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The Class V Underground Injection Control Study

Volume 19

Heat Pump and Air Conditioning Return Flow Wells

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HEAT PUMP AND AIR CONDITIONING RETURN FLOW WELLS

The U.S. Environmental Protection Agency (USEPA) conducted a study of Class V underground injection wells to develop background information the Agency can use to evaluate the risk that these wells pose to underground sources of drinking water (USDWs) and to determine whether additional federal regulation is warranted. The final report for this study, which is called the Class V Underground Injection Control (UIC) Study, consists of 23 volumes and five supporting appendices. Volume 1 provides an overview of the study methods, the USEPA UIC Program, and general findings. Volumes 2 through 23 present information summaries for each of the 23 categories of wells that were studied (Volume 21 covers 2 well categories). This volume, which is Volume 19, covers Class V heat pump and air conditioning return flow wells.

1. SUMMARY

Ground-source heat pump/air conditioning (HAC) systems heat or cool buildings by taking advantage of the relatively constant temperature of underground hydrogeologic formations. They extract heat energy from ground water for use in heating buildings, and use ground water as a heat sink when cooling buildings. Two types of ground-source HAC systems are generally used: closed-loop systems and open-loop systems. Closed-loop systems circulate water entirely within a system of closed pipes, involve no subsurface injection of wastewater, and are therefore not subject to oversight and regulation by the UIC program. Open-loop HAC systems withdraw ground water from a source well, pass it through the HAC heat exchanger, and then discharge the water. Many open-loop HACs return used ground water to the subsurface via injection wells. These “return flow wells” are classified as Class V wells under the UIC program, and are the focus of this study.

Because water is not consumed by HAC systems, the quantity of return flow water (injectate) is generally the same as that withdrawn. The quality of HAC injectate also usually reflects the characteristics of the source ground water. However, HAC injectate may differ from source water in several ways. HAC injectate is generally 4 to 10 degrees Fahrenheit cooler or warmer than the source water (depending on whether the HAC is in heating or cooling mode). In some cases, the temperature drop can cause salts and other dissolved solids to precipitate into suspension, or the temperature increase can cause suspended solids to dissolve into solution. HAC injectate can also contain: metals leached from the pipes and pumps; bacteria (where oxygen, nutrients, and a source of bacteria are present); precipitated ferric iron solids (where dissolved iron is present in source water, and the HAC system introduces oxygen); and chemical additives (sometimes used for disinfection or corrosion prevention). Very little data on injectate properties were available for this study. However, the available data indicate that HAC injectate has in some cases exceeded the primary drinking water maximum contaminant levels (MCLs) for lead and copper and the secondary MCLs for chloride and total dissolved solids (TDS).

HAC systems most commonly re-inject ground water into the same formation from which it is withdrawn. The aquifer used is relatively porous in order to provide adequate ground water flow to source wells and from return wells. Dual-aquifer systems may be feasible where another formation (a different formation from which source water is withdrawn) is more readily accessible for return flow discharge, and is capable of handling HAC return flow. Dual-aquifer systems that withdraw from contaminated aquifers and re-inject into USDWs can contaminate the receiving USDWs. As a result, several states prohibit dual-aquifer HAC systems, or require that HAC source aquifers be of higher quality than return aquifers.

A few USDW contamination incidents have been reported for HAC return flow wells. In 1996, a well in New York was found to have contaminated a USDW with chloride and TDS above the secondary MCLs. The incident was attributed to leaking well casings and inter-aquifer contamination. In Minnesota, a water sample from a well in 1984 indicated high levels of lead, while another sample taken from a different well in 1985 showed high levels of lead and copper (all above the primary standards). This was attributed to leaching of metals from the HAC system pipes and pumps. In North Carolina, well samples have been reported to contain high levels of iron and coliform, attributed to poor HAC well construction and operation allowing introduction of oxygen and contaminants. As the quality of HAC injectate industry-wide is unknown, it is not clear whether these known contamination cases are isolated cases, or indicative of a wider problem with this type of well.

HAC return flow wells are generally part of systems that are completely closed above ground, and are generally located on private property. Therefore, the likelihood of USDW contamination by spills or illicit discharges at HAC return flow wells is very low.

According to the state and USEPA Regional survey conducted for this study, there are 27,921 documented HAC return flow wells in 34 states.[1] The estimated number of wells existing in the U.S. is more than 32,804 wells (but probably not more than 35,000), in over 40 states. Approximately 88 percent of all documented wells are in four states: Texas (12,828 wells, or 46 percent), Virginia (7,769, or 28 percent), Florida (3,101, or 11 percent), and Tennessee (1,000, or 4 percent). Another 30 states collectively account for the remaining 11 percent of the total documented U.S. inventory, with each state having less than 3 percent of the total. However, many states do not have accurate well counts and well definitions used by some states differ from the USEPA definitions.

Nearly all of the states with HAC return flow wells have statutory and regulatory requirements at the state level, some of which regulate the size, design, and/or additives used in these systems. Of the states in which the largest numbers of HAC wells are found, USEPA directly implements the UIC program for all Class V injection wells (including HAC return flow wells) in Arizona, Michigan, Minnesota, New York, Pennsylvania, Tennessee, and Virginia. The other states with many HAC return flow wells are UIC Primacy States for Class V wells, and

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[1] This number includes some closed-loop systems, as not all states use the same definitions as USEPA for “open-loop” and “closed-loop” systems.

authorize the wells by rule (Illinois, Kansas, Nebraska, North Dakota, Ohio, South Carolina, Texas, West Virginia, and Wyoming) or issue individual permits (Delaware, Florida, Maryland, Missouri, Nevada, North Carolina, Oregon, Vermont, and Washington). In Wisconsin, which is also a Primacy State for Class V wells, discharge to a shallow absorption system located in unsaturated soils is allowed under a general permit, but discharge directly into a saturated soil or aquifer is prohibited.

A number of relatively straight-forward best management practices are available that can virtually ensure that HAC wells do not contaminate USDWs. Judging by the very low incidence of recorded USDW contamination (relative to the number of wells), it appears that HAC owners and operators are aware of and generally apply best management practices.

2. INTRODUCTION

At depths below the influence of atmospheric temperatures, and in areas not affected by geothermal heating or the cooling effect of seasonal glacial and snow mass melting, subsurface hydrogeologic formations typically maintain fairly constant temperatures year round. These relatively uniform ground temperatures in the United States range from approximately 42 degrees Fahrenheit (6 degrees Celsius) near the Canadian border to 77 degrees Fahrenheit (25 degrees Celsius) in southern Florida (Oklahoma State University, 1988). Ground-source HAC systems withdraw ground water at this temperature and either extract the heat energy from the water for use in heating buildings, or use the water as a heat sink to carry off excess heat when cooling buildings. Water is not consumed in the process; once the ground water has passed through the heat exchange process it is discharged, commonly through re-injection into the ground. By making use of the natural heat energy or heat removal capacity of ground water, heat pumps require less fossil fuel or electrical energy to heat or cool buildings, and are therefore regarded as an energy efficient technology.

There are two main types of ground-source HAC systems: closed-loop and open-loop systems. Closed-loop systems (also known as ground-coupled heat pumps) are, as the name implies, completely closed systems in which fluids (e.g., water, or propylene glycol and water) are circulated continuously through a loop of pipes that pass underground and through the heat exchanger of the HAC system. Because the circulating fluids do not have contact with the outside environment, closed-loop HAC systems are not considered to involve Class V wells (USEPA, 1997), and are outside the scope of this study. All references to HAC systems in the remainder of this study refer to open-loop HAC systems, unless otherwise specified.

Open-loop HAC systems (also known as ground water heat pumps) withdraw water from an underlying aquifer, pass it one or more times through the heat pump(s), and then discharge the water. Common means of water disposal are: surface discharge, generally to existing bodies of water such as ponds and streams; and re-injection to the subsurface via an injection well separate from the withdrawal well. Injection wells used for subsurface disposal (or return) of water from HAC systems are classified as Class V underground injection wells (USEPA, 1997). Thus, the focus of this study is the injection wells associated with open-loop HAC systems that dispose of water via underground injection. These are commonly referred to as HAC return flow wells.

According to the UIC regulations in 40 CFR 146.5(e)(1), Class V wells include “air conditioning return flow wells used to return to the supply aquifer the water used for heating or cooling in a heat pump.” In some cases, water is withdrawn from the supply aquifer, circulated through the HAC system, and reinjected into a different aquifer.

As currently defined in the UIC regulations (40 CFR 144.3), a “well means a bored, drilled or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension.” Therefore, any hole that is deeper than it is wide or long qualifies as a well. In the case of HAC return flow wells, this includes holes drilled and cased with pipe, as well as “infiltration galleries” consisting of one or more vertical pipes leading to an array of horizontal, perforated pipes laid below the ground surface, designed to release wastewater underground. As described in more detail below, this design is used for disposal of water by some HAC systems. Each of the vertical pipes in an infiltration gallery system (exclusive of the network of horizontal subsurface piping), individually or in a series, is considered an injection well subject to UIC authorities (Elder and Lowrance, 1992).

3. PREVALENCE OF WELLS

For this study, data on the number of Class V HAC return flow wells were collected through a survey of state and USEPA Regional UIC Programs. The survey methods are summarized in Section 4 of Volume 1 of the Class V Study. Table 1 lists the number of Class V HAC return flow wells in each state, as determined from this survey. The table includes the documented number and estimated number of wells in each state, along with the source and basis for any estimate, when noted by the survey respondents. If a state is not listed in Table 1, it means that the UIC Program responsible for that state indicated in its survey response that it did not have any Class V HAC return flow wells.

Inventory data quality and quantity is not consistent across all states. In some cases, the difference between the number of documented wells and the estimated number of actual wells (documented and undocumented wells) may be great and estimates can only be made using best professional judgement. In addition, it is apparent that some state definitions for closed-loop (non-Class V) and open-loop HAC systems are different than those used by USEPA. Industry-approved definitions, such as those provided by the International Ground Source Heat Pump Association or the American Society of Heating, Refrigerating and Air-Conditioning Engineers (see ASHRAE, 1995), are not used uniformly by state and federal agencies. The definition of closed-loop wells used by some states actually encompasses open-loop wells as defined by USEPA (and as defined in this study). In such cases, the wells in the state’s closed-loop HAC well inventory were included in the open-loop HAC return flow wells inventory presented here.

As presented in Table 1, almost 28,000 Class V HAC return flow wells are documented in the U.S., based on data from state, USEPA, and other sources. The estimated number of wells

Table 1. Inventory of Heat Pump/AC Return Wells in the U.S.

State	Documented Number of Wells	Estimated Number of Wells	
		Number	Source of Estimate and Methodology[1]
USEPA Region 1			
MA	2	2	N/A
NH	2	2	N/A
RI	1	1	N/A
VT	NR	25	Best professional judgement (estimated that some operators may not know that a permit is required).
USEPA Region 2			
NY	18	500	Best professional judgement, based on conversations with installation contractors and State of New York staff.
USEPA Region 3			
DE	526	526	N/A
MD	0	815	Onsite review of water appropriations permits.
PA	34	> 34	N/A
VA	7,769	> 7,769	N/A
WV	2	> 1,000	N/A
USEPA Region 4			
AL	11	> 11	Best professional judgement and discussions with regulated community; State of Alabama officials believe that more wells exist but cannot form an accurate estimate.
FL	3,101	NR	N/A
MS	NR	184	N/A
NC	85	170	Best professional judgement based on assumption by state officials that approximately half of the state's HAC wells are documented.
SC	467	900-1,300	Best professional judgement based on determination by state officials that 55 percent of well drillers submit required documentation.
TN	1,000	1,000	N/A
USEPA Region 5			
IL	0	< 59	Estimated 59 wells are believed to be mostly closed-loop systems.
MI	832	NR	Documented number is based on a 1988 study.

Table 1. Inventory of Heat Pump/AC Return Wells in the U.S. (cont'd)

State	Documented Number of Wells	Estimated Number of Wells	
		Number	Source of Estimate and Methodology[1]
MN	6	39	Estimated number is based on a 1981 study; state staff could not confirm the estimate. State staff suspect that some of these wells may no longer be active.
OH	5	50 - 500	Best professional judgement, based on a January 1997 site visit by USEPA to Ohio EPA.
WI	3	75	Best professional judgement; WDNR estimated one HAC well with drain field discharge in each of the 72 counties in the state in addition to the three documented systems.
USEPA Region 6			
AR	20	20	N/A
LA	10	NR	State officials indicate that more HAC wells may exist in LA than reported, but did not give an estimate.
OK	1	1	N/A
TX	12,828	12,828	Based on UIC database. Authorizations listed for 748 of the total number of wells.
USEPA Region 7			
IA	17	100	Best professional judgement and discussions with heat pump installers.
KS	457	> 1,000	Best professional judgement. State officials believe that some documented wells may be inactive or misclassified. However, there may be significant numbers of undocumented wells in Wichita, Hutchinson, and Garden City. It is suspected that several thousand wells exist in total.
MO	472	≥ 472	Heat pump wells serving single family residences, or serving up to eight family residences and injecting/withdrawing less than 600,000 BTU/hr, are not required to obtain operating permits and are not documented.
NE	104	104	N/A
USEPA Region 8			
CO	3	3	N/A
MT	1	>1	USEPA Region 8 Montana Operations Office believes some HAC wells may exist, but neither the state nor the USEPA Region tracks information on this well type.
ND	10	50	Best professional judgement. Only commercial and industrial wells are documented; thus, there are incomplete records on private and residential heat pump injection wells.

Table 1. Inventory of Heat Pump/AC Return Wells in the U.S. (cont'd)

State	Documented Number of Wells	Estimated Number of Wells	
		Number	Source of Estimate and Methodology[1]
UT	11	≥ 11	Inventory forms received in FY 1998 are not reflected in the documented number because of an anticipated change in data systems. Additionally, 3 wells are under construction and 2 wells are temporarily abandoned.
WY	3	3	Information provided by Lucht, 1999.
USEPA Region 9			
AZ	0	< 50 systems	Drilling permit requests, best professional judgement (note: each system may contain >1 well).
CA	9	9	N/A
NV	0	40-50	Best professional judgement.
USEPA Region 10			
AK	13	NR	USEPA Region 10 suspects that more wells may exist in AK than documented, but did not give an estimate.
ID	0	NR	219 wells are documented in ID, but these are believed to be all closed-loop wells.
OR	14	50	Best professional judgement, based on review of personal and state departmental files.
WA	81	81	N/A
All USEPA Regions			
All States	27,918	>32,801	Total estimated number counts the documented number when the estimate is NR.

[1] Unless otherwise noted, the best professional judgement is that of the state or USEPA Regional staff completing the survey questionnaire.

N/A	Not available.
NR	Although USEPA Regional, state and/or territorial officials reported the presence of the well type, the number of wells was not reported, or the questionnaire was not returned.

is nearly 33,000 (the total estimated number uses the documented number when an estimate was not reported for a given state). USEPA Regions 3, 4, and 6 have the greatest number of documented wells, with each USEPA Region having thousands of wells. Within these USEPA Regions, several states have 1,000 or more documented wells, including Texas (12,828), Virginia (7,769), Florida (3,101), and Tennessee (1,000). West Virginia, South Carolina, and Kansas are estimated to have greater than one thousand wells each, but are documented to have only two, 467, and 457 wells, respectively. USEPA Regions 1, 2, 8, 9, and 10 each has approximately one hundred or fewer documented HAC return flow wells.

Data for Illinois indicate that an estimated 59 HAC wells exist in that state, but these are believed to include both open-loop and closed-loop systems, with the majority being closed-loop systems by USEPA's definition. Because the available information does not allow distinction between open- and closed-loop systems, all 59 systems were included in the estimated U.S. inventory in Table 1.

