CONSTRUCTION

OF

GEOTECHNICAL BOREHOLES

AND

GROUNDWATER MONITORING SYSTEMS

HANDBOOK

PREPARED BY THE

LOUISIANA DEPARTMENT OF ENVIRONMENTAL QUALITY

AND

LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

DECEMBER 2000

CONSTRUCTION OF GEOTECHNICAL BOREHOLES AND GROUNDWATER MONITORING SYSTEMS HANDBOOK

December 2000

REVIEW COMMITTEE MEMBERS:

ZAHIR "BO" BOLOURCHI
NARENDRA M. DAVE
MYRNA MOLINE
DOUGLAS BRADFORD
WILLIAM H. SCHRAMM
JOSEPH BALL

CONTRIBUTORS:

DAVID BARDSLEY
MIKE KYLE
RAY STURDIVANT
JEFF NESS

Copies of this publication are available by writing to the Louisiana Department of Transportation and Development, Water Resources Section, P.O. Box 94245, Baton Rouge, Louisiana 70804-9245.

To download copies of this document, please visit either of our websites: http://gis.dotd.state.la.us/wells/intro.html or www.deq.state.la.us Comments, questions or suggestions to improve this document may be sent to the above address or by e-mail to bschramm@deq.state.la.us with cc to BoBolourchi@dotd.state.la.us

FOREWORD

This handbook has been prepared by the Louisiana Department of Environmental Quality (LDEQ) and the Louisiana Department of Transportation and Development (LDOTD) after review of guidance documents prepared be the U.S. Environmental Protection Agency, American Society of Testing Materials, U.S. Army Toxic and Hazardous Materials Agency, and the National Ground Water Association. Much of the information contained in this document has been obtained from these publications and adapted to the hydrogeology of the State.

This document is intended to provide a reliable and uniform reference of the preferred materials, procedures and practices for the construction and plugging and abandonment of groundwater monitoring and recovery systems and boreholes. It is not intended to present any specific regulation or regulatory program, however, it will guide the user in meeting regulatory requirements. The user should always consult the specific regulation or contact the appropriate regulatory authority.

The use of procedures or materials that deviate form this guidance, without prior approval, may result in the work not being accepted.

The LDOTD has licensing authority over well drilling contractors operating in the State. All borehole, monitoring well, recovery well and piezometer installations, including plugging and abandonment, shall be in accordance with this handbook and the Louisiana Water Well Rules and Regulations and Standards and shall be registered with that authority.

Both Departments thank the regulated community for their patience, input, and cooperation during the preparation of this handbook. The LDEQ and LDOTD are optimistic that following the construction and plugging and abandonment procedures contained in this document will result in well installation capable of providing quality samples for groundwater analysis and also insure that adequate plugging and abandonment procedures are practiced.

This handbook may be revised periodically upon mutual consent of both the LDEQ and LDOTD.

J. Dale Givens
Secretary
Louisiana Department of
Environmental Quality

Kam K. Movassaghi
Secretary
Louisiana Department of
Transportation and Development

TABLE OF CONTENTS

INNOVATIVE TECHNOLOGIES

1.0 DEFINITIONS AND ABBREVIATIONS

ASTM -	American Society for Testing and Materials
HAZWOPER -	Hazardous Waste Operator
LDEQ -	Louisiana Department of Environmental Quality
LDNR -	Louisiana Department of Natural Resources
LDOTD -	Louisiana Department of Transportation and Development
NGVD -	National Geodetic Vertical Datum
NSF -	National Sanitation Foundation
OSHA -	Occupational Safety and Health Administration
PVC -	Polyvinyl chloride
SDR -	Standard Dimension Ration
UIC-	Underground Injection Control Program
UST -	Underground Storage Tank

Annular Space – Annulus: The Space between the wall or side of a well borehole and the well casing.

Appropriate Regulatory Authority: For the purpose of this handbook, this refers to the appropriate divisions within the LDEQ and the LDOTD. The appropriate divisions shall be determined by the program, which requires collection of geotechnical and/or hydrogeological information from the installation of a monitoring well(s) or geotechnical borehole(s) in order for it to carry out its mission under the regulations and statues on the State of Louisiana.

Bailer: A tubular device, generally equipped with a bottom check valve, that is lowered into a well to obtain samples of the groundwater or to remove cuttings from the borehole.

Bentonite: A highly expansive clay consisting predominantly of montmorillonite. Bentonite as used in this handbook is to be predominantly sodium montmorillonite. Bentonite is available in the following forms:

1. Bentonite Powder - means #200 mesh pure bentonite without additives.
2. Bentonite Granules - means #8 mesh pure bentonite without additives.
3. Bentonite Chips - means commercially processed angular fragments of bentonite without additives.
4. Bentonite Pellets - means commercially manufactured tablets made by compressing pure bentonite, without additives, into forms greater than ¼ inch in size.

NOTE: Some commercially available forms of bentonite may be coated with or contain ethanol or an ethanol derivative.

Bentonite Grout: A high solids well sealing material composed of predominantly sodium montmorillonite clays.

Borehole: Any hole advanced for the purpose of obtaining geotechnical, hydrologic or stratigraphic information. If the hole is to remain open for greater than 30 days, it must be converted to a permanent well or be properly plugged and abandoned. Anyone installing a borehole or well in Louisiana must be licensed by the LDOTD.

Casing: A tubular retaining structure, generally metal or PVC, which is installed in a drilled, bored, driven or augered hole to maintain the well opening.

Cement-Bentonite Grout (Slurry): A mixture in the proper proportions of cement, bentonite and water, consisting of not more than seven percent (7%) bentonite by dry weight of cement and a maximum of ten (10) gallons of water per sack (94 pounds) of cement (**see EXHIBIT 1**).

Centralizer: A device attached to the well casing used to center the casing in the borehole and to provide a uniform annular space for effective grouting.

Coefficient of Uniformity: A measure of the grading uniformity of particle sizes. It is define by the ration of D_{60} / D_{10} where :

$$C_u = \frac{D_{60}}{D_{10}}$$

D_{60} = particle diameter (mm) corresponding to 60% passing (finer) and
D_{10} = particle diameter (mm) corresponding to 10% passing (finer), by weight.

Contamination (Groundwater): The introduction into the groundwater of any chemical, organic material, live organism(s) or radioactive material that degrades the quality of the groundwater.

Drilling Contractor: A person, firm or corporation who is licensed by the LDOTD to engage in the drilling, reworking or installation of water wells, monitoring wells, heat pump wells or hole, geotechnical boreholes and/or the plugging and abandonment of wells or holes, excluding oil and gas wells.

Effective Size: The sieve size that retains 90%, passes (finer) 10% of the formation material. Often referred to as the D_{10} size.

Environment: This term includes water, air, land and all plants, animals and mankind living therein and the interrelationships, which exists among them.

Filter Pack: The inert, usually siliceous material placed in and around the annular space between the borehole and a perforated casing or well screen to prevent the movement of finer material into the well.

Geologist: A person who studies the scientific origin, history, structure and processes of the earth and other celestial bodies. He/she is a graduate of an accredited institution of higher education who has successfully completed a minimum of 30 semester hours or 45 quarter hours of course work in the science of geology and has in his/her possession a minimum of a Baccalaureate degree.

Geotechnical Borehole: An exploratory borehole drilled, augered, bored, cored or driven to obtain soil and/or groundwater samples to be analyzed for chemical and/or physical properties.

Groundwater: Any water beneath the land surface.

Lysimeter: A device that allows the extraction of liquids from soil pore spaces which are not completely filled with water, commonly using a negative pressure to overcome the surface tension of water partially filling the pore spaces in the unsaturated zone.

Monitoring Well: Any permanent cased hole that is drilled, augered, bored, cored, driven, washed, dug, jetted or otherwise constructed to obtain hydrologic and water quality data, usually installed at or near a known or potential source of groundwater contamination.

National Geodetic Vertical Datum of 1929 (NGVD)[1]: A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called the "Mean Sea Level of 1929". The current national standard is the North American Datum of 1983 (NAD 83), which incorporates the NGVD of 1927 as updated in 1929.

Piezometer: A small diameter, non-pumping well used to measure the elevation of the water table or potentiometric surface.

Recovery Well: A well used to recover contaminated groundwater.

Reference Point: A permanent point, marked or otherwise affixed to the top surface of the concrete surface slab around the well that states the elevation (NGVD) of that point. Used to determine the potentiometric elevation when measuring the depth to water.

Saturated Zone or Zone of Saturation: That part of the subsurface in which all voids are filled with water.

Static Water Level: The elevation of the water in a non-pumping well that has reached equilibrium with the surface (atmospheric) pressure and expressed in feet above or below Mean Sea Level (NGVD).

Transmissivity: The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Tremie Pipe: A device, usually a small diameter pipe, that carries grouting materials to the bottom of the hole and which allows pressure grouting from the bottom up without introduction of appreciable air pockets.

Unsaturated Zone or Zone of Aeration: The zone between the land surface and the water table in which the soil pores are not completely filled with liquid.

