of Registration for Professional Engineers and Land Surveyors and practicing under the Rules of Professional Conduct, specifically Canon II.

EPA - The United States Environmental Protection Agency.

Geologist - A person who holds a license as a professional geologist under the Alabama Professional Geologist Licensing Act.

GPS Method – Method for the determination of latitude and longitude at a point using Global Positioning System (GPS), collected and differentially corrected data to an EPA accepted accuracy of 25 meters at a specified datum (*i.e.,* NAD 83).

Global Positioning System (GPS) - The location of items on the earth's surface by determining their coordinates in relation to a series of satellites.

Land-Use Controls (LUCs) – LUCs are non-engineered controls instruments such as administrative and/or legal controls that minimize the potential for human exposure to contamination by limiting land or resource use.

Land Surveyor - A person registered as a Land Surveyor with the State of Alabama Board of Registration for Professional Engineers and Surveyors and practicing under the Rules of Professional Conduct (Code of Ethics).

National Pollutant Discharge Elimination System (NPDES) - The national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits for the discharge of pollutants into waters of the state.

Person - Any and all persons, natural or artificial, including, but not limited to, any individual, partnership, association, society, joint stock company, firm, company, corporation, institution, trust, other legal entity, business organization or any governmental entity and any successor, representative, responsible corporate officer, agent or agency of the foregoing.

RCRA - The Federal Resource Conservation and Recovery Act of 1976, as amended, (42 U.S.C. §§ 6901 et seq.).

Regional Administrator - The Regional Administrator for the EPA Region in which the facility is located, or his designee.

Regulated Substance - Any substance defined in section 101(14) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 (but not including any substance regulated as a hazardous waste under Division 14 of the ADEM Administrative Code); and petroleum, including crude oil or any fraction thereof that is liquid at standard conditions of temperature and pressure (60 degrees Fahrenheit and 14.7 pounds per square inch absolute). The term "regulated substance" includes, but is not limited to, petroleum and petroleum-based substances comprised of a complex blend of hydrocarbons derived from crude oil through processes of separation, conversion, upgrading, and finishing, such as motor fuels, jet fuels, distillate fuel oils, residual fuel oils, lubricants, petroleum solvents, and used oils.

Remediation waste - All solid and hazardous wastes, and all media (including groundwater, surface water, soils, and sediments) and debris that contain listed hazardous wastes or that themselves exhibit a hazardous characteristic and are managed for implementing cleanup.

SARA - The Superfund Amendments and Reauthorization Act of 1986.

Solid waste - means a waste as defined by ADEM Admin. Code R. 335-14-2-.01(2).

Spill - An unplanned, accidental, or unpermitted discharge, deposit, injection, leaking, pumping, pouring, emitting, dumping, placing, or releasing of hazardous wastes, or materials which when spilled become hazardous wastes, into or on the land, the air, or the water.

State Health Officer - The Health Officer for the State of Alabama as set out in § 22-2-8, Code of Alabama 1975, or his designee provided by law.

Appendix B

Monitoring Well Installation/Development/Abandonment Guidelines

APPENDIX B - MONITORING WELL INSTALLATION/DEVELOPMENT/ABANDONMENT GUIDELINES

B.1. Appendix Outline

B.2. Monitoring Well Drilling Methods

The following are commonly utilized drilling methods that should be considered when plans are being made to install a permanent monitoring well. The final drilling method selection should be based on site-specific conditions.

B.2.1 Hollow-Stem Auger - This type of auger consists of a hollow, steel stem or shaft with continuous, spiraled steel flight, welded onto the exterior side of the stem, connected to an auger bit and when rotated transports cuttings to the surface. This method is best suited in soils that have a tendency to collapse when disturbed. A monitoring well can be installed inside of the hollow-stem augers with little or no concern for the caving of soils and/or water table.

B.2.2 Solid-Stem Auger - This type of auger consists of a solid stem or shaft with a continuous spiraled steel flight, welded on the outer side of the stem, connected to an auger bit and when rotated transports cuttings to the surface. This auger method is used in cohesive and semi-cohesive soils that do not have a tendency to collapse when disturbed.

B.2.3 Rotary Method - This method consists of a drill pipe or drill stem coupled to a drilling bit that rotates and cuts through the soils. The cuttings produced from the rotation of the drilling bit are transported to the surface by drilling fluids, which generally consists of water, drilling mud, or air. The water, drilling mud, or air are forced down through the drill pipe, and out through the bottom of the drilling bit. The cuttings are then lifted to the surface between the borehole wall and the drill pipe. The type of rotary method used is dependent upon site-specific conditions and the information desired for the investigation (e.g.: the mud rotary method provides good information on soil strength properties).

B.2.4 Rotosonic Drilling – This method combines high frequency vibrations, downward pressure, and relatively slow rotations to advance a dual string of drill pipe. This combination of forces advances the drill pipe through soil and rock without the use of drilling fluids. The dual string of drill pipe is used to sample and advance the hole and consists of an inner core barrel sampler and an outer pipe casing. The core barrel is driven ahead of the outer casing and is used to collect a representative continuous core sample. Once the core barrel is driven to the required depth, the outer casing is then driven down over the core barrel. The outer casing prevents the hole from collapsing when the core barrel is extracted for sample retrieval. Drilling can be completed without the use of fluids, but water is commonly used during the driving of the outer casing to flush material from the annual space between the core barrel and the pipe casing.

B.2.5 Other Methods - Other methods such as the cable-tool method, the jetting method, the boring (bucket auger) method, and direct push technologies (e.g.: GeoProbe®) are available. If these and/or other methods are proposed for installing monitoring wells, specific details with respect to the equipment and drilling fluids that will be used, and the activities that will be performed should be included in the work plan. Prior approval by the Department will also be required before initiation of the proposed monitoring well installation activities.

B.3. Monitoring Well Construction Methods

B.3.1 Type-I/Temporary Monitoring Wells or Piezometers - A temporary monitoring well is any well that is used for the establishment of groundwater flow conditions, the delineation of contaminant plumes at a point in time, and for some site screening purposes. They are not intended to replace permanent monitoring wells. Perhaps the best use for temporary wells is in conjunction with a mobile laboratory , where quick analytical results can be used to delineate contaminant plumes. Temporary monitoring wells 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 (as normally applies to permanent monitoring wells). Temporary wells are generally installed, purged, sampled, removed and backfilled in a matter of hours. Temporary wells may be left overnight for sampling the following day, but the well must be secured if the well is not sampled immediately after construction.

The materials used in construction of temporary monitoring wells or piezometers are the same standard materials used in the construction of permanent monitoring wells. Sand used for the filter pack (if any) should be as specified in Section 6.6.3 of USEPA Region IV's Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (latest edition).

There are six types of temporary monitoring well installation techniques that have been demonstrated as acceptable. The type selected for a particular site is dependent upon the conditions. The project leader and site geologist should be prepared to test temporary well installations on site and select the best solution. Temporary wells are cost effective, may be installed quickly, and provide a synoptic picture of groundwater quality. These include:

(a) No Filter Pack – After the borehole is completed, the casing and screen are simply inserted. This type is extremely sensitive to turbidity fluctuations, because there is no filter pack. This is the most inexpensive and fastest well to install.

(b) Inner Filter Pack – This type differs from the "No Pack" only in that a filter pack is placed inside the screen to a level approximately 6 inches above the well screen. This ensures that all water within the casing has passed through the filter pack. For this type well to function properly, the static water level must be 6-12 inches above the filter pack.

(c) Traditional Filter Pack – The screen and casing is inserted into the borehole. Sand is poured into the annular space surrounding the screen and casing. The well should then be developed to establish in situ aquifer or saturated conditions.

(d) Double Filter Pack – the borehole is advanced to the desired depth. As with the "inner filter pack" the well screen is filled with filter pack material and the well screen and casing inserted until the tip of the filter pack is at least 6 inches below the water table. Filter pack material is poured into the annular space around the well screen. This type temporary well construction is very effective in aquifer where fine silts or clays predominate.

(e) Well-in-a-Well – The borehole is advanced to the desired depth. At this point, a 1-inch well screen and sufficient riser is inserted into a 2-inch well screen with sufficient riser, and centered. Filter pack material is then placed into the annular space surround the 1-inche well screen, to approximately 6 inches above the well screen. The well is then inserted into the borehole.

(f) Temporary Well Installation using the Geoprobe® Screen Point 15 Groundwater Sampler – The Geoprobe® Screen Point 15 Groundwater Sampler is a discrete interval groundwater sampling device that can be pushed to pre-selected sampling depths in saturated, unconsolidated materials, opened and sampled as a temporary well. It is a selled sample device, opened at the desired depth, yielding a representative, uncompromised sample from that depth. Using knock-out plugs, this method also allows for grouting of the push hole during sample tool retrieval after sample collection.

For additional information refer to the USEPA Region IV's Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (latest edition) section 6.10.

B.3.2 Permanent Type-II Monitoring Wells

(a) The borehole should be bored, drilled, or augered as close to vertical as possible, and checked with a plumb bob or level. Slanted boreholes will not be appropriate unless specified in the design.

(b) The well casings should be secured to the well screen by flush-jointed threads and placed into the borehole and plumbed by the use of centralizers and/or a plumb bob and level. Another method of placing the well screen and casing into the borehole and plumbing it at the same time is to suspend the string of well screen and casings in the borehole by means of the wire-line on the drill rig. Teflon tape can be used to wrap the threads to insure a tight fit and minimize leakage.

(c) Before placing the well screen and casing on to the bottom of the borehole, at least 6 inches of filter material should be placed at the bottom of the borehole to serve as a firm footing.

(d) The string of well screen and casings should then be placed into the borehole and plumbed. Centralizers can be used to plumb a well but should be placed below the well screen and above the bentonite pellet seal.

(e) All permanent wells should have a maximum screened interval of 10 feet, a minimum inside diameter of 2 inches and should be constructed of materials that are based on the geologic conditions and resistant to leaching and deterioration from the COPCs. There are some exceptions that are allowed but must be approved by the Department on a case-by-case basis. Permanent wells installed utilizing direct push technologies is program dependent and determined site-specifically. A plan should be submitted to the Department and approved prior to any small diameter permanent well installation.

(f) When placing the well screen and casing through hollow stem augers, the augers should be slowly extracted as the filter pack, bentonite seal, and grout are tremied into place. After the string of well screen and casing is plumbed in the open borehole, the filter material should then be placed around the well screen, by tremie method, to a minimum of 2 feet above the top of the well screen.

(g) A bentonite seal should then be tremied onto the filter pack to a minimum thickness of 2 feet. The bentonite seal should then be allowed to hydrate for a minimum of 8 hours or the manufacturer's recommended hydration time, whichever is longer.

(h) After hydration of the bentonite seal has been completed, the grout (bentonite/grout mixture) should be pumped by the tremie method into the annular space around the casing up to within 2-feet of the ground surface or below the frost line, whichever is greater. The grout should be allowed to set for a minimum of 24 hours before the surface pad and protective casing are installed.

(i) A protective casing with a locking cap should be installed around the monitoring well, with concrete or neat cement surface pad installed around the monitoring well and the protective casing. The surface pad should have the dimensions of 2 feet by 2 feet square, and an approximate thickness of 6 inches (4 inches above the ground surface). The surface pad should be angled such that water flows away from the monitoring well.

(j) Bumper guards should be placed around the concrete surface pad in a configuration that provides maximum protection to the well. The bumper guards should extend above the ground surface at a minimum of 3 feet and have a total minimum length of 5 feet.

(k) If the monitoring wells are installed in a high traffic area, the monitoring wells may be finished to the ground surface and installed with watertight flush-mounted traffic and/or manhole covers. The flush-mounted covers should be installed as far above grade as practical to minimize standing water and promote runoff.

(l) All monitoring wells should include a padlock or specialized locks and should be permanently marked with the well number, date installed, site name, top-of-casing elevation and ground elevation.

B.3.3 Permanent Type-III (Double-Cased) Monitoring Wells

(a) Type-III or double cased monitoring wells should be constructed when there is a reason to believe that interconnection of the two aquifers by well construction may cause cross contamination, and/or when flowing sands make it impossible to install a monitoring well using conventional methods.

(b) A pilot borehole should be drilled through the overburden and/or the contaminated zone into a confining clay layer, to bedrock, or through the first saturated zone. The borehole should be extended into the clay, bedrock or unsaturated zone underlying the initial saturated zone at a minimum of 2 feet, if possible (1 foot into bedrock is adequate). The final depth should be approved by a senior field geologist.

(c) An outer casing should be placed into the borehole and sealed with grout. The size of the outer casing should be of sufficient inside diameter to contain the inner casing, and the 2-inch minimum annular space.

(d) The outer casing should be grouted by the tremie method from the bottom to within 2 feet of the ground surface. The grout should be pumped into the annular space between the outer casing and the borehole wall. A minimum of 24 hours should be allowed for the grout plug (seal) to cure before attempting to drill through it. The grout mixture used to seal the outer annular space should be neat cement,

cement/bentonite, cement/sand, or a 30% solids bentonite grout. However, the seal or plug at the bottom of the borehole and outer casing should consist of a Type-I Portland cement/bentonite or cement/sand mixture. The use of pure bentonite grout for a bottom plug or seal is not appropriate. After the grout plug has been allowed to cure, the boring for the inner casing should be advanced to the next saturated zone or aquifer, followed by the installation of a permanent monitoring well. When drilling through the seal, care should be taken to avoid cracking, shattering, and/or washing out the seal. Removal of the outer casing after the well screens and casings have been installed and grouted is not appropriate.

(e) During the investigation to determine the vertical extent of contamination, it may require additional outer casings to be installed (telescoping methods). Each outer casing should be installed in accordance with the above guidance.

B.3.4 Permanent Bedrock Wells

(a) The first method is to drill or bore a pilot borehole through the soil overburden into the bedrock (1-foot minimum).

(b) An outer casing is then installed into the borehole by setting it into the bedrock, and grouting it into place as described in the previous sections.

(c) After the grout has been allowed to set (minimum of 24 hours), the borehole should be advanced through the grout seal or plug into a water producing zone in the bedrock by rock coring methods.

(d) An inner casing and well screen with a filter pack, bentonite seal and annular grout should then be installed.

(e) The well is completed with a surface protective casing and concrete pad.

B.3.5 Nested or Cluster Wells

(a) Nested or Cluster Wells are two or more wells that are screened at different elevations in a single aquifer or multiple aquifers and typically installed within 5 feet of each well.

(b) Nested or Cluster Wells typically consist of one Type-II well and one or more Type-III well(s) (See above construction requirements for Type-II and Type-III wells).

B.4. Monitoring Well Development Methods

The main purpose of developing new monitoring wells is to remove the residual materials remaining in the wells after installation has been completed and to try to re-establish the natural hydraulic flow conditions of the formations that may have been disturbed by the well construction activities.

B.4.1 Time Period - A newly completed monitoring well should not be developed for at least 24 hours after the surface pad and outer protective casing are installed.

B.4.2 Development - A new monitoring well should be developed until the column of water in the well is free of visible sediment, and the pH, temperature, turbidity, and specific conductivity have stabilized. In some cases, this may require continuous flushing or development activities over a period of several days.

B.4.3 Methods - Well development can be performed by the following methods. The methods listed below can be used individually or in combination. Since site conditions vary, even between wells, a general rule-of-thumb is to wait 24 hours after development to sample a well. Wells developed with stressful measures may require as long as a 7-day interval before sampling. In particular, air surge developed wells require 48 hours or longer after development so that the formation can dispel the compressed air and restabilize to pre-well construction conditions.

(a) Over-pumping – Over-pumping is the most commonly employed well development technique. A pump is installed into a well and pumping is initiated to induce groundwater flow towards the well. Fine particulate material that moves into the well is discharged by the pump. In over-pumping, the pump is operated at a capacity that substantially exceeds the ability of the formation to deliver water. This flow velocity into the well usually exceeds the flow velocity that will subsequently be induced during the sampling process. The increased velocity causes rapid and effective migration of particulates toward the pumping well and enhances the development process. Proper design is needed to avoid well collapse, especially in deep wells. The USEPA recognizes over-pumping as an effective development method if flow reversal or surging activities are also conducted to avoid the occurrence of bridging in the well pack. When monitoring well installations are to be made in formations that have low hydraulic conductivity, this well development method will be unsatisfactory.

(b) Backwashing - A pump is installed into a well and pumping is initiated to induce groundwater flow towards the well. Fine particulate material that moves into the well is discharged by the pump. Where there is no backflow prevention valve installed, the pump is alternately started and stopped. This starting and stopping process allows the column of water that is initially picked up by the pump to be alternately dropped and raised up in a surging action. Each time the water column falls back into the well, an outward surge of water flows into the formation. This surge tends to loosen the bridging of the fine particles so that the upward motion of the column of water can move the particles into and out of the well. In this manner, the well can be pumped, over-pumped and back-flushed alternately until such time as satisfactory development has been attained. When monitoring well installations are to be made in formations that have low hydraulic conductivity, this well development method will be unsatisfactory.

(c) Surge Block - Surge blocks can be used effectively to destroy bridging and to create the agitation that is necessary to develop a well. A surge block is used alternately with either a bailer or pump so that material that has been agitated and loosened by the surging action is removed. The cycle of surging-pumping/bailing is repeated until satisfactory development has been attained. The surge block is lowered to the top of the well intake and then operated in a pumping action with a typical stroke of approximately 3 feet. The surging is usually initiated at the top of the well intake and gradually is worked downward through the screened interval. The surge block is removed at regular intervals and the fine material that has been loosened is removed by bailing and/or pumping. Surging begins at the top of the well intake so that sand or silt loosened by the initial surging action cannot cascade down on top of the surge block and prevent removal of the surge block from the well. Surging is initially gentle and the energy of the action is gradually increased during the development process.

(d) Bailer - In relatively clean, permeable formations where water flows freely into the borehole, bailing is an effective development technique. The bailer is allowed to fall freely through the borehole until it strikes the surface of the water. The contact of the bailer produces a strong outward surge of water that is forced from the borehole through the well intake and into the formation. This tends to break up bridging that has developed within the formation. As the bailer fills and is rapidly withdrawn, the drawdown created in the borehole causes the particulate matter outside the well intake to flow through the well intake and into the well. Subsequently bailing removes the particulate matter from the well. To enhance the removal of the sand and other particulate matter from the well, the bailer can be agitated by rapid short strokes near the bottom of the well. This agitation makes it possible to bail the particulates from the well by suspending or slurrying the particulate matter. Bailing should continue until the water is free from suspended particulate matter and until stabilization of all field parameters (pH, specific conductivity, temperature, and turbidity) is achieved.

(e) Airlift Pumping - Air lifting, without exposing the formations being developed directly to air, can be accomplished by properly implemented pumping. To do this, the double pipe method of air lifting is preferred. The bottom of the airlift should be lowered to within no more than 10 feet from the top of the well intake and in no event should the airlift be used within the well intake. If the airlift is used to surge the well, by alternating the air on and off, there will be mixing of aerated water with the water in the well. Therefore, if the well is to be pumped by airlifting, the action should be one of continuous, regulated discharge. This can be effectively accomplished only in relatively permeable aquifers. The introduction of air into the aquifer, such as conducting air surging activities, is not appropriate. When monitoring well installations are to be made in formations that have low hydraulic conductivity, this well development method will be unsatisfactory.