4. WASTEWATER CHARACTERISTICS AND INJECTION PRACTICES

4.1 Injectate Characteristics

The injectate from HAC systems generally reflects the characteristics of the source ground water. Data from individual facilities therefore tends to be rather site-specific. In the following paragraphs, the general constituents and physical properties of HAC injectate is examined.

Open-loop HAC systems utilizing subsurface disposal to the original source aquifer -- if properly constructed and operated -- are considered by some industry experts to function essentially as closed-loop systems (Knape, 1984). In these open-loop systems, water is withdrawn from the HAC supply well, pumped through the heat exchanger, and returned to the same aquifer from which it was withdrawn without being exposed to outside sources of contamination. The chemical and physical properties of the HAC return flow (injectate) are therefore essentially identical to those of the water from the supply well, with the exception of a change in temperature, generally of less than 10º Fahrenheit. Well-designed HAC systems that return water to the same aquifer from which it is withdrawn (hereafter referred to as single-aquifer HAC systems) therefore have minimal impacts on this aquifer. Where the aquifer in use is a USDW, return flow (injectate) does not degrade the quality of the USDW. Where the aquifer in use is not a USDW, the system poses no threat to USDWs.

In such systems, temperature changes and associated changes in the physical properties of the return flow water are the main issues associated with HAC return flow. The temperature difference between supply and return water is usually on the order of 4-10 degrees Fahrenheit. HAC systems typically cause a 4-8 degrees Fahrenheit decrease in water temperature while operating in the heating cycle, and an 8-10 degrees Fahrenheit increase in water temperature while operating in the cooling cycle (Rawlings, 1999). In some cases, slight temperature changes can result in precipitation of salts and solids from the water, or the dissolution of salts or solids into the water. The greatest temperature change usually occurs within the HAC system heat exchangers, sometimes resulting in the precipitation of salts and the formation of scale on the inner walls of the heat exchanger. Thus where water is withdrawn from and returned to the same aquifer the dissolved solids and suspended solids content of the return flow water can differ from those of the water in the aquifer. This effect is usually minimal, however, and has no implications for human health.

The injectate from HAC wells may contain other types of contaminants. A greater potential for contamination of USDWs exists where HAC systems withdraw water from and re-inject the water into different aquifers (hereafter referred to as dual-aquifer systems). Dual-aquifer systems pose a threat to USDWs when the source aquifer is contaminated, and return water is re-injected into a USDW. In such cases, return flow water (injectate) properties will reflect the characteristics of the supply aquifer, and could contain both chemical and microbiological contaminants. The greater potential for USDW contamination by dual-aquifer HAC systems is well recognized, and many states and jurisdictions prohibit, or have much more complex permitting requirements for, dual-aquifer systems. However, inventory data do not distinguish between single-aquifer and dual-aquifer systems, and the prevalence of dual-aquifer systems can not be determined. No data on injectate properties in dual-aquifer HAC systems are available.

Closed-loop HAC systems commonly circulate a solution of water and various additives (e.g., propylene glycol) to prevent corrosion, to fight microbial cultivation, and/or to depress the freezing point of the solution. Similar additives may also be used in some open-loop systems, although the prevalence of additive use or types of additives used could not be determined from the data available for this report. In the inventory of HAC wells conducted for this report, state and USEPA Regional officials were asked whether additives were allowed or used in Class V HAC return flow wells. For the majority of states, officials indicated that additives are either not allowed or not used in open-loop HAC systems. However, for several states the use of additives is less clear. The States of Arizona, Louisiana, Michigan, Nevada, and Texas allow the use of additives in open-loop HAC systems under some circumstances, although data are not available indicating whether additives are actually used in such systems in these states. No specific cases of additive use in open-loop HAC systems were identified during this study and no data are available regarding additive concentrations in injectate. While few, if any, system manufacturers and industry participants recommend using chemical additives in open-loop systems (Rawlings, 1999), it is possible that additives are occasionally used in open-loop systems. The question of additive use in open-loop HAC systems remains as a gap in the understanding of the potential impact of these systems on USDWs.

Constituents leached into the water from the pipes or pumps of the HAC system itself are also potential contaminants in HAC return flow wells. Based on empirical evidence, metals may be introduced to HAC return flow water in this way, potentially contaminating the receiving aquifer. However, the prevalence of this phenomenon is unknown. It is only reported once in the HAC return flow well inventory (see Section 5.2 for details), and the extent to which HAC return flow is monitored for heavy metals is not known. Significant leaching of toxic metals from HAC systems into return flow water would require specific conditions, including relatively acidic or corrosive water, and a HAC system design in which relatively large surfaces containing toxic metals are in contact with water.

4.2 Well Characteristics

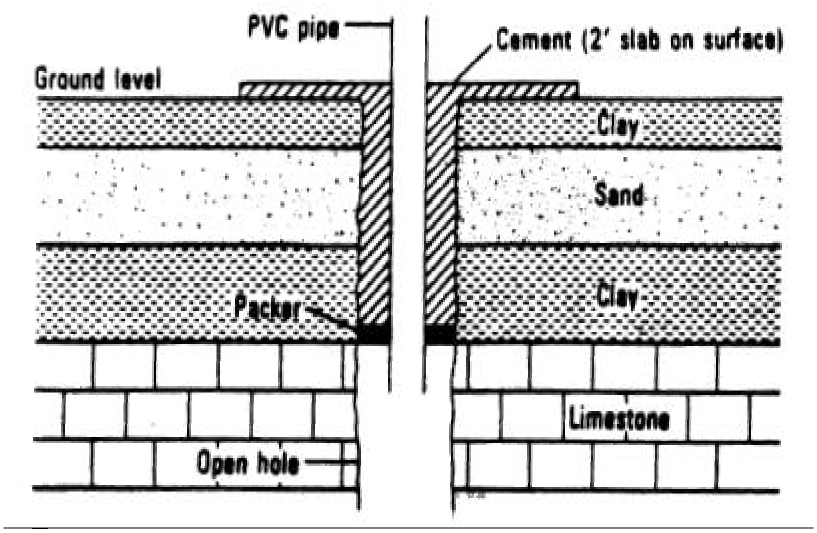
4.2.1 Well Types

HAC systems vary in terms of well arrangement and disposal method. Two types of subsurface systems are used to return used water: horizontal drains and vertical injection wells. Horizontal drains are generally designed as typical leaching fields, where vertical pipes direct water underground for discharge through a network of horizontal, perforated pipes. The horizontal pipes are installed in trenches on top of beds of gravel or other highly porous material, and are covered with more gravel, and then 1-2 feet of original soil from the site. Return flow water percolates from the pipes, down through the bed of porous material, and into the underlying strata and aquifer. This type of system functions well in sandy or highly porous soil.

Most HAC systems that re-inject return flow water to the subsurface use vertical injection wells. There are two types of vertical injection well systems: standing column wells and two-well systems with separate source and return flow (recharge) wells. Standing column wells, sometimes called turbulent wells, are used for both supply and discharge of water. Ground water is pumped to the surface by a submersible pump located at the bottom of the well. Water is circulated through the heat exchanger of the HAC system and returned to the top of the well (Orio, 1994). This design is generally used for domestic systems. In a two-well system, supply and return flow wells are installed separately. The recharge water in two-well systems can be returned either to the same or to a different aquifer from which it was withdrawn.

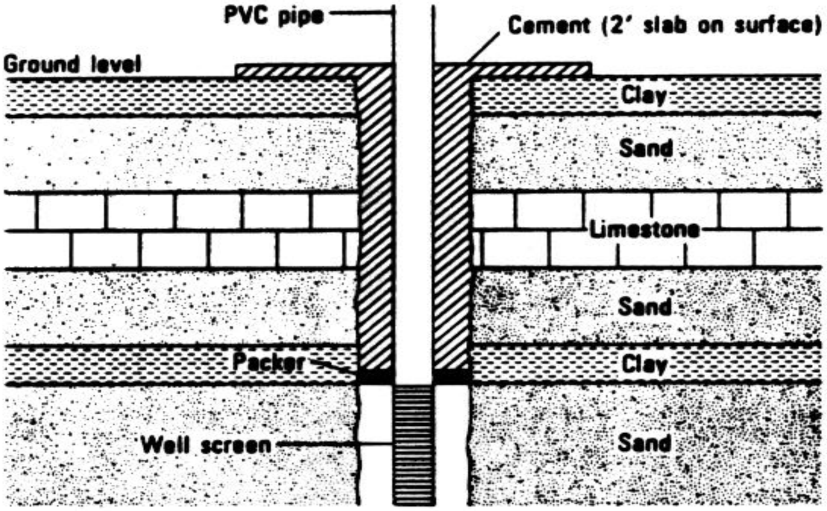
Figures 1 and 2 show standard configurations for HAC return flow wells, installed in consolidated and unconsolidated formations, respectively. Figure 3 shows the design of a typical two-well system using a single aquifer.

Figure 1. A HAC Return Flow Well in a Consolidated Formation



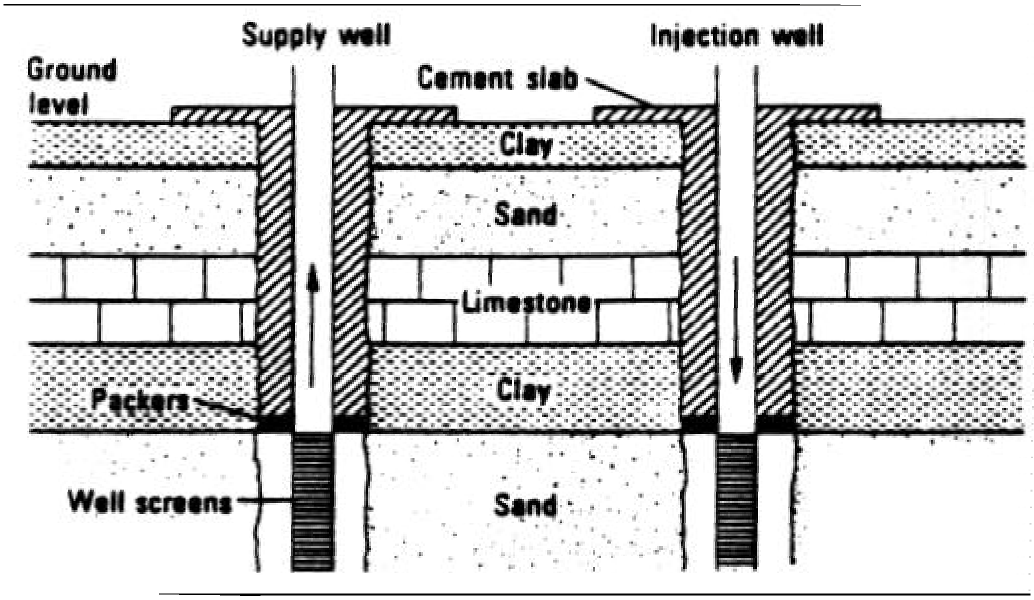
Source: Knape, 1984.

Figure 2. A HAC Return Flow Well in an Unconsolidated Formation



Source: Knape, 1984.

Figure 3. Typical Two-Well System



Source: Knape, 1984.

4.2.2 Well Design

HAC supply and recharge wells are generally similar in design and construction to drinking water wells and other types of wells (see USEPA, 1975, for water well design and construction details). However, air, cable tool, and reverse circulation drilling methods are preferable to rotary drilling for injection wells because they use less damaging drilling fluids (i.e., air or clean water rather than mud) and as a result pose less of a threat to the performance of the completed injection well (Kavanaugh and Rafferty, 1997).

The depth of the HAC return flow well and the acceptance rate of the receiving aquifer are important factors in well design. Depths of HAC return flow wells are dictated by the hydrogeology of each site. HAC return flow well depths (based on the HAC return flow well inventory) include: from 200 to 400 feet in Texas; as deep as 1500 to 2000 in New York; and from 200 to 2000 feet in Nevada. Installing both the supply and return flow wells of single-aquifer systems, and the return flow wells of dual-aquifer systems, in an aquifer with relatively high porosity and water flow rates will ensure sufficient infiltration. For well design recommendations related to water acceptance capacity, see Section 6.1.4.

For the single-aquifer two-well system, it is important to prevent recharge water from causing thermal degradation of supply waters. The spacing between the supply and return flow wells is a critical factor affecting the effectiveness of heat exchange of the heat pump (see Section 6.1.3 for important parameters to consider when evaluating spacing needs). If these wells are too close together, the potential exists for return flow water to move through the aquifer and be withdrawn again by the supply well before the temperature of this water has an opportunity to return to the natural temperature of the aquifer. This can reduce the efficiency of the HAC system.

A dual-aquifer system may be feasible where two aquifers, one with sufficient supply capacity and one with sufficient porosity to accept the return flow, are available. The distance between the two wells is less important for dual-aquifer systems. However, in dual-aquifer HAC systems, water withdrawn from the supply aquifer is not replaced. As is the case with any system involving relatively high rates of water withdrawal from an aquifer, this has the potential to result in land subsidence and, in coastal areas, salt water intrusion into the supply aquifer. While these issues are related to water withdrawal, not underground injection, and no cases involving HAC return flow wells have been identified, they are nevertheless factors often considered in the planning of HAC systems, and in contemplating possible regulation of such systems. These problems are largely avoided with single-aquifer HAC systems.

4.3 Operational Practices

During operation, the typical water consumption of a residential HAC system can be from 3 to 12 gallons per minute (gpm), or 4,320 to 17,280 gallons per day (gpd) (PA DEP, 1996). Others have noted that since HAC systems do not typically run 24 hours per day -- in fact, annual average run time may be only 35 to 40 percent, and continuous operation only occurs during rare extreme weather periods -- actual water usage is probably as low as 1 to 3 gpm per nominal ton of capacity

(Kavanaugh, 1998; Rawlings, 1999). The actual water flow requirement is a function of many variables, including ground water temperature, loop supply and return temperatures, heat exchanger performance, pump performance, and building peak block load (Kavanaugh and Rafferty, 1997).

HAC system return flow wells most commonly operate by gravity flow. Where the receiving aquifer can not accept water at the peak return flow rate, storage tanks may be installed to even out the return flow at a rate that can be absorbed by the return flow well. Where the return flow well can not accept the overall average return water flow rate, pumps are used to re-inject return flow water under pressure.

Return flow water from HAC systems is always warmer (when HAC system is in the cooling mode) or cooler (when the HAC system is in the heating mode) than the supply water. When re-injected, this return flow creates a thermal plume -- or a volume of water within the aquifer surrounding the discharge point that is either warmer or cooler than the natural aquifer temperature. If this thermal plume extends to the intake point of the supply well (in a single-aquifer system), the efficiency of the HAC system will be reduced. Some HAC systems take advantage of the thermal storage capacity of an underlying aquifer by reversing supply and return wells in winter and summer. In this way, cooler water from the cool plume created in the aquifer during winter (HAC system heat mode) is withdrawn during the summer (HAC system cooling mode), increasing the cooling efficiency of the HAC system in summer. Well roles are again reversed in winter, so that warmer water is supplied to the HAC system while it is in heating mode.

Under standard industry practice, HAC water systems are carefully and sufficiently sealed and generally do not allow the entrainment of air. Air bubbles can, however, become lodged in the open spaces of an aquifer and the pressure of recharge water can prevent the upward movement of bubbles to the water table. These bubbles could have the same effect as clay particles and reduce the flow rate of recharge water into the aquifer. An experiment conducted by the U.S. Geological Survey showed that air entrainment can reduce the capacity of the return flow well by as much as fifty percent (Snyder and Lee, 1980).

It should also be noted that HAC return flow wells are generally part of systems that are completely closed above ground, and are generally located on private property. Therefore, the likelihood of USDW contamination by illicit discharges is very low. However, it is possible that some facilities may operate without proper registration and permits. For example, State of Minnesota officials reported that a single well was being operated illegally without a permit “for some time” before state officials discovered it. Upon inspection, a state sanitarian discovered a leak in the injection well. The leak was later corrected and it is not known whether any USDW contamination occurred.