Well Development: The process whereby drilling fluids, solids and other mobile particulates are removed from a well and the adjacent filter pack. The act of repairing damage to the formation caused by drilling procedures and increasing the permeability of the materials surrounding the intake portion of the well.

[1] U.S Environmental Protection Agency, Office of Ground Water and Drinking Water, Washington, D.C., Definitions For The Minimum Set of Data Elements For Ground Water Quality, EPA 813/b-98-002, July, 1992, p. 13.

2.0 INTRODUCTION

Louisiana has an abundant resource of fresh groundwater. This groundwater provides drinking water for 61% of Louisianians, is the source for about 85 percent of all public-supply drinking water systems and is the major source for industrial, agricultural and most rural water users.

The registration and cataloguing of water wells and holes, licensing of drillers and gathering and dissemination of water data are the responsibility of the LDOTD. This agency provides computerized access to well data through their website (**http://gis.dotd.state.la.us/wells/intro.html**) and publishes valuable reports on the availability and quality of groundwater throughout the State.

The protection and preservation of this valuable resource is one of the most critical functions of Louisiana regulatory agencies including LDEQ and LDOTD. In an attempt to fulfill this important obligation, the LDEQ regulates and monitors the activities of operations that may pose a threat to the environment of the State. An important part of this responsibility is monitoring the groundwater quality. Many of these activities and studies can be found on their website (**www.deq.state.la.us/index.htm**)

The groundwater monitoring well and/or geotechnical borehole is a tool that allows access to an unseen environment. The chemical analyses of groundwater samples and physical data obtained from subsurface investigations are used to evaluate the environmental impact of a facility, to allow the early detection of chemical releases to the groundwater, to determine the extent, nature and fate of groundwater contamination and the effectiveness of groundwater recovery systems.

These subsurface investigations shall be conducted and monitoring systems constructed in such a manner so as not to impact the nature of the groundwater or provide an avenue for contaminants to be introduced from the surface or from one aquifer to another. It is for that reason that cleanliness and the restricted use of potential contaminants are stressed throughout this document.

The procedures outlined in this document are applicable to geotechnical boreholes, monitoring systems, recovery wells and piezometers.

When conditions allow, wells installed at UST facilities must meet ALL of the requirements in this document. It is understood that in certain instances, wells installed at these facilities will be required to be constructed differently than those installed at other regulated facilities because of existing conditions and restrictions such as high traffic volume, shallow saturated zones and light non-aqueous phase liquids. Provisions are made in this document to allow exceptions to accommodate these special conditions.

The design and approval of recovery wells is determined on a site by site basis by the LDEQ.

3.0 PRIOR TO CONSTRUCTION

3.1 Safety Training

The drilling contractor has a responsibility to the drilling and well construction personnel not to place them in a situation where they are unduly exposed to any health risks during the construction of the well or geotechnical borehole. Therefore, the contractor should provide adequate safety training. Since sites where environmental groundwater investigations are carried out may result in exposure to contaminated media, the safety training should not only address equipment operations safety, but also include training

in the Occupational Safety and Health Administration (OSHA) requirements for respiratory protection and personal protection.

3.2 Design of the Filter Media and Well Screen Selection

The purpose of the filter media is to create an area of high hydraulic conductivity around the well screen while holding back the formation material in the monitored zone while not adversely impacting the chemistry of the groundwater,

The proper design of the filter media and the screen slot size is critical and is based on the grain size distribution of the formation to be monitored.

The filter media should be designed first. The filter media grain size should be selected by taking the 70% retained size of the finest formation material and multiplying that size by a factor of Four (4) or Six (6). The Four factor should be used for formations that are fine and uniform, and Six for formation that are coarse and nonuniform. In either instance, the coefficient of uniformity (C_u 4) should be less than 2.5.

The plotted grain size distribution curves should be smooth and gradual.

The slot size of the well screen can only be determined **after** the filter media has been designed. The slot size should be selected that will retain at least 90% of the filter pack.

3.3 Approval of Design

Installation and the plugging and abandonment of groundwater monitoring systems or boreholes at facilities under the regulatory authority of the LDEQ require prior written approval. This approval is obtained by submitting the intended design of the well and the location and function of the well to the appropriate regulatory division(s) within LDEQ. Design components include: screen length and diameter, slot size, grout mixture (see EXHIBIT 1), protective casing, slab dimensions and any other aspect of construction that may deviate from typical installations.

3.4 Cleanliness of Construction Equipment

All equipment used in the construction of a monitoring system shall be free of contamination. Such equipment includes: drill rig, augers, drill stem, samplers, tools, water tank, recirculation tanks, pumps and any other auxiliary equipment. The interior of the water tank(s) should be free of rust and other scale. All cleaning and decontamination should be performed in areas that will prevent the wash water from entering the site of construction and, in an area that will allow for the collection and treatment of the wash water. If the decontamination was done prior to arrival on the site, the equipment should be washed with potable water upon arrival and once again completely decontaminated before relocation to the next boring site. Before leaving the site of the monitoring system and/or geotechnical borehole, all construction equipment shall be decontaminated. The methodology used to decontaminate equipment when drilling at facilities under regulatory authority is subject to prior approval.

3.5 Water Used in Construction

The water to be used for drilling, grouting, sealing, filter pack placement, well installation or equipment washing shall be potable and should not adversely impact the chemical and biological quality of the groundwater.

If a water source other than a public drinking water supply is used, then prior approval of the source should be obtained from the appropriate regulatory authority. This request should be accompanied with the following information:

1. The address and telephone number of the water source owner.

2. The location of the water source.

3. Any treatment of the water source and the type of treatment ie: chlorination, fluoridation, softening, etc.

4. The results and date of the most recent chemical analysis if available. Include the name and address of the analytical laboratory.

The contractor has the responsibility to procure, transport and store the water required for the project need in such a manner as to avoid the chemical contamination or degradation of the water.

The tanks or tank trucks used for transport of the water should be free of loose rust, scaling or any other materials that might alter the properties of the water transported. Tanks should be thoroughly cleaned prior to use in water transport.

4.0 CONSTRUCTION OF THE BOREHOLE

4.1 Licensing Requirements for Drillers and Contractors

Anyone intending to drill, install or plug and abandon a borehole or well shall meet the licensing requirements for a "contractor or driller" as set forth in Chapter 5 of the Water Well Rules, Regulations and Standards State of Louisiana and follow those regulations. This document is available from the Louisiana Department of Transportation and Development, Water Resources Section.

4.2 Installation of the Borehole

The method used to create the borehole at a facility under regulatory authority is subject to approval of that authority.

The operation of the equipment used to create the borehole should not introduce any contaminants into the borehole or the groundwater environment.

The only additive to the drilling fluid should be bentonite. The use of polymers or other materials to enhance the nature of the drilling fluid is prohibited unless the **appropriate regulatory authority** grants a variance.

All boreholes should be vertical to the extent practicable unless otherwise approved by the **appropriate regulatory authority**.

Surface runoff, ie: precipitation, wasted or spilled drilling fluid, or miscellaneous spills and leaks, shall be prevented from entering any borehole or well.

All cuttings and debris generated by the construction of a borehole must be characterized and properly stored (storage shall not exceed regulatory time limits) and properly disposed.

4.3 Logging of the Borehole

Facilities **regulated by the LDEQ** are required to define the stratigraphy at the site of construction. Soil types and condition of the soils encountered during the boring operation should be described in detail. Logging of these boreholes should be done by an individual(s), preferably a geologist, with sufficient experience to identify soil types, lithology, secondary soil features like slickensides, jointing, macrofractures and the presence of contaminants and all other relevant information necessary to fully document subsurface conditions.

In addition to the data desired by the owner/operator, the following information shall be entered on the boring log or attached to the log:

1. The name of the drilling crew supervisor, driller and individual logging the boring,

2. The surface elevation of the borehole (NGVD),

3. The depths at which soil types change or groundwater is encountered should be recorded to the nearest tenth (0.1) foot,

4. The soil types encountered in the boring shall be described in as great a detail as possible, avoiding general terms such as clay, sand, etc. However, upon completion of any laboratory testing, the soil should also be classified in accordance with the Unified Soil Classification System (USCS) (equivalent to ASTM 2487 and 2488),

5. The lithology of the boring for shallow holes shall be described using sample that are collected with the use of a shelby tube or split spoon sampling device for the entire length of the borehole unless a different procedure is approved by the appropriate regulatory authority. Laboratory testing shall be performed on samples taken from each significant change in lithology. The interval sampled shall be indicated on the boring log.

6. The descriptions of the samples should include the following parameters:

	PARAMETER	EXAMPLE
A.	Classification	Sandy Clay
B.	USCS Symbol	CL
C.	Secondary Components	Sand: 25%, & Estimated Fine Sand 5%, Coarse Sand 20%
D.	Color	Dark Grey (5Y4/1)
E.	Plasticity	Low
F.	Consistency (Cohesive Soil)	Stiff

G.	Density (Non-cohesive Soil)	Loose
H.	Moisture Content	Use a relative term ie: dry, moist, wet, etc. Do not express as a percentage unless a value has been measured.
I.	Observed Organic Content	Wood, roots, etc.
J.	Odor(s) encountered	Sulphur, gasoline, sweet, etc.
K.	Organic Vapor reading	Usually in ppm.
L.	Visual indication of contaminant	Oil, phase material, color change, etc.
M.	Munsell Soil Color Chart Number	Use of this chart is optional.

