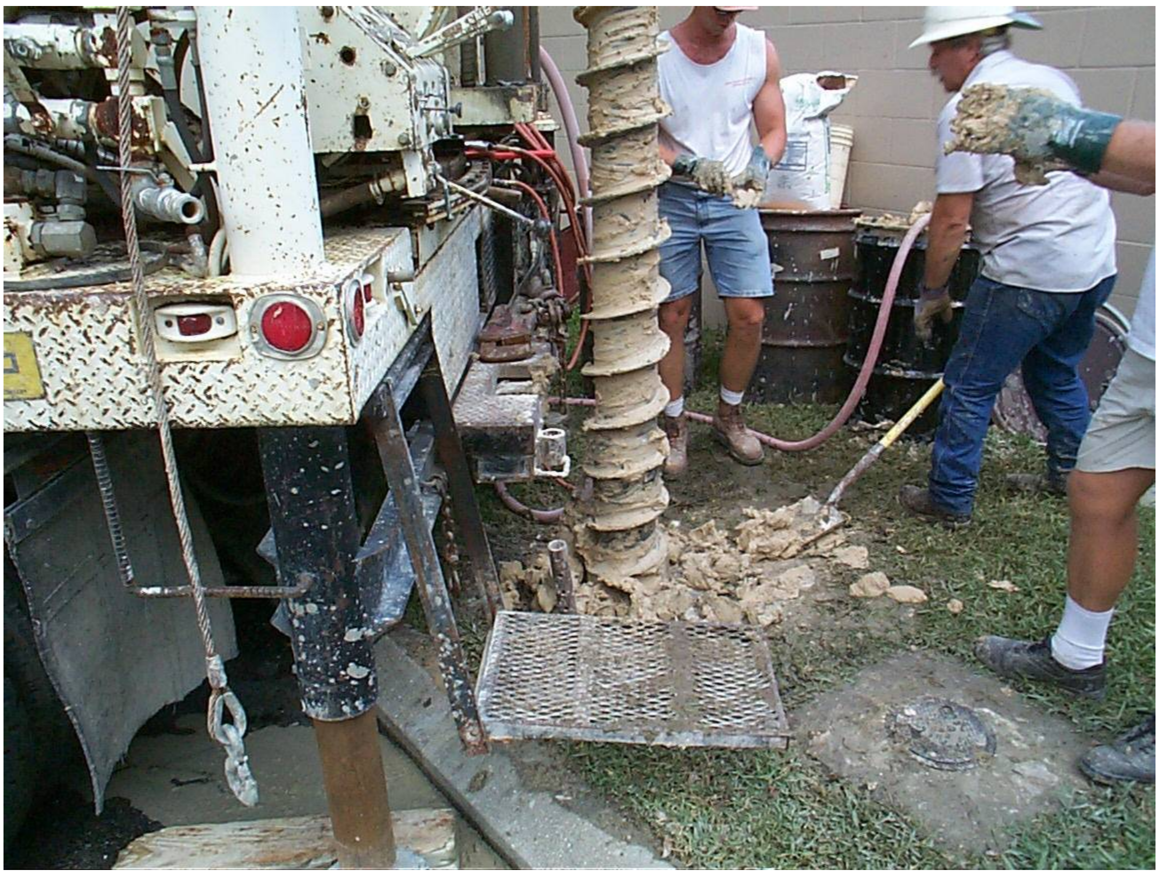
Monitoring Well Design and Construction Guidance Manual



Florida Department of Environmental Protection
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Monitoring Well Design and Construction Guidance Manual

1.0 Introduction

1.1 Purpose

This guidance manual provides the protocols and recommended procedures for the proper design and construction of monitoring wells such that quality ground water samples representative of actual conditions can be collected. A properly designed, installed and developed ground water monitoring well provides ground water samples that exhibit the physical and chemical properties of that portion of the aquifer screened by the well.

1.2 Planning

Each monitoring well within a network requires a design that considers project objective, site geology, hydrology, site history, waste site operational history (if applicable), ground water quality, and anticipated contaminants of concern. Prior to monitoring well design and installation, development of a conceptual hydrogeologic framework that identifies potential flow path and the target monitoring zone(s) is necessary. The following site characterization data elements should be utilized to form a conceptual model of the site:

1) Site geology and hydrology;

2) Potential contaminant sources, properties, and distribution;

3) Release mechanism and rates;

4) Fate and transport processes;

5) Current and potential receptors;

6) Potential remedial options; and

7) Other available site characterization data.

1.3 Design Considerations

The design and installation of monitoring wells should consider 1) permanence, 2) installation methodology, and 3) well construction requirements. Many factors must be considered when evaluating each of these three components, utilizing only the most reliable data and information. Monitoring requirements and project timeline and objectives will, in part, determine the need for temporary and/or permanent wells. Site conditions, geological and hydrological settings will influence the types of required drilling method, installation procedures and well construction characteristics. When designing monitoring wells, the U.S. Environmental Protection Agency (USEPA) document, *Environmental Investigations Standard Operating Procedure and Quality Assurance Manual*, Section 6, (2001), recommends the following considerations:

1) Short- and long-term objectives,
2) Purpose(s) of the well(s),
3) Probable duration of the monitoring program,
4) Contaminants likely to be monitored,
5) Types of well construction materials to be used,
6) Surface and subsurface geologic conditions,
7) Properties of the aquifer(s) to be monitored,
8) Well screen placement,
9) General site conditions, and
10) Potential site health and safety hazards.

A ground water monitoring and well installation plan can be developed from these data and information. The plan should address all phases of the installation and monitoring program, including site access, health and safety, drilling techniques, decontamination protocol, well installation, well development, well abandonment, sample collection, waste management, and site surveys.

2.0 Drilling Operations

A driller, water well contractor or water well consultant should ensure that all materials and equipment for drilling and installing any given well are available and onsite prior to commencing drilling activities. For long schedules, it should be ensured that the above-mentioned materials needed for at least 2 days of operation are onsite prior to drilling. Site-specific factors that preclude the availability of needed secure storage areas should be identified and resolved in a ground water monitoring plan.

2.1 Logistics

2.1.1 Permitting, Licenses and Registration

The driller, water well contractor, and/or water well consultant is responsible for identifying all applicable permits, licenses, professional registration, rights-of-entry, and applicable State and local regulatory procedures for drilling, well installation, and well abandonment (to include any requirements for the submission of well logs, samples, etc). Acquisition and submittal of these items to State or local authorities should be coordinated between the driller, contactor, and/or consultant, with the responsibilities of each specified in a ground water monitoring plan and subcontract agreements.

2.1.2 Access and Security

The need for any rights-of-entry should be specified in a ground water monitoring plan along with the organization(s) responsible for their acquisition. The driller or water well contractor shall comply with all security policies at a project site. The driller is responsible for securing his own equipment, and should prepare for any special situations identified in a ground water monitoring plan.

2.1.3 Site Safety

Safety precautions should be implemented for any drilling operation and in particular for activities related to the investigation and monitoring of hazardous and potentially hazardous materials sites. When appropriate, a site health and safety plan should be developed and followed during all drilling activities. The driller or designated safety person should be responsible for the safety of the drilling team during all drilling activities. All personnel involved with drilling activities should be qualified in proper drilling and safety procedures. Guidance related to drilling activities is available in Occupational Safety and Health Administration (OSHA) documents, particularly 29 CFR 1910.120 and 29, CFR 1926.

2.1.4 Site Preparation, Well Installation and Restoration

2.1.4.1 Site Reconnaissance

Site visits should be made prior to drilling activities to evaluate physical conditions and equipment and logistical requirements. Particular interests include site access, proximal utilities, barriers and hindrances to movement of equipment, potential hazards, and geographical locations of support facilities (i.e., drilling supplies, drilling water, sample shipment facilities, and emergency facilities). Site modifications and adaptations to drilling plans should be made accordingly and as is practical.

2.1.4.2 Utility Clearances

Prior to drilling or excavation activities, the driller, water well contractor, water well consultant, or appropriate person must coordinate with the appropriate utility locator services to identify and locate all underground utilities and other subsurface features that could obstruct or be damaged by such activities. Digging permits may be required and a locator service given notice to allow adequate time to locate and mark utilities prior to any onsite operations. Overhead utilities and structures should also be considered with respect to clearance space required by the drilling equipment.

As appropriate, boreholes should be advanced to a minimum of two to three feet below land surface (or more as required or needed) with a hand auger or post hole digger. The diameter of the manually advanced borehole should be at least as wide as the largest auger or other equipment to be placed within the borehole.

2.1.4.3 Equipment

The driller should arrive at the site with all the necessary personnel, supplies, and equipment to complete the specified tasks described in Chapter 3.0, Well Design and Material Specifications. All equipment must have been properly inspected, serviced, maintained, and tested prior to relocation to the site to ensure that it is in proper working condition, and to minimize the potential for delays. Sufficient replacement or repair equipment and supplies shall be kept on hand or readily available in the event of mechanical failures or malfunctions.

2.1.4.4 Borehole Requirements

The borehole shall be drilled and constructed so as to 1) allow for the proper construction of the monitoring well, 2) properly monitor the parameters of interest and 3) meet the objectives of the ground water monitoring program. Generally, monitored parameters occur in ground water as aqueous (those dissolved in the ground water) non-aqueous phase liquids (NAPLS) and particulate matter (colloid-sized particles that may be inert or biologically active. The borehole must allow for the proper placement of the well screen so as to allow for monitoring of parameters based upon chemical and physical characteristics.

The borehole shall be drilled as close to vertical as possible. Slanted boreholes are not acceptable unless specified in the design. The depth and volume of the borehole, including any overdrilling if applicable, should be calculated such that appropriate quantities of materials are procured and installed during well construction. Table A-1 Appendix A, provides several typical volume calculations for use during boring and well installation. If the well boring is drilled too deeply, it should be backfilled to the desired installation depth with pure bentonite pellets (for fine-grained aquifers) or filter sand (for coarse-grained aquifers). If bentonite pellets are used, a minimum of 1 foot of filter sand should be placed above the bentonite prior to screen installation. This will protect the bottom of the well screen from bentonite intrusion.

The selected hollow-stem augers, temporary casing, or permanent surface casing should have an inside diameter (I.D.) sufficient to allow the installation of the prescribed diameter screen and well riser plus annular space for a tremie pipe through which to place the filter pack and annular sealants. It is advantageous that the I.D. of the drill casing or hollow-stem auger be at least 4 inches greater than the outside diameter (O.D.) of the centered well riser and screen. This increased borehole size will allow placement of a wider filter pack, annular seal, and annular grout. This will also allow the use of a 1.5-inch O.D. tremie pipe for emplacing well construction materials. However, larger diameter augers will also result in additional drilling time, increased cost of well installation, and increased production of investigations-derived waste (IDW), including drill cuttings and fluids removed from the borehole and monitoring well. Depending upon the project objectives and regulatory requirements, the advantages must be weighed against the disadvantages such that the project objectives are met with the minimum cost incurred.

When telescoping outer casings (one casing within another), the specified annulus may not be practical or functional. In this case, a lesser spacing allowing for proper grout placement may be acceptable, depending on site specifics and project objectives.

A separate pilot boring should be advanced if significant drilling beyond the desired screen interval(s) is required (as for defining stratigraphy or locating a zone of interest). Upon completion of the exploration, the pilot boring should be properly abandoned and a new boring advanced for the placement of a monitoring well. ASTM Standard D5299 provides guidance for abandonment of boreholes and ground water wells.

2.1.4.5 Well Installation Schedule

Ideally, well installation should begin immediately after boring completion. Once installation has begun, no breaks in the installation process should be made until the well has been grouted and temporary drill casing removed. This includes interruptions due to the end of the driller's work shift, weekend, or holiday. This does not include the time required for proper hydration of the bentonite seal.

Unscheduled delays may occur, including personal injury, equipment breakdowns, or sudden inclement weather. Scheduled delays may also occur such as the time required for downhole geophysical surveys. In such cases, the type of delay, beginning and ending times of the delay, and the delay interval should be noted on a well construction diagram (Section 3.2). In instances where a cased hole into bedrock is to be partially developed prior to well insertion, well installation should begin within 12 hours after this initial development.

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 wall 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.

Any materials, especially soils, blocking the bottom of the drill casing or hollow-stem auger should be dislodged and removed from the casing prior to well insertion. The use of a bottom plug, dove-tail bit, or internal drill rods during drilling may be beneficial for reducing and/or eliminating soil blocking and heaving sands. If used, the composition of any disposable bottom plug (such as stainless steel or wooden plug) must be appropriate considering the analytical parameters of interest.

2.1.4.6 Restoration

All work areas around the wells and/or borings should be restored to a condition equivalent to that prior to installation. This includes the disposal of borehole cuttings and rut repair. IDW, i.e., borehole cuttings, discarded samples, drilling fluids, equipment cleaning residue, water removed from a well during installation, development, or aquifer testing, and personal protection equipment (PPE) must be disposed of in a manner consistent with a waste management plan and all applicable Federal, State, and local regulations and ordinances. Restoration, disposal procedures, and responsibilities should be discussed in detail in a ground water monitoring plan.

2.2 Oversight

A site geologist, engineer or geotechnical engineer, suitably qualified to conduct hydrogeologic investigations should be present at each operating drill rig. The site geologist, engineer or geotechnical engineer must be familiar with all State, Federal, and local laws, regulations, and requirements pertaining to the geologist's, engineer's or geotechnical engineer's duties and responsibilities. The geologist, engineer or geotechnical engineer shall be responsible for logging, acquisition, and shipment of samples, boring logs and well construction diagrams, and recording the well installation and abandonment procedures. Ideally, each site geologist, engineer or geotechnical engineer should be responsible for only one operating rig. The geologist, engineer or geotechnical engineer should have onsite sufficient tools, forms, and professional equipment in operable condition to efficiently perform the duties as outlined in this manual or other relevant project documents.

2.3 Drilling Methodology

2.3.1 Objectives

The objectives of selecting a drilling method for monitoring well installation are to use that technique which:

1) Provides representative data and samples consistent with project objectives;

2) Eliminates or minimizes the potential for subsurface contamination and/or cross-contamination; and

3) Minimizes drilling costs.

2.3.2 Methods

There are several drilling methods that can be used for site characterization and to install acceptable monitoring wells. Additional information and details on the various drilling methods can be found in Driscoll (1986), U.S. Army Corp of Engineers (USCOE) (1998), National Ground Water Association (1998) and Section 6.3 of the EPA manual, as well as numerous other sources. In addition, ASTM International maintains standards, ASTM D6286 and ASTM D5092, for selection of drilling methods for site characterization and the design and installation of ground water monitoring wells, respectively, as well as method-specific standards for many drilling techniques. The following drilling methods are most typically used in the installation of monitoring wells:

1) Hollow-stem augers;

2) Solid-stem augers;

3) Water/mud rotary;

4) Air/pneumatic rotary;

5) Sonic;

6) Direct Push; and

7) Casing or cable

The drilling method must be specified and described in a ground water monitoring plan. The plan should also contain detailed rationale for the selection of the specified method including, but not limited to, how the anticipated drilling conditions are accounted for by the selected method and how cross-contamination would be minimized.