B.4.4 Completion - The onsite geologist should make the decision as to the development completion of each well. All field decisions should be documented in the field logbook.

B.5. Well Abandonment Procedures

The objectives of the abandonment procedure are to: 1) eliminate physical hazards; 2) prevent groundwater contamination; 3) conserve aquifer yield and hydrostatic head; and 4) prevent intermixing of desirable and undesirable waters.

The Department requires that all test holes, including test wells, partially completed wells, and completed wells be properly plugged and abandoned upon completion of either the site investigation phase or remediation phase. The purpose of sealing an abandoned boring or monitoring well is to prevent any further disturbance to the pre-existing hydrogeologic conditions in the subsurface. No materials that could impart taste, odor or toxic compounds to water may be used in the sealing process. The guiding principle to be followed by the contractor in the sealing of abandoned wells is the restoration, as far as feasible, of the controlling geological conditions that existed before the well was drilled or constructed.

B.5.1 Soil Borings - Soil borings should be abandoned in accordance with the following:

(a) A boring should be measured for depth before it is sealed to ensure freedom from obstructions that may interfere with effective sealing operations.

(b) All borings should be sealed by backfilling with concrete, grout, neat cement or a grout/cement mixture.

(c) All backfill material should be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method).

(d) The top 2 feet of the borehole should be poured with concrete to ensure a surface seal (plug).

ADEM will review alternative soil boring abandonment proposals on a site-by-site basis. All alternative soil boring abandonment proposals should be approved by ADEM prior to implementation.

B.5.2 Monitoring Wells - Regulatory requirements and accepted procedures for the abandonment of monitoring wells, public water supply wells and domestic water wells vary depending upon the regulatory program. The appropriate subsections listed below should be consulted prior to developing a well abandonment plan. To view an acceptable outline for a well abandonment plan, see Attachment 1 of Appendix B.

(a) Solid Waste Program Sites

The requirements for monitoring well abandonment at facilities permitted under the Solid Waste Regulations, 335-13, include the following:

i. The owner or operator should notify the Department that the design, installation, development, and/or abandonment of any monitoring wells, piezometers and other measurement, sampling, and analytical devices have been documented, and placed in the operating record.

ii. The monitoring wells, piezometers, and other measurement, sampling, and analytical devices should be operated and maintained so that they perform to design specifications throughout the life of the monitoring program.

iii. Abandoned wells and boreholes should be abandoned in accordance with the procedures outlined in this document in order to prevent contamination of groundwater resources. A plan of abandonment should be submitted and approved by the Department prior to implementing abandonment of any well.

iv. A well should be measured for depth prior to sealing to ensure that it is free from any obstructions that may interfere with sealing operation.

v. Where feasible, wells should be completely filled with neat cement. If the well cannot be completely filled, the sealing material for the top 20 feet should be neat cement and no material that could impart taste, odor, or toxic components to water may be used in the sealing process.

vi. The casing should be removed from each well in order to ensure placement of an effective seal. If the casing cannot be readily removed, it should be perforated to ensure that proper sealing is obtained.

vii. Concrete, cement grout, or neat cement should be used as primary sealing materials and should be placed from the bottom upwards using methods that will avoid segregation or dilution of material.

viii. Complete, accurate records of the abandonment procedure should be kept for each well abandoned. The record of abandonment should include, at a minimum, the depth of each layer of all sealing and backfill material, the quantity of sealing materials used, measurements of static water levels and depths, and any changes made in the well during the plugging or sealing, such as perforating casing. A copy of these records should be submitted to the Department and a copy placed in the operating record.

(b) Public Water Supply Wells

Public water supply wells should be abandoned only after consultation with the ADEM Water Supply Branch. ADEM Admin. Code R. 335-7-5-.16 states that abandoned wells, partially completed wells, and boreholes should be filled and sealed to prevent contamination of groundwater formations. Where feasible, or when required by the Department, wells should be completely filled with neat cement. Other wells should be sealed in accordance with American Water Works Association (AWWA) Standard A100 Section 13 as outlined in the following:

American Water Works Association Standards A100-(latest edition)

Section 13.1 General

Abandoned test holes, including test wells, partially completed wells, and completed wells, should be sealed.

Section 13.1.1 Need for sealing wells

Wells need to be sealed for the following reasons:

- To eliminate physical hazards,
- To prevent contamination of groundwater,
- To conserve yield and hydrostatic head of aquifer, and
- To prevent intermingling of desirable and undesirable waters.

Section 13.1.2 Restoration of geological conditions

The guiding principle to be followed by the contractor in the sealing of abandoned wells is the restoration, as far as feasible, of the controlling geological conditions that existed before the well was drilled or constructed.

Section 13.2 Sealing requirements

A well should be measured for depth before it is sealed to ensure freedom from obstructions that may interfere with effective sealing operations.

Section 13.2.1 Casing removal

Removal of casing from some wells may be necessary to ensure placement of an effective seal.

Section 13.2.2 Exception to removing casing

If the casing cannot be readily removed, it should be perforated to ensure the proper sealing required.

Section 13.2.3 Sealing materials and placement

Concrete, cement grout, sealing clay or neat cement should be used as primary sealing materials and should be placed from the bottom upward by methods that will avoid segregation or dilution of material.

Section 13.3 Records of Abandonment Procedures

Complete, accurate records should be kept of the entire abandonment procedure to provide detailed records for possible future reference and to demonstrate to the governing state or local agency that the hole was properly sealed.

Section 13.3.1 Depths sealed

The depth of each layer of all sealing and backfilling materials should be recorded.

Section 13.3.2 Quantity of sealing material used

The quantity of sealing materials used should be recorded. Measurements of static water levels and depths should be recorded.

Section 13.3.3 Changes recorded.

Any changes in the well made during the plugging or sealing, such as perforating casing, should be recorded in detail.

(c) Hazardous Waste Management Sites

i. The ADEM Hazardous Waste Program considers improperly abandoned monitoring wells to be a serious concern. Any boreholes or monitoring wells that are improperly constructed or unused should be properly abandoned after the proper approval has been received from ADEM.

ii. Experienced geologists, geotechnical engineers and drillers should be consulted prior to abandonment.

iii. If the well to be abandoned is contaminated, the safe removal and proper disposal of the well materials should be ensured by the owner/operator.

iv. Appropriate measures should be taken to protect the health and safety of individuals when abandoning a well or borehole.

v. The monitoring well or borehole should be sealed so that it can not act as a conduit for the migration of contaminants from the ground surface to the water table or between aquifers.

vi. The preferred method should be to completely remove the well casing and screen from the borehole. This may be accomplished by augering with a hollow stem auger over the well casing down to the bottom of the borehole, thereby removing the grout and filter pack materials from the hole. The well casing can then be removed from the hole with the drill rig or other appropriate equipment. If it is determined that the well casing cannot be removed, approval should be sought from the Department to perforate the casing to ensure that a proper seal is obtained when backfilling and leave the casing in place. Approval will be granted on a site-by-site basis and is dependent upon the unique conditions that may exist at a site preventing the removal of the casing.

vii. The clean borehole can then be backfilled with the appropriate grout material (e.g.: concrete, bentonite grout, or neat cement). The backfill material should be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method).

viii. The top 2 feet of the borehole should be poured with concrete to ensure a secure surface seal (plug). If the area has very heavy traffic use, and/or the well locations need to be permanently marked, then a protective surface pad and/or steel bumper guards should be installed. The concrete surface plug can also be recessed below ground surface if the potential for construction activities exists.

ix. Because of its brittleness, PVC wells may be more difficult to remove than metal casing wells. If the PVC well casing breaks during removal, the borehole should be cleaned out by using a drag bit or roller cone bit with the wet rotary method to grind the casing into small cuttings that will be flushed out of the borehole by the selected drilling fluid. Another method is to use a solid-stem auger with a carbide auger head to grind the PVC casing into small cuttings that will be brought to the surface on the rotating flights. After the casing materials have been removed from the borehole, the borehole should be cleaned out and pressure grouted with the approved grouting materials. As previously stated, the borehole should be finished with a concrete surface plug and adequate surface protection, unless directed otherwise (EPA, 1991).

(d) State Groundwater Program Sites

i. The State Groundwater Program is administered by the Groundwater Branch of ADEM. The Groundwater Branch generally follows the most recent edition of USEPA Region IV Environmental Investigations Standard Operating Procedures (SOPs) and Quality Assurance Manual for the abandonment of monitoring wells.

ii. A well abandonment plan should be developed and submitted to the ADEM Project Hydrogeologist. ADEM approval of all well abandonment plans is required prior to implementing any well abandonment activities. Appropriate measures should be taken to protect the health and safety of individuals when abandoning a well or borehole.

iii. While this document is typically used to prepare an abandonment plan, it is understood that factors may arise that make the methods given below impractical or inappropriate for a given site. For this reason, methods other than those listed may be undertaken if prior approval is obtained.

a) As indicated in the EPA SOPs, when a decision is made to abandon a monitoring well, the borehole should be sealed in such a manner that the well can not act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers. To properly abandon a well, the preferred method is to completely remove the well casing and screen from the borehole, clean out the borehole, and backfill with a cement or bentonite grout, neat cement, or concrete.

b) Abandonment Procedures

i) The well casing and screen from the borehole should be completely removed. This may be accomplished by augering with a hollow-stem auger over the well casing down to the bottom of the borehole, thereby removing the grout and filter pack materials from the hole. The well casing should then be removed from the hole with the drill rig.

ii) The clean borehole can then be backfilled with the appropriate grout material.

iii) The backfill material should be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method).

iv) The top 2 feet of the borehole should be poured with concrete to insure a secure surface seal (plug). If the area has heavy traffic use, and/or the well locations need to be permanently marked, then a protective surface pad(s) and/or steel bumper guards should be installed. The concrete surface plug can also be recessed below ground surface if the potential for construction activities exists.

v) Wells having 6-inch or larger diameters, the use of hollow-stem augers for casing removal is very difficult or almost impossible. Instead of trying to ream the borehole with a hollow-stem auger, it is more practical to force a drill stem with a tapered wedge assembly or a solid-stem auger into the well casing and extract it out of the borehole.

vi) Wells with little or no grouted annular space and/or sound well casings can be removed by forcing a drill stem with a tapered wedge assembly or a solid-stem auger into the well casing and extract it out of the borehole.

vii) Old wells with badly corroded casing sand/or thickly grouted annular space have a tendency to twist and/or break off in the borehole. When this occurs, the well will have to be grouted with the remaining casing left in the borehole. The preferred method in this case should be to pressure grout the borehole by placing the tremie tube to the bottom of the well casing, which will be the well screen or the bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter material and up the inside of the well casing sealing holes and breaks that are present. The tremie tube should be retracted slowly as the grout fills the casing. The well casing should be cut off even with the ground surface and filled with concrete to a depth of 2 feet below the surface. If the casing has been broken off below the surface, the grout should be tremied to within 2 feet of the surface and then finished to the ground surface with concrete. The surface pad or specified surface protection should then be installed.

c) The following information should be included with the well abandonment plan submitted to ADEM:

i) Site name and address.

ii) Type of well(s) (monitoring, piezometer, extraction, etc.) to be abandoned and reason for abandoning.

iii) Latitude and longitude of well(s).

iv) Topographic map and site map illustrating the location of well(s).

v) Diameter and length of well(s) including length of screen and interval(s) screened prior to well abandonment.

vi) Description of method to be employed to abandon well(s).

vii) Type of grout used and method used to place grout in well.

viii) Quantity of grout used to seal well.

ix) The following information should be included in the final well abandonment report upon completion of all approved activities:

- Site name and address.
- Type of well(s) (monitoring, piezometer, extraction, etc.) abandoned and reason for abandoning.
- Identification of the well(s).
- Date well(s) was abandoned and the name of person(s) overseeing abandonment.
- Latitude and longitude of well(s).
- Site map illustrating the location of the well(s).
- Description of method employed to abandon the well(s).
- Photograph(s) of abandoned well(s).
- Date of well abandonment activities.

(e) Individual (Private) Potable Water Supply Wells

Individual water supply wells are relatively shallow in depth and serve one to several households with enough water for domestic purposes. These wells are typically one of three types: shallow-dug wells, driven or sand point wells or drilled or augered wells. As with other types of wells, the type and depth of the well should be determined prior to plugging. Any obstructions in the well should be removed prior to initiating the plugging operation and under no circumstances should any part of the casing be allowed to remain above the surface of the ground after plugging.

Accurate records (See Attachment I – Water Supply Well Abandonment Plan) should be kept of the well location, depth, filling material, date of plugging, etc.

i. Shallow-Dug Wells – Hand-dug wells that extend down to the aquifer and are sometimes blasted or chipped into bedrock to reach the aquifer. Stone or concrete walls called curbing sometimes are necessary to keep the well from collapsing. These wells are rarely deeper than a few tens of feet and have diameters that are usually several feet across.

   a) Pumps, piping or debris should be removed and the top 3 to 5 feet of curbing should be broken up prior to filling.

   b) Any portion of the well that extends into bedrock should be filled with a concrete-bentonite grout.

   c) The remainder of the well should be filled with clean native materials that approximate the permeability of the aquifer and overlying soils in the vicinity of the well.

   d) The soil should be compacted to prevent settling and ponding of water in the location of the former well.

ii. Driven or Sand Point Wells - A well that is driven to the desired depth, either by hand or machine and may employ a well-point, or alternative equipment. These wells typically have a small diameter (2 inches or less) with a short screen near the pointed end and can only be used in soft sandy sediments or soils.

   a) Driven or sand point wells should be removed if their diameter is 2 inches or less and their depth is 25 feet or less.

   b) The hole should be filled with a bentonite-cement grout.

   c) If greater than 25 feet in depth, larger than 2 inches in diameter, or cannot be removed, the well should be filled with a bentonite-cement grout from bottom to top using the pump-down method with a tremie pipe.

iii. Drilled Wells - Diameters of 2 inches to 20 inches are typical for these wells, which are installed with the use of a drilling rig and may be several tens to several thousands feet deep. In Alabama, drilled domestic wells are generally less than 250 feet deep. Drilled domestic wells are often unique in design and depth and should be abandoned only by a licensed well driller.

   a) If possible, the casing should be removed and the borehole filled with a cement-bentonite slurry.

   b) If the casing cannot be removed, the entire well should be filled with a cement-bentonite slurry using the pump-down method with a tremie pipe.

c) In areas subject to subsidence and/or farming, the top of the casing should be cut off a minimum of 3 feet below ground surface before plugging operations begin.

d) After filling the well with the cement-bentonite slurry, the excavation above the top of the cement plug should be filled with compacted soil to minimize future hazards to farming equipment, etc. In other areas, the top of the casing should be cut off at or below the ground surface.

(f) **Underground Storage Tank (UST) Petroleum Sites** - The Department may require that all installed monitoring wells be properly plugged and abandoned upon completion of either the site investigative phase or remediation phase. In accordance with ADEM ADMIN. Code R. 335-6-15-.29(8) the wells may be required to be "properly closed". The purpose of sealing an abandoned boring or monitoring well is to prevent any further disturbance to the pre-existing hydrogeologic conditions that exist in the subsurface. In accordance with this purpose, no material that could impart taste, odor, or toxic components to water may be used in the sealing process.

Allowable procedures for abandonment of the various types of wells which may be installed at a UST site are as follows:

Abandonment of Borings:

i. Unconsolidated Formations

Borings extending into unconsolidated formations may be adequately sealed by filling with concrete, grout, neat cement or a grout/cement mixture.

The boring may be backfilled with cuttings if all of the following conditions are met:

The boring is in a well-drained area with no tendency to have standing surface water,

The boring is 25 feet or less in depth,

The boring does not penetrate an aquifer, and is not in an area of contamination.

If the boring is filled with concrete, grout, neat cement or a grout/cement mixture, the sealing material may be brought up to about two or three feet below grade and finished with clay or excavated cuttings. If the boring is located in a paved area, the finishing fill should include a final covering comparable to the original surface, for example, concrete or asphalt patching. Materials that could crack and provide a vertical conduit should be avoided.

ii. *Competent Rock*

Borings that extend into competent bedrock should be filled from the bottom with concrete, grout, neat cement or a grout/cement mixture. If the bedrock is overlain by residual soils, the sealing material may be brought up to about two or three feet below grade and finished with clay or cuttings as in unconsolidated formations site is paved.

Abandonment of Monitoring Wells

Wells can be abandoned either by removing the casing or by leaving all or part of the casing in place and cutting the casing off below ground level. Because the primary purpose of well abandonment is to eliminate vertical fluid migration along the borehole, the preferred method of abandonment involves casing removal. Abandonment methods for various types of wells are as follows:

i. Temporary Monitoring Wells

Temporary monitoring wells should have the casing puled and the borehole sealed as with a boring.

ii. Permanent Monitoring Wells

Permanent monitoring wells should have the casing pulled and the borehole sealed as with a boring.

Casing material, depth of the well, deviation of the well, or other reasons may make pulling the casing impossible. In this situation, the casing may be cut off two or three feet below grade and completely filled with concrete, grout, neat cement, and or a grout/cement mixture to prevent channeling. The hole should be finished up to the ground as with a soil boring.

The casing may be removed by over-drilling if necessary. The casing and debris should be removed and borehole sealed as with a boring.

iii. Multiple Casing Monitoring Wells

Multiple cased monitoring wells are built to insure that vertical migration does not affect groundwater quality. Therefore, if the construction design is known to be satisfactory and the casing integrity has not been affected, it may be left in the ground and filled with concrete, grout, neat cement or a grout/cement mixture. The casing should be cut off two or three feet below grade and filled from the bottom up as with a permanent monitoring well. The hole should be finished up to the ground surface as with a boring.

ATTACHMENT 1 - WATER SUPPLY WELL ABANDONMENT PLAN

Name/Telephone # of well owner: ______________________________________

Name/Telephone # of person owning property on which the well is located (If different from the owner): ____

*Stage of construction: _________

Location of Well: Latitude: +Degrees_ _ Minutes _ _ _ Seconds _ _ ._ _ _
Longitude: +Degrees_ _ Minutes _ _ _ Seconds _ _ ._ _ _

Name/Telephone # of person who knows the location of the well:
____

Attach an 8 ½ x 11 copy of a 7.5 Minute USGS Topographic Map and mark the location of the well. Give the name of the topographic map (usually located in the upper right hand corner of the original map). Attach an 8½ x 11 cross sectional drawing showing the details of the well.