7. Each log should record the drilling sequence. This should include all special problems and their resolutions on the log, ie: hole caving, recurring problems at a particular depth, sudden tool drops, excessive grout takes, drilling fluid losses, casing installation problems, etc.

8. The log should include the dates and times for the start and completion of the boring.

9. For shallow boreholes, the first encountered free water shall be identified and the depth recorded on the log along with the method of determination. The first encountered water should be allowed to stabilize for at least 15 minutes and the second level and time recorded and all subsequent levels and times recorded until the level is stable. The time necessary for the stabilization of this water surface will vary according to the transmissivity of the water bearing unit.

10. Any special abbreviations used on the log should be defined where they are used, or in a general legend.

11. Soil samples obtained for laboratory testing should be tested for the following physical parameters:

    A. Moisture content (ASTM D-2216),

    B. Liquid Limit, Plastic Limit and Plasticity Index (ASTM D-4318),

    C. Organic Content (ASTM D-2974). This test should be used only for those soils displaying organic matter present during sampling or during preparation for laboratory testing or when the weight of a liquid limit test sample is 75% or greater that that of the oven-dried weight.

    D. Particle-Size Analysis of Soils (ASTM D-422 or ASTM C-136). Test method D-422 should only be applied to fine-grained soils with a Plasticity Index (P.I.) of 5 or less. Test method C-136 should be used for coarser soils such as sands. The grain size analysis is critical for the formation or zone to be monitored.

12. The test data generated from the soil testing should be reported on the boring log.

13. All descriptions and notations made on the original log should be indelibly transcribed. Any corrections made on the log should be done by a single line drawn through the error followed by the correction, date of correction and the initials of the person making the correction.

14. Electric or radioactive logging of a borehole may be included in the work plan submitted for approval by the **appropriate regulatory authority**. Logging should follow industry or ASTM standards.

15. Any and all laboratories used to obtain analytical or geotechnical data for LDEQ regulated projects must be accredited by the LDEQ.

5.0 MATERIALS AND CONSTRUCTI0N OF THE SYSTEM

The construction of the monitoring system shall be done under the direct supervision of an individual with sufficient well construction experience to respond to unforeseen events. This individual should be present at all times during the construction of the well.

The borehole created for the monitoring system should be of sufficient size as to provide a minimum annular space of two (2) inches for drilled boreholes. Wells without annular space, installed by direct push technology are excluded from this requirement.

Provision should be made to maintain the annular space during emplacement or well materials. With hollow stem auger equipment, or if temporary casing is used, the filter pack, bentonite and grout shall be placed as the auger or casing is slowly (partially) being with drawn so that the material slumps against the side walls of the boring.

5.1 Materials for Casing and Screen

Monitor wells should be of sufficient diameter to allow commonly available equipment to be used to collect appropriate quantities of water. The wall thickness for polyvinyl chloride (PVC) and polytetrafluoroethylene (PTFE) casing should be at least schedule 40 or meet SDR 26, whichever casing thickness is greater. Stainless steel shall be either Type 304 or Type 316. For stainless steel installations, the well casing wall thickness shall be sufficient to withstand anticipated formation and hydrostatic pressures imposed on the casing during its installation, well development and use.

The use of PVC, PTFE or stainless steel for casing and screen is recommended. However, with justification, other materials such as fiberglass and galvanized pipe can be used if prior approval is obtained from the **appropriate regulatory authority**. All connections used in well construction shall be threaded, no glues, solvents, epoxies, rivets or thermal processes are acceptable. The use of teflon tape as a gasket is acceptable.

All PVC screens, casings and fittings should conform to National Sanitation Foundation (NSF) Standard 14 for potable water usage.

All screens, casings and centralizers should be new and selected to be as chemically inert to the site environment as technically possible. The pipe shall be marked with the nominal size, standard dimension

ratio or schedule, type of material, either the designation "PVC 1120" or "PVC 1220", the wording "well casing", designation "ASTM F-480", manufacturers name or trademark and the NSF-WC designation. Designations printed on well casings shall be removed from the casing without the use of solvents prior to installation.

The well screens should be commercially fabricated, slotted or continuously wound and have an inside diameter equal to or greater than the inside diameter of the well casing. For PVC and PTFE screens, their thickness should be the same as the well casing. No fittings should restrict the inside diameter of the joined casing and/or screen.

5.2 Casing, Centralizers and Screen Placement

Well screens and well casings should be free of foreign matter ie: adhesive tape, labels, soil, grease, etc. and washed with potable water prior to use. Solvents should not be used to remove any of this material.

The washed screen and casing should be stored and protected to prevent them from becoming contaminated.

The use of a silt trap or sump at the base of the screen is required. The silt trap should be attached by a threaded connection and be of the same composition as the screen. The length of the silt trap or sump shall not exceed two (2) feet and shall be noted on the well construction diagram. The casing shall extend at least two (2) feet below the ground surface.

If the casing and/or screen connectors require the use of gaskets or O-rings, they should be manufactured of a material that is inert and will not alter the quality of the groundwater.

The use of centralizers for wells shallower than twenty (20) feet is at the option of the contractor. The use of centralizers is recommended for wells over twenty (20) feet in depth. Well centralizers and fasteners, when used, should be constructed of inert materials, compatible with the casing. No centralizer should be attached to the well screen or to that part of the well casing exposed to the bentonite seal.

The well screen and filter pack shall be installed such that only one water-bearing zone will be sampled per well.

The borehole should be purged or flushed of drill cuttings and any bentonite clays used during construction. If during construction, unstable soils are encountered or other factors result in side wall caving, the use of temporary casing is recommended. The temporary casing should be clean and rinsed with potable water prior to use. For a well(s) penetrating zones of known or suspected contamination, surface casing shall be used to seal off all such zones. When setting casing through contaminated zones, equipment shall be decontaminated prior to proceeding to a deeper zone.

Prior to the placement of the monitoring system components into the borehole, a direct measurement of the borehole depth by the use of a clean, chemically inert, weighted measuring tape should be made. The depth from the ground surface, to the nearest foot should be recorded on the well construction log.

The casing should extend above the ground surface (stick-up) approximately three (3) feet except in areas where the stick-up of the well poses a hazard or is just not practical due to the location of the well. In this case, the well head must be completed as a flush mount with a surface mounted road box that is manufactured for monitor well installations and is clearly labeled as a monitor well.

5.3 Filter Pack

The filter pack should be placed after placement of the well column and purging of the well of cuttings and drilling fluid.

The filter pack should consist of a washed and contaminant free, 95+% siliceous material. The total amount of water-soluble material should not exceed 1%. The use of a packaged filter pack designed for this use is strongly recommended.

5.4 Filter Pack Placement

The filter pack should be placed in the well by either tremie pipe or poured down and around the annulus of the well in such a manner as to be distributed around the screen at a uniform height and density.

Generally, the filter pack should extend from the base of the sump to a minimum of one (1) foot and maximum of two (2) feet above the screen unless site conditions warrant otherwise. The final height of the filter pack should be recorded on the well construction log.

5.5 Bentonite Seal

It is the function of the bentonite seal to protect the monitored zone from surface infiltration of contaminants, cross contamination between permeable zones and to prevent the material used for grouting the well annulus from entering the monitored zone.

The bentonite seal should be at lease three (3) feet in thickness where practicable and must be placed in such a manner as to be uniform in thickness around the casing (only one foot in thickness is required for UST groundwater monitoring systems). In placing dry bentonite material, great care must be exercised so as not to incorporate any of the accumulated bentonite fines from the bottom of the packaging container into the annulus. These fines react very quickly with water and can result in "bridging" of the bentonite seal and other placement problems.

Immediately after placement of the bentonite seal, a layer of fine sand, one to two (1-2) feet thick should be place on top of the pellets (Figure 1). This layer of sand provides weight during the hydration of the bentonite seal and will enhance the expansion of the bentonite sideways and not simply upward. For wells in which the depth is not appropriate (too shallow or too deep) for the placement of the fine sand, it may be omitted.

The adequate hydration of the bentonite seal is crucial. Without proper hydration, the bentonite seal will not retain the annular grout to be placed above the seal. This failure can result in high pH grout entering the screen area and altering the chemical environment of the monitored formation. If bentonite pellets or chips are used to create the seal, the bentonite should be given a minimum of eight (8) hours to hydrate. For wells in which the bentonite seal is above the saturated zone, potable water must be added until the seal is completely hydrated.

The elevation of the top of the bentonite seal should be determined and recorded on the well construction log.

5.6 Grouting of the Well Annulus

Once the bentonite seal has been given sufficient time to hydrate, the annulus of the well can be sealed by pumping the grouting material down the annulus.

