GEOTHERMAL HEAT EXCHANGE WELLS

WELL STANDARDS

DRAFT

April 1999

STANDARDS

SPECIAL NOTE: The first three pages of this draft are to be included in the Introduction of the new California Well Standards, Bulletin 74-99. Bulletin 74-99 will be one document including standards for water wells, monitoring wells, cathodic protection wells, and geothermal heat exchange wells.

Exemption Due to Unusual Conditions -- If the enforcing agency finds that compliance with any of the requirements prescribed herein is impractical for a particular location because of unusual conditions or that compliance would result in an unsatisfactory well, or that there is a best available technology (BAT) or state-of-the-art technology not enumerated in these standards that would provide suitable protection, the enforcing agency may waive compliance and prescribe alternative requirements that would afford the same level of protection provided by these standards.

Geothermal Heat Exchange Well Locations -- Geothermal heat exchange wells that are sealed their entire length may be installed closer to contaminant or pollutant sources or structures than the distances specified for water wells in DWR Bulletin 74-90 and subsequent revisions. Iron markers, trace tapes, or wire shall be installed at each well to facilitate locating the buried wells.

Exclusions -- The geothermal heat exchange well standards prescribed in Bulletin 74-99 do not apply to shallow construction systems as defined in Bulletin 74-99. The enforcing agency may prescribe additional regulations when the fluid is circulated in a loop in a shallow system. To prevent groundwater contamination, the enforcing agency shall prescribe additional regulations for the destruction of shallow geothermal heat exchange systems.

Driller Qualifications -- In accordance with the provisions of Section 13750.5 of the California Water Code:

Section 13750.5. Person responsible for construction, alteration, destruction, or abandonment; license necessary

No person shall undertake to dig, bore, or drill a water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well, to deepen or reperforate such a well, or to abandon or destroy such a well, unless the person responsible for that construction, alteration, destruction, or abandonment possesses a C-57 Water Well Contractor's License.@

Reports -- Reports concerning a water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well shall be prepared in accordance with

the provisions of California Water Code Section 13751. The description of the site prepared under 13751. (b)(2)(A) shall be sufficiently exact to permit location of each geothermal heat exchange well.

Section 13751. Report of completion

(a) Every person who digs, bores, or drills a water well, cathodic protection well, groundwater monitoring well, or geothermal heat exchange well, abandons or destroys such a well, or deepens or reperforates such a well, shall file with the department a report of completion of that well within 60 days from the date its construction, alteration, abandonment, or destruction is completed.

(b) The report shall be made on forms furnished by the department and shall contain information as follows:

(1) In the case of a water well, cathodic protection well, or groundwater monitoring well, the report shall contain information as required by the department, including, but not limited to all of the following information:

(A) A description of the well site sufficiently exact to permit location and identification of the well.

(B) A detailed log of the well.

(C) A description of type of construction.

(D) The details of perforation.

(E) The methods used for sealing off surface or contaminated waters.

(F) The methods used for preventing contaminated waters of one aquifer from mixing with the waters of another aquifer.

(G) The signature of the well driller.

(2) In the case of a geothermal heat exchange well, the report shall contain all of the following information:

(A) A description of the site that is sufficiently exact to permit the location and identification of the site and the number of geothermal heat exchange wells drilled on the same lot.

(B) A description of borehole diameter and depth and the type of geothermal heat exchange system installed.

(C) The methods and materials used to seal off surface or contaminated waters.

(D) The methods used for preventing contaminated water in one aquifer from mixing with the water in another aquifer.

(E) The signature of the well driller.@

Reports submitted on water wells, monitoring wells, or cathodic protection wells are subject to California Water Code Section 13752. Reports submitted on geothermal heat exchange wells are open for public inspection.