Type of geological formation: ___Consolidated ___Unconsolidated ___Other (Explain):____
Screen: diameter _______Type ______ Length ______
Depth of the well: ______Diameter of the casings ________________________
Casing to be removed: ___Yes ___No If no explain why not:
____
Method proposed to remove casing:____________________________________
Depth of casing grouting:_________________**Type well:_________________
Describe the proposed plan for abandoning the well: _______________________
____
____
____
____
____
____
____
____

Note: Add additional pages as needed to provide complete information
* 1= Test Hole; 2=Test Well; 3=Partially completed well; 4 Completed well
** A=Rock Wall; B=Gravel wall; C=Other Explain

Appendix C

Sampling Methods

APPENDIX C - SAMPLING METHODS

C.1. Appendix Outline

C.2 Soil Sampling Methods

C.2.1 Soil Boring Drilling and Sampling Methods - Soil borings may be advanced for sampling by either manual techniques, mechanical equipment, or by specialized equipment.

(a) Manual Techniques - Manual techniques are usually selected for surface or subsurface soil sampling. As the depth of the sampling interval becomes greater, some type of power sampling equipment is usually necessary to overcome the torque induced by soil resistance. The more commonly used manual equipment are stainless steel spoons, shovels, hand-augers, post-hole diggers, push tubes and disposable syringes.

i. Stainless Steel Spoons, Shovels, Hand-Augers and Post-Hole Diggers - These sampling devices should be properly decontaminated and wrapped in aluminum foil prior to all soil sampling activities at the beginning of each day. They should also be properly decontaminated in accordance with Appendix E of this document between each sample collected and each soil boring such that cross-contamination does not occur.

ii. Split spoon samplers are manually pushed into the surface soils for the collection of a surface soil samples. Split spoon samplers are approximately 3-inches to 5-inches in diameter and may be 2 feet to 3 feet in length. The sample is transferred from the split-spoon sampler to a pan where the soil is mixed prior to being placed in the appropriate sample containers. Split spoon samplers are appropriate for use when the sample will be analyzed for volatile organic constituents, however, certain precautions must be taken. When sampling soil for VOCs using a split spoon sampler, the collected sample must either be placed in the final sample container (e.g.: 40 ml pre-prepared vial) immediately or the sample may be immediately placed into an intermediate sample container with no head space. If an intermediate container (usually 2 oz. soil jar) is used, the sample must be transferred to the final sample container as soon as possible not to exceed 30 minutes. After collection of the sample into an approved container, the sample must immediately be stored in an ice chest and cooled.

iii. Shelby tubes (or an equivalent) are thin-walled tube, generally of stainless steel construction and having a beveled leading edge, which is twisted and pushed directly into the soil. This type of sampling device is particularly useful if a relatively undisturbed sample is required. The sampling device is removed from the push-head, and then the sample is extruded from the tube into the pan with a spoon or special extruder. Even though the push-head is equipped with a check valve to help retain samples, the Shelby tube will generally not retain loose and watery soils, particularly of collected at lower depths.

iv. EnCore™ Samplers (or an equivalent) can be used when total VOC concentrations in the soil/sediment are expected to be less than 200 µg/kg.

Samples may be collected directly with EnCore™ samplers (or an equivalent). Once the sample has been collected, the sampler is simply capped and secured in a plastic bag. The sampler provides accurate in situ VOC results without the lost of VOCs that may occur during the transfer of the samples from the sampling device to the sample container. All soil samples collected by EnCore™ Samplers (or an equivalent) should be extracted and analyzed by the appropriate USEPA approved SW-846 test method.

v. Disposable Plastic Syringes are also used when total VOC concentrations in the soil/sediment are expected to be less than 200 μg/kg. If using non-tared sample containers, place the sample container on the scale and zero out the weight of the container. Add about 3.7 cc (approximately) of the sample material to the 40 ml containers, 0.5 cc (approximate) to 5 ml containers and record weight to nearest 0.01 gram on the sample tag and in field notes. The final weight of the added sample material should be between 4.5 to 5.5 grams for the 40 ml containers and 0.5 to 1.5 grams for the 5 ml containers. The procedure is the same for tared containers, but the recorded weight need only be to the nearest 0.5 grams. Secure the containers in a plastic bag. When using the syringes, it is important that air is not allowed to become trapped behind the sample prior to extrusion, as this will adversely affect the sample. All soil samples collected by Disposable Plastic Syringes should be extracted and analyzed by the appropriate USEPA approved SW-846 test method.

(b) Mechanical Equipment - Mechanical Equipment is typically used to advance a soil boring to depths that does not allow the use of manual boring devices. This equipment is typically used for the collection of subsurface soil samples. Mechanical equipment that is commonly used includes two-man power augers, drill rigs and backhoes.

i. Power augers of the Little Beaver variety (or an equivalent), are commonly used to aid in the collection of subsurface soil samples at depths where hand augering is impractical. This type of equipment is technically a sampling aid and not a sampling device, and on rare occasions, has been used to advance holes as deep as 40 feet below ground surface. It is used to advance a hole to the required sampling depth, at which point most commonly a hand auger, or less commonly, push tubes or split-spoons are used to collect the samples.

ii. Drill rigs offer the capacity of collecting soil samples form great depths. When used in conjunction with drilling, split-spoon samplers are usually driven either inside a hollow stem auger or inside an open borehole after rotary-drilling equipment has been temporarily removed. The spoon is driven with a 140-lb hammer through a distance of up to 24 inches and removed. Continuous split-spoon samplers are commonly used to obtain 5-foot long continuous samples.

iii. Backhoes may be used in shallow to deep subsurface soil sampling programs. Samples may be collected form the large chunks removed by the bucket or they may be collected from the trench wall, if proper safety protocols are followed. Trenches also offer the ability to collect samples from very specific intervals and allow visual correlation with vertically and horizontally adjacent material. Prior to collecting samples from trench walls, the wall surface should be dressed with a stainless steel shovel, spatula knife, or spoon to remove the surface layer of soil that was smeared across the trench wall as the bucket passed. Samples from the bucket should be collected from within the large chunks that have not come into contact with the bucket surface.

(c) Specialized Direct Push Technology includes Geoprobe® and Cone Penetrometer Rigs (or their equivalents). The technology allows the sampler to obtain soil samples from the desired depths without producing drill cutting and other Investigation-Derived Waste (IDW), and to collect in situ geophysical measurements of the subsurface material. Direct push technologies are most applicable in unconsolidated sediments typically to depths less than 100 feet and have played a major role in the development of expedited site assessments. Direct Push Systems are composed of two different systems, a single-rod system, and a cased system. Soil sampling tools used with the direct push systems include non-sealed soil samplers such as barrel samplers, split-barrel samplers, and thin-wall tube samplers, and sealed soil (piston) samplers.

Presently, direct push technology may be used as a screening tool to establish the boundaries of a groundwater contamination plume, applicable for the collection soil samples, and for establishing subsurface conditions through the various geophysical tools. Permanent monitoring wells installed by conventional drill rigs will be required to verify groundwater quality conditions.

Following the collection of a soil sample, the sample container should immediately be placed in an ice chest and cooled.

C.3 Groundwater Sampling Methods

Groundwater sampling may be required for a variety of reasons such as examining potable or industrial water supplies, checking for and/or tracking contaminant plume movement in the vicinity of a land disposal or spill site, Resource Conservation Recovery Act (RCRA) compliance monitoring, and/or evaluating a site where historical information is minimal or non-existent but where it is thought that groundwater contamination may have occurred.

Groundwater samples are usually obtained from either temporary or permanently installed groundwater monitoring wells. Groundwater samples may also be obtained from a drilled boring or from a boring produced by the various direct push techniques. All groundwater samples from borings produced by drilling or a direct push technique are appropriate for screening only. A permanently installed groundwater monitoring well in accordance with Appendix B is required to verify all screening data.

C.3.1 Purging and Purge Adequacy - Purging is a process of removing stagnant water from a monitoring well immediately prior to sampling. Purging is conducted to ensure that all stagnant water has been removed from the well and that groundwater samples that are representative of actual aquifer conditions will be collected. In order to determine when a well has been adequately purged, field investigators should monitor the pH, specific conductance, temperature, and turbidity of the groundwater removed during purging. In addition, a minimum of 3 to 5 total well volumes should be removed. Prior to purging, the amount of water standing in the water column (water inside the well riser and screen) should be determined. Initially, the field investigator should determine the diameter of the well. The water level and total well depth should then be measured and recorded. Specific methods to obtain the water level and total well depth are outlined in Section C.3.2 of this Appendix. The volume of water to be purged can then be determined by using several methods. One equation is $V=0.041d^2h$, where h = depth of water in feet, d = diameter of well in inches, and V = volume of water in gallons. Alternatively, the volume may be determined using a casing volume per foot factor for the appropriate diameter well. The water level is subtracted from the total depth, providing the length of the water column. This length is multiplied by the factor in the table below that corresponds to the appropriate well diameter, providing the amount of water (gallons) contained in the well. Other appropriate methods include the use of nomographs or other equations or formulas.

Well Casing Diameter vs. Volume (Gals)/Feet of Water	
Casing Size	Gallons/Ft of Water
1	0.041
2	0.163
3	0.367
4	0.653
5	1.02
6	1.469
7	1.999
8	2.611
9	3.305
10	4.08
11	4.934
12	5.875

An adequate purge is achieved when a minimum of 3 to 5 total well volumes of standing water has been removed, and when the pH, specific conductance, and temperature of groundwater have stabilized and the turbidity has either stabilized or is below 10 Nephelometric Turbidity Units (NTUs). Stabilization of the groundwater chemistry parameters occurs when pH measurements remain constant with 0.1 Standard Unit (SU), specific conductance varies no more than 10 percent, and the temperature is constant for at least three consecutive reading. Standard procedure is to collect an initial set of the groundwater chemistry parameters prior to all purging activities, with a set of parameters measured after each well volume has been removed. The conditions of all purging and sampling activities should be noted in the field log and on the Groundwater Sampling Data Form. If a well is pumped or bailed dry, this is considered an adequate purge and the well can be sampled following sufficient recovery (enough volume to allow filling of all sample container). It is not necessary to evaluate the well to dryness three times before it is sampled. The pH, specific conductance, temperature, and turbidity should be measured during collection of the sample from the recovered volume, as the measurements of record for the sampling event. All efforts should be made to avoid purging monitoring wells to dryness. This may be accomplished by slowing the purge rate.

C.3.2. Water Level and Total Well Depth Measuring Techniques

(a) Measuring the depth to the free groundwater surface can be accomplished by utilizing one of the following methods: electronic water level indicators, weighted tape, chalked tape, and/or other methods (for closed systems or permanent wells - sliding float method, air line pressure method, and electrical and automatic recording methods. Acoustic water level indicators are also available). The method chosen to measure water levels should be capable of measuring to the nearest 0.1 foot. All water levels should be made to an established reference point on the well casing. The reference point should be tied in with the NGVD (National Geodetic Vertical Datum). All water levels should be documented in the field records and on a Groundwater Sampling Data Form.

(b) The total well depth measurement techniques, which can be used to determine the total well depth, include the bell sounder, weighted tape, and electronic water level indicators. This is accomplished by lowering the tape or cable until the weighted end is felt resting on the bottom of the well. All total well depth measurements should be made and recorded to the nearest 0.1 foot. All total well depth measurements should be made to an established reference point on the well casing. The reference point should be tied in with the NGVD. All total well depth measurements should be documented in the field records and on a Groundwater Sampling Data Form. All water level and total depth measuring equipment should be decontaminated in accordance with decontamination procedures outlined in Appendix E.

C.3.3 Purging Techniques – Monitoring well purging is accomplished by using in-place plumbing and dedicated pumps or , by using portable pumps/equipment when dedicated systems are not present. The equipment may consist of a variety of pumps, including peristaltic, large and small diameter turbine (electrical submersible), bladder, centrifugal, gear-driven positive displacement, or other appropriate pumps. The use of any of these pumps is usually a function of the depth of the well being sampled and the amount of water that is to be removed during purging. Whenever the head difference between the sampling location and the water level is less thanthe limit of suction and the volume to be removed is reasonably small, a peristaltic pump should be used for purging. Bailers may also be used for purging in appropriate situations. If a bailer is used it should be a closed-top bailer to attempt to inhibit turbid conditions.

The pump/hose assembly or bailer used in purging should be lowered into the top of the standing water column to pull water from the formation into the screened area of the well and up through the casing so that the entire static volume can be removed. If the pump is placed deep into the water column, the water above the pump may not be removed, and the subsequent samples, particularly if collected with a bailer, may not be representatives of the groundwater. After the pump is removed from the well, all wetted portions of the hose and the pump should be cleaned as outlined in Appendix E. Careful consideration should be given to using pumps to purge wells, which are excessively contaminated with oily compounds, because it may be difficult to adequately decontaminate severely contaminated pumps under field conditions. When wells of this type are encountered, alternative purging methods, such as bailers, should be considered.

(a) Wells Without Plumbing or In-Place Pumps

i. Purging with Pumps - When peristaltic pumps or centrifugal pumps are used, only the intake line is placed into the water column. The line placed into the water should be either standard-cleaned (See Appendix E) Teflon® tubing for peristaltic pumps, or standard-cleaned stainless steel pipe attached to a hose for centrifugal pumps. When submersible pumps (bladder, turbine, displacement, etc.) are used, the pump itself is lowered into the water column. The pump should be cleaned as specified in Appendix E of this document.

ii. Purging with Bailers - Standard-cleaned closed-top Teflon® bailers with Teflon® leaders and arid new nylon rope are lowered into top of the water column, allowed to fill, and removed. The water should be contained and managed as investigation-derived waste. It is critical that bailers are slowly and gently immersed into the tip of the water column, particularly during the final stages of purging, to minimize turbidity and disturbance of volatile organic constituents.

iii. General Low Flow/Low Stress Method Preference - Low flow/low stress purging is a procedure using a device with the lowest pump or water removal rate, and creating the least amount of stress to a well. If a bailer and a peristaltic pump both works in a given situation, the pump should be selected because it will greatly minimize turbidity, providing a higher quality sample. If a Fultz® pump or a Grundfos Redi-Flo® (or their equivalents) could both be used, the Redi-Flo® (or its equivalent) may be given preference because the speed can be controlled to provide a lower pump rate, thereby minimizing turbidity.

iv. Low flow/low volume purging techniques/procedures are procedure(s) used to minimize purged water volumes. Flow rates do not exceed the recharge rate of the aquifer (no decrease in the water level in the monitoring well). The pump intake is placed within the screened interval at the zone of sampling, preferably, the zone with the highest flow rate. The water level is monitored with a water level recorder or similar device while pumping. These techniques are only acceptable under certain hydraulic conditions and are not considered standard procedures. A plan documenting that the required hydraulic conditions do exist at the site under investigation will be required for ADEM review and approval determination.

(b) Wells with In-Place Plumbing

i. Permanent Monitoring Wells - Permanent monitoring wells generally are sampled only occasionally and require purging as described for wells without in-place pumps (i.e.:, 3 to 5 well volumes and stable parameters).

ii. Continuous Running Pumps - If the pump runs more or less continuously, no purge (other than opening a valve and allowing it to flush for a few minutes) is necessary. If a storage tank is present, a spigot, valve or other sampling point should be located between the pump and the storage tank. Otherwise, locate the valve closest to the tank. Measurements of pH, specific conductance, temperature, and turbidity are recorded at the time of sampling.

iii. Intermittently Running Pumps - If the pump runs intermittently, it is necessary to determine, if possible, the volume to be purged, including storage/pressure tanks that are located prior to the sampling location. The pump should then be run continuously until the required volume has been purged. If construction characteristics are not known, best judgment should be used in establishing how long to run the pump prior to collecting the sample. Generally, under these conditions, 30 minutes will be adequate. Measurements of pH, specific conductance, temperature and turbidity should be made and recorded at intervals during the purging, and the final measurements made at the time of the sampling.

(c) Temporary monitoring wells from permanent wells because temporary wells are installed in the groundwater for immediate sample acquisition. Wells of this type may include standard well screen and riser placed in boreholes created by hand augering, power augering, or by drilling. They may also consist of a rigid rod and screen that is pushed, driven, or hammered into place to the desired sampling interval, such as the Direct Push Wellpoint®, the Geoprobe® and the Hydropunch® (or their equivalents). As such, the efforts to remove several volumes of water to replace stagnant water do not necessarily apply in these situations because, generally, stagnant water is non-existent. However, the longer a temporary well is in place and not sampled, the more appropriate it may be to apply, to the extent possible, standard permanent monitoring well purging criteria to it. Temporary wells to be sampled immediately may require purging to mitigate the impacts of the installation activities that have resulted in increased turbidity. Therefore, purging may be conducted to reduce the turbidity and remove the volume of water in the area directly impacted by the installation activities. If the water level is no greater than approximately 25 feet below the pump head elevation, a peristaltic pump may be used to purge temporary monitoring wells and collect low turbidity samples by low-flow purging and sampling techniques. At the onset of purging, the tubing should be slowly lowered to the bottom of the screen and used to remove any formation material which may have entered the well screen. After formation material is removed from the bottom of the well, the tubing is slowly raised through the water column to near the top of the column. If the water level is determined to be stable, the tubing should be secured and maintain this pumping rate until relatively clear, low turbidity water samples can be collected. If the water level is lowered, and the pump is not in a variable speed, continue to lower the tubing as the water level is lowered. If the water level continues to lower, “chase” the water column until the well is evacuated. The recovered water column, after complete evacuation of the well, may be relatively free of turbidity and can be sampled. It may take several episodes of recovery to provide an adequate volume of water for all required samples. If a variable speed peristaltic pump is being used and drawdown is observed on initiation of pumping, reduce the pump speed and attempt to match the drawdown of the well. Sustained pumping at these slow rates should be conducted until relatively clear, low turbidity water samples can be collected. With many of the direct push sampling techniques, no purging is conducted. The sampling device is simply pushed to the desired depth, opened, and the sample is collected and retrieved.

C.4. Groundwater Sampling

Groundwater sampling is the process of obtaining, containerizing, and preserving a groundwater sample after the purging process is complete. Submersible, centrifugal and Fultz® pumps (or their equivalents) are not appropriate for the collection of groundwater samples from any monitoring wells. The only devices that should be used to collect groundwater samples from monitoring wells are: peristaltic pump/vacuum jug assembly, a stainless steel and Teflon® bladder pump, and a closed-top, Teflon® bailer (or its equivalent). Industrial or municipal supply wells or private residential wells, where a well may be equipped with a dedicated pump from which a sample would not normally be collected, should be sampled in accordance to this guidance document and USEPA Region 4 Standard Operating Procedures and Quality Assurance Manual (recent edition). Groundwater samples should be collected in the order of the volatilization (highest ability to volatilize to the lowest). Groundwater samples for VOC analysis should be collected initially prior to all other samples. All sampling equipment, including pumps, bailers, water level measurement equipment, etc., which comes into contact with the water in the well must be decontaminated in accordance with the decontamination procedures as described in Appendix E prior to its use in all subsequent monitoring wells. When conducting groundwater sampling, the following evaluations should also be conducted and noted in the field logbook and in a Groundwater Sampling Data Form. First, determine the order in which the wells will be sampled (least contaminated to the most contaminated). Note the construction and condition of the well (pad condition, ponding of water, or vertical openings between the casing and the backfill material). Note any standing water inside the protective casing (if this freezes, may collapse casing). There should be a weep hole at the bottom of the protective casing to prevent standing water. Note if the well is locked and the condition of the lock (broken, rusted, or missing). Note the condition of all well construction materials and any damage that may need to be repaired, or if the well should be abandoned and replaced. Check for dangerous vapors with the proper air monitoring equipment. Finally, note the time of the sampling, the sample station location, the method of sampling, the color of sample, any odors detected, and any sediment observed.