Grouting of well annuli is accomplished by the use of either two methods; a cement-bentonite mixture or a high solids bentonite designed for grouting. Use of high solids bentonite for grouting purposes requires prior approval from the **appropriate regulatory authority**. A copy of the letter of approval shall be attached to the LDOTD registration form.

Cement-bentonite grout, as the name implies, is composed of Portland cement, bentonite and water. The bentonite should be in powdered form. The bentonite may not contain any additives that may compromise analytical data indicative of the actual condition of the groundwater. Contact the **appropriate regulatory authority** for site specific approval. The cement must not contain lumps indicating storage under wet conditions prior to use. The cement should be low alkaline (0.6% total alkalies or less) Portland cement Type I or API Class A. The water should be potable of the same quality as used for the construction of the borehole.

There is a definite relationship between the amount of each component in a cement-bentonite grout mix. The most critical factor is the cement to water ratio. Excessive water thwarts the bonding ability of the cement and may lead to micro-annular features around the well casing.

EXHIBIT 1 provides a ready reference for recommended proportions of cement-bentonite-water for grout mixtures.

The high solids (25+%) bentonite grouts are composed of 90% sodium montmorillonite clays, specially designed as a grouting material for well boreholes and well annuli seals. These mixtures should be free of any polymer additives and must achieve a density of at least 9.4 pounds per gallon (lbs/gal). Grouts consisting of Attapulgite clay instead of bentonite may be used for installation of wells in saline aquifers with the approval of the **appropriate regulatory authority**.

Mixing of the grout material should be done by a mechanical paddle device or recirculation with a grout pump. Manual mixing is discouraged. Mixing activities should continue until a smooth, lump-free consistency is achieved. Once a uniform blend is achieved, the grout weight should be determined with a calibrated mud balance (ASTM-D-4380). The weight of the mixture should be + or – 0.2 pounds per gallon (lbs/gal) of the appropriate weight obtained from Exhibit 1. The weight of the pumped mixture should be recorded on the well construction log.

All grout materials should be placed by a rigid, side discharge tremie pipe, using a pump specifically designed and manufactured to pump grout materials. The use of pumps associated with the recirculation system of the drilling equipment is not allowed. Rig pumps may not be able to accommodate the weight or viscosity of the grout and may contaminate the grout unless decontaminated after each use. Pump failures have resulted in the rejection of the grout mix and extensive delays in well completion.

During the initial grouting, the side discharge tremie pipe should be placed about six (6) inches above the top of the fine sand that caps the bentonite seal and slowly withdrawn as the grout is pumped. Pumping of the grout should continue until undiluted grout exits the annulus at the surface. The grout flowing onto the surface should be sampled and weighed with the mud balance. When the unit weight of the pumped

grout equals the original grout, grouting activities may stop. This procedure will remove any excess water and drill cuttings from the annulus and assure the integrity of the grouted annulus.

The total volume of the grout pumped into the annulus should be recorded on the well construction log.

The next day, or at least 12 hours after grouting, the well should be inspected for settlement of the grout column and additional grout added as needed. The volume of additional grout should be recorded on the well construction log.

The protective casing for the well must be set into the grout column rather than the concrete slab to allow the **appropriate regulatory authority** to inspect the integrity of the grout seal. Care should be taken to properly stage these final construction steps to minimize problems later.

5.7 Well Development

The development of the well may be accomplished with a pump, surge block or jetting and may be supplemented with a bottom discharge/fill bailer (for sediment removal). Air lifting, although not recommended, may be used. If air equipment is used, an oil free compressor or a compressor equipped with an air filtering system capable of removing any possible contaminants from the compressed air shall be used. A flexible hose may be used for development provided the applied air pressure does not result in damage to the screen and that there is no metal nipple or similar device attached to the end of the hose.

Whatever method is used to develop the well, the development should be accomplished in such a manner as not to damage the well screen, filter pack or formation.

No dispersing agents, acids, disinfectants or other additives should be introduced into the well unless prior approval is obtained from the **appropriate regulatory authority**. For the development of horizontal recovery wells, dispersing agents or acids are necessary to break the drilling fluid. These additives shall be specified in the work plan submitted to the **appropriate regulatory authority**.

The addition of water to the well (jetting) may be necessary for the development. The water added must be potable and may not adversely impact the chemical nature of the groundwater.

Well development should continue until the specified conductance and/or pH measurements become constant and reproducible after a 24-hour period.

5.8 Well Protection

5.8.1 Standard wells

Every well should be provided with a vented cap and covered with a locking, protective cover and casing. The protective cover and casing should be manufacture from a corrosion resistant material.

Both the cover and casing should be clean and free of any coatings except paint or primer applied by the manufacturer. If they are not manufactured from a corrosion resistant material, the exteriors should be painted with a weather resistant paint (preferable prior to installation). The use of aerosols or spray guns for painting after placement is not allowed. This is to prevent the introduction of the volatile components of the paint into the well or groundwater.

The protective cover should be lockable and designed to prevent the entrance of unauthorized personnel, rain, wind-blown dust particle or insects into the casing.

The size of the protective casing should be sufficient to provide a minimum space of two (2) inches between the outside of the well casing and the inside of the protective casing.

The protective casing should be firmly set into the grout column and surrounded by a concrete surface slab (see Figure 1). Failure to follow this procedure will result in the mandatory replacement of the protective casing and concrete slab.

Reference points shall be established on the concrete slab close to the protective casing and on the inner well casing. These surveyed points are used to accurately determine water surface elevations.

The protective casing should be provided with a threaded hole and drain plug at the base of the exposed portion of the casing, immediately above the top of the grout column. This drain port allows the removal of any water that accumulates in the area between the well stick-up and the protective casing.

The top of the protective cover should extend at least six (6) inches above the top of the vented cap.

The inside of the locking cover should have the following inscribed, stamped or otherwise permanently affixed:

1. Well identification numbers
   A. LDOTD Registration Number (obtained from the LDOTD or their website),
   B. Owner designated number (MW-99-01),
2. Well depth (NGVD),
3. Screen length,
4. Date of installation,
5. Elevation of both reference points (NGVD) and
6. Elevation of top of screen (NGVD).

The well designation number such as **MW-5** should be placed on the outside of the protective cover or casing. Designations for a well that must be replaced due to damage or plugging of the screen shall be assigned an identification number indicating the number of replacements ie: **MW-5R1** for the first replacement and **MW-5R2** for the second, etc.

All painting shall be completed and dry prior to the initial sampling of the well.

The ground surface around the well shall be covered by a concrete slab conforming to a nominal thickness of four (3.5 to4) inches of concrete (as would be achieved by using a 1x4 or 2x4 dimensional lumber for framing material), extending a minimum of one (1) foot from the protective casing. The surface of the slab shall be sloped to drain away from the well. Considering the cost of the construction of a monitoring well and the projected use of the well for 30+ years, it is prudent to install protective post around the well. These posts shall not be installed in the surface slab to protect the well from shearing off if the protective post receives a severe impact. The posts should be of sufficient strength to prevent vehicular damage to the well. They should be placed so as not to interfere with the inspection or sampling of the well.

Periodic inspection of the surface slab should be made to assure the slab is in complete contact with the ground. Shrinking clays and erosion can remove the ground support for the slab and leave it hanging from the grout column, or well casing. This condition must be corrected as soon as identified and may require complete replacement of the slab, protective casing and survey marks.

5.8.2 Flush Mount Wells

In many circumstances, it is impractical if not impossible to install wells with casing above the surface. When these circumstances arise, flush mounted wells shall be installed using the following methods. However, all efforts must be made to install wells as provided in Section 5.8.1, including wells installed at UST facilities. Approval to install wells flush with the surface must be obtained from the **appropriate regulatory authority**. Approval to install flush mounted wells at UST facilities is not necessary.

Flush mounted wells must be installed with road boxes specifically manufactured for wells. The road box must be of the type with bolt-down lids, waterproof and able to sustain vehicular traffic. The lid should be clearly labeled as a monitor well.

The road box shall be firmly anchored to or embedded into a concrete surface seal.

The actual well cap must be locking and waterproof. No vent hole shall be drilled in the cap or casing.

Elevation reference points shall be established on the road box and the inner casing.

The road box shall extend slightly above the surface (1 to 2 inches) to prevent pooling of water on top of the bolt-down lid. The concrete seal around the road box must be sloped away from the box, providing drainage for water and easy vehicular traffic.

Wells installed in areas without concrete or asphalt pavement must be install with concrete slabs that meet the requirements listed in Section 5.8.1.

The inside of the road box lid shall have the following inscribed, stamped or otherwise permanently affixed:

1.0 Well identification numbers
   A. LDOTD Registration Number (obtained from the LDOTD or their website),
   B. Owner designated number (MW-99-01),
2.0 Well depth,
3.0 Screen length,
4.0 Date of installation,
5.0 Elevation of both reference points (NGVD) and
6.0 Elevation of top of screen (NGVD).