Section 13752. Inspection of reports

Reports made in accordance with paragraph (1) of subdivision (b) of Section 13751 shall not be made available for inspection by the public, but shall be made available to governmental agencies for use in making studies. However, any report shall be made available to any person who obtains a written authorization from the owner of the well.@

Geothermal Heat Exchange Well Standards

PART I. General

Section 1. Definitions

A. Geothermal heat exchange well. Any uncased artificial excavation by any method for the purpose of using the heat exchange capacity of the earth for heating and cooling and in which the ambient ground temperature is 86E Fahrenheit (30E Celsius) or less and which uses a closed loop fluid system to prevent the discharge or escape of its fluid into the surrounding aquifers or geologic formations. Geothermal heat exchange wells are also known as ground source heat pump wells. Such wells or boreholes are not intended to produce water or steam.

B. Types of systems. Geothermal heat exchange systems may use a number of different combinations of circulating fluids, construction methods, and heat sources. These are commonly classified as follows:

1. Circulating fluid systems. This refers to the type of piping system used to circulate heat exchange fluids.

   a. Closed loop system. This type of system features continuous piping systems which prevent the circulating fluid from coming in contact with the aquifers or geologic formations. The fluid is repeatedly recirculated. The fluid is commonly water, but may be some other approved fluid.

   b. Open loop system. An open loop system results when the circulating fluid is discharged from the piping systems after the heat exchange. The most common open loop system consists of groundwater being pumped from a well and then injected back into the aquifer through the same well or through a second well. Open loop systems, if approved by the Regional Water Quality Control Board or by the enforcing agency, shall conform to Water Well Standards prescribed in DWR Bulletin 74-90 and subsequent revisions.

2. Construction method systems. This refers to the type of construction and the depth to which the excavation(s) penetrate the

ground. Based upon their normal orientation with the surface, a shallow construction system is sometimes called a "horizontal system," while a well construction system is often described as a "vertical system" or a "vertical borehole system."

a. Shallow construction system. This type of system is defined as any heat exchange system having an excavation whose bottom does not exceed a depth of 20 feet from ground surface. The standards prescribed in Parts II & III do not apply to shallow construction systems as defined above. The enforcing agency may prescribe additional regulations for a shallow construction system.

b. Well construction system. This type of system is defined as any heat exchange system in which the bottom of the excavation exceeds 20 feet from ground surface.

3. Heat exchange systems. This refers to the heating or cooling source for a geothermal heat exchange system.

a. Ground source heat exchange system. This system results from the placement of the closed loop circulating pipes directly into the ground, and backfilling the excavation around the circulating pipes with grout or other impervious material. Ground source heat exchange systems shall be constructed as either vertical borehole or shallow systems. Such systems shall be approved by the enforcing agency prior to construction.

b. Groundwater source heat exchange system.

(1). Closed loop. A geothermal heat exchange system using a standing column of groundwater within a water well as the heat source. The fluid is circulated through a closed loop submerged in the groundwater. The standing groundwater in the well is the heat exchange medium. The water well shall conform to water well standards prescribed in DWR Bulletin 74-90 and subsequent revisions.

(2). Open loop. These systems shall be approved by the enforcing agency and the Regional Water Quality Control Board prior to construction. The water well shall conform to water well standards prescribed in

DWR Bulletin 74-90 and subsequent revisions. Open loop groundwater geothermal heat exchange systems should only be considered in aquifers where high quality groundwater is plentiful and in which water wells can provide adequate water flow.

(a). Standing column well system. A geothermal heat exchange system using a standing column of groundwater within a water well as the heat source. Groundwater is extracted from the bottom of the well and pumped directly to the heat exchanger. After circulating through the heat exchanger, the water is pumped back into the top of the column. There shall be sufficient groundwater present to maintain the standing column of water.

(b). Open loop 2-well system. Groundwater is extracted from one well and pumped through the heating/cooling system and back into the ground through a second well, the recharge well.