2.3.3 Concerns Related to Drilling Methodology

Dry methods: Dry methods advance a boring using purely mechanical means without the aid of an aqueous or pneumatic drilling "fluid" for cuttings removal, bit cooling, or borehole stabilization. In this way, the chemical interaction with the subsurface is minimized, though not eliminated. Local aeration and heating of the borehole wall, for example, may occur simply by the removal of compacted or confining soil or rock (USCOE, 1998).

Aqueous methods: Aqueous drilling methods use fluid, usually either approved water or water and bentonite slurry, for cuttings removal, bit cooling, and borehole stabilization (USCOE, 1998). For environmental work, the use of these materials increases the potential to add a new contaminant or suite of contaminants to the subsurface environment adjacent to the boring. Even the removal of one or more volumes of water equal to the volume lost during drilling will not remove all of the lost fluid. The level of effort to be expended upon well development is directly related to the amount of fluid lost during drilling: a minimum of five times the volume lost should be removed during development. Therefore, the less fluid loss, the less the development effort, time, and cost.

Air/Pneumatic Rotary methods: Air/pneumatic rotary methods involve the use of compressed air to evacuate cuttings. Potential problems with this method include the introduction of pollutants such as hydrocarbons into the subsurface from the compressed air source, volatilization/stripping of contaminants from the subsurface, and mobilization of dust and/or vapor phase components to create a potential breathing hazard. However, this method may be advantageous in materials where circulation of other fluids cannot be maintained. Appropriate dust collection/suppression equipment must be provided. Wells installed using this method must be developed until the water becomes clear and free of sediment.

Sonic methods: The fundamental difference between the sonic drilling method and other rotary-type methods is that it employs a combination of rotation and high-frequency vibration for drill bit penetration. This method is suitable for use in either consolidated or unconsolidated materials. The advantages of this technology are rapid drilling rates and relatively minimal amounts of waste generated. Disadvantages include potential disturbance to samples collected for geotechnical analyses and volatilization of chemical samples.

Direct push Technologies: Direct push technologies (DPT) utilize equipment that push or drive steel rods into the ground. They allow cost-effective, rapid sampling and data collection from unconsolidated soils and sediments. A tremendous variety of equipment is available, particularly in the type of attachments used at the end of rods to collect samples and data. These attachments may collect soil, soil gas, or ground water samples; they may conduct *in situ* analysis of contaminants; or they may collect geophysical data that are continuously logged as the DPT rods are advanced. Continuous logs of subsurface conditions are particularly valuable because they help to develop a three-dimensional conceptual site model.

Tables 1 and 2 provide a brief description and comparison of some common drilling methods.

Table 1: Drilling Methods for Monitoring Wells

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Auger, Hollow-Stem and Solid-Stem ASTM D5784, ASTM D1452	Successive 5-foot (1.5m) flights of spiral-shaped drill stem are rotated into the ground to create a borehole. Cuttings are brought to the surface by the rotation of the auger flights	150 (45)	• May be inexpensive • Fairly simple, quick setup time and moderately fast operation • Rigs are highly mobile and can reach most drilling sites • No drilling fluid or lubricants used, eliminating contamination from additives • Can be used to avoid hole caving • Hollow-stem allows formation water to be sampled during drilling via screened auger or advancing a well point ahead of the augers • Small-diameter wells can be built inside hollow-stem flights • Hollow-stem allows the collection of split-spoon samples, continuous sampling possible • Natural gamma-ray logging can be done inside hollow-stem flights	• Limited to unconsolidated or semiconsolidated (weathered rock) materials Compact, gravelly materials may be hard to penetrate • Possible problems controlling heaving sands • Rips and smears borehole wall, creating problems with connecting to the aquifer during well development • Well points yields low rates of water • Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated • May not be able to run a complete suite of geophysical logs

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Water/Mud Rotary (Hydraulic Rotary) ASTM D5783	Rotating bit breaks formation; cuttings are brought to the surface by a circulation fluid (mud). Mud (which should be contaminant-free water and bentonite without additives) is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and borehole wall. Cuttings are removed by settling in a mud pit at the ground surface and the mud is circulated back down the drill stem.	5,000+ (1,500+)	• Drilling is fairly rapid in all types of geologic materials, unconsolidated and consolidated • Borehole may stay open from formation of a mud wall on the sides of borehole by the circulating mud • Geologic cores can be collected • A complete suite of geophysical logs can be obtained in the open borehole • Many options for well construction. Can use casing-advancement drilling method, or casing may not be required • Smaller rigs can reach most drilling sites • Borehole can be gravel packed and easily grouted	• May be expensive, requires experienced driller and a fair amount of peripheral equipment; overburden casing required • Drilling fluids mix with formation water, may contaminate and can be difficult to remove. • Completed well may be difficult to develop, especially small diameter wells, due to mud cake invading the formation and is difficult to remove • Geological logging by visual inspection is only fair, can miss strata and composition • Location of water-bearing zones during drilling may be difficult to detect • Drilling fluid circulation is often lost and difficult to maintain in fractured rock, and gravel or cavernous zones • Difficult drilling in boulder and cobble zones • Circulation of drilling mud through a contaminated zone can create a hazard a ground surface and cross-contaminate clean zones • Organic drilling fluids can interfere with bacterial and/or organic-related analyses and are not allowed; bentonitic fluids with metal analyses, but may be necessary.

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Reverse Rotary ASTM D5781	Similar to hydraulic rotary, except the drilling fluid is circulated down the borehole outside the drill stem and is pumped up the inside; the reverse of the usual rotary method. Water is used as the drilling fluid and the borehole is kept open by the hydrostatic pressure of the water standing in the borehole.	5,000+ (1,500+)	• Drilling is readily accomplished in most geologic materials, unconsolidated and consolidated • Drilling is relatively fast and can be used for drilling large diameter boreholes • Large borehole diameter facilitates ease of well installation • Geophysical logs can be run prior to installation of well • Creates a "clean" borehole, not contaminated by introduced fluids • Split-spoon sampling possible	• May be expensive, requires experienced driller and a fair amount of peripheral equipment; overburden casing required • May be difficult to drill in boulder, cobble or cavernous zones • The addition of drilling lubricants may be required: lubricants interfere with borehole wall composition and water chemistry • Cross-contamination from circulating water is likely • A large water supply is needed to maintain hydrostatic pressure in deep holes and when highly conductive formations are encountered • Geologic samples brought to surface are generally of poor quality; fine-grained materials are washed out
Air Rotary ASTM D5782	Similar to hydraulic rotary. Air is used as the primary drilling "fluid" as opposed to mud or water	5,000+ (1,500+)	• Can be used in all geologic formations; most successfully in highly fractured environments • Useful at almost any depth • Drilling rates are usually fast • Can use the casing-advancement method • Drilling mud or water is not required • Borehole is accessible to geophysical logging prior to well installation • Geologic sampling is excellent in hard, dry formations • First water zone easily detected • Well development is relatively easy	• Relatively expensive, requires experienced drill crew • Overburden casing usually required • Air mixes with borehole water and blown from the hole, creating potential for cross-contamination, surface contamination, health and environmental risks • Water flow between zones with different hydrostatic pressures will occur between the time that drilling is completed and the hole is properly cases and grouted • Compressor discharge to air may contain hydrocarbons • Organic foam additives to aid cuttings removals may cause cross contamination

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Air-Percussion Rotary or Down-the-Hole Hammer (DTH) ASTM D5781	Air rotary with a reciprocating hammer connecting to the bit used to fracture rock.	600 (2,00)	• Very fast drill rates • Useful in all geologic formations • Only small amounts of water need for dust and bit temperature control • Cross-contamination potential can be reduced by driving casing • Can use casing-advancement method • Well development relatively easy	• Relatively expensive • As with most hydraulic rotary methods, the rig is large, heavy and has limited accessibility • Overburden casing usually required • Vertical mixing of water and air craters cross contamination potential • Hazard posed to surface environment if toxic compounds are encountered • DTH hammer drilling can cause hydraulic fracturing of borehole wall • The DTH hammer required lubrication during drilling • Organic foam additives for cuttings removal may contaminate samples
Sonic (Vibratory) ASTM D6914	Uses high-frequency mechanical vibration to take continuous core samples of overburden soils and most hard rocks.	500 (150)	• Can obtain large diameter, continuous and relatively undisturbed cores of almost any soil material without the use of drilling fluids • Can drill through boulders, wood, concrete and other construction debris • Can drill and sample most softer rock with a high percentage of core recovery • Drill rates are faster than most other methods • Large reduction of investigation-derived wastes	• Relatively expensive • Equipment is not readily available • Rock drilling requires the addition of water or air or both to remove drill cuttings • Extraction of casing can smear borehole wall with clays and silts • Extraction of casing can damage well screen

Method and ASTM Standard	Drilling Principle	Depth Limitation Feet (meters)	Advantages	Disadvantages
Direct Push ASTM D6724, ASTM D6725	Advances a sampling device into the subsurface by applying static pressure, impacts, or vibrations or any combination thereof to the above ground portion of the sampler extensions until the samples has been advanced its full length into the soil strata.	100 (30)	• Avoids use of drilling fluids and lubricants during drilling • Equipment is highly mobile • Disturbance of geochemical conditions during installation is minimized • Drilling and well screen installation is fast, considerably less labor intensive • Does not produce drill cuttings, reduction of investigation-derived wastes	• Limited to fairly soft materials such as clay, silt, sand and gravel • Compact, gravelly materials may be hard to penetrate • Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated • The small diameter drive pipe generally precluded conventional borehole geophysical logging • The drive points yield relatively low rates of water
Cable-Tool (Percussion) ASTM D5875, ASTM D5872	Borehole is created by dropping a heavy “string” of drill tools into well bore, crushing materials at the bottom. Cuttings are removed occasionally by bailer. Generally, casing is driven just ahead of the bottom of the hole; a hole greater than 6 inches in diameter is usually made	1,000+ (300+)	• Can be used in consolidated and unconsolidated formations • Can drill boulder, cobble, fractured and cavernous zones • Fairly accurate logs can be made from cuttings if collected often enough • Core samples easily obtained • Driving casing ahead of hole minimizes cross-contamination via vertical leakage of formation waters, maintains borehole stability • Excellent method for drilling in soils and rock where loss of circulation fluids is problematic • Recovery of borehole fluid samples excellent • Excellent method for detecting thin water-bearing zones • Excellent for well development	• The potential for cross-contamination of samples is very high • Steel casing must be used • Heavy steel drive pipe and drilling “tools” can limit accessibility • Heavier wall, larger diameter casing than that used for other drilling methods normally used • Cannot run a complete suite of geophysical logs due to the presence of the drive pipe • Temporary casing can cause problems with placement of effective filter pack and grout seal • Usually a screen must be set before a water sample can be collected • Heaving of unconsolidated sediment into bottom of casing can be problematic

Adapted from U.S. Army Corps of Engineers, November 1998

Table 2: Comparison of Drilling Methods

Drilling Method	Shallow and Intermediate Boreholes	Deep Boreholes	Water Sampling	Soil Sampling	Well Installation	Boulders and other obstructions	Control of Hydrostatic Pressure	Downhole Geophysics
Hollow-Stem Auger	E	P	E	E	E	P	F	L
Solid-Stem Auger	E	P	NA	NA	F	P	P	NA
Water/ Mud Rotary	E	E	P	P	F	G	E	E
Reverse Rotary	E	E	P	P	F	P	E	E
Air Rotary	E	E	P	P	F	G	P	P
Sonic	E	G	E	E	E	E	E	E
Direct Push	E	F	E	E	G	L	E	L
Cable-Tool (Cased Boring)	E	F	E	E	E	G	E	L

Notes:
E = Excellent
G = Good
F = Fair
P = Poor
L = Limited application
NA = Not applicable

2.3.4 Special Concerns

2.3.4.1 Recirculation Tanks and Sumps

Portable recirculation tanks should be used for mud or water rotary operations and similar functions. The use of dug sumps or pits (lined or unlined) are expressly prohibited to minimize cross-contamination and to optimize both personal safety and work area restoration (USCOE, 1998).

2.3.4.2 Surface Runoff

Surface runoff, e.g., precipitation, wasted or spilled drilling fluid, and miscellaneous spills and leaks, should not enter any boring or well either during or after construction. To help avoid such entry, the use of temporary casing, recirculation tanks, berms around the borehole, or temporary surficial bentonite packs is recommended (USCOE, 1998).

2.3.4.2 Drilling Fluids

To the extent practical, the use of water during drilling, and any other water used during well installation and completion, should be held to a minimum. When use of water is deemed necessary, the source of any water used must be specified in the ground water monitoring plan and approved by the appropriate authority. The driller should have the responsibility to procure, transport, and store the approved water required for project needs in a manner that avoids the chemical contamination or degradation of the approved water once obtained.

If there is a suitable source of approved water onsite, the source should be used. If no onsite approved water is available, a potential source must be located and water quality evaluated and approved prior to the arrival of any drilling equipment onsite. It is important that the approved water be free of site-related analytes. It is advantageous that the drilling water be pretested (sampled and analyzed) for the contaminants of interest. Knowledge of the water chemistry is the most important factor for water quality approval. Surface water bodies must not be used as a water source.

Pure bentonite (no additives) is the only drilling fluid additive that is typically allowed under normal circumstances. This includes any form of bentonite (powders, granules, or pellets) intended for drilling mud or sealants. The use of any bentonite shall be adequately discussed in the ground water monitoring plan, including documentation of the manufacturer’s recommendations and product constituents. Bentonite shall only be used if absolutely necessary to ensure that the borehole will not collapse or to improve cuttings removal (USCOE, 1998).

2.4 Decontamination

ASTM Standard D5088 provides guidance for decontamination of field equipment. All drilling equipment that is utilized in drilling or sampling activities must be cleaned or washed with high pressure hot water and decontaminated prior to arriving at the site or at the designated decontamination area before entering the site. This includes drilling rigs, support vehicles, water tanks (inside and out), augers, drill casings, rods, samples, tools, and recirculation tanks. The initial cleaning must be adequate to remove all rust, soil, or other material that may have been transported from another site. Any downhole auguring, drilling, and sampling equipment with paint, rust, or scale that cannot be removed by pressure washing or steam cleaning must be sandblasted prior to arrival on site. All equipment shall be inspected prior to site entry to confirm that all seals and gaskets are intact; no fluids are leaking; and all oil, grease, and other fluids have been removed. No oils or grease may be used to lubricate drill rods or any other equipment being used above or in the borehole without specific approval from the site geologist, engineer or geotechnical engineer. Such approval must be recorded on the well construction form.