C.4.1 Sampling Techniques

(a) Monitoring Wells with In-Place Plumbing - Following all purging activities, reduce the flow rate to minimize sample disturbance (particularly if VOCs are the COPCs). If the well is purged to dryness, the pump should be shut off and the well should be allowed to recharge such that the required groundwater samples can be collected. Collect all groundwater samples from dedicated, decontaminated Teflon® tubing directly into the appropriate sample containers.

(b) Potable Water Supply Wells with In-Place Plumbing - Purge the system for at least 15 minutes. If the samples must be collected at a point in the water line beyond pressurization or holding tank, a sufficient volume of water should be purged to provide a complete exchange of fresh water into the tank and at the location where the sample is collected. After purging for 15 minutes, measure the turbidity, pH, specific conductivity and temperature of the groundwater. Continue to monitor these parameters until three consistent readings are obtained. Disconnect any hoses, filters, or aerators attached to the tap before sampling. Reduce the flow rate of the tap or spigot and collect all groundwater samples directly into the appropriate sample containers (see Table 1 of Appendix G). When sampling for bacterial content, the sample container should not be rinsed before use due to possible contamination of the sample container or removal of the thiosulfate dechlorinating agent (if used). When filling the sample container, care should be taken so that splashing drops of water from the ground or sink do not enter into either the bottle or cap. Obtain the name(s) of the resident or water supply owner/operator, the resident's exact mailing address, and the resident's home and work telephone numbers.

(c) Wells Without Pumps

i. A peristaltic pump/vacuum jug can be used for sample collection because it does not allow the sample to come into contact with the pump tubing. Place a Teflon® transfer cap assembly onto the neck of a standard cleaned 4-liter (1-gallon) glass container. Connect Teflon® tubing (1/4-inch outside diameter) from the glass container to both the pump and the sample source. The pump creates the vacuum in the container, thereby drawing the sample into the container without it coming into contact with the pump tubing. Samples for VOC analysis should be collected using a bailer or by filling the Teflon® tube, by one of two methods, and allowing it to drain into the sample vials. The tubing is momentarily attached to the pump to fill the tube with water. After the water is discharged through the pump head, the tubing is quickly removed from the pump and a gloved thumb placed on the tubing to stop the water from draining out. The tubing is then removed from the well and the water is allowed to drain into the sample vials. The tubing is lowered into the well at the desired depth. A gloved thumb is placed over the end of the tubing to stop the water from draining out. The tubing is then removed from the well and the water is allowed to drain into the sample vials. Under no circumstances should the sample for VOC analysis be collected from the content of any other previously filled container.

ii. Bladder Pumps - After purging is completed with the bladder pump, the sample should be collected directly from the pump discharge. If the discharge rate of the pump during the purging is too great, so as to make sample collection difficult, care should be taken to reduce the discharge rate at the onset of actual sample collection. This is necessary to minimize sample disturbance, particularly with respect to samples collected for VOC analysis.

iii. Bailers - Place new plastic sheeting on the ground around each well to provide a clean working area. Attach nylon rope to the bailer. Lower the bailer slowly and gently into the top of the water column until just filled. Carefully remove the bailer and empty its contents into the appropriate sample containers (see Table 1 of Appendix G).

(d) Direct-Push Technologies - Groundwater sampling using direct push (DP) technology is generally used during a one-time sampling event, and for screening purposes only. Once the contamination plume is delineated using DP technology, permanent monitoring wells installed using conventional methods should be used to verify DP screening results. Permanent wells installed utilizing direct push technologies is program dependent and determined site-specifically. A plan should be submitted to the Department and approved prior to any small diameter permanent well installation (see Appendix B-3). DP technology may also be used for determining groundwater gradients early in the site investigation. DP tools used for single-event sampling are divided into two groups – exposed-screen samplers and sealed-screen samplers. Exposed-screen samplers have a short (e.g.: 6 inches to 3 feet) interval of exposed fine mesh screens, narrow slots, or small holes at the terminal end of the tool. There are several varieties of exposed-screen samplers – a well point, drive-point profiler, and an innovative exposed-screen sampler used in conjunction with cone penetrometer testing. The advantage of the exposed screen is that it allows multi-level sampling in a single DP hole without withdrawing the DP rods. The disadvantages of the exposed screen are the following:

i. Dragging down of NAPLs, contaminated soil, and/or contaminated groundwater in the screen can occur;

ii. Clogging of the exposed screen (by silts and clays) typically occurs as it passes through sediments;

iii. Significant purging of sampler and/or the sampling zone because of drag down and clogging concerns are necessary; and,

iv. The fragility of the sampler because of the perforated open area.

Sealed-screened samplers are groundwater samplers that contain a well screen nested inside a watertight sealed body. The screen is exposed by retracting the probe rods once the desired sampling depth has been reached. The design of sealed-screen samplers is extremely variable. The advantages of sealed-screen samplers are the following:

i. The well screen is not exposed to soil while the tool is being pushed to the depth, thus, the screen cannot become plugged or damaged;

ii. The potential for sample cross-contamination is greatly reduced;

iii. Can collect depth-discrete groundwater samples beneath areas with soil in the vadose zone;

iv. Screened samplers do not require purging;

v. Some allow sample collection by bailers, check-valve pumps, peristaltic pumps, and bladder pumps (used with wide diameter cased DP systems only); and,

vi. Can be used in cased DP systems for the collection of deeper groundwater samples.

The disadvantages of this type of sampler are:

i. The o-rings must be replaced frequently; and,

ii. Sealed-screened samplers that collect groundwater in sealed chambers:

A. if the storage chamber is above the screen intake, groundwater samples must be collected sufficiently below the water table to create enough hydrostatic pressure to fill the chamber; and,

B. only sample chambers located below the screen intake are useful for collecting groundwater or LNAPL samples at or above the water table.

C.4.2 Sample Preservation - The minimum amount of preservative needed should be added to the sample immediately (See Table 1 of Appendix G). Care should be taken not to touch the preservative container to the sample bottle. After preserving, the sample pH should be checked by pouring a small volume over a piece of pH paper. Do not put pH-paper or probe into the sample container. Sample preservation should be done ASAP. Laboratories that supply the required sample containers may submit all containers with the required preservative. These sample containers are appropriate; however, the pH of the final sample should be checked with the results recorded in the field logbook and Groundwater Sampling Data Form.

C.4.3 Special Sample Collection Procedures

(a) Trace Organic Compounds and Metals - All sampling equipment, including pumps, bailers, water level measurement equipment, etc., which comes into contact with the water in the well, should be decontaminated in accordance with the decontamination procedures described in Appendix E of this document. Pumps should not be used for sampling unless the interior and exterior portions of the pump and the discharge hoses are thoroughly decontaminated (Appendix E). Blank samples should be collected to determine the adequacy of cleaning prior to collection of any sample using a pump. Filtered groundwater sample results will not be accepted as representative of existing aquifer conditions.

(b) Filtering will only be used for flow system analysis and for the purpose of geochemical speciation modeling.

(c) Bacterial Sampling - Whenever wells (normally potable wells) are sampled for bacteriological parameters, care should be taken to ensure the sterility of all sampling equipment and all other equipment entering the well.

C.4.4 Specific Sampling Equipment Quality Assurance Techniques - All equipment used to collect groundwater samples should be cleaned and repaired, if necessary, before being stored at the conclusion of field studies as outlined in Appendix E of this document. Cleaning procedures or repairs utilized in the field should be thoroughly documented in the field records or field logbook.

C.5. Surface Water and Sediment Sampling

Before any sampling is conducted, an initial reconnaissance should be made to locate suitable sampling locations. Bridges and piers are normally good choices as sites since they provide ready access and permit water sampling at any point across the width of the water body. However, these structures may alter the nature of the water flow and thus influence sediment deposition or scouring. Additionally, bridges and piers are not always located in desirable locations with reference to waste sources, tributaries, etc. Wading for water samples in lakes, ponds and slow-moving rivers and streams should be done with caution since bottom deposits are easily disturbed, thereby resulting in increased sediments in the overlying water column. On the other hand, wadeable area may be best for sediment sampling. In slow-moving or deep water, a boat is usually required for sampling.

C.5.1 Sampling Site Selection

(a) Rivers, Streams and Creeks - In the selection of a surface water sampling site in rivers, streams, or creeks, areas that exhibit the greatest degree of cross-section homogeneity should be located. When several locations along a stream reach are to be sampled, they should be strategically located at the following locations:

i. At intervals based on time of water travel, not distance (e.g.: sampling stations may be located about one-half day time-of-water-travel for the first three days downstream of a waste source (the first six stations) and then approximately one day through the remaining distance).

ii. At the same locations, if possible, when the data collected are to be compared to a previous study.

iii. Wherever a marked physical change occurs in the stream channel. When major changes occur in a stream reach, an upstream, downstream, and intermediate stations should be selected. Major changes may consist of:

A. A wastewater discharge;
B. A tributary flow;
C. Non-point source discharge (farms or industrial sites); and,
D. A significant difference in channel characteristics.

iv. To isolate major discharges as well as major tributaries. Dams and weirs cause changes in the physical characteristics of a stream. They usually create quiet, deep pools in river reaches that previously were swift and shallow. Such impoundments should be bracketed with sampling stations. When time-of-water-travel through the pools is long, stations should be established within the impoundments. To determine the effects of certain discharges or tributary streams on ambient water quality, stations should be located both upstream and downstream from the discharges. In addition to the upstream and downstream stations bracketing a tributary, a station should be established on the tributary at a location upstream and out of the influence of the receiving stream. Tributaries should be sampled as near the mouth as feasible. Frequently, the mouths of tributaries are accessible by boat. Care should be exercised to avoid collecting water samples from stratified locations that are due to difference in density resulting from temperature, dissolved solids, or turbidity.

v. Actual sampling locations will vary with the size of the water body and the mixing characteristics of the stream or river. Generally, for small streams less than 20 feet wide, a sampling site should be selected where the water is well mixed. In such cases, a single grab sample taken at mid-depth at the center of the channel is adequate to represent the entire cross-section. A sediment sample could also be collected in the same vicinity if available.

vi. For slightly large streams, at least one vertical composite should be collected from mid-stream. Samples should be collected just below the surface, at mid-depth, and just above the bottom. For larger streams and rivers, at least quarter point (¼, ½, and ¾ width) composite samples should be collected. Dissolved oxygen, pH, temperature, and conductivity should be measured from each aliquot of the vertical composite.

vii. For large rivers, several locations across the channel width should be sampled. Vertical composites across the channel width should be located in a manner that is roughly proportional to the flow (*i.e.,* they should be closer together toward mid-channel where most of the flow is, than toward the banks where the proportion of total flow is less).

In most circumstances, a number of sediment samples should be collected along a cross section of a river or stream in order to adequately characterize the bed material. A common procedure is to sample at quarter points along the cross-section. When the sampling technique or equipment requires that the samples be extruded or transferred on-site, they may be combined into a single composite sample. However, samples of dissimilar composition should not be combined but should be stored for separate analysis in the laboratory. To insure representative samples, the preferred method is diver-deployed coring tubes.

(b) Lakes, Ponds, and Impoundments - Lakes, ponds, and impoundments have a much greater tendency to stratify than rivers and streams. The relative lack of mixing generally requires that more samples be obtained. Occasionally, an extreme turbidity difference may occur where a highly turbid river enters a lake. For these situations, each layer of the vertically stratified water column needs to be considered. The number of water sampling stations on a lake, pond, or impoundment will vary with the objective of the investigation as well as the size and shape of the basin. In ponds and small impoundments, a single vertical composite at the deepest point may be sufficient. Dissolved oxygen, pH, and temperature are generally measured for each vertical composite aliquot. In naturally-formed ponds, the deepest point is usually near the center; in impoundments, the deepest point is usually near the dam. In lakes and larger impoundments, several vertical subsamples should be composited to form a single sample. These vertical sampling locations are often collected along a transection or grid. In lakes with irregular shapes and with several bays and coves that are protected from the wind, additional separate composite samples may need to adequately determine water quality. Similarly, additional samples should be collected where discharges, tributaries, land use characteristics, etc., are suspected of influencing water quality. When collecting sediment samples in lakes, ponds, and reservoirs, the sampling site should be approximately at the center of the water mass. The shape, inflow pattern, bathymetry, and circulation should be considered when selecting sediment-sampling sites in lakes or reservoirs.

(c) Estuarine Waters - A reconnaissance investigation should be conducted for each estuarine study unless prior knowledge of the estuarine type is available. The reconnaissance should focus upon the freshwater and oceanic water dynamics with respect to the study objective of the National Oceanic Atmospheric Administration (NOAA) tide tables and United States Geological Survey (USGS) freshwater surface water flow records that provide valuable insights into the estuary hydrodynamics. Water sampling in estuarine areas is normally based upon the tidal phases, with samples collected on successive slack tides. All estuarine sampling should include vertical salinity measurements at one to five-foot increments coupled with vertical dissolved oxygen and temperature profiles. A variety of water sampling devices are used, but in general, the Van Dorn (or similar type) horizontal sampler or peristaltic pump are suitable. Samples are normally collected at mid-depth areas where the depths are less than 10 feet unless the salinity profile indicates the presence of a halocline (salinity stratification). In that case, samples are collected from each stratum. Depending upon the study objective, when depths are greater than 10 feet, water samples may be collected at the one-foot depth from the surface, mid-depth, and one-foot from the bottom. Generally, estuarine investigations are two-phased, with study investigations conducted during wet and dry periods. Depending upon the freshwater inflow sources, estuarine water quality dynamics cannot normally be determined by a single season study.

(d) Control Stations - In order to have a basis of comparison of water quality, the collection of samples from control stations is always necessary. A control station upstream from the waste source is as important as the stations downgradient, and should be chosen with equal care to ensure representative results. In some situations it is desirable to have background stations located in similar, nearby estuaries that are not impacted by the phenomena or pollutants being investigated. At times it may be desirable to locate two or three stations downstream from the waste inflow to establish the rate at which the unstable material is changing.

C.5.2 Surface Water Sampling Equipment

(a) Dipping Using Sample Container - A sample may be collected directly into the sample container when the surface water source is accessible by wading or other means. The sampler should face upstream and collect the sample without disturbing the sediment. The surface water sample should always be collected prior to a sediment sample at the same location. The sampler should be careful not to displace the preservative from a pre-preserved sample container such as the 40-mil VOC vial.

(b) Scoops - Stainless steel scoops are useful for reaching out into a body of water to collect a surface water sample. The scoop may be used directly to collect and transfer a surface water sample to the sample container, or it may be attached to an extension in order to access the selected sampling location. The scoop is one of the most versatile sampling tools available to the field investigator.

(c) Peristaltic Pumps - Another device that can be effectively used to sample a water column is the peristaltic pump/vacuum jug system. The use of a metal conduit to which the tubing is attached allows for the collection of a vertical sample (up to about a 25-foot depth) that is representative of the water column. Commercially available pumps vary in size and capability with some being designed specifically for the simultaneous collection of multiple water samples.

(d) Discrete Depth Samplers - When discrete samples are desired from a specific depth, and the parameters to be measured do not require a Teflon® coated sampler, a standard Kemmerer or Van Dorn sampler may be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the ends of the sampler open while being lowered in a vertical position, thus allowing free passage of water through the cylinder. The Van Dorn sampler is plastic and is lowered in a horizontal position. In each case, a messenger is sent down a rope 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 respective sample containers. With a rubber tube attached to the valve, dissolved oxygen sample bottles can be properly filled by allowing an overflow of the collected water. With multiple depth samples, care should be taken not to stir up the bottom sediment and thus bias the sample.

(e) Bailers - Teflon® bailers may also be used for surface water sampling if the study objectives do not necessitate a sample from a discrete interval of the water column. A closed top bailer with a bottom check-valve is sufficient for many studies. As the bailer is lowered through the water column, water is continually displaced through the bailer until the desired depth is reached, at which point the bailer is retrieved. This technique may not be successful where strong currents are found.

(f) Buckets - A plastic bucket can be used to collect samples for in situ analyses (*e.g.*, pH, temperature and conductivity). However, the bucket should be rinsed twice with the sample water prior to collection of the sample.

C.5.3 Sediment Sampling Equipment

(a) Scoops and Spoons - If the surface water body is wadeable, sediment samples should be collected by using a stainless steel scoop or spoon. The sample is collected by wading into the surface water body and, while facing upstream (into the current), scooping the sample along the bottom of the surface water body in the upstream direction. Excess water may be removed from the scoop or spoon. However, this may result in the loss of some fine particle size material associated with the bottom of the surface water body. Aliquots of the sample are then placed in a glass pan and homogenized. In surface water bodies that are too deep to wade, but less than eight feet deep, a stainless steel scoop or spoon attached to a piece of conduit can be used either from the banks if the surface water body is narrow or from a boat. The sediment is placed into a glass pan and homogenized. If the surface water body has a significant flow and is too deep to wade, a BMH-60 sampler may be used. The BMH-60 is not particularly efficient in mud or other soft substrates because its weight will cause penetration to deeper sediments, thus missing the most recently deposited material at the sediment water interface. It is also difficult to release secured samples in an undisturbed fashion that would readily permit subsampling. The BNH-60 may be used provided that caution is exercised by only taking subsamples that have not been in contact with the metal wall of the sampler.

(b) Dredges - For routine analyses, the Peterson dredge can be used when the bottom is rocky, in very deep water, or when the stream velocity is high. The dredge should be lowered very slowly as it approaches bottom since it can displace and miss fine particle size sediment it allowed to drop freely. The Eckman dredge has only limited usefulness. It performs well where the 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 velocities. It should not be used from a bridge that is more than a few feet above the water because the spring mechanism, which activates the sampler, can be damaged by the messenger if dropped from too great a height. The Ponar dredge is a modification of the Peterson dredge and is similar in size and weight. It has been 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 turbulence around the dredge. 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. The "mini" Ponar dredge is a smaller, much lighter version of the Ponar dredge. It is used to collect smaller sample volumes when working in industrial tanks, lagoons, ponds, and shallow water bodies. It is a good device to use when collecting sludge and sediment containing hazardous constituents because the size of the dredge makes it more amenable to field cleaning.