C. Enforcing Agency. An agency designated by duly authorized local, regional or State government to administer and enforce laws or ordinances pertaining to the protection of water quality, construction, alteration, maintenance or destruction of geothermal heat exchange wells.

Section 2. Application to type of well

A. These standards shall apply to all geothermal heat exchange wells using a closed loop circulating fluid ground source heat exchange system.

In all geothermal heat exchange wells that use a groundwater source heat exchange system with either an open or a closed loop, well construction and destruction shall conform to the water well standards prescribed in DWR Bulletin 74-90 and subsequent revisions.

Section 3. Best Available Technology (BAT)

April 1999, Draft, Draft, California Department of Water Resources, 916-327-8861

1. These standards provide a minimum level of protection for groundwater resources of California. New materials and techniques that are developed in the future that are approved and adopted by industry groups, including, but not limited to, International Ground Source Heat Pump Association**,** National Ground Water Association, or California Groundwater Association, and that provide equal or greater protection for California=s groundwater quality shall be encouraged and allowed. Such new materials and techniques must equal or exceed the standards in this publication in performance and level of protection.

PART II. Geothermal Heat Exchange Well Construction

Section 4. Borehole diameter of geothermal heat exchange wells

A. Diameter of borehole. The smaller the diameter of the borehole, the greater the thermal exchange efficiency. It may be necessary to drill a variable borehole diameter to allow proper construction to the design depth. The system designer shall consider the impact of borehole diameter on heat transfer as well as the diameter of the loop piping and the need to install a properly sized tremie pipe for successful grouting of the borehole.

The borehole diameter of a geothermal heat exchange well shall be sufficient to allow placement of a 1 1/4 inch tremie pipe, in addition to the loop pipes, to emplace material in the borehole that surrounds the loop pipes. It may be necessary to use a larger diameter tremie pipe in deeper holes to ensure proper placement of the sealing material and filler material.

Such material includes the sealing material and any thermal conductive material that is placed in the borehole in lieu of sealing material to enhance heat exchange. Both sealing material and thermal conductive material shall fill the hole and surround all loop pipes. The diameter of the tremie pipe shall be adequate to ensure proper placement of the sealing material, any thermal conductive material, and filler material. Gravity installation or free fall of sealing material or fill materials without use of a tremie pipe is not permitted. A grout pump shall be required for placing sealing material through a tremie pipe. Any clean fill placed between seals shall be chlorinated.

Section 5. Sealing geothermal heat exchange wells

A. Depth of seal. The sealing of a geothermal heat exchange well shall be completed immediately after the well is drilled to avoid cave-in of the uncased borehole. Full-length sealing material placed by tremie pipe is required to prevent surface contamination or to prevent contaminated water from one aquifer from mixing with waters of another aquifer. The enforcing agency may waive the requirement for full-length sealing in vertical borehole systems provided the agency prescribes alternative

sealing methods that meet the minimum standards of this Section and Section 7.

B. Sealing materials. The following sealing materials are approved for use in geothermal heat exchange wells:

1. Bentonite slurry. The seal shall consist of high solids sodium bentonite slurry made from bentonite grout or an 8 mesh granulated bentonite polymer slurry meeting NSF Standard 61 (National Sanitation Foundation) with a minimum of twenty percent (20%) by weight solids (9.4 pounds per gallon grout weight) mixed according to the manufacturer's specification.

   Drilling mud or cuttings shall not be used as sealing materials. Water used in preparing bentonite slurry shall meet the standards in Section 9.D.1. of the Water Well Standards. Bentonite slurry shall be emplaced using a tremie pipe from the bottom of the geothermal heat exchange well to the top of the borehole, excluding the excavation for the header assembly. The tremie pipe may be left in place provided it is completely filled with the high solids bentonite slurry.

   It is recommended that high solids sodium bentonite slurry be used in all geothermal heat exchange wells.

2. Other grout. Other types of grout may be used if approved by Bulletin 74-90 and subsequent revisions or is considered a BAT and has been approved by industry organizations in accordance with Section 3, above.