5. POTENTIAL AND DOCUMENTED DAMAGE TO USDWs

5.1 Potential Injectate Impacts to USDWs

5.1.1 Thermal Alteration

The 1987 *Class V UIC Report to Congress* (USEPA, 1987) stated that one of the most serious threats to USDWs associated with HAC systems is thermal degradation. The increase in the temperature of return flow water (in the cooling cycle) can cause the dissolution of suspended solids into the water, increasing the concentration of total dissolved solids in the return flow and in the aquifer where the return flow is re-injected. As previously noted, the decrease in temperature of return flow water during the heating cycle can cause certain salts and metals to precipitate from the ground water, increasing the suspended solids content.

The magnitude and significance of thermal alteration of the ground water is determined by many factors, including the number of aquifers used (i.e., a single- vs. dual-aquifer system), the distance between the supply and injection wells, the recharge volume and temperature, the water chemistry, viscosity, permeability and porosity, and other ground water characteristics. Both Knape (1984) and USEPA (1997) have stated that the temperature change of water in HAC systems is generally less than ten degrees Fahrenheit. USEPA (1997) indicated that returning water to the same aquifer year-round may essentially negate the effects of thermal degradation due to the seasonal alternation of HAC return flow between cooler and warmer water.

Thermal degradation to aquifers may not be evident until several years after the system goes into operation and may be observed only at distances relatively close to the HAC return flow well. Andrews (1978), using a single-aquifer mathematical model to estimate temperature change over 10 years of operation, indicated that the change in aquifer water temperature will be less than 1 degree centigrade at a distance greater than 40 meters from the HAC return flow well. According to another study, a single-aquifer, 20-ton HAC system will not produce any noticeable thermal effects at distances greater than 100 feet from the return well (Williams and Sveter, 1987).

A temperature change in an aquifer may alter its ability to transmit fluid (Knape, 1984). If the ground water temperature were to decrease due to cold water injection during a HAC system heating cycle, the viscosity of the ground water can be increased, and the aquifer can transmit fluid less easily. Knape (1984), however, notes no significant hazard to aquifers due to the potential change in aquifer transmissivity. No data have been identified relating to HAC return flow well impacts on aquifer transmissivity.

Knape (1984) also states that the solubility of most common salts, such as calcium or magnesium, is generally more dependent on the degree of acidity of the solution rather than the temperature. While the precipitation of salts may result in pore clogging in the receiving aquifer, this is likely to be restricted to areas near the outlet of the return flow well. Pore clogging therefore could conceivably affect performance of the HAC system, but is not likely to have a significant effect on the aquifer as a whole. No data on pore clogging from salt precipitation have been identified during the course of this study.

Armitage et al. (1980) list several studies on thermal degradation of aquifers, and indicate that none have shown serious adverse effects to the aquifer.

5.1.2 Mineral Precipitation Due to Changes in Water Pressure or Oxygen Levels

In addition to differences in temperature, return flow water is different from supply water in that the pressure and dissolved oxygen levels may be altered by the HAC system. Changes in water pressure and oxygen levels may potentially lead to metal precipitation and iron oxide development (USEPA, 1997). Williams and Sveter (1987) indicate that "pressure changes can alter the equilibrium of dissolved constituents and result in precipitation," and they identify calcium and iron precipitation to be a major problem in HAC systems in Texas. Armitage et al. (1980) state that calcium carbonate can precipitate when the injectate contains high levels of calcium, bicarbonate, and carbonate and is injected into a carbon dioxide deficient aquifer.

Although air leaks are generally not tolerated in a well-designed HAC system (Rawlings, 1999), some poorly-designed or constructed HAC systems allow entrainment of or exposure to air, increasing the oxygen level in the water. When oxygen-rich ground water is injected into a reducing aquifer, the precipitation of ferric hydroxide is likely. Increased oxygen levels also aid in the growth of oxygen-dependent bacteria, which oxidize ferrous iron and contribute to the precipitation of ferric hydroxide (Snyder and Lee, 1980).

HAC injection wells do not change the pH-Eh conditions of return flow water, but in dual-aquifer systems the compatibility of the pH-Eh equilibrium between two aquifers is a significant consideration. If this equilibrium is radically different in the two aquifers, solids precipitation and clay colloid dispersion is likely, and the result can be a significant reduction in aquifer permeability in areas affected by the return flow plume (Armitage et al., 1980).

5.1.3 Chemical Contamination

Construction and operation of any type of borehole/well system can potentially lead to the contamination or cross-contamination of aquifers, particularly if such systems are poorly designed, built, or managed. This is not a problem specific to HAC injection wells, but experience has shown that poor well design, construction, and/or management can result in USDW contamination by HAC well systems.

Potential sources of contamination during the drilling of HAC wells include contaminants present in or on surface soils, hydraulic fluids or fuels from the drilling rig, residual drilling fluid constituents (if used), materials encountered during drilling (e.g., accidental puncture of sewage lines, encountering buried wastes, etc.), and airborne pollutants that could migrate down the hole

(PA DEP, 1996). If significant amounts of water are spilled on the ground during drilling, surface contaminants can infiltrate the ground and contaminate the underlying ground water, depending on the depth to ground water and local hydrogeologic conditions (USEPA, 1997).

USDWs can also be contaminated by dual-aquifer HAC systems, when water in the source aquifer is contaminated or non-potable, and the return flow is injected into a clean USDW. In any inter-aquifer contamination case of this kind, the properties of the return flow water will reflect the properties of the supply aquifer. While undocumented inter-aquifer contamination incidents may have occurred, broad statements cannot be made at this time given the available information. The specific contaminants, the concentrations of these contaminants, and the significance of inter-aquifer contamination are specific to the properties of the aquifer from which the contamination emanates, and the particulars of each case.

As with other types of wells, unintended inter-aquifer transfer of water can occur when HAC wells are poorly built, and allow seepage of water from contaminated or non-potable aquifers into or out of the system. This problem is generally due to lack of training, care, or expertise on the part of the driller or well installation contractor, and this same problem exists for all types of wells, not just HAC wells. The problem can occur in both single- and dual-aquifer systems, even when the intended supply and return flow aquifers are uncontaminated, if wells with porous or leaky liners pass through aquifers with contaminated or non-potable water. Where well liners are permeable or HAC systems are inadequately sealed, both the withdrawal and injection processes associated with HAC systems can cause unintended transfer of water between aquifers, including the transfer of contaminated or non-potable water to USDWs. This can happen in two ways for HAC systems: (1) when water from a contaminated aquifer seeps into an HAC system designed to withdraw water from a clean aquifer and re-inject it into a USDW; and (2) when water seeps out of an HAC system using contaminated or non-potable aquifer, and the seepage reaches a USDW. Contaminants reaching the USDW in such cases will reflect the characteristics of the contaminated or non-potable aquifer involved. Section 5.2 details the lone documented incident of this type of contamination from a well in New York.

The inter-aquifer contamination scenario is most likely to occur when the HAC supply well is located near sources of contamination such as areas of heavy commercial fertilizer or pesticide use, landfills, livestock pens, underground fuel or chemical storage tanks, or septic systems (USEPA, 1997). Clearly, inter-aquifer contamination can also occur if the supply well taps saline coastal aquifers, or other aquifers with naturally high dissolved solids (salts) content.

USDWs may also be contaminated by chemical additives used to maintain HAC well function. The environment found in the HAC pipes can encourage the growth of several types of bacteria, including *Crenothrix* and *Leptothrix*, which oxidize ferrous iron and lead, increasing ferric hydroxide precipitation (Snyder and Lee, 1980). Additives may be used to control the growth of these biological organisms, and to prevent them from clogging the pipes and pumps. Chlorine, for example, is a relatively common additive used in many types of water wells infested with bacteria. Chlorine and other chemical additives can enter the USDW with the return flow water. Data regarding the prevalence of additive use, types of additives used, and concentrations of these additives in open-loop HAC injectate are not available.

Finally, USDWs can potentially be contaminated by materials leached from the pipes and pumps of the HAC system itself. This is particularly a concern where the supply water is acidic or corrosive, and HAC water contacts large surfaces of toxic metals or other materials. For example, excessive flows can lead to significant copper leaching from the heat exchanger. Only two documented contamination incidents due to metal leaching have been reported. In Minnesota, two wells were found to exceed the MCL for lead and one of these wells was found to exceed the MCL for copper, and this contamination was attributed to metal leaching (see Section 5.2 for details of these incidents).

5.1.4 Water Quantity

HAC systems can affect the quantity of water in USDWs. Gravity alone is often not sufficient to cause return flow water to flow into recharge wells at sufficient rates (e.g., in aquifers with low permeabilities) (USEPA, 1987). In fact, most aquifers will not accept 100 percent of their yields without pressurizing the return flow. If the injected return flow from single-aquifer HAC systems is not pressurized to ensure sufficient infiltration rates (and excess water is discharged to the surface or used in another way), then the quantity of water in the aquifer may be reduced (for injection pressure calculations and requirements, see Kavanaugh and Rafferty, 1997). However, a single-aquifer HAC system that effectively returns used water to the aquifer via underground injection will minimize future drawdown problems and will maintain the ground water resource relatively well over the long term (Kavanaugh and Rafferty, 1997). Clearly, dual-aquifer HAC systems can also affect the water supply in the source aquifer because the source aquifer is not being replenished.

Important considerations relating to water removal from USDWs include aquifer drawdown and well interference, land subsidence, and salt water intrusion. Aquifer drawdown and well interference can take place in areas where yields are low, use of ground water is high, or where supply wells are close to each other (PA DEP, 1996). The results are lower water levels in wells and smaller yields. In some cases, water levels may drop below pump intake levels and result in “dry wells.” Land subsidence may result from changes in water quantity and ground water flow, although other factors include the composition of the underlying carbonate rock and the surface water drainage (PA DEP, 1996). In coastal areas, salt water intrusion may occur when fresh-water aquifers are drawn down by excessive pumping.

5.2 Observed Impacts

Relative to the number of HAC wells that exist in the U.S., the number of documented cases where USDWs have been negatively affected by HAC return flow wells is small. The few incidents uncovered during the Class V well survey conducted for this study are described in this section. (For information on the health effects associated with contaminants found above drinking water standards and health advisory levels, see Appendix D of the Class V UIC Study. For halflives and mobility information for certain constituents found in injectate of HAC return flow wells and other Class V wells, see Appendix E of the Class V UIC Study).

Samples from a HAC return flow well in Albany, New York, indicated that an underlying USDW was being contaminated by contaminants in the return flow water. Indications are that this was caused by seepage of water from a non-potable water supply into the HAC water system, due to poor design and failure to extend HAC well casings to an adequate depth. Water samples from the return flow well contained over 14,000 mg/l of TDS and 9,000 mg/l chlorides (Kushwara, 1998). Secondary drinking water MCLs of 500 mg/l and 250 mg/l have been established for TDS and chloride, respectively. Due to high levels of TDS and chloride, the Albany well has since been closed (Lynes, 1998).

There are two cases documented in Minnesota. In 1985, water from a HAC return flow well owned by the Itasca-Mantrap Co-op was observed to contain 0.61 mg/l of lead and 1.8 mg/l of copper (Englund, 1985). The maximum contaminant level goal for lead has been established at 0 and the MCL is dictated by treatment techniques, with an action level of 0.015 mg/l (USEPA, 1998). The MCL for copper is also dictated by treatment techniques, and the action level is 1.3 mg/l (USEPA, 1998). A Minnesota Pollution Control Agency official stated in a July 7, 1992, memo to the Minnesota Department of Health that the lead in Itasca-Mantrap injection well samples was probably “coming from the heat pump system, related plumbing, or wells” and suggested that further samples be taken (Convery, 1992). In addition, it was recommended that the heat pump system be treated for coliform bacteria which was discovered in the injection well (O’Brien, 1992).

Separately, a sample taken in 1984 from a HAC return flow well in Maplewood, Minnesota revealed a level of 0.061 mg/l of lead in the water (Englund, 1984). There is no further information reported on the current status of this well, remedial steps taken to halt the contamination, or specific causes of contamination.

Additionally, officials in North Carolina have reported that iron and coliform have been observed in HAC return flow wells at levels higher than those found in the supply aquifer. Data on actual concentrations, however, were not provided by state officials. State officials presume that most of the problems resulted from poor well construction or operation. These problems were reportedly resolved by simple measures such as disinfection of the well or replacement of the fixtures containing rusty components. No additional information is available. It is possible that impacts may have occurred to the receiving aquifer.

6. BEST MANAGEMENT PRACTICES

The primary concerns associated with HAC return flow wells are impacts on ground water quality and ground water quantity (see Section 5), geologic impacts (e.g., sinkholes, land subsidence), and degradation of the integrity and long-term functionality of the HAC system itself. A variety of best management practices (BMPs) can be used to minimize the risk of environmental impacts and HAC system degradation and/or failure. These BMPs, described below, are grouped into the following categories: (1) well design and siting; (2) well construction; and (3) well operation, maintenance, and monitoring. The following discussion is neither exhaustive nor represents a USEPA preference for the stated BMPs. Each state or USEPA Region may require certain BMPs to be installed and maintained based on that state's or USEPA Region's priorities and site-specific considerations.

6.1 Well Design and Siting

Careful pre-construction HAC well design and siting practices can minimize potential damage to the aquifer(s). The type of system employed and the location and arrangement of wells are important considerations that can significantly affect a system's potential for affecting USDWs.

6.1.1 Alternative Technological Design

The advantages of open-loop HAC systems compared to closed-loop HAC systems are that they are lower in cost, water well contractors are widely available, and the technology has been used for decades (Kavanaugh and Rafferty, 1997). However, all potential environmental or maintenance/operational problems associated with open-loop HAC systems can be avoided through the use of the closed-loop HAC system (Armitage et al., 1980). In fact, in 1987, Tennessee and Utah recommended using only closed-loop systems (USEPA, 1987). The selection of the type of system will depend on many factors, including the availability of ground water, soil type, size of lot (i.e., available ground area), and energy requirements (PA DEP, 1996). Many existing open-loop systems can also be converted to closed-loop systems.

6.1.2 Pre-Construction Practices

Several pre-construction BMPs are available to minimize the impacts of HAC return flow wells. During the design and siting phase, a broad assessment can be conducted to determine the effect of the proposed well on the surrounding area. This will provide baseline data which can be used later (during monitoring) to evaluate changes in the aquifer that may result from the well. This assessment can be conducted for HAC systems using any type of subsurface disposal (e.g., vertical injection wells and horizontal drains) and might include the following information (PA DEP, 1996)[2]:

- the proposed well spacing, water use, and withdrawal amounts;
- the effect on aquifer quantity and quality (relevant parameters might include temperature, pH, specific conductance, total dissolved solids, and bacterial levels);
- changes relative to adjacent land and water use;
- the stability of bedrock and the effect of increased ground water movement;
- the precautions that will be taken to prevent aquifer drawdown and well interference;
- future changes in water use; and
- water use plans.

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[2] For an alternative discussion on complete pre-construction site surveys, see Caneta Research (1995).

6.1.3 Siting Issues

USEPA (1997) recommends that source wells be sited away from sources of pollution or contamination, including areas of heavy commercial fertilizer or pesticide application, landfills, livestock pens, underground storage tanks, and septic systems (see Section 5.1.3). If installation of the system near such an area is unavoidable, the well must be placed upgradient from the pollution source. Another attribute for a potential well area is adequate surface drainage away from the well. If a well is located in a low-lying area, standing water may accumulate and could seep down along the borehole and, if contaminated, affect the underlying ground water (USEPA, 1997).