(c) Coring – Core samplers are used to sample vertical columns of sediment. They are particularly useful when a historical picture of sediment deposition is desired since they preserved the sequential layering of the deposit, and when it is desirable to minimize the loss of material at the sediment-water interface. Many types of coring devices have been developed depending on the depth of the water from which the sample is to be obtained, the nature of the bottom material, and the length of core to be collected. They vary from hand push tubes to weight or gravity driven devices. Coring devices are particularly useful in pollutant monitoring because turbulence created by descent through the water is minimal, thus fines of the sediment-water interface are only minimally disturbed. The sample is withdrawn intact permitting the removal of only those layers of interest. Core liners manufactured of glass or Teflon® can be purchased; thus, reducing possible sample contamination and the samples are easily delivered to the lab for analysis in the tube in which they are collected. The disadvantage of coring devices is that a relatively small surface area and sample size is obtained often necessitating repetitive sampling in order to obtain the required amount of material for analysis. Because it is believed that this disadvantage is offset by the advantages, coring devices are recommended in sampling sediments for trace organic compounds or metals analyses. In shallow, wadeable waters, the direct use of a core liner or tube manufactured by Teflon®, plastic, or glass is recommended by the USEPA Region 4 for the collection of sediment samples. Teflon® or plastic is preferred to glass since they are unbreakable which reduces the possibility of sample loss. Stainless steel push tubes are also appropriate and provide a better cutting edge and higher strength than Teflon®. The use of glass or Teflon® tubes eliminates any possible metals contamination from core barrels, cutting heads, and retainers. The tube should be approximately 12 inches in length if only recently deposited sediments (8 inches or less) are to be sampled. Longer tubes should be used when the depth of the substrate exceeds 8 inches. Soft or semi-consolidated sediments such as mud and clays have a greater adherence to the inside of the tube and thus can be sampled with larger diameter tubes. Because coarse or unconsolidated sediments such as sands and gravel tend to fall out of the tube, a small diameter is required for them. A tube about two inches in diameter is usually the best size. The thickness of the tube wall should be about 1/3 inch for Teflon®, plastic or glass. The core tube is pushed into the substrate until four 4 inches or less of the tube is above the sediment-water interface. When sampling hard or coarse substrates, a gentle rotation of the tube while it is being pushed will facilitate greater penetration and decrease core compaction. The top of the tube is then capped to provide suction and reduce the chance of losing the sample. A Teflon® plug or a sheet of Teflon® held in place by a rubber stopper or cork may be used. After capping, the tube is slowly extracted with the suction and adherence of the sediment keeping the sample in the tube. Before pulling the bottom part of the core above the water surface, it too should be capped.

Appendix D

Quality Assurance/Quality Control

APPENDIX D - QUALITY ASSURANCE/QUALITY CONTROL

D.1. Outline

D.2. QA/QC Requirements

Quality Assurance/Quality Control procedures, and EPA required decontamination procedures should be utilized to ensure sample quality. (See USEPA Region IV's Standard Operating Procedures and Quality Assurance Manual – latest edition). It is the responsibility of the field sampling staff to assure that the samples collected arrives at the laboratory in the appropriate container, with the appropriate preservative, and within the holding times for each analysis.

D.3. Sample Containers & Preservation

All samples should be placed in the appropriate containers and preserved as recommended in Table 1 of Appendix G of this document. All sample containers should be new, pre-cleaned or properly decontaminated with the appropriate certification.

D.4. Sample Handling

The effectiveness of sample handling techniques will be measured by collecting split and blank samples. Blanks are required of water systems, grout, preservatives, sand, bentonite, soil trip blanks, and field cleaned equipment. The following samples are examples of Quality Control Samples that may be collected or required:

D.4.1 Control Sample - Typically a discrete grab sample collected to isolate a source of contamination. Isolation of a source could require the collection of both an upstream sample at a location where the medium being studied is unaffected by the site being studied, as well as a downstream control that could be affected by contaminants contributed from the site under study.

D.4.2 Background Sample - A sample (usually a grab sample) collected from an area, water body, or site similar to the one being studied, but located in an area known or thought to be free from the constituents of concern.

D.4.3 Split Sample - A sample that has been portioned into two or more containers from a single sample container or sample mixing container. The primary purpose of a split sample is to measure sample handling variability.

D.4.4 Duplicate Sample - two or more samples collected from a common source. The purpose of a duplicate sample is to estimate the variability of a given characteristic or contaminant associated with a population.

D.4.5 Trip Blanks - A sample that is prepared prior to the sampling event in the actual container and is stored with the investigative samples throughout the sampling event. They are then packaged for shipment with the other samples and submitted for analysis. At no time after their preparation are trip blanks to be opened before the reach the laboratory. Trip blanks are used to determine if samples were contaminated during storage and/or transport back to the laboratory (a measure of sample handling variability resulting in positive bias in contaminant concentration). If samples are to be shipped, trip blanks are to be provided with each shipment but not for each cooler.

D.4.6 Spike - A sample with known concentrations of contaminants. Spike samples are often packaged for shipment with other samples and sent for analysis. At no time after their preparation are the sample containers to be opened before they reach the laboratory. Spike samples are used to measure negative bias due to sample handling or analytical procedures or to assess the performance of a laboratory.

D.4.7 Equipment Field Blank - A sample collected using organic-free water that has been run over/through sample collection equipment. These samples are used to determine if contaminants have been introduced by contact of the sample medium with sampling equipment. Equipment field blanks are often associated with collecting rinse blanks of equipment that has been field-cleaned.

D.4.8 Pre- and Post-Preservative Blank - A sample that is prepared in the field and used to determine if the preservative used during field operations was contaminated, thereby, casing a positive bias in the contaminant concentration. On small studies, usually only a post-preservative blank is prepared at the end of all sampling activities. On studies extending beyond one week, a pre-preservative blank should also be prepared prior to beginning sampling activities. At the discretion of the project leader, additional preservative blanks can be prepared at intervals throughout the field investigation. These blanks are prepared by putting organic/analyte-free water in the container and then preserving the sample with the appropriate preservative.

D.4.9 Field Blank - A sample that is prepared in the field to evaluate the potential for contamination of a sample by site contaminants from a source not associated with the sample collected (e.g.: air-borne dust or organic vapors that could contaminate a soil sample). Organic-free water is taken to the field in sealed containers or generated on-site. The water is poured into the appropriate sample containers at pre-designed locations at the site. 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.

D.4.10 Material Blanks - Samples of sampling materials, construction materials, or reagents collected to measure any positive bias from sample handling variability. Commonly collected material blanks are:

(a) Wipe Sample Blank – a sample of the material used for collecting wipe samples.

(b) Grout Blank – a sample of the material used to make seals around the annular space in monitoring wells.

(c) Filter Pack Blank – a sample of the material used to create an interface around the screened interval of a monitoring well.

(d) Construction Water Blank – a sample of the water used to mix or hydrate construction material such as monitoring well grout.

(e) Organic/Analyte Free Water Blank – a sample collected from a field organic/analyte free water generating system. The sample is normally collected at the end of sampling activities since the organic/analyte-free water system is recharged prior to use on a study. On large studies, samples can be collected at intervals at the discretion of the project leader. The purpose of the organic/ analyte-free water blank is to measure positive bias from the sample handling variability due to possible localized contamination of the organic/analyte-free water-generating system or contamination introduced to the sample containers during storage at the site. Organic/analyte-free water blanks differ from field blanks in that the sample should be collected in as clean an area as possible.

D.5. Sample Identification

1. Samples collected for specific field analysis or measurement data should be recorded directly in bound field logbooks, sample collection forms, or recorded directly on the Chain-of-Custody Record. Samples collected for laboratory analyses should include sample labels or sample tags. The following information should be written on the sample labels or tags using waterproof, non-erasable ink:

(a) Project number;
(b) Field identification or sample station number;
(c) Date and time of sample collection;
(d) Designation of the sample as a grab or composite;
(e) Type of sample (water, wastewater, leachate, soil, sediment, etc.);
(f) The preservative used (if any); and

(g) The general types of analyses to be performed.

2. Information to be retained in a bound logbook or sample collection form should include:

   (a) Project number;

   (b) Field identification or sample station number;

   (c) Date and time of sample collection;

   (d) Designation of the sample as a grab or composite;

   (e) The signature of either the sampler(s) or the designated sampling team leader and the field sample custodian;

   (f) Whether the sample was preserved or unpreserved, and if preserved, identify the preservative used;

   (g) The general types of analyses to be performed;

   (h) All field measurements collected during the purging of monitoring wells (pH, Specific Conductivity, Temperature, and Turbidity);

   (i) Water levels and total well depths measured during the sampling event; and,

   (j) Any relevant comments (such as readily detectable or identifiable odor, color, or known toxic properties).

D.6. Chain-of-Custody

The original or copies of the chain-of-custody forms should be submitted with all the original laboratory reports to the Department. If copies are submitted, the copies should represent the same data and information, which are present on the original chain-of-custody forms. All information on the chain-of-custody forms should be recorded in a legible manner. Chain-of-custody forms should originate in the field immediately upon sampling soils or groundwater. The chain-of-custody forms should stay with the samples at all times until properly relinquished to the laboratory for analysis. Information which should be present on all chain-of-custody forms includes the following:

1. Site name and address.
2. Date and time of sampling of each sample.
3. Sample identification numbers.
4. Name of sampler(s).
5. Analytical laboratory to be utilized.
6. Analytical methods to be used.
7. Type of sample (i.e.: composite, grab, etc.).
8. Matrix sampled (soil, water sludge, etc.).
9. Number and type of sample container.
10. Remarks regarding sampling, if applicable.

11. Preservatives used for each sample (also indicate if placed on ice).
12. Personnel relinquishing samples; times and dates.
13. Personnel receiving samples; times and dates.

D.7. Investigation Derived Waste (IDW)

A number of materials may become IDW. Personnel protective equipment (PPE) (e.g.: disposable coveralls, gloves, booties, respirator canisters, splash suits, etc.), Disposable equipment (e.g.: plastic ground and equipment covers, aluminum foil, conduit pipe, composite liquid waste samplers, Teflon® tubing, broken or unused sample containers, sample container boxes, tape, etc.), soil cuttings from drilling or hand augering, drilling mud or water used for water rotary drilling, ground water obtained through well development or well purging, cleaning fluids such as spent solvents and washwater and packing and shipping materials. All IDW (non-hazardous and hazardous) shall be handled and disposed in accordance with Table 2, located in Appendix G.

Appendix E

Field Decontamination Procedures

APPENDIX E - FIELD DECONTAMINATION PROCEDURES

E.1. Appendix Outline

E.2. Standard Cleaning Liquids

1. Soap should be a standard brand of phosphate-free laboratory detergent such as Liquinox®. Use of other detergent should be justified and documented in the field logbooks and inspection or investigative reports.

2. Solvent should be pesticide-grade isopropanol. Use of a solvent other than pesticide-grade isopropanol for equipment cleaning purposes should be justified in the study plan. Otherwise its use should be documented in field logbooks and inspection or investigative reports.

3. Tap water may be used from any municipal water treatment system. Use of an untreated potable water supply is not an appropriate substitute for tap water. Analyte free water (deionized water) is tap water that has been treated by passing through a standard

deionizing resin column. At a minimum, the finished water should contain no detectable heavy metals or other inorganic compounds (i.e.: at or above analytical detection limits) as defined by a standard inductively coupled Argon Plasma Spectrophotometer (ICP) (or equivalent) scan. Analyte-free water obtained by other methods is appropriate as long as it meets the above analytical criteria. Organic/analyte free water is defined as tap water that has been treated with activated carbon and deionizing units. A portable system to produce organic/analyte free water under field conditions is available. At a minimum, the finished water should meet the analytical criteria of analyte free water and should contain no detectable pesticides, herbicides, or extractable organic compounds, and no VOCs above minimum detectable levels as determined by the Region 4 laboratory for a given set of analyses. Organic/analyte free water obtained by other methods is appropriate, as long as it meets the above analytical criteria.

4. Other solvents may be substituted for a particular purpose if required. For example, removal of concentrated waste materials may require the use of either pesticide-grade hexane or petroleum ether. After the waste material is removed, the equipment should be subjected to the standard cleaning procedure. Because these solvents are not miscible with water, the equipment should be completely dry prior to use.

E.3. Decontamination Pad

E.3.1 Decontamination Pad Specifications - The pad should be constructed in an area known or believed to be free of surface contamination. The pad should retain all decontamination fluids and site contaminants. If possible, locate the pad on a level, paved surface that is well drained. Pads located off pavement are subject to being shut down for extended periods following rain events due to standing water, equipment mired in mud, excessive mud on the pad, etc. The pavement also provides a firm support for heavy items such as augers. The pad should include a berm or wall that is 8 to 12 inches and completely surrounds the pad. Low cost walls can be constructed of unmortared concrete blocks, railroad ties, lumber, etc. The pad should include a small shallow sump dug in one corner of the pad. A hole can be made in the pavement, or a corner of the pad can extend beyond the paved area. The sump should be deep enough to contain the intake line of a pump. The pad should be lined with an impervious material with no seams within the pad. This material should either be easily relaced (disposable) or repairable. If a disposable liner is not chosen for the liner, a patch kit should be available to repair holes and tears. The area the liner is to cover should be swept or pressure washed prior to laying down the liner. Sawhorses or racks constructed to hold equipment while being cleaned should be high enough above the ground to prevent equipment from being splashed. The sawhorses or rack legs should be cushioned with small pieces of lumber, rubber, etc., to avoid puncturing the liner.

E.3.2 Operation of the Decontamination Pad - When drilling wells, organic-free water should be generated on-site to provide a sufficient quantity to avoid serious project delays. Both organic-free water and solvent should be applied using Teflon® spray nozzles. Spent solvent is a hazardous waste. Unless specifically cited in the approved study plan, spent solvent should be kept separate from other decontamination fluids. The decontamination pad should be drained as needed to keep standing water to a minimum. Standing water easily splashes onto cleaned equipment. Cleaned equipment should be moved from the working area of the pad and completely wrapped to avoid splashing.

Gasoline powered equipment (pump, steam jenny, generator, etc.) should be kept downwind of the decontamination pad while it is running. Safety glasses with splash shields or goggles, and latex gloves should be worn during all cleaning operations. Solvent rinsing operations will be conducted in the open (never in a closed room). No eating, smoking, drinking, chewing, or any hand to mouth contact should be permitted during cleaning operations. At the completion of site activities, the decontamination pad should be deactivated. The pit or sump should be backfilled with the appropriate material designated by the site project leader, but only after all waste/rinse water has been pumped into containers for disposal. No solvent rinsates will be placed in the pit. Solvent rinsates should be collected in separate containers for proper disposal. See Appendix D.7 of this document for proper handling and disposal of these materials. If the decontamination pad has leaked excessively, soil sampling may be required.

E.4. Decontamination of Drilling Equipment

E.4.1 Introduction - Cleaning and decontamination of all equipment should occur at a designated area (decontamination pad) on the site. Tap water (potable) brought on the site for drilling and cleaning purposes should be contained in a pre-cleaned tank of sufficient size so that drilling activities can proceed without having to stop and obtain additional water. A steam cleaner and/or high pressure hot water washer capable of generating a pressure of at least 2500 PSI and producing hot water and/or steam (200° F plus), with a soap compartment, should be obtained.

E.4.2 Preliminary Cleaning and Inspection - All drilling, and sampling equipment should be sandblasted before use if painted, and/or there is a buildup of rust, hard or caked matter, etc., that cannot be removed by steam cleaning (soap and high pressure hot water), or wire brushing. Sandblasting should be performed prior to arrival on-site, or well away from the decontamination pad and areas to be sampled. Any portion of the drill rig, backhoe, etc., that is over the borehole (kelly bar or mast, backhoe buckets, drilling platform, hoist or chain pull-downs, spindles, cathead, etc.) should be steam cleaned (soap and high pressure hot water) and wire brushed (as needed) to remove all rust, soil, and other material which may have come from other hazardous waste sites before being brought on-site. Printing and/or writing on well casing, tremie tubing, etc., should be removed before use. Emery cloth or sandpaper can be used to remove the printing and/or writing. Most well material suppliers can supply materials without the printing and/or writing if specified when ordered. The drill rig and other equipment associated with the drilling and sampling activities should be inspected to insure that all oils, greases, hydraulic fluids, etc., have been removed and all seals and gaskets are intact with no fluid leaks. PVC or plastic materials such as tremie tubes should be inspected. Items that cannot be cleaned are not appropriate and should be discarded.

E.4.3 Drill Rig Field Cleaning Procedure - Any portion of the drill rig, backhoe, etc., that is over the borehole (kelly bar or mast, backhoe buckets, drilling platform, hoist or chin pull-downs, spindles, cathead, etc.) should be steam cleaned (soap and high pressure hot water between boreholes.

E.4.4 Field Cleaning Procedure for Drilling Equipment - The following is the standard procedure for field cleaning augers, drill stems, rods, tools, and associated equipment. This procedure does not apply to well casings, well screens, or split-spoon samplers used to obtain samples for chemical analyses. Clean with tap water and soap, using a brush if necessary, to remove particulate matter and surface films. Steam cleaning (high pressure hot water with soap) may be necessary to remove matter that is difficult to remove with the brush. Drilling equipment that is steam cleaned should be placed on racks or saw horses at least two feet above the floor of the decontamination pad. Hollow-stem augers, drill rods, etc., that are hollow or have holes that transmit water or drilling fluids, should be cleaned on the inside with vigorous brushing. Rinse thoroughly with tap water. Remove from the decontamination pad and cover with clean, unused plastic. If stored overnight, the plastic should be secured to insure that it stays in place.

E.5. Decontamination Procedures for Sampling Equipment

E.5.1 Trace Organic and Inorganic Constituent Sampling Equipment (Teflon® and Glass) - Wash equipment thoroughly with soap and hot tap water using a brush or scrub pad to remove any particulate matter or surface film. Rinse equipment thoroughly with hot tap water. Rinse equipment with 10 % nitric acid solution. Small and awkward equipment such as vacuum bottle inserts and well bailer ends may be soaked in the nitric acid solution instead of being rinsed with it. Fresh nitric acid solution should be prepared for each cleaning session. Rinse equipment thoroughly with analyte-free water. Rinse equipment thoroughly with solvent and allow to air dry for at least 24 hours. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a “tab” to allow for easy removal. Seal the foil wrapped equipment in plastic and label. Note: If the sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone, hexane, or petroleum ether to remove the materials before proceeding with the first step. In extreme cases, it may be necessary to steam clean the field equipment before proceeding with Step 1. If the equipment cannot be cleaned utilizing these procedures, it should be discarded.

E.5.2 Stainless Steel or Steel - Wash equipment thoroughly with soap and hot tap water using a brush or scrub pad to remove any particulate matter or surface film. Rinse equipment thoroughly with hot tap water. Rinse equipment thoroughly with analyte-free water. Rinse equipment thoroughly with solvent and allow to air dry for at least 24 hours. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a “tab” to allow for easy removal. Seal the foil wrapped equipment in plastic and label. Note: If the sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone, hexane, or petroleum ether to remove the materials before proceeding with the first step. In extreme cases, it may be necessary to steam-clean the field equipment before proceeding with Step 1. If the equipment cannot be cleaned utilizing these procedures, it should be discarded.

E.5.3 Cleaning Procedures for Tubing (Silastic® Pump Tubing) - The Silastic® pump tubing in the automatic samplers and peristaltic pumps should be replaced after each study. After installation, the exposed ends should be capped with clean, unused aluminum foil. Only new Teflon® should be used for the collection of samples for trace organic compounds or ICP analyses and should be pre-cleaned as follows:

(a) Teflon® tubing should be precut in 10, 15 or 25-foot lengths before cleaning.
(b) Rinse outside of tubing with solvent.
(c) Flush interior of tubing with solvent.
(d) Dry overnight in the drying oven.
(e) Coil and cap ends with aluminum foil.
(f) Wrap tubing in one layer of aluminum foil.
(g) Roll edges of foil into a "tab" to allow for easy removal.
(h) Seal the foil wrapped tubing in plastic and label.

