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(DRAFT)

US Army Corps
of Engineers

ENGINEERING AND DESIGN

Monitor Well Installation at Hazardous and Toxic Waste Sites

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ENGINEER MANUAL

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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314-1000

EC 1110-7-1(FR)

Engineer Circular
No. 1110-7-1(FR)

9 November 1990

EXPIRES 30 SEPTEMBER 1991
Engineering and Design
MONITOR WELL INSTALLATION AT HAZARDOUS AND TOXIC WASTE SITES

1. Purpose. This circular transmits a draft engineer manual (EM) for interim use and comment.

2. Applicability. This circular is applicable to all USACE elements having military and/or civil works responsibilities and/or programs within Superfund, the Defense Environmental Restoration Program, non-mission work for other (nonCorps) offices, host nation agreements, and/or any other Corps managed activities involving a known or suspected hazardous and/or toxic waste (HTW) component.

3. Discussion. This draft EM provides the essential requirements of USACE elements for the planning, execution, and reporting of their geotechnical activities involving the installation of monitor wells (and other similar devices) at projects known or suspected to have HTW components.

4. Action Required. This draft EM should be used as interim guidance pending publication of the final EM prior to the expiration date of this EC. Any comments regarding improvements and/or clarifications during this interim period are to be submitted to HQUSACE (CECW-EG), WASH., DC, 20314-1000. (RCS exempt: AR 335-15, paragraph 5-2g.)

FOR THE COMMANDER:

HUGH F. BOYD III
Colonel, Corps of Engineers
Executive Director of
Civil Works

STEWART H. BORNHOFT
Colonel, Corps of Engineers
Executive Director
Directorate of Military
Programs

1 Enclosure
Encl - Draft Engineer Manual

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2. Applicability. This manual is applicable to all USACE elements having military and/or civil works responsibilities and/or programs within Superfund, the Defense Environmental Restoration Program, non-mission work for other (nonCorps) offices, host nation agreements, and/or any other Corps managed activities involving a known or suspected HTW component.

3. Discussion. The technical understanding and evaluation of HTW studies involves an appreciation of the interactions between geology, hydrology, and chemistry. This scenario is complicated by the trace (low parts per billion) levels of regulated chemical species that are detectable in the environment; and which when detected or suspected, may trigger intricate and costly response actions. Slight deviations from prescribed drilling, well installation, sampling, or analytical procedures may bias or invalidate both the reported concentrations of these regulated species and the technical basis upon which the Corps makes decisions. This sensitivity requires that, where warranted, procedures be standardized, documented, understood, and followed.

FOR THE COMMANDER:

ROBERT L. HERNDON
Colonel, Corps of Engineers
Chief of Staff

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D. C. 20314

EM 1110-7-XX(FR)

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CHAPTER 1

INTRODUCTION

1-1. Purpose. This manual provides minimum requirements to United States Army Corps of Engineers (USACE) elements for the planning, execution, and reporting of their geotechnical activities supporting monitor well installation at hazardous and toxic waste (HTW) sites. These requirements are a compilation of those procedures for the acquisition of environmentally representative geotechnical samples and data, using conservative methods documented in a comprehensive manner.

1-2. Applicability.

a. This manual is applicable to all USACE elements and their contractors (including architect-engineers (AE's) having military and/or civil works HTW responsibilities and/or programs within the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Resource Conservation and Recovery Act (RCRA); the Superfund Amendments and Reauthorization Act (SARA); the Defense Environmental Restoration Program (DERP); non-mission HTW work for other (non-Corps) offices; host nation agreements; or any other corps managed HTW activities.

b. Only HTW work involving chemical issues are covered within this manual. Radiological and biological aspects are not addressed. Supplemental entries will be provided as appropriate procedures are identified. In the interim, any requests for radiological or biological assistance should be directed to the Missouri River Division (MRD) Design Center, United States Army Toxic and Hazardous Materials Agency (USATHAMA), or Headquarters, United States Army Corps of Engineers (HQUSACE), either CEMP-R or CECW-EG.

c. The specific application of and adherence to these requirements must be tailored to each project as a function of the contaminants of concern, geohydrologic environment, geotechnical judgement, available resources, regulatory setting, public concerns, and project mission.

1-3. References.

a. Required Publications.

(1) Annual Book of ASTM Standards, Volume 04.01: Cement; Lime; Gypsum.

(2) Annual Book of ASTM Standards, Volume 04.08: Soil and Rock, Building Stones; Geotextiles.

(3) Annual Book of ASTM Standards, Volume 08.04: Plastic Pipe and Building Products.

(4) Code of Federal Regulations, 29 CFR 1910.120: Hazardous Waste Operations and Emergency Response.

(5) Code of Federal Regulations, 29 CFR 1926: Safety and Health Regulations for Construction.

(6) EM 385-1-1 Safety and Health Requirements Manual.

(7) EM 1110-1-1804 Geotechnical Investigations.

(8) EM 1110-2-505 Guidelines Preliminary Selection of Remedial Action for Hazard Waste Sites.

(9) EM 1110-2-1906 Laboratory Soils Testing.

(10) EM 1110-2-1907 Soil Sampling.

(11) ENG Form 1836 Drilling Log.

(12) ENG Form 1836-A Drilling Log (Continuation Sheet).

(13) ER 385-1-92 Safety and Occupational Health Document Requirements for Hazardous Waste Site Remedial Actions.

(14) ER 1110-1-263 Chemical Quality Management-Toxic Hazardous Waste.

(15) ER 1110-1-1802 Provision for Spacers to Show Voids and Core Losses in Core Samples and Requirements for Photographic Record of Cores.

(16) ER 1110-1-1803 Care, Storage, Retention, and Ultimate Disposal of Exploratory and Other Cores.

(17) ER 1110-2-1807 Use of Air Drilling in Embankments and Their Foundations.

(18) Federal Geodetic Control Committee, September 1984 Standards and Specifications for Geodetic Control Networks.

(19) HQUSACE: Hazardous/Toxic Waste Management Plan, June 1988.

(20) HQUSACE: Memorandum Draft Guidance on Hazardous and Toxic Wastes (HTW) for Civil Works Studies and Projects, CECW-PO, 30 July 1990.

(21) NSF Standard 14: Plastics Piping System Components and Related Materials.

(22) USEPA, EPA 600/4-79-020: Methods for Chemical Analysis of Water and Wastes.

(23) USEPA, SW-846: Test Methods for Evaluating Solid Waste, Physical/Chemical Methods.

b. Related Publications.

(1) EM 1110-1-1802 Geophysical Exploration.

(2) Benson, R. C., Glaccum, R. A., and Noel, M. R., 1982: Geophysical Techniques for Sensing Buried Wastes and Waste Migration, Environmental Monitoring Systems Laboratory, USEPA, Las Vegas, Nevada.

(3) Everett, L. G., Wilson, L. G., and Hoylman, E. W., 1984: Vadose Zone Monitoring for Hazardous Waste Sites, Noyes Data Corporation, Park Ridge, New Jersey.

(4) USEPA, EPA 600/2-87/078: Nondestructive Testing Techniques to Detect Contained Subsurface Hazardous Waste, September 1987.

(5) USEPA, EPA/540/G-88/003, OSWER Directive 9283.1-2: Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, December 1988.

(6) USEPA, OSWER-9950.1: RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, September 1986.

1-4. Terminology.

a. General. As in any relatively new field using the principles, terminology, and personnel of several others, one finds a certain degree of confusion and ambiguity over the jargon used to express the concepts within this new endeavor. The situation is further clouded by the variety of mechanisms, both traditional and innovative, to perform the actual projects. The additional requirements for permits, licenses, and other Federal and state regulatory procedures, not to mention the potential for litigation, only add to the HTW lexicon.

b. Corps Situation.

(1) Within USACE, a given HTW project may be performed totally in-house, partially in-house, or totally by one or more contractors/AE's (either independently reporting to the Corps or through a system of prime and subcontracting). One Corps office may even broker the work to another who in turn contracts the effort. In some cases, one Corps field operating activity (FOA) may design a project and award the contract while a second FOA supervises the construction.

(2) Providing program level technical guidance in this administrative montage requires the guidance to be specific, while allowing any FOA to adapt

the guidance to their needs. The explicit intent is to require defense of site specific variances; not the defense of prescribed methods and procedures. This approach is warranted to provide the Corps compatibility and continuity of HTW investigations while allowing functional flexibility. With this in mind, the following 3 terms are introduced: the responsible FOA, the field drilling organization (FDO), and the drilling and well installation plan. These terms are defined in sections 1-4.c(9), (2), and (1), respectively. Generically, these terms refer to a client-contractor-contract relationship. This relationship can be applied to both in-house and contracted efforts, thereby providing an internal, technical consistency for the geotechnical portion of the Corps HTW program.

c. Definitions (alphabetically arranged). These definitions are intended to guide the reader through the use of this manual. While other terms with equivalent definitions may be familiar to some readers; the terminology as defined here, provides a common basis for the CONSISTENT understanding by ALL readers.

(1) Drilling and Well Installation Plan/Drilling Plan: A document, prepared by elements of the responsible FOA or FDO, and approved by the responsible FOA before field activities begin. The plan specifies the particulars of the field effort; for example: borehole/well/sample locations, depths, equipment, materials, procedures and alternatives, and other topics required by the responsible FOA. Implementation is by the FDO.

(2) Field Drilling Organization: That office within the Corps, or that company (or agency) directly contracted by the Corps, and is responsible for the execution of the drilling plan. In a contracted arrangement, the prime contractor is regarded as the Field Drilling Organization. Subcontracted organizations, even though they may physically perform the field work, are the responsibility of the prime contractor, whom the Corps holds contractually accountable.

(3) Firm Bedrock: That portion of solid, or relatively solid, moderately to unweathered bedrock where the frequency of loose and fractured rock is markedly less than in the overlying, highly weathered bedrock.

(4) Geotechnical Data Quality Management: The development and application of those policies and procedures to obtain and utilize accurate and representative geotechnical information throughout the entire HTW project cycle, from predesign investigations to postconstruction monitoring.

(5) Hazardous and/or Toxic Waste: The federal definitions of hazardous and toxic waste were established in regulations promulgated by RCRA and the Toxic Substance Control Act (TSCA), based on the identification of specific products, byproducts or waste, presence or concentration of specific chemical, or the result of specific tests.

(6) Monitor Well: A monitor well is a device designed and constructed for the acquisition of groundwater samples that are representative of the chemical quality of the aquifer adjacent to the screened interval, unbiased by the well materials and installation process; and which, if so designed, provides access to measure the potentiometric surface across that screened interval.

(7) Peeling: A process whereby that portion of a sample which was in direct contact with a sampler, as well as the ends of the sample, are removed and discarded.

(8) Redevelopment/Well Rehabilitation: A procedure which removes sediment or other built-up materials from a "clogged," existing well.

(9) Responsible FOA, the FOA: That Corps element minimally headed by a commander or director; e.g., district, laboratory, or agency, assigned or otherwise acquiring the task to administer a contract, agreement; or in-house Corps procedure to research, investigate, design, and/or construct a project involving hazardous and/or toxic waste.

(10) Screened Interval: That portion of a monitor well which is directly open to the host aquifer by way of openings in the well screen AND indirectly open to the aquifer by way of the filter pack (or other permeable material) extending continuously below and/or above the screen.

(11) Site Safety and Health Plan/Safety Plan: A project unique, written document prepared by USACE or a USACE contractor and approved, prior to any drilling, by the responsible FOA for FDO compliance. The plan describes the methods by which the contractor or USACE personnel will meet the safety and health requirements of OSHA standards, 29 CFR 1910 and 1926 (specifically 1910.120), ER 385-1-92, EM 385-1-1, and the technical contract specification provision - SAFETY, HEALTH, AND EMERGENCY RESPONSE, if applicable. Included are an identification of hazardous substances present, recommended action upon encountering those substances, project/site safety requirements, organizational safety responsibilities, and the identification of supporting health and safety activities.

(12) Well Development: A procedure which locally improves or restores the aquifer's hydraulic conductivity and removes well drilling fluids, muds, cuttings, mobile particulates, and entrapped gases from within and adjacent a newly installed well.

d. Acronyms.

(1)	AE	Architect-Engineer
(2)	ASTM	American Society of Testing Materials

(3)	CECW-EG	Geotechnical and Materials Branch, Engineering Division, Directorate of Civil Works, Headquarters, U.S. Army Corps of Engineers
(4)	CEMP-R	Environmental Restoration Division, Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers
(5)	CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
(6)	CFR	Code of Federal Regulations
(7)	D.C.	District of Columbia
(8)	DERP	Defense Environmental Restoration Program
(9)	EM	Engineer Manual
(10)	ENG	Engineer
(11)	ER	Engineer Regulation
(12)	FDO	Field Drilling Organization
(13)	FOA	Field Operating Activity
(14)	GDQM	Geotechnical Data Quality Management
(15)	GSA	Geological Society of America
(16)	HQUSACE	Headquarters, United States Army Corps of Engineers
(17)	HTW	Hazardous and/or Toxic Waste
(18)	ID	Inside Diameter
(19)	mm	Millimeter
(20)	MRD	Missouri River Division
(21)	NSF	National Sanitation Foundation
(22)	N.W.	Northwest
(23)	OD	Outside Diameter
(24)	OSHA	Occupational Safety and Health Administration
(25)	PCB	Polychlorinated biphenyl
(26)	PTFE	Polytetrafluoroethylene
(27)	PVC	Polyvinyl chloride
(28)	RCRA	Resource Conservation and Recovery Act
(29)	SARA	Superfund Amendments and Reauthorization Act
(30)	SPCS	State Plane Coordinate System
(31)	TSCA	Toxic Substance Control Act
(32)	um	Micrometer
(33)	U.S.	United States
(34)	USACE	United States Army Corps of Engineers
(35)	USATHAMA	United States Army Toxic and Hazardous Materials Agency
(36)	USEPA	United States Environmental Protection Agency
(37)	UTM	Universal Transverse Mercator
(38)	'	Foot or Feet
(39)	"	Inch or Inches
(40)	%	Percent

1-5. Background.

a. USACE HTW Programs. The Corps HTW programs are broadly discussed in the "Hazardous/Toxic Waste Management Plan" (HQUSACE, 1988) and in a memorandum: "Draft Guidance on Hazardous and Toxic Wastes (HTW) for Civil Works Studies and Projects" (HQUSACE, 1990). The former document includes elements of Superfund, DERP, and non-mission work for others. The "Draft Guidance" in being circulated to formulate the HTW approach within traditional Civil Works projects. Within the "Management Plan," the concept of Geotechnical Data Quality Management (GDQM) is introduced. Though definitions may vary, the essence of GDQM is to develop and apply those policies and procedures to obtain and utilize accurate and representative geotechnical information throughout the entire HTW project cycle, from predesign investigations to postconstruction monitoring.

b. Monitor Well Installation Manual. As a GDQM mechanism, this manual provides requirements for the collection and documentation of geotechnical information. Combined in these requirements are the experience and thoughts provided by numerous individuals based upon their years of HTW involvement. Site specific deviations must be described and supported in the planning/execution documents.