6.0 POST-CONSTRUCTION

The work area around the well should be restored to a physical condition that will allow ready access to the well. This includes the filling of any ruts created by drilling equipment. Borehole cuttings, drilling fluids, decontamination water, excess grouting material and water removed from the well during installation, development and purging should be collected and disposed in a manner previously agreed to

with the client and in compliance with any applicable regulations. Care should be taken to fill in and maintain soil around the perimeter of the surface slab.

6.1 Determination of Well Location

The vertical and horizontal position of each installation in the system shall be determined and subsequently mapped. The well location map should include the location of all monitoring wells in the system and their respective identification number, elevation of the top of the riser position to be used as the reference point for water level measurement and the elevation of the reference point on the slab. The locations and elevations of all permanent benchmarks and pertinent boundary markers located on-site or used in the survey should also be plotted on the map.

The water level measurement reference point should be permanently marked, for instance, by cutting a V-notch into the top edge of the riser pipe. This vertical reference point should be surveyed to the nearest one hundredth (0.01) of a foot in reference to the nearest NGVD reference point.

The horizontal location of all installations, active or decommissioned, should be determined by reference to a standardized grid to the nearest one tenth (0.1) of a foot. For LDOTD registration purposes, the latitude and longitude of the wells shall be determined to the nearest one (1) second of a degree.

Geographic Positioning System (GPS) surveys may be used if they meet the appropriate accuracy or are previously approved by the **appropriate regulatory authority**.

6.2 Well Diagram

The installed well should be depicted on a well diagram as built. This diagram should be attached to the boring log for that well and should graphically note, by depth from the ground surface, the following:

1. The bottom of the boring (the portion most deeply penetrated by drilling and/or sampling,
2. Screen Interval,
3. Filter Pack (top),
4. Bentonite Seal (top),
5. Fine sand 1,
6. Fine sand 2,
7. Cave-in(s),
8. Centralizers,
9. Height of riser (without cap/plug) NGVD,
10. Borehole diameter and
11. Describe on, or attach to the construction diagram:

    A. The actual volume and composition of the grout, seals and filter pack used for the well,
    B. The screen slot size (in inches) slot configuration, outside diameter, inside diameter, schedule/thickness and composition,
    C. The outside diameter, nominal inside diameter, schedule/thickness and composition of the casing,
    D. The joint design,
    E. Centralizer location(s), design and composition,
    F. Date and time of placement of the bentonite seal,
    G. Date and time of initial placement of the annular grout,

H. Protective casing composition and nominal inside diameter and
I. Special problems and their resolution, ie: grout in well, lost casing and/or screen, bridging and any variances from approved well design.

All abbreviations used on the boring log and well diagrams should be defined on the document or in an attached general legend.

The diagram should be attached to the boring log as well as any other logs (electrical, radioactive, caliper, etc.) and submitted to the **appropriate regulatory authority** within 30 working days after the well installation is complete.

7.0 DEVIATIONS FROM APPROVED CONSTRUCTION PLANS

Due to the complex geology and hydrology of the State, this document cannot address every possible situation. Where compliance with the approved construction plan is impractical, the contractor, facility owner/operator or its representative shall request a variance from the approved plan. All construction variance requests shall be addressed to the **appropriate regulatory authority or authorities** prior to its implementation.

Situations will occur during construction where immediate actions are necessary to preserve the integrity of the well or borehole and protect the groundwater environment. For minor variances from an approved construction plan, approval (verbal or otherwise) by the **appropriate regulatory authority** must be obtained prior to implementation. However, written documentation of all changes must be submitted within fourteen (14) days after the changes are approved. All such variances from an approved plan should be documented on the well construction log. This documentation should include a written justification for the variance.

8.0 WELL REGISTRATION AND DOCUMENTATION

The Water Well Rules, Regulations and Standards administered by LDOTD Water Resources Section, require that all groundwater monitoring wells, recovery wells and piezometers shall be registered with that authority. Registration is to be done by use of the Water Well Registration Short Form (DOTD-GW-1S). This form is readily available from the LDOTD (see **EXHIBIT 2**).

A copy of the completed form should be provided to **all appropriate regulatory authorities**.

9.0 PLUGGING AND ABANDONMENT

Equally important as proper construction is the abandonment or plugging procedures.

Investigation boreholes should be left open only as long as necessary to obtain core samples, water samples and establish the initial and stabilized water level(s). If subsequent samples or water level readings are to be taken, the hole shall be completed as a permanent well with suitable casing and annular seal.

Every groundwater monitoring system, recovery well, piezometer and borehole can, through the lack of maintenance or damage, become a ready conduit for surface contaminants to enter the groundwater environment. Any groundwater monitoring system, recovery well, piezometer or investigative borehole that no longer serves a purpose, that is damaged beyond repair or is to be abandoned due to closure of the monitored unit, shall be plugged by a LDOTD licensed water well contractor. For monitor wells, recovery wells and piezometers, the plugging and abandonment shall take place within 30 calendar days after approval of a plugging and abandonment plan. All boreholes shall be plugged as soon as possible or within 30 calendar days after cessation of the sampling program.

9.1 Plugging Requirements

Prior to plugging and abandonment, a monitoring well listing shall be obtained from the LDOTD or their web page, to verify the identity of the well. The well to be plugged shall be identified on the plugging and abandonment form (**EXHIBIT 3**). In the event that the identity of the well can not be verified, accurate latitude and longitude of the well, to the nearest one (1) second of a degree, Section, Township and Range, and ground elevation (NGVD) and U.S.G.S. Quadrangle map number shall be placed on the form.

Construction and/or abandonment of groundwater monitoring or recovery systems or boreholes at facilities under the regulatory authority of the LDEQ require prior written approval. This approval is obtained by submitting the intended design or work plan for the well program and the location and function of the well(s) to the **appropriate regulatory authority within LDEQ**. The following information is required when requesting plugging and abandonment from the LDEQ:

1. Name and address of the facility,
2. Well identification and exact location,
3. Well construction data including:
   A. Well depth and stratigraphy,
   B. Screen length and material,
   C. Casing size and material,
   D. Annular seal description and
4. Reason for abandonment,
5. Proposed abandonment method including sealing method and materials and
6. Other pertinent data.

The **appropriate regulatory division of LDEQ** may accept the proposal or require modification as deemed necessary to protect the groundwater.

If the monitoring well was installed prior to November 1, 1985, the well was never registered or the well was improperly constructed, the well casing shall be removed before grouting the well (unless physical obstructions that can not be removed prevent casing removed). If the monitoring well was installed after November 1, 1985, in accordance with the provisions of the Louisiana Water Well Rules, Regulations and Standards and was properly registered with LDOTD, then removal of the well casing may not be required. For a facility regulated by LDEQ, removal of the casing shall be subject to the **appropriate regulatory authority within LDEQ**. If the casing and screen can not be physically pulled from the borehole, over-drilling should be considered. When the depth of the well or other factors make such efforts impractical, an attempt shall be made to split or otherwise perforate the casing to allow the grout to not only plug the casing, but also to enter any voids existing in the annulus.

The monitoring system and/or borehole shall then be completely filled with cement-bentonite slurry using the pump-down method. Use of other equivalent technology will require prior approval from the **appropriate regulatory authority**. As with the grouting during construction, the guidelines for grouting in Section 5.6 should be followed with the exception that the plugging of geotechnical boreholes and monitor wells may be accomplished by using an open-ended tremie pipe instead of a side discharge tremie pipe.

If it is the intention of the owner/operator to remove all physical presence of the abandoned monitor well/borehole, the point at which the monitor well/borehole exists shall be accurately determined and a record of the location kept by the owner/operator. In areas subject to farming or other work, to prevent damage to plows or other machinery, the casing may be cut below the ground surface before back-filling the hole.

10.0 PLUGGING DOCUMENTATION

Water Well Rules, Regulations and Standards administered by the LDOTD require that the plugging and abandonment of all groundwater monitoring wells, recovery wells and piezometers shall be registered with the LDOTD. This notification is to be done by the use of the Water Well Plugging and Abandonment Form (DOTD-GW-2) and shall include the LDOTD well number for all registered wells. For unregistered wells, latitude and longitude to the nearest one (1) second of a degree, Section, Township and Range, ground elevation (NGVD) and U.S.G.S. Quadrangle map number shall be provided. The form is readily available from the LDOTD (see **EXHIBIT 3**).

11.0 GROUND WATER SAMPLING IN VERY SHALLOW CONDITIONS

Special groundwater sampling devices such as lysimeters may be employed for use when conditions do not allow for the installation of monitoring wells such as for investigations of contaminant plumes at depths less than six (6) feet below land surface. Lysimeters may be employed in the saturated zone and in the determination of the quality of soil pore moisture in the unsaturated zone. The use of lysimeters at facilities regulated by LDEQ must have prior approval.

12.0 AQUIFER REMEDIATION INJECTION WELLS

12.1 Basic Definitions/Terminology

Class IV and V Injection wells are typically shallow injection systems used to place a variety of fluids below the land surface. Injection wells are regulated by the U.S. EPA and the States through the Underground Injection Control Program (the LDNR in Louisiana) in order to protect underground sources of drinking water from contamination. However, injection wells may also be used for aquifer remediation. For the purpose of guidance in this document, only the type of injection well used for aquifer remediation will be addressed. Materials and methods used for aquifer remediation may include enhancements such as microbial additives, bioremediation stimulants, fertilizers or oxygenators[2].