E.5.4 Stainless Steel Tubing - Wash with soap and hot tap water using a long, narrow, bottle brush. Rinse equipment thoroughly with hot tap water. Rinse equipment thoroughly with analyte-free water. Rinse equipment thoroughly with solvent and allow to air dry for at least 24 hours. Cap ends with aluminum foil. Wrap tubing in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal. Seal the foil wrapped tubing in plastic and date. Note: If the sampling equipment is used to collect samples that contain oil, grease, or other hard to remove materials, it may be necessary to rinse the equipment several times with pesticide-grade acetone, hexane, or petroleum ether to remove the materials before proceeding with the first step. In extreme cases, it may be necessary to steam-clean the field equipment before proceeding with Step 1. If the equipment cannot be cleaned utilizing these procedures, it should be discarded.

E.5.5 Glass Tubing - New glass tubing should be cleaned by rinsing thoroughly with solvent and air dried for at least 24 hours. Tubing should be wrapped completely with aluminum foil and sealed in plastic (one tube/pack) to prevent contamination during storage.

E.5.6 Cleaning Procedures for Miscellaneous Equipment:

(a) Well Sounders and Tapes - Wash with soap and tap water. Rinse with hot tap water. Rinse with analyte-free water. Allow to air dry overnight. Wrap equipment in aluminum foil, seal in plastic, and date.

(b) Fultz® Pump - Caution: to avoid damaging the Fultz® Pump never run pump when dry and never switch directly from forward to reverse mode without pausing in the "OFF" position. Pump a sufficient amount of hot soapy water through the hose to flush out any residual purge water. Using a brush or scrub pad, scrub the exterior of the contaminated hose and pump with hot soapy water. Rinse hose with analyte-free water and recoil onto the spool. Pump a sufficient amount of tap water through the hose to flush out soapy water (approximately one gallon). Pump a sufficient amount of analyte-free water through the hose to flush out the tap water, and then empty the pump and hose by placing pump in reverse. Do not allow pump to run dry. Rinse the pump housing and hose with analyte-free water. Place pump and reel in clean polyethylene bag or wrap in clean polyethylene film. Ensure that a complete set of new rotos, tow fuses and a set of cables are attached to the reel.

(c) Goulds® Pump - Caution: never plug the pump in while cleaning. Remove garden hose (if attached), and clean separately. Using a brush or scrub pad, scrub the exterior of the hose, electrical cord and pump with soap and tap water. Do not wet the electrical plug. Rinse with analyte-free water. Air dry. Place pump and hose in clean plastic bag and label.

(d) Redi-Flo® Pump - Caution: make sure that the controller is not plugged in and do not wet the controller. Wipe the controller box with a damp cloth. Remove any excess water immediately. Let the controller box dry completely. Caution: make sure the pump is not plugged in. Remove garden hose (if attached) and ball check valve. Clean these items separately. Using a brush or scrub pad, scrub the exterior of the electrical cord and pump with soap and tap water. Do not wet the electrical plug. Rinse with tap water. Rinse with analyte-free water. Completely air dry. Place equipment in clean plastic bag. Completely dismantle ball check valve. Check for wear and/or corrosion, and replace as needed. Using a brush, scrub all components with soap and hot tap water. Rinse with analyte-free water. Completely air dry. Reassemble the ball check valve and re-attach to Redi-Flo® pump head. Note: The analyte-free water within the Redi-Flo® pump head should be changed upon return from the field according to the manufacturer's instructions.

(e) Little Beaver® - The engine and power head should be cleaned with a power washer, steam jenny, or hand washed with a brush using soap to remove oil, grease, and hydraulic fluid from the exterior of the unit. Do not use degreasers. Rinse thoroughly with tap water. Auger flights and bits should be inspected thoroughly. If severe rust, corrosion, paint, or hardened grout is present, the equipment will require sandblasting prior to cleaning. Clean with tap water and soap, using a brush if necessary, to remove particulate matter and surface films. Steam-cleaning (high pressure hot water with soap) may be necessary to remove matter that is difficult to remove with the brush. Augers that are steam-cleaned should be placed on racks or saw horses at least 2 feet above the ground. Rinse thoroughly with tap water. Completely air dry. Remove and wrap with clean, unused plastic and return to storage.

(f) Field Analytical Equipment - Field instruments for in situ water analysis should be wiped with a clean, damp cloth. The probes on these instruments (pH, conductivity, DO, etc.) should be rinsed with analyte-free water and air-dried. Any desiccant in these instruments should be checked and replaced, if necessary, each time the equipment is cleaned.

(g) Ice Chests and Shipping Containers - Ice Chests and reusable containers should be washed with soap (interior and exterior) and rinsed with tap water and air-dried before storage. If in the opinion of the field investigators the container is severely contaminated with concentrated waste or other toxic material, it should be cleaned as thoroughly as possible, rendered unusable, and properly disposed.

(h) Garden Hose - Brush exterior with soap and tap water. Rinse with tap water. Flush interior with tap water until clear (minimum of one gallon). Completely air dry. Coil and place in clean plastic bag.

E.6. Preparation of Disposable Sample Containers

No disposable sample container (with the exception of the glass and plastic compositing containers) may be reused. All disposable sample containers will be stored in their original packing containers. When the packages of uncapped sample containers are opened, they should be placed in new plastic garbage bags and sealed to prevent contamination during storage.

E.6.1 Plastic Containers used for "Classical" Parameters - Plastic containers used for oxygen demand, nutrients, classical inorganics, and sulfides have no pre-cleaning requirement. However, only new containers may be used.

E.6.2 Glass Bottles for Semi-Volatile GC/MS Analytes - These procedures are to be used only if the supply of pre-cleaned, certified sample bottles is disrupted. If desired, pesticide-grade methylene chloride may be substituted for pesticide-grade isopropanol. In addition, 1:1nitric acid may be substituted for the 10% nitric acid solution. Wash bottles and jugs, Teflon® liners, and caps with hot tap water and soap. Rinse three times with tap water. Rinse with 10% nitric acid solution. Rinse three times with analyte-free water. Rinse bottles, jars, and liners (not caps) with solvent. Oven-dry bottles, jars, and liners at 125°C and allow to cool. Place liners in caps and closed containers. Store in contaminant-free area.

E.6.3 Glass Bottles for Volatile GC/MS and TOX Analyses - These procedures are to be used only if the supply of pre-cleaned, certified sample bottles is disrupted. Wash vials, bottles and jars, Teflon® liners and septa, and caps with hot tap water and laboratory detergent. Rinse all items with analyte free analyte-free water. Oven-dry at 125°C and allow to cool. Seal vials, bottles and jars with liners or septa as appropriate and cap. Store in a contaminant-free area.

E.6.4. Plastic Bottles for ICP Analytes - These procedures are to be used only if the supply of pre-cleaned, certified sample bottles is disrupted. Wash bottles and caps with hot tap water and soap. Rinse both with 10% nitric acid solution. Rinse three times with analyte-free water. Invert bottles and dry in contaminant-free environment. Cap bottles. Store in contaminant-free area.

Appendix F

Remediation Technologies

APPENDIX F - REMEDIATION TECHNOLOGIES

F.1 Appendix Outline

F.2. Introduction

This appendix addresses the various remediation technologies that are available to facilities and consultants when determining the most effective remedial technology for a site. The various remediation technologies were reviewed by representatives from the U.S. EPA, Department of Energy, Department of Defense, U.S. Department of the Interior, Department of the Navy, Department of the Air Force and the Department of the Army (collectively known as the Federal Remediation Technologies Roundtable). The technologies were evaluated to establish each technology's effectiveness with respect to the type of contaminant and the type of media impacted. The following discussion is a brief description of each of the technologies available to a facility today. Additional information regarding the following technologies can be obtained in the document "Remediation Technologies Screen Matrix and Reference Guide, Version 3.0, Federal Remediation Technologies Roundtable."

F.3. Soil, Sediment, and Sludge

F.3.1 In Situ Biological Treatment Technologies

(a) Bioventing is a new technology that stimulates the natural in situ biodegradation of any aerobically degradable compounds in soil by providing oxygen to excite soil microorganisms. Bioventing uses low air flow rates to provide only enough oxygen to sustain microbial activity. Oxygen is most commonly supplied through direct air injection into residual contamination in soil. In addition to degradation of adsorbed fuel residuals, volatile compounds are biodegraded as vapors move slowly through biologically active soil. Bioventing is a medium to long-term technology. Cleanup ranges from a few months to several years. Bioventing techniques have been successfully used to remediate soils contaminated by petroleum hydrocarbons, nonchlorinated solvents, some pesticides, wood preservatives, and other organic chemicals.

(b) Enhanced Bioremediation is a process in which indigenous or inoculated microorganisms (e.g.: fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in soil and/or groundwater, converting them to innocuous end products. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials. In the presence of sufficient oxygen (aerobic conditions) and other nutrient elements, microorganism will ultimately convert many organic contaminants to carbon dioxide, water, and microbial cell mass. In the absence of oxygen (anaerobic conditions), the organic contaminants will be ultimately metabolized to methane, limited amounts of carbon dioxide, and trace amounts of hydrogen gas. Under sulfate-reduction conditions, sulfate is converted to sulfide or elemental sulfur. Under nitrate-reduction conditions, dinitrogen gas is ultimately produced. Enhance bioremediation of the soil typically involves the percolation or injection of groundwater or uncontaminated water mixed with nutrients and saturated with dissolved oxygen. Sometimes acclimated microorganisms (bioaugmentation) and/or another oxygen source such as hydrogen peroxide are also added. Infiltration gallery or spray irrigation is typically used for shallow contaminated soils, and injection wells are used for deeper contaminated soils. Bioremediation techniques have been successfully used to remediate soils, sludges, and groundwater contaminated with petroleum hydrocarbons, solvents, pesticides, wood preservatives, and other organic chemicals. Care should be taken when utilizing the aforementioned technology not to misinterpret the resulting analytical data. In many cases the resulting data following injection of bacteria, microbes, peroxide, or other additives may suggest that bioremediation is taking place, while in reality only dilution is occurring. It is for this reason that it is recommended that the resulting concentrations be presented to the Department in a mol/kg (mol/L for liquids) format in addition to either mg/kg or μg/kg (mg/L or μg/L for liquids).

(c) Land Treatment is a full-scale bioremediation technology in which contaminated soils, sediments, or sludges are turned over (i.e.: tilled) and allowed to interact with the soil and climate at the site. The waste, soil, climate, and biological activity interact dynamically as a system to degrade, transform, and immobilize waste constitutes. Wastes are periodically tilled to aerate the waste. Soil conditions are often controlled to optimize the rate of contaminant degradation. Conditions normally controlled include:

i. Moisture content (usually by irrigation or spraying).

ii. Aeration (by tilling the soil with a predetermined frequency).

iii. pH (buffered near neutral pH by adding crushed limestone or agricultural lime).

iv. Other amendments (e.g.; soil bulking agents, nutrients, etc.).

A Land Treatment site should be managed properly to prevent both on-site and off-site problems with groundwater, surface water, air, or food chain contamination. Adequate monitoring and environmental safeguards are required. Land Treatment is a medium- to long-term technology.

(d) Natural Attenuation in Soils - Natural biotransformation processes such as dilution, dispersion, volatilization, biodegradation, adsorption, and chemical reactions with soil materials can reduce contaminant concentrations to appropriate levels. Natural attenuation is not a "technology" per se, and there is significant debate among technical experts about its use at hazardous waste sites. Consideration of this option usually requires constant site modeling and evaluation of contaminant degradation rates, and pathways and predicting contaminant concentration at down-gradient receptor points. Natural attenuation is not considered a "no action" technology. Target contaminants for natural attenuation are VOCs, SVOCs, and fuel hydrocarbons.

(e) Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment. The mechanism of phytoremediation includes enhanced rhizosphere biodegradation, phytoextraction (also called phyto-accumulation), phyto-degradation, and phyto-stabilization. Phytoremediation may be applicable for the remediation of metals, pesticides, solvents, explosives, crude oil, PAHs, and landfill leaches. Currently, trees are under investigation to determine their ability to remove organic contaminants from groundwater, translocate and transpiration, and possibly metabolize them either to CO^2 or plant tissue.

F.3.2 In Situ Physical/Chemical Treatment Technologies

(a) Electrokinetic Separation - The Electrokinetic Remediation (ER) process removes metals and organic contaminants from low permeability soil, mud, sludge, and marine dredging. ER uses electrochemical and electrokinetic processes to desorb, and remove metals and polar organics. This in situ soil processing technology is primarily a separation and removal technique for extracting contaminants from soils. Two approaches are taken during electrokinetic remediation: "Enhance Removal" and "Treatment without Removal." "Enhance Removal" is achieved by electrokinetic transport of contaminants toward the polarized electrodes to concentrate the contaminants for subsequent removal and ex situ treatment. "Treatment without Removal" is achieved by electro-osmotic transport of contaminants through treatment zones placed between electrodes.

(b) Fracturing - Cracks are developed by fracturing beneath the surface in low permeability and over-consolidated sediments to open new passageways that increase the effectiveness of many in situ processes and enhance extraction efficiencies. Technologies commonly used in soil fracturing include pneumatic fracturing (PF), blast-enhanced fracturing, and Lasagna™ process. Fracturing is applicable to the complete range of contaminant groups with no particular target group. The technology is used primarily to fracture silts, clays, shale, and bedrock.

(c) Soil Flushing - In situ soil flushing is the extraction of contaminants from the soil with water or other suitable aqueous solutions. Water or water containing an additive to enhance contaminant solubility is applied to the soil or injected into the groundwater to raise the water table into the contaminated soil zone. Contaminants are leached into the groundwater, which is then extracted and treated. A type of soil flushing is cosolvent flushing known as Cosolvent Enhancement. Cosolvent flushing involves injecting a solvent mixture (e.g.: water plus a miscible organic solvent such as alcohol) into vadose zone, saturated zone, or both to extract organic contaminants. Cosolvent flushing can be applied to soils to dissolve either the source of contamination or the contaminant plume emanating from it. The cosolvent mixture is normally injected upgradient of the contaminated area, and the solvent with dissolved contaminants is extracted down-gradient and treated above ground. The duration of the soil flushing process is generally short- to medium-term. The target contaminant groups for soil flushing are inorganics including radioactive contaminants. The technology can be used to treat VOCs, SVOCs, fuels, and pesticides, but it may be less cost-effective than alternative technologies.

(d) Soil Vapor Extraction - Soil vapor extraction (SVE) is an in situ unsaturated (vadose) zone soil remediation technology in which a vacuum is applied through wells to create a pressure/concentration gradient that induces gas-phase volatiles to be removed from soil through extraction wells. This technology also is known as in situ soil venting, in situ volatilization, enhanced volatilization, or soil vacuum extraction. The duration of operation and maintenance for in situ SVE is typically medium- to long-term. The target contaminant groups for in situ SVE are VOCs and some fuels.

(e) In Situ Solidification/Stabilization - Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization). This technology seeks to trap or immobilize contaminants within their "host" medium (*i.e.,* the soil, sand, and/or building materials that contain them), instead of removing them through chemical or physical treatment. Leachability testing is typically performed to measure the immobilization of contaminants. A specific type of solidification/stabilization technique is In Situ Vitrification (ISV). ISV uses an electric current to melt soil or other earthen materials at extremely high temperatures (1600^{o}C to 2000^{o}C or 2900^{o}F to 3650^{o}F) and thereby immobilize most inorganics and destroy organic pollutants by pyrolysis. The timeframe for in situ solidification/stabilization is short- to medium-term, while in situ ISV process is typically short-term. The target contaminant groups for this technology are generally inorganics (including radionuclides). The ISV process can destroy or remove organics and immobilize most inorganics.

F.3.3 In Situ Thermal Treatment Technologies

(a) Thermally Enhanced Soil Vapor Extraction - Thermally enhanced SVE is a full-scale technology that uses electrical resistance/electromagnetic/fiber optic/radio frequency heating, or hot-air/steam injection to increase the volatilization rate of semi-volatiles and facilitate extraction.

(b) Electrical resistance heating uses an electrical current to heat less permeable soils such as clays and fine-grained sediments so that water and contaminants trapped in these relatively conductive regions are vaporized and ready for vacuum extraction.

(c) Radio frequency heating (RFH) is an in situ process that uses electromagnetic energy to heat soil and enhance SVE.

(d) Another type of thermal enhanced soil vapor extraction technology is the injection of hot air or steam. Hot air or steam is injected below the contaminated zone to heat up contaminated soil. The heating enhances the release of contaminant from soil matrix. Some VOCs and SVOCs are stripped from the contaminated zone and brought to the surface through soil vapor extraction. Thermally enhanced SVE is normally a short- to medium-term technology.

F.3.4 Ex Situ Biological Treatment (assuming excavation)

(a) Biopile treatment is a full-scale technology in which excavated soils are mixed with soil amendments and placed on a treatment area that includes leachate collection systems and some form of aeration. It is used to reduce concentrations of petroleum constituents in excavated soils through the use of biodegradation. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation. Biopile is a short-term technology. Biopile treatment has been applied to treatment of nonhalogenated VOCs and fuel hydrocarbons. Halogenated VOCs, SVOCs and pesticides can also be treated, but the process effectiveness will vary.

(b) Composting is a controlled biological process by which organic contaminants (e.g.: PAHs) are converted by microorganisms (under aerobic and anaerobic conditions) to innocuous, stabilized byproducts. Contaminated soil is excavated and mixed with bulking agents and organic amendments such as wood chips, hay, manure, and vegetative (e.g.: potato) wastes. Proper amendment selection ensures adequate porosity and provides a balance of carbon and nitrogen to promote thermophilic, microbial activity. The composting process may be applied to soils and lagoon sediments contaminated with biodegradable organic compounds.

(c) Fungal Biodegradation refers to the degradation of a wide variety of organopollutants by using their lignin-degrading or wood-rotting enzyme system. White rot fungus has been tested under two different treatment configuration: in situ and bioreactor. White rot fungus has the ability to degrade and mineralize a number of organopollutants including the predominant conventional explosives TNT, RDX, and HMX. In addition, white rot fungus has the potential to degrade and mineralize other recalcitrant materials such as DDT, PAH, PCB, and PCP[2-4].

(d) Landfarming is a full-scale bioremediation technology that usually incorporates liners and other methods to control leaching of contaminants, which requires excavation and placement of contaminated soils, sediments, or sludges. Contaminated media is applied into lined beds and periodically turned over or tilled to aerate the waste. Landfarming has been proven most successful in treating petroleum hydrocarbons, diesel fuel, No.2 and No.6 fuel oils, JP-5, oily sludge, wood-preserving wastes (PCP and creosote), coking wastes, and certain pesticides.