Thermal alteration of the aquifer can cause environmental problems and can lead to HAC system performance problems (see Section 5.1.1). The spacing of the source and return flow wells is essential for single-aquifer systems, since inadequate separation of these two wells will not allow the return flow water to reach the natural temperature of the aquifer before it flows through the aquifer to the supply well withdrawal point. PA DEP (1996) recommends that wells generally be more than 100 feet (horizontal distance) apart. A different model seeking to determine the optimal distance between supply and return flow wells in single-aquifer HAC systems suggests that a distance of 50 to 75 feet is typically adequate to prevent thermal contamination (Clyde and Madabhushi, 1983). It is apparent that optimal spacing varies depending on many case-specific factors. Specifically, evaluation of the well supply and recharge capacities, ground water flow velocity, relative well heads (water levels) in supply and return flow wells, aquifer transmissibility, aquifer thickness, duration of heat pump operation, natural ground water gradient, natural ground water temperature, and effective porosity will aid in the determination of the appropriate distance between supply and return wells.[3]

Ideally, wells are sited so that the advancement of the aquifer's thermal front will follow the natural flow of the aquifer. The thermal plume moves more rapidly and temperatures in the aquifer change more rapidly when supply wells are located downgradient from injection wells. Therefore, in areas with significant ground water flow, many recommend that the supply well be located upgradient from the return flow well, and the wells positioned so that the ground water flow is parallel to the line joining the two wells (Clyde and Madabhushi, 1983; USEPA, 1987).

6.1.4 Design Features

Perhaps the single most important BMP for HAC systems is to restrict these systems to a single-aquifer design. This design can generally ensure that ground water quality and quantity in the utilized aquifer is maintained (PA DEP, 1996). Dual-aquifer design is already not accepted in many jurisdictions unless the supply and return aquifers are chemically compatible (USEPA, 1987).

When designing a HAC system, the well contractor must consider the acceptance rate of the

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[3] For a simple calculation to determine typical well spacing, see Orio (1994). For a matrix of recommended spacing distances under various thermal and hydraulic parameters, see Kazmann and Whitehead (1980).

receiving aquifer. By designing the return flow wells to handle twice the needed water flow rate of the HAC system, the potential for clogging and capacity loss will be greatly minimized. Water acceptance capacity of return flow wells can be maximized by increasing well screen diameter and length.

Clyde and Madabhushi (1983) note that in dense communities where surface area limits the spacing of wells (and supply and return flow wells are located in closer proximity than is optimal), wells should be designed so that water can be pumped from the top of the aquifer and re-injected to the bottom of the aquifer. This design reduces the risk of intra-aquifer thermal alteration. For housing subdivisions and other dense communities with limited well sites, Armitage et al. (1980) recommend implementing a cluster well concept (i.e., several houses with individual heat pump units being supplied by the same supply and recharge well).[4]

6.2 Heat Pump Injection Well Construction

PA DEP (1996) lists the acceptable methods of well drilling to include rotary, cable tool, and auger. However, as discussed earlier in Section 4.2.2, Kavanaugh and Rafferty (1997) recommend that the conventional rotary method be avoided in favor of methods using less damaging drilling fluids, such as the air rotary drilling, cable tool, and reverse circulation methods.

When a driller constructs a well, one of the primary concerns is the prevention of aquifer contamination. Well construction could result in both downward and upward migration of contamination. Extensive drilling data can and should be recorded for all wells, including well location, depth, diameter, materials, dates of work, and a geologic log (PA DEP, 1996).

To prevent surface contamination from reaching the aquifer, PA DEP (1996) recommends that casing be used (see USEPA, 1975, for further details). Installing the casing through the overburden of unconsolidated material and into solid material will act to prevent the collapse of the hole. Kavanaugh and Rafferty (1997) recommend that the casing should be at least two nominal sizes larger than the outside diameter of the pump bowl assembly (which includes the impellers, or the rotary parts of the pump, and their housing). Strong casing material will protect the well during construction and over the anticipated life of the well.

PA DEP (1996) also notes that grout should be placed in the entire annular space between the surface casing and the drill hole to prevent the seepage of water down along the outside of the casing and to minimize the potential for the entry of surface or subsurface pollutants into the well water. The grout, which can be either bentonite- or cement-based, can be placed by gravity or by pumping. Rawlings (1999), however, recommends that only the pumping method be used because gravity placement can cause bridging (e.g., if a fluid, such as water or a water/drilling mud solution, is present in the annulus and is then lost over time) and the remaining open space can become a

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[4] For further discussion on the design of the HAC system, as well as quantitative methods to estimate system requirements (e.g., size, ground water flow), see Kavanaugh and Rafferty (1997).

pathway for the upward or downward flow of contaminants along the casing. For wells deeper than 30 feet, where the annular space cannot be seen to the bottom, the well should be grouted from the bottom to the surface using a tremie pipe (i.e., a pipe that is lowered into the borehole, through which the grout material is delivered until the annular space is filled to the surface). For wells penetrating more than one aquifer, other grouting methods, such as sleeves, packers, and other devices, can be employed to prevent inter-aquifer flow and the spread of contamination (USEPA, 1997).

The most commonly used material for well piping is polyvinyl chloride (PVC), because it is economical, durable, and corrosion-resistant (PA DEP, 1996). The heat pump exchanger and water-side piping are typically made of copper or cupro-nickel. This is a solution to many corrosion problems, unless the water contains hydrogen sulfide or ammonia (Caneta Research, 1995). Most manufacturers use lead-free solder (Rawlings, 1999).

Careful design and construction of the return flow well (i.e., sufficient diameter and depth) will aid in the acceptance of the maximum discharge from the HAC return flow system and prevent clogging due to the precipitation of minerals. Kavanaugh and Rafferty (1997) recommend that the screen lengths for injection wells be doubled compared to those used in production wells for the same flow. An extended pumping test (e.g., 12-24 hours) is recommended to help determine the hydraulic characteristics of the injection well. The installation of a back valve can help to prevent pressure differences that could result in the precipitation of minerals. Installing a blind flange allows for the emergency surface discharge of water, should this become necessary.

These construction-phase BMPs seek to both minimize environmental impacts and ensure long-term HAC well function. Practices that prevent surface contamination from reaching the underground aquifer are sensible ways to prevent aquifer quality damage. The use of certain construction materials and the estimation of the optimum well size, while primarily seeking to preserve well functionality and integrity, also act to protect the aquifer by minimizing changes in water quality.

6.3 Heat Pump Injection Well Operation, Maintenance, and Monitoring

The avoidance and the containment (if necessary) of ground water contamination is a top priority. In the event that water does become contaminated, backlashing the injection well is a technique that can recover contaminated water. Backlashing is made possible by installing pumps in both the supply and injection wells (Knape, 1984; Williams and Sveter, 1987). The contaminated water withdrawn during backlashing can be disposed of by a method other than subsurface injection.

Backlashing also acts to reduce clogging due to sediment. The use of surface-mounted separators to remove solids prior to re-injection further limits clogging (Williams and Sveter, 1987). However, separators can present a chronic maintenance problem under high-volume flows. Rawlings (1999) notes that although the volume of water typically used and needed by a residence, for example, may be relatively small, the volume of water required for the HAC system to operate will be considerably larger and thus a larger-than-anticipated burden will be placed on the separators. Separators can be an effective means of sediment removal, but it is important to evaluate their potential maintenance requirements using the expected flow rate required for the HAC system rather than the typical water usage associated with a given type of facility (i.e., commercial or residential).

The reversal of well flows (roles) between heating and cooling seasons can be used to alleviate well plugging due to mineral precipitation in those wells where it is a problem. USEPA (1997) discusses several preventative operational practices that can be used to limit mineral precipitation before it begins. First, most precipitation can be avoided by ensuring that return flow waters do not free-fall back into the return well, as free-fall results in the entrainment of oxygen into the return flow water, which in turn can cause the precipitation of solids. Free-fall can be limited through the use of a simple dip tube or avoided outright by discharging the return flow below the standing water level, greatly reducing turbulence and air entrainment (Kavanaugh and Rafferty, 1997). Second, any other means of aeration of the return flow water should be avoided. If a surface reservoir or tank is used to store water before it is returned to the ground, for example, it can be a “diaphragm” type tank, or one that does not allow venting to the atmosphere.

As discussed earlier in Section 5.1.3, additives may currently be used in some HAC systems to control the growth of biological organisms. Although disinfection (e.g., chlorination) is sometimes prescribed to remedy this problem (Knape, 1984; Williams and Sveter, 1987; USEPA, 1997; see USEPA, 1975 for disinfection details), the use of chlorine or other chemical additives (for any purpose) is not universally recommended due to potential water quality impacts (see PA DEP, 1996). While other additives such as antifreeze are used in closed-loop systems, they should not be used in open-loop HAC systems. In addition to the environmental problems these practices might pose, the use of chemical additives many change the legal classification of the return flow well (PA DEP, 1996). If the use of chemical additives is judged necessary, for whatever reason, it is best to carefully analyze the site-specific conditions and solicit expert opinions before they are used.

In addition to water quality considerations, BMPs can act to minimize impacts on water quantity. As noted earlier in Section 5.1.4, gravity alone is sometimes not sufficient to return water to the return flow well. The use of pumps to pressurize the return flow will ensure sufficient infiltration rates. Alternatively, the temporary storage of used water can help to slow the return flow rates and prevent spillage of excess water out on the ground (USEPA, 1987). Furthermore, the volume of water withdrawn from the source well is dependent on the recharge capacity of the aquifer. To avoid legal issues and prevent water quantity problems, hydrogeological investigations can be conducted by qualified professionals to assess recharge capacity and use limits prior to the construction of a new HAC system (USEPA, 1997).

Continual system monitoring is an integral part of sound HAC well management. The use of monitoring wells is especially important for very large systems (e.g., hundreds of wells) and for systems that are very close to large municipal water supplies (PA DEP, 1996). Several states specifically recommend that volumes and temperatures of return flow (injected) waters be monitored, and that periodic analyses of the receiving aquifer be conducted to monitor changes in aquifer temperature and chemistry (USEPA, 1987). Maintenance of these and other data by county and state agencies will allow for more accurate assessment of well number, density, and overall impact that HAC return flow wells have on USDWs. A complete monitoring program includes a baseline analysis of the injectate and ground water prior to injecting, a monitoring schedule (sampling frequency), parameters to be measured, location of sampling point(s), and a discussion of the technical basis for selecting the sampling point(s).

7. CURRENT REGULATORY REQUIREMENTS

Several federal, state, and local programs exist that either directly manage or regulate Class V HAC return flow wells. On the federal level, management and regulation of these wells falls primarily under the UIC program authorized by the Safe Drinking Water Act (SDWA). Some states and localities have used these authorities, as well as their own authorities, to extend the controls in their areas to address concerns associated with HAC return flow wells.

7.1 Federal Programs

Class V wells are regulated under the authority of Part C of SDWA. Congress enacted the SDWA to ensure protection of the quality of drinking water in the United States, and Part C specifically mandates the regulation of underground injection of fluids through wells. USEPA has promulgated a series of UIC regulations under this authority. USEPA directly implements these regulations for Class V wells in 19 states or territories (Alaska, American Samoa, Arizona, California, Colorado, Hawaii, Indiana, Iowa, Kentucky, Michigan, Minnesota, Montana, New York, Pennsylvania, South Dakota, Tennessee, Virginia, Virgin Islands, and Washington, DC). USEPA also directly implements all Class V UIC programs on Tribal lands. In all other states, which are called Primacy States, state agencies implement the Class V UIC program, with primary enforcement responsibility.

HAC return flow wells currently are not subject to any specific regulations tailored just for them, but rather are subject to the UIC regulations that exist for all Class V wells. Under 40 CFR 144.12(a), owners or operators of all injection wells, including HAC return flow wells, are prohibited from engaging in any injection activity that allows the movement of fluids containing any contaminant into USDWs, “if the presence of that contaminant may cause a violation of any primary drinking water regulation . . . or may otherwise adversely affect the health of persons.”

Owners or operators of Class V wells are required to submit basic inventory information under 40 CFR 144.26. When the owner or operator submits inventory information and is operating the well such that a USDW is not endangered, the operation of the Class V well is authorized by rule. Moreover, under section 144.27, USEPA may require owners or operators of any Class V well, in USEPA-administered programs, to submit additional information deemed necessary to protect USDWs. Owners or operators who fail to submit the information required under sections 144.26 and 144.27 are prohibited from using their wells.

Sections 144.12(c) and (d) prescribe mandatory and discretionary actions to be taken by the UIC Program Director if a Class V well is not in compliance with section 144.12(a). Specifically, the Director must choose between requiring the injector to apply for an individual permit, ordering such action as closure of the well to prevent endangerment, or taking an enforcement action. Because

HAC return flow wells (like other kinds of Class V wells) are authorized by rule, they do not have to obtain a permit unless required to do so by the UIC Program Director under 40 CFR 144.25. Authorization by rule terminates upon the effective date of a permit issued or upon proper closure of the well.

Separate from the UIC program, the SDWA Amendments of 1996 establish a requirement for source water assessments. USEPA published guidance describing how the states should carry out a source water assessment program within the state's boundaries. The final guidance, entitled *Source Water Assessment and Programs Guidance* (USEPA 816-R-97-009), was released in August 1997.

State staff must conduct source water assessments that are comprised of three steps. First, state staff must delineate the boundaries of the assessment areas in the state from which one or more public drinking water systems receive supplies of drinking water. In delineating these areas, state staff must use "all reasonably available hydrogeologic information on the sources of the supply of drinking water in the state and the water flow, recharge, and discharge and any other reliable information as the state deems necessary to adequately determine such areas." Second, the state staff must identify contaminants of concern, and for those contaminants, they must inventory significant potential sources of contamination in delineated source water protection areas. Class V wells, including HAC return flow wells, should be considered as part of this source inventory, if present in a given area. Third, the state staff must "determine the susceptibility of the public water systems in the delineated area to such contaminants." State staff should complete all of these steps by May 2003 according to the final guidance.[5]

7.2 State and Local Programs

As discussed in Section 3 and shown in Table 1 above, the nearly 28,000 documented HAC wells in the U.S. are distributed across 34 states. While only four states have 1,000 or more documented wells each (i.e., Texas, Virginia, Florida, and Tennessee), many other states are documented or estimated to have dozens or hundreds of wells. Attachment A to this volume describes how the twenty-six states containing nearly all of the HAC return flow wells (approximately 99 percent of the documented and estimated HAC wells) currently address these wells. In brief:

- USEPA directly implements and authorizes by rule the federal UIC program for all Class V injection wells in several states, including: Arizona, Michigan, Minnesota, New York, Pennsylvania, Tennessee, and Virginia.

- The other states with many HAC return flow wells are UIC Primacy States for Class V wells and may authorize by rule or issue individual permits.

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[5] May 2003 is the deadline including an 18-month extension.

-- Those that authorize by rule in accordance with the minimum federal requirements include: Illinois, Kansas, Nebraska, North Dakota, Ohio, South Carolina, Texas, West Virginia, Wisconsin, and Wyoming.

-- Those that issue individual permits include: Delaware, Florida, Maryland, Missouri, Nevada, North Carolina, Oregon, Vermont, and Washington.

ATTACHMENT A
STATE AND LOCAL PROGRAM DESCRIPTIONS

This attachment describes the statutory and regulatory requirements and guidance applied to HAC return flow wells in those states in which the largest numbers of such wells are found. In several states, this category of well is permitted by rule or is permitted through a general permit that does not apply a detailed set of siting, construction, operating, or monitoring requirements or guidance.

For some of those states that do have specific programs for Class V HAC systems, state definitions for “open-loop” and “closed-loop” HAC systems differ somewhat from the definitions used by USEPA. The state and local program descriptions include information about “closed-loop” HAC systems if: (1) “closed-loop” system (as defined by the state) requirements or guidance seems to apply to “open-loop” systems (as defined by USEPA), (2) “open-loop” requirements or guidance could not be found, or (3) such information is relevant for comparison purposes.