All drilling, sampling, and associated downhole equipment that contacts the sample medium shall be cleaned and decontaminated by the following procedures:

1) Clean with approved water, laboratory-grade, phosphate-free detergent, and brush to remove particulate matter and surface films. Steam cleaning or high pressure hot water washing may be used in lieu of, or in addition to, brushing. Equipment that is hollow or perforated to transmit water or drilling fluids must be cleaned inside and outside. The steam cleaner or high pressure hot water washer must be capable of generating a pressure of at least 2500 PSI and producing hot water or steam of at least 200 ° F;

2) Rinse thoroughly with approved water. Approved water may be applied with a pump sprayer. All other decontamination liquids must be applied with non-interfering containers made of glass, Teflon ®, or stainless steel. Rinsing operations will be inspected by the site geologist, engineer or geotechnical engineer prior to initiation of work;

3) Rinse thoroughly with approved decontamination water;

4) Unless otherwise specified, rinse twice with pesticide-grade isopropanol;

5) Rinse thoroughly with approved decontamination water and allow to air dry;

6) Any equipment that will be stored or transported must be wrapped in aluminum foil (or clean plastic if equipment has been air dried);

7) Any printing or writing on well casing, tremie pipe, etc., arriving on site must be removed with sandpaper or emery cloth prior to initial cleaning; and

8) Well casing, tremie pipe, or other materials constructed of plastic or polyvinyl chloride (PVC) must be solvent rinsed during the cleaning and decontamination process.

After the onsite cleaning, only the equipment used or soiled at a particular boring or well should need to be cleaned between each boring or well at a given project. Paint applied by the equipment manufacturer may not have to be removed from drilling equipment, depending upon the paint composition and its contact with the environment and contaminants of concern. All equipment must 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 may be necessary before setting each string of smaller casing and before drilling beyond any casing. To the extent practical, all cleaning should be performed in a single remote area that is surficially cross gradient or downgradient and downwind from the clean equipment drying area and from any sited to be sampled. Waste solids and water from the cleaning and decontamination process shall be properly collected and disposed, as discussed in Chapter 5.0, Management of Investigation-Derived Waste. This may require that cleaning be conducted on a concrete pad or other surface from which the waste materials may be collected.

2.5 Sampling and Coring

A sufficient number of soil or rock samples should be collected and evaluated by the site and/or project geologist. The purpose of this collection is to provide a sound basis for the design of the ground water monitoring system. A “sufficient number of samples” is dependent on project-specific objectives, and should be described in the ground water monitoring plan. Soil samples should be collected according to ASTM Standards D1452, D1586, D3550, or D1587, whichever is appropriate given the anticipated characteristics of the soil samples. Rock samples should be collected using ASTM Standard D2113. Additional guidance on both soil and rock sampling can be found in ASTM Standard D6169.

2.5.1 Soil Sampling

The primary purpose of collecting soil samples, other than for chemical analysis, is the characterization of the subsurface lithology and stratigraphy. Typically, intact soil samples for physical descriptions are collected every 5 feet (1.5

meters) or at each change of material, whichever occurs first. Alternate sampling plans, with supporting information, should be detailed in the ground water monitoring plan. Additionally, a sufficient number of representative samples of the intervals significant to well design and hydrogeologic characterization should be collected for physical analyses; these results should then be used to support well design. These samples should be representative of the geographic and geologic range of materials within the project area and should specifically include the screened interval of a representative number of wells. Samples should be obtained with driven (e.g., split spoon), pushed (e.g., thin-wall Shelby tube), or rotary (e.g., Dennison) type samplers. Borehole cuttings do not usually provide the desired information and, therefore, are not usually satisfactory. Sampling procedures should be detailed in the ground water monitoring plan. Lithological logging of samples should be recorded according to the procedures listed in Section 2.9. Disposition of samples should be in accordance with Chapter 5.0

2.5.2 Rock Coring

Bedrock should be cored unless the ground water monitoring plan specifies otherwise. Coring, 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, tri-cone, etc., to penetrate bedrock should only be considered for the confirmation of the "top of rock" (where penetration is limited to a few feet), enlargement of a previously cored hole, or drilling of highly fractured intervals. Lithologic logging of the core should be conducted in accordance with Section 2.9, Documentation.

Rock cores should be retrieved and stored in such a way as to reflect natural conditions and relative stratigraphic position. Gaps in the core and intervals of lost core should be noted in the core sequence. Cores should be stored in covered core boxes to preserve their relative position by depth. Boxes should 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. Each box shall clearly denote the top and bottom of the rock core present in that box. Any core box known or suspected to contain contaminated core should be appropriately marked on the log and on the box cover, (inside and out), and on both ends. Storage of rock cores must be in accordance with the approved ground water monitoring plan, and disposition must be in accordance with Chapter 5.0.

If photographs of the core are taken, the core surface must be cleaned or peeled, as appropriate, and wetted. Photographs should be taken in color.

2.6 Drilling through Contaminated Zones

When drilling through contaminated strata to reach lower, possibly uncontaminated, strata, the potential for “drag down” of contamination should be minimized by drilling technique. In this procedure, an 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 drill fluids used to reach this point are disposed of according to Chapter 5.0 and replaced by a fresh supply. This system can be repeated, resulting in telescopic drill casing through which the final well casing is placed. These situations should be specifically addressed in the ground water monitoring plan.

2.7 Drilling Fluid Loss and Removal

When a borehole, made with or without the use of drilling fluid, contains an excessively thick, particulate-laden fluid that would preclude or hinder the specified well installation, the borehole fluid should be removed. This removal should facilitate the proper placement of casing, screen, granular filter, and seal.

Note: Unless the borehole wall has been supported by casing, the wall is likely to partially or completely collapse during fluid removal. Therefore, when no casing is present the fluid must be removed with great caution and the condition of the borehole monitored. Fluid losses in this operation must be recorded on the well diagram or boring log and later on the well development record. Any fluid removal prior to well replacement should be contingent upon the site geologist, engineer or geotechnical engineer’s evaluation of hole stability (i.e. sufficient for the desired well and seal placement).

If large drilling fluid losses occur in bedrock, the drilling operator should remove some of this fluid 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 the loss. Development of the completed well can then be reduced by a volume equal to that which was removed through the above procedure.

2.8 Abandonment

All soil borings not completed as wells must be abandoned in accordance with Chapter 7.0, Well and Boring Abandonment. In addition, wells that are deemed to be unnecessary for continued site monitoring or remediation system performance or to be structurally unsound should be abandoned.

2.9 Documentation

2.9.1 General

Each boring log should fully describe the subsurface environment and the procedures used to gain that description. Unless otherwise specified in the ground water monitoring plan, a log shall be produced for every boring completed. The information in subsection 2.9.3, Routine Entries, is required on boring logs although not necessarily in the format illustrated. Example soil and rock parameters for logging are included in Tables B-1 and B-2, respectively.

2.9.2 Time of Recording

Boring logs should be recorded directly in the field without transcription from a field book or other document. This technique minimizes the chance of errors of manual copying and allows the completed document to be field-reviewed closer to the time of drilling.

2.9.3 Routine Entries

In addition to specific data required by the ground water monitoring plan, the following information should be routinely entered on the boring log:

1) Each boring and well (active and abandoned) should be uniquely numbered in accordance with an established well designation plan (discussed in Subsection 3.1.1);

2) Depths and heights (and reference to the appropriated datum) should be recorded in feet and decimal fractions (tenths of feet);

3) Field soil classification must be in accordance with the Unified Soil Classification System (USCS) or Standard D2487 and D2488, and shall be recorded in the field at the time of the sampling by the geologist. Such terms as “trace,” “some", “several,” must be consistent with the USCS or ASTM Standard D2488;

4) Each soil sample collected should be fully described on the log. Sample colors should be described using a Munsell soil and/or rock color chart. Samples should be described when wetted;

5) When used to supplement other sampling techniques, disturbed samples (e.g., wash samples, cuttings, and auger flight samples) should be described in terms of the appropriated soil/rock parameters

6) Rock cores should be fully described on the boring log. Sample colors should be described using a Munsell rock color chart. Samples should be described when wetted;

7) For rock core the log will include, denoting by depth, the location, orientation, and nature (natural or mechanical) 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. Also note, by depth, the intervals of all lost core and hydrologically significant details. This sketch should be prepared at the time of core logging, concurrent with drilling;

8) All special problems and their resolution should be recorded in the field logbook, with appropriated entries on the log form. Examples of problems include, hole squeezing, recurring problems at a particular depth, sudden tool drops, excessive grout takes, drilling fluid losses, unrecovered tools in hole, and lost casings;

9) The dates and times for the start and completion of borings should be recorded on the log;

10) Each sequential boundary between the various soils and individual lithologies should be noted on the log by depth and elevation;

11) The depth of the first encountered free water should be indicated. Before proceeding, the first encountered water should be allowed to partially stabilize for a minimum of 5 to 10 minutes and recorded along with the time between measurements. It is important to note if the measured water level increases or decreases over time;

12) The purpose and interval by depth for each sample collected, classified, and/or retained should be noted on the log;

13) A record of the blow counts, hammer type and weight, and length of hammer fall for driven samplers should be made when standard penetration samplers are used. For thin-wall samplers, indicate whether the sampler was pushed or driven and the pressure/blow count per drive. Blow counts should be recorded in half-foot increments when standard penetrations samplers (1-⅜ inch I.D. X 2

inch O.D.) are used. For penetration less than a half-foot, annotate the count with the distance over which the count was taken. Blow counts, in addition to their engineering significance and classification purpose, may be useful for stratigraphic correlation;

14) When drilling fluid is used, a quantitative record in the field logbook should be maintained of fluid losses and/or gains and the interval over which they occur. Adjustment should be made for fluid losses due to spillage and intentional wasting (e.g., recirculation tank cleaning) to more closely estimate the amount of fluid lost to the subsurface environment. Losses should be noted by time and depth interval;

15) Record the total depth of drilling and sampling on the log;

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

17) Soil gas and breathing zone readings, if taken, should be recorded on the log. Each notation should include interval sampled and reading. When possible, a general note on the log should indicate meter manufacturer, model, serial number, and calibration material. If several meters are used, key the individual readings to the specific meter; and

18) Special abbreviations used on the log and/or well diagram should be defined where used.

2.9.4 Soil Boring Abandonment

For each soil boring, its final status (abandoned; converted to a monitoring well, etc.) should be recorded on the boring log form. If the boring is abandoned, the date(s) of abandonment and the abandonment method should be included. The boring abandonment procedures should comply with Chapter 7.0 of the manual.

2.9.5 Well Abandonment

For each abandoned monitoring well or piezometers, a record of the abandonment must be provided on the Well Abandonment Form. An example of this form is included in Appendix B. Well abandonment procedures should comply with Chapter 7.0 of the manual.

3.0 Well Design and Material Specifications

3.1 Well Design Specifications

This section describes the design specifications for the various monitoring well components. Figure 1, Single-Cased Monitoring Well Schematic Diagram, illustrates typical single-cased well components described in the following subsections. Well construction specifications for monitoring wells installed with conventional drill rigs are outlined in Sections 6.4 through 6.6 of the USEPA guidance document (USEPA, 2001) and for direct-push micro wells in the ASTM Standard 6725. Variations from standard practices should be based upon site, geologic, and hydraulic conditions and must be approved prior to installation by the appropriate regulatory authorities and must follow appropriate regulatory procedures. Persons with authority to address and grant variances should be identified in the ground water monitoring plan. Circumstances and factors leading to variances must be properly documented.

3.1.1 Well Designation

Each well at a site should have a unique label that distinguishes it from all other wells located at the installation. Prior to assigning a well label, all wells at the site should be checked to ensure no duplication. An example of a naming convention is given below:

Site:	Johnson Bulk Tank Farm No. 2
Well Number (Name):	JBTF-N2-MW01;
Where:	JBTF = Johnson Bulk Tank Farm N2 = Farm No. 2 MW01 = monitoring well 01

It is preferred that wells be labeled with an identification tag. A metal tag containing the well designation should be attached to the protective casing of each monitoring well. Figure 2 presents a diagram of a well identification tag. The following specification can be applied to the use and installation of well tags:

Specifications:

4”X4”X0.032” stainless steel or aluminum
3/16” lettering
1/8” diameter mounting holes
black printed or stamped lettering

Printing:

A printing press can be used to complete as much information as possible before mobilizing to the site. Required information to be included in on a tag is shown in Figure 2. Information that is not available at the time of printing must be hand stamped in the field.