(e) Slurry Phase Biological Treatment involves the controlled treatment of excavated soil in a bioreactor. Aqueous slurry is created by combining soil, sediment, or sludge with water and other additives. The slurry is mixed to keep solids suspended and microorganisms in contact with the soil contaminants. Upon completion of the process, the slurry is dewatered and the treated soil is disposed. Bioreactors are favored over in situ biological techniques for heterogeneous soils, low permeability soils, areas where underlying groundwater would be difficult to capture, or when faster treatment times are required. Slurry phased bioreactors are used primarily to treat nonhalogenated SVOCs and VOCs in excavated soils or dredged sediments. Ordnance compounds may also be treated. Slurry phased bioreactors containing cometabolites and specially adapted microorganisms are both used to treat halogenated VOCs and SVOCs, pesticides, and PCBs in excavated soils and dredge sediments.

F.3.5 Ex Situ Physical/Chemical Treatment (assuming excavation)

(a) Chemical Extraction includes the combination of waste contaminated soil and extractant in an extractor in order to dissolve the contaminants from the soil. The extracted solution is then placed in a separator, where the contaminants and extractant are separated for treatment and further use. There are two principal types of chemical extraction: acid extraction and solvent extraction. Acid extraction uses hydrochloric acid to extract heavy metal contaminants from soils. Solvent extraction is a common form of chemical extraction using an organic solvent. Organically bound metals can be extracted along with the target organic contaminants, thereby creating residuals with special handling requirements. Solvent extraction has been shown to be effective in treating sediments, sludges, and soils containing primarily organic contaminants such as PCBs, VOCs, halogenated solvents, and petroleum waste. Acid extraction is suitable to treat sediments, sludges, and soils contaminated by heavy metals.

(b) Chemical Reduction/Oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorite, chlorine, and chlorine dioxide. The target contaminant group for chemical redox is inorganics.

(c) Dehalogenation Reagents are added to soils contaminated with halogenated organics. The dehalogenation process is achieved by either the replacement of the halogen molecules, or the decomposition and partial volatilization of the contaminants. The Base-Catalyzed Decomposition (BCD) process was developed by EPA's Risk Reduction Engineering Laboratory, in cooperation with the Naval Facilities Engineering Services Center to remediate soils and sediments contaminated with chlorinated organic compounds, especially PCBs, dioxins, and furans. Glycolate is a full scale technology in which an alkaline polyethylene glycol (APEG) reagent is used. The target contaminant groups for dehalogenation treatment are halogenated SVOCs and pesticides. APEG dehalogenation is one of the few processes available other than incineration that has been successfully field tested in treating PCBs. The BCD can also be used to treat halogenated VOCs but will generally be more expensive than other alternative technologies.

(d) Separation techniques concentrate contaminated solids through physical and chemical means (i.e.: Gravity Separation, Magnetic Separation, and Sieving/Physical Separation). These processes seek to detach contaminants from their medium (i.e.: the soil, sand, and/or binding materials that contain them). Gravity separation is a solid/liquid separation process, which relies on a density difference between the phases. Magnetic separation is used to extract slightly magnetic radioactive particles from host materials such as water, soil, or air. Sieving and physical separation processes use different size sieves and screens to effectively concentrate contaminants into smaller volumes. Physical separation is based on the fact the most organic and inorganic contaminants tend to bid, either chemically or physically, to the fine (i.e.: clay and silt) fraction of a soil. The target contaminant groups for ex situ separation processes are SVOCs, fuels, and inorganics (including radionuclides). Magnetic separation is specifically used on heavy metals, radionuclides, and magnetic radioactive particles, such as uranium and plutonium compounds.

(e) Soil Washing is a water-based process for scrubbing soils ex situ to remove contaminants. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals. The process removes contaminants from soils by dissolving or suspending them in the wash solution (which can be sustained by chemical manipulation of pH for a period of time) or by concentrating them into a smaller volume of soil through particle size separation, gravity separation, and attrition scrubbing (similar to those techniques used in sand and gravel operations). Soil washing is generally considered a media transfer technology. The contaminated water generated from the soil washing is treated with the technology suitable for the contaminants. Soil washing systems incorporating most of the removal techniques offer the greatest promise for application to soils contaminated with a wide variety of heavy metal, radionuclides, and organic contaminants.

(f) Ex Situ Soil Vapor Extraction (SVE) is a full-scale technology in which soil is excavated and placed over a network of aboveground piping to which a vacuum is applied to encourage volatilization of organics. The target contaminant group for ex situ SVE is VOCs.

(g) Solar Detoxification is a process that destroys contaminants by photochemical and thermal reactions using the ultraviolet energy in sunlight. In this process, vacuum extraction is used to remove contaminants from soils. After condensation, contaminants are mixed with a semiconductor catalyst and fed through a reactor, which is illuminated by sunlight. This technology completely destroys the toxic compounds instead of simply removing or displacing them. The target contaminant groups for solar detoxification are VOCs, SVOCs, solvents, pesticides, and dyes. The process may also remove some heavy metals from water.

(h) Ex Situ Solidification/Stabilization - Contaminants are physically bound or enclosed with in a stabilized mass (solidification), or chemically reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization). Ex situ solidification/stabilization (S/S) typically requires proper disposal of the resultant materials. Nine distinct innovated processes or groups of processes are bituminization, emulsified asphalt, modified sulfur cement, polyethylene extrusion, possolan/Portland cement, radioactive waste solidification, sludge stabilization, soluble phosphates, and vitrification/molten glass. The target contaminant group for ex situ S/S is inorganics, including radionuclides. Most S/S technologies have limited effectiveness against organics and pesticides, except vitrification which destroys most organic contaminants.

F.3.6 Ex Situ Thermal Treatment (assuming excavation)

(a) Hot Gas Decontamination involves raising the temperature of the contaminated equipment or material for a specified period of time. The gas effluent from the material is treated in an afterburner system to destroy all volatilized contaminants. This method is applicable for process equipment requiring decontamination for reuse. It is also applicable for explosive items, such as mines and shells, being demilitarized (after removal of the explosives) or scrap material contaminated with explosives. This method can also be used for buildings or structures associated with ammunition plants, arsenals, and depots involved in the manufacture, processing, loading, and storage of pyrotechnics, explosives, and propellants.

(b) Incineration is a process of destroying contaminants by heat. Various incineration methods used include: Circulating Bed Combustor, Fluidized Bed, Infrared Combustion, and Rotary Kiln. Target contaminant groups of incineration are VOCs, SVOCs, Fuels and Explosives.

(c) Open Burn/Open Detonation (OB/OD) operations are conducted to destroy excess, obsolete, or unserviceable munitions and energetic materials. In OB operations, explosives or munitions are destroyed by self-sustained combustion, which is ignited by an external source, such as flame, heat, or a detonation wave. In OD operations, detonatable explosives and munitions are destroyed by a detonation, which is generally initiated by the detonation of an energetic charge.

(d) Pyrolysis is formally defined as chemical decomposition induced in organic materials by heat in the absence of oxygen. Organic materials are transformed into gaseous components and a solid residue (coke) containing fixed carbon and ash. If volatile or semivolatile materials are present in the waste, thermal desorption will also occur. Conventional thermal treatment methods, such as rotary kiln, rotary hearth furnace, or fluidized bed furnace, are used for waste pyrolysis. Molten salt process may also be used for waste pyrolysis and involves the use of a molten salt incinerator that uses a molten, turbulent bed of salt, such as sodium carbonate, as a heat transfer and reaction/scrubbing medium to destroy hazardous materials. The target contaminant groups for pyrolysis are SVOCs and pesticides.

(e) Thermal Desorption is a physical separation process and is not designed to destroy organics. Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to a gas treatment system. Two common thermal desorption designs are the rotary dryer and thermal screw. Three types of thermal desorption available are Direct Fired, Indirect Fired, and Indirect Heated. Based on operating temperature of the desorber, thermal desorption processes can be categorized into two groups: High Temperature Thermal Desorption (HTTD), and Low Temperature Thermal Desorption (LTTD). The target contaminants for HTTD systems are SVOCs, PAHs, PCBs, and pesticides; however, VOCs and fuels also may be treated. The target contaminants for LTTD systems are nonhalogenated VOCs and fuels.

F.3.7 Containment

(a) Landfill Capping is the most common form of remediation and is used for contaminant source control. The design of the landfill cap is site-specific and depends on the intended functions of the system. Landfill caps can range form a one-layer system of vegetated soil to a complex multi-layer system of soils and geosynthetics. Typical kinds of landfill caps include (1) Asphalt/Concrete Caps (most effective single-layer cap), RCRA Subtitle C Cap (used in RCRA Hazardous Waste applications), and RCRA Subtitle D Cap (for non-hazardous waste landfills).

(b) Landfill Cover Enhancements reduce or eliminate contaminant migration (*e.g.*, percolation). Water harvesting and vegetative cover are two ways for landfill cover enhancements. Water harvesting uses runoff enhancement to manage landfill site water balance. Vegetative cover reduces soil moisture via plant uptake and evapotranspiration.

F.3.8 Other Treatment by Excavation, Retrieval, and Off-Site Disposal - Contaminated material is removed and transported to permitted off-site treatment and/or disposal facilities. Some pretreatment of the contaminated media is usually required in order to meet land disposal restrictions.

F.4. Groundwater, Surface Water, and Leachate

F.4.1 In Situ Biological Treatment

(a) Co-Metabolic Process is an emerging application involving the injection of a dilute solution of primary substrate (e.g.: toluene, methane) into the contaminated groundwater zone to support the co-metabolic breakdown of targeted organic contaminants. The primary target contaminants for co-metabolism are the chlorinated solvents.

(b) Bioremediation is a process in which indigenous or inoculated microorganisms (i.e.: fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in soil and/or groundwater. The rate of bioremediation of organic contaminants by microbes is enhanced by increasing the concentration of electron acceptors and nutrients in groundwater, surface water, and leachate. Oxygen is the main electron acceptor for aerobic bioremediation. Nitrate serves as an alternative electron acceptor under anoxic conditions. Oxygen enhancement can be achieved by either air sparging below the water table, or circulating hydrogen peroxide throughout the contaminated groundwater zone. Under anaerobic conditions, nitrate is circulated throughout the groundwater contamination zone to enhance bioremediation. Additionally, solid-phase peroxide products (e.g.: oxygen releasing compound (ORC)) can also be used for oxygen enhancement and to increase the rate of biodegradation. Target contaminants for enhanced biodegradation processes are nonhalogenated VOCs, nonhalogenated SVOCs, and fuels. Care should be taken when utilizing the aforementioned technology not to misinterpret the resulting analytical data. In many cases the resulting data following injection of bacteria, microbes, peroxide, or other additives may suggest that bioremediation is taking place, while in reality only dilution is occurring. It is for this reason that it is recommended that the resulting concentrations be presented to the Department in a mol/L (mol/kg for solids) format in addition to either mg/L or μg/L (mg/kg or μg/L for solids).

(c) Monitored Natural Attenuation (MNA) - Natural subsurface processes such as dilution, volatilization, biodegradation, dispersion; radioactive decay, sorption, and chemical or biological stabilization, transformation, or destruction of contaminants that are allowed to act without human intervention to reduce the mass, toxicity, mobility, volume, or contaminant concentrations to site-specific remediation objectives. The Department will review the long-term monitoring results of the MNA to ensure that reduction of contaminant concentrations are occurring at a reasonable rate that is comparable to the time frame generally offered by other more active methods and is consistent with meeting cleanup objectives. Furthermore, time frames for constituent degradation rates should be established and modified as necessary as sampling information is gathered and analyzed. When relying on natural attenuation processes for site remediation, those processes that degrade or destroy contaminants are required as opposed to processes that rely on dilution. It is this reason why the Department suggests that contaminant concentrations be reported in mol/L and also mg/L or μg/L to ensure that degradation is occurring as opposed to dilution. Also, the Department generally expects that MNA will only be appropriate for sites that have a low potential for contaminant migration.

The Department advocates using the most appropriate technology for a given site and does not consider MNA to be a “presumptive” or “default” remedy – it is merely one option that should be evaluated with other applicable remedies. The Department does not view MNA to be a “walk-away” approach meaning that both continued monitoring and evaluation are necessary. As with any other remedial alternative, MNA should be selected only where it meets all relevant remedy selection criteria, and where it will meet site remediation objectives within a time frame that is reasonable compared to that offered by other methods. In the majority of cases where MNA is proposed as a remedy, its use may be appropriate as one component of the total remedy, that is, either in conjunction with active remediation or as a follow-up measure. MNA should be used very cautiously as the sole remedy at contaminated sites. Furthermore, the availability of MNA as a potential remediation tool does not imply any lessening of the Department's longstanding commitment to pollution prevention. Waste minimization, pollution prevention programs, and minimal technical requirements to prevent and detect releases remain fundamental parts of the Department's waste management and remediation programs.

Due to the uncertainty associated with the potential effectiveness of MNA to meet remediation objectives that are protective of human health and the environment, the Department expects that source control and long-term performance monitoring will be fundamental components of any MNA remedy.

It is common practice in conducting remedial actions to focus on the most obvious contaminants of concern, but other contaminants may also be of significant concern in the context of MNA remedies. In general, since engineering controls are not used to control plume migration in an MNA remedy, decision makers need to ensure that MNA is appropriate to address all contaminants that represent an actual or potential threat to human health or the environment. Several examples are provided below to illustrate the need to assess both the obvious as well as the less obvious contaminants of concern when evaluating an MNA remedial option.

i. Mixtures of contaminants released into the environment often include some that may be amenable to MNA, and others that are not addressed sufficiently by natural attenuation processes to achieve remediation objectives. For example, benzene, toluene, ethylbenzene and xylenes (BTEX) associated with gasoline have been shown in many circumstances to be effectively remediated by natural attenuation processes. However, a common additive to gasoline (i.e.:, methyl tertiary-butyl ether [MTBE]) has been found to migrate large distances and threaten down-gradient water supplies at the same sites where the BTEX component of a plume has either stabilized or diminished due to natural attenuation. In general, compounds that tend not to degrade readily in the subsurface (e.g.: MTBE and 1,4-dioxane) and that represent an actual or potential threat should be assessed when evaluating the appropriateness of MNA remedies.

ii. Analyses of contaminated media often report chemicals that are identified with a high degree of certainty, as well as other chemicals labeled as "tentatively identified compounds" (TICs). It is often assumed that TICs will be addressed by remedial action along with the primary contaminants of concern. This may be a reasonable assumption for an active remediation system (e.g.: pump and treat) of contaminated groundwater, but might not be appropriate for an MNA remedy that is relying on natural processes to prevent contaminant migration. Where MNA is being proposed for sites with TICs, it may be prudent to identify the TICs and evaluate whether they too will be sufficiently mitigated by MNA.

iii. At some sites the same geochemical conditions and processes that lead to the biodegradation of chlorinated solvents and petroleum hydrocarbons can chemically transform naturally occurring minerals (e.g.: arsenic and manganese compounds) in the aquifer matrix to forms that are more mobile and/or more toxic than the original materials. A comprehensive assessment of an MNA remedial option should include evaluation of whether naturally occurring metals will become contaminants of concern.

Addressing the above concerns does not necessarily require sampling and analysis of extensive lists of parameters at every monitoring location in all situations. The location and number of samples collected and analyzed for this purpose should be determined on a site-specific basis to ensure adequate characterization and protection of human health and the environment.

Natural attenuation is not a "technology" per se, and there is significant debate among technical experts about its use at hazardous waste sites. Consideration of this option usually requires constant site modeling and evaluation of contaminant degradation rates, and pathways and predicting contaminant concentration at down-gradient receptor points. Natural attenuation is not considered a "no action" technology. Target contaminants for natural attenuation are VOCs, SVOCs, and fuel hydrocarbons.

(d) Phytoremediation is a set of processes that uses plants to remove, transfer, stabilize and destroy organic/inorganic contamination in groundwater, surface water, and leachate. The mechanisms of phytoremediation include: Enhanced Rhizosphere Biodegradation, Hydraulic Control, Phyto-degradation, and Phyto-volatilization. Phytoremediation can be used to clean up organic contaminants from surface water, groundwater, leachate, and municipal and industrial wastewater.

F.4.2 In Situ Physical/Chemical Treatment

(a) Aeration is the process by which the area of contact between water and air is increased, either by natural methods or by mechanical devices, for the purpose of promoting biological degradation. The target contaminant groups for aeration are SVOCs, pesticides, and fuels. VOCs can be stripped from wastewater and treated by aeration followed by off-gas treatments.

(b) Air Sparging is an in situ technology in which air is injected through a contaminated aquifer. Injected air traverses horizontally and vertically in channels through the soil column, creating an underground stripper that removes contaminants by volatilization. This injected air helps to flush the contaminants up into the unsaturated zone where a vapor extraction system is usually implemented to remove the generated vapor phase contamination. The target contaminant groups for air sparging are VOCs and fuels.

(c) Bioslurping is the adaptation and application of vacuum-enhanced dewatering technologies to remediate hydrocarbon-contaminated sites. Bioslurping utilizes elements of both, bioventing and free product recovery. Bioventing stimulates the aerobic bioremediation of hydrocarbon-contaminated soils. Vacuum enhanced free-product recovery extracts LNAPLs from the capillary fringe and the water table.

(d) Directional Wells - Drilling techniques are used to position wells horizontally, or at an angle to reach contaminants not accessible by direct vertical drilling. Directional drilling may be used to enhance other in situ or in-well technologies such as groundwater pumping, bioventing, SVE, soil flushing, and in-well air stripping. Directional well technology is applicable to the complete range of contaminant groups with no particular target group.

(e) Dual Phase Extraction (DPE), also known as multi-phase extraction, vacuum-enhanced extraction, or sometimes bioslurping, is a technology that uses a high vacuum system to remove various combinations of contaminated groundwater, separate-phase petroleum product, and hydrocarbon vapor for the subsurface. Extracted liquids and vapor are treated and collected for disposal, or re-injected to the subsurface (where permissible under applicable state laws). The target contaminant groups for DPE are VOCs and fuels (e.g.: LNAPLs).

(f) Fluid/Vapor Extraction systems consist of a high vacuum systems that are applied to simultaneously remove liquid and gas from low permeability or heterogeneous formations. Once the extracted water and vapor are brought to the surface, they can be treated separately. The target contaminant groups for Fluid/Vapor Extraction are VOCs and fuels.

(g) Hot Water or Steam Flushing/Stripping - Steam is forced into an aquifer through injection wells to vaporize volatile and semivolatile contaminants. Vaporized components rise to the unsaturated zone where they are removed by vacuum extraction and then treated. Hot water or steam-based techniques include Contained Recovery of Oil Waste (CROW), Steam Injection and Vacuum Extraction (SIVE), In Situ Steam-Enhanced Extraction (ISEE), and Steam-Enhanced Recovery Process (SERP). Hot water or steam flushing/stripping is a pilot-scale technology. In situ biological treatment may follow the displacement and is continued until groundwater contaminant concentrations satisfy statutory requirements. The process can be used to remove large portions of oily waste accumulations and to retard downward and lateral migration of organic contaminants. The process is applicable to shallow and deep contaminated areas. The target contaminant groups for hot water or steam flushing/stripping are SVOCs and fuels.