(1) The technical understanding and evaluation of HTW studies involves an appreciation of the interactions between many fields, including geology, hydrology, and chemistry. This scenario is complicated by the trace (low parts per billion) levels of regulated chemical species that are detectable in the environment; and which when detected or suspected, trigger intricate and costly response actions. Slight deviations from prescribed drilling, well installation, sampling, or analytical procedures may bias or invalidate the reported concentrations. This sensitivity requires that procedures be standardized, documented, understood, and followed.

(2) The specific content of this manual will be periodically updated based upon reader suggestions, lessons learned, technological advances, and Corps needs. Issues of significant concern will be disseminated Corpswide in a more expeditious manner.

(3) Not all geotechnical personnel will agree on every practice advocated herein. Any such variations should be over a matter of degree, not substance. If the reader perceives a technical difficulty in any of the contents, the reader is requested to contact the proponent.

1-6. Proponency. The technical proponent for this manual is the Geotechnical and Materials Branch, Engineering Division, Directorate of Civil Works, Headquarters, U.S. Army Corps of Engineers. All comments and suggestions should be directed to HQUSACE, CECW-EG, 20 Massachusetts Avenue, N.W., Washington, D.C. 20314-1000.

CHAPTER 2

BOREHOLES AND WELLS: LOCATIONS, QUANTITIES, AND DESIGNATIONS

2-1. Locations and Quantities. The locations and quantities of boreholes and wells shall be selected to effectively ascertain desired geologic, hydrologic, and/or geochemical parameters. The FDO shall neither relocate a boring or well nor alter the number of borings or wells specified by the responsible FOA without prior coordination with the FOA. The drilling and well installation plan will allow relocations when necessitated by proximal utilities or drilling difficulties.

2-2. Designations. Borehole and well designations (identification numbers) shall not be unilaterally changed in the field or in a centralized computer database without prior approval of the installing Corps FOA or non-Corps agency once the boring or well has been created. After receiving approval, the requesting FOA shall physically renumber those sites where a designation is posted in the field. Temporary conversions not involving the alteration of either field markings or centralized database may be done for reporting or study purposes without the approval of the installing FOA or agency. A conversion table should be included in the final report to document any permanent or temporary boring/well designation changes.

CHAPTER 3

DRILLING OPERATIONS

3-1. Physical Security. The FDO shall comply with any security policies at the project site. The FDO is totally responsible for securing his own equipment and the wells under construction. The FDO shall address any special situations in the drilling plan.

3-2. Drilling Safety and Underground Utility Detection. When drilling in areas of known or suspected hazardous materials, appropriate health and safety precautions must be implemented. Guidance adaptable for drilling activities is available in Occupational Safety and Health Administration (OSHA) documents (particularly 29 CFR 1910.120 and 29 CFR 1926), ER 385-1-92, EM 385-1-1, and EM 1110-2-505. The FOA, in coordination with the FDO, should determine any and all applicable regulations, requirements, and permits with regard to drilling safety and underground utility detection. These items shall be included in the site safety and health plan (SSHP/"safety plan"). The SSHP shall be approved by the responsible FOA prior to any drilling.

3-3. Permits, Licenses, and Rights-of-Entry. The FOA shall be responsible for ascertaining all applicable boring, well drilling and/or surveying permits, licenses and/or procedures required by state and local authorities and for determining all applicable state or local regulations with regard to the submission of well logs, samples, etc. Acquisition and submission of these items to state or local authorities shall be coordinated between the FOA and FDO with the responsibilities of each specified in the drilling plan. The need for any rights-of-entry will be specified in the drilling plan along with the organization responsible for the acquisition.

3-4. Site Geologist. A "site geologist" (geologist, hydrogeologist, or geotechnical engineer) experienced in HTW projects, soil and rock logging, and monitor well installation, shall be present at each operating drill rig. This geologist shall be responsible for the logging (and possibly the shipment) of samples, monitoring of drilling operations, recording of water losses/gains and groundwater data, preparing the boring logs and well diagrams, and recording the well installation procedures of that rig. Each site geologist shall be responsible for only one operating rig. The geologist shall have onsite sufficient tools, forms, and professional equipment in operable condition to efficiently perform his/her duties as outlined in this manual and other relevant project documents. Items in the possession of each site geologist shall include, as a minimum: a copy of this manual, a copy of the approved drilling and well installation plan, log forms, the approved safety plan, a 10-power (minimum) hand lens, and a tape (weighted with bronze, brass, steel, or chemically stable, nonmetallic material), long enough to measure the deepest boring/well within the project, heavy enough to reach that depth, and small enough to readily fit within the appropriate annulus or opening. Each site geologist shall also have onsite a water level measuring device (preferably

electrical), pH and electrical conductivity meters, and materials necessary to prepare the samples for storage or shipment. At some sites, the geologist is also responsible for monitoring gases during drilling. If so, the geologist shall have the necessary instruments and be proficient in their use.

3-5. Equipment.

a. Condition. All drilling, sampling and support equipment brought to a site shall be in operable condition and free of leaks in the hydraulic, lubrication, fuel, and other fluid systems that would or could be detrimental to the project effort. All switches (to include safety switches), gages, and other electrical, mechanical, hydraulic, and pneumatic systems shall be in a safe and operable condition prior to arrival onsite.

b. Cleaning. All drilling equipment shall be cleaned with steam or pressurized hot water before arriving at the project installation/site. After arrival but prior to project commencement, all drilling equipment to include rigs, support vehicles, water tanks (inside and out), augers, drill casings, rods, samplers, tools, recirculation tanks, etc., shall be cleaned with steam or pressurized hot water using approved water at the installation decontamination point. A similar cleaning shall also occur between each boring/well site. After the on-site cleaning, only the equipment used or soiled at a particular boring or well needs to be recleaned between sites. Unless circumstances require otherwise, water tank interiors do not have to be cleaned between each boring/well at a given project. Prior to use, all casings, augers, recirculation and water tanks, etc., shall be devoid both inside and out of any asphaltic, bituminous, or other encrusting or coating materials, grease, grout, soil, etc. Paint, applied by the equipment manufacturer, need not be removed from drilling equipment. All equipment should be decontaminated before it is removed from the project site. If drilling requires telescoping casing because of differing levels of contamination in subsurface strata, then decontamination will be necessary before setting each string of smaller casing and before drilling beyond any casing. To the extent practical, all cleaning shall be performed in a single area that is remote from and surficially cross- or downgradient from any site to be sampled. Waste solids and water from the cleaning/decontamination process shall be properly collected and disposed of. This may require that cleaning be conducted on a concrete pad or other surface from which the waste materials may be collected.

3-6. Drilling Methods.

a. Objective. The object of drilling method selection is to use that technique which:

(1) Provides representative data and samples.

(2) Eliminates or minimizes the potential for subsurface contamination or cross contamination.

(3) Minimizes drilling costs.

b. To this end, the following drilling methods are typically used:

(1) Hollow stem augers.

(2) Cable tool/churn drill.

(3) Water/mud rotary.

(4) Air systems.

c. Methods. Of these, hollow stem auger is technically advantageous in most situations because of its "dry" method of drilling. The drilling method shall be specified and described in the drilling plan.

3-7. Air Systems.

a. Precautions. Drilling with air is prohibited on embankments and their foundations as discussed in Engineer Regulation (ER) 1110-2-1807. When air usage is allowed in other situations, the drilling plan should present a detailed discussion of the following items:

(1) Situation favoring air usage.

(2) Air drilling method to be used.

(3) Expected subsurface contaminants; and how field personnel will be protected from any adverse effects caused by these contaminants in the returned air and particles blown from the borehole or well.

(4) The potential effects of air usage upon the chemical analyses of groundwater and soil (especially for volatile species) and the mitigation procedures to negate the detrimental aspects of these effects.

(5) The potential effects of air usage upon the physical, hydrological, and structural character of the surrounding soil and/or rock and the mitigation to negate the negative aspects of these effects.

b. Criteria. In general, air system plans shall:

(1) Specify the type of air compressor and compressor lubricating oil and require pint samples of the initial reservoir and any refill oil be retained by the FDO, along with a record of oil loss (on the boring log), for evaluation in the event of future problems. The oil sample(s) may be disposed of upon project completion.

(2) Require an air line oil filter and that the filter be changed per manufacturer's recommendation during operation with a record kept (on the boring log) of this maintenance. More frequent changes shall be made if oil is visibly detected in the filtered air: as by an oil stain on clean, writing paper after directing the filtered air from a hose onto the paper a foot away for 15 seconds.

(3) Prohibit the use of any additive except approved water for dust control and cuttings removal.

(4) Detail the use of any downhole hammer/bit with emphasis upon those procedures to be taken to preclude residual groundwater sample contamination caused by the lubrication of the downhole equipment.

(5) Discuss the volume of air and pressure rating required for drilling and whether a downhole hammer, rotary bit, or both can be used. Air volume and pressure shall be adequate for the hole diameter, equipment, and depth to be drilled.

(6) Detail the use of any bottled gas with emphasis on air composition, quality, method of bottling, and anticipated use.

c. Reporting. Air usage shall be fully described in the log to include equipment description(s), manufacturer(s), model(s), air pressures used, frequency of oil filter change, and evaluation of the system performance, both design and actual.

3-8. Recirculation Tanks and Sumps. Portable recirculation tanks are required for mud/water rotary operations and similar requirements. The use of dug sumps or pits (lined or unlined) is expressly prohibited to minimize cross contamination and to enhance both personal safety and work area restoration.

3-9. Materials.

a. Bentonite. Bentonite is the only drilling fluid additive allowed under normal circumstances. This includes any form of bentonite (powders, granules, or pellets) intended for drilling mud, grout, seals, etc. Organic additives shall not be used. Exception may be made for some high yield bentonites to which the manufacturer has added a small quantity of polymer. The use of any bentonite shall be discussed in the drilling plan and approved by the responsible FOA. The following data shall be included in the drilling plan and submitted along with a sample of the material for approval:

(1) Brand name(s).

(2) Manufacturer(s).

(3) Manufacturer's addresses and telephone number(s).

(4) Product description(s) from package label(s)/manufacturer's brochure(s), to include any polymer or other additives.

(5) Intended use(s) for this product.

(6) Potential effects or chemical analyses of subsequent sampling.

b. Water.

(1) The source of any water to be used in drilling, grouting, sealing, filter placement, well installation, or equipment washing will be approved by the responsible FOA prior to arrival of the drilling equipment onsite and specified in the drilling plan. Desirable characteristics for the source include:

(a) An uncontaminated aquifer origin.

(b) Wellhead upgradient of potential contaminant sources.

(c) Free of survey-related contaminants by virtue of pretesting (sampling and analysis) by the FDO using a laboratory validated by USACE for those contaminants using methods within that validation. Knowledge of the water-chemistry is the most important factor in water approval.

(d) The water shall be nontreated and nonfiltered.

(e) The tap shall have an accessibility and capacity to be compatible with project schedules and equipment.

(f) Only one designated tap shall be used for access.

(2) Surface water bodies should not be used, if at all possible.

(3) If a suitable source exists onsite, that source should be used. If no onsite water is available, the FDO shall both locate a potential source and submit the following data in writing to the FOA for approval prior to the arrival of any drilling equipment onsite. A suggested format is given in Figure 1.

(a) Owner/address/telephone number.

(b) Location of tap/address.

(c) Type of source (well, pond, river, etc.). If a well, specify static water level (depth), date measured, well depth, and aquifer description.

(d) Type of any treatment and filtration prior to tap (none, chlorination, fluoridation, softening, etc.).

(e) Time of access (e.g.; 24 hours per day, 7 days per week, etc.).

(f) Cost per gallon charged by owner/operator.

(g) Results and dates of all available chemical analyses over past 2 years. Include the name(s) and addresses of the analytical laboratory(s).

(h) Results and date(s) of chemical analysis for project contaminants by a laboratory validated by the FOA for those contaminants.

(4) The FDO has the responsibility to procure, transport, and store the water required for project needs in a manner to avoid the chemical contamination or degradation of the water once obtained. The FDO is also responsible for any heating, thermal insulation, or agitation of the water to maintain the water as a fluid for its intended uses.

c. Grout.

(1) Materials and Mixing Sequence. Grout, when used in monitor well construction or borehole/well abandonment, should be composed of Type II portland cement (Annual Book of American Society of Testing and Materials (ASTM) Standards: Volume 04.08; C 150), bentonite (4 to 5 pounds of bentonite powder per 94-pound sack of cement), and a maximum of 8 gallons of approved water per sack of cement. The amount of water per bag of cement should be reduced if bentonite is not used. Neither additives nor borehole cuttings should be mixed with the grout. Bentonite should be added after the design amount of cement is mixed with water. The later blending of bentonite may tend to increase the need for additional water to maintain a pumpable mix. Dry mixing of bentonite and cement before adding water has been successful also. However, the net result may necessitate additional water for pumpability. The use of air-entrained cement should be avoided to negate potential analytical interference in groundwater samples by the entraining additives.

(2) Equipment. All grout materials shall be combined in an above-ground rigid container or mixer and mechanically (not manually) blended onsite to produce a thick, lump-free mixture throughout the mixing vessel. The mixed grout shall be recirculated through the grout pump prior to placement. Grout shall be placed using a grout pump and pipe. The grout pipe shall be of rigid construction for vertical control of pipe placement. Drill rods, rigid polyvinyl chloride (PVC) or metal pipes are acceptable stock for tremies. If hoses or flexible plastics must be used, they may have to be fitted with a length of steel pipe at the downhole end to keep the flexible material from curling and embedding itself into the borehole wall. This is especially true in cold weather when the coiled material resists straightening. Grout pipes shall have SIDE discharge holes, NOT end discharge. The side discharge will help to maintain the integrity of the underlying material (especially the bentonite seal).

d. Granular Filter Pack.

(1) All granular filters will be approved by the responsible FOA prior to drilling and discussed in the drilling plan. Discussions shall include composition, source, placement, and gradation. If the actual gradation is to be determined during drilling, then more than one filter pack gradation may have to be on hand so that well installation will not be unnecessarily delayed. A one-pint representative sample for visual familiarization, of each proposed granular filter pack, accompanied by the data below, shall be submitted by the FDO to the FOA for approval prior to drilling. Each sample shall be described, in writing (see Figure 2 for submittal form), in terms of:

(a) Lithology.

(b) Grain size distribution.