Arizona

USEPA Region 9 directly implements the UIC program for Class V injection wells in Arizona. The state has not enacted regulations pertaining to underground injection wells. The state has enacted a ground water protection statute, however, that could address HAC return flow wells. Under the Arizona Revised Statutes (Title 49, Chapter 2, Article 3 - Aquifer Protection Permits) any facility that “discharges” is required to obtain an Aquifer Protection Permit (APP) from the Arizona Department of Environmental Quality (ADEQ) (§49-241.A). An injection well is considered a discharging facility and is required to obtain an APP, unless ADEQ determines that it will be “designed, constructed, and operated so that there will be no migration of pollutants directly to the aquifer or to the vadose zone” (§49-241.B).

The aquifer protection statute provides that an applicant for an APP may be required to provide information on the design, operations, pollutant control measures, hydrogeological characterization, baseline data, pollutant characteristics, and closure strategy. Operators must demonstrate that the facility will be designed, constructed, and operated as to ensure greatest degree of discharge reduction and aquifer water quality will not be reduced or standards violated. By rule, presumptive best available demonstrated control technology, processes, operating methods or other alternatives, in order to achieve discharge reduction and water quality standards, are established by ADEQ (§49-243).

An APP may require monitoring, recordkeeping and reporting, a contingency plan, discharge limitations, a compliance schedule, and closure guidelines. The operator may need to furnish information, such as past performance, and technical and financial competence, relevant to its ability to comply with the permit terms and conditions. A facility must demonstrate financial assurance or competence before approval to operate is granted. Each owner of an injection well to whom an individual permit is issued must register the permit with ADEQ each year (§49-243).

ADEQ designates a point or points of compliance for each facility receiving a permit. The statute defines the point of compliance as the point at which compliance with aquifer water quality standards shall be determined and is a vertical plane downgradient of the facility that extends through the uppermost aquifer underlying that facility. If an aquifer is not or reasonably will not foreseeably be a USDW, monitoring for compliance may be established in another aquifer. Monitoring and reporting requirements also may apply for a facility managing pollutants that are determined not to migrate (§49-244).

Permitting

The Arizona Aquifer Protection Permit Rules (Chapter 19, sub-chapter 9, October 1997) define an injection well as "a well which receives a discharge through pressure injection or gravity flow." Any facility that discharges is required to obtain an individual APP from ADEQ, unless the facility is subject to a general permit. Permit applications must include specified information, including topographic maps, facility site plans and designs, characteristics of past as well as proposed discharge, and best available demonstrated control technology, processes, operating methods, or other alternatives to be employed in the facility. In order to obtain an individual permit, a hydrogeologic study must be performed. This study must include a description of the geology and hydrology of the area; documentation of existing water quality in the aquifers underlying the site; any expected changes in the water quality and ground water as a result of the discharge; and the proposed location of each point of compliance (R18-9-108).

Well Construction Standards

The construction of HAC return flow wells greater than 100 feet in depth is regulated by the Arizona Department of Water Resources, Ground Water Management Support Section. In general, all water wells drilled must be at least 100 feet (preferably uphill) from septic tanks or sewage disposal areas, landfills, hazardous waste facilities, hazardous material storage areas, or petroleum storage areas and tanks, unless authorized in writing by the Director. In addition, wells must be properly capped, and have a proper surface seal (consisting of a steel casing extending from one foot above ground level to a depth of 20 feet surrounded by cement grout. Also, any drilling fluids and cuttings must be contained in a manner which prevents discharge into any surface water (AAC R12-15-801 through 822).

No injection wells may be constructed unless an APP has been completed and approved. Wells are required to be constructed in such as manner as not to impair future or foreseeable use of aquifers. Specific construction standards are determined on a case-by-case basis.

Operating Requirements

Each APP has specific operating requirements. All wells must be operated in such a manner that they do not violate any rules under Title 49 of the Arizona Revised Statutes, including Article 2, relating to water quality standards, and Article 3, relating to APPs. Water quality standards must be met in order to preserve and protect the water quality in all aquifers for all present and reasonably foreseeable future uses.

Monitoring Requirements

Monitoring of both injectate and the injection site generally will be required for HAC return flow wells. The permit establishes, on a case-by-case basis, alert levels, discharge limitations, monitoring, reporting, and contingency plan requirements. Alert level is defined as a numeric value, expressed either as a concentration of a pollutant or a physical or chemical property of a pollutant, which serves as an early warning indicating a potential violation of any permit condition. If an alert level or discharge limitation is exceeded, an individual permit requires the facility to notify ADEQ and implement the contingency plan (R18-9-110).

Plugging and Abandonment

Temporary cessation, closure, and post-closure requirements are specified on a case-by-case basis in an APP. The facilities are required to notify ADEQ before any cessation of operations occurs. A closure plan is required for facilities that cease activity without intending to resume. The plan describes the quantities and characteristics of the materials to be removed from the facility; the destination and placement of material to be removed; quantities and characteristics of the material to remain; the methods to treat and control the discharge of pollutants from the facility; and limitations on future water uses created as a result of operations or closure activities. A post-closure monitoring and maintenance plan is also required. This plan specifies duration, procedures, and inspections for post-closure monitoring (R-18-9-116). Additional specific abandonment requirements are found at R12-15-816.

Financial Responsibility

An individual APP requires that a owner have and maintain the technical and financial capability necessary to fully carry out the terms and conditions of the permit. The owner must maintain a bond, insurance policy, or trust fund for the duration of the permit (R-18-9-117).

Delaware

Delaware is a UIC Primacy State for Class V wells. The Delaware Regulations Governing Underground Injection Control (Parts 122, 124, and 146) set forth the detailed requirements of the state's UIC program. The state's UIC regulations are generally equivalent in substance to the federal UIC requirements.

Permitting

Delaware requires permits for the construction, use, operation, or modification of any Class V well, with certain exceptions. These exceptions include air conditioning return flow wells (Delaware UIC Regulations, Section 122.23).

Siting and Construction

Section 6023 of the Delaware Environmental Protection Act (7 Delaware Code Chapter 60) stipulates that well drillers and septic tank installers must be licensed by the Secretary. New HAC return flow wells must meet construction and siting requirements. These construction requirements are specified in "Delaware Regulations Governing the Construction and Use of Wells." The states's construction requirements for HAC return wells specifically address siting, casing, screens, grouting, caps, well disinfection, well maintenance and repair, and abandonment. Closed-loop heat pump wells are not considered injection wells, and construction requirements are therefore different for open-loop and closed-loop systems (Sections 5.04 and 5.05 respectively). Inspections generally are performed during or immediately following construction.

Siting requirements consist primarily of set-backs from existing or potential contamination sources. For example, heat pump recharge wells must be at least 50 feet from any potential or existing contamination sources such as septic tanks, tile fields, and manure pits.

Operating Requirements

A heat pump recharge well is required to re-inject water into its source aquifer; injectate must not include any additives; and wells must be properly capped.

Florida

Florida is a UIC Primacy State for Class V wells. Chapter 62-528 of the Florida Administrative Code (FAC), effective June 24, 1997, establishes the UIC program, and Part V (62-528.600 to 62-528.900) addresses criteria and standards for Class V wells. Florida groups Class V wells into eight categories, with wells associated with thermal energy exchange processes, including air conditioning return flow wells, placed in Group 1. Such wells may be part of an open-loop or closed-loop system, with or without additives (62-528.600(2)(a) FAC). Florida's rules provide different requirements for open- and closed-loop systems and for systems with and without additives.

Permitting

Underground injection through a Class V well is prohibited except as authorized by permit by the Department of Environmental Protection (DEP). Owners and operators are required to obtain a Construction/Clearance Permit before receiving permission to construct. The applicant is required to submit detailed information, including well location and depth, description of the injection system and of the proposed injectate, and any proposed pretreatment. When site-specific conditions indicate a threat to a USDW, additional information must be submitted. Finally, all Class V wells are required to obtain a plugging and abandonment permit.

Closed-loop ground water heat pumps are authorized through a general permit (62-528.705 FAC). However, operators of air conditioning return flow wells serving single family units are not required to obtain a Class V permit or general permit prior to construction. Only inventory information must be submitted for such wells (62-528.630 FAC). All other ground water heat pumps are considered open-loop and require an individual permit. Ground-coupled (i.e., closed-loop) heat pumps are not regulated under the UIC program because there is no discharge of fluids. Such wells must satisfy the conditions in Rule 62-528.630 (3) through (6), which provide that the well may not cause or allow movement of fluid containing any contaminant into a USDW, and that the DEP may take actions to address violations of primary drinking water standards or other threats to health from the well.

Siting and Construction

Specific construction standards for Class V wells have not been enacted by Florida, because of the variety of Class V wells and their uses. Instead, the state requires the well to be designed and constructed for its intended use, in accordance with good engineering practices, and approves the design and construction through a permit. The state can apply any of the criteria for Class I wells to the permitting of Class V wells, if it determine that without such criteria the Class V well may cause or allow fluids to migrate into a USDW and cause a violation of the state's primary or secondary drinking water standards, which are contained in Chapter 62-550 of the FAC. However, if the injectate meets the primary and secondary drinking water quality standards and the minimum criteria contained in Rule 62-520-400 of the FAC, Class I injection well permitting standards will not be required.

Class V wells are required to be constructed so that their intended use does not violate the water quality standards in Chapter 62-520 FAC at the point of discharge, provided that the drinking water standards of 40 CFR Part 142 (1994) are met at the point of discharge. These standard Class V siting and construction requirements apply to HAC return flow wells. Construction of such wells must be certified upon completion. Siting is established on a case-by-case basis.

Operating Requirements

All Class V wells are required to be used or operated in such a manner that they do not present a hazard to a USDW. Pretreatment of injectate must be performed, if necessary to ensure the fluid does not violate the applicable water quality standards in 62-520 FAC (62-528.610 FAC).

Monitoring Requirements

Injectate monitoring generally will be required for open-loop systems or those using additives (62-528.615(1)(a)1 FAC). Monitoring is not required for air conditioning return flow wells receiving a general permit under Rules 62-528.705 or -528.710 FAC. The Department determines the frequency of monitoring based on the location of the well, the nature of the injected fluid, and, where applicable, the requirements of Chapters 62-600 and 62-601, FAC. The monitoring parameters and frequency shall be addressed in the permit or authorization to use a Class V well (62-528.615 FAC).

Plugging and Abandonment

The Department will order a Class V well plugged and abandoned when it no longer performs its intended purpose, or when it is determined that the presence of the well may cause or allow a violation of a primary or secondary drinking water standard, or may otherwise adversely affect the health of persons. A plugging and abandonment plan shall be submitted to the Department with the construction permit application. Prior to abandonment, the well shall be plugged with cement in a manner that will not allow movement of fluids between USDWs. The proposed method of plugging and type of cement shall be approved by the Department as a condition of the permit (62-528.625 FAC). Plugging must be performed by a licensed water well contractor.

Illinois

Illinois is a UIC Primacy State for Class V wells. The Illinois Environmental Protection Agency (IEPA), Bureau of Land has promulgated rules establishing a Class V UIC program (35 Illinois Administrative Code (IAC) 704) that are intended to be identical in substance to USEPA rules in 40 CFR 144. The state regulations address permitting, construction requirements, operating requirements, monitoring and reporting, plugging and abandonment, financial responsibility, and mechanical integrity that closely parallel the federal requirements.

Permitting

Any underground injection, except into a well authorized by permit or rule, is prohibited. The construction of any well required to have a permit is prohibited until the permit has been issued (704.121 IAC). Class V wells will be inventoried and assessed and regulatory action will be established at a later date (704.102 IAC). Injection into Class V wells is authorized by rule until requirements under future regulations become applicable (704.146 IAC).

Operating Requirements

Owners or operators of wells authorized by rule must submit inventory information to IEPA (704.148 IAC). In addition, IEPA may require submission of other information deemed necessary (704.149 IAC).

Kansas

Kansas is a UIC Primacy State for Class V wells. The state has incorporated by reference the federal UIC regulations (40 CFR 124, 40 CFR 144, 40 CFR 145) in Kansas Administrative Regulations (KAR) 28-46. In addition, the Kansas Department of Health and Environment (KDHE) has a ground water non-endangerment regulation (KAR 28-46-27), which it uses to prevent construction of industrial wells.

Permitting

Class V wells are authorized by rule, with the exception of aquifer remediation wells, which are permitted. Class V injection wells are authorized to operate until regulations concerning that class of injection wells are adopted, provided the requirements of 40 CFR 144.12 are satisfied (KAR 28-46-26). When conditions require that a permit be issued for a Class V well, the permit shall be effective for a term of no more than 10 years (KAR 28-46-10(a)). KDHE does not consider closed-loop systems to be Class V wells.

Siting and Construction

Wells that inject into USDWs must meet the construction and siting requirements specified in the state's water well construction requirements at KAR 28-30-6, which address casing, grouting, and set-backs from known sources of contamination, buildings, and property lines. In particular, the casing-borehole annulus must be grouted from the surface to a minimum of 20 feet or five feet into the first clay or shale layer, if one is present, whichever is greater; wells must be cased from the surface to the top of the producing zone of the aquifer; and wells must be located at least 50 feet from a pollution source (e.g., septic tanks; sewer lines; seepage pits; fuel, fertilizer or pesticide storage areas; feed lots; or barn yards).

Operating Requirements

The state has incorporated the federal UIC regulations by reference. General operating, monitoring, and reporting requirements for injection wells are found at KAR 28-46-30, although these requirements explicitly do not apply to Class V wells. Inventory and assessment requirements for Class V wells are addressed at KAR 28-46-38.

Plugging and Abandonment

The state has incorporated the federal UIC regulations by reference (see KAR 28-46-34). In addition, KAR 28-30-7 sets forth specific requirements for plugging of abandoned wells, as well as cased and uncased test holes, although these requirements do not apply explicitly or exclusively to Class V wells. Heat pump holes drilled for closed-loop heat pump systems are required to be plugged by filling the entire hole with an approved grouting material from the bottom of the hole to the bottom of the horizontal trench, using a grout tremie pipe or similar method approved by the department (KAR 28-30-7(d)(3)).

Maryland

Maryland is a UIC Primacy State for Class V wells. Maryland has incorporated the federal UIC regulations (42 CFR 124, 40 CFR 144, 40 CFR 145) by reference.

Permitting

Permits are not required under the state UIC regulations for Class V wells (COMAR 26.08.07.01.B). However, a well construction permit is required for any well that injects water into a formation from which ground water may be produced. Such wells must meet construction requirements for casing, screens, and grouting. Construction permits are generally issued by local health departments in conjunction with the Maryland Department of Environment (MDE). HAC return flow wells are covered by the construction requirements.

Owners and operators of closed-loop systems are not required to obtain water appropriations permits.

Siting and Construction

Heat pump wells must meet the state's water well construction requirements. Wells must be sited in appropriate hydrogeologic settings, cased and grouted, and properly maintained. The casing must meet nationally recognized standards; the required minimum length depends upon the hydrogeologic setting. Grouting requirements depend upon the hydrogeologic setting and the flow rate (COMAR 26.04.04).

Operating Requirements

Residential permit holders must return water to the same aquifer from which it is withdrawn. Commercial permit holders may re-inject or discharge to a surface water body. MDE generally does not inspect HAC return flow wells unless there is a complaint.

Michigan

USEPA Region 5 directly implements the UIC program for Class V injection wells in Michigan. Class V owners and operators contact the USEPA Region 5 UIC program directly to report inventory or are referred to the USEPA Regional UIC program by state, city, or county staff or consultants. The USEPA Region retains all records regarding well location, injectate information, and regulatory requirements. Michigan does not plan to seek primacy in the near future.