Figure 1: Typical Monitor Well Construction, Single-Cased Monitor Well

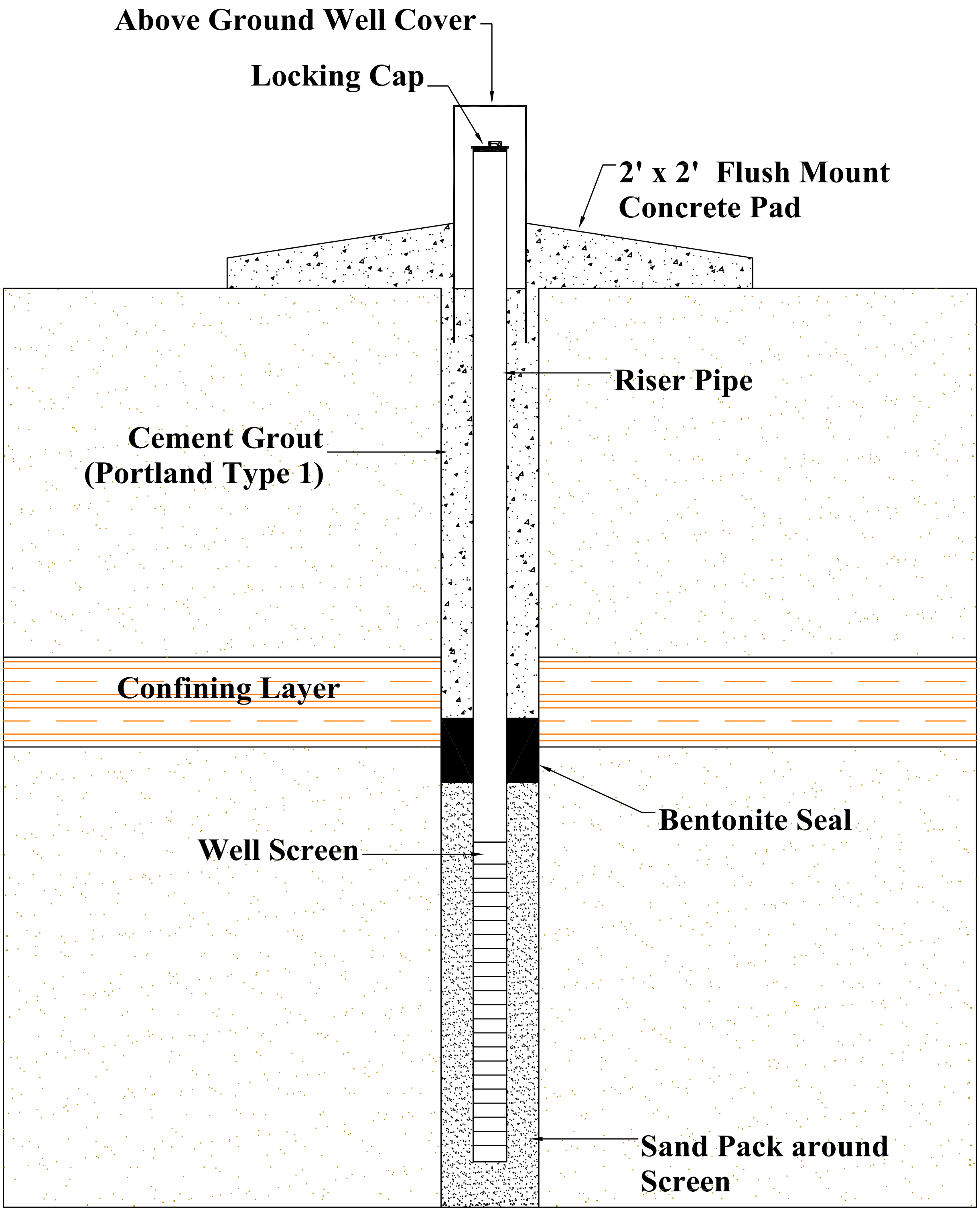


Figure 2: Monitoring Well Identification Tag

3.1.1.1 The Florida Unique Well Identification Program

The Florida Unique Well Identification (FLUWID) program provides a means to simplify the identification and exchange of water well information between state agencies and other interested parties. Under the program, water wells are assigned a unique alphanumeric code called the FLUWID identification number (example: AAA0000). The alphanumeric code is printed on a weather resistant adhesive tag/label and attached to a wellhead or pump house for identification. The FLUWID identification number serves as the primary water well identification number which enables different state agency water well databases to be cross referenced and queried. The FLUWID identification number is meant to be used in conjunction with any other numbering identification scheme such as the permit numbering system for water well construction and identification water well samples.

The naming convention in subsection 3.1.1 can still be used; however the FLUWID number can either replace the well number or be used in conjunction with the well number. For example a FLUWID number, AAB2123, queried from the database would show that this FLUWID number is associated to the original site name JBT-N2-MW01, and the FLUWID number would associate any sample identifications related to JBT-N2-MW01, as well as any other related data and information associated with that well.

The FLUWID Coordinator maintains the FLUWID Program Database (database). The database records the agency that is issued FLUWID tags, the date of issuance, differential global positioning system (DGPS) coordinates and other well information. The primary function of the database is to simplify water well data inquires by directing all request to the party issued the FLUWID tags. The database is not a repository for water well historical data.

The FLUWID Program is not mandated by law, but implemented voluntarily to facilitate water well data collection The FLUWID Program only works if all parties participate and report data associated to the FLUWID ID numbers that are issued to said parties. It is most important that all data be returned to the FLUWID coordinator in a timely fashion in order to maintain an up-to-date and accurate database.

3.1.2 Well Material Specifications

The selected well construction materials should be chosen based on site and hydrogeological conditions and the physical and chemical monitoring objectives. The prime concern when selecting well materials is that these materials will not contribute foreign constituents to the ground water quality sample or alter the surrounding environment, either by leaching or sorption. The introduction of foreign matter or alteration of ground water quality may compromise the integrity of the well and of any analytical data. Also, well materials must not absorb any of the contaminants of interest that may be present in the ground water. An additional concern is that all well materials must be durable enough to withstand installation and well development and endure for the entire designed monitoring period. ASTM Standard D5092 presents an excellent discussion of material terminology and definitions. Deviations from acceptable well material specifications should be specified the ground water monitoring plan and approved prior to installation.

PVC and stainless steel are the most commonly used monitoring well screen and riser materials. However, in some situations, other materials, such as Teflon®, or carbon steel (for riser pipe) may meet project objectives. Typically, the riser is constructed of the same material as the well screen. However, depending upon the project objectives, PVC or carbon steel riser pipe material may be used to reduce the material cost when stainless steel well screens are specified. Where a different riser material is used to produce a “hybrid” well, the materials anticipated to be in contact with the ground water must be consistent with the material of the well screen. Table A-2, Appendix A, provides a comparison of stainless steel and PVC material characteristics. Table A-3, Appendix A, provides a comparison of the relative compatibility of miscellaneous well materials to potentially reactive substances.

All PVC screens, casings, and fittings are typically Schedule 40 or 80 and shall conform to National Sanitation Foundation (NSF) Standard 14 for approved water usage or ASTM Standards F480 or D1785. If the driller uses a screen and/or casing manufacturer or supplier who removes or does not apply this logo, a written statement from the manufacturer/supplier that the screens and/or casing have been appropriately rated by NSF or ASTM should be included in the ground water monitoring plan.

Stainless steel well screen is typically Type 316 or 304. The stainless steel well screen must have flush threaded joints, sealing “O” rings of compatible material with the project objectives, and conform to ASTM Standard A312/A312M.

A Teflon® well screen must have flush threaded joins, sealing Teflon® “O” rings, and conform to ASTM Standard D4894 or D4895. Specific materials must be specified in the ground water monitoring plan. All materials should be as chemically inert as technically practical with respect to the site environment. Marking, writing, or paint strips are not allowed.

All monitoring well joints must be water tight. Couplings with the casing and between the casing and screen must be compatibly threaded. Thermal- or solvent-welded couplings on PVC pipe shall not be used. This restriction also applies to threaded or to slip-joint couplings thermally welded to the casing by the manufacturer or in the field. Gaskets, pop rivets, or screws are not normally used on monitoring wells. Exceptions are: 1) manufactured flush-joint casing requiring an o-ring to seal the joint and 2) stainless steel screws required to attach a bottom cap to a nonstandard length of screen material where the normal joint structure is missing. Exceptions should be approved prior to installation and must be recorded in the well completion report. All screen bottoms must be securely fitted with a cap or plug of the same composition as the screen. Solvents or glues are not permitted in the construction of a monitoring well.

All well screens and well casings must be free of foreign matter (e.g., adhesive tape, labels, soil, grease, etc.). Typically, well casing and screen materials are prepared, wrapped, and boxed by the manufacturer with a certificate of being “clean”. If the cleanliness of the well materials is in doubt, the casing and screen must be decontaminated using an approved protocol. Cleaned materials must be stored in appropriate containers until just prior to installation. Pipe nomenclature stamped or stenciled directly on the well screen and/or blank casing within and below the bentonite seal must be removed by means of sanding, unless removable with approved water. Solvents, except approved water, must not be used for removal of markings.

3.1.3 Well Screen Usage

Each well should be constructed with new, machine-slotted or continuously-wound screen section. The end plug should be composed of the same material as the well screen. The screen assembly must be able to withstand installation and development pressures without collapsing or rupturing.

Although many wells set into bedrock could be installed as open-hole installations, the extra cost and effort for screen installation can be more than offset by the assurance of an unobstructed opening to the required depth during repeated usage. Well integrity and consistent access to the original sample interval during prolonged monitoring is thereby maintained.

3.1.4 Well Screen Length

Well screen lengths should be selected based on the purpose of the well. Some wells are designed to determine the presence or absence of contaminants. Others are designed to monitor a discrete zone for a particular contaminant type. Design of screen length must take into account hydrostratigraphy, temporal considerations, environmental setting, analytes of concern, fate and transport of contaminants, and/or regulatory requirements.

In most situations, monitoring wells are designed to double as ground-water quality sampling points and as piezometers to monitor water levels or hydraulic head at that particular location and depth. In order to satisfy these dual roles, monitoring well screen lengths may range from as short as 2 feet to greater than 20 feet. Typically, though, well screen lengths are 5 or 10 feet, and rarely exceeding 20 feet. It is important that well screen lengths be specified in the ground water monitoring plan.

3.1.5 Well Screen Diameter

The inside diameter (I.D.) of the well screen should be chosen based on anticipated use of the well. Generally, a 2-inch I.D. well is sufficient to allow sampling with most types of sampling devices such as bailers or low-flow samplers. If the well may be used as part of a remedial system, a greater I.D. may be considered (e.g., 4-inch or 6 inch), however, the advantages of this increased diameter should be evaluated with respect to cost increases in drilling, material, and disposal of waste material.

The actual inside diameter of a nominally sized well is a function of screen construction and the wall thickness/schedule of the screen, casing, and joints. In the case of continuously-wound steel screens, their interior supporting rods may reduce the full inside diameter. Additionally, the welded couplings on 2-inch I.D. stainless steel well pipe frequently reduces the inside diameter to slightly less than 2 inches. This consideration is critical when sizing pumps, bailers, surge devices, etc.

All well screens must be commercially fabricated, slotted or continuously wound, and have an I.D. equal to or greater than the I.D. of the well casing. An exception may be warranted in the case of continuously-wound screens. No fitting should restrict the I.D. of the joined casing and/or screen.

3.1.6 Well Screen Slot Size

The grain size distribution of the screened formation and the filter pack gradation are the primary parameters that should be used when selecting a slot size for the well screen. Therefore, the grain size of the aquifer material should be the determining factor in selecting well screen slot size.

The largest practical slot size that is compatible with the aquifer and available filter material should be used. This will allow maximum intake volume per unit screen length. The slot size should retain at least 90 percent (preferably 99 percent) of the filter pack material. The method for determining the appropriate gradation of filter pack material is described in paragraph 3.1.11.2, Primary Filter Pack.

3.1.7 Well Screen Placement

The screen shall be place such that the parameters of concern can be properly monitored. Chemical constituents with a specific gravity greater than water tend to sink and may accumulate as a dense non-aqueous phase liquid (DNAPL). If the well screen is to be installed in a location known or suspected to be impacted by DNAPLs, then the borehole must not be overdrilled and the screen must be placed at the bottom of the borehole. The screen must be placed with no filter pack beneath the base of the screen as this construction may provide a sediment trap and the DNAPLs may sink and not be detected. DNAPLs may exhibit an overall vertical migration, even with a predominant horizontal ground water flow. Therefore, screens need to be place at the bottom of a saturated zone or just above a confining layer. Screen lengths should be as short as possible, at the most 10 feet and preferably 5 feet (or less), to decrease the likelihood of cross contamination of deeper portions of an aquifer.

Overdrilling of a borehole is sometimes performed for such activities as definition of stratigraphy, location of a confining unit or to creation of a sediment trap. It is preferred that exploratory activities (i.e., stratigraphic definition and strata location) are conducted in a pilot hole and then the borehole be properly abandoned. A separate borehole should be advanced for the monitoring well.

Overdrilling to create sediment traps is not encouraged. If, however, overdrilling is performed to create a sediment trap, the bottom of a well screen may be placed at a minimum of 6 inches, but no more than 3 feet above the bottom of the borehole. If bentonite pellets are used to seal the bottom of the borehole, a minimum of one foot of filter sand must be placed above the bentonite prior to screen placement. Overdrilling must be appropriate for site conditions and the monitoring parameters of concern. The use and style of sediment traps must be discussed in the ground water monitoring plan.

3.1.8 Well Riser

The I.D. of the riser should be chosen based on the anticipated use of the well. Usually a minimum of 2-inch I.D. riser is required to allow use of most sampling devices and water level indicators. In most cases, the well riser will be fabricated of the same material and be the same I.D. as the selected well screen. Couplings within casing segments and between the casing and screen must be compatibly threaded.

Each riser section should be installed as straight and level as possible. For deep installations (greater than 40 feet) centralizers should be used to ensure a constant annular spacing between the borehole and well materials. The top of the uppermost riser pipe, i.e., the top of the well, must be level. A point on the top of the well should be marked such that survey and water level measurements are collected from the same location. Traditionally, this mark is placed on the north side of the riser.

3.1.9 Surface Casing

Outer well casing used as a permanent part of the installation when multi-cased wells are installed must be composed of new material. The casing must be free of interior and exterior protective coatings and must be steam cleaned or washed with a high-pressure water device (if appropriate for the selected material) using approved water immediately before installation. The type of material and wall thickness of the casing must be adequate to withstand the installation process. Surface casing must consist of steel meeting ASTM Standard A53/A53M-06 or Schedule 40 or 80 PVC, and shall have a minimum wall thickness of 0.25 inch, unless otherwise specified. The ends of each casing section should be either flush-threaded or beveled for welding.

At sites where multiple aquifers may be penetrated or where a confined or semi-confined aquifer must remain isolated from potential surface water infiltration, surface casing is required to prevent cross-contamination between the separate zones. When used to seal a confining layer or bedrock surface, well casing is typically installed 3 feet to 5 feet into the top of the unit. This should provide a sufficient isolation of the aquifer to be protected. For thin confining layers or thin saprolite horizons, a shallower penetration depth may be appropriate.

Different casing sizes may be required depending on the types of geologic materials encountered at the drilling site and the anticipated purpose of the well. The site geologist, engineer or geotechnical engineer should anticipate these conditions and design the monitoring wells accordingly. Casing diameters for filter-packed wells should be selected so that a minimum annular space of 2 inches is maintained radially between the inside diameter of the surface casing and outside diameter of the monitoring well riser. Also, the diameter of all casings in multi-cased wells should be sized so that a minimum of 2 inches of annular space is maintained between the surface casing and the borehole. For example, a 2-inch diameter well screen will require a 6-inch diameter casing inside a 10-inch diameter boring.

3.1.10 Granular Filter Packs

3.1.10.1 Filter Pack Materials

All granular filters should be discussed in a ground water monitoring plan, including composition, source, placement, and gradation. If the actual gradation is to be determined during drilling, then more than one filter pack gradation should be available so that well installation will not be unnecessarily delayed. A 1-pint representative sample should be collected for possible future analysis.

Granular filter packs must be at least 98 percent pure silica sand, visually clean (as seen through a 10-power hand lens), free of materials that would pass through a No. 200 U.S. Standard sieve, inert, composed of rounded grains, and of appropriated size for the well screen and host environment. The filter material should be packaged in bags by the suppliers and therein delivered to the site.

Filter packs are placed in the borehole and around the well screen to prevent natural formation material from entering the well screen. The use of a tremie pipe for filter pack placement is recommended; especially when the boring contains thick drilling fluid or mud or is sufficiently deep such that bridging is likely. Exceptions to the use of a tremie pipe for filter pack placement may include vadose zone wells or surficial well with less than approximately 10 feet of standing water.