3. Cement is not permitted as a sealing material because of the expansion of the polyethylene loop pipe caused by the heat of hydration of the cement, and subsequent contraction of the pipe after cooling. Such expansion and contraction does not provide an effective seal.

C. Placement of sealing material. Before placing the sealing material, all loose cuttings or other obstructions shall be removed from the borehole. Sealing material shall be placed in a continuous operation from the bottom of the geothermal heat exchange well to the top of the borehole, excluding the excavation for the header assembly. The sealing material shall be emplaced by pressure pumping through a 1 1/4 inch or larger tremie pipe. The pump shall be such that it can adequately complete the pumping to

the total depth of the borehole. The discharge end of the tremie pipe shall be continuously submerged in the sealing material until the zone to be sealed or filled is completed. The sealing material shall fill the hole and surround all heat exchange loop pipes.

If the heat exchange loop pipe can not be emplaced to the total depth of the borehole, the contractor shall ensure that the borehole is sealed from the top of the borehole to the total depth. The tremie pipe may be left in place provided it is completely filled with the high solids bentonite slurry. Gravity installation or free fall of sealing materials without use of a tremie pipe is not permitted.

Section 6. Construction materials

A. Casing. Temporary casing may be used to install geothermal heat exchange wells. Such casing shall be removed upon completion of the well. If a permanent casing must be used, the casing material and installation methods and sealing shall comply with the applicable provisions for casing materials, installation and sealing as specified for water wells in DWR Bulletin 74-90 and subsequent revisions.

B. Heat exchange loop materials.

1. Type of material. In a geothermal heat exchange well, the material used to make up the heat exchange loop must meet industry standards for this application as specified by the International Ground Source Heat Pump Association (IGSHPA). PVC (polyvinyl chloride) pipe shall not be used as loop materials in geothermal heat exchange wells. Generally, closed loop materials are composed of high density polyethylene pipe. Other materials that conform to IGSHPA standards may be used in geothermal heat exchange wells.

2. Connections. All heat exchange loop pipe connections to be placed in the borehole shall be thermally fused according to manufacturer's instructions and shall not leak after assembly. Only fused fittings or non-metallic mechanical stab fittings that meet ASTM D-2513, Section 6.10.1, Category 1, may be used in the header assembly and manifold.

3. Installation. Heat exchange loop materials shall be installed and sealed immediately upon completion of drilling of each geothermal heat exchange well borehole.

4. Metal pipe and fittings. If metal pipe or fittings are to be installed underground, cathodic protection shall be provided. Such a cathodic protection system shall be maintained in operating condition.

C. Loop fluids. Fluids circulated in the loop as the heat exchange medium in geothermal heat exchange wells shall have low toxicity as defined below, and shall be biodegradable. Such fluids are typically water, or water plus a freeze protection additive. Pure water should be used whenever possible. Any water used in the fluid shall be from a potable source.

Commonly used and acceptable freeze protection additives include propylene glycol and ethanol.

The loop fluid, including the water and any additives, shall have an LD_{50} for humans of greater than 25,000 mg/kg of body weight. LD_{50} is the dose that will be lethal to 50% of the population who ingest the fluid in 1 hour.

Undiluted freeze protection additives shall have an LD_{50} for humans of greater than 5,000 mg/kg of body weight. If the LD_{50} for humans is known for a specific additive, that LD_{50} shall be used when calculating the toxicity of the loop fluid. In the absence of human toxicity data, the estimated LD_{50} shall be based on the toxicity data of the most sensitive species, using uncertainty factors as appropriate and in accordance with standard practices in toxicology.

D. Final testing. If pressure testing with water or air to 150 percent above the manufacturer=s heat pump operating specifications for a period of 30 minutes shows that any geothermal heat exchange loop leaks, the leaking loop shall be repaired or replaced. If the loop can not be repaired, the loop shall be replaced. If the loop can not be repaired or replaced, the loop and the borehole shall be destroyed in accordance with Part III.