(h) Hydrofracturing (enhancement) is a pilot-scale technology in which pressurized water is injected to increase the permeability of consolidated material or relatively impermeable unconsolidated material. Fissures created in the process are filled with a porous medium that can facilitate bioremediation and/or improved extraction efficiency. Hydrofracturing is applicable to a wide range of contaminant groups with no particular target group.

(i) In-Well Air Stripping is conducted in specially constructed wells with two separate well screens (upper and lower screens) known as Circulating Wells. Air is injected into the double screened well, lifting the water in the well and forcing it out the upper screen. Simultaneously, additional water is drawn in the lower screen. Once in the well, some of the VOCs in the contaminated groundwater are transferred from the dissolved phase to the vapor phase by air bubbles. The contaminated air rises in the well to the water surface where vapors are drawn off and treated by a soil vapor extraction system. Because groundwater is not pumped above ground, pumping cost and permitting issues are reduced and eliminated. In addition to groundwater treatment, Circulating Well systems can provide simultaneous vadose zone treatment in the form of bioventing or soil vapor extraction. The target contaminant groups for In Well Air Stripping are halogenated VOCs, SVOCs, and fuels.

(j) Passive/Reactive Treatment Walls - A permeable reactive wall is installed across the flow path of a contaminant plume, allowing the water portion of the plume to passively move through the wall. These barriers allow the passage of water while prohibiting the movement of contaminants by employing such agents as zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others. The contaminants will be either degraded or retained by the barrier material. There are two types of passive reactive treatment walls, Funnel and Gate, and Iron Treatment Wall. Target contaminant groups for passive treatment walls are VOCs, SVOCs, and inorganics.

F.4.3 Ex Situ Biological Treatment (assuming pumping)

(a) Bioreactors - Contaminants in extracted groundwater are put into contact with microorganisms in attached or suspended growth biological reactors. In suspended systems, such as activated sludge, contaminated groundwater is circulated in an aeration basin. In attached systems, such as rotating biological contractors and trickling filters, microorganisms are established on an inert support matrix. Bioreactors are used primarily to treat SVOCs, fuel hydrocarbons, and any biodegradable organic material. Bioreactors with cometabolites are used to treat PCBs, halogenated VOCs, and SVOCs in extracted groundwater.

(b) Constructed Wetlands - The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in an artificial wetland ecosystem to accumulate and remove metals, explosives, and other contaminants from influent waters. The process can use a filtration or degradation process. Constructed wetlands have most commonly been used in wastewater treatment for controlling organic matter; nutrients, such as nitrogen and phosphorous; and suspended sediment. The wetland process is also suitable for controlling trace metals, and other toxic materials.

(c) Adsorption/Absorption - In liquid adsorption, solutes concentrate at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase. Adsorption mechanisms are generally categorized as either physical adsorption, chemisorption, or electrostatic adsorption. The most common adsorbent is granulated activated carbon (GAC). Other natural and synthetic adsorbents include activated alumina, forage sponge, lignin adsorption, sorption clays, and synthetic resins. The target contaminant groups for adsorption/absorption processes are most organic contaminants and selected inorganic contaminants form liquid and gas streams.

(d) Air Stripping is a full-scale technology in which volatile organics are partitioned from groundwater by greatly increasing the surface area of the contaminated water exposed to air. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration. Air stripping is used to separate VOCs from water. It is ineffective for inorganic contaminants.

(e) Granulated Activated Carbon (GAC)/Liquid Phase Carbon Adsorption - Liquid phase carbon adsorption is a full-scale technology in which groundwater is pumped through one or more vessels containing activated carbon to which dissolved organic contaminants adsorb. Periodic replacement or regeneration of saturated carbon is required. The target contaminant groups for carbon adsorption are hydrocarbons, SVOCs, and explosives.

(f) Ion Exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. They also may be inorganic and natural polymeric materials. Ion exchange can remove dissolved metals and radionuclides form aqueous solutions. Other compounds that have been treated include nitrate, ammonia nitrogen, and silicate.

(g) Precipitation/Coagulation/Flocculation - This process transforms dissolved contaminants into insoluble solids, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation. Precipitation is used mainly to convert dissolved ionic species into solid-phase particulates that can be removed from the aqueous phase by coagulation and filtration. Remedial application of this technology usually involves removal of dissolved toxic metals and radionuclides.

(h) Separation processes seek to detach contaminants from their medium (*i.e.,* groundwater and/or binding material that contain them). Ex situ separation of the waste stream can be performed by many processes (i.e.: distillation, filtration, ultrafiltration, microfiltration, freeze crystallization, membrane pervaporation, and reverse osmosis. The ex situ separation process is used mainly as a pre-treatment or post-treatment process to remove contaminants from wastewater. It can be applied to aqueous waste streams such as groundwater, lagoons, leachate, and rinse water. The target contaminant groups for ex situ separation processes are VOCs, SVOCs, pesticides, and suspended particles.

(i) Sprinkler Irrigation is a relatively simple treatment technology used to volatilize VOCs from contaminated wastewater. The process involves the pressurized distribution of VOC-laden water through a standard sprinkler irrigation system. Sprinkler irrigation transfers VOCs from the dissolved aqueous phase to the vapor phase, whereby the VOCs are released directly to the atmosphere. Another aerating wastewater treatment is the trickling filter. The trickling filter consists of a bed of highly permeable media, a water distributor, and an underdrain system. Wastewater is distributed over the tip of the filter bed through which wastewater is trickled. The microorganisms attached to the filter medium degrade the organic contaminants in wastewater. Sprinkler irrigation can be utilized for any contaminant that readily transfers from the dissolved phase to the vapor phase (VOCs). The target contaminant groups for trickling filters are VOCs, SVOCs, fuels, explosives, and pesticides.

(j) Ultraviolet (UV) Oxidation, ozone, and/or hydrogen peroxide are used to destroy organic contaminants as water flows into a treatment tank. If ozone is used as the oxidizer, an ozone destruction unit is used to treat collected off gases from the treatment tank and downstream units where ozone gas may collect or escape. UV Photolysis is the process by which chemical bonds of the contaminants are broken under the influence of UV light. Practically any organic contaminant that is reactive with the hydroxyl radical can potentially be treated. A wide variety of organic and explosive contaminants are susceptible to destruction by UV/oxidation, including petroleum hydrocarbons; chlorinated hydrocarbons used as industrial solvents and cleaners; and ordnance compounds.

F.4.4 Containment

(a) Groundwater Pumping is a component of many pump-and-treat processes, which are some of the most commonly used groundwater remediation technologies at contaminated sites. Possible objectives of groundwater pumping include removal of dissolved contaminants form the subsurface, and containment of contaminated groundwater to prevent migration. The application of surfactant miceles or steam to the groundwater can facilitate the groundwater pumping process by increasing the mobility and solubility of the contaminants sorbed to the soil matrix. Pump drawdown nonaqueous-phase liquid (NAPL) recovery systems are designed to pump NAPL and groundwater from recovery wells or trenches. Pumping removes water and lowers the water table near the extraction well to create a cone of depression.

(b) Slurry Walls - These subsurface barriers consist of vertically excavated trenches filled with slurry. The slurry, usually a mixture of bentonite and water, hydraulically shores the trench to prevent collapse and retards groundwater flow. Slurry walls are used to contain contaminated groundwater, divert contaminated groundwater from the drinking water intake, divert uncontaminated groundwater flow, and/or provide a barrier for the groundwater treatment system.

Appendix G

Tables

APPENDIX G - TABLES

Table 1 - Recommended Containers, Holding Times, & Preservatives

The following tables summarize the amount of sample required, typical containers, preservative (if any) and holding times for many analysis, by media.

Soil and Sediment – *Organic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Dioxin/Dibenzofurans	8 oz.	G	ice	30
Extractable Organic Compounds/ pesticides/PCBs	8 oz.	G	ice	14
Extractable Organic Compounds - TCLP	8 oz.	G	ice	14
Organic Halide	8 oz.	G	ice	28
VOC ≤ 200 µg/kg (water suspension)	120 ml.	G/S	ice	48 hours
VOC ≤ 200 µg/kg	15 g.	E	ice	48 hours
VOC ≤ 200 µg/kg(water suspension)	120 ml.	G/S	$NaHSO_4$ (pH<2), ice	14
VOC ≥ 200 µg/kg	120 ml.	G/S	CH_3OH, ice	14
VOC ≥ 200 µg/kg	15 g.	E	ice	48 hours
VOC ≥ 200 µg/kg	2 oz.	G/S	ice	48 hours
VOC – TCLP Analysis	2 oz.	G	ice	14

Soil and Sediment – *Inorganic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Chloride	8 oz.	G	NA	NS
Chromium – hexavalent	8 oz.	G	ice	30
Cyanide	8 oz.	G	ice	NS
COD	8 oz.	G	ice	NS
Fluoride	8 oz.	G	NA	NS
Grain size	8 oz.	G	NA	NS
Mercury	8 oz.	G	ice	28
Mercury – TCLP	8 oz.	G	NA	28
Metals	8 oz.	G	ice	180
Metals – TCLP	8 oz.	G	NA	180
Metals – EP	8 oz.	G	NA	180
Nitrate	8 oz.	G	ice	NS
Nitrite	8 oz.	G	ice	NS
Nutrients (ammonia, TKN, NO2, NO3, N, total phosphate	8 oz.	G	ice	NS
pH	8 oz.	G	NA	NS
Sulfates	8 oz.	G	NA	NS
Sulfides	8 oz.	G	ice	NS
TOC	8 oz.	G	ice	NS

Water and Waste Water - *Biological*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Bacteriological	150 ml.	P, G, W	ice	6 hours
Toxicity, acute	1 gal.	C	ice	36 hours
Toxicity, chronic	1 gal.	C	ice	36 hours

Water and Waste Water – *Organic Compounds*				
Analysis	Amt.[1]	Container Type (2)	Preservative[3]	Holding Time[4]
Alcohol – Percent	1 gal.	G/A	ice	NS
Dioxin/Dibenzofurans	2 L.	L/A	ice (0 - 4 C)	365
Dioxin/Dibenzofurans – residual chloride	2 L.	L/A	ice (0 - 4 C) 80 mg. sodium thiosulfate /L	365
Methane/Ethane/Ethene	120 ml.	G/S	HCL (pH<2), ice	14
Extractable Organic Compounds/ pesticides/ PCBs	1 gal.	G/A	ice	7
Extractable Organic Compounds/ pesticides/ PCBs – residual chlorine present	1 gal.	G/A	3 ml. of 10% sodium thiosulfate per gallon	7
Extractable Organic Compounds	1 gal.	G/A	ice	14
Organic Halide	1 L.	G/A	H_2SO_4 (pH<2), ice	28
Phenols	1 L.	G/A	H_2 SO_4 (pH<2), ice	28
Volatile Organic Compounds	120 ml.	G/S	ice	7
Volatile Organic Compounds	120 ml.	G/S	HCL (ph<2), ice	14
Volatile Organic Compounds	120 ml.	G/S	$NaHSO_4$ (pH<2), ice	14
Volatile Organic Compounds – residual chlorine present	120 ml.	G/S	HCL (pH<2), ice	14
Volatile Organic Compounds - TCLP	120 ml.	G/S	ice	14

Water and Waste Water – *Inorganic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Ammonia	1 L.	P	H_2SO_4 (pH<2), ice	28
Alkalinity	1 L.	P	ice	14
BOD5	2 L.	P	ice	2
Bromide	1 L.	P	ice	28
Chlorine – Residual	500 ml.	P	NA	ASAP
Chloride	1 L.	P	NA	28
Chromium - hexavalent	1 L.	P	ice	24hours
COD	1 L.	P	H_2SO_4 (pH<2), ice	28
Color	1 gal.	G/A	ice	2
Conductivity	500 ml.	P	ice	28
Cyanide	1 L.	P	NaOH (pH>12), ice	14
Cyanide – Residual chlorine	1 L.	P	see footnote 6	14
DOC	1 L.	P	$NaHSO_4$ (pH<2), ice	28
Fluorine	1 L.	P	NA	28
Hardness	1 L.	P	HNO_3 (pH<2)	180
Iron (Fe^{2+})	1 L.	P	NA	ASAP
Mercury	1 L.	P	HNO_3 (pH<2)	28
Mercury – TCLP	1 L.	P	NA	28
Metals	1 L.	P	HNO_3 (pH<2)	180
Metals – TCLP	1 L.	P	NA	180
Metals – EP	1 L.	P	NA	180
Nitrate	2 L.	P	ice	2
Nitrite	1 L.	P	ice	2
Nutrients (Ammonia, TKN, NO2, NO3, -N, total phosphorous)	2 L.	P	H_2SO_4 (pH<2), ice	28

Water and Waste Water – *Inorganic Compounds (continued)*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Oil and Grease	1 L.	P	H_2SO_4 (pH<2), ice	28
Oxygen – dissolved	40 ml.	G	NA	ASAP
pH	500 ml.	P	NA	ASAP
Phenols	1 L.	P	H_2SO_4 (pH<2), ice	28
Phosphate – ortho	1L.	P	ice	2
Phosphate – dissolved	1L.	P	H_2SO_4 (pH<2), ice	28
Solids Series	2 L.	P	ice	7
Solids – Settleable	2 L	P	ice	2
Sulfates	1 L	P	ice	28
Sulfides	1 L.	P	2 ml zinc acetate, NaOH (pH>9), ice	7
Temperature	500 ml.	P	none	ASAP
TOC	1 L.	P	H_2SO_4 (pH<2), ice	NS
Turbidity	500 ml.	P	ice	2

Waste – *Organic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Alcohol – Present				
Dioxin/Dibenzofurans				
Extractable Organic Compounds/pesticides/PCBs				
Extrctable Organic Compounds – TCLP				
VOC ≤ 200 μg/kg				
VOC ≤ 200 μg/kg				
VOC ≥ 200 μg/kg				
Volatile Organic Compounds – TCLP				
Waste – *Inorganic Compounds*				
Analysis	Amt.[1]	Container Type[2]	Preservative[3]	Holding Time[4]
Ash Content	8 oz.	G	NA	NS
BTU Content	8 oz.	G	NA	NS
Chromium – hexavalent	8 oz.	G	NA	NS
Cyanide	8 oz.	G	NA	NS
Dermal Corrosion	8 oz.	G	NA	NS
Flashpoint	8 oz.	G	NA	NS
Mercury	8 oz.	G	NA	180
Mercury – TCLP	8 oz.	G	NA	NS
Metals	8 oz.	G	NA	28
Metals – TCLP	8 oz.	G	NA	NS
Metals – EP	8 oz.	G	NA	28
pH	8 oz.	G	NA	NS
Sulfides	8 oz.	G	NA	NS

Footnotes:

1. Amount - The amounts listed must be considered approximate requirements that are appropriate for most media. If a particular media to be sampled is very light, more sample may be required to obtain the necessary mass for the analysis.

2. Container Type:

G = Glass
P = Polyethylene
E = Encore™
C = Cubitainer
S = Septum Seal
A = Amber
W = Whirl-Pak™

3. ice: Sufficient ice must be placed in the shipping/transport container to ensure that ice is still present when the samples are received at the laboratory

NaHSO4: The proper amount of NaHSO4 (Sodium Bisulfate) is added to the sample container at the laboratory prior to sampling.

CH3OH: The proper amount of CH3OH (Methanol) is added to the sample container at the laboratory prior to sampling.

HCl: HCl (Hydrochloric Acid) used as a preservative must be present at concentrations of 0.04% or less by weight (pH about 1.96 or greater), as specified in 40 CFR 136.3, Table II, footnote 3. The proper amount of HCl is added to the sample container at the laboratory prior to sampling.

H2SO4: H2SO4 (Sulfuric Acid) used as a preservative must be present at concentrations of 0.35% or less by weight (pH about 1.15 or greater), as specified in 40 CFR 136.3, Table II, footnote 3. Approximately 5 ml. of the laboratory prepared preservative is added to the sample.

NaOH: NaOH (Sodium Hydroxide) used as a preservative must be present at concentrations of 0.080% or less by weight (pH about 12.30 or less), as specified in 40 CFR 136.3, Table II, footnote 3. Four tablets are added to the sample after collection.

HNO3: HNO3 (Nitric Acid) used as a preservative must be present at concentrations of 0.15% or less by weight (pH about 1.62 or greater), as specified in 40 CFR 136.3, Table II, footnote 3. Approximately 5 ml. of the laboratory prepared preservative is added to the sample.

NA: Not Applicable. No sample preservation is required

4.Holding Time – Holding time is stated in days unless marked otherwise. A holding time of ASAP indicates the sample is to be analyzed within 15 minutes. A holding time of NS indicates that no holding time is specified in the analytical method.

5. Collect sample in 8 oz. glass container containing ascorbic acid solution prepared by the laboratory. Gently mix sample and transfer to sample containers prepared by the laboratory with the proper amount of HCl.

6. Use ascorbic acid only if the sample contains residual chlorine. To test for residual chlorine, place a drop of sample on potassium iodide-starch test paper. If the test paper turns blue, residual chlorine is present. Add a few crystals of ascorbic acid and re-test until the test paper no longer turns blue. Add an additional 0.6 gram of ascorbic acid for each liter of sample.

Table 2 - Disposal of IDW

Type	Hazardous	Non-Hazardous
PPE – disposable	Containerize in plastic 5-gallon bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise return to FEC for proper disposal.	Place waste in trash bag. Place in dumpster with permission of site operator, otherwise return to the Field Equipment Center (FEC) for disposal in dumpster.
PPE – nondisposable	Decontaminate as per Appendix E, if possible. If the equipment cannot be decontaminated, containerize in plastic 5-gallon bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise return to FEC for proper disposal.	Decontaminate as per Appendix E.
Spent Solvents	Containerize in original containers. Clearly identify contents. Leave on-site with permission of site operator, otherwise return to FEC for proper disposal.	NA
Soil Cuttings	Containerize in 55-gallon drum with tightfitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with WMD site manager for testing and disposal.	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave onsite with permission of site operator, otherwise arrange with site manager for testing and disposal.
Groundwater	Containerize in 55-gallon drum with tightfitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with WMD site manager for testing and disposal.	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave onsite with permission of site operator, otherwise arrange with site manager for testing and disposal.
Decontamination Water	Containerize in 55-gallon drum with tightfitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with WMD site manager for testing and disposal.	Containerize in 55-gallon drum with tight-fitting lid. Identify and leave onsite with permission of site operator, otherwise arrange with site manager for testing and disposal.
Disposable Equipment	Containerize in 55-gallon	Containerize in 55-gallon

	drum or 5-gallon plastic bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with WMD site manager for testing and disposal.	drum or 5-gallon plastic bucket with tight-fitting lid. Identify and leave on-site with permission of site operator, otherwise arrange with site manager for testing and disposal.
Trash	NA	Place waste in trash bag. Place in dumpster with permission of site operator, otherwise return to FEC for disposal in dumpster.

Appendix H

References

APPENDIX H - REFERENCES

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