The final depth to the top of the granular filter should be directly measured (by fiberglass or stainless steel tape measure or rod) and recorded on a well construction form. Final depths must not be estimated based on volumetric measurements of placed filter sand.

When installing a monitoring well in karst or highly fractured bedrock, the borehole configuration of void spaces within the formation surrounding the borehole is often unknown. Therefore, the installation of a filter pack becomes difficult and may not be feasible.

3.1.10.2 Primary Filter Pack

The primary filter pack consists of granular, siliceous material or glass beads. These materials should be clean and free of materials that would compromise the integrity of the representative ground water quality.

The filter pack shall extend from the bottom of the boring to a minimum of 3 feet above the top of the screen unless otherwise specified in the work plan. As mentioned in Subsection 2.1.4.4, Borehole Requirements, the filter pack is not placed beneath the screen when potential contaminants with a specific gravity greater than that of water (i.e. DNAPLs) are suspected. Once the filter pack material is in place the well should be surged to break bridged filter pack materials in the borehole and to consolidate those materials around the screened interval.

As appropriate, up to 5 feet of filter pack can be placed above the top of the screen. This additional filter pack thickness will allow for settling from infiltration and compaction of the filter pack during development and repeated sampling events. The additional filter also helps to maintain a separation between the bentonite seal and well screen. The selected filter pack material should be uniformly graded and composed of siliceous particles that have been appropriately washed and screened. The filter pack grain-size is based on the smallest natural formation material. The following table presents a comparison of typical filter pack mesh sizes and appropriate screen size openings:

Table 3: Comparison of Screen Slot Size and Filter Pack

Screen Size Opening (Inches)	Screen Size Slot Number	Typical Sand Pack Mesh Size (U.S. Standard Sieve Number)
0.005	5	100
0.010	10	20 to 40
0.020	20	10 to 20
0.030	30	10 to 20

3.1.10.3 Secondary Filter Pack

As appropriate and as borehole depth and hydrogeologic conditions allow, a minimum 1- to 2-foot thick secondary filter pack should be used during well installation. A fine-grained sand (i.e. 30/65) may be used as a secondary filter pack.

The objective of a secondary filter pack is to prevent intrusion of the bentonite seal into the primary filter pack. Additionally, a secondary filter pack can also be used between the bentonite seal and the grout backfill to prevent intrusion of the grout into the bentonite seal. Finally, for wells completed with the seal located above the static ground water level, a secondary filter pack should be installed to replace the bentonite seal.

3.1.11 Annular Seal

The objective of an annular seal is to prevent intrusion of the annular grout into the primary and/or secondary filter pack. An annular seal of fine-grained, washed silica sand is recommended in situations where monitor well screen sections are designed to intercept the water table. In situations where the annular seal is assured to remain below the water table and saturated, a bentonite seal is appropriate. Bentonite has the ability to expand when completely hydrated to form a dense clay mass with very low in-place permeability, thereby providing an effective barrier to water migration. However, bentonite is not effective when 1) improperly hydrated, 2) allowed to desiccate in place or 3) placed in high or low pH environments. To allow for adequate hydration and avoid desiccation bentonite seals must be placed at a depth below the lowest anticipated static ground water level in the well.

Because bentonite has a high cation exchange capacity and high pH, it may adversely affect water-quality samples that come in contact with, or have migrated through or past the bentonite seal. Additional concerns include the use of bentonite in ground water that exhibits high total dissolved solids or high chloride content, or may contain chemicals reactive to the bentonite's cation exchange capacity and pH. For these reasons, the rationale and design specifications for bentonite seals should be detailed in a work plan. If selected for use during the design process, the bentonite seal should have a minimum 2-foot thickness.

Bentonite used in drilling slurries and as annular sealant shall be powdered, granular, chipped or pelletized. Pelletized or chipped bentonite should be used for bentonite seals, whereas powdered or granular bentonite should be used when required in preparing slurries and grout. The materials must be a 100 percent pure sodium bentonite (montmorillonite) supplied in sacks or plastic buckets. The bentonite must be free of any additives or other material that may negatively affect water quality in the resulting monitoring well. The diameter of the bentonite pellets used should be less than one fifth the width of the annular space into which they are placed. This will help reduce the possibility of the material bridging in the annular space.

The preferred method of placing bentonite pellets or chips is by positive displacement or by use of a tremie pipe. Use of the tremie method minimizes the risk of pellets or chips bridging in the borehole, but time and care must be taken to prevent plugging of the tremie pipe. Pouring of the pellets is acceptable in shallow boreholes (less than 40 feet). In order to provide accurate measurement of bentonite pellet thickness in the well boring, the pellet seal should be tamped during measurement. Bentonite pellet/chips seals should be measured during and immediately after placement, without allowance for swelling. Granular or chip bentonite may be used if the seal is set in a dry condition.

If the proposed seal location is above the anticipated static ground water level, a bentonite seal should not be used. In this case, a 1- to 2-foot layer of fine-grained sand (secondary filter pack) placed atop the primary filter pack will enhance resistance to downward grout migration.

Slurry seals should be used only as a last resort, as when the seal location is too far below water to allow for pellet or chips or containerized-bentonite placement or within a narrow well-borehole annulus. Typically, the specific gravity of cement grout placed atop the slurry seal will be greater than that of the slurry. Therefore, the intent to use a slurry seal should be detailed in the ground water monitoring plan, and details should include a discussion of how the grout will be precluded from migrating through the slurry. An option includes a secondary filter pack of fine-grained sand and the use of a side discharging tremie pipe. Slurry seals should have a thick, batter-like (high viscosity) consistency with a placement thickness of 3 feet to 5 feet.

The final depth of the top of the bentonite seal should be directly measured (by tape or rod) and recorded. Final depths should not be estimated based on volumetric measurements of placed bentonite.

In a well designed to monitor competent bedrock, the bottom of the bentonite seal should be located at 3 feet below the top of firm bedrock, as determined by drilling. “Competent bedrock” refers to that portion of solid or relative solid, moderately weathered to unweathered bedrock where the frequency of loose and fractured rock is markedly less than in the overlying, highly weathered bedrock. Special designs will be needed to monitor fractured bedrock.

3.1.12 Annular Grout

Grout used in monitoring well construction and borehole/well abandonment should be one of the five Portland cement types specified in ASTM Standard C150. Type I Portland cement is most commonly used for monitoring well construction. Bentonite-based grouts (30 percent solids) can be used when the grout needs to remain somewhat flexible. The cement-based grout should be composed of Type I Portland cement , 100 percent pure sodium bentonite (10 percent dry bentonite per 94-lb. sack of dry cement), and shall not exceed 6 gallons of water per 94 pounds of Portland cement. The amount of approved water used should be kept at a minimum. Use of 10 percent bentonite, by weight, added to a cement–based grout is advantageous when lower shrinkage, better workability, and reduced weight are important. The considerations of using bentonite include reduced set strength, increased set time, and potential incompatibility with some ground water chemistry conditions

When a sulfate-resistant grout is needed, Types II or V cement should be used instead of Type I. Quick-setting cements containing additives must not be used for monitoring well installation. These additives may leach from the cement and adversely affect the chemistry of the water samples collected from the resulting monitoring well. Generally, the use of air-entrained cements should be avoided to negate potential analytical interference in ground water samples by the entraining additives. Neither additives nor borehole cuttings shall be mixed with the grout.

3.1.13 Surface Completion

Protective casing should be installed around each monitoring well the same day as the initial grout placement. Any annulus formed between the outside of the protective casing and the borehole or between the monitoring well and protective casing should be filled to the ground surface with grout as part of the overall grouting procedure. Specific details of well protection should be detailed in the ground water monitoring plan. Details and specific elements of well protection should be included in well completion diagrams. Figures 3 and 4 present schematic diagrams for flush-mounted and stick-up protective casing, respectively. ASTM Standard D5787 provides guidance for monitoring well protection.

All protective casing should be steamed or hot-water-pressure cleaned prior to placement; free of extraneous openings; and devoid of any asphaltic, bituminous, encrusted, and/or coating materials, except the paint or primer applied by the manufacturer.

As specified in Subsection 3.1.1, Well Designation, a metal identification tag containing the well designation should be attached to the protective casing of each monitoring well or placed square on the protective concrete pad, centered on the northern or northwestern side of the pad, with the top of the tag toward the well head. For new pads, the tag shall be placed and pinned during pad construction. For existing pads, the tag should be epoxy grouted and cement screwed.

The material type of the surface completion casing should be adequate to protect the completed monitoring well. The surface completion materials need to be selected such that they provide adequate protection against physical destruction, tampering, natural degradation, and the environment.

Unless otherwise specified, surface completion materials should conform to the following specifications:

1) Locking 16-gauge steel or aluminum protective well cover, round or square and 5-feet in length, or flush-mounted 22-gauge steel, water resistant, welded box with 3/8-inch steel lid;

2) Cement consisting of one of the five Portland cement types that are specified in Standard C 150 as discussed in Paragraph 3.1.12, Annular Grout;

3) Brass, corrosion resistant, keyed-alike padlock;

4) Protective bumper posts constructed of 4-inch diameter and minimum 5-foot long steel or aluminum pipe (four per well). Each post must be set into concrete outside the corners of the concrete pad and filled with concrete;

5) Paint that matches existing monitoring wells at the installation. Where no wells exist, it is recommended to use high visibility yellow epoxy paint;

6) A well identification tag as detailed in Subsection 3.1.1, Well Designation; and

7) Cement consisting of one of the five Portland cement types that are specified in Standard C 150 as discussed in Paragraph 3.1.12, Annular Grout.

The primary purpose of a properly designed surface completion is to maintain the integrity of the well for the designed monitoring period. After the well is installed, it shall be completed at the ground surface in one of two ways:

1) Construct around the protective casing a 2-foot by 2-foot, 4-inch thick concrete pad, sloping from the casing to the perimeter such that water will drain away from the well. The bottom of the concrete pad should be installed partially or completely below grade to protect against undermining. Bentonite grout should then be placed in the annular space below ground level within the protective casing. Pea gravel should then be placed in the annular space above the bentonite to about 6 inches from the top of the well riser.

2) Where monitoring well protection must be flush-mounted with the ground, a locking security internal cap must be on top of the riser within the steel manhole or vault. This cap must be leak proof so that if the vault or manhole should fill with water, the water will not enter the well casing. A bolt-down manhole cover should be required for security. The manhole cover should be installed into a 6-inch thick, 2-foot square, concrete pad, sloped (1 inch per foot) to provide water drainage away from the well, and finished flush to existing grade. Ideally the manhole cover should also be leak-proof.

If the well is completed above ground the protective casing should extend from slightly above the well casing to below ground with a minimum of 2.5 feet below grade. The protective casing should be waterproof and held firmly in lean concrete placed around the outside of the protective casing. The casing should be placed in alignment with the well riser pipe.

Figure 3: Flush-Mounted Protective Casing

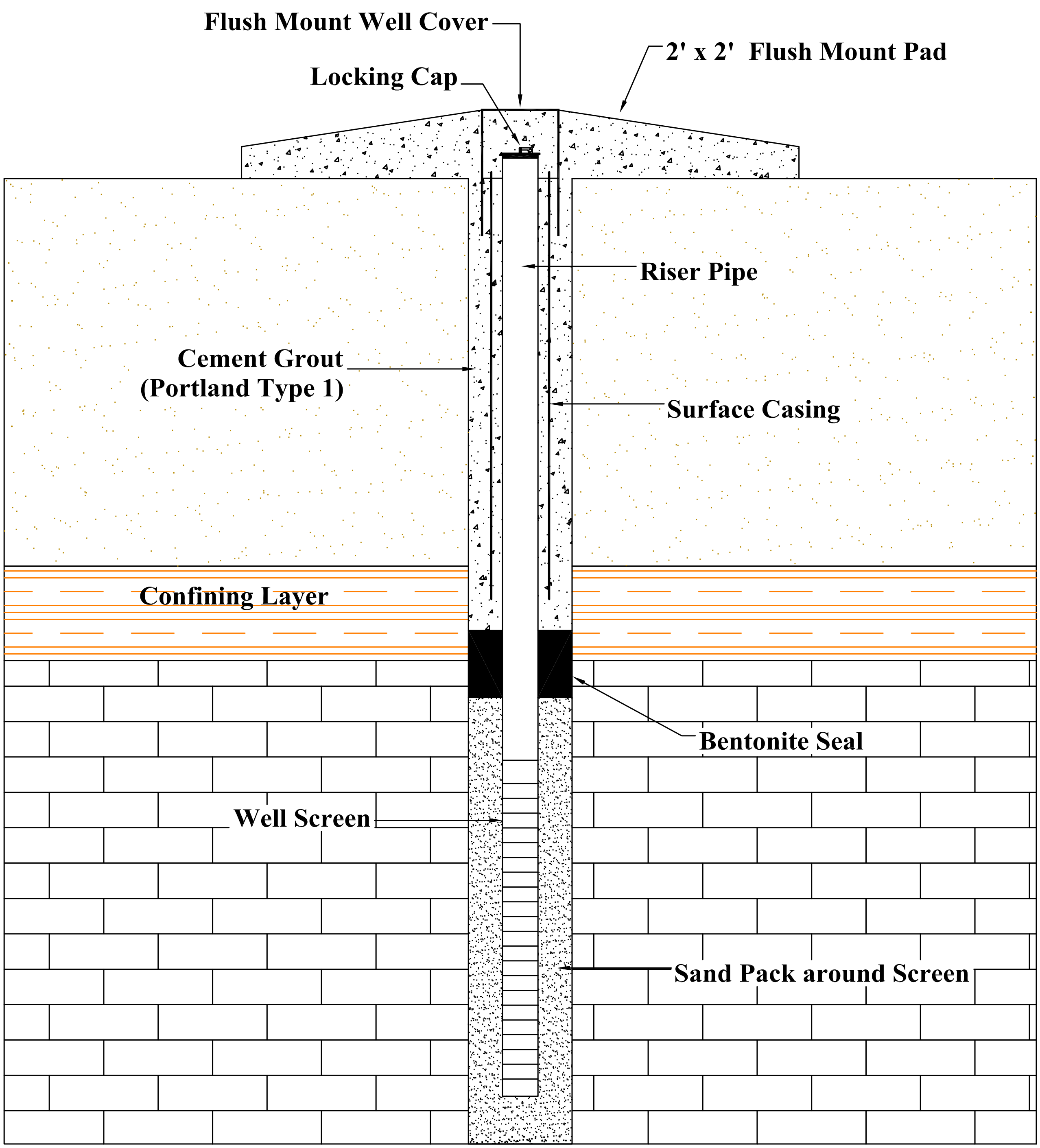
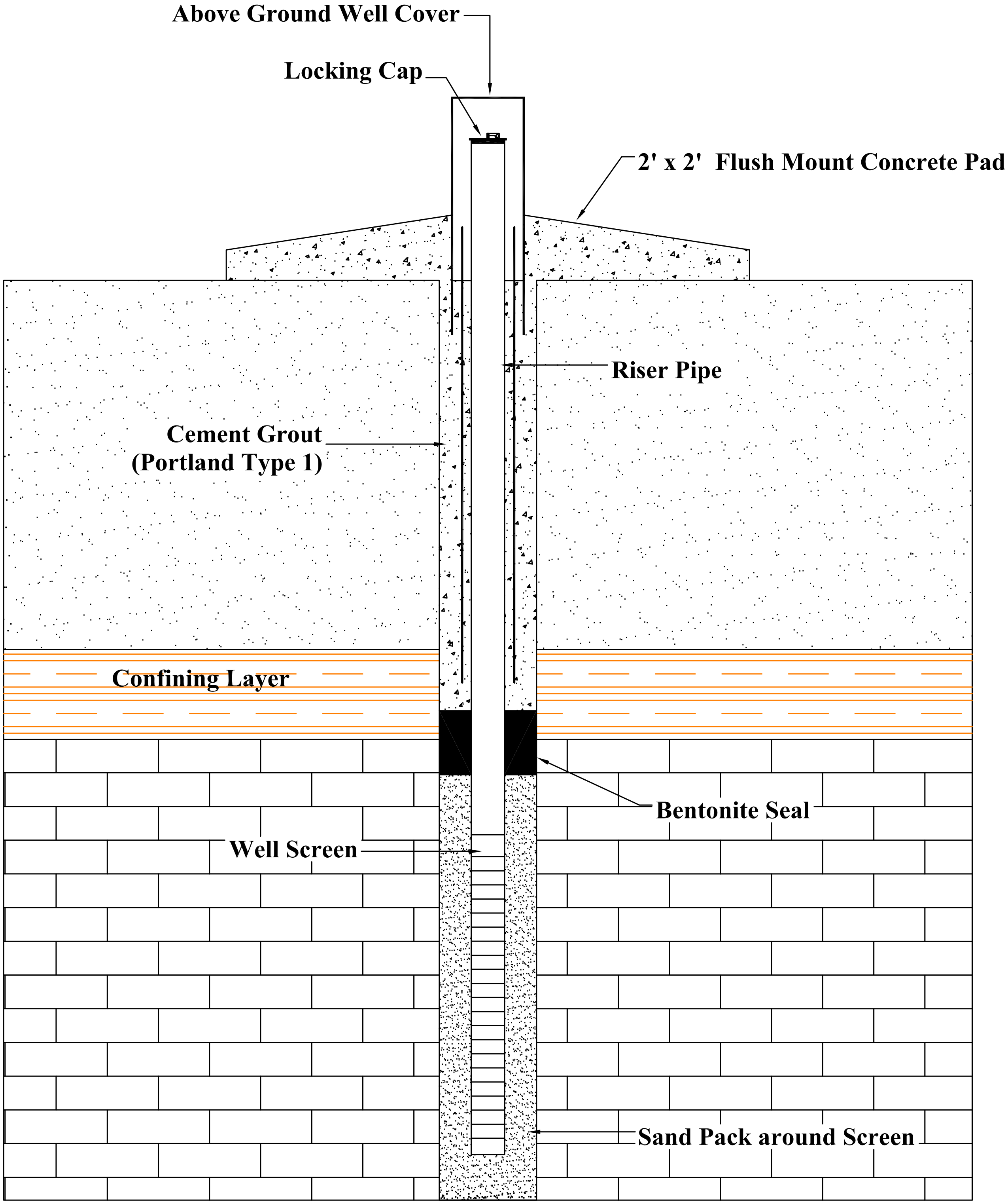