[2] "Class V Injection Wells" EPA Fact Sheet, EPA 816-F-99-016, November 1999.

12.2 Recommended Guidance

Class IV injection wells must meet stringent Federal and State requirements. For these wells, the operator must have a current RCRA permit issued by the LDEQ.

Class V injection wells are currently regulated by the UIC program under the authority of the Safe Drinking Water Act. Under existing Federal Regulations, Class V wells are "authorized by rule" (40 CFR 144). That is, these wells do not require a permit if they do not endanger underground sources of drinking water and they comply with other UIC program requirements. These program requirements include:

1. Submitting basic information about Class V well to EPA or State Primacy Agencies (LDNR),

2. Constructing, operating and closing class V wells in a manner which protect underground sources of drinking water.

The **regulatory authority** may ask for additional information or require a permit in order to ensure that groundwater quality is adequately protected.

All Class IV and V injection wells including aquifer remediation wells used to deliver enhancement material to clean up an aquifer must be approved under the Federal UIC Program administered by the LDNR as well as any other **appropriate regulatory authorities**.

INNOVATIVE TECHNOLOGIES

REGULATORY AGENCIES RECOGNIZE THAT INNOVATIVE TECHNOLOGIES HAVE MADE A SIGNIFICANT IMPACT IN THE ENVIRONMENTAL INDUSTRY AND ARE CONTINUALLY DEVELOPING.

THE APPLICATION OF INNOVATIVE TECHNOLOGIES IS ENCOURAGED, BUT DETAILED EXPLANATIONS AND PROCEDURES SHOULD BE INCLUDED IN WORK PLANS SUBMITTED FOR REVIEW AND APPROVAL BY THE APPROPRIATE REGULATORY AUTHORITY.

THE REGULATORY AGENCIES RECOGNIZE THE IMPORTANCE OF THESE CONTRIBUTIONS AND THE NEED TO PROVIDE SOME BASIC GUIDANCE WHEN USING NEW TECHNOLOGIES.

THE FOLLOWING IS THE RECOMMENDED GUIDANCE FOR THOSE TECHNOLOGIES PRESENTED IN THIS DOCUMENT:

NOTE: ALL APPLICATIONS OF THESE TECHNOLOGIES MUST BE PERFORMED BY LDOTD LICENSED WATER WELL CONTRACTORS.

13.0 HORIZONTAL WELLS

13.1 Basic Terminology/Definitions[3]

Types of well completions:

1. Continuous wells are similar to utility or river crossings. The drill bit enters the ground at an angle of 10^0 or 20^0 above horizontal. The bit is then steered to the target depth using a steering tool (radio beacon or wireline tool). The hole is then drilled at a constant depth until the end of the screen section is reached. The bit is then steered towards the surface until it exits at an angle of 10^0 to 20^0 above horizontal. The diameter of the hole is then increased to the final size by one or more reaming passes with increasingly larger bits. When the final borehole size is achieved, the well screen and casing are pulled from the exit side of the borehole, through the borehole and back to the drill rig.

2. Blind wells are installed in borehole that have only one access point. The beginning of a blind well is the same as a continuous well. However, when the total length of the borehole is achieved, it does not return to the surface. The borehole is then forward or push reamed to enlarge the hole to the final diameter. Once this is achieved, the drill pipe is removed and the well screen and casing pushed into the open hole.

Applications for both types of well have been found in various environmental settings such as; pump and treat, air sparging/soil vapor extraction, bio-sparging and free product removal. They may also be used to produce potable water.

13.2 Recommended Guidance

1. Any company or individual installing horizontal wells or providing horizontal well rehabilitation for environmental applications must be an LDOTD licensed contractor. The contractor should have a basic knowledge of vertical well installation techniques and be able to modify those techniques for horizontal well completions.

2. The selection of materials for use in horizontal well construction must be based on the type of contamination present, geology, well installation method, strength of well material and cost. Well materials used in horizontal well construction include PVC, high-density polyethylene (HDPE), fiberglass, carbon steel and stainless steel.

PVC is typically used for shallow, short continuous well installations. The ASTM F-480 flush thread connection commonly used is not designed for the stresses of long or deep continuous or blind completion methods.

HDPE is the most common horizontal well material and is the material of choice for most continuous well completions. HDPE pipe is formed from high molecular weight polyethylene and is flexible, light weigh and has excellent collapse and chemical resistance properties. Heat fusion welding is the normal method of connecting HDPE joints of pipe. This provides a single continuous length of pipe with no joints or threaded connection. Personnel performing fusion welding should be certified in the methodology.

[3] David S. Bardsley, "Horizontal Environmental Well Overview", Longbore, Inc., Houston, TX, April, 2000.

Steel materials, both carbon and stainless, are typically used for very long or deep continuous wells or blind well installations. For continuous wells, welding is the most common method of attaching joints, while steel materials for blind completions are usually furnished with flush treaded joints.

Well screens should be designed such that the maximum open area vrs. the required strength needed for installation is provided. The anticipated tensile or compressive forces should be calculated prior to materials procurements. The open area vrs. loss of strength for the screen should then be calculated. Slot pattern can be perpendicular or parallel to the pipe axis.

3. Due to the difficulty in placing a gravel/filter pack around the screen in a horizontal borehole, either prepacked screens or no additional filter materials are used for well completions (the formation material is used to make the filter pack). Prepacked screens can be manufactured with carbon/stainless steel, PVC or HDPE.

In many instances, filter material is not required for the horizontal well due to the extremely slow flow rate and relatively long screen section. Many wells in Louisiana have been completed with screen sections over 500' long and have achieved pumping rates of 20 gallons per minute or more.

Centralizers should not be required because of the difficulty in completing both blind and continuous wells. The centralizers normally do not survive the installation process and tear off during completion activities. This leads to the potential of well material failure if the broken centralizer becomes entangled with the screen or casing.

4. Two types of drilling fluids are normally used for horizontal well installations:

   A. Bentonite based fluids are normally used to install wells completed below the water table including groundwater/free phase contaminant recovery and air sparging applications. These fluids are relatively inexpensive, readily available and development methods for removing bentonite fluids from boreholes have been used for many years in both petroleum and water well drilling. In certain instances, additives are required to increase the gel strength of bentonite fluids. Typically, mixed metal hydroxides (MMH) or mixed metal silicates (MMS) additives are used to increase the gel strength without adding weight to the bentonite fluid system. Approval for using these additives must be obtained from the **appropriate regulatory authority** prior to use.

      Well development procedures for horizontal wells with bentonite based drilling fluids are similar to vertical wells drilled with the same fluids. Mechanical activities such as surging, jetting and over-pumping are used along with chemical treatments such as the introduction of polyphosphates (SAPP) and acids (citric and acetic). The metal additives are normally removed during development by reducing the pH of the fluids in the borehole. Use of chemical treatments in development of the well requires prior approval from the **appropriate regulatory authority**.

   B. Biodegradable polymer based drilling fluids are typically used for soil vapor extraction wells completed above the water table. The biopolymer fluids consist of a starch base (zanthan or guar gum) powder with stabilizers to prevent spoilage. The biodegradable fluids are expensive (up to $100/50lb) and are not provided by all well drilling suppliers.

Well development for wells completed with biopolymer drilling fluids, consists of washing/jetting the well with a solution containing chlorine or a specially designed enzyme "breaker fluid". Any introduction of chemicals or other material must have the prior approval for the **appropriate regulatory authority**.

5. One of the most common problems encountered during drilling and installation of a horizontal well is a "frac out" or inadvertent return of the drilling fluid to the ground surface along the pathway of the well. Frac outs can occur at any depth and are caused by natural fractures in the subsurface formation or high drilling fluid pressures.

   The horizontal drilling contractor must be aware of the potential for drilling fluids to vent to the surface. If fluids vents to the surface in an uncontrolled manner, or in a sensitive area such as a roadway, stream or offsite property, the drilling operation must be stopped until the frac out is controlled. The contractor must have pumps, hoses and containment vessels to contain the spilled fluid. If the frac out occurs in an area of contamination, properly trained (**HAZWOPER**) workers must handle the containment and clean up.

6. The surface completion for horizontal wells should be designed to prevent unauthorized entry of personnel, rain/flood water, insects or dust/dirt into the casing. A surface concrete slab or flush mount road box as specified for vertical wells should be constructed for the horizontal well.

7. The borehole size for horizontal well installation should be a minimum of two (2) inches larger than the outside diameter of the casing. Annular grout should be placed from the ground surface as deep as possible using a tremie pipe/pump down method. At least the top thirty (30) feet of measured depth (pipe length) should be grouted using the same grout mixtures as described for vertical wells (see **EXHIBIT 1**).

8. Surface casing, if used for blind wells, may be cemented from the end of the casing to the ground surface using a drillable float shoe.

9. Thixotropic cements that develop gel strength may be allowed for use in horizontal wells with the approval of the **appropriate regulatory authority**.