Michigan's Natural Resources and Environmental Protection Act (NREPA) (1994 P.A. 451, Part 31) defines "waters of the state" to include ground waters (§3101) and provides that a person may not discharge directly or indirectly into the waters of the state a substance that is or may become injurious to the public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational or other uses that are being made or may be made of such waters (§3109(1)(a) and (b)). Discharge of waste is prohibited without a permit from the Department of Environmental Quality (DEQ) (§3112(1)).

The Department of Natural Resources, Water Resources Commission has promulgated rules under the authority of Part 31 NREPA that provide for the non-degradation of ground water quality in usable aquifers, define the requirements for hydrogeological study before permitting a discharge into ground waters, and establish ground water monitoring requirements for ground water discharges (Part 22 Rules 323.2201 - 323.2211). The Water Resources Commission also has promulgated requirements for wastewater discharge permits (Part 21 Rules 323.2101- 323.2192). According to these rules, a "point source discharge" includes a well from which wastewater is discharged (R 323.2104(vi)). Waste and wastewater are defined broadly under the rules to include liquid waste discharges from industrial and commercial processes (R 323.2104(q) and (r)). An open-loop HAC well with additives may be required to satisfy the state's ground water protection requirements.

Minnesota

USEPA Region 5 directly implements the UIC program for Class V injection wells in Minnesota. However, the state has promulgated regulations for HAC return flow wells implemented by the Minnesota Pollution Control Agency.

The state adheres to a non-degradation policy for ground water. The Minnesota Department of Health (MDH) has adopted stringent construction requirements for all wells in the state, including a very broad definition of "well." Under that definition, a well is a drilled, dug, or bored excavation that ends below the water table. Both MDH and MPCA have banned injection directly into the saturated zone (Minnesota Rules, 7060.0600).

Permitting

Prior to 1981, heat pump return flow wells were prohibited in Minnesota except through a variance from Part 4725.2050. In 1981, the Minnesota Legislature authorized MDH to issue a maximum of 210 permits for ground water thermal exchange device (i.e., heat pump) return flow wells. Minnesota Statutes, Chapter 103I, Section 621, and Minnesota Rules, Part 4725.1831 authorize the issuance of permits for the re-injection of water by a properly constructed well into the same aquifer from which the water was drawn for the operation of a ground water thermal exchange device. Other more general water use permit requirements and penalties also apply to permit recipients. To date, only seven of the possible 210 permits have been issued.

Minnesota Rules, Part 4725.1833 addresses permit requirements for vertical heat exchanger construction.

Siting and Construction

Chapter 103I of the Minnesota Statutes contains a number of requirements regarding well construction. A person may not drill construct, repair, or seal a well unless the person has a well contractor's license (also addressed in Minnesota Rules 4725.0475). Other requirements set forth in Chapter 103I and Part 4725 of the regulations address set-backs from sources of contamination, well sealing, casing, permit fees, and acceptable construction materials (e.g., screens, fluids, and grouts). Section 103I.641 of the statute and Part 4725.7050 of the Minnesota Rules set forth specific construction and siting requirements for vertical heat exchangers.

Withdrawal and re-injection for a ground water thermal exchange device must be accomplished by a closed system in which the waters drawn for thermal exchange do not have contact or commingle with water from other sources or with polluting material or substances (Chapter 103I.621).

In addition, the Minnesota Water Well Construction Code (Minnesota Rules, Chapter 4725) sets out construction, siting, maintenance, and abandonment requirements for wells. For example, it prohibits wells completed in more than one aquifer, requires grouting in the casing-borehole annulus, and requires that steel casing meet ASTM or API specifications. It also contains setback requirements from surface water bodies and contamination sources. HAC return flow wells must meet these requirements. Newly permitted wells are inspected to ensure compliance with construction standards.

Minnesota has a separate construction permit program for vertical closed-loop systems.

Operating Requirements

Part 4725.2050 of the Water Well Construction Code prohibits the use of a well or a boring for disposal of surface water, ground water, or any other liquid, gas, or chemical. However, heat pump return flow wells are specifically exempted from this prohibition. Also, given the definition of the term “well,” this prohibition does not apply to injection into the unsaturated zone (such as with infiltration galleries, dry wells, or grainfields) or to injection into naturally occurring depressions (such as sinkholes).

Additives are prohibited in HAC return flow well injectate.

Missouri

Missouri is a UIC Primacy State for Class V wells. The Missouri Department of Natural Resources (DNR) regulates Class V wells by permit. Construction permit applications must be submitted to DNR at least 180 days prior to well construction. Operating permit applications must be submitted to DNR 30 days before the well receives wastewater.

Permitting

Operators of heat pump wells serving single family residences, or serving up to an eight-family residence with a combined injection/withdrawal rate of less than 600,000 BTU/hr, are not required to obtain operating permits (10 CSR 20-6.070(1)(A)). The Clean Water Commission requires an operating permit for systems greater than 600,000 BTU/hr. An operating permit is valid for a period of up to five years (10 CSR 20-6.070).

Siting and Construction

Vertical heat pumps must be located at least 300 feet from storage areas for chemicals and pesticides, landfills, lagoons, or above ground storage tanks. They must also be at least 100 feet from manure storage areas, cesspools, unplugged abandoned wells, and subsurface disposal fields. They must be at least 50 feet from existing operating wells, septic tanks, buried sewers, pits, or sumps. Variances from siting requirements may be obtained with Department permission (10 CSR 23-5.040).

Open-loop systems must meet construction standards in 10 CSR 23-3, Chapters 1, 2, and 3 concerning casing, casing depth, well seal, borehole, grouting, and reporting (10 CSR 23-5.060). Steel well casing may be used. The annular space must be sealed so that it does not leak. Casing materials used will vary based on the stress the pipe is subjected to during construction and the corrosiveness of the ground water. 10 CSR 23-3.030 also sets forth recommended amounts of grout depending on borehole diameter and the type of grout used.

The depth of the injection well may not exceed the depth of the supply well. Water must be returned to the aquifer from which it was taken. A water well installation permit is required to drill and construct an open-loop system (10 CSR 23-5.060).

Return wells for open-loop systems used for non-domestic purposes will be approved on a case-by-case basis. System approval takes into account water quality and quantity, geology, hydrology, and water usage in the area (10 CSR 23-5.060). Regulations also require the installation of monitoring wells to ensure compliance with water quality regulations. Submission of reports is required on a set schedule (10 CSR 20-6.070(4)).

Construction requirements differ for closed- and open-loop systems. Open-loop systems must be constructed in accordance with 10 CSR 23 Chapters 1, 2, and 3. Closed-loop systems must be constructed in accordance with standards set in 10 CSR 23-5.050.

Operating Requirements

Only large systems (greater than 600,000 BTU/hr) that require permits have operating requirements. Such operating requirements are specified in the permit.

Monitoring Requirements

If a permit is required, an annual report must be submitted. The annual report must include the volume of water injected and withdrawn, temperature records for every monitoring well, and copies of any water quality analyses performed (10 CSR 20-6.070(10)).

The maximum, minimum, and average water temperature, and the maximum, minimum, and average injection and withdrawal rates must be measured and recorded monthly. Total dissolved solids must also be measured and recorded monthly (10 CSR 20-6.070(8)-(9)).

Plugging and Abandonment

Open-loop heat pump wells must be plugged as set forth in 10 CSR 23-3.110, and a registration report form submitted as if it were a water supply well.

When the Division determines that a heat pump well is improperly constructed, it must be brought into compliance with the rules or plugged. To plug an improperly constructed heat pump well, the following specifications must be met:

- Remove all pipes from hole;
- Clean out well bore of loose material;
- Plug well full-length with approved grout; and
- Submit registration report form and fee (10 CSR 23-5.080).

Nebraska

Nebraska is a UIC Primacy State for Class V wells and has promulgated regulations for all Class V wells. The construction and operation of Class V wells, except for large capacity septic systems, is currently authorized by rule by the Nebraska Department of Environmental Quality (DEQ) under the Nebraska Administrative Code (NAC Title 122)

Permitting

While Class V wells are currently authorized by rule in accordance with 122 NAC 5, if DEQ learns at any time that a Class V well may cause a violation of primary drinking water regulations or the Nebraska Ground Water Protection Standards or may otherwise be adversely affecting the health of persons, DEQ will require the owner or operator to obtain an individual or area UIC permit (NAC Title 122, Chapter 4). Permit applications may require a $5,000 fee (NAC Title 122, Chapter 38). Once granted, the permit is effective for a fixed term not to exceed ten years (NAC Title 122, Chapter 23). DEQ may also order the owner or operator to take such actions (including, where required, closure of the injection well) as may be necessary to prevent the violation, or take enforcement action against the owner or operator (NAC Title 122, Chapter 4).

The Director may require any Class V injection well authorized by rule to apply for and obtain an individual or area UIC permit for one of the following reasons: The injection well is not in compliance with one or more requirements; the well is not or no longer is within the category of wells and types of well operations authorized by Title 122, Chapter 7; the protection of USDWs required that the injection operation be regulated by requirements, such as for corrective action, monitoring and reporting, or operation, or the well may cause a violation of primary drinking water standards or the Nebraska Ground Water Protection Standards (NAC Title 122, Chapter 7).

Siting and Construction

All Class V well operators must submit an Application for Injection to DEQ. Open-loop systems must be constructed in accordance with the construction standards for Domestic Water Wells, described in NAC Title 178, Chapter 12.

Water wells must be constructed to prevent the introduction of microbiological, chemical, or radiological substances into the aquifers penetrated by the wells. Water wells must have a well casing, an annular space filled with grout, a well screen, and a gravel pack (NAC Title 178, Chapter 12). A water well, by definition, is any excavation that is drilled, cored, bored, washed, driven, dug, jetted, or otherwise constructed for the purpose of exploring for ground water, monitoring ground water, utilizing the geothermal properties of the ground, or extracting water from or injecting water into the aquifer.

Water wells constructed as a source of water for a ground water heat pump system shall be constructed in accordance with NAC Title 178, Chapter 12, Section 004, Domestic Water Wells.

Operating Requirements

The person authorized by rule shall retain all records concerning the nature and composition of injected fluids until five years after completion of any required plugging and abandonment procedures. The person authorized by rule also shall report any noncompliance which may endanger health or cause pollution of the environment, orally within 24 hours of becoming aware of the circumstances, and in writing within five days (NAC Title 122, Chapter 7).

At least 90 days advance notice is required before conversion or abandonment of a Class V well (NAC Title 122, Chapter 7).

Mechanical Integrity Testing

The owner or operator of a Class V well must be able to demonstrate its mechanical integrity as defined in Chapter 16 of Title 122 (NAC Title 122, Chapter 7). In conducting and evaluating the tests of mechanical integrity, the owner or operator and Director shall apply methods and standards generally accepted in the industry. When the owner or operator reports the results of the mechanical integrity tests to the Director, he shall include a description of the test(s) and method(s) used (NAC Title 122, Chapter 16).

Plugging and Abandonment

Class V wells must be plugged and abandoned in accordance with the Regulations Governing Water Well Construction, Pump Installation, and Water Well Decommissioning Standards promulgated by the Nebraska Department of Health and Human Services, Regulation, and Licensure at NAC Title 178, Chapter 12 (NAC Title 122, Chapter 36).

Financial Responsibility

Permittees shall maintain financial responsibility (as prescribed by NAC Title 122, Chapter 37) to close, plug, and abandon the wells and to restore the affected resources in a manner that has been approved by the Director. The permittee must show evidence of financial responsibility to the Director by the submission of a surety bond or other adequate assurance acceptable to the Director in an amount set by the Director (NAC Title 122, Chapter 9).

Nevada

Nevada is a UIC Primacy State for Class V wells and its Division of Environmental Protection (DEP) administers the UIC program. Nevada Revised Statutes (NRS) §§ 445A.300 - 445A.730 and regulations under the Nevada Administrative Code (NAC) §§ 445A.810 - 445A.925 establish the state's basic UIC program. The injection of fluids through a well into any waters of the state, including underground waters, is prohibited without a permit issued by DEP (445A.465 NRS), although the statute allows both general and individual permits (445A.475 NRS and 445A.480 NRS). Furthermore, injection of a fluid that degrades the physical, chemical, or biological quality of the aquifer into which it is injected is prohibited, unless the DEP exempts the aquifer and USEPA does not disapprove the exemption within 45 days (445A.850 NRS).

Permitting

General permits are issued, among others, for a closed-loop well used to inject fluids for heating or cooling by a heat pump (445A.869 NAC). Operators of open-loop systems are required to obtain individual permits. The UIC regulations specify detailed information that must be provided in support of permit applications, including proposed well location, description of geology, construction plans, proposed operating data on rates and pressures of injection, analysis of injectate, analysis of fluid in the receiving formation, proposed injection procedures, and corrective action plan (445A.867 NAC). The DEP may, however, modify the permit application information required for a Class V well for good cause and upon determination that additional or less information will ensure that the proposed injection well will not degrade a USDW (445A.891 NAC).

Siting and Construction

The state specifies, among other siting requirements, that the well must be sited in such a way that it injects into a formation that is separated from any USDW by a confining zone that is free of known open faults or fractures within the area of review. It must be cased from the finished surface to the top of the zone for injection and cemented to prevent movement of fluids into or between USDWs (445A.908 NAC).

Operating Requirements

Under an individual permit, monitoring frequency for injection pressure, pressure of the annular space, rate of flow, and volume of injected fluid are specified by the permit (445A.913

NAC). Analysis of injected fluid must be conducted with sufficient frequency to yield representative data.

Mechanical Integrity Testing

If required by the state, mechanical integrity testing must be conducted at least once every five years for the life of the well, or more frequently if conditions of operation warrant, by a specified method (445A.916 NAC). Methods of testing are listed in 445A.917 - 445A.919 NAC.

Plugging and Abandonment

For an individually permitted well, a plugging and abandonment plan and cost estimate must be prepared, included with the permit application, and reviewed annually. Before abandonment, a well must be plugged with cement in a manner that will not allow the movement of fluids into or between USDWs (445A.923 NAC). If the Director determines that a well is abandoned, he may order it to be plugged (445A.924 NAC).

New York

USEPA Region 2 directly implements the UIC program for Class V injection wells in New York. However, under the State of New York's Environmental Conservation Law, the Department of Environmental Conservation, Division of Water Resources (DWR) has promulgated regulations in the State Code Rules and Regulations, Title 6, Chapter X, Parts 703, 750, 754, and 756. These regulations establish water quality standards and effluent limitations, create a state pollutant discharge elimination system requiring permits for discharges into the waters of the state, specify that such discharges must comply with the standards in Part 703, and provide for monitoring in Part 756.

Permitting

Applications for a State of New York Pollution Discharge Elimination System (SPDES) permit must be submitted on a required form, describe the proposed discharge, and supply such other information as the DWR requests. These applications are subject to public notice. SPDES permits must ensure compliance with effluent limitations and standards, and will include schedules of compliance, monitoring requirements, and records and reports of activities (Parts 751 - 756).

With regard to HAC return flow wells, only open-loop systems require a permit. Closed-loop systems do not require a permit if no chemicals are added to the water and the heat added is not significant enough to be considered a pollutant and if the discharge is from a single household and is less than 1,000 gallons per day.

Operating Requirements

Effluent limits (Part 703) and monitoring and reporting requirements in the SPDES permit must be met. For HAC return flow wells, injectate may not exceed MCLs, and no additives are allowed. Siting and construction requirements also may apply to HAC return flow wells.

North Carolina

North Carolina is a UIC Primacy State for Class V wells. The state’s requirements for HAC return flow wells are found primarily at North Carolina Administrative Code, Title 15A, Department of Environment, Health, and Natural Resources, Division of Water Quality, Subchapter 2C, Section .0200, Well Construction Standards, Criteria and Standards Applicable to Injection Wells.