(c) Brand name, if any.

(d) Source, both manufacturing company and location of pit or quarry of origin.

(e) Processing method; e.g., pit run, screened and unwashed, screened and washed with water from well/river/pond, etc.

(f) Slot size of intended screen.

(2) Granular filter packs shall be chemically clean (as seen through a 10-power hand lens), free of material that would pass through a No. 200 (75 um) sieve, inert, siliceous, composed of rounded grains and of appropriate size for the well screen and host environment. A chemical analysis; including analytes of concern, may be advisable in some circumstances. However, the reproducibility of that result should be evaluated against the spacial and temporal variability of the aggregate source and processing methods. The filter material shall be packaged in bags by the supplier and therein delivered to the site.

e. Well Screens, Casings, and Fittings.

(1) Typically, only polyvinyl chloride (PVC), polytetrafluoro-ethylene (PTFE), and/or stainless steel shall be used. All PVC screens, casings, and fittings shall conform to National Sanitation Foundation (NSF) Standard 14 for potable water usage or Annual Book of ASTM Standards; Volume 08.04, F 480 and bear the appropriate rating logo. If the FDO uses a screen and/or casing manufacturer or supplier who removes or does not apply this logo, the FDO shall include in the drilling plan a written statement from the manufacturer/ supplier (and endorsed by the FDO) that the screens and/or casing have been appropriately rated by NSF/ASTM. Specific materials shall be specified in the drilling plan approved by the responsible FOA. All materials shall be as

chemically inert as technically practical with respect to the site environment.

(2) All well screens shall be commercially fabricated, slotted, or continuously wound, and have an inside diameter (ID) equal to or greater than the ID of the well casing. An exception is made in the case of continuously wound screens because their interior supporting rods may reduce the full inside diameter. For PVC and PTFE screens, their schedule/thickness shall be the same as that of the PVC/PTFE well casing. Stainless steel screens may be used with PVC or PTFE well casing. No fitting shall restrict the ID of the joined casing and/or screen. All screens, casings, and fittings shall be new. Screens shall have the largest open area per unit length that is practical for the aquifer of concern and available filter.

(3) Couplings within the casing and between the casing and screen should be compatibly threaded. Thermal or solvent welded couplings on plastic pipe shall not be used. This prohibition includes threaded or slip joint couplings thermally welded to the casing by the manufacturer or in the field. Several thermally welded joints have been known to break during well installation on a single project. The avoidance shall remain until the uniform integrity of thermal welds in the field has been substantiated.

(4) Gaskets, pop rivets, or screws shall not be used on monitor wells. Particular problems with their use include anomalous analytical results, restriction of the well ID, and a loss of well integrity at the point of application.

f. Well Caps and Centralizers.

(1) The tops of all well casings shall be telescopically covered with a slip joint-type cap. Each cap shall be composed of PVC, PTFE, or stainless steel and LOOSELY fitted to the riser. The caps shall be constructed to preclude binding to the well casing due to tightness of fit, unclean surface, or frost; and secure enough to preclude debris and insects from entering the well. Caps and risers may be threaded. However, sufficient annular space must be allowed to enable one to thaw any frosted threads. No vents shall be placed in these caps or in the well risers/stickup. Therefore, the caps should be LOOSE enough to allow stabilization between hydrostatic and atmospheric pressures. Special cap (and riser) designs shall be provided by the FOA or FDO for wells in flood plains.

(2) The use of well centralizers is optional. When used, they shall be of PVC, PTFE, or stainless steel and attached to the casing via stainless steel fasteners or strapping. Centralizers shall not be attached to the well screen or to that part of the well casing exposed to the granular filter or bentonite seal.

g. Well Protection Materials. Elements of well protection are intended to protect the monitoring well from physical damage, to prevent erosion and/or ponding in the immediate vicinity of the monitoring well, and to enhance the validity of the water samples.

(1) The potential for physical damage is lessened by the installation of protective iron/steel casing over the monitoring well and iron/steel posts around the monitor well. The casing and posts will be new. The casing diameter or minimum dimension will be four inches greater than the nominal diameter of the monitoring well and the nominal length shall be five feet. The post will be at least three inches in diameter and the top will be modified to preclude the entry of water. Nominal length of the post shall be six feet. Special circumstances necessitating different materials shall be addressed in the drilling plan.

(2) Erosion and/or ponding in the immediate vicinity of the monitoring well shall be prevented by assuring that the ground surface slopes away from the monitoring well protective casing and the spreading of a six-inch thick, eight-foot diameter blanket of 3/4 to 3-inch gravel around the monitoring well.

(3) The validity of the water samples is enhanced by a locking cover on the protective casing. The cover may be hinged or telescoped but not threaded. All locks installed shall be opened by a single key and, if possible, should match any locks previously installed at the site(s).

h. Glues and Solvents. The use of glues and solvents in monitor well installation is prohibited.

i. Tracers. Tracers or dyes shall not be used or otherwise introduced into borings, wells, grout, backfill, groundwater, or surface water unless specifically approved in the drilling plan. The drilling plan shall describe the approved usage, chemical and/or biological composition of the substances, and potential effects upon subsequent chemical/biological analyses and visual appearance of the media into which the substances are to be introduced. The discussion shall also include relevant Federal and state regulations and/or their opinions relative to the approved usage.

j. Lubricants. If lubrication is needed on the threads or couplings of downhole drilling equipment, only vegetable oil/shortening, petroleum jelly, polytetrafluoroethylene (PTFE) tape, lithium grease, Dow Corning fluorosilicone grease FS-3451, Dow Corning fluorosilicone lubricant FS-33452, DuPont KRYTOX grease (or a technical equivalent to the Dow/DuPont products) may be used. Note: any reference contained in this manual to a product name or manufacturer is intended solely for the purpose of illustration and is not an endorsement of the product or manufacturer by USACE. Additives containing lead or copper shall not be used. The only lubricant recommended on monitor

well joints is PTFE tape. The use and type of lubricants shall be included in the drilling plan and boring log/well construction diagram.

k. Hydraulic Fluids. Any hydraulic or other fluids in the drilling rig, pumps, transmissions, or other field equipment/vehicles shall NOT contain any polychlorinated biphenyls (PCBs).

l. Antifreeze. The use of any antifreeze (either a commercially available automotive variety or a local derivation) should require responsible FOA approval. If antifreeze is added to any pump, hose, etc., where contact with drilling fluid is possible, this antifreeze should be completely purged with approved water prior to the equipment's use in drilling, mud mixing, or any other part of the overall drilling operation. Only antifreeze without rust inhibitors and/or sealants should be considered. Antifreeze usage should be noted on the boring log; including the dates, reasons, quantities, composition, and brand names of antifreeze per above. Antifreeze usage should be a last resort. No antifreeze shall be used in the drilling operation.

m. Agents and Additives. The use of any materials or substances other than those recommended herein for drilling, well installation, or development is prohibited. Included in this prohibition are lead shot, lead wool, burlap, dispersing agents (e.g., phosphates), acids, explosives, disinfectants, etc.

n. Summary. A usage summary shall be provided of any drilling/well construction materials which potentially could have a bearing on subsequent interpretation of the analytical results. An example summary is provided at Figure 3.

3-10. Surface Runoff. Surface runoff; e.g., precipitation, wasted or spilled drilling fluid, and miscellaneous spills and leaks, shall not enter any boring or well either during or after construction. To help avoid such entry, the use of starter casing, recirculation tanks, berms around the borehole, surficial bentonite packs, etc., are recommended.

3-11. Drilling Through Contaminated Zones. Many borings and wells are drilled in areas that are clean relative to the deeper zones of interest. However, circumstances do arise which require drilling where the overlying soils or shallow aquifer may be contaminated relative to the underlying environment. This situation may be addressed by the placement of, at least, double casing: an outer permanent (or temporary) casing sealed in place and cleared of all previous drill fluids prior to proceeding into the deeper, "cleaner" environment. In this procedure, the outer drill casing is set and sealed within an "impermeable" layer or at a level below which the underlying environment is thought to be "cleaner" than the overlying environment. The drilling fluids used to reach this point are appropriately discarded, replaced by a new or fresh supply and drilling equipment is cleaned. This system can be repeated, resulting in telescopic drill casing through which the final well casing is placed. These situations shall be addressed on a case-by-case basis

in the drilling plan, incorporating applicable Federal and/or local requirements. All prudent steps shall be taken to avoid contamination of a "clean" environment.

3-12. Soil Sampling.

a. Unless otherwise specified in the drilling plan, intact soil samples for physical descriptions, retention, and physical analyses shall be taken continuously and retained for the first 10 feet and every 5 feet or at each change of material, whichever occurs first, thereafter. These samples shall be representative of their host environment and should be obtained with driven (e.g., split spoon), pushed (e.g., thin wall), or rotary (e.g., Denison) type samplers. Borehole cuttings will not satisfy this requirement. Sampling procedures shall be detailed in the drilling plan.

b. At the detection of any anomalous odors (or vapor readings) from the boring or intact samples, drilling shall cease for an evaluation of the odors and crew safety. After the field safety representative completes this evaluation and implements any appropriate safety precautions, drilling can resume. If the odors or vapor readings are judged by the field crew to be contaminant-related, intact soil samples shall be continuously taken until the odors/readings are within background ranges. These samples shall be retained in appropriate screw-capped sample jars for possible chemical analysis. With the resumption of background readings routine sampling shall resume. Specific procedures shall be detailed in the drilling and safety plans. Some field air monitoring equipment is described in EM 1110-2-505, Chapter 3.

c. Representative soil samples of sufficient volume for physical testing from each sampled interval shall be retained for future reference or appropriate analysis. Upon boring completion, the samples for that boring may be reduced, retaining at least representative samples of major units, key samples, and those for testing requirements. Minimum information on each sample container shall include the project, boring and sample number. All samples known or suspected to contain contaminants of concern shall be so marked on both the sample container and boring log. No geotechnical data shall appear on the container that is not specified on the boring log. Containers shall be kept from becoming frozen. Soil samples known or suspected of being contaminated may have to be handled, stored, tested, and/or disposed of as hazardous waste. Storage, packaging and shipment instructions for soil samples for physical testing shall be prescribed in the drilling plan.

d. Physical soil testing is a function of the project. The drilling plan shall detail specific testing guidance and requirements. Physical soil testing shall be conducted on 10 to 20 percent of the soil samples using procedures and equipment described in the current U.S. Army Corps of Engineers document: EM 1110-2-1906, Laboratory Soils Testing (or Annual Book of ASTM Standards; Volume 04.08, D 2487). Downhole geophysical logging may reduce this requirement. Tested samples shall be representative of the range and

frequency of soil types encountered and shall specifically include the screened interval of each completed well. In addition, they shall be obtained from borings that cover the geographic and geologic range within the project area. The FDO shall select the particular samples. Tests shall include moisture content and those tests necessary to determine the Unified Soil Classification. Laboratory and summary sheets shall be submitted to the responsible FOA after final test completion. The drilling and safety plans shall address any contaminant related safety precautions for the physical analysis of these samples. Samples for physical analysis known or suspected to be contaminated shall be tested only in a soils laboratory equipped and managed to process contaminated samples.

e. Soil Samples for Chemical Analysis:

(1) Samples shall be extracted from their insitu environment in as near an intact, minimally disturbed condition as technically practical. Once at the surface, the sampler shall be opened, sample extracted, peeled, and bottled in as short a time as possible. "Peeling" is a process whereby that portion of the sample which was in direct contact with the sampler, as well as the ends of the sample, are removed and discarded. Samples for volatile analysis shall be peeled, bottled, and capped within 15 seconds from the time of opening the sampler. Each soil sample for volatile analysis should have minimal head space for representative analytical results.

(2) All sampling equipment that will contact the sample must be thoroughly decontaminated between samples. This can be accomplished by the use of a hot-water pressure washer; or as follows.

(a) Scrub equipment with a low-sudsing, non-phosphate detergent in approved water.

(b) Rinse with approved water.

(c) When sampling for metals, rinse with 0.1 N nitric acid (4.2 mL of concentrated nitric acid added to 1000 mL of water, caution: add acid to water, never add water to concentrated acid) followed by rinsing with distilled or deionized water. If the sampling equipment being used is made of stainless steel, the use of 0.1 N hydrochloric acid (rather than 0.1 N nitric acid) is preferred to avoid oxidation (rusting) of the stainless steel. The 0.1 N hydrochloric acid is prepared by adding 3.1 mL of concentrated hydrochloric acid to 1000 mL of water; the same caution applies: add the concentrated acid to the water, not the water to the acid.

(d) When sampling for organic volatiles, semi-volatiles, or pesticides/PCB, rinse with pesticide grade iso-propanol followed by rinsing with distilled or deionized water.

(3) Additional acquisition, preservation, and handling criteria for the chemical analysis of soils are found in U.S. Environmental Agency (USEPA) SW-846, Test Methods for Evaluating Solid Waste,Physical/ Chemical Methods and a forthcoming revision of ER 1110-1-263.

f. If sample liners are used, the following are applicable:

(1) Use clear liners or take extra samples to ensure that the sample is of sufficient quantity and quality for the intended analyses.

(2) Liner seams and ends shall be "air tight"; i.e., "chemically impermeable."

(3) Borehole/drilling fluids shall not be trapped within the liner.

(4) Liner or sealant interaction with the sample will not alter the sample's chemical composition.

g. All soil samples, except those for physical and/or chemical analysis and reference shall remain onsite, neatly stored at an FOA - designated location. The disposition of these samples shall be arranged by the FOA. Samples from HTW sites, other than those samples which will be subjected to physical or chemical analyses, may have to be stored, and later disposed of, as hazardous waste. Sample retention and disposal shall be given detailed attention in the drilling and well installation plan.