Figure 4: Above-Ground Protective Casing



Prior to protective casing installation, a ⅛-inch diameter vent hole should be drilled or slotted in the well riser approximately 6 inches below the cap to allow the well to vent. A second ¼-inch diameter hole (or weep hole), should be drilled in the surface casing immediately above the concrete pad to allow water to drain from the inside of the protective casing. Vent holes should not be used for flush-mounted well completions. Enough clearance, usually 6 inches, should be left between the lid of the protective casing and the tip of the riser to allow the introduction of sampling equipment and/or pumps. All materials chosen shall be documented.

Monitoring wells located in high traffic areas should be flush mounted whenever possible. If a well can not be flush-mounted in high traffic areas or areas where heavy equipment is operated, the well should be protected with four steel bumper posts. This type of protection may not be necessary at all monitoring well locations.

Additional design details for a typical aboveground protective casing include the following:

1) A 5-foot minimum length of steel or aluminum protective casing shall extend approximately 2.5 feet above ground surface and set into the protective apron (aluminum should be used in coastal environments due to its corrosion resistant characteristics);

2) The protective casing inside diameter shall be at least 4 inches greater than the nominal diameter of the well riser;

3) An aluminum-hinged cover or loose-fitting telescopic slip-joint-type cap should be used to keep precipitation and cap runoff out of the casing;

4) All protective casing covers/caps shall be secured to the protective casing by means of a padlock at the time the protective casing is installed;

5) If practical, all padlocks at a given site should be keyed alike;

6) No more than a 2-inch clearance should be left between the top of the protective casing and the top of the well riser. This spacing may be required for installation of monitoring and/or pumping devices. If, however, acoustical equipment will be used for water-level determinations, a smaller spacing (2 inches or less) may be necessary;

7) Only the outside of the protective casing, hinges (if present), and covers/caps must be prepainted or painted with a paintbrush (no aerosol can). Paint shall dry prior to initially sampling that well;

8) A metal identification tag should be placed on the outside of the protective casing; and

9) In high traffic areas, install four steel or aluminum bumper posts. Each post should be radially located 4 feet from the well (immediately outside each corner of the concrete pad) and placed a minimum 2 feet below ground surface, having a minimum of 3 feet above ground surface. The posts should be set into and filled with concrete. Flagging or signposts in areas of high vegetation may be helpful. The bumper posts should be prepainted or painted using a brush.

3.1.14 Quality Assurance Sampling

Certain well construction materials used during installation should be collected for quality assurance (QA) purposes. It is not always necessary to perform chemical analyses on collected materials. However, with the exception of the approved water, the materials should be archived until the chemical results are received from the environmental samples at that location in case that the results appear to be anomalous. In this case, it may be desirable to analyze some or all of the well construction materials. Such materials include drilling fluids (approved water and any additives, if used), annular filter pack, bentonite, and cement.

3.2 Documentation

Unless otherwise specified in the ground water monitoring plan, a well construction diagram and a certificate of conformance must be produced for every monitoring well constructed.

3.2.1 Well Construction Diagram

Each diagram must be attached to, or placed on the original boring log and maintained by the site geologist, engineer or geotechnical engineer until completion of the field effort. Figure 3-1 presents an example of a completed well construction diagram included on a soil boring log. The original diagram and boring log should be retained for later reference, as needed. Special abbreviations used on the well completion diagram must be defined on the diagram.

The following information should be attached to the original boring log and graphically denote, by the 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 type and interval;

3) Joint type and depths;

4) Granular filter pack type and depth interval;

5) Seal type and depth interval;

6) Grout type and depth interval;

7) Cave-in, if any;

8) Centralizer locations;

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

10) The following protective casing details; and
    a. Height of protective casing, without cap/cover, above ground surface;
    b. Base of protective casing below ground;
    c. Weep hole location and size;
    d. Concrete pad thickness, height, and extent, and;
    e. Protective post configuration.

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

In addition to the graphical presentation discussed above, the following items should be described on each diagram:

1) The actual quantity and composition of the grout, bentonite seal, and granular filter pack used for each well;

2) The screen slot-size in inches, slot configuration type, 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. For pumps, include the voltage, phase requirements, and electrical plug configuration;

8) Protective casing composition, length, and nominal inside diameter;

9) Special problems and their solutions; e.g., grout in well, lost casing and/or screens, bridging, casing repairs and adjustments, etc.; and

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

3.3 Special Concerns

3.3.1 Shallow Wells

During shallow well construction (i.e., less than approximately 15 feet) sufficient depth may not be available to install the desired thickness of typical well components (filter pack, bentonite seal, grout, etc.). Tailored well designs and deviations from standard well construction requirements should be detailed in a ground water monitoring plan. The design, if modified, should minimize the potential infiltrations of surface water.

3.3.2 Well Clusters

Unless otherwise specified in an approved work plan, each well in a cluster shall be installed in a separate boring rather than co-located within one large-diameter boring. Each monitoring well is a mechanism through which to obtain a ground water sample representative of the aquifer zone monitored and, if so designed, to measure the potentiometric surface in that well. To ensure this representation, each well in a cluster must be constructed and installed in a separate boring. Multiple well placements in a singe boring are too difficult for effective execution and evaluation to warrant single hole usage. One exception includes the intentional design and installation of well clusters such as bundled piezometers for DNAPL characterization. Such exemptions must be detailed in a ground water monitoring plan.

4.0 Well Development

4.1 General

Borehole drilling activities may retard the ability of an aquifer to transmit water to a monitoring well. Obstructions can be caused by physical alteration of the aquifer material, or by formation damage as a result of the introduction of drilling fluids or solids in the aquifer, causing reduced permeability adjacent to the borehole. Well development is necessary to correct this damage and improve hydraulic conductivity in the immediate vicinity of the monitoring well. The objective of well development is to remove all or as much as possible of the introduced drilling fluids, mud, cuttings, mobile particulates, and entrapped gases from within and adjacent to a newly installed well, thus providing an improved connection between the well screened interval and the aquifer. The resulting inflow to the well should be physically and chemically representative of that portion of the aquifer adjacent to the screened interval. The appropriate development method or procedure to use will vary according to the hydrologic characteristics of the aquifer, the drilling method used, and the type of well completion.

4.2 Development Methods

The method most appropriate for monitoring well development is dependent upon the construction material and size of the well screen and casing, design of the filter pack, characteristics of the formation material, disposal considerations of development fluids, borehole drilling method used, impact of development method on aquifer chemistry, well depth, and cost. ASTM Standard D5521 provides guidance for the development of monitoring wells in granular aquifers.

The following are some of the most commonly used methods:

<u>Mechanical Surging</u> This method involves use of a swedge (surge) block that is moved up and down the well screen and casing. Water is alternately forced in and out of the screen to loosen sediment bridges and draw fine-grained material into the well, which is then pumped out. This is the preferred method of well development. Fine-grained materials can become trapped between the swedge and the inner wall of the screen and well casing causing the swedge to freeze in the well as well as scouring the well materials.

<u>Overpumping</u> The well is pumped at a higher rate than when it will be purged and sampled. Theoretically, the high flow rates dislodge fine-grained materials, opening the flow paths between the well and the aquifer. This method is subject to sediment bridging, requires large pumps that may be difficult to fit into small

diameter wells, generates large volumes of water that must be disposed, and results in poor development of wells with long screen intervals.

Rawhiding In this method, the well is alternately pumped and stopped at intervals that draw water into the well and back out, developing the filter pack by fluid surging. The technique can cause a high rate of wear on the pump and in certain situations may not produce a sufficient surge action for development.

Jetting This method uses high velocity streams of water to loosen fine-grained material and drilling fluids from the formation. The material that enters the wells is then pumped out. This method requires an external water supply and high velocity streams can damage the well screen. Jetting may be appropriate for redevelopment of wells that have become fouled with silt and clay or other fine matter.

Air Lift Air Lift involves forcing air out through the screen and into the monitoring well to clean debris from the well. This method alters the chemistry of the aquifer, may introduce contaminants to the aquifer via the air supply, may release contaminants to the air via mists from the well, and may damage the screen and filter pack.

4.3 Timing and Record Submittal

The development of monitoring wells should not be initiated sooner than 12 hours after or longer than 7 days beyond placement of grout. Well development should be appropriately documented on a monitoring well development record and included with the boring log.

4.4 Oversight

The development of a monitoring well should be overseen and recorded by a site geologist, engineer or geotechnical engineer.

4.5 Development Criteria

Well development should continue until representative water; free of drilling fluids, cuttings, or other materials introduced during well construction is obtained. In other words, the well should be developed until the water is non-turbid. Well discharge water should be metered in the field until it can be established that development has attenuated and stabilized turbidity to the maximum degree possible. All turbidity sampling times and measurements should be recorded on a well completion form.

Suggested minimum volumes to be withdrawn from a well are:

1) For those wells where the boring was made without the use of drilling fluid, but approved water was added to the well installation, remove five times the amount of any water unrecovered from the well during installation (in addition to five times the standing volume).

2) For those wells where the boring was made or enlarged (totally or partially) with the use of drilling fluid, remove five times the measured, or estimated, amount of total fluids lost while drilling, plus five times that used for well installation (in addition to the five times the standing volume). Exceptions may be warranted during the drilling of deep well borings where significant water was lost in a previous hydrologic zone.

Note: Developing a well for too short a period is a common and major cause for poor well performance. Also, water should not be added to a well as part of the development once the initial bentonite seal atop the filter pack is placed.

If any of the following circumstances occur, the site geologist, engineer or geotechnical engineer should document the event in writing and use an alternate plan of action:

1) After extensive development, a non-turbid sample cannot be collected due to a significant fraction of fine-grained material in the surrounding aquifer;

2) Persistent water discolorations remain after the required volumetric development; and

3) Excessive sediment remains after the required volumetric removal.

4.6 Development – Sampling Break

Well development must be completed at least 24 hours before well sampling. The intent of this hiatus is to provide time for the newly installed well and backfill materials to sufficiently equilibrate to their new environment and for that environment to re-stabilize after disturbance of drilling. Applicable Federal, State, and local regulations may require up to 14 days before well sampling can begin.

4.7 Pump/Bailer Movement

During development, water should be removed throughout the entire water column in the well by periodically lowering and raising the pump intake (or bailer stopping point).

4.8 Well Washing

Well development should include the washing of the entire well cap and the interior of the well riser 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 casing, between the top of the well and the water table. The washing should be conducted before and/or during development, and not after development.

4.9 Well Development Record

The following data shall be recorded on a monitoring well development record during development:

1) Name of the responsible site geologist, engineer or geotechnical engineer;
2) Well designation and location;
3) Site name and location;
4) Date(s) of well installation;
5) Date(s) and time of well development;
6) Description of surge/development technique;
7) Type, size, capacity, and pumping rate of pump and/or bailer used;
8) Depth from top of well casing to bottom of well;
9) Well and casing inside diameter;
10) Static water level (equilibrium) from top of well casing before and after development;
11) Field measurements of pH, specific conductance, temperature, and turbidity before, at least twice during, and after development;
12) Screen length and interval;

13) Physical character of removed water, to include changes during development in clarity, color, particulates, and any noted incidental odor;

14) Cumulative water volume or pumping rate;

15) Quantity of fluids/water removed and time interval for removal (present both incremental and total values); and

16) Drilling company.