14.0 SOIL VAPOR EXTRACTION/AIR SPARGING WELLS

14.1 Basic Terminology/Definitions[4]

1. Air injection wells are wells connected to an air compressor which forces air into the ground.

2. Air sparging (AS) is a process of pumping air into the saturated zone to help flush (bubble) contaminants upwards into the unsaturated zone where SVE extraction wells can remove them.

3. Air sparging systems are designed to deliver compressed air throughout the contaminated zone to aid in the exchange of VOC's and SVOC's into the vapor phase.

[4] EPA "A Citizen's Guide to Soil Vapor Extraction and Air Sparging" EPA 542-F-96-008, April, 1996

4. AS/SVE Systems consist of vapor extraction wells, air injection wells or air vents installed in the contaminated area.

5. Saturated zone is all soils having pore spaces completely filled with water, below the water table.

6. Soil vapor extraction (SVE) is a simple process that physically separates contaminants from soil. SVE is sometimes called in situ volatilization, enhanced volatilization, in situ soil venting, forced soil venting, in situ air stripping or soil vacuum extraction.

7. SVE Systems are designed to remove contaminants that have a tendency to volatilize or evaporate easily. SVE removes volatile organic compounds (VOC's) and some semi-volatile organic compounds (SVOC's) from soil in the unsaturated zone. By applying a vacuum through a system of wells, contaminants are pulled to the surface as vapor or gas. Often, in addition to vacuum extraction wells, air injection wells are installed to increase airflow and improve removal rates of the contaminants and to stimulate bioremediation of some compounds.

8. SVOC's are semi-volatile organic compounds such as those found in heavy fuels and creosote. Common compounds are anthracene, dibenzofuran, naphthalene, phenol, etc.

9. Treatment systems consist of varied methodologies used to remove or destroy contaminants recovered by the AS/SVE system. These methods include; carbon absorption, catalytic oxidation, condensation, biological treatment, incineration and ultraviolet oxidation.

10. Unsaturated zone is that part of the subsurface located above the water table and lacks water filled pore spaces.

11. Vapor extraction wells can be either vertical or horizontal. Typical placement is vertical to penetrate the lower portion of the unsaturated zone to provide a conduit for the removal of soil vapor and contaminants.

12. VOC's are volatile organic compounds such as those found in solvents and lightweight fuels. Common compounds are benzene, toluene, ethylbenzene, xylene, trichloroethylene, percholoroethylene, etc.

Applications for AS/SVE systems are commonly at UST sites, although many sites with chlorinated organic compounds have installed these remediation systems.

14.2 Recommended Guidance

1. General installation of AS/SVE wells should follow standard installation methods for regular monitor wells.

2. Proper care should be taken in the design of the surface seal to ensure that it is as tight as possible. Typically, these wells are installed at much shallower depths. Specialized construction techniques should be used to achieve the proper seal.

3. Screen design and placement must account for seasonal variations in groundwater levels.

4. Additional information can be found in the document "How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers", EPA 510-B-94-003, October, 1994, Chapters 2 and 7.

15.0 DIRECT PUSH TECHNOLOGY

15.1 Basic Terminology/Definitions[5]

Direct push technology also known as DPT is a procedure that uses a Soil Probing Machine (SPM) designed to quickly install small diameter geotechnical boreholes and/or groundwater monitoring wells for the purpose of collecting soil cores, soil gases, or groundwater samples. The SPM is a vehicle-mounted, hydraulically powered machine that utilizes static and percussion to advance small diameter tools into the subsurface. DPT is useful in tight spaces and is cost effective in cases where numerous, shallow wells or boreholes must be installed. DPT eliminates drill cuttings subject to disposal requirements. DPT does not allow for the placement of the typical grout column.

In areas of known contamination, DPT may drag shallow contaminants downward to deeper zones. Extreme care must be taken to prevent this drag down. Some successful attempts to push through contamination have been accomplished by pushing a separate casing into the underlying aquitard to separate contaminated from uncontaminated zones.

The monitor wells are typically constructed of PVC risers and specially designed, prepacked screens. The prepacked screens are usually three (3) or five (5) feet sections with selected inside and outside diameters. The inner component of the prepacked screen may consist of a selected schedule PVC screen with appropriate slot size. The outer component is usually stainless steel wire mesh of a selected pore size. The screens are usually prepacked with a 20/40 grade silica sand prior to installation.

Monitor well installation can be divided into five main steps:

1. Anchoring the well assembly at depth,
2. Providing a sand pack and grout barrier,
3. Installing a bentonite seal above the screen,
4. Grouting the well annulus and
5. Installing a surface cover.

15.2 Recommended Guidance

1. Sand pack and grout barrier: If the formation does not collapse, a sand pack must be placed from the surface. This portion of the well installation is important because an inadequate barrier will allow grout to reach the well screen.

2. Bentonite seal: The seal is formed either by pouring granular bentonite into the annulus, or by injecting a high bentonite slurry directly above the grout barrier. Use of bentonite chips is limited to cases in which the top of the screen ends above the water table. Whichever method is used, at least two (2) feet of bentonite must be placed above the sand pack.

[5] Geoprobe Technical Bulletin No. 96-2000, September, 1996.

3. Grouting the well annulus: The placement of grouting material within the well annulus provides additional protection from vertical contaminant migration. Most grout mixes are composed of neat cement, high-solids bentonite slurry or a combination of cement and bentonite. Such mixes must be delivered with a high-pressure grout pump.

4. Surface cover: A surface cover/casing protects the PVC well riser from damage and tampering. Above ground or flush mount well covers may be used for the site specific application.

5. Well Development: The well development serves to: remove most of the finer grained material from the well screen and filter pack that may interfere with water quality analyses, restores groundwater properties disturbed during the probing process, improves the hydraulic characteristics of the filter pack and hydraulic communication between the well and the aquifer. Development should continue until consecutive samples yield water representative of the normal aquifer. This is determined by stabilized field parameter measurements (pH, conductivity, temperature and turbidity) and visual clarity of the water.

   The two most common methods of well development are bailing or pumping (purging) and mechanical surging. Mechanical surging may damage the well screen and/or reduce groundwater flow across the filter pack if performed incorrectly or under improper conditions. Development procedures should take into account the field conditions and follow standard practices[6].

16.0 CONE PENETROMETER TESTING

16.1 Basic Terminology/Definitions[7]

Cone penetrometer testing or cone penetration testing (CPT) is advancement of a series of rod and gauges at a constant rate, through soil, to obtain geotechnical and stratigraphic information and to collect soil and groundwater samples. The stratigraphic information is gained by logging the test with electronic strain gauges to measure the penetration resistance of the core and the friction resistance of the rods and a pore pressure sensor to measure the hydrostatic pressure below the water table.

Other types of sensors available are:

1. Conductivity/Resistivity: Measures electrical resistance of soil/water matrix around the CPT instrument,

2. Seismic: Measure shear wave velocity profile for liquifaction analysis,

3. Laser Induced Fluorescence: Used for mapping and delineation of hydrocarbon plumes (phase) in conjunction with standard CPT logging suite,

[6] ASTM D-5521, Standard Practice for Design and Installation of Groundwater Monitoring Wells in Granular Aquifers: 1996 Annual Book of Standards, Vol. 0409, Philadelphia, PA

[7] "Cone Penetrometer Testing", Fugro Geosciences, Inc., Houston Texas, June 2000, Jeff Ness

4. Pressuremeter: Which measures the radial response of soil to radial expansion and contraction of cell.

16.2 Recommended Guidance

1. During CPT investigations, each location may require a stratigraphic push and additional sampling pushes for each target zone.

2. Open Holes from CPT investigations must be grouted in accordance with one of these three methods:

   A. Inserting the tremie pipe down the open hole and pumping grout from the bottom up

   B. Removing the test rods from the hole and reinserting a second set of hollow grout rods with a disposable "dummy" tip. Then, removing the rods while pumping the grout from the bottom up.

   C. Attaching a grout sub just behind the cone with a detachable sleeve in place. When the test is completed, the cable is removed, the grouting head attached and the grout introduced while the rods are pulled. The grout is pumped from the bottom up.