3-13. Rock Coring. Bedrock shall be cored unless specified otherwise in the drilling plan. This method, using a diamond or carbide studded bit, produces a generally intact sample of the bedrock lithology, structure, and physical condition. The use of a gear-bit, tricone, etc., to penetrate bedrock shall only be considered for the confirmation of the "top of rock" (where penetration is limited to a few feet), the enlargement of a previously cored hole, or the drilling of highly fractured intervals.

a. The coring of bedrock or any firm stratigraphic unit shall be conducted in a manner to obtain maximum intact recovery. The physical character of the bedrock; i.e., fractures, poor cementation, weathering, or solution cavities, may lessen recovery, even with the best of drillers and equipment.

b. The minimum core size shall be an "N" series, 2 (plus)-inch diameter.

c. While drilling in bedrock, and especially while coring, drilling fluid pressures shall be adjusted to minimize drilling fluid losses and hydraulic fracturing. All pumping pressures shall be recorded.

d. Rock cores shall be stored in covered core boxes in such a manner as to preserve their relative position by depth. Intervals of lost core shall be noted in the core sequence. Boxes shall be marked on the cover (both inside

and outside) and on the ends to provide project name, boring number, cored interval, and box number in cases of multiple boxes. Any core box known or suspected to contain contaminated core shall be appropriately marked on the box cover (inside and out) and on both ends. The weight of each fully loaded box should not exceed 75 pounds. No geotechnical or contaminant data shall appear on or within the box that is not specified on the boring log. As a minimum, the estimated number of boxes required for each boring shall be on hand prior to coring that site.

e. The core within each completed box shall be photographed after the core surface has been cleaned or peeled, as appropriate, and wetted. Photos shall be taken using color film (film speed as appropriate), 35mm camera, 55mm (or normally provided) lens, light meter, with 1 box per frame. Each photo shall be in sharp focus and contain both a legible scale in feet and tenths of feet (or centimeters) and an FOA-supplied photographic color chart for color comparison. The core shall be oriented so that the top of the core is at the top of the photo. Each photo shall be annotated on the back as to the project name, bore/well designation, box number, cored depths denoted in the photograph, and date photographed. One set of glossy color prints shall be sent to the FOA after the last coring. In addition, all negatives shall be delivered to the FOA after the FOA has received the prints.

f. All rock core, except that for analysis and reference, shall be neatly stored at an FOA-designated location. The disposition of these samples shall be arranged by the FOA.

g. Bedrock cores known or suspected of being contaminated may have to be handled, stored, tested, and/or disposed of as hazardous waste. Such a consideration and determination shall be made prior to drilling plan approval. This determination may alter drilling methods, coring frequency, data quality, costs, etc. Geophysical downhole logging or borehole camera techniques could be considered as alternatives in some cases. The drilling plan shall reflect the final decision and possible alternatives that retain viability. Specific instructions as to the storage, or required packaging and method of shipment to the laboratory shall be provided in the drilling plan.

3-14. Abandonment. Abandonment (also known as "decommissioning") is that procedure by which any boring or well is permanently closed. Abandonment procedures shall preclude any current or subsequent discharges from entering along the axis or endpoints of any boring or well and thereby terminate access to and intracommunication within the subsurface environment.

a. Planned abandonment requirements and procedures shall be described in the drilling plan and incorporate applicable state and/or Federal regulatory requirements.

b. The closure of any borings or wells not scheduled for abandonment per drilling plan, shall be approved by the responsible FOA prior to any casing

removal, sealing, or backfilling. Abandonment requests shall be submitted telephonically by the FDO to the responsible FOA with the following data, plus recommendation. A written followup memorandum containing the same data shall be submitted by the FDO.

(1) Designation of boring/well in question.

(2) Current status (depth, contents of hole, stratigraphy, water level, etc.).

(3) Reason for closure.

(4) Action taken, to include any replacement boring or well.

c. Each boring or well to be abandoned will be sealed by grouting from the bottom of the boring/well to ground surface. This shall be done by placing a tremie pipe to the bottom of the boring/well (i.e., to the maximum depth drilled/bottom of well screen) and pumping grout through this pipe until undiluted grout flows from the boring/well at ground surface. Any open or ungrouted portion of the annular space(s) between the innermost well casing and borehole (to include any casings in between) will be grouted in the same manner also.

d. After 24 hours, the FDO will check the abandoned site for grout settlement. That day, any settlement depression shall be filled with grout and rechecked 24 hours later. Additional grout shall be added using a tremie pipe inserted to the top of the grout unless the depth of the unfilled portion of the hole is less than 15 feet and this portion is dry. This process is repeated until firm grout remains at ground surface.

e. An abandoned well may be grouted with the well screen and casing in place. However, a lack of data concerning well construction, condition, or other factors may dictate the removal of the well materials and a partial or total hole redrilling prior to sealing the well site.

f. For each abandoned boring/well, a record shall be prepared to include the following as applicable.

(1) Project and boring/well designation.

(2) Location with respect to the replacement boring or well (if any); e.g., 20 feet north and 20 feet west of Well 14.

(3) Open depth of well/annulus/boring prior to grouting.

(4) Casing or items left in hole by length, depth, composition, description, and size.

(5) Copy of the boring log.

(6) Copy of construction diagram for abandoned well.

(7) Reason for abandonment.

(8) Description and total quantity of grout used initially.

(9) Description and daily quantities of grout used to compensate for settlement.

(10) Dates of grouting.

(11) Water or mud level (specify) prior to grouting and date measured.

(12) Remaining casing above ground surface: type (well, drill, protective) height above ground, size, and composition of each. Report all depths/heights from ground surface. The original record should be submitted to the FOA.

g. Replacement well/borings (if any) shall be offset at least 20 feet from any abandoned site in a presumed up- or cross-gradient groundwater direction.

3-15. Work Area Restoration and the Disposal of Drilling and Cleaning Residue. All work areas around the wells and/or borings installed as part of any contract shall be restored to a condition essentially equivalent to that of preinstallation. This includes the disposal of borehole cuttings and rut removal. Borehole cuttings, discarded samples, drilling fluids, equipment cleaning residue, and water removed from a well during installation, development, and aquifer testing shall be handled, treated if necessary, and disposed of both in a manner approved by the responsible FOA, host installation/property owner and consistent with applicable state and Federal regulations. Whatever procedures are followed, the leaving of barrels containing drill cuttings, excess samples, and fluids at various unsecured locations around the site at the completion of well installation is prohibited. Any container (barrel) used shall be labeled and recorded so that its contents can be identified as to materials and source. Restoration, handling, treatment, and disposal procedures (to include disposal location(s)) shall be discussed in the drilling and well installation plan.

CHAPTER 4

SAFETY AND HEALTH CONSIDERATIONS

(to be provided)

CHAPTER 5

BOREHOLE LOGGING

5-1. General. Each boring log shall fully describe the subsurface environment and the procedures used to gain that description.

5-2. Format. All borings shall be recorded in the field on Engineer (ENG) Form 1836 and 1836-A, per EM 1110-1-1804 or on an equivalent log form modified specifically for HTW work. This requirement applies to in-house and contracted activities. Suggested data for recording is discussed throughout this manual. Because of the large quantity of information routinely required on logs at HTW sites, a scale of 1 inch on the log equaling 1 foot of boring is preferred. Suggested formats are presented in Figures 4 and 5.

5-3. Submittal. Each original boring log shall be submitted directly from the field to the responsible FOA after each boring is completed. In those cases where a monitor well or other instrument is to be inserted into the boring, both the log for that boring and the installation diagram may be submitted together.

5-4. Originals. Only the original boring log (and diagram) shall be submitted from the field to the FOA. Carbon, typed, or reproduced copies shall not suffice. The original shall be of sufficient legibility and contrast so as to provide comparable quality in reproductions.

5-5. Time of Recording. Logs shall be recorded directly in the field without transcribing from a field book or other document. This technique lessens the chance for errors of manual copying and allows the completed document to be field-reviewed closer to the time of drilling.

5-6. Routine Entries. In addition to the data desired by the FDO and uniquely required by the drilling plan, the following information shall be routinely entered on the boring log:

a. All borings and wells (active and abandoned) shall be uniquely numbered and located on a sketch map as part of the log.

b. Depths/heights shall be recorded in feet and fractions thereof (tenths of feet). Metric measurements are acceptable if typically used by the site geologist.

c. Soil classifications shall be in accordance with the Unified Soil Classification System and shall be prepared in the field at the time of sampling by the geologist.

d. Each soil sample taken shall be fully described on the log. The descriptions of intact samples shall include the following parameters:

PARAMETER	EXAMPLE
Classification	Sandy Clay
Depositional Environment and Formation, if known	Glacial till, Twin Cities Formation
Unified Soil Classification Symbol	CL
Secondary Components and Estimated Percentages	Sand: 25% (Fine sand 5%, Coarse sand 20%)
Color (using Munsell Soil or Geological Society of America (GSA) Rock Color Chart). Each chart can be used for both soil and rock. Give both narrative and numerical description and note which chart was used.	Gray: 7.5 YR 5.0 (Munsell)
Plasticity	Low Plasticity
Consistency (cohesive soil)	Very soft, soft, medium stiff, very stiff, hard
Density (non-cohesive soil)	Loose, medium loose, dense, very dense
Moisture Content. Use relative term. Avoid a percentage unless a value has been measured.	Dry, damp, moist, wet, saturated
Structure and Orientation	No apparent bedding: numerous vertical, iron-stained, tight fractures
Grain Angularity	Rounded

e. In the field, visual numeric estimates shall be made of secondary soil constituents; e.g., "silty sand with 20-percent fines" or "sandy gravel with 40-percent sand." If such terms as "trace," "some," "several," etc., are used, their quantitative meaning shall be defined on each log.

f. When used to supplement other sampling techniques, disturbed samples, e.g., wash samples, cuttings, and auger flight samples, shall be described in terms of the appropriate soil/rock parameters to the extent practical. "Classification" shall be minimally described for these samples, along with a

description of drill action and water losses/gains for the corresponding depth. Notations should be made on the log that these descriptions are based on observations of material other than samples; e.g., "from cuttings."

g. Rock core shall be visually described for the following parameters:

PARAMETER	EXAMPLE
Rock Type	Limestone, Sandstone, Granite
Formation	Anytown Formation
Modifier Denoting Variety	Shaly, Calcareous, Siliceous, Micaceous
Bedding/Banding Characteristics	Laminated, Thin bedded, Massive, Cross bedded, Foliated
Color (using Munsell Soil or GSA Rock Color Chart). Each chart can be used for both soil and rock. Give both narrative and numerical description and note which chart was used.	Moderate brown: 5 YR 3/4 (GSA)
Hardness	Very soft, Soft, Moderately hard, Hard, Very hard
Degree of Cementation	Poorly cemented, Well cemented
Texture	Dense, Fine-, Medium-, Coarse-grained, Glassy, Porphyritic, Crystalline
Structure and Orientation	Horizontal bedding, Dipping beds at 30°, Highly fractured, Open vertical joints, Healed 30° faults/ fractures, Slickensides at 45°, Fissile
Degree of Weathering	Unweathered, Slightly weathered, Highly weathered
Solution or Void Conditions	Solid, Cavernous, Vuggy with partial infilling by clay

PARAMETER	EXAMPLE
Primary and Secondary Permeability, include estimates and rationale	Low primary: Well cemented High secondary: Several open joints
Lost Core, interval and reason for loss	50-51', noncemented sandstone likely

h. For rock core, a scaled graphic sketch of the core shall be provided on or with the log denoting by depth: the location, orientation, and nature (natural or coring-induced) of all core breaks. Also mark the breaks purposely made to fit the core into the core boxes. If fractures are too numerous to be individually shown, their location may be drawn as a zone and described on the log. Note also the intervals by depth of all lost core and hydrologically significant details. This sketch shall be prepared at the time of core logging, concurrent with drilling.

i. Record the brand name and amount of any bentonite used for each boring along with the reason for and start (by depth) of this use. If measured, record mud viscosities and weights.

j. The drilling equipment used shall be generally described on each log. Record such information as rod size, bit type, pump type, rig manufacturer and model.

k. Each log shall record the drilling sequence; e.g.:

(1) Opened hole with 8" auger to 9'.

(2) Set 8" casing to 10'.

(3) Cleaned out and advanced hole with 8" roller bit to 15' (clean water, no water loss).

(4) Drove 1 3/8" ID × 2" OD sampler to 16.5'.

(5) Advanced with 8" roller bit to 30', 15-gallon water loss.

(6) Drove 1 3/8" ID × 2" OD sampler to 31.5'.

(7) Hole heaved to 20'.

(8) Mixed 25 pounds of ABC bentonite in 100 gallons of water for hole stabilization and advanced with 8" roller bit to 45', etc.

l. Record all special problems and their resolution on the log; e.g., hole squeezing, recurring problems at a particular depth, sudden tool drops,

excessive grout takes, drilling fluid losses, unrecovered tools in hole, lost casings, etc.

m. The dates and times for the start and completion of borings shall be recorded on the log along with notation by depth for drill crew shifts and individual days.

n. Each sequential boundary between the various soils and individual lithologies shall be noted on the log by depth. When depths are estimated, the estimated range should be noted along the boundary.

o. The depth of first encountered free water shall be indicated along with the method of determination; e.g., "37.6′ from direct measurement after drilling to 40.0′;" or "40.1′ from direct measurement in 60′ hole when boring left overnight, hole dry at end of previous shift;" or "25.0′ based on saturated soil sample while sampling 24-26′." Before proceeding, the first encountered water shall be allowed to partially stabilize (5 to 10 minutes) and recorded along with the time between measurements. Any other district water level(s) found below the first shall also be described.

p. The interval by depth for each sample taken, classified, and/or retained shall be noted on the log. Record the length of sampled interval, length of sample recovery, and the sampler type and size (diameter and length).

q. A record of the blow counts, hammer type and weight, and length of hammer all for driven samplers shall be made. For thin wall samplers, indicate whether the sampler was pushed or driven and the pressure/blow count per drive. Blow counts shall be recorded in half foot increments when standard penetration samplers (1 3/8" ID × 2" OD) are used. For penetration less than a half foot, annotate the count with the distance over which the count was taken.

r. When drilling fluid is used, quantitatively record fluid losses and/or gains and the interval over which they occur. Adjust fluid losses for spillage and intentional wasting (e.g., recirculation tank cleaning) to more closely estimate the amount of fluid lost to the subsurface environment.

s. Record the drilling fluid pressures typically used during all drilling operations (aqueous and pneumatic) and the driller's comments on drillability, drill speed, down pressure, rotation speed, etc.

t. Note the total depth of drilling and sampling on the log.

u. Record significant color changes in the drilling fluid return, even when intact soil samples or rock core are being obtained. Include the color change (from and to), depth at which change occurred, and a lithologic description of the cuttings before and after the change.

v. Soil gas readings, if taken, shall be recorded on the log. Each notation should include interval sampled and reading. A general note on the log should indicate meter manufacturer, model, and calibration material. If several meters are used, key the individual readings to the specific meter.

w. Special abbreviations used on a log and/or well diagram shall be defined in the log/diagram where used.

CHAPTER 6

MONITOR WELL INSTALLATION

6-1. General. A "monitor well" is a device principally designed and constructed for the acquisition of groundwater samples that are representative of the chemical quality of the aquifer adjacent to the screened interval, unbiased by the well materials and installation process; and which, if so designed, provides access to measure the potentiometric surface for that screened interval. The "screened interval" consists of that portion of the device which is directly open to the host aquifer by way of openings in the well casing (hereafter called the "screen") AND indirectly open to the aquifer by way of the filter pack (or other permeable material) extending continuously below and/or above the screen. While the length of the screened interval is fixed for a given well, the effective or functional length may vary with water table fluctuations or sampling techniques. In this manual, the term "monitor well" is used in a generic sense to include observation wells and open tube piezometers. Open tube piezometers are usually of small inside diameter to allow a quicker response to pressure change. Wellpoints are a rapid and uncontrolled means to obtain groundwater levels. They may be used, with FOA approval, to supplement potentiometric data in areas of known stratigraphy. Lysimeters may be used to sample interstitial fluids in the vadose or unsaturated zone. Specific criteria for monitor wells and any special instrumentation shall be discussed in the drilling plan.