4.10 Determination of Hydraulic Conductivity from Specific Capacity

Immediately following well development, estimates of hydraulic conductivity can be obtained by conducting specific capacity tests. Specific capacity of a well is the well yield per unit drop of water level in the well. Immediately after monitoring well development, the specific capacity can be measured and used to provide an estimate of the hydraulic conductivity. If the well does not sustain pumping rates of at least 0.5 gallons per minute without excessive drawdown, other aquifer tests, such as slug tests, should be conducted.

Inherent in the calculation of hydraulic conductivity from specific capacity data are certain assumptions, therefore the responsible site geologist, engineer or geotechnical engineer should account for the following potential sources of error when calculating the hydraulic conductivity from specific capacity data:

1) Effects of variable discharge;

2) Effects of partial penetration of the well;

3) Calculation of well losses;

4) Appearance of delayed yield in the aquifer; and

5) Estimates of aquifer storativity.

Appendix C presents details on the performance of specific capacity tests.

5.0 Management of Investigation-Derived Waste

Investigation-Derived Waste (IDW) is defined as waste materials generated during environmental field activities. IDW may include drilling muds, cuttings, and purge water from test pit and well installation; purge water, soil, and other materials from sample collection; residues such as ash, spent carbon, well development purge water for testing of treatment technologies; contaminated PPE; and solution used to decontaminate equipment and non-disposable PPE. An IDW management plan should be developed as part of a ground water monitoring plan.

5.1 IDW Management Requirements

The fundamental purpose of IDW management is to choose options that are:

1) Protective of human health and the environment; and

2) In compliance with regulations and applicable or relevant and appropriate requirements (ARARs).

5.2 General Objectives for IDW Management

General objectives that site managers should consider include:

1) Protectiveness;

2) Minimization of IDW generation; and

3) Management of IDW consistent with the final remedy for the site.

To the extent that the objectives can be achieved is highly dependent on site-specific conditions.

5.2.1 Protectiveness

Factors that should be considered in determining if a specific management or disposal option is protective include the following:

1) The contaminants, their concentrations, and total volume of IDW;

2) Potentially affected media under management options;

3) Location of the nearest population(s) and likelihood or degree of site access;

4) Potential exposure to workers; and

5) Potential for environmental impacts.

Generally, best professional judgment will be required to make this determination.

5.2.2 IDW Management

Site managers should attempt to minimize the generation of IDW to reduce the need for special storage or disposal requirements that may result in substantial additional costs yet provide little or no reduction in site risks relative to the final remedial action. Generation of IDW can be minimized through proper planning of all remedial activities that may generate IDW, as well as through use of screening information during the site inspection. The potential problems of managing IDW should be a factor in choosing an investigation method.

5.2.3 Consistency with Final Remedy

Most IDW generated during the course of an investigation are intrinsic elements of the site. If possible, IDW should be considered part of the site and should be managed with other wastes from the site, consistent with the final remedy. This will avoid the need for separate treatment and/or disposal arrangements. Because early planning for IDW can prevent unnecessary costs and the use of treatment and disposal capacity, IDW management should be considered as early as possible during the remedial process. A key decision to be made is whether the waste will best be treated or disposed of immediately or addressed with the final remedy. In addition, when IDW is stored on site, it should be managed as part of the first remedial action that addresses the affected media.

5.3 Selection of IDW Disposal Options

The manner of waste disposal must be consistent with applicable Federal, State, and local regulations. Actual disposal and/or treatment techniques for contaminated materials are the same as those for any hazardous substance, that is, incineration, deposition in a landfill, treatment, etc. Protocols and the parties responsible for the handling and disposal of IDW should be included in the ground water work plan.

Disposal option selection should be based on the previously discussed factors:

1) The type and quantity of IDW generated;

2) Risk posed by managing the IDW on site;

3) Compliance to regulations, standards, and ARARs;

4) IDW minimization; and

5) Whether the final remedy is anticipated to be an off site or and onsite remedy.

6.0 Topographic Survey

6.1 Licensing

When practical or if site circumstances require, topographic survey efforts should be conducted by a Florida-licensed surveyor. Exceptions may include low resolution surveys, temporary point locations, and relative location surveys performed by personnel familiar with land surveying but not state certified.

6.2 Horizontal Control

Each boring and/or well installation should be topographically surveyed to determine its location referenced to either a Universal Transverse Mercator (UTM) grid or the State Plane Coordinate System (SPCS). These surveys should be connected to the UTM or SPCS by third order, Class II control surveys in accordance with the Standards and Specifications for Geodetic Control Networks (Federal Geodetic Control Committee, 1984). If the project is 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 be acceptable. An accuracy of +/- 0.10 foot is expected for monitoring well locations. Under typical conditions, all borings, temporary wells, temporary and/or permanent markers should also have an accuracy of +/- 1.0.

6.3 Vertical Control

Elevations for a designated point (marked measuring point) on the rim of the uncapped well casing (not the protective casing) for each bore/well site should be surveyed to within +/- 0.010 foot and referenced to the National Geodetic Vertical Datum (NGVD) of 1988. If elevations for the natural ground surface at the bore/well site (not the top of the concrete pad) are required, the survey should be within +/- 0.10 foot and referenced to the NGVD 1988. These surveys should be connected by third order leveling to the NGVD in accordance with the Standards and Specification for Geodetic Control Networks. If the project is in an area remote to NGVD benchmarks and such vertical control is not warranted, then elevations measured from a project datum may suffice, at least on a temporary basis.

6.4 Benchmark Placement

Temporary benchmarks may be installed to perform survey work. Temporary benchmarks typically consist of one or more of the following:

1) Iron pin (#4 rebar minimum, 24 inches in length);

2) Railroad spike in utility pole or tree;

3) Masonry nail driven in pavement;

4) Chiseled square on a concrete structure; and

5) Painted portion of a fixed object, such as a specific part of a fire hydrant.

Permanent benchmarks may be required to provide future control at a site. Permanent benchmarks will consist of a concrete monument a minimum of 5 inches square and two feet in depth with an iron pin imbedded full depth of the concrete and set flush with the top of the concrete, or a brass marker set in a five inches square, two-foot deep concrete monument.

6.5 Field Data

The topographic survey should be completed as near to the time of the last well completion as possible. Survey field data (as corrected), should include loop closures and other statistical data in accordance with the Standards and Specifications. Closure should be within the horizontal and vertical limits referenced above. These data shall be clearly listed in tabular form; the coordinates (and system) and elevation (ground surface and top of riser) for all borings, wells, and reference marks. All permanent and semi permanent reference marks used for horizontal and vertical control (benchmarks, caps, plates, chiseled cuts, rail spikes, etc.) should be described in terms of their name, character, physical location, and reference value. These field data should become part of the project records maintained by the site geologist, engineer, geotechnical engineer, project manager, or other appropriate person.

6.6 Survey Reports

The survey report should include the following:

1) A map showing the locations of the monitoring wells, reference points, and benchmarks. Elevations must be included for all wells (ground surface and top of well riser) and benchmarks;

2) A copy of all checked field notes taken during the field work; and

3) A copy of all coordinates and elevations for the monitoring wells, soil borings, surface water/sediment locations, etc., and temporary control points (baseline and traverse points).

6.7 Geographic Positioning System

As an alternative to conventional land surveying, a Geographic Positioning System (GPS) may be used to determine the horizontal and vertical location of points in the field. GPS may provide greater convenience, reduce equipment and personnel demands, and reduce the time required to conduct a survey as opposed to more traditional methods. GPS is particularly suited for point positioning in remote locations away from established benchmarks. Adequate GPS units must be employed, though, as typical well location and elevation determinations require high resolution surveying.

7.0 Well and Boring Abandonment

7.1 General

Abandonment procedures are designed to permanently close a boring or monitoring well. As such they are designed to preclude current or subsequent fluid media from entering or migrating within the subsurface environment along the borehole vertical axis. It is therefore important that a borehole be sealed in such a manner that it cannot act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers.

All soil borings not completed as monitoring wells must be abandoned in accordance with the following procedures and must be documented on the boring log as such. The date(s) of abandonment and the abandonment method must be included on the boring log.

7.2 Methodology

Each boring to be abandoned should be sealed by grouting from the bottom of the boring/well to ground surface. This should be done by placing a tremie pipe to the bottom for the boring (i.e., to the maximum depth drilled) and pumping grout through the pipe until undiluted grout flows from the boring at ground surface. The ground sealant must consist of high-solids, 100 percent-pure sodium bentonite grout. The amount of approved water used should be kept to a minimum. Neither additives nor borehole cuttings should be mixed with the grout. No borehole shall be backfilled with cuttings.

After 24 hours, the driller, site geologist, engineer, geotechnical engineer, or other field representative, should check the abandoned site for grout settlement. Any settlement depression should be immediately filled even with the ground surface and rechecked 24 hours later. Additional grout should be added using a tremie pipe inserted to the top of the firm grout, unless the depth of the unfilled portion of the hole is less than 5 feet and that portion is dry. The process should be repeated until firm grout remains at the ground surface. It may be necessary to grout the boring to a depth of 2 feet below grade and complete the backfill with lean concrete or asphalt, depending upon the composition of the original surface.

References Cited

29 CFR 1910,120, Code of Federal Regulations, 29 CFR 1910,120, Hazardous Waste Operations and Emergency Response

29 CFR 1926, Code of Federal Regulations, 29 CFR 1926, Safety and Health Regulations for Construction

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ASTM A312/A312M, “Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipe,” ASTM International

ASTM C150, “Standard Specification for Portland Cement”, ASTM International

ASTM, D1452, “Standard Practice for Soil Investigation and Sampling by Auger Borings,” ASTM International

ASTM D1586, “Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils,” ASTM International

ASTM D1587, “Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes,” ASTM International

ASTM D1785, “Standard Specification for Poly Vinyl Chloride (PVC) Plastic Pipe, Schedules 40, 80, and 120,” ASTM International

ASTM D2113 Historical Standard, “Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation,” ASTM International

ASTM D2487, “Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System),” ASTM International

ASTM D2488, “Standard Practice for Description and Identification of Soils,” ASTM International

ASTM D3550, “Standard Practice for Thick Wall, Ring-lined, Split Barrel, Drive Sampling of Soils,” ASTM International

ASTM D4894, “Standard Specification of Polytetraflurorethylene (PTFE) Granular Molding and Ram Extrusion Materials,” ASTM International

ASTM D4895, “Standard Specification for Polytetraflurorethylene (PTFE) Resin Produced From Dispersion,” ASTM International

ASTM D5088, “Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites,” ASTM International

ASTM D5092, “Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers,” ASTM International

ASTM D5299, “Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities,” ASTM International

ASTM D5521, “Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers,” ASTM International

ASTM D5781, “Standard Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5782, “Standard Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5783, “Standard Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5784, “Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5787, “Standard Practice for Monitoring Well Protection,” ASTM International

ASTM D5872, “Standard Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D5875, “Standard Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices,” ASTM International

ASTM D6169, “Standard Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations,” ASTM International

ASTM D6286, “Standard Guide for Selection of Drilling Methods for Environmental Site Characterization,” ASTM International

ASTM D6724, “Standard Guide for Installation of Direct Push Ground Water Monitoring Wells”, ASTM International

ASTM D6725, “Standard Guide for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers,” ASTM International

ASTM D6914, “Standard Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices,” ASTM International

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USCOE, EM 385-1-1, Safety and Health Requirements Manual

USCOE, ER 385-1-92, Safety and Occupational Health Document Requirements for Hazardous, Toxic, and Radioactive (HTRW) and Ordnance and Explosive Waste (OEW) Activities

U. S. Environmental Protection Agency, Environmental Investigations Standard Operating Procedure and Quality Assurance Manual, Section 6: Design and Installation of Monitoring Wells, November 2001

Other Suggested References

ASTM D 5876, "Standard Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices," ASTM International

ASTM D 5978, "Standard Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells," ASTM International

ASTM D 5979, "Standard Guide for Conceptualization and Characterization of Ground-Water Systems," ASTM International

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Appendix A – Tables

- Table 4: Typical Borehole and Annulus Volume Calculations
- Table 5: Comparison of Stainless Steel, PVC, and Teflon® for Monitoring Well Construction
- Table 6: Relative Compatibility of Rigid Well Casing Material (Percent)

Table 4: Typical Borehole and Annulus Volume Calculations

Inside Diameter of Borehole (inches)	Outside Diameter of Casing Within Borehole (inches)	Cubic Feet per Foot of Depth	U.S. Gallons per Foot of Depth
1.0	NA	0.005	0.04
1.5	NA	0.012	0.09
2.0	NA	0.022	0.16
2.5	NA	0.034	0.25
3.0	NA	0.049	0.37
3.5	NA	0.067	0.50
4.0	NA	0.087	0.65
4.0	2.5	0.053	0.40
4.5	NA	0.110	0.83
5.0	NA	0.136	1.02
5.5	NA	0.165	1.23
6.0	NA	0.196	1.47
6.0	2.5	0.162	1.21
6.0	4.5	0.086	0.64
6.5	NA	0.230	1.72
7.0	NA	0.267	2.00
8.0	NA	0.349	2.61
8.0	2.5	0.315	2.36
8.0	4.5	0.239	1.78
8.0	6.5	0.119	0.89
9.0	NA	0.442	3.30
10.0	NA	0.545	4.08
10.0	2.5	0.511	3.82
10.0	4.5	0.435	3.25
10.0	6.5	0.315	2.36
11.0	NA	0.660	4.94
12.0	NA	0.785	5.87
12.0	2.5	0.751	5.62
12.0	4.5	0.675	5.05
12.0	6.5	0.555	4.15
14.0	NA	1.069	8.00
14.0	4.5	0.959	7.17
14.0	6.5	0.839	6.27
16.0	NA	1.396	10.44
16.0	4.5	1.286	9.62
16.0	6.5	1.186	8.72

Table 5: Comparison of Stainless Steel, PVC, and Teflon® for Monitoring Well Construction

Characteristic	Stainless Steel	Schedule 40 PVC	Teflon
Strength	Use in deep wells to prevent compression and closing of screen and/or riser	Use when shear and compression strength are not critical	Low-strength capabilities limit deep-well construction
Weight	Relatively heavier	Light-weight	Relatively light
Cost	Relatively expensive	Relatively inexpensive	Expensive
Corrosivity	Deteriorates more rapidly in corrosive water, particularly when exposed to H_2SO_44	Non-corrosive – may deteriorate in presence of high concentrations of ketones, aromatics, alkyl sulfides, or some chlorinated hydrocarbons	Nearly totally resistant to chemical and biological attack, oxidation, weathering and ultraviolet radiation
Ease of Use	Difficult to adjust size or length in the field	Easy to handle and work with in the field	Fairly easy to handle and work with in the field
Preparation for Use	Should be steam cleaned if organics will be subsequently sampled	Never use glue fillings – pipes should be threaded or pressure fitted. Should be steam cleaned when used for monitoring wells is not certified clean	Should be steam cleaned if not wrapped by manufacturer and if organics will be subsequently sampled
Interaction with contaminants	May sorb organic or inorganic substances when oxidized	May sorb or release organic substances	Almost completely chemically inert; may react to halogenated compounds, and sorption of some organic compounds, (Reynolds and Gillham, 1985). Except in the case of very low yield wells which preclude purging prior to sampling, these reactions are unlikely to cause significant sample bias.