3. Proper and through decontamination should be performed on all equipment entering the ground between each hole.

4. Suggested references that may be of use for proper procedures and recommended practices in the performance of cone penetrometer testing are:

   ASTM Volume 04.09 Designation D5778-95 and

   Cone Penetration Test Performance and Design
   U.S. Department of Transportation
   FHWA-TS.78-209

EXHIBIT 1

RECOMMENDED MIX DESIGNS FOR CEMENT-BENTONITE GROUT

Materials		4% Mix		5% Mix		6% Mix		7% Mix	
Sacks of Cement	Pounds of Cement	Pounds of Bentonite	Gallons of Water	Pounds of Bentonite	Gallons of Water	Pounds of Bentonite	Gallons of Water	Pounds of Bentonite	Gallons of Water
1	94	3.8	7.8	4.7	8.5	5.6	9.1	6.6	9.8
2	188	7.5	15.6	9.4	17.0	11.2	18.2	13.2	19.6
3	282	11.3	23.4	14.1	25.5	16.9	27.3	19.7	29.4
4	376	15.0	31.2	18.8	34.0	22.6	36.4	26.3	39.2
5	470	18.8	39.0	23.5	42.5	28.2	45.5	32.9	49.0
6	564	22.6	46.8	28.2	51.0	33.8	54.6	39.5	58.8
7	658	26.3	54.6	32.9	59.5	39.5	63.7	46.1	68.6
8	752	30.1	62.4	37.6	68.0	45.1	72.8	52.6	78.4
9	846	33.8	71.2	42.3	76.5	50.8	81.9	59.2	88.2
10	940	37.6	78.0	47.0	85.0	56.4	91.0	65.8	98.0
SLURRY WEIGHTS		14.1 lbs/gal		13.8 lbs/gal		13.5 lbs/gal		13.3 lbs/gal	

Halliburton Cementing Tables ©, Halliburton Services, Duncan, Oklahoma

LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
WATER RESOURCES SECTION
WATER WELL REGISTRATION SHORT FORM (DOTD-GW-1S)

PLEASE PRINT IN INK OR TYPE WHEN COMPLETING THIS FORM

1. USE OF WELL (Check Appropriate box)

☐ DOMESTIC ☐ RIG SUPPLY ☐ MONITORING ☐ PIEZOMETER ☐ RECOVERY

☐ HEAT PUMP HOLE ☐ HEAT PUMP SUPPLY ☐ ABANDONED PILOT HOLE ☐ OTHER _____
(Please Specify)

2. WELL OWNER _____ PHONE ( ) _____

3. WELL OWNER'S ADDRESS _____

4. OWNER'S WELL NUMBER OR NAME (if any) _____

5. DATE COMPLETED _____ DEPTH OF HOLE _____ FT. DEPTH OF WELL _____ FT.

6. STATIC WATER LEVEL _____ FT. BELOW GROUND SURFACE MEASURED ON _____
(Date)

7. CASING _____ IN. ☐ METAL ☐ PLASTIC ☐ OTHER LENGTH _____ FT.

8. SCREEN _____ IN. ☐ METAL ☐ PLASTIC ☐ OTHER SLOT SIZE _____ LENGTH _____ FT.

9. CEMENTED FROM _____ FT. TO GROUND SURFACE, USING ☐ PUMP DOWN METHOD OR ☐ GRAVITY METHOD

10. LOCATION OF WELL: PARISH _____ WELL IS NEAR _____
(Town or City)

APPROXIMATELY _____ MILES FROM _____
(Crossroads, Railroad, Any Landmark, etc.)

_____
(Please draw sketch on back of Original)

11. REMARKS: _____

12. DRILLER'S LOG (Description and color of cuttings, such as shale, sand, etc. in feet)

FROM	TO	DESCRIPTION	FROM	TO	DESCRIPTION

13. FOR HEAT PUMP ONLY: AVG. DEPTH _____ FT. NUMBER OF HOLES _____

14. ABONDONMENT INFORMATION: DOES THE NEW WELL REPLACE AN EXISTING WELL? YES ☐ NO ☐

15. NAME OF PERSON WHO DRILLED THE WELL: _____

(REV. 7/93)

_____
Name of Water Well Contractor

LICENSE NUMBER **WWC-** _____

_____
Authorized Signature **Date**

MAIL ORIGINAL TO:

LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
ATTN.: CHIEF – WATER RESOURCES SECTION
P.O. BOX 94245
BATON ROUGE, LA 70804-9245
(225) 379-1434

FOR OFFICE USE ONLY

PARISH WELL NO.

IDENTIFICATION NUMBER

0

REVISED COORDINATES

Geologic Unit

Use of Well

SECTION TOWNSHIP RANGE

ELEV. QUAD. NO.

INPUT BY: _____ DATE: _____

INSPECTED BY: _____ DATE: _____

REMARKS: _____

FOR MONITOR/PIEZO/RECOVERY WELLS ONLY

LATITUDE LONGITUDE

SECTION TOWNSHIP RANGE

ELEV. QUAD. NO.

SITE ADDRESS: _____

_____

EXHIBIT 2
WATER WELL REGISTRATION SHORT FORM (DOTD-GW-1S)

PLEASE PRINT IN INK OR TYPE WHEN COMPLETING THIS FORM

LOUISIANA DEPARTMENT OF TRANSPORTION AND DEVELOPMENT

WATER RESOURCES SECTION

WATER WELL PLUGGING AND ABANDONMENT FORM (DOTD-GW-2)

MAIL ORIGINAL TO
Department of
Transportation and Development
Attn: Chief – Water Resources Section
P.O. BOX 94245
Baton Rouge, LA 708049245
(225) 379-1434

1. WELL OWNER: (if different from owner when drilled, note in item 5) _____

_____

ADDRESS: _____

OWNERS WELL NUMBER (if any) _____

2. LOCATION OF WELL: Parish _____, Well is Near _____

Approximately _____ miles from _____
(Crossroads, Town, City, Railroad, Any Landmark, etc.)

_____
(Please draw sketch on back of Original)

3. WELLINFO: Casing material _____, Diameter of casing _____ in.,

Depth of well _____ ft., Date drilled _____ by (give name

of water well contractor who installed well or hole): _____

4. Describe in detail how well the hole was plugged: (materials used, amount of casing and/or screen removed, or left in hole, etc.) _____

_____

_____

_____

_____

_____

_____

5. REMARKS: _____

_____

I certify that this work was done and completed in accordance with Rules and Regulations

of the State on _____ by (name and no. of

contractor) _____ WWC- _____

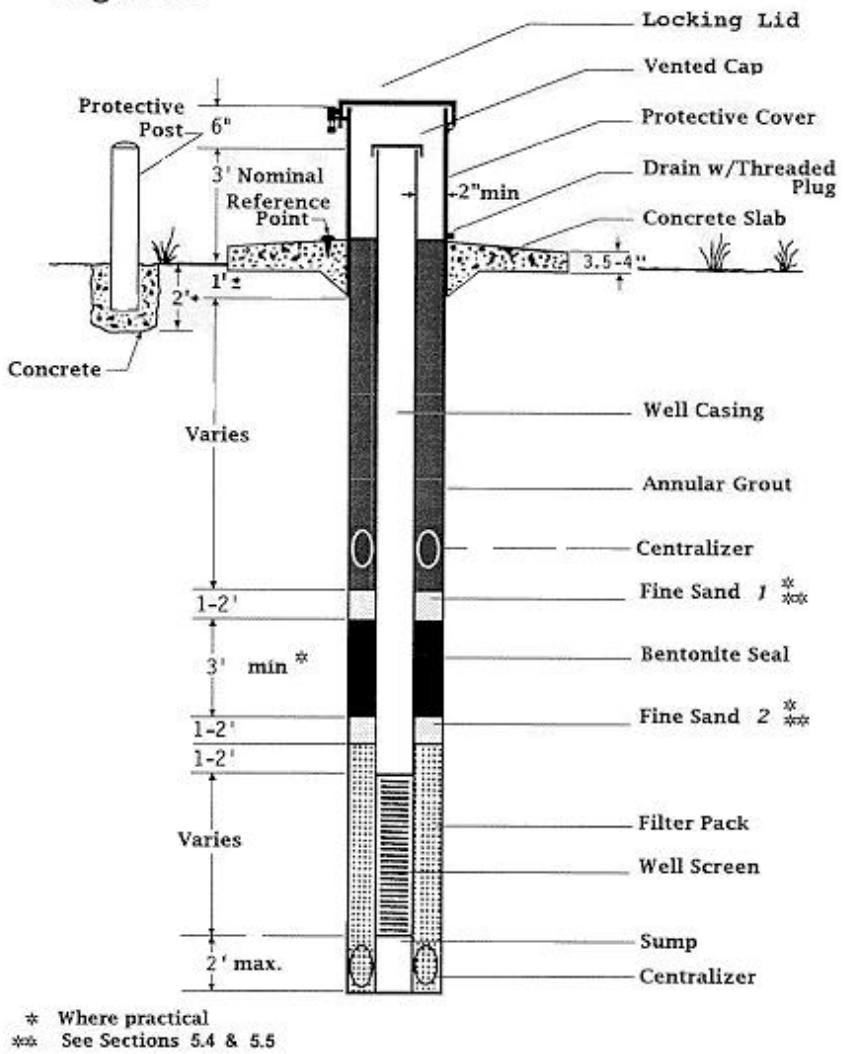
Authorized Signature: _____ Date: _____

State	Parish	Local Well No.	Identification Number	**OFFICE USE ONLY**	Section	Township	Range	Quad. No
22		-	0					

EXHIBIT 3

WATER WELL PLUGGING & ABANDONMENT FORM (DOTD-GW-2)

Figure 1



✲ Where practical
✲✲ See Sections 5.4 & 5.5

GROUNDWATER MONITORING WELL
(TYPICAL)
(Not to Scale)

Figure 2

SURFACE MOUNT DETAIL