6-2. Well Clusters. Each monitor well is a mechanism through which to obtain a representative sample of groundwater and (if so designed) to measure the potentiometric surface seen by that well. To help ensure this representation in the case of well clusters, each well of a cluster shall be installed in a separate boring. Multiple well placements in a single boring are too difficult for effective execution and evaluation to warrant single hole usage.

6-3. Well Screen Usage. Each well, overburden or bedrock, shall have a screen per Figures 6 and 7, or as specified per drilling plan. The extra effort for screen installation in bedrock wells can be more than offset by the assurance of an unobstructed opening to the required depth during repeated usage. Consistency of the sampled interval during prolonged monitoring is thereby maintained.

6-4. Beginning Well Installation.

a. The installation of each monitor well shall begin within 12 hours of boring completion for holes uncased or partially cased with temporary drill casing. Installation shall begin within 48 hours in holes fully cased with temporary drill casing. Once installation has begun, no breaks in the installation process shall be made until the well has been grouted and drill casing removed. Anticipated exceptions shall be requested in writing by the FDO to the FOA prior to drilling. Data to include in this request are:

(1) Well(s) in question.

(2) Circumstances.

(3) Recommendation and alternatives.

b. In cases of unscheduled delay such as personal injury, equipment breakdowns, sudden inclement weather; or scheduled delays such as borehole geophysics, no advance approval of delayed well installation is needed. In those cases, resume installation as soon as practical. In cases where a partially cased hole into bedrock is to be partially developed prior to well insertion, the well installation shall begin within 12 hours after this initial development.

c. Temporary casing and hollow stem augers may be withdrawn from the boring prior to well installation if the potential for cross-contamination is not likely and if the borehole walls will not slough during the time required for well installation. This procedure is usually successful in firm clays, and in bedrock that is not intensely fractured or highly weathered.

d. If the borehole will not remain stable long enough to complete placement of all necessary well materials in their proper position, it will be necessary to install some or all of the well materials prior to removal of the casing or hollow stem augers. In this situation, the hollow stem augers or casing shall have an inside diameter sufficient to allow the installation of the prescribed diameter screen and casing plus annular space for a pipe through which to place the filter pack and grout.

e. Any materials, especially soils, blocking the bottom of the drill casing or hollow stem auger shall be dislodged and removed from the casing prior to well insertion. This action both reduces the potential for cross-contamination and makes well installation easier.

f. Once begun, well installation shall not be interrupted due to the end of the driller's work shift, darkness, weekend, or holiday.

g. The FDO shall ensure that all materials and equipment for drilling and installing a given well are available and onsite prior to drilling that well. The FDO shall have all equipment and materials onsite prior to drilling and installing any well if the total well drilling and installation effort is scheduled to take 14 days or less. For longer schedules, the FDO shall ensure that the above materials needed for at least 14 days of operation are onsite prior to well drilling. The balance of materials shall be in transit prior to well drilling. Any site specific factors that preclude the availability of needed secure storage area should be identified and resolved in the drilling plan.

6-5. Well Screens, Casings, and Fittings.

a. All well screens and well casings shall be free of foreign matter (e.g., adhesive tape, labels, soil, grease, etc.) and washed with approved water prior to use. Prewashing is not necessary if the materials have been packaged by the manufacturer and have their packaging intact up to the time of installation. Pipe nomenclature stamped or stenciled directly on the well screen and/or blank casing within and below the bentonite seal shall be removed via SANDING, unless removable in approved water. Solvents, except approved water, shall NOT be used for marking removal. Washed screens and casings should be stored in plastic sheeting prior to insertion.

b. Bottoms of well screens shall be placed no more than 3 feet above the bottom of the drilled borehole. If significant overdrilling is required (as for determining stratigraphy), a pilot boring shall be used. The intent here is to both narrow the interval of aquifer being sampled, limit the potential for stagnant or no-flow areas near the screen, and preclude unwanted backfill materials; e.g., grout or bentonite from entering or passing through the interval to be screened and sampled.

c. All screen bottoms shall be securely fitted with a threaded cap or plug of the same composition as the screen. This cap/plug shall be within 0.5′ of the open portion of the screen. No solvents or glues are permitted for attachment.

d. Silt or sediment traps (also called "cellars" "tail pipes," or "sumps") shall NOT be used. A silt trap is a blank length of casing attached to and below the screen. Trap usage fosters a stagnant, turbid environment which could influence analytical results for trace concentrations.

e. The top of each well shall be level such that the differences in elevation between the highest and lowest points on the top of the well casing or riser should be less than or equal to 0.02′.

f. The borehole shall be of sufficient diameter to permit at least 2 inches of annular space between the borehole wall and all sides of the well (centered riser and screen). When telescoping casings (one casing within another), the full 2-inch annulus may not be practical or functional. In this case, the lesser spacing will be acceptable.

g. Well screen lengths may be a function of hydrostratigraphy, temporal considerations, environmental setting, analytes of concern, and/or regulatory mandate. Screen lengths shall be specified in the drilling plan.

h. The actual inside diameter of nominally sized well is a function of screen construction and the wall thickness/schedule of both the screen and casing. In the case of continuously wound screens, their interior supporting

rods may reduce the full inside diameter. This consideration is critical when planning the sizes for pumps, bailers, surge devices, etc.

i. The larger open-area per unit length of continuously wound screens has an advantage over the slotted variety when screen clogging is anticipated.

6-6. Granular Filter Pack.

a. The use of a tremie pipe for filter pack placement is recommended, especially when the boring contains drilling fluid or mud.

b. The filter pack shall extend from the bottom of the boring to 3-5 feet above the top of the screen unless otherwise specified in the drilling plan. The filter pack location shall not cross any confining layer.

c. The final depth to the top of the granular filter shall be directly measured (via tape or rod) and recorded. Final depths shall not be estimated; as, for example, based on volumetric measurements of placed filter.

6-7. Bentonite Seals.

a. Bentonite seals (especially those set in water) shall be composed of commercially available pellets. Pellet seals shall be 3-5 feet thick as measured immediately after placement, without allowance for swelling. Granular bentonite may be an alternate if the seal is set in a dry condition. Tremie pipes are not recommended for pellet placement due to the potential for bridging problems. The slow release of pellets through the well annulus coupled with frequent depth measurements is recommended.

b. Slurry seals shall be used only as a last resort, as when the seal location is too far below water to allow for pellet or containerized-bentonite placement or within a narrow well-borehole annulus. Slurry seals shall have a thick, batter-like (high viscosity) consistency with a placement thickness of 3 to 5 feet.

c. In wells designed to monitor bedrock, the bottom of the bentonite seal shall be located at least 3 feet below the top of firm bedrock, as determined by drilling. "Firm bedrock" refers to that portion of solid or relatively solid, moderately to unweathered bedrock where the frequency of loose and fractured rock is markedly less than in the overlying, highly weathered bedrock. Figure 7 denotes the seal location.

d. The final depth to the top of the bentonite seal shall be directly measured (via tape or rod) and recorded. Final depths shall not be estimated; as, for example, based on volumetric measurements of placed bentonite.

e. Numerous opinions have been expressed regarding bentonite hydration time, bentonite placement procedures underwater versus in a dry condition, and

the potential installation delays and other consequences caused by these factors. These and related issues are still being investigated. In the meanwhile, the use of a 3 to 5-foot bentonite pellet seal is considered an adequate barrier to protect the screen and filter pack from downhole grout migration. If the seal is located above borehole fluid levels, a 1 or 2-foot layer of fine to medium sand placed atop the bentonite seal may enhance this barrier to downward grout migration. Therefore, any time delay in well installation to allow for bentonite hydration, in a wet or dry hole, is not necessary.

6-8. Grouting. All prescribed portions of grout material should be combined in an above-ground rigid container and mechanically (not manually) blended to produce a thick, lump-free mixture throughout the mixing vessel.

a. Grout should be placed around the monitor well as follows:

(1) The grout shall be placed from within a rigid grout pipe located just over the top of the seal.

(2) Prior to exposing any portion of the borehole above the seal by removal of any drill casing (to include hollow-stem augers), the annulus between the drill casing and well casing shall be filled with sufficient grout to allow for planned drill casing removal. The grout shall not penetrate the well screen or granular filter pack. Disturbance of the bentonite seal shall be minimal.

(a) If all drill casing is to be removed in one operation, the grout shall be pumped through the grout pipe until undiluted grout flows from the annulus at ground surface forming a continuous grout column from the seal to ground surface. The drill casing shall then be removed making certain that no portion of the borehole is exposed. When removing hollow stem augers, this may necessitate reinsertion of the grout pipe and additional grout before the entire drill string is removed.

(b) If drill casing is to be incrementally removed with intermittent grout addition, the grout shall be pumped through the grout pipe until it reaches a level which will permit at least 10 feet of grout to remain in the well-drill casing annulus AFTER removing the selected length of drill casing. This method requires that at least 20 feet of grout be to within the drill casing before removing 10 feet of driven casing or considerably more than 20 feet of grout for the removal of 10 feet of hollow stem auger. With this method, the grout pipe needs only to be reinserted to the base of the casing yet to be removed before repeating the grout insertion process.

(3) If the ungrouted portion of the hole is less than 15 feet deep and without fluids after casing removal, the ungrouted portion may be filled by pouring grout from the surface without a pipe.

(4) If drill casing (to include hollow-stem auger) was not used, proceed with grouting to surface in one, continuous operation.

(5) Once begun, the grouting process should be continuous until all the drill casing has been removed and all annular spaces are grouted to the ground surface.

(6) Install protective casing on the same day.

(7) After 24 hours, the FDO shall check the site for grout settlement and that day add more grout to fill any depression. Repeat this process until firm grout remains at ground surface. Incremental quantities of grout added in this manner shall be recorded on the well completion diagram to be submitted to the FOA.

(8) A special circumstance that permits deviation from prescribed practice is:

(a) For grout placement in a dry and open hole less than 15 feet deep, the grout may be manually mixed and poured in from the surface as long as seal integrity is maintained.

(9) No grout shall be placed below the well screen.

6-9. Well Protection.

a. Protective casing shall be installed around each monitor well the same day as initial grout placement around that well. Any annulus formed between the outside of the protective casing and borehole or between the monitor well and protective casing shall be filled to ground surface with grout as part of the overall grouting procedure. Specific details of well protection shall be approved by the responsible FOA and specific well protection elements to be included in the well construction diagrams are to be described in the drilling and well installation plan.

b. All protective casing shall be steam or hot water-pressure cleaned prior to placement, free of extraneous openings, devoid of any asphaltic, bituminous, encrusting, and/or coating materials (except the black paint or primer applied by the manufacturer).

c. Minimum elements of protection design are:

(1) A 5-foot minimum length of new, black iron/steel pipe extending about 2.5 feet above ground surface and set in grout (see Figures 6 and 7).

(2) A protective casing inside diameter at least 4 inches greater than the nominal diameter of the well riser.

(3) A hinged cover or loose fitting telescopic slip joint-type cap to keep direct precipitation and cap runoff out of the casing. Threaded covers shall be avoided because of the tendency to rust shut.

(4) All protective casing covers/caps secured to the casing by means of a padlock from the date of protective casing installation.

(5) All padlocks at a given site opened by the same key. The FDO shall provide 4 of these keys to an FOA designated representative at the project.

(6) No more than .2' from the top of protective casing to the top of well casing. This, or a smaller spacing, is needed for subsequent water level determination via some acoustical equipment.

(7) The outside only of the protective casing, hinges (if present), and covers/caps painted orange with a paint brush (not aerosol can). Painting required to be completed and dry prior to initially sampling that well. Any color deviations will be conveyed to the FDO by the FOA.

(8) The painting of the well designation on the outside of the protective casing, using white paint and a brush. The identification shall be done after the casing is painted as described above. Painting required to be completed and dry prior to initially sampling that well.

(9) The erection of 4 steel posts with a minimum diameter of 3 inches around each well. Each post should be radially located 4 feet from the well and placed 2 to 3 feet below ground surface, having 3 feet minimally above ground surface with flagging in areas of high vegetation (see Figure 8). The posts shall be painted orange, using a brush. Installation shall be completed prior to sampling the well.

(10) The above posts shall be supplemented with 3-strand barbed wire in livestock grazing areas. Post and wire installation are required prior to sampling.

(11) The placement of an internal mortar collar within the well-protective casing annulus from ground surface to 1/2 foot above ground surface and a 1/4 inch diameter hole (drainage port) in the protective casing centered 1/8 inch above this level. The mortar mix shall be (by weight) 1 part cement to 2 parts sand (the granular filter used around the well screen), with minimal water for placement. Placement is required on the day of firm grout remaining at ground surface and at least 48 consecutive hours prior to well development.

(12) The application of at least a .5' thick coarse gravel (3/4" to 3" particle size) blanket extending 4' radially from the protective casing (see Figure 9 for layout and dimensions). Prior to placement of this gravel pad, any depression around the well shall be backfilled to slightly above the level

of the surrounding ground surface with near-surface drill cuttings from that well or with clay. This will prevent a "bath tub" effect of water collecting in the gravel pad around the well casing. Construction of the gravel blanket is required prior to development. Some long-term, heavy traffic, or high visibility locations may warrant a concrete pad, specially designed for site conditions. Any concrete pad usage, especially in cold climates should be designed to withstand frost heaving. Frost uplift may adversely affect well and pad integrity.

(13) All elements of well protection shall be detailed in the drilling plan. In addition, unique well protection requirements for flood plains, frost heaving, heavy traffic areas, parking lots, wells finished at or below grade, and other special circumstances, shall also be covered on a case-by-case basis, in the drilling plan.

6-10. Shallow Wells. Shallow (less than 15-foot) well construction may be more problematical than deep. The responsible FOA personnel will tailor design criteria to the actual environment and project objectives for appropriate shallow well construction.

6-11. Drilling Fluid Removal. When a borehole, made with or without the use of drilling fluid, contains and excessively thick, particulate-laden fluid which would preclude or hinder the specified well installation, the borehole fluid should be removed or displaced with approved water. This removal is intended to remove or dilute the thick fluid and thus facilitate the proper placement of casing, screen, granular filter, and seal. Fluid losses in this operation shall be recorded on the well diagram or boring log and later on the well development record. Any fluid removal prior to well placement should be contingent upon the driller's and the geologist's evaluation of hole stability: long enough for the desired well and seal placement.