Table 6: Relative Compatibility of Rigid Well Casing Material (Percent)

Potentially-Reactive Substance	Type of Casing Material						
	PVC 1	Galvanized Steel	Carbon Steel	Lo-Carbon Steel	Stainless Steel 304	Stainless Steel 316	Teflon®*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Mineral Acid/High Solids Content	100	48	57	60	80	82	100
Aqueous/ Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

Preliminary Ranking of Rigid Materials:

1. Teflon®*
2. Stainless Steel 316
3. Stainless Steel 304
4. PVC
5. Lo-Carbon Steel
6. Galvanized Steel
7. Carbon Steel

*Teflon is a registered product of DuPont

Appendix B – Forms

- Form 1: Soil Parameters for Logging
- Form 2: Rock Parameters for Logging
- Form 3: Monitoring Well Completion Report
- Form 4: Application to Construct, Repair, Modify or Abandon a Well

Form 1: Soil Parameters for Logging

Parameter	**Example**
Classification	
Depositional Environment and formation, if known	
ASTM D 2488 Group Symbol	
Secondary Components and estimated percentages	
Color: *Give both narrative and numerical description and what chart was used – Munsell Soil and/or GSA Rock Color*	
Plasticity	
Consistency (cohesive soil)	
Density (non-cohesive soil)	
Moisture content (use relative terms)	
Structure and orientation	
Grain angularity	

Source: U.S. COE, 1988

Form 2: Rock Parameters for Logging

Parameter	**Example**
Rock Type	
Formation	
Modifier denoting variety	
Bedding/banding characteristics	
Color: *Give both narrative and numerical description and what chart was used – Munsell Soil and/or GSA Rock Color*	
Hardness	
Degree of cementation	
Texture	
Structure and orientation	
Degree of Weathering	
Solution or Void Conditions	
Primary and secondary permeability, including estimates and rationale	
Rock quality designation	

Source: U.S. COE, 1988

Form 3: Monitoring Well Completion Report

DEP Form # 62-520.900(3)
Form Title MONITORING WELL COMPLETION REPORT
Effective Date
DEP Application No.
(Filled in by DEP)

Florida Department of Environmental Protection

Bob Martinez Center, 2600 Blair Stone Road Tallahassee, Florida 32399-2400

MONITORING WELL COMPLETION REPORT

PART I: GENERAL INFORMATION

Well ID:	Site Name:		Well Install Date
Facility ID	Alternate ID	FLUWID #	WMD Permit #
Well Purpose ☐ Background ☐ Intermediate ☐ Compliance ☐ Other (explain)			
Latitude (to nearest 0.1 seconds)		Longitude (to nearest 0.1 seconds)	
Latitude and Longitude collection method: ☐ DGPS ☐ AGPS ☐ MAP ☐ ZIPCODE ☐ DPHO ☐ UNKNOWN ☐ OTHER			

PART II: WELL CONSTRUCTION DETAILS

Water Well Contractor Name	Contractor License #
Company Name	
Construction Method: ☐ Hollow Stem Auger ☐ Solid Stem Auger ☐ Water/Mud Rotary ☐ Air Rotary ☐ Cable Tool ☐ Direct Push ☐ Sonic ☐ Other (describe)	Aquifer Monitored
Top of Casing Elevation (NVGD or NAVD)	Ground Surface Elevation (NVGD or NAVD)

Casing

Material	Inside Diameter	Outside Diameter	Depth (ft.) From	Depth (ft.) To

Screen

Material	Inside Diameter	Outside Diameter	Depth (ft.) From	Depth (ft.) To	Slot Size

Annulus

Material including additives for sealant	Size of Material	Amount (# of bags)	Depth (ft.) From	Depth (ft.) To	Installation Method

PART III: WELL DEVELOPMENT DETAILS

<table>
<tr><td>Well Development Date</td><td colspan="3">Well Development Method: ☐ Surge/Pump ☐ Pump ☐ Compressed Air
☐ Other (explain)</td></tr>
<tr><td rowspan="2">Development Duration</td><td colspan="3"></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Pumping Rate</td><td>Maximum Drawdown</td><td>Well Purged Dry
☐ yes ☐ no</td><td>Pumping Condition
☐ continuous ☐ intermittent</td></tr>
<tr><td colspan="3">Turbidity (if Measured):</td><td rowspan="2">Stabilized Water Level (BLS)</td></tr>
<tr><td>Start:</td><td colspan="2">End:</td></tr>
<tr><td colspan="4">Water appearance (color and odor) at start of development:</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Water appearance (color and odor) at end of development:</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
</table>

Report Prepared By:	Date
Title/Company	License #

PLEASE ATTACH BORING LOG

Remarks

Form 4: Application to Construct, Repair, Modify or Abandon a Well

STATE OF FLORIDA PERMIT APPLICATION TO CONSTRUCT, REPAIR, MODIFY, OR ABANDON A WELL

☐ Southwest
☐ Northwest
☐ St. Johns River
☐ South Florida
☐ Suwannee River

CHECK BOX FOR APPROPRIATE DISTRICT. ADDRESS ON BACK OF PERMIT FORM.

THIS FORM MUST BE FILLED OUT COMPLETELY.

The water well contractor is responsible for completing this form and forwarding the permit to the appropriate delegated county where applicable.

Permit No. ______
Florida Unique I.D. ______
Permit Stipulations Required (See attached)
62-524 well ☐
CUP/WUP Application No. ______

ABOVE THIS LINE FOR OFFICIAL USE ONLY

Fold at this line in order that address is visible through envelope window

1. ______
Owner, Legal Name of Entity if Corporation | Address | City | Zip | Telephone Number

2. ______
Well Location — Address, Road Name or Number, City

3. ______
Well Drilling Contractor | License No. | Telephone No.

______
Address

______
City | State | Zip

4. ______ **1/4 of** ______ **1/4 of Section** ______
(smallest) (biggest)
(Indicate Well on Chart)

NW NE SW SE

5. Township ______ **Range** ______

6. ______ | ______ | ______ | ______ | ______
County | Subdivision Name | Lot | Block | Unit

7. Number of proposed wells ______ **Check the use of well:** (See back of permit for additional choices) ______ Domestic Monitor (type) ______

______ Irrigation (type) (See Back) Public Water Supply (type) ______ (See Back) List Other ______

Distance from septic system ______ ft. **Description of facility** ______ **Estimated start of construction date** ______

8. Application for: ______ New Construction ______ Repair/Modify ______ Abandonment ______ (Reason for Abandonment)

Date Stamp

9. Estimated: Well Depth ______ Casing Depth ______ Screen Interval from ______ to ______
Casing Material: Blk-Steel / Gal / PVC Casing Diameter ______ Seal Material ______

10. If applicable: Proposed Grouting Interval
From ______ to ______ Seal Material ______
From ______ to ______ Seal Material ______
From ______ to ______ Seal Material ______

11. Telescope Casing ______ **or Liner** ______ (check one) Diameter ______
Blk-Steel / Galvanized / PVC Other (specify: ______

12. Method of Construction: ______ Rotary ______ Cable Tool ______ Combination
______ Auger ______ Other (specify:) ______)

13. Indicate total No. of wells on site ______. **List number of unused wells on site** ______.

14. Is this well or any other well or water withdrawal on the owner's contiguous property covered under a Consumptive/Water Use Permit (CUP/WUP) or CUP/WUP Application? ___No ___Yes
(If yes, complete the following) CUP/WUP No. ______
District well I.D. No. ______
Latitude ______ Longitude ______
Data obtained from GPS ____ or map ____ or survey ____ (*map datum NAD 27____ NAD 83____*)

Draw a map of well location and indicate well site with an "X". Identify known roads and landmarks; provide distances between well and landmarks.

North
N
West
East
South

15. I hereby certify that I will comply with the applicable rules of Title 40, Florida Administrative Code, and that a water use permit or artificial recharge permit, if needed, has been or will be obtained prior to commencement of well construction. I further certify that all information provided on this application is accurate and that I will obtain necessary approval from other federal, state, or local governments, if applicable. I agree to provide a well completion report to the District within 30 days after drilling or the permit expiration, whichever occurs first.

I certify that I am the owner of the property, that the information provided is accurate, and that I am aware of my responsibilities under Chapter 373, Florida Statutes, to maintain or properly abandon this well; or, I certify that I am the agent for the owner, that the information provided is accurate, and that I have informed the owner of his responsibilities as stated above. Owner consents to personnel of the WMD or a representative access to the well site.

______
Signature of Contractor | License No. | Owner's or Agent's Signature | Date

DO NOT WRITE BELOW THIS LINE — FOR OFFICIAL USE ONLY

Approval Granted By: ______ Issue Date: ______ Hydrologist Approval ______ Initials

Owner Number: ______ Fee Received: $ ______ Receipt No.: ______ Check No.: ______

THIS PERMIT NOT VALID UNTIL PROPERLY SIGNED BY AN AUTHORIZED OFFICER OR REPRESENTATIVE OF THE WMD. IT SHALL BE AVAILABLE AT THE WELL SITE DURING ALL DRILLING OPERATIONS. ***This permit is valid for 90 days from date of issue.***

WHITE: ORIGINAL FILE
YELLOW: DRILLING CONTRACTOR
PINK: OWNER

SRWMD FORM 40B-3-1 REV. 12/95

Appendix C- Specific Capacity Testing

The purpose of specific capacity testing can be multi-fold, and depends on project demands. Specifically, some of the objectives of specific capacity testing include:

1) Determine the maximum pumping rate for a given well;

2) Obtain data to calculate first estimate of hydraulic conductivity and storativity; and

3) Obtain data to determine well efficiency.

Specific capacity tests can be conducted during or following development, or during purging for sampling. Specific capacity testing should be considered if the well is capable of sustaining a measurable yield, and if the test well pump is capable of sustaining a constant rate discharge. Specific capacity is defined as yield divided by drawdown, and is normally expressed as gallons per minute/feet of drawdown. Both pumping rate and drawdown are measured simultaneously in the tested well after a given amount of time has elapsed. Dividing the yield rate by the stabilized drawdown, gives the specific capacity. Specific capacity can vary with pumping duration, with specific capacity decreasing as pumping time increases. Additionally, specific capacity also generally decreases as discharge rate increases. Both of these responses are due to the dewatering of the aquifer within the domain of the cone of depression; for a given amount of drawdown, the yield progressively becomes less as the saturated thickness of the aquifer is reduced. Specific capacity may also vary with yield as function of the system efficiency, including the pump, well, discharge piping, well efficiency, etc., which all add an element of friction to the process.

The analysis of specific capacity test data is relatively straightforward, and based on equations presented in Jacob (1946) and Lohman (1972). Bradbury and Rothschild (1985) compiled a computer program to accept specific capacity data and output aquifer transmissivity. This program accounts for well loss and partial penetration, and is easily compiled from the reference. The treatment of partial penetration in the program is straightforward, and is treated mathematically in the reference. Well loss is less apparent, and is discussed further.

Well loss in an important factor in the analysis of specific capacity data when yield rate is substantially high. Well loss, or head loss due to well inefficiency, is due to turbulent flow of water through the well bore, into the well, and into the pump. Well loss is expressed as a percentage, or as a coefficient.

The equation representing general well loss (Walton, 1987) is expressed as:

Equation 1 $$S_\omega = CQ^2$$

Where:

- S_ω = drawdown component due to well loss, in feet
- C = well coefficient, in sec²/ft^5
- Q = production well discharge rate, in cubic feet per second (cfs) (1 cfs = 449 gallons per minute [gpm])

Values of the well loss coefficient as used in the Bradbury and Rothschild program for production wells are generally less than 10 and are more often than not less than 2 (Walton, 1987). Typically, well loss is calculated using step drawdown test data. During a step drawdown test, yield rate and drawdown are measured synoptically while the pump is operated at successive stages at some fraction of full capacity. Using a step test data, the well loss coefficient may be estimated by the following equation (Walton, 1987):

Equation 2 $$C = \frac{(\Delta S_n/\Delta Q_n) - (\Delta S_{n-1}/\Delta Q_{n-1})}{(\Delta Q_{n-1} + \Delta Q_n)}$$

The following example illustrates a typical well loss coefficient calculation: A step drawdown test was performed. The pumping rates and times are shown below:

Start Time	End Time	Pumping Rate (gpm)
10:30	12:40	13.3
12:40	14:00	25.0
14.00	14.20	42.0

During the pumping periods, the water levels in the pumping well were recorded using an electronic water/level indicator. Data required to calculate the well loss coefficient are shown below:

Step # (n)	Q (gpm)	Q (cfs)	ΔQ (cfs)	s (ft)	Δ s (ft)
1	13.3	0.0296	0.0296	5.6	5/.6
2	25.0	0.0557	0.0261	11.6	6.0
3	42.0	0.0935	0.0378	21.2	9.6

Where:

- Q = Actual discharge for the time step
- ΔQ = Increase in discharge for the time step
- S = Drawdown at the time step pumping rate
- ΔQ = Increase in drawdown from the previous time step

Using Equation 2, the well loss coefficients are:

C 1.2 = 730.7 sec^2 / ft^5
C 2.3 = 377.1 sec^2 / ft^5

Therefore, the average well loss coefficient is 553.9 sec^2 / ft^5. Using Equation 1, the well loss at 42 gpm is theoretically calculated to be 4.8 feet.

The importance of determining the well loss coefficient will depend on the yield rate of the test. Because of the association with turbulent flow, calculation of the well loss coefficient may be impractical and unnecessary for a yield rate of a few gallons per minute or less.

The procedure for conducting a specific capacity test is quite simple, and consists of the following general steps:

1) Open the well to vent;

2) Measure the static water level;

3) Insert pump into well and allow to equilibrate;

4) Remeasure water level to ensure equilibration following pump insertion;

5) Initiate pumping;

6) Measure yield rate and drawdown synoptically at regular and frequent intervals, and record on the specific capacity test form;

7) Pump until drawdown stabilized (subjective determination; generally measurements within 0.03 feet over a ten minute interval can be considered stable);

8) Terminate pumping; and

9) Measure water levels at frequent intervals during recovery to ensure original static water level is reached; the water level measured when residual drawdown stabilized should be used as the static water level.