Permitting

Closed-loop heat pump systems that re-circulate potable water are authorized by rule (.0211(u)(2) NCAC). Operators of closed-loop heat pump systems that use additives in their cooling fluids and operators of open-loop systems are required to obtain an individual permit for construction and operation. Such wells may only be approved by the Director if the temperature of the injection fluid is not in excess of 30 degrees Fahrenheit above or below the naturally occurring temperature of the receiving ground water (.0209(e)(3)(A) NCAC).

State staff will not issue a permit for the injection of wastes or any substance of a composition and concentration such that, if it were discharged to the land or waters of the state, it would create a threat to human health or would otherwise render those waters unsuitable for their intended best usage unless specifically provided for by statute or rules (.0211(a) NCAC).

In addition to identification information, a permit application must include the following (.0211(a) - (c), and (d)(1) NCAC):

- Description of the proposed injection activities;
- Detailed map showing wells, boundaries, buildings, existing or abandoned wells; existing sources of known or potential ground water contamination, and surface water bodies within the area of review;
- Chemical, physical, biological, and radiological characteristics of the proposed injectate;
- Proposed average and maximum daily rate and quantity of fluid to be injected;
- Detailed plans of the construction of the system;
- Listing of all permits and approvals; and
- Other information as required by the Department.

Permits are issued for a period not to exceed five years from the date of issuance. The permit may be modified, revoked and reissued, or terminated by the Director in whole or in part for actions which adversely impact human health or the environment (.0211(j)(l) NCAC).

Siting and Construction

Class V wells may not be located in an area generally subject to flooding. The minimum horizontal separation for HAC return flow wells between the well and potential sources of ground water contamination are specified by rule (.0213 (a)(4) NCAC). The methods and materials used in construction shall not threaten the physical and mechanical integrity of the well during its lifetime (i.e., it shall be designed and constructed to operate for the projected life of the well) and shall be compatible with the proposed injection activities (.0213 (c)(1)(C) NCAC).

Operating Requirements

An individually permitted well must be inspected by the Department following construction before injection can commence. The Department must approve the proposed operating procedures, and there must be a satisfactory demonstration of mechanical integrity. The Department may establish maximum injection volumes and pressures (.0211(h) NCAC). The permittee must at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with permit conditions (.0211(k) NCAC).

Injection wells and effluent return water must comply with the state's drinking water standards so as not to contaminate or degrade the aquifer of injection. Monitoring requirements may be specified by the Department as necessary -- generally on a site-specific basis -- to demonstrate adequate protection of USDWs (.0213(f) NCAC). Generally, influent and effluent water samples are taken to insure no contamination is occurring to the injected aquifer.

Mechanical Integrity

Mechanical integrity testing is required, using specified procedures (.0207 NCAC).

Plugging and Abandonment

Procedures for temporary and permanent abandonment are specified. When a drilled well is permanently abandoned, it is required to be completely filled with cement grout (.0214 NCAC).

Financial Responsibility

Individual permittees must maintain financial responsibility in the form of performance bonds or other equivalent forms of financial assurance, to close, plug, and abandon the injection operation (.0208 NCAC).

North Dakota

North Dakota is a UIC Primacy State for Class V wells. The state has promulgated specific UIC regulations, found at Chapter 33-25-01 of the North Dakota Administrative Code (NDAC).

Permitting

Most Class V wells are authorized by rule, although the Department of Health may require owners and operators to obtain a permit in some circumstances. The Director of the Division of Water Supplies and Pollution Control at the North Dakota Department of Health may require Class V well operators to obtain a permit if the injection well is not in compliance with appropriate rules, the injection well is no longer within the category of wells authorized by rule, or if protection of a USDW requires that the injection operation be regulated. In addition, owner/operators may request a permit, rather than rule authorization.

Class V permits -- when issued -- are effective for a term not to exceed ten years. Permit applications must include the location of the proposed facility, with references to the nearest lines of governmental section (NDAC 33-25-01-06(3); NDAC 43-02-07-06).

Siting and Construction

All wells must be constructed by a certified water or monitoring well contractor. All facilities, all fluids, and all additives must be approved by the State Geologist prior to installation (North Dakota Century Code 33-18; NDAC 43-02-07-10).

Operating Requirements

North Dakota's UIC regulations specify that the owner or operator of a proposed Class V injection well must demonstrate that the construction, operation, maintenance, plugging, and abandonment of the proposed well will not allow movement of fluid to a USDW which could cause an adverse health effect or a violation of MCLs (NDAC 33-25-01-04).

All rule authorized well operators must submit inventory information to the Director. Inventory information shall include the name of the owner/operator; number of wells and location by township, section, range; nature and volume of injected fluids; construction features including well depth, screened interval, and casing size and type; and other requested information (NDCC 33-25-01-16).

Plugging and Abandonment

None specified by statute or regulations (NDAC plugging and abandonment regulations refer only to closed-loop systems).

Financial Responsibility

Permittees must maintain financial responsibility and resources to properly close, plug, and abandon the UIC operation. Evidence of financial responsibility must be submitted to the Director in the form of a surety bond or other adequate assurances, such as financial statements (NDAC 43-02-07-09; NDAC 33-25-01-10(4)).

Ohio

Ohio is a UIC Primacy State for Class V wells. The State of Ohio UIC program requirements are found primarily in the Ohio Administrative Code (OAC), Chapter 3745-34, Rules 3745-34-01 through 3745-34-62.

Permitting

All Class V wells are authorized by rule, unless they inject sewage, industrial wastes, or other wastes into or above a USDW. In such cases, individual drilling and operating permits are required (OAC 3745-34-14(A)), although in practice very few wells are permitted. In addition, owners and operators of Class V wells are required to submit inventory information to Ohio EPA, including the name and location of the facility, legal contact, ownership of the facility, and the nature, type, and status of the injection well (OAC 3745-34-13(B)). No HAC return flow wells are currently permitted by the Ohio UIC program.

If at any time the Director learns that a Class V well may cause a violation of any drinking water standard or otherwise adversely affect the health of persons, the injector will be required to obtain an individual permit; take whatever action (up to and including closure of the well) that may be necessary to prevent the violation; or be subject to enforcement action (OAC 3745-34-07).

Siting and Construction

OAC 3745-34 sets forth construction, siting, and operating requirements for permitted Class V wells, although the requirements often do not apply since most types of Class V wells are not permitted. There are no construction or siting requirements specific to HAC return flow wells.

Oregon

Oregon is a UIC Primacy State for Class V wells. The UIC program is administered by the Department of Environmental Quality (DEQ). Under the State of Oregon's Administrative Rules (OAR) pertaining to underground injection, a "waste disposal well" is defined as any bored, drilled, driven or dug hole, whose depth is greater than its largest surface dimension, which is used or is intended to be used for disposal of sewage, industrial, agricultural, or other wastes and includes drain holes, drywells, cesspools and seepage pits, along with other underground injection wells (340-044-0005(22) OAR). Construction and operation of a waste disposal well without a water pollution control facility (WPCF) permit is prohibited.

OAR 632-020-0005 sets forth specific regulations addressing construction, operation, maintenance, and abandonment of wells in a manner that safeguards the life, health, property, and welfare of the people of the state. Specific topics addressed include drilling, redrilling, and deepening; alteration of casing; permits; completion and abandonment; plugging methods and procedures; well spacing; disposal of wastes; and construction of injection wells.

Certain categories of wells are prohibited entirely, including wells used for underground injection activities that allow the movement of fluids into a USDW if such fluids may cause a violation of any primary drinking water regulation or otherwise create a public health hazard or have the potential to cause significant degradation of public waters. The Department of Water Resources issues permits for HAC return flow wells.

Permitting

Any underground injection activity that may cause, or tend to cause, pollution of ground water must be approved by the DEQ, in addition to any other permits or approvals required by other federal, state, or local agencies (340-044-0055 OAR). Permits are not to be issued for construction, maintenance, or use of waste disposal wells where any other treatment or disposal method which affords better protection of public health or water resources is reasonably available or possible (340-044-0030 OAR). A waste disposal well, unless absolutely prohibited, must have a WPCF permit (340-044-0035 OAR, 340-045-0015 OAR).

Wells that re-inject air conditioning or heat pump transfer water to the same aquifer or one of equivalent quality may be exempted from the permit requirement on a case-by-case basis.

Siting and Construction

Permits for construction or use of waste disposal wells include minimum conditions relating to their location, construction, and use (340-044-0035 OAR). In general, injection wells must be constructed in conformance with OAR 690-200-0005 to 690-225-0110 (Well Construction and Maintenance, Well Driller Licensing, Well Construction Standards, Abandonment of Wells). Wells must be constructed in a manner that protects ground water from contamination, waste, loss of artesian pressure, and substantial thermal alteration (OAR 690-230-0030). Special standards (OAR 690-230-005 to 690-230-0140) are applied by rule on an ad hoc basis. Permit conditions are on an ad hoc basis.

Operating Requirements

Procedures required to inject effluent into an injection well must not cause failure of the well casing and/or seal materials or other components of well structure, including movement, displacement, or fracturing of overburden (OAR 690-230-0100). An injection plan must be filed with the Director. In addition, adequate wellhead protection equipment to ensure public safety and the protection of ground water resources must be installed on any well when the temperature of the fluid being withdrawn from the well bore exceeds 150 degrees F (OAR 690-230-0070).

Plugging and Abandonment

Upon discontinuance of use or abandonment a waste disposal well is required to be rendered completely inoperable by plugging and sealing the hole. All portions of the well which are surrounded by “solid wall” formation must be plugged and filled with cement grout or concrete. The top portion of the well must be effectively sealed with cement grout or concrete to a depth of at least 18 feet below the surface of the ground, or if this method of sealing is not effective, in a manner approved by the DEQ.

Pennsylvania

USEPA Region 3 directly implements the UIC program for Class V injection wells in Pennsylvania. The Bureau of Water Quality Management in the Pennsylvania Department of Environmental Protection has developed policies on wastewater discharges to ground water. No state policies are available on HAC wells.

South Carolina

South Carolina is a UIC Primacy State for Class V wells. The Department of Health and Environmental Control (DHEC) oversees the Class V UIC program. Rules addressing the UIC program are found at Chapter 61, section R61-87.1 *et seq*. of the South Carolina Department of Health and Environmental Control (DHEC) regulations.

South Carolina's regulations divide Class V wells into two groups: (A) and (B). Class V(A) wells include storm water drainage, recharge, and industrial wells; DHEC issues individual permits for these well types. Class V(B) wells include all injection wells used to return to the supply aquifer the water which has passed through a non-contact system, including HAC return flow wells. These well types are authorized by rule. Closed-loop systems are not regulated by the UIC program.

Permitting

The injection of any fluids to the subsurface or ground waters of the state by means of an injection well is prohibited except as authorized by a Department permit or rule (R61-87.4). DHES issues individual permits for Class V(A) wells (R61-87.13.A). Permits are issued for a period not to exceed ten years from the date of issuance for a Class V(A) well (R61-87.13.W). The permit may be modified, revoked and reissued, or terminated for cause (R61-87.13.Y).

Class V(B) wells are authorized by rule and do not require a permit. However, no person may construct, use or operate a well of this class for injection in violation of R61-87.5 (R61-87.11.F).

Siting and Construction

Minimum standards for construction and abandonment of injection wells are those stated for all wells in the South Carolina Well Standards and Regulations (R.61-71). Injection may not commence until construction is complete, the permittee has submitted notice of completion of construction to the Department, and the Department has inspected or otherwise reviewed the injection well and finds it in compliance with these regulations (R61-87.13.U).

Operating Requirements

Operating requirements are not specified for wells permitted by rule. For individually permitted wells, the Department may establish maximum injection volumes and pressures and such other permit conditions as necessary to assure that fractures are not initiated in the confining zone adjacent to a USDW; that injected fluids do not migrate into USDWs; that formation fluids are not displaced into any USDW; and to assure compliance with operating requirements (R61-87.13.V).

Monitoring Requirements

Monitoring requirements are not specified for wells permitted by rule. For individually permitted wells an appropriate number of monitoring wells shall be installed in the injection zone and any USDWs that could be affected by the injection operation (R61-87.14.G). Permittees are required to retain copies of records of all monitoring information, including all calibration and maintenance records, all original strip chart recordings for continuous monitoring instrumentation, and copies of all reports required by the permit, for a period of at least three years from the date of the sample, measurement, report, or application (R61-87.13.CC). The permittee shall report any monitoring or other information which indicates that any contaminant may endanger a USDW and any noncompliance with a permit condition or malfunction of the injection system which may cause fluid migration into or between USDWs (R61-87.13.EE).

Mechanical Integrity Testing

Mechanical integrity testing is not specified for wells permitted by rule. For individually permitted wells, prior to granting approval for the operation of any injection well the Department will require a satisfactory demonstration of mechanical integrity (R61-87.13.U). Permittees must demonstrate mechanical integrity at least once every five years during the life of the well (R61-87.14.G.3.c).

Plugging and Abandonment

Plugging and abandonment requirements are not specified for wells permitted by rule. For individually permitted wells, prior to plugging or abandonment the permittee must provide 180 days advance notice, and submit a plugging and abandonment plan to the Department that demonstrates technical adequacy. The well to be abandoned must be in a state of static equilibrium with the mud weight equalized top to bottom. Prior to final approval to abandon an injection well, the permittee shall demonstrate to the satisfaction of the Department that the well has been plugged in a manner that will not allow the movement of fluids either into or between USDWs (R61-87.15).

Tennessee

USEPA Region 4 directly implements the UIC program for Class V injection wells in Tennessee. The state generally authorizes the use of Class V wells under the authority of state statutes at Section 69-3-105 of the Tennessee Administrative Code, and state regulations at 1200-4-6

TCA. The state largely runs its UIC Class V well program with support and oversight from USEPA Region 4.

Texas

Texas is a UIC Primacy State for Class V wells. The Injection Well Act (Chapter 27 of the Texas Water Code) and Title 3 of the Natural Resources Code provide statutory authority for the UIC program. Regulations establishing the UIC program are found in Title 30, Chapter 331 of the Texas Administrative Code (TAC).

Permitting

Underground injection is prohibited, unless authorized by permit or rule (331.7 TAC). Injection into a Class V well is authorized by rule, although the Texas Natural Resources Control Commission (TNRCC) may require the owner or operator of a well authorized by rule to apply for and obtain an injection well permit (331.9 TAC). No permit or authorization by rule is allowed where an injection well causes or allows the movement of fluid that would result in the pollution of a USDW. A permit or authorization by rule must include terms and conditions reasonably necessary to protect fresh water from pollution (331.5 TAC).

Siting and Construction

All Class V wells are required to be completed in accordance with explicit specifications in the rules, unless otherwise authorized by the TNRCC. These specifications are listed below:

- A form provided either by the Water Well Drillers Board or the TNRCC must be completed.

- The annular space between the borehole and the casing must be filled from ground level to a depth of not less than 10 feet below the land surface or well head with cement slurry. Special requirements are imposed in areas of shallow unconfined ground water aquifers and in areas of confined ground water aquifers with artesian head.

- In all wells where plastic casing is used, a concrete slab or sealing block must be placed above the cement slurry around the well at the ground surface (the rules include additional specifications concerning the slab).

- In wells where steel casing is used, a slab or block will be required above the cement slurry, except when a pitless adaptor is used (the rules contain additional requirements concerning the adaptor).

- All wells must be completed so that aquifers or zones containing waters that differ significantly in chemical quality are not allowed to commingle through the borehole-casing annulus or the gravel pack and degrade any aquifer zone.

C The well casing must be capped or completed in a manner that will prevent pollutants from entering the well.

C When undesirable water is encountered in a Class V well, the undesirable water must be sealed off and confined to the zone(s) of origin (331.132 TAC).

Operating Requirements

None specified. Chapter 331, Subpart H, “ Standards for Class V Wells” addresses only construction and closure standards (331.131 to 331.133 TAC).

Mechanical Integrity Testing

Injection may be prohibited for Class V wells that lack mechanical integrity. The TNRCC may require a demonstration of mechanical integrity at any time if there is reason to believe mechanical integrity is lacking. The TNRCC may allow plugging of the well or require the permittee to perform additional construction, operation, monitoring, reporting, and corrective actions which are necessary to prevent the movement of fluid into or between USDWs caused by the lack of mechanical integrity. Injection may resume on written notification from the TNRCC that mechanical integrity has been demonstrated (331.4 TAC).

Plugging and Abandonment

Plugging and abandonment of a well authorized by rule is required to be accomplished in accordance with §331.46 TAC (331.9 TAC). In addition, closure standards specific to Class V wells provide that closure is to be accomplished by removing all of the removable casing and filling the entire well with cement to land surface. Alternatively, if the use of the well to be permanently discontinued, and if the well does not contain undesirable water, the well may be filled with fine sand, clay, or heavy mud followed by a cement plug extending from the land surface to a depth of not less than 10 feet. If the use of a well that contains undesirable water is to be permanently discontinued, either the zone(s) containing undesirable water or the fresh water zone(s) must be isolated with cement plugs and the remainder of the wellbore filled with sand, clay, or heavy mud to form a base for a cement plug extending from the land surface to a depth of not less than 10 feet (331.133 TAC).

Financial Responsibility

Chapter 27 of the Texas Water Code, “Injection Wells,” provides TNRCC with the authority to implement financial responsibility requirements for persons to whom an injection well permit is issued (§ 27.073). Detailed financial responsibility requirements are contained in Chapter 331, Subchapter I of the state’s UIC regulations (331.141 to 331.144 TAC). Permittees are required to secure and maintain a performance bond or other equivalent form of financial assurance or guarantee to ensure the closing, plugging, abandonment, and post-closure care of the injection operation.

However, this requirement, unless incorporated into a permit, applies specifically only to Class I and Class III wells (331.142 TAC).

Vermont

Vermont is a UIC Primacy State for Class V wells. The State of Vermont Agency of Natural Resources, Department of Environmental Conservation (DEC) implements Vermont's UIC program. Title 10, Chapter 47 of Vermont's statutes ("Water Pollution Control") establishes the state's water quality policy and requires a permit to inject any potentially hazardous discharge. Chapter 11 of Vermont's Water Pollution Control Regulations[6] incorporate many elements of 40 CFR 146, including the definition of Class V wells (see Appendix II to that Chapter).

Permitting

The state requires individual permits for all discharges. Permits require compliance with drinking water standards at a drinking water supply or property line. HAC return flow wells, however, are authorized by rule (13 UIC 25(a)(1)). In addition, if a discharge is regulated by another permit, no UIC permit is required.

If at any time the Secretary learns that a Class V well may cause a violation of any drinking water standard or otherwise adversely affect the health of persons, he or she will require the injector to obtain an individual permit; order the injector to take whatever action (up to and including closure of the well) may be necessary to prevent the violation; or take enforcement action (13 UIC 24(c) and (d)).

Permits are issued for a maximum of five years (13 UIC 25(h)).

Siting and Construction

To qualify for authorization by rule, ground water heat pump return wells must be constructed such that the water is not exposed to the atmosphere or any substance other than the interior of the well; flow is less than 25,000 gpd; water is withdrawn from and discharged to the same aquifer; the return water does not cascade down the well, but is instead injected below the water level; and return water does not cause a violation of drinking water standards (13 UIC 25(a)(1)). Return water also must be unaltered (13 UIC 25(a)(1)).

Operating Requirements

No owner or operator of an injection well may construct, operate, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid

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[6] While the numbering of the relevant portion of the state regulations apparently has been changed from Subchapter 13 to Chapter 11, we were working from a set of regulations printed before this change was instituted. Thus, citations of the state regulations given below are still shown as "13 UIC(x)."

containing any contaminant into USDWs, if the presence of that contaminant may cause a violation of any drinking water standard or may otherwise adversely affect the health of persons (13 UIC 24(a)).

All owners or operators of Class V injection wells must submit inventory information (e.g., facility name and location, name and address of legal contact, ownership of facility, nature, type, and operating status of injection wells) to the Secretary unless the discharge is already authorized by the Secretary under other authorities. Owners or operators of existing but unauthorized Class V injection wells must submit inventory information no later than 45 days after notice by the Secretary (13 UIC 25(b)).

Monitoring Requirements

State regulations stipulate that all permits shall specify requirements concerning the proper use, maintenance, and installation of monitoring equipment or methods; required monitoring, including type, intervals, and frequency sufficient to yield data that are representative of the monitored activity including, when appropriate, continuous monitoring; and applicable reporting requirements based on the impact of the regulated activity (13 UIC 16; see also Sections 146.13, 146.23, and 146.33 in Appendix II of the state UIC rule (adopted from the federal UIC regulations)).

Virginia

USEPA Region 3 directly implements the UIC program for Class V injection wells in Virginia. While there are no specific state regulations for injection wells other than septic systems, the state does regulate ground water quality through an anti-degradation policy. The state requires that ground water quality be maintained per the numerical standards set forth in 9 VAC 25-260-210.

The state’s general ground water quality policy is set forth at 9 VAC 25-260-5 *et seq*. Specifically, 9 VAC 25-260-200 states that if the concentration of any constituent in ground water is less than the limit set forth by ground water standards, the natural quality for the constituent shall be maintained; natural quality shall also be maintained for all constituents, including temperature, not set forth in ground water standards. If the concentration of any constituent in ground water exceeds the limit in the standard for that constituent, no addition of that constituent to the naturally occurring concentration shall be made. Variance to this policy shall not be made unless it has been affirmatively demonstrated that a change is justifiable to provide necessary economic or social development, that the degree of waste treatment necessary to preserve the existing quality cannot be economically or socially justified, and that the present and anticipated uses of such water will be preserved and protected.

Permitting

Ground water withdrawal permits are required where water is withdrawn from an aquifer in a ground water management zone (9 VAC 25-610-40). However, operators of heat pumps that inject water into the same aquifer from which the water was withdrawn are not required to obtain a ground water withdrawal permit (9 VAC 25-610-50).

Washington

Washington is a UIC Primacy State for Class V wells. Chapter 173-218 of the Washington Administrative Code (WAC) establishes the UIC program. Under the program, the policy of the Department of Ecology is to maintain the highest possible standards to prevent the injection of fluids that may endanger ground waters which are available for beneficial uses or which may contain fewer than 10,000 mg/l TDS. Consistent with that policy, all new Class V injection wells that inject industrial, municipal, or commercial waste fluids into or above a USDW are prohibited (172-218-090(1) WAC). Operators of existing wells must obtain a permit to operate.

Permitting

A permit must specify conditions necessary to prevent and control injection of fluids into the waters of the state, including all known, available, and reasonable methods of prevention, control, and treatment; applicable requirements in 40 CFR Parts 124, 144, 146; and any conditions necessary to preserve and protect USDWs. Any injection well that causes or allows the movement of fluid into a USDW that may result in a violation of any primary drinking water standard under 40 CFR Part 141 or that may otherwise adversely affect the beneficial use of a USDW is prohibited (173-218-100 WAC).

Siting and Construction

WAC 173-160-010(3)(e) specifically excludes injection wells regulated at chapter 173-218 WAC from the requirements of WAC 173-160-010 through -560.

Operating Requirements

The water quality standards for ground waters establish an antidegradation policy. The injectate must meet the state ground water standards at the point of compliance (173-200-030 WAC).

Plugging and Abandonment

WAC 173-160-010(3)(e) specifically excludes injection wells regulated at chapter 173-218 WAC from the requirements of WAC 173-160-010 through -560.

West Virginia

West Virginia is a UIC Primacy State for Class V wells. Regulations establishing the UIC program are found in Title 47-13 of the West Virginia Code of State Regulations. The state does not identify a separate category of Class V industrial wells, but does specify that Class V includes injection wells not included in Classes 1, 2, 3, or 4 (47-13-4.5. WVAC).

Permitting

Class V injection wells are authorized by rule, unless the Office of Water Resources within the Division of Environmental Protection requires an individual permit (47-13-12.4.a and 47-13-13.2 WVAC). Injection is authorized initially for five years under the permit by rule provisions.

Operating Requirements

Owners or operators of Class V wells are required to submit inventory information describing the well, including its construction features, the nature and volume of injected fluids, alternative means of disposal, the environmental and economic consequences of well disposal and its alternatives, operation status, and location and ownership information (47-13-12.2 WVAC).

Rule-authorized wells must meet the requirements for monitoring and recordkeeping (requiring retention of records pursuant to 47-13-13.6.b. WVAC concerning the nature and composition of injected fluids until three years after completion of plugging and abandonment); immediate reporting of information indicating that any contaminant may cause an endangerment to USDWs or any malfunction of the injection system that might cause fluid migration into or between USDWs; and prior notice of abandonment.

The rules enact a general prohibition against any underground injection activity that causes or allows the movement of fluid containing any contaminant into a USDW, if the presence of that contaminant may cause a violation of any primary drinking water regulations under 40 CFR Part 142 or promulgated under the West Virginia Code or may adversely affect the health of persons. If at any time a Class V well may cause a violation of the primary drinking water rules, the operator may be required to obtain a permit or take such other action, including closure, that will prevent the violation (47-13-13.1 WVAC). Inventory requirements for Class V wells include information regarding pollutant loads and schedules for attaining compliance with water quality standards (47-13-13.2.d.1 WVAC).

If required for protection of a USDW, the injection operation may be required to satisfy requirements (e.g., corrective action, monitoring and reporting, or operation) that are not contained in the UIC rules (47-13-13.2.c.1.C. WVAC).

Mechanical Integrity

Operators of permitted Class V well are required to demonstrate that the well has mechanical integrity (47-13-13.7.h WVAC).

Plugging and Abandonment

Class V well operators required to obtain individual permits must ensure that the plugging and abandonment of the well will not allow the movement of fluids either into a USDW or from one USDW to another. A plan for plugging and abandonment must be submitted (47-13-13.7.f WVAC).

Financial Responsibility

Class V well operators required to obtain individual permits must demonstrate financial responsibility for plugging and abandonment (47-13-13.7.g WVAC).

Wisconsin

Wisconsin is a UIC Primacy State for Class V wells. The Wisconsin Department of Natural Resources (DNR) oversees the Class V UIC program. Wisconsin Admin. Code S. NR 812.05 stipulates that the use of any well, drillhole, or water system for the underground placement of any substance is prohibited unless it is approved by DNR for purposes of remediation or to construct, rehabilitate, or operate a well.

Permitting, Siting, and Construction

Operators must notify DNR of their intent to construct a well. If DNR authorizes the well by rule, DNR issues a letter of approval, which may contain siting, design, or monitoring requirements. DNR generally requires that well casings meet ASTM standards and be grouted. In addition, a HAC return flow well must be sited at least 50 feet from the nearest water supply well. Well construction reports must be submitted to DNR for review and approval.

Operating Requirements

Use of additives in open-loop systems is prohibited. In addition, DNR may impose operating requirements in the letter of approval sent to operators prior to well construction.

DNR has the authority to conduct inspections of HAC return flow wells. In practice, inspections are conducted every one to five years for vertical wells, and on a complaint-driven basis for horizontal wells.

Monitoring Requirements

Operators must report to DNR results of monitoring requirements specified in either the letter of approval or established under a general WPDES permit.

Wyoming

Wyoming is a Primacy State for UIC Class V wells. The Wyoming Department of Environmental Quality, Water Quality Division, oversees the Class V UIC Program. Wyoming Statute 35-11-301(a)(i) & (ii) provides that no person, except when authorized by a permit, may discharge any pollution or wastes into the waters of the state or alter the physical, chemical, radiological, biological, or bacteriological properties of any waters of the state. All ground water within Wyoming, including water in the vadose zone, is considered water of the state. Because altering the physical properties of the waters of the state is considered to include altering the temperature of the water, all HAC return flow wells, regardless of whether they are open- or closed-loop systems, are required to have a permit.

Permitting

On April 14, 1998, the Water Quality Division promulgated Chapter 16, Wyoming Water Quality Rules and Regulations (WWQR&R). HAC return flow wells are designated type 5A2 systems (16 WWQR&R Appendix A). Type 5A2 systems are not required to have an individual permit (16 WWQR&R Section6(a)). Such wells are required to be covered by a general permit within six months of the date when a general permit is issued (16 WWQR&R Section 4(b) and (7)). To date, the general permit has not been issued and these systems are temporarily authorized by rule (16 WWQR&R Section 4(c) and (8)). A separate permit to construct is not required for Class V wells (16 WWQR&R Section 5(a)(v)).

Prior to the promulgation of Chapter 16, operators of HAC return flow wells were required to obtain individual permits under Chapter 9 of WWQR&R. Under that requirement a total of seven open-loop systems were permitted, with stringent monitoring requirements. Of these four have been plugged and abandoned.

Siting and Construction

The Class V UIC rules include construction requirements. All wells must meet the design standards in Chapter 11, WWQR&R, Parts B and G. They must be constructed to allow the use of testing devices and to provide for metering of the injectate volume (16 WWQR&R Section10). The requirements in 11 WWQR&R Part G include requirements for well location, sealing the annular space, surface construction, casing, sealing strata, and plugging and abandonment.

Operating Requirements

Chapter 16 WWQR&R Section 10(c) requires that all heating and cooling facilities (including type 5A2 wells) shall include: (I) Provisions for the use of non-toxic circulating medium in closed-loop systems or an operating system which cannot be made to operate with fluid leaking; (ii) Provisions for operations without the use of corrosion inhibitors, biocides, or other toxic additives in open-loop systems; (iii) Provisions to control the total dissolved solids of waters injected into open-loop systems to the class of use standard; (iv) Provisions for automatic shutdown of the system in the event of a fluid loss from a closed-loop system or any loss of product to an open-loop system; (v) Provisions to ensure that injected water does not come to the surface or flood any subsurface structure in the immediate vicinity of the injection system; and (vi) Provisions to insure that known ground water contamination is not spread by the direct injection of contaminated water or by movement of contamination from one zone to another caused indirectly by the injection.

Chapter 16 WWQR&R Section 9 (e) provides that no heating and cooling facility, including type 5A2 wells, shall be constructed so as to directly receive any waste other than cooling water. No corrosion inhibitors, scale inhibitors, antifreeze agents, salts or refrigerants shall be added to the water prior to injection.

Plugging and Abandonment

Chapter 16 WWQR&R Section 12 establishes abandonment standards for all Class V wells, including HAC return flow wells. Section 12(a) through (c) applies to air conditioner return flow wells and provides that Class V facilities may be abandoned in place if the following conditions are met and if it can be demonstrated to the satisfaction of the administrator that: (1) no hazardous waste has ever been discharged through the facility; (2) no radioactive waste has ever been discharged through the facility; (3) all piping allowing for the discharge has either been removed or the ends of the piping have been plugged in such a way that the plug is permanent and will not allow for a discharge; and (4) all accumulated sludges are removed from any septic tanks, holding tanks, lift stations, or other waste handling structures prior to abandonment. Facilities which cannot demonstrate compliance with these requirements may be abandoned in place if: (1) tests are run on sludges accumulated in the septic tanks, holding tanks, lift stations, or other waste handling structures and show that none of these materials contain characteristic hazardous waste or radioactive waste; (2) monitoring of the ground water in the immediate area of the facility shows that there are no toxic materials (substances) present in the ground water at levels higher than class of use standards and which are present as a result of the injection; or (3) some other method acceptable to the administrator. Facilities which cannot make the demonstrations required under either approach must be excavated to the point where contamination is no longer visible in the soil. At that point, samples shall be taken of the soil for all hazardous constituents which may have been discharged through the system. Materials excavated shall be removed from the site for disposal under approval of the Solid and Hazardous Waste Management Division.

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