6-12. Drilling Fluid Losses in Bedrock. If large drilling fluid losses occur in bedrock and if the hole is cased to bedrock, the FDO may remove at least 5 times this volumetric loss prior to well insertion. The intent here is to allow the placement of a larger pump in the borehole than otherwise possible in the well casing, thereby reducing subsequent development time and removing the lost water closer to the time of loss. Development of the completed well could then be reduced by a volume equal to that which was removed as above.

6-13. Well Construction Diagrams.

a. Each installed well shall be depicted in a well diagram. This diagram should be attached to the original bore log for that installation and graphically denote, by depth from ground surface:

(1) The bottom of the boring (that part of the boring most deeply penetrated by drilling and/or sampling) and boring diameter(s).

(2) Screen location.

(3) Joint locations.

(4) Granular filter pack.

(5) Seal.

(6) Grout.

(7) Cave-in.

(8) Centralizers.

(9) Height of riser (stickup) without cap/plug above ground surface.

(10) Protective casing detail.

(a) Height of protective casing, without cap/cover, above ground surface.

(b) Base of protective casing below ground surface.

(c) Drainage port location and size.

(d) Internal mortar collar location.

(e) Gravel blanket height and extent.

(f) Protective post configuration.

(11) Water level 24 hours after completion with date and time of measurement.

b. Describe on the diagram:

(1) The actual quantity and composition of the grout, bentonite seals, and granular filter pack used for each well.

(2) The screen slot size (in inches), slot configuration, total open area per foot of screen, outside diameter, nominal inside diameter, schedule/thickness, composition, and manufacturer.

(3) The material between the bottom of the boring and the bottom of the screen.

(4) The outside diameter, nominal inside diameter, schedule/thickness, composition, and manufacturer of the well casing.

(5) The joint design and composition.

(6) Centralizer design and composition.

(7) Depth and description of any permanent pump or sampling device.

(8) Protective casing composition and nominal inside diameter.

(9) Special problems and their resolutions; e.g., grout in wells, lost casing and/or screens, briding, casing repairs or adjustments, etc.

(10) Dates and times for the start and completion of well installation.

c. Each diagram shall be attached to the original boring log and submitted from the field to the responsible FOA.

d. Only the original well diagram and boring log shall be submitted to the FOA. Carbon, typed, or reproduced copies shall not suffice. A legible copy of the well diagram may be used as a base for the supplemental protection diagram.

e. Special abbreviations used on the well completion diagram shall be defined on the diagram.

CHAPTER 7

WELL DEVELOPMENT

7-1. General. Well development is that process which restores or locally improves the aquifer's hydraulic conductivity and removes well drilling fluids, muds, cuttings, mobile particulates, and entrapped gases from within and adjacent the well. The resulting inflow should be physically and chemically representative of the aquifer.

7-2. Timing and Record Submittal. The development of monitor wells shall be initiated not sooner than 48 hours after, nor longer than 7 days beyond internal mortar collar placement. The record of well development shall be submitted to the FOA.

7-3. Pump and Bailer Usage. Development shall be accomplished with a pump and may be supplemented with a bottom discharge/filling bailer (for sediment removal) and surge block. Pumps may be replaced by bottom filling bailers where well size or slow recharge rates restrict pump usage. Bailers shall not be left inside the wells after development is completed. Such storage promotes accidental bailer release or loss down the well and inhibits convenient and accurate water level measurements. The use of a surge block or periodically stopping the pump can agitate and mobilize particulates around the well screen. By pumping the well at a higher rate than that expected during sampling, one may remove the mobilized particulates, thereby providing a cleaner well for sampling. However, a disadvantage of only pumping (especially overpumping) a well is that the smaller fraction of the filter pack and/or aquifer may bridge in or near the screen. To lessen this potential, pumping may be coupled with backwashing or surging and the pumping rate may be reduced.

7-4. Development Criteria. Development shall proceed until the follow criteria are met:

a. The well water is clear to the unaided eye.

b. The sediment thickness remaining within the well is less than 1 percent of the screen length or less than 0.1' for screens equal to or less than 10 feet long.

c. In addition to minimally removing 5 times the standing water volume in the well (to include the well screen and casing plus saturated annulus, assuming 30 percent porosity), the following shall apply:

(1) For those wells where the boring was made without the use of drilling fluid(mud and/or water), 5 times any water used in granular filter pack placement shall be removed.

(2) For those wells where the boring was made or enlarged (totally or partially) with the use of drilling fluid (mud and/or water), remove an additional 5 times the measured amount of total fluids lost while drilling plus 5 times that used in filter pack placement as above.

(3) Should recharge be so slow that the required volume cannot be removed in 48 consecutive hours, the water remains discolored, or excess sediment remains after the 5 volume removal; contact the FOA for guidance.

d. Water SHALL NOT be added to a well as part of development once the initial seal atop the filter pack is placed.

e. The use of air to develop a well SHALL NOT be allowed. The introduction of air into a well enhances the occurrence of chemical, physical, and biological changes to the local aquifer system monitored by the well. Furthermore, procedures involving compressed air at HTW sites increases potential exposure/health risks to site personnel from the volatization and misting of the aerated water.

7-5. Development-Sampling Break. Well development shall be completed at least 14 days before well sampling. The intent of this hiatus is to provide time for the newly installed well and backfill materials to surficially equilibrate to their new environment and for that environment to re-stabilize after the disturbance of drilling. Though a significant volume of water may be pulled through the well during development, the well and granular backfill surfaces over which this water passes are not likely to be at chemical equilibrium with the aquifer. Intuitively, the hiatus allows time for that equilibrium to be created, thereby enhancing the probability of the resulting sample to be more representative of the host aquifer. While the 14-day hiatus is an arbitrary value, initiated in the early 1980's by USATHAMA, the value has not been technically challenged using supportive data. Therefore, if a different value is suggested based upon technical data or overall project considerations, then such a change shall be evaluated and, if deemed appropriate, implemented.

7-6. Pump/Bailer Movement. During development, water shall be removed throughout the entire water column in the well by periodically lowering and raising the pump intake (or bailer stopping point).

7-7. Development Water Sample. For each well, a 1 pint sample of the last water to be removed during development shall be placed in a clear glass jar, labeled with well number and date. No preservation of these samples is required. Each sample shall be individually agitated and immediately photographed close-up by the FDO with a 35 mm camera and color print film, using a back-lit set-up to show water clarity. These photos, minimally 5" x 7", individually identified with project name, well number, and photo date; shall be provided to the FOA after all wells are developed. The FDO shall dispose of these samples in the same manner as the rest of the water removed during

development. The film negatives should also be provided to the FOA after the FOA has received the prints.

7-8. Well Washing. Part of well development shall include the washing of the entire well cap and the interior of the well casing above the water table using only water from that well. The result of this operation will be a well casing free of extraneous materials (grout, bentonite, sand, etc.) inside the well cap and blank casing, between the top of the well and the water table. This washing shall be conducted before and/or during development, not after development. Where free phase contaminants are present; e.g., petroleum products, the need for washing should be reevaluated by the FOA.

7-9. Problems. If problems are encountered during development, contact the FOA for guidance.

7-10. Well Development Record. The following data shall be recorded as part of development and submitted:

a. Project name, location.

b. Well designation, location.

c. Date(s) and time(s) of well installation.

d. Date(s) and time(s) of well development.

e. Static water level from top of well casing before and 24 hours after development.

f. Quantity of mud/water:

(1) Lost during drilling.

(2) Removed prior to well insertion.

(3) Lost during thick fluid displacement.

(4) Added during granular filter placement.

g. Quantity of fluid in well prior to development:

(1) Standing in well.

(2) Contained in saturated annulus (assume 30 percent porosity).

h. Field measurement of pH, conductivity, and temperature before, twice during, and after development using an appropriate device and method according to EPA 600/4-79-020: Methods for Chemical Analysis of Water and Wastes.

i. Depth from top of well casing to bottom of well.

j. Screen length.

k. Depth from top of well casing to top of sediment inside well, before and after development (from actual measurements at time of development).

l. Physical character of removed water, to include changes during development in clarity, color, particulates, and any noted odor.

m. Type and size/capacity of pump and/or bailer used.

n. Description of surge technique, if used.

o. Height of well casing above ground surface (from actual measurement at time of development).

p. Typical pumping rate.

q. Estimated recharge rate.

r. Quantity of fluid/water removed and time for removal (present both incremental and total values).

s. Quantity of sediment removed.

7-11. Potential Difficulties. Many difficulties may arise during development and presample purging. Some are readily apparent but troublesome to resolve; e.g., a well that is easily pumped dry but slow to recharge; or one that will not produce clear, particulate free water. Other difficulties are not easily observed but may bias the analytical results; e.g., pulling-in distant parts of the aquifer in an effort to achieve a repetitively consistent field reading; or aerating the aquifer adjacent the well in a hurried attempt at well development. The anticipation, evaluation, and tentative solution for these problems shall begin early in the formulation of each drilling plan.

CHAPTER 8

WELL AND BORING ACCEPTANCE CRITERIA

8-1. Well Criteria. Wells shall be acceptable to the responsible FOA. Well acceptance shall be on a case-by-case basis. The following criteria shall be used along with individual circumstances in the evaluation process.

a. The well and material placement shall meet the construction and placement specifications of the drilling and well installation plan unless modified, if at all, by any amendments.

b. Wells shall not contain portions of drill casing or augers unless they are contractually required as permanent casing.

c. All well casing and screen materials shall be free of any unsecured couplings, ruptures or other physical breakage/defects before and after installations.

d. The annular material (filter pack, bentonite, and grout) of the installed well shall form a continuous and uniform structure, free of any detectable fractures, cracks or voids.

e. Any casing or screen deformation or bending shall be minimal to the point of allowing the insertion and retrieval of the pump and/or bailer optimally designed for that size casing (e.g., a 3-inch pump in a 4-inch schedule 80, PVC casing is optimal; a 2-inch pump in a 4-inch casing is not optimal).

f. All joints shall be constructed to provide a straight, nonconstricting, and watertight fit.

g. Completed wells shall be free of extraneous objects or materials; e.g., tools, pumps, bailers, packers, excessive sediment thickness, grout, etc. This prohibition shall not apply to intentionally installed equipment per drilling plan.

h. For those monitor wells where the screen depth was determined by the FDO, the well shall have sufficient free water at the time of the water level measurement to obtain a representative groundwater level for that well. These same wells shall have sufficient free water, at the time of initial sampling, which is representative of the desired portion of the aquifer for the intended chemical analysis.

i. All boring logs, well diagrams, development records, topographic survey data, and related photographs and negatives shall have been completed per drilling plan and received by the responsible FOA.

j. Keys to the padlocks securing the well covers should be in the possession of the responsible FOA and the FOA project representative prior to well acceptance.

8-2. Abandoned Borings and Wells. Borings not completed as wells should be abandoned per section 3-14.

8-3. Well and Boring Rejection. Wells and borings not meeting drilling plan criteria are subject to rejection by the responsible FOA.

CHAPTER 9

WATER LEVELS

9-1. Measurement Frequency. The frequency of water level measurement is a function of each project. At a minimum, for those projects involving the installation of any monitoring wells, at least 1 complete set of static water level measurements shall be made over a single, consecutive 10 to 12-hour period for all wells, both newly installed and specified, existing wells. These measurements shall be taken at least 24 hours after development or sampling. Static levels in borings not converted to wells shall be included if practical and technically appropriate. This set of measurements should include a notation for the presence of any streams, lakes, and/or open water bodies (natural and manmade), within proximity; i.e., about 300 feet, of these wells. The measurement of any surficial bodies shall be a consideration within the drilling and well installation plan.

9-2. Vertical Control. The depth to groundwater shall be measured and reported to the nearest .01 foot. Measurement shall be made from the highest point on the rim of the well casing or riser (not protective casing). This same point on the well casing shall be surveyed for vertical control. Surface water levels shall be measured at least to the nearest .1 foot using an adjacent temporary or permanent survey marker as a datum for future reference.

9-3. Reporting and Usage. All water level data should be presented as elevations in tabular form. Where sufficient data points exist, the elevations should be contoured to denote flow directions, gradients, and any hydrological interconnections between aquifers and surficial water bodies.

CHAPTER 10

TOPOGRAPHIC SURVEY

10-1. Licensing. All topographic survey efforts conducted under contract shall be certified by a surveyor with a current, surveyor's license in the project state. Any licensing requirements within the project state for contract or Corps of Engineers surveyors shall be determined by the responsible FOA.

10-2. Horizontal Control. Each boring and/or well installation shall be locationally surveyed to determine its map coordinates referenced to either a Universal Transverse Mercator (UTM) grid or the State Plane Coordinate System (SPCS). These surveys shall be connected to the UTM or SPCS by 3rd order, class II control surveys in accordance with the "Standards and Specifications for Geodetic Control Networks." If the project is in an area remote from UTM or SPCS benchmarks and such horizontal control is not warranted, then locations measured from an alternate system depicted on project plans may suffice, at least on a temporary basis. All borings, wells temporary and/or permanent markers shall have an accuracy of ± 1 foot within the chosen system.

10-3. Vertical Control. Elevations for the natural ground surface (not the top of the coarse gravel blanket) and a designated point on the rim of the uncapped well casing (not protective casing) for each bore/well site shall be surveyed to within ± 0.01 foot referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929). These surveys shall be connected by 3rd order leveling to the NGVD of 1929 in accordance with the "Standards and Specifications for Geodetic Control Networks." If the project is in an area remote from NGVD benchmarks and such vertical control is not warranted, then elevations measured from a project datum may suffice, at least on a temporary basis.

10-4. Field Data. The topographic survey shall be completed as near to the time of last well completion as possible. Survey field data (as corrected), to include loop closures and other statistical data in accordance with the "Standards and Specifications" referenced in paragraphs 10-2 and 10-3 should be provided to the responsible FOA. Closure should be within the horizontal and vertical limits given above. These data shall clearly be listed in tabular form: the coordinates (and system) and elevation (ground surface and top of well) as appropriate, for all borings, wells, and reference marks. All permanent and semipermanent reference marks used for horizontal and vertical control (bench marks, caps, plates, chiseled cuts, rail spikes, etc.) shall be described in terms of their name, character, physical location, and reference value. These field data shall become part of the project records maintained by the responsible FOA.

CHAPTER 11

GEOPHYSICS

11-1. Usage and Reporting. The use of geophysical techniques, if required, will be specified in the drilling plan. In the absence of this specification, the FDO should consider these techniques for site specific applicability to enhance the technical acuity and cost-effectiveness of their efforts. Special applications may be useful in unexploded ordnance detection, disturbed area delineation, contaminant detection, depth to bedrock determination, buried drum detection, borehole and well logging, etc. When approved for use, geophysical techniques shall be discussed in the drilling plan, to include the purpose, particular method(s) and equipment, selection rationale, physical and procedural assumptions, limitations (theoretical and site specific), resolution, accuracy, and quality control. Safety aspects of geophysical applications shall be included in the safety plan, especially for those areas where induced electrical currents or seismic waves could detonate unexploded ordnance or other explosive materials.

11-2. Methods. General geophysical methodology is covered in EM 1110-1-1802. Geophysical techniques applied to HTW studies are found in USEPA, EPA 600/2-87/078, Nondestructive Testing Techniques to Detect Contained Subsurface Hazardous Waste; and Benson, R. C., et al, Geophysical Techniques for Sensing Buries Wastes and Waste Migration.

CHAPTER 12

VADOSE ZONE MONITORING

12-1. Usage and Reporting. Data acquisition from the vadose (unsaturated) zone shall be addressed on a case-by-case basis. The use of lysimeters in a silica flour matrix, soil-gas monitors, and analysis of bulk soil samples are mechanisms which may be employed. When vadose zone monitoring is proposed, the drilling plan shall include the purpose, particular method(s) and equipment, selection rationale, physical and procedural assumptions, limitations (theoretical and site-specific), quality control, and any analytical variances from the current USACE protocol.

12-2. Methods. A general discussion of vadose monitoring is found in Everett, L. G. et al, Vadose Zone Monitoring for Hazardous Waste Sites.

CHAPTER 13

BACKGROUND SAMPLING

13-1. Physical-Chemical Aspects. Within the areal boundaries of a project, "background" samples shall be comparable to "downgradient" samples in terms of current environmental setting, depositional environment, and physical composition. This means, for example, that if a potentially contaminated soil is an outcropping lacustrine clay, then the background sample shall be acquired from a similar lacustrine clay outcrop (ideally an extension of same clay unit) that is chemically, hydrologically, topographically, and meteorologically upgradient of the suspect contaminated area. This same logic of environmental comparability and direction also applies to the background sampling of surface water and groundwater. The evaluation of physically comparable environmental data is of the utmost importance if trace level variations within the chemical environment are to be determined.

CHAPTER 14

DATA MANAGEMENT SYSTEM

14-1. Benefits. The use of a computerized system will enhance reporting procedures via intrareport consistency, reduction of editorial review, broadening of graphical capabilities, and ease of data retrieval for project review and interproject comparisons. Each FOA is encouraged to establish a computerized Data Management System for technical data. Assistance can be obtained from MRD and USATHAMA.

APPENDIX A

FIGURES

WATER APPROVAL

Project for Intended Use:

1. Water source:
   Owner:
   Address:
   Telephone Number:

2. Water tap location:
   Operator:
   Address:

3. Type of source:
   Aquifer:
   Well depth:
   Static water level from ground surface:
   Date measured:

4. Type of treatment prior to tap:

5. Type of access:

6. Cost per gallon charged by Owner/Operator:

7. Attach results and dates of chemical analyses for past two years. Include name(s) and address(s) of analytical laboratory(s).

8. Attach results and dates of chemical analyses for project analytes by the laboratory certified by, or in the process of being certified.

SUBMITTED BY:

Company:

Person:

Telephone Number:

Date:

FOA APPROVAL (A)/DISAPPROVAL (D)	(check one)	
Project Officer:	A	D
Project Geologist/Date:	A	D

FIGURE 1

GRANULAR FILTER PACK APPROVAL

Project for Intended Use:

1. Filter Material Brand Name:
2. Lithology:
3. Grain Size Distribution:
4. Source:

   Company that made product:

   Location of pit/quarry of origin:
5. Processing Method:
6. Slot Size of Intended Screen:

Submitted by:

Company:

Person:

Telephone:

Date:

FOA APPROVAL (A)/DISAPPROVAL (D)	(check one)	
Project Officer Name/Date:	A	D
Project Geologist Name/Date:	A	D

FIGURE 2

MATERIALS SUMMARY

PROJECT: GENERAL AAP

Date: Oct-Nov 1987

Material (Example Entries)	Brand/Description (Example Entries*)	Source/Supplier (Example Entries*)
PVC Casing	4.0" ID, Schedule 40, flush threaded; 2" ID, Schedule 40, flush threaded	ABC Mfg; Aville, Minnesota
PVC Screen	.05" slot, 4.0" ID, Schedule 40, flush threaded, .02" slot, 2" ID, Schedule 40, flush threaded	ABC Mfg; Aville, Minnesota
Bentonite (drilling fluid and grout)	Tru-gel	A. O. Bentonite, Bville, Wyoming
Granular Bentonite (seal)	Gran-Bent	White Mud, Cville, Montana
Bentonite Pellets (seal)	(No brand name available)	PELBENT, Dville, Utah
Sand (filter pack)	8-12 silica sand	State Sand, Mville, Colorado; supplier: EFG, Co. Eville, Utah
Cement (grout)	Portland Type II	A. Lumber Co., Eville, Utah
Drilling Water	St. Peter Sandstone	Production Well #1, Tap at well house
Drilling Rod Lubricant	Slick Turn	Oil Products, Co., Fville, Texas
Air Compressor Oil	Oil #40	Oil Products Co., Fville, Texas

*All commercial brands and suppliers named in these examples are fictitious.

FIGURE 3

Hole No. 87-14

DRILLING LOG	DIVISION ABD	INSTALLATION EF DISTRICT	SHEET 1 OF 3 SHEETS
1. PROJECT GENERAL AAP		10. SIZE AND TYPE OF BIT 6" ROCK + NW CORE	
2. LOCATION (Coordinates or Station) SEE SKETCH		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) GROUND SURFACE	
3. DRILLING AGENCY ACME COMPANY		12. MANUFACTURER'S DESIGNATION OF DRILL ABC 20	
4. HOLE NO. (As shown on drawing title and file number) 87-14		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 8; UNDISTURBED —	
5. NAME OF DRILLER JARK JONES		14. TOTAL NUMBER CORE BOXES — 1 —	
		15. ELEVATION GROUND WATER 7.0' (8 NOV 87)	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		16. DATE HOLE: STARTED 7 NOV 87; COMPLETED 8 NOV 87	
7. THICKNESS OF OVERBURDEN 10.9'		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK 19.1'		18. TOTAL CORE RECOVERY FOR BORING 84.6 %	
9. TOTAL DEPTH OF HOLE 30.0'		19. SIGNATURE OF INSPECTOR J. Smith	

ELEVATION (FT)	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
	0			0		
	.8	OL	ORG CLAY, SANDY DK RED BRN 5YR3/4 (MUNSELL), V. MOIST L. PLAST, ROOTMAT TOPSOIL	S#1 JAR .8	3x3½ 3	NOTES 1. ALL SAMPLERS DRIVEN BY 140# HAMMER, 30" DROP 2. DEPTHS + RECOVERY IN FT
	1	SM	TRANSITIONAL .8–1.5		2	
			SILTY SAND 20% FINES F-M SAND < 60% F < 20% M MOIST, LOOSE YEL BRN 10YR 5/4 FAINTLY BEDDED FLAT LYING, X-BEDS <5% SILTY CLAY (CL) LAMINAE FLUVIAL	1.5	R1.5	NOTE 0' 1. DROVE 3X TO 1.5 2. DROVE 2X TO 3.5 3. DROVE STD TO 5.0 4. SET HSA W/ PLUG TO 5', PULLED PLUG (HSA: 3¼" ID 7" OD)
	2			S#2 JAR 3.0	2x2½ 4	
	3			3.5	6 R1.5	
	4			S#3 JAR 4.6	STD 2 4	
	.6		SHARP			
	5	SP	SAND <5% FINES F-C SAND {60% C, 10% M, 25% F} V. MOIST – SAT NO APPARENT BEDDING LOOSE, LT RED BRN 5YR 6/4 FLUVIAL	5.0	5 R1.5	END 7 NOV 87
	6			S#4 JAR 6.0	3X 10	START 8 NOV NOTE 5' 1. HOLE DRY & OPEN TO 5' 2. DROVE 3X TO 6.5' 3. DROVE 2X TO 8.5' 4. FREE WATER ON SAMPLER + IN SAMPLE 5. MEAS. H_2O AT 7.0' W/ ELEC. TAPE. AFTER 5 MIN, STILL AT 7.0'. 6. DROVE STD TO 10' 7. SET HSA W/ PLUG TO 10', PULLED PLUG
				6.5	5 R1.0	
	7		V. MOIST SAT	S#5 JAR 7.5	2X 8	
			SHARP		10	
	8	GP	SANDY GRAVEL 20% F-C SAND 80% F GRAVEL LT. RED BRN 5YR 6/4 MED DENSE SAT, NO APPARENT BEDDING, FLUVIAL	8.5	R1.0	
	9			S#6 JAR	STD 2	
	10					

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BORING LOG FORMAT

FIGURE 4

Page 1 of 3

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 87-14

PROJECT GENERAL AAP | INSTALLATION EF DISTRICT | SHEET 2 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		GP	SANDY GRAVEL (CONT'D)	S#7 JAR 10.5	3X 100 R.5	NOTE 10' 1. DRIVE 3X TO 10.9 (REFUSAL)
	10.9		APPROX (10.5–11.5)		10.9	2. PULLED ALL HSA, SET 6" CSG TO 11.5
	11	L C	TOP OF WEATHERED ROCK LIMESTONE (LM) BASED ON CUTTINGS 1.1 LOST DUE TO DRILL. METHOD		GEAR BIT 12.0	3. DRILLED W/ 6" GEAR BIT TO 12.0. WATER LOSS 30 GAL 11.5–12.0
	12	L C	LM, .5 LOST DUE TO WEATH. + FRACTURES	12.5		
			TOP OF SL. WEATH. ROCK		RUN #1	NOTE 12
	13	CIB	LIMESTONE SANDY (SILICEOUS) FOSSILIFEROUS NUMEROUS CORALS & GASTROPODS		R 1.5 14.0	1. START CORE RUN (NX) AT 12' W/ DOUBLE TUBE + BOT. DISC BIT.
	14	CIB	THIN, HORIZONTAL BEDDING YEL BRN 10YR 5/4 HARD	BOX 1 OF 1		2. RUN #1 40 GAL WATER LOST 12–12.5
	15	NB	WELL CEMENTED DENSE-COARSE GRAINED		RUN #2	0 LOSS 12.5–14 SOUNDED HOLE 14.0
		NB	SEAT (<5%) TIGHT			
	16	NB	45° FRACTURES No STAINING			NOTE 14
			SOLID, LOW PRIMARY & SECONDARY PERM.			1. RUN #2. NO WATER LOSS 14–18
	17	CIB	ST. GEORGE FORMATION			COMPLETE LOSS (50 GAL) 18–18.5 SH = 18.5
				18.0	R 4.0	NOTE 18.5
	18	L C	.5 LOST, LM BADLY FRACTURED	18.5	19.5	1. TOO FRACTURED TO CORE, USE GEAR BIT TO 30'
	19		11.5' LOST, HIGHLY FRACTURED LM (CUTTINGS) V. ROUGH DRILLING	S#8 JAR	GEAR BIT	2. LOST 500 GAL 3. HOLE OPEN TO 30'
	20	L C		20		NOTE 30 1. SET 2" WELL (PVC) 2. PULLED ALL CSG
	30		BOTTOM OF HOLE 30'			

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BORING LOG FORMAT (Continued)

FIGURE 4

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 87-14

PROJECT GENERAL AAP | INSTALLATION EF DISTRICT | SHEET 3 OF 3 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

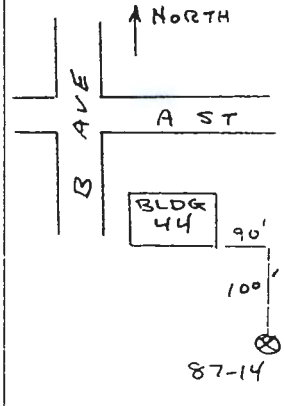
ABBRVEATIONS — MEANING

3X3 1/2 } ID & OD OF SPLIT BARREL
2X2 1/2 } SAMPLER

STD - 1 3/8X2 STANDARD SAMPLER
R - RECOVERY
CIB - CORING INDUCED BREAK
NB - NATURAL BREAK
LC - LOST CORE
3X - 3X3 1/2 SAMPLER
2X - 2X2 1/2 SAMPLER
AAP - ARMY AMMUNITION PLANT

NOTE:
COMPONENT PERCENTAGES ARE ONLY APPROXIMATIONS.

LOCATION



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BORING LOG FORMAT (Continued)

FIGURE 4

HTW DRILLING LOG

		HOLE NO.
1. COMPANY NAME	2. DRILLING SUBCONTRACTOR	SHEET 1 OF SHEETS
3. PROJECT	4. LOCATION	
5. NAME OF DRILLER	6. MANUFACTURER'S DESIGNATION OF DRILL	
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	8. HOLE LOCATION	
	9. SURFACE ELEVATION	
	10. DATE STARTED	11. DATE COMPLETED
12. OVERBURDEN THICKNESS	15. DEPTH GROUNDWATER ENCOUNTERED	
13. DEPTH DRILLED INTO ROCK	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	
14. TOTAL DEPTH OF HOLE	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX NO. e	ANALYTICAL SAMPLE NO. f	BLOW COUNTS g	REMARKS h

PROJECT	HOLE NO.

MRK FORM JUN 69 55

HTW DRILLING LOG

FIGURE 5

Page 1 of 2

HTW DRILLING LOG

HOLE NO.

PROJECT	INSPECTOR	SHEET OF SHEETS

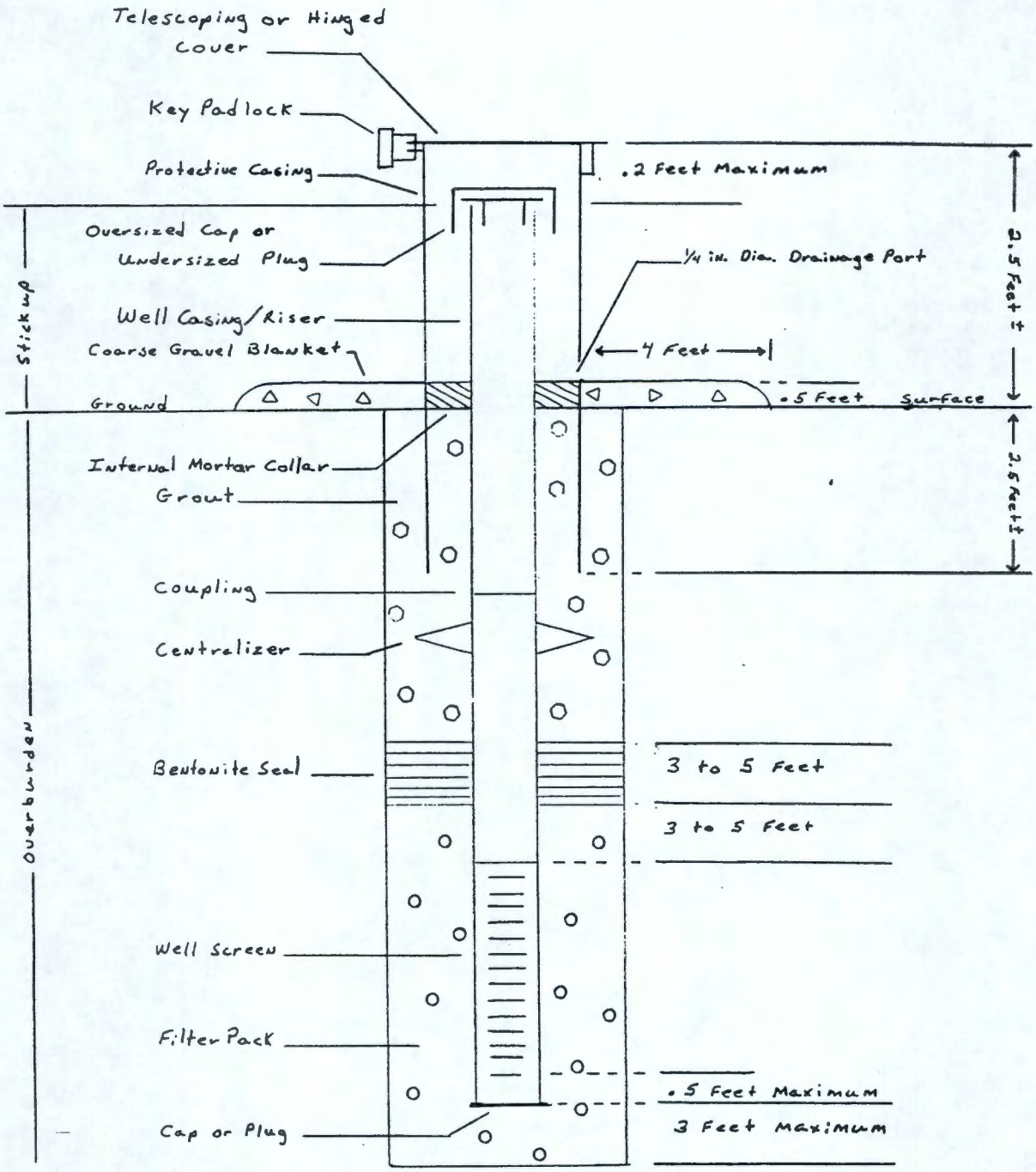
ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX NO. e	ANALYTICAL SAMPLE NO. f	BLOW COUNTS g	REMARKS h

MRK FORM JUN 89 55-2 | PROJECT | HOLE NO.

HTW DRILLING LOG (Continued)

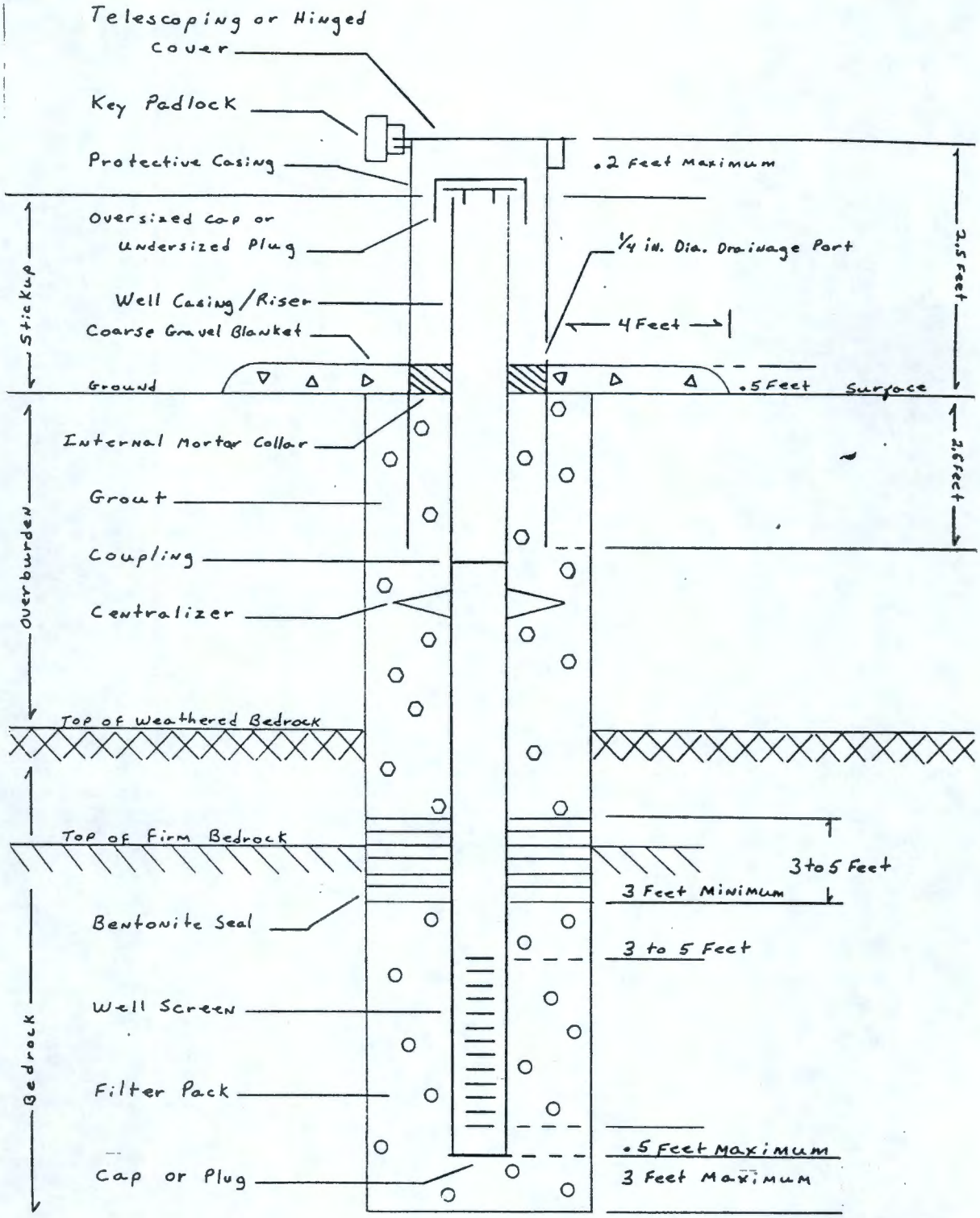
FIGURE 5

Page 2 of 2



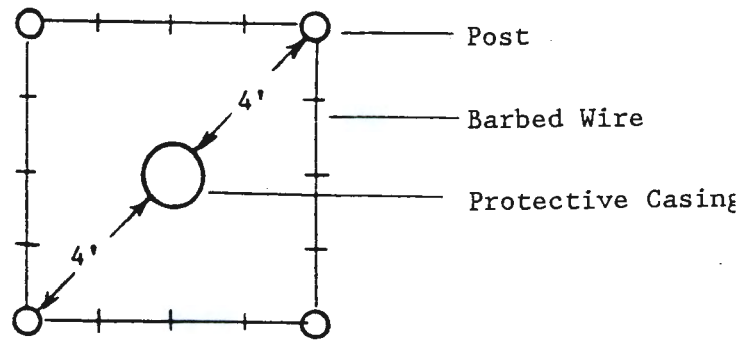
SCHEMATIC CONSTRUCTION OF OVERBURDEN WELL

FIGURE 6

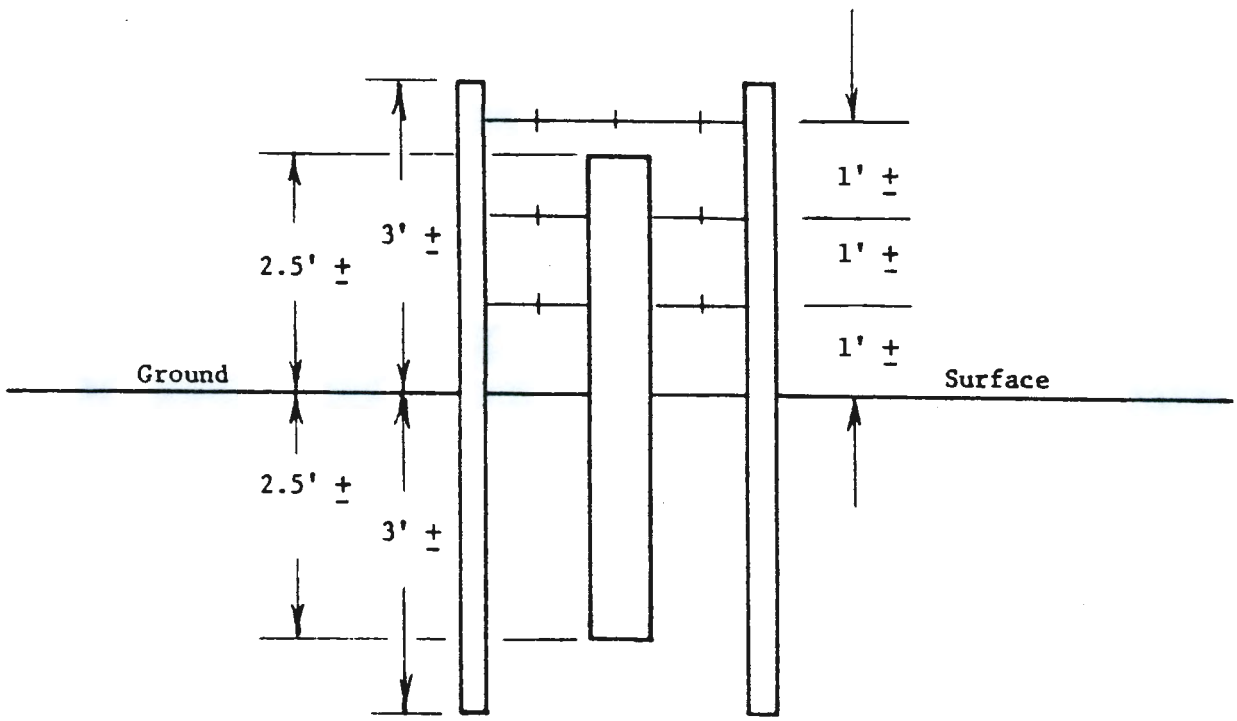


SCHEMATIC CONSTRUCTION OF BEDROCK WELL

FIGURE 7



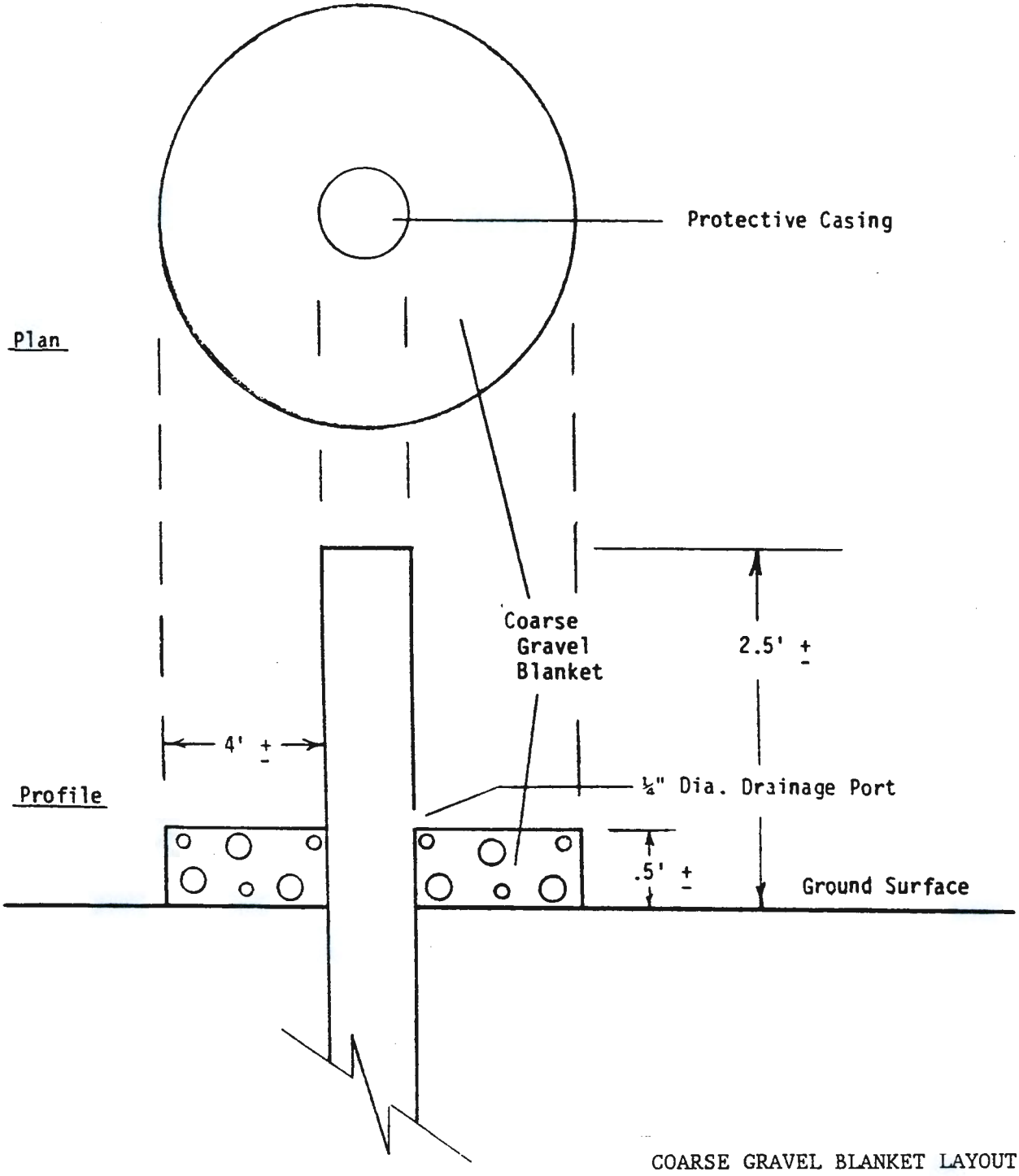
Plan



Profile

POST PLACEMENT AROUND WELLS

FIGURE 8



COARSE GRAVEL BLANKET LAYOUT

FIGURE 9