Section 7. Minimum requirements for non-fully sealed geothermal heat exchange systems

A. Hydrogeology and groundwater quality. Construction of non-fully sealed geothermal heat exchange wells shall require knowledge about the site

hydrogeology and groundwater quality sufficient to ensure that construction of non-fully sealed wells does not degrade groundwater quality. If such knowledge about the site is not available, only fully sealed geothermal heat exchange wells shall be permitted.

Where groundwater quality meets drinking water standards, no additional action is necessary. Where groundwater quality does not meet drinking water standards as determined by site exploration, the strata containing that poor quality water shall be sealed in accordance with paragraph D below.

B. Borehole size requirements. See Section 4, above.

C. Minimum depth of seals. If the borehole is not sealed throughout its entire length, the minimum depth of surface annular seal shall be the same as specified for domestic water wells in DWR Bulletin 74-90 and subsequent revisions.

D. Sealing between aquifers. If full-length sealing is not done and the geothermal heat exchange well penetrates more than one aquifer and one or more of the aquifers contains water that, if allowed to mix in sufficient quantity, may result in a significant deterioration of the quality of the water in the other aquifer(s), the strata producing such poor-quality water shall be sealed off to prevent mixing of this water with other aquifers. The seal shall extend no less than ten feet (10') above and ten feet (10') below the strata to be sealed off, even if the strata to be sealed is less than 10 feet in thickness. If the stratum to be sealed is at the bottom of the well, the seal need extend only in the upward direction. The sealing material shall fill the borehole and any surrounding void spaces in the interval to be sealed. The seal shall be placed by 1 1/4 inch tremie pipe and adequate pump from bottom to top of the interval to be sealed. Gravity installation or free fall of sealing materials without use of a tremie pipe is not permitted.

E. Fill material. Any fill materials used in non-fully sealed wells shall meet the standards of Bulletin 74-90 and subsequent revisions and shall have appropriate thermal characteristics for the intended heat exchange purpose. Such fill material shall be emplaced by means of a tremie pipe. Gravity installation or free fall of fill materials without use of a tremie pipe is not permitted. Any clean fill placed between seals shall be chlorinated.

F. Placement of fill. Fill material shall be emplaced by use of a 1 1/4 inch tremie pipe. The tremie pipe shall be lowered to the bottom of the zone being filled, and raised slowly as the material is introduced. All fill shall be

emplaced in one continuous operation upward from the bottom of the borehole. When using the tremie pipe method to install fill material, the bottom of the tremie shall be maintained as close as possible to, but not inside of, the emplaced fill.

Gravity installation or free fall of fill materials without use of a tremie pipe is not permitted.

G. Sealing materials. Sealing materials shall meet the standards prescribed in Section 5. B.

PART III. Destruction of Geothermal Heat Exchange Wells

Section 8. Destroying a closed loop ground source heat exchange system

A. To destroy a geothermal heat exchange well using a closed loop, ground source heat exchange system, the following procedures shall be completed:

1. Fluid removal. All fluid in the heat exchange loop shall be displaced and disposed of properly.

2. Near surface excavation. A hole shall be excavated at least five feet below the surface around the borehole. The loop pipe in this excavation shall be removed.

3. Sealing the loop in the borehole. The remaining loop shall be completely filled with a high solids bentonite slurry as specified in Section 5.B.(1). The slurry shall be allowed to spill into the excavation to provide a cap at least one foot (1') thick above the loop pipe. The remainder of the excavation shall be filled with compacted earth or pavement.

Section 9. Destroying an open loop or closed loop, groundwater source heat exchange system

A. Destruction of an open loop or closed loop groundwater source heat exchange system shall be completed in conformance with the destruction standards for water wells in DWR Bulletin 74-90 and subsequent revisions.