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The Class V Underground Injection Control Study

Volume 18

Geothermal Direct Heat Return Flow Wells

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GEOTHERMAL DIRECT HEAT 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 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 18, covers Class V geothermal direct heat return flow wells.

1. SUMMARY

Geothermal fluids are used to heat individual homes and/or communities or to provide heat to greenhouses, aquaculture, and other commercial and industrial processes in several (primarily western) states. Following use of geothermal fluids for such heating application, some facilities use geothermal direct heat return flow wells to return these geothermal fluids to the subsurface.

The temperature and chemical characteristics of geothermal fluids used for heating vary substantially from site to site. At some sites, the geothermal fluids are of drinking water quality and, in fact, are used as drinking water and not reinjected. More commonly, concentrations of some constituents exceed maximum contaminant levels (MCLs) or health advisory levels (HALs). Available data indicate that arsenic, boron, sulfate, and fluoride exceed primary MCLs or HALs and that total dissolved solids (TDS), chloride, iron, manganese, and sulfate exceed secondary MCLs. TDS concentrations are generally <10,000 mg/l except in the comparatively rare situations where high temperature geothermal fluids used for power production are also used for heating.

When geothermal fluids used for heating are reinjected into the subsurface following use (rather than discharged to surface water or used for drinking, irrigation, or livestock watering), they typically are reinjected into the same hydrothermal formation from which they were produced. In addition, the composition of the geothermal fluids normally does not change appreciably as a result of use for heating, although traces of pump lubricating oil may be added in some cases.

No documented cases of USDW contamination by geothermal direct heat return flow wells have been reported. In addition, the wells typically are not vulnerable to receiving accidental spills or other illicit discharges, because the geothermal fluids are handled in closed piping systems. Typically, the geothermal fluids are produced from a well, passed through a heat exchanger, and injected down another well.

The survey results indicate that there are 31 documented geothermal direct heat return flow wells and another 17 more wells estimated to exist. Although these wells exist in as many as 11 states, more than 80 percent of the documented wells are in only five states: Oregon (8), Nevada (7), Utah (4), New Mexico (4) and Idaho (3). All of the 17 estimated wells are in Oregon, but Alaska also indicated the potential presence of these wells without providing an estimated number.

Individual permits are required for geothermal direct heat return flow wells in all five of the states that have most of these wells. In Idaho, an individual permit is not required if the well is <18 feet deep, but all of the geothermal direct heat return flow wells are substantially deeper than 18 feet. Individual permit requirements, which also apply in California, are similar in many respects to those for Class II wells. Further, for wells located on federal land, Bureau of Land Management (BLM) approval of well drilling, testing, and abandonment is also required by regulations promulgated under the Geothermal Steam Act of 1970.

2. INTRODUCTION

The existing UIC regulations in 40 CFR 146.5 (e) define Class V wells to include "injection wells associated with the recovery of geothermal energy for heating, aquaculture, and the production of electric power." Geothermal injection wells are most commonly associated with electric power generation. However, Class V injection wells also include wells used in association with recovery of geothermal energy sources for purposes other than electric power production. These injection wells are the subject of this information summary. Often referred to as "direct heat" applications, these non-power applications use low to moderate temperature (50^{o}C-150^{o}C) geothermal fluids to heat individual homes and/or communities and provide heat to greenhouses, aquaculture, and other commercial and industrial processes (food dehydration, laundries, gold mining, milk pasteurizing, etc.) (USDOE, 1996). Applications that tap the energy in ground water at "normal" temperatures are not included here; rather, they are considered in the heat pump and air conditioner return flow well category. Similarly, geothermal wells with down-hole heat exchangers used in direct heat applications are not included here because they are closed loop systems that are not injection wells subject to USEPA's Class V UIC regulations.

Following heat extraction, the spent (cooled) geothermal fluids can be reinjected, usually into the source reservoir.[1] Underground injection of spent geothermal fluids occurs for various reasons including: subsidence prevention, water and heat conservation, maintenance of aquifer water and pressure levels, disposal of effluent, and legal (e.g., water rights) and regulatory requirements. In many cases, regulatory requirements provide the principal stimulus for geothermal fluid reinjection because surface discharge, where permitted, is generally less costly than injection (Culver, 1988, 1989). For example, in 1990, the city of Klamath Falls, Oregon implemented a ban on surface disposal of geothermal fluids which resulted in an increase in

[1] Discharge to surface water or use for other purposes, such as drinking water and live stock watering, in lieu of injection is common in some areas. Such discharges and uses are not covered in this document.

subsurface injection. In contrast, there are an estimated 5,000 users of geothermal heat from the Madison formation in South Dakota, but no reported geothermal injection wells in South Dakota, because surface discharge is allowed (Geo-Heat Center, 1998a).

3. PREVALENCE OF WELLS

For this study, data on the number of Class V geothermal direct heat 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 numbers of Class V geothermal direct heat 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 geothermal direct heat return flow wells.

As shown in Figure 1, geothermal resources with sufficient temperature for development of direct heat applications occur primarily in the western United States, but some are located in the eastern United States as well. Where geothermal resources are developed for direct heat applications, injection of the spent geothermal fluid appears to be used relatively infrequently. For example, a 1988 study reported that of 1,030 identified direct heat use applications, only 17 used injection wells. The other direct use applications employ surface disposal methods (i.e, release into trenches, ponds, streams, etc.) to dispose of spent geothermal fluids (Culver, 1988).

There are an estimated 48 UIC Class V geothermal direct heat return flow wells in the United States, as indicated in Table 1. The majority of the 31 documented wells are located in a few western states: Oregon (8), Nevada (7), New Mexico (4), Utah (4), and Idaho (3). The additional 17 wells are believed to occur in Oregon. Direct heat return flow wells are also reported in Florida (in the Central District of the Florida Department of Environmental Protection), Michigan (based on the 1987 Report to Congress on Class V wells), Louisiana, and California.[2]

Use of geothermal energy sources for direct heat applications has been increasing about 5 percent per year on a heat energy basis (Fortuna, 1999). If this trend continues, the number of direct heat return flow wells would be expected to increase as well, but not necessarily by the same amount, because: (1) not all geothermal fluids extracted for heating are reinjected; (2) some uses may involve closed loop systems; and (3) expanded use of geothermal fields that already have injection wells may not require additional wells.

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[2] In Louisiana, the one documented well, which was drilled in 1957 for disposal of fluids from a geothermal spa, is inactive, based on an inspection conducted in December, 1998 by the Louisiana Department of Natural Resources, Office of Conservation.

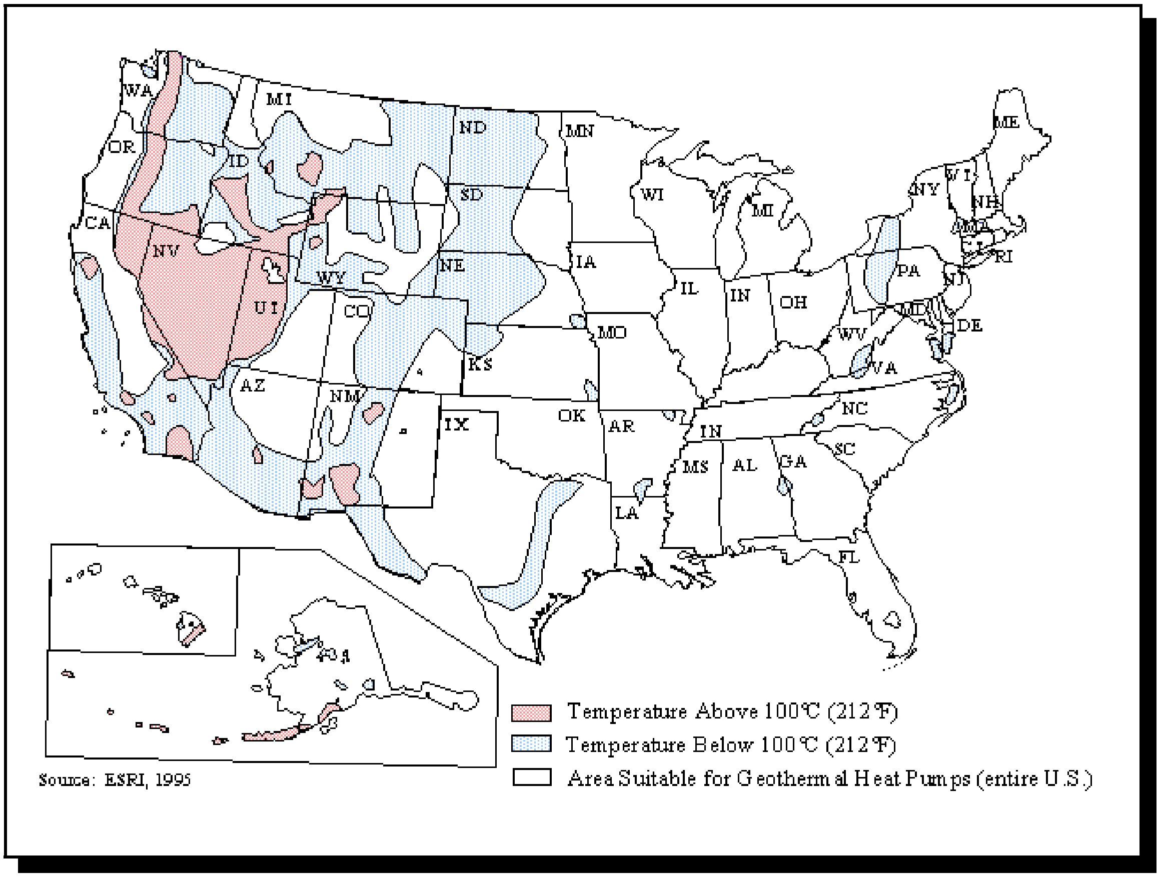
Table 1. Inventory of Direct Heat Geothermal Return Flow Wells in the U. S.

State	Documented Number of Wells	Estimated Number of Wells	
		Number	Source of Estimate and Methodology[1]
USEPA Region 1 -- None			
USEPA Region 2 -- None			
USEPA Region 3 -- None			
USEPA Region 4			
FL	1	Unknown	N/A
USEPA Region 5			
MI	2	NR	N/A
USEPA Region 6			
LA	1	1	N/A
NM	4	4	N/A
USEPA Region 7 -- None			
USEPA Region 8			
UT	4	4	Best professional judgement.
USEPA Region 9			
CA	1	1	N/A
NV	7	7	N/A
USEPA Region 10			
AK	NR	NR	State indicates that these wells may exist in AK, but none are reported.
ID	3	3	N/A
OR	8	25	Data collected by Calvin Terada, Region 10, per telephone conversations with state personnel.
All USEPA Regions			
All states	31	48	Total estimated number counts the documented number when the estimated 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.
Unknown	Questionnaire completed, but number of wells is unknown.

Figure 1. Geothermal Resources in the U.S.



Source: Geo-Heat Center, 1998b

4. INJECTATE CHARACTERISTICS AND INJECTION PRACTICES

4.1 Injectate Characteristics

This section presents data on the chemical characteristics of geothermal fluids associated with direct heat applications. In general, the chemical characteristics of the injected fluids are very similar to those of the produced fluids and the receiving formation, which normally is also the producing formation. The available data provide information on the characteristics of the produced geothermal fluids, the injected fluids, and the receiving formation, depending on the site. Changes in chemical characteristics may occur when the produced geothermal fluids are exposed to atmospheric conditions (e.g., pressure, sunlight), but are generally minor. Data presented below on the characteristics of injected geothermal fluids as well as the quality of the water in the formation, are organized by state.

- **New Mexico.** Table 2 presents the results of six samples collected in 1982 and 1983 that indicate the characteristics of the geothermal fluids produced from three wells at New Mexico State University (NMSU) and the characteristics of the fluids in the formation at the point of injection. As shown, these data indicate that TDS, arsenic, chloride, iron, and manganese concentrations in the produced (and reinjected) fluids exceed drinking water standards or HALs. The data also show that concentrations of these constituents in the receiving formation generally are similar to those in the injected fluids. One exception is arsenic, which is present below the HAL in the receiving formation at one injection well.[3]

- **Idaho.** Table 3 presents water quality data for the geothermal system in and around Boise. The data in column 1, which are based on information compiled by the U. S. Geological Survey over a period of several years, indicate the range of concentrations observed in geothermal production wells throughout the area. Columns labeled 1, 3, and 4 each provide data for a sample collected during well installation that indicate the characteristics of the fluids in the formation at the point of injection. As shown, these data indicate that arsenic and fluoride concentrations exceed drinking water standards or HALs. Exceedences are also indicated for lead and iron. In general, these data also indicate that water quality of the injected fluids and the receiving formations are comparable.

- **Oregon.** Table 4 provides data on the water quality characteristics of geothermal fluids around Klamath Falls, Oregon. Data compiled for more than 100 geothermal wells over a period of several years indicate that the concentrations of boron, iron, and sulfate in the geothermal fluids typically exceed drinking water standards or HALs. Data from specific injection and production wells indicate that the concentrations of arsenic routinely exceed HALs in produced (and then injected) fluids and the receiving formation. In addition, TDS concentrations sometimes exceed secondary drinking water standards in some produced (and then injected) fluids and the receiving formation. It appears that manganese and fluoride concentrations may sometimes exceed drinking water standards as well.

- **Nevada**. Data on the water quality characteristics of five geothermal direct heat sites with injection wells are presented in Table 5. As shown, the concentrations of TDS, arsenic, and boron routinely exceed drinking water standards or HALs both in the injected fluid and the receiving formation. Data for the Peppermill Hotel Casino show a noteworthy difference in characteristics for the injectate and receiving formation, because the geothermal fluids are produced from a formation

[3] At NMSU, the production wells are located in the lower Santa Fe group in a zone of geothermal upflow from the underlying limestone formation while the primary injection well (GD-2) is located in the outflow plume of the geothermal system in the upper Santa Fe. Thus, injection occurs “downstream” of the production wells and into the same geothermal system despite the difference in the depth of the wells.

Table 2. Injectate and Formation Characteristics at New Mexico State University

Constituents	Drinking Water Standards*		Health Advisory Levels **		University of New Mexico, Las Cruces Concentrations in mg/l unless otherwise noted					
					Production Wells			Injection Wells		
	mg/l	P/S	mg/l	N/C	PG-1 (1)	PG-2 (1)	PG-3 (1)	NMSU #4 (1)	GD-2 LRG - 3648 (2)	
					860 ft	505 ft	870 ft	607 ft	468 ft	840 ft
TDS	500	S			2000	1980	2010		1948	1787
pH (Std. units)	6.5-8.5	S	--		7.95	8.36	6.8	7.37	7.65	7.8
Arsenic	0.05	P	0.002	C	0.002	0.013		0.003	<0.001	0.001
Barium	2	P	2	N	<0.4			<0.4	0.08	0.09
Bicarbonate (HCO_3^{-1})	--		--		612.6	508.9		547.9	422.2	494.2
Boron	--		0.6	N	0.10	0.23		0.09	0.30	0.30
Cadmium	0.005	P	0.005	N	<0.005			<0.005	<0.005	<0.005
Calcium	--		--		138	188	138	131.7	130	114.5
Chloride	250	S	--		590.6	610	546	391.4	573.7	440.3
Chromium	0.1	P	0.1	N	<0.05			<0.05	<0.002	<0.002
Copper	1.3	P	--					<0.10		
Fluoride	4.0	P	--		1.31	1.31		1.52	1.29	0.55
Iron	0.3	S	--		0.28	0.55		3.95	1.28	6
Lead	0.015	P	--		<0.005			<0.005	0	0.005
Magnesium	--		--		19	21	17.4	23	36.0	36.6
Manganese	0.05	S	--		0.06	1.05		0.16	0.09	0.13
Mercury	0.002	P	0.002	N	<0.0002			<0.0002	<0.0002	<0.0002
Nitrate (NO_3^{-1})	10	P	--		0.02			0.01	0.01	0.02
Potassium	--		--		57.9	51	52	33.6	43.8	34.8
Selenium	0.05	P	--		0.002			0.002	<0.001	0.001
Silica ($SI0_2$)	--		--		92	57.5		60.9	23.2	36
Silver	0.1	S	0.1	N	<0.05			<0.01	0.05	0.05
Sodium	--		--		488.0	450	488	321.4	427.6	386.2
Sulfate (SO_4^{-2})	500/250	P/S	--		285	226.2		147.5	315.0	280.0

* Drinking Water Standards: P= Primary, S= Secondary
** Health Advisory Levels: N=Noncancer lifetime, C= Cancer Risk

Sources:
(1) Cunniff, Houghton & Clanton, 1982, except TDS values, which are from reference (2).
(2) NMSU, 1983.

Table 3. Constituent Data from Selected Geothermal Wells in Idaho

Constituents	Drinking Water Standards**		Health Advisory Levels ***		Boise, Idaho Geothermal Wells Concentrations in mg/l unless otherwise noted			
	mg/l	P/S	mg/l	N/C	(1)	(2)	(3)	(4)
Sampling Date	--		--			4/24/98	1/8/87	
Well Completion Date	--		--			4/9/98	12/13/86	
Well Depth (ft.)	--		--			3200	2300	2152
TDS	500	S	--		254-330	270.3		
pH (Std. units)	6.5-8.5	S	--			8.3	8.3	
Aluminum	0.05 - 0.2	S	--			1.680		
Arsenic	0.05	P	0.002	C		0.0048		0.01
Boron	--		0.6	N	0.08 -0.09	0.09		0.31
Cadmium	0.005	P	0.005	N		ND		0.001
Calcium	--		--		1.6-5.5	1.77		3.2
Chloride	250	S	--		7.2-8.7	7.31*		6.85
Chromium	0.1	P	0.1	N		<0.0005		0.05
Copper	1.3	P	--			ND		0.01
Fluoride	4.0	P	--		12-19	16.2	14.0	16.9
Iron	0.3	S	--			0.871		0.02
Lead	0.015	P	--			ND		0.05
Magnesium	--		--		ND-0.13	0.27		0.5
Manganese	0.05	S	--					0.01
Mercury	0.002	P	0.002	N				0.001
Nickel	0.1	P	0.1	N		ND		
Nitrate (NO_3^{-1})	10	P	--			ND		
Total NO_2 * NO_3 as N	--		--					0.006
Phosphorus	--		--		0.01	0.011		
Potassium	--		--		0.8-1.6	1.11		0.8
Silica ($SI0_2$)	--		--		55-80	85.0*	115	52.4.
Silver	0.1	S	0.1	N		ND		0.001
Sodium	--		--		80-89	64.0		88
Sulfate (SO_4^{-2})	500/250	P/S	--		21-24	20.3*	18	22
Zinc	5	S	2	N		0.004		0.004
Gross Alpha (pCi/L)	15	P	15	C				<0.8
Gross Beta (pCi/L)	–		--					1.3

* Sample exceeded recommended holding time before analysis.
** Drinking Water Standards: P= Primary, S= Secondary
*** Health Advisory Levels: N=Noncancer lifetime, C= Cancer Risk

(1) USGS Database Range of concentrations from Boise geothermal aquifer. Montgomery Watson, 1998.
(2) Julia Davis Park Injection Well. Montgomery Watson, 1998.
(3) V.A. Medical Center Injection Well. Montgomery, 1987.
(4) Capital Mall Exploratory Well # 1. Anderson, 1981

Table 4. Constituent Data for Selected Geothermal Wells in Klamath Falls, Oregon
(concentrations in mg/l unless otherwise specified)

	Drinking Water Standards*		Health Advisory Levels**		OIT Injection Well # 1			OIT Production Well No.5	O'Neil Elementary School (1) injection well	O'Neil Elementary School (1) production well		Aggregate Data for over 100 Klamath Falls geothermal wells (h)	
Constituents	mg/l	P/S	mg/l	N/C	(a)	(b)	(c)	(d)	(e)	(f)	(g)	Average	Standard Deviation
Sampling Date	--		--		3/5/90		6/5/90		6/1/90	3/28/90	3/31/88		
Temperature (ºC)	--		--		52.2		58.7				46.0	72.6	2.47
TDS	500	S	--		737		223	737	177	664	693		
EC (Fmhos/cm)	--		--		990	340	1,332	993	665	970	819	1,210	287
pH (Std. units)	6.5-8.5	S	--		8.27	6.9	7.89	8.45	7.6	8.7	8.7	8.08	0.337
Arsenic	0.05	P	0.002	C	0.048	.014	0.030	0.047	0.003	0.010	0.014		
Bicarbonate (HCO_3^{-1})	--		--		27.3	104		25.6		52.4			
Boron	--		0.6	N	73.6	.070	1.00	.916	0.46	0.68	<0.10	0.78	0.10
Calcium	--		--		25	30.5			10.3	12	2.2	21.8	8.48
Carbonate (CO_3^{-2})	--		--		12.8			22.7					
Chloride	250	S	--		37.0	41.0	37.0	46.4	20.0	36.2	35.8	49.1	7.95
Fluoride	4.0	P	--		1.23	7.9	1.2	1.3					
Iron	0.3	S	--		0.44	0.454			0.43	0.29	<0.10	3.06	6.12
Magnesium	--		--		0.15	0.734			1.7	0.15	1.9	0.20	0.34
Manganese	0.05	S	--		< 0.01	0.212			0.03	< 0.01	<0.01		
Potassium	--		--		8.0	1.5			4.3	7.5	10.2	4.80	1.11
Silica (SIO_2)	--		--		8.6	38.9			95.7	20.4	29.9	91.3	21.4
Sodium	--		--		394	39.0			114	370	204	201.0	47.7
Sulfate (SO_4^{-2})	500/250	P/S	--		490	7.6	340		180	295	301	410.0	73.1

* Drinking Water Standards: P= Primary, S= Secondary
** Health Advisory Levels: N=Noncancer lifetime, C= Cancer Risk

Sources:
(a) KES, 1990a.
(b) Culver, 1990b.
(c) KES, 1990b.
(d) Culver, 1990b.
(e) KES, 1990c.
(f) KES, 1990d.
(g) KES, 1988.
(h) Lund, 1989.

at a depth of about 750 feet bgs while injection is into an aquifer 2,500 to 3,000 feet bgs (Land, 1999b). At some locations in Nevada, higher temperature geothermal resources that are used for power production are also used for direct heat applications. Data for two of these sites (Amor II and Brady) provided in the electric power geothermal injection well information summary show that concentrations of dissolved constituents are generally several times greater in high temperature geothermal fields than in the lower temperature geothermal resources represented in Table 5 below. At one or both of these sites, fluoride, iron, and manganese concentrations also exceed drinking water standards or HALs.

Table 5. Constituent Data for Selected Geothermal Wells in Nevada
(concentrations in mg/l unless otherwise specified)

Constituent	Drinking Water Standards *		Health Advisory Levels **		Warren Estates		Virginia Lake Townhouse			Century Wellness Center		Peppermill Hotel Casino				Caliente
					Injectate		Injectate		Formation	Injectate		Injectate		Formation		Formation
	mg/l	P/S	mg/l	N/C	5/13/96	12/10/96	11/19/92	3/25/96	10/10/85	12/4/95	12/10/96	11/20/92	12/24/98	3/1/89	9/1/89	8/1/96
TDS	500	S	--		1,002	1,016	694	761	618	596	587	681	672	1,148	1,365	505
EC	–		--		1,350	1,450	890	1,082	0	850	850	935	930	0	0	740
pH	6.5 - 8.5	S	--		7.98	8.09	8.20	8.14	8.40	8.22	8.15	8.17	7.15	8.50	7.30	7.75
Arsenic	0.05	P	0.002	C	0.11	0.14	0.077	0.091	0.16	0.087	0.13	0.19	0.11	0.16	0.077	0.036
Barium	2	P	2	N	0	0	0.03	0.04	0	0	0	0.04	0	0	0	0
Boron	--		0.6	N	0	2.1	1.1	1.1	0.9	1.2	1.2	1.3	0.81	2.9	4.0	1.4
Cadmium	0.005	P	0.005	N	0	0	<0.1	0	0	0	0	<0.01	0	0	0	<0.001
Calcium	--		--		0	28	18.8	21	20	16	14	21	17	15	43	43
Chloride	250	S	--		0	51	34	30	36	27	27	36	29	50	157	66
Chromium	0.1	P	0.1	N	0	0	<0.05	0	0	0	0	<0.05	0	0	0	0.029
Copper	1.3	P	--		0	0	<0.02	0.01	0	0	0	0.05	0	0	0	0.02
Fluoride	4.0	P	--		5.2	4.6	2.8	2.64	0.4	2.6	2.3	2.1	2.1	3.6	14	1.2
Iron	0.3	S	--		0	0.28	0.07	0.03	0.03	0	0	0.09	0	1.12	2.2	0.06
Lead	0.015	P	--		0	0	0.003	0	0	0	0	0.005	0	0	0	0.005
Lithium	--		--		0	0.3	0	0	0	0	0	0	0	0	0	0
Magnesium	--		--		0	0.13	0.9	0	0.2	0.4	0.51	0.4	0.42	1.0	2.5	15
Manganese	0.05	S	--		0	0.05	0.02	0.03	0.2	0	0	0.03	0	0.05	0.38	0.01
Mercury	0.002	P	0.002	N	0	0	<0.0005	0	0	0	0	<0.0005	0	0	0	0
Nitrate	10	P	--		0	<0.1	<0.1	0	<0.1	0	0	<0.1	<0.2	0	0	0.4
Potassium	--		--		0	8	7.7	8	6	3.6	3.4	7.3	7.1	7.9	15	7.9
Selenium	0.05	P	--		0	0	<0.001	0	0	0	0	<0.001	0	0	0	0
Silica	--		--		0	105	90	84	47	52	56	0	79	0	0	43
Silver	0.10	S	0.1	N	0	0	<0.02	0	0	0	0	<0.02	0	0	0	<0.001
Sodium	--		--		0	280	193	204	185	240	140	176	180	315	550	100
Sulfate	500/250	P/S	--		0	510	266	0	300	250	260	294	300	509	694	62
Zinc	5	S	2	N	0	0	<0.02	0.01	0	0	0	0.21	0	0	0	0.088

* Sample exceeded recommended holding time before analysis.
** Drinking Water Standards: P= Primary, S= Secondary

Source: Land, 1999a

C **California**. Though direct heat uses of geothermal resources occur in several parts of the state, injection is only reported to occur at one location. Data available shown in Table 6 indicate that concentrations of TDS and sulfate exceed secondary drinking water standards while boron concentrations exceed HALs in both the injected fluids and the receiving formation.

Table 6. Constituent Data for Selected Geothermal Wells in Susanville, California
(concentrations in mg/l unless otherwise noted)

Constituent	Drinking Water Standards (MCLs)		Health Advisory Levels (HALs)		Injection Well (sample from the well on 10/25/82)	Production Wells		
	mg/l	P/S*	mg/l	N/C*		Susan 1 (11/23/80)	Susan 1 (10/27/81)	Naef (4/17/84)
EC**	–		--		1180	1129	1400	1200
pH***	6.5 - 8.5	S	--		8.73	8.91	8.40	8.90
Temp. (°C)	–		--			73	77	66
TDS	500	S	--		728	886	949	906
Calcium	--		--		20.4	30.0	28.0	26.0
Magnesium	--		--		0.42	0.35	0.06	0.12
Sodium	--		--		227.0	245.0	240.0	260.0
Potassium	--		--		3.2	6.8	7.0	4.6
HCO_3	--		--		30.3	0.0	32.9	29.0
CO_3	--		--		4.2	12.2	0.0	10.0
SO_4	500/250	P/S	--		321.0	379.0	450.0	380.0
Chloride	4	P	--		128.0	127.0	130.0	140.0
Boron	--		0.6	N	2.8	2.5	2.4	3.3
Fluoride	4/2	P/S	--			0.00	2.20	2.10
SiO_2	--		--		6	83	73	66

* P=primary, S=secondary, N=non-cancer, C=cancer
** electrical conductivity, micromhos/cm
*** standard units
Source: GeothermEx, 1984

These data, in combination with data for higher temperature geothermal resources provided in Volume 17, show that chemical characteristics of injected geothermal fluids vary considerably depending on the nature of the geothermal resource. They also show that the concentrations of some constituents such as TDS, arsenic, and boron, based on available data, exceed drinking water standards or HALs in both the injected fluids and the receiving formations. Injectate may also contain traces of lubricants from equipment (e.g., oil lubrication of the bearings in a lineshaft pump), but no data were found to quantify the effect (if any) on injectate quality.

4.2 Well Characteristics

Geothermal injection wells used in various direct heat applications are generally 200 feet to 2,000 feet deep, although some (see Figure 2) are deeper. The wells are typically constructed with a single casing cemented to the top of the injection zone and a screen or a perforated liner installed in the injection zone. In the example shown in Figure 2, a surface casing is also used for this relatively large diameter well. In the example shown in Figure 3, no surface casing was used.

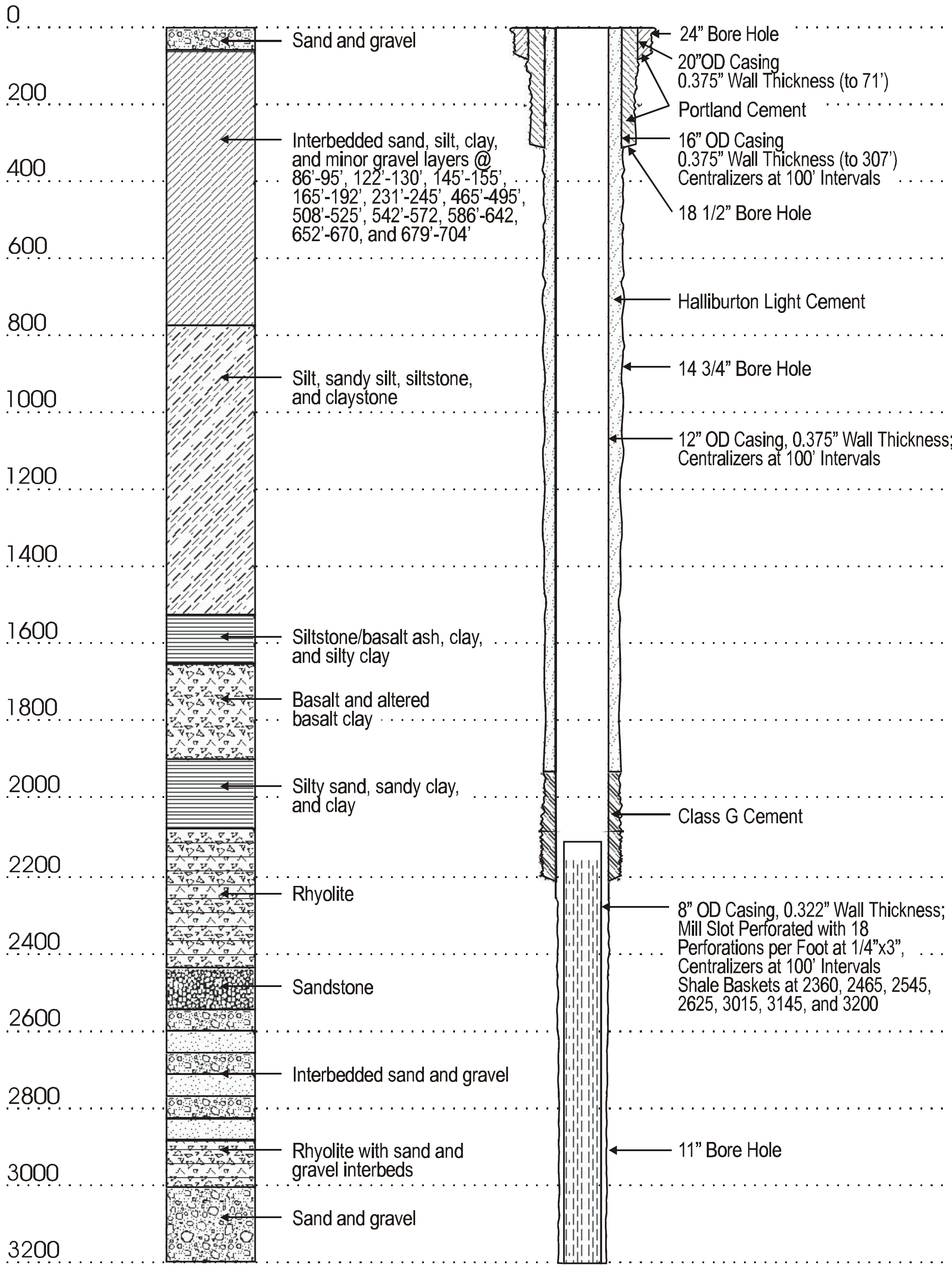
The specific well designs and materials used for direct heat injection wells vary depending upon the chemical nature of the geothermal resource, well depth, and the geology of the injection zone (USEPA, 1987). In general terms, there is a correlation between the chemical characteristics of geothermal fluids and the reservoir depth and temperature. Lower temperature fluids from shallower depths are typically less corrosive than fluids found at greater depth and higher temperature (U.S. House of Representatives, 1992). The choice of well casing materials is highly dependent upon the geothermal fluid chemistry. Standard carbon steel pipe may be used with non-aggressive waters, while corrosion-resistant alloys may be necessary when corrosive fluids are injected. Similarly, casing and piping thickness vary according to the area’s geologic structural stability and expected length of heating operations. In addition, casing selection and related design features also are affected by geothermal formation pressure. In general, geothermal formation pressures associated with direct heat applications are much lower than in the higher temperature resources used for power production, but in some cases are still high enough for the injection well to have artesian or “near artesian” flow when the well is initially drilled. For example, injection wells in Boise have demonstrated artesian flow, and a 3,400 feet injection well in Louisiana showed a static water level 69 feet below ground surface (Montgomery Watson, 1998; Turcan, 1959).

4.3 Well Siting

Siting of direct heat return flow wells is normally governed by geothermal reservoir management considerations. Specifically, the injection wells need to be sited where the cooled fluid will be returned to a location that does not cause a drop in temperature at the production wells. In the example shown in Figure 3, the well was drilled to a depth of nearly 1,000 feet to ensure that the geothermal injection zone did not overlie a potable water aquifer and that the injection horizon would be located within the outflow from the geothermal reservoir system. Analysis of temperature logs, water chemistry, and lithology information led to the conclusion that injection should occur in approximately the 370 feet to 470 feet interval. Thus, the lower 500 feet of the well were backfilled and then sealed with a cement plug (Cunniff, 1983).

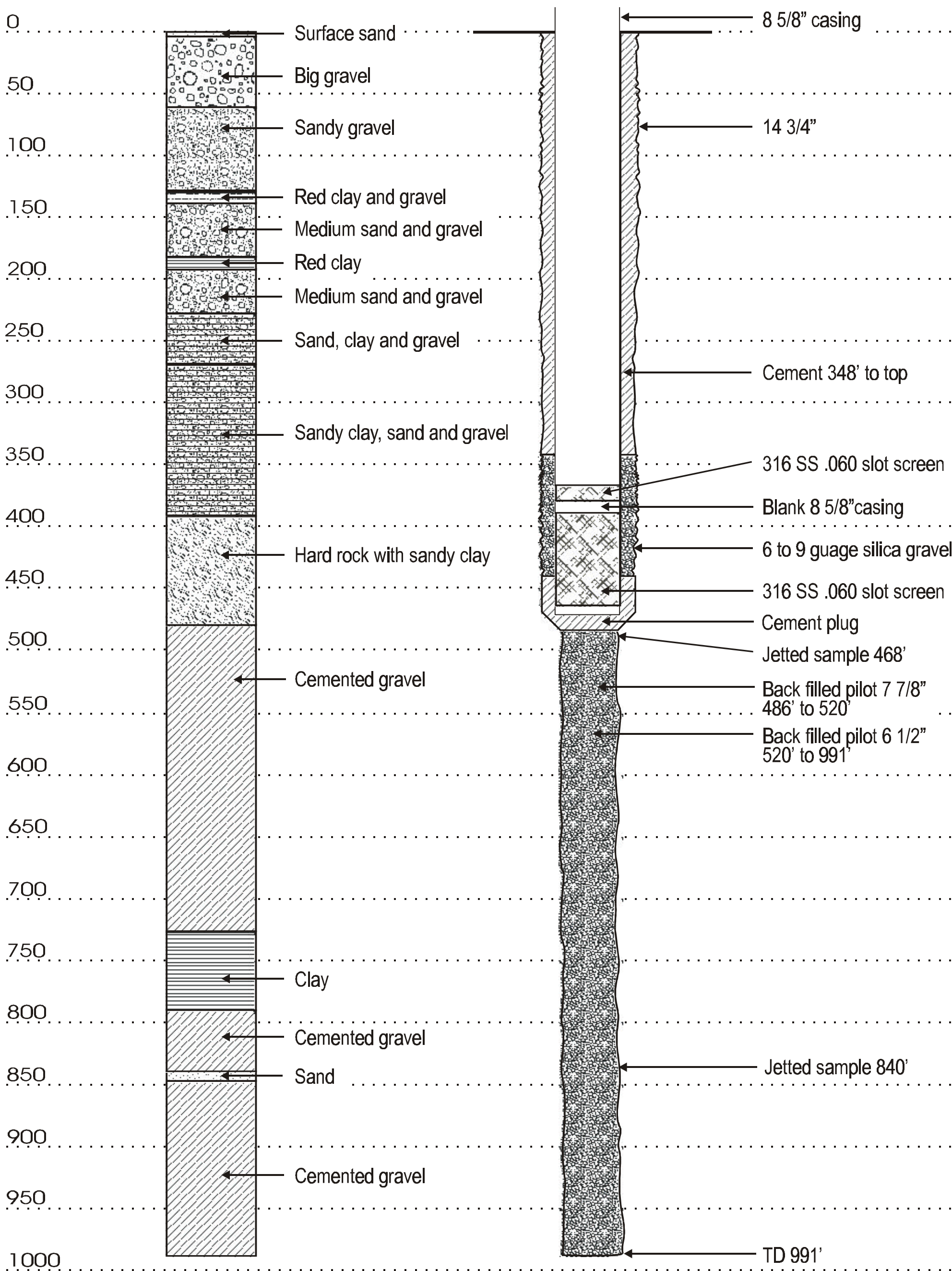
In addition, land surface considerations typical for any well (e.g., access for maintenance) also apply. Because injected geothermal fluids are delivered to the wells in a closed pipeline system, well siting is not expected to affect injectate quality.

Figure 2. Example of a Direct Heat Return Flow Well -- Boise, ID
(Depths in feet below ground surface)



Source: Montgomery Watson, 1998.

Figure 3. Example of a Direct Heat Return Flow Well -- New Mexico
(Depths in feet below ground surface)



Source: NMSU, 1983.

4.4 Well Operation

Prior to being placed in operation, the integrity of the casing and overall well construction may be tested by a variety of means. Testing may include an evaluation of the cement job (e.g., cement bond log) and a pressure test of the well casing. Monitoring and periodic testing may also be performed as part of on-going well operation, depending onsite conditions and requirements. On-going (e.g., daily, weekly) monitoring of injection pressures and flow rates is often conducted as part of well operation to collect data that will aid in the management of the geothermal reservoir, especially where flow rates and pressures vary seasonally with changes in the demand on the direct heat system.[4] Periodically (e.g., every five years), well operation may be temporarily suspended for pressure testing of the casing if the well passes through a USDW and corrosion is a potential concern due to the characteristics of the geothermal fluids.

The injections wells are operated as part of an integrated fluid extraction, heat recovery, and injection cycle. Throughout this cycle, the fluids are handled in closed piping systems and so are generally not vulnerable to receiving accidental spills or other illicit discharges. Injection wells used in association with district heating systems, however, are potentially vulnerable to contamination, because each customer is a potential point of contamination if they modify their piping to allow waste water from other sources, such as shallow ground water cooling wells or back up boiler systems, to be pumped into the geothermal fluid flow (Johnson, 1999).

5. POTENTIAL AND DOCUMENTED DAMAGE TO USDWs

5.1 Injectate Constituent Properties

The primary constituent properties of concern when assessing the potential for Class V geothermal direct heat return flow wells to adversely affect USDWs are toxicity, persistence, and mobility. The toxicity of a constituent is the potential of that contaminant to cause adverse health effects if consumed by humans. Appendix D of the Class V Study provides information on the health effects associated with contaminants found above drinking water standards or HALs in the injectate of geothermal direct heat return flow wells and other Class V wells.

Persistence is the ability of a chemical to remain unchanged in composition, chemical state, and physical state over time. Appendix E to the Class V Study presents published half-lives of common constituents in fluids released in geothermal direct heat return flow wells and other Class V wells. All of the values reported in Appendix E are for ground water. Caution is advised in interpreting these values, because ambient conditions have a significant impact on the persistence of both inorganic and organic compounds. Appendix E also provides a discussion of the mobility of certain constituents found in the injectate of geothermal direct heat return flow wells and other Class V wells.

[4] At some sites, system demand is less dependent on seasonal temperatures, as in the case of the onion dehydration plants that have year-round, 24-hours a day operation.

Based on the information presented in Section 4.1, the concentrations of arsenic, boron fluoride, and sulfate in injected geothermal fluids exceed drinking water standards or HALs. Chloride, iron, manganese, and TDS have been measured above secondary drinking water standards in some injected geothermal fluids. In general, these constituents are persistent and mobile following injection to approximately the same extent as they were before extraction, because the spent (injected) geothermal fluids are injected into the producing formation.

5.2 Observed Impacts

None of the states that reported having direct heat return flow wells (see Table 1) indicated that this type of injection well is known to have contributed to the contamination of a USDW. A study of injection attempts in Susanville, California found that injectate fluids reached the surface during the initial mechanical integrity testing (MIT) of a direct heat return flow injection well. It is not clear from the available information whether the leak, which was caused by an improperly cemented seal on the new well, resulted in release to subsurface formations other than the intended injection zone (Culver, 1990a). Corrosion in wells associated with direct heat applications has also been documented (Lund, 1990). Much of the study on corrosion in direct heat applications has focused on components other than injection well casing, such as distribution piping and down-hole heat exchangers. While far less of a problem than with electric power geothermal injection wells, some geothermal fluids are sufficiently corrosive that they may cause well failures unless appropriate precautions are taken during well design and operation.

6. BEST MANAGEMENT PRACTICES

Several best management practices (BMPs) can be implemented to provide increased protection of USDWs (when present) and, in many cases, also provide improved safety and cost performance for direct heat return flow wells. The following discussion is neither exhaustive nor represents a USEPA preference for the stated BMPs. Each state, USEPA Region, and federal agency may require certain BMPs to be installed and maintained based on that organization's priorities and site-specific considerations.

Siting of direct heat return flow wells to enhance protection of USDWs (if present) and operation of the heat recovery system is improved by careful investigation and understanding of the geothermal resource. Through investigation, operators gain the necessary conceptual and physical understanding of the resource area. Knowledge of the hydrogeological, structural, and chemical nature of the resource aids in siting decisions and well design. Hydrogeological information is important for predicting the flow of the injected water once it enters the subsurface. Understanding existing flow rate, direction, and volumes gives insight into how injected fluids behave and travel in the formation. For example, small geothermal sources that are characterized by high transmissivity may not permit effective injection without excessive thermal breakthrough (Culver, 1988). Techniques such as injectivity, transmissivity, and tracer testing can be used to acquire information beneficial to siting decisions.

Well life and operation are improved if well design and material selection include consideration of factors such as how the well will be operated, the nature of the formations that the well is drilled through, and the corrosion potential of the geothermal fluids. If well operation results in alternating periods of use and disuse, thermal expansion/contraction of well casing may cause a fracturing in the cement seals in unconsolidated formations and, thus, allow interzonal fluid migration. Placing a cement seal above the perforations in the injection well, and using bentonite filling (rather than cement) can reduce the potential for fluid movement in the borehole in applications where changes in well casing temperatures are anticipated (Culver, 1990b).

Various constituents found in geothermal fluids, including air, oxygen, carbon and carbon oxides, sulfur-containing gases, hydrogen, and metal halides, may cause corrosion of direct heat return flow wells (METALogic NV, 1998). Thus, corrosion potential is site specific. Although in general, corrosion problems increase with increasing fluid solids content and temperature. Most direct heat return flow wells are constructed with steel casing, but stainless steel well screens are sometimes used. Stainless steel may be used to resist the corrosive effects of some geothermal fluids. In other situations, stainless steel may be used to withstand repeated acidizing of a well (to remove deposits from the screen).

After the well is constructed, initial pressure testing of the casing and a survey of the cementing integrity (e.g., cement bond log) serve to verify that the well construction was accomplished as planned. On-going monitoring of injection flow rates and pressures both provides data for use in managing the geothermal reservoir and for checking the proper operation of the well. Periodic re-testing of casing and cementing integrity provides added assurance that fluids continue to be injected into the intended formation.

As indicated in Section 4, injection wells used in association with district heating systems are potentially vulnerable to contamination because each customer is a potential point of contamination. Monitoring of the chemical composition of the fluid flow can help guard against such potential contamination. In Boise, for example, geothermal water has high fluoride levels. Therefore, a protocol for testing fluoride levels in water being injected has been developed as the first step to detect unauthorized waste flows being added to the spent geothermal fluids (Johnson, 1999).

7. CURRENT REGULATORY REQUIREMENTS

Several federal, state, and local programs exist that directly manage or regulate Class V geothermal direct heat return flow wells. On the federal level, management and regulation of these wells fall primarily under the UIC program authorized by the Safe Drinking Water Act (SDWA). In addition, the BLM has enacted regulations under the authority of the Geothermal Steam Act to control the use of geothermal resources on federal lands. 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 geothermal direct heat return flow wells.

7.1 Federal Programs

7.1.1 SDWA

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.

Geothermal direct heat 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 geothermal direct heat 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 geothermal direct heat 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 geothermal direct heat 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]

7.1.2 Geothermal Steam Act

The BLM regulates use of geothermal resources on federal lands administered by the Department of the Interior or the Department of Agriculture, on lands conveyed by the U.S. where geothermal resources were reserved to the U.S., and on lands subject to Section 24 of the Federal Power Act, as amended (16 U.S.C. 818) with concurrence from the Secretary of Energy. Guidance on geothermal classification, leasing, exploration, operations, and resource protection and utilization is provided in 43 CFR parts 3200, 3210, 3220, 3240, 3250, and 3260. The BLM can issue geothermal resource operational orders, under the Geothermal Steam Act of 1970, for nationwide requirements; notices to lessees for statewide or regional requirements; and other orders and instructions specific to a field or area. The BLM can also issue permit conditions or approval and verbal orders.

Permitting Requirements

In order to use federal lands for access to geothermal resources, a site license and construction permit must be issued before starting any site activities. A plan showing the proposed site plans and a draft of a proposed site license agreement must be submitted to BLM. The BLM reviews these materials and decides on the issuance of a permit and license to proceed with work.

To get approval for drilling operations and well pad construction the following must be submitted to BLM: a completed drilling permit application, a completed operations plan, a complete drilling program, and an acceptable bond. A drilling program describes the operational aspects of the proposed drilling, completion, and testing of the well. The drilling program requires numerous items, including the casing and cementing program, the circulation media (mud, air, foam, etc.), a description of the logs that will be run, and a description and

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

diagram of the blowout prevention equipment that will be used during each phase of the drilling. An operations plan describes how to drill and test for the geothermal resources.

Within 30 days of completion of the well, a geothermal well completion report (form 3260-4) must be submitted to BLM.

Operational Requirements

The rules establish general standards that apply to drilling operations. They include meeting all environmental and operational standards, preventing unnecessary impacts to surface and subsurface resources, conserving geothermal resources and minimizing waste, protecting public health, safety and property, and complying with the requirements of the Act; implementing regulations; Geothermal Resource Operational Orders; notices to lessees; lease terms and stipulations; approved plans and permits; conditions of approval; verbal orders from BLM which will be confirmed in writing; other instructions from BLM; and any other applicable laws and regulations (43 CFR 3200.4). Federal regulations 43 CFR subparts 3260 through 3267 establish permitting and operational procedures for drilling wells, conducting flow tests, producing geothermal fluids, and injecting fluids into a geothermal reservoir. Also included in these regulations are redrilling, deepening, plugging back and other well re-work operations.

BLM operational requirements for drilling include: keeping the wells under control at all times, conducting training during operation to ensure trained and competent personnel can perform emergency procedures effectively, and using properly maintained equipment and materials. Other requirements include employing sound engineering principles using all pertinent data, selecting drilling fluid types and weights, providing a system to control fluid temperatures, providing blowout prevention equipment, and providing a casing and cementing program.

Mechanical Integrity Testing

Generally, BLM requires that wells be tested once every two years unless problems have occurred with a well. Casing failures or other problems can lead to orders from BLM specifying more frequent MIT.

BLM also may specify particular types of MITs, such as hydraulic pressure tests and electronic casing log tests, or approve other methods proposed by operators on a case-by-case basis. Hydraulic pressure tests require a bridge plug to be placed as close as possible to the injection zone and the casing tested to a surface pressure of 1,000 psi or 200 percent of the maximum injection pressure, whichever is greater. However, the test pressure is not to exceed 70 percent of the minimum internal yield. If pressure declines more than 10 percent in 30 minutes, corrective action must be taken to identify and correct the cause of the pressure loss. Electronic casing log tests are run every two years and require injection well casing thickness to be no less than 75 percent of new nominal wall thickness. If the well fails this test, it must be placed out of service until BLM approves reactivation.

Financial Responsibility

Before initiating any operation, operators are required to deposit a security or personal bond, subject to approval by BLM.

Plugging and Abandonment

In order to abandon a well, a notice that documents the proposed plugging and abandonment program must be approved before closure begins. The local BLM office must also be notified before beginning abandonment so that they can witness the closure. Furthermore, a well abandonment report must be submitted to BLM within 30 days after completion of abandonment. The abandonment report includes a description of each plug, including the amount and type of cement used, the depth that the drill pipe or tubing was run to set the plug, the depth to the top of the plug, if the plug was verified, whether pressure testing or tagging was used, and a description of the surface restoration procedures.

Geothermal Resources Operational Order Number 3, effective February 1, 1975, states specific requirements for well plugging and abandonment. Cement used to plug any geothermal well, except for surface plugging, must be placed into the well hole by pumping through a drill pipe or tubing. Plugging cement should consist of a high temperature resistant admix, unless waived by the Site Supervisor. In uncased portions of the well, as well as in production perforations, cement plugs must be placed to protect all subsurface mineral resources including fresh water aquifers. These plugs must extend a minimum of 100 feet below and, if possible, 100 feet about the aforementioned zones. Intervals of the hole not filled with cement must be filled with good quality heavy mud. All open annuli extending to the surface must be plugged with cement and the innermost casing string which reaches ground level must be cemented or concreted to a minimum depth of 50 feet measured from 6 feet below ground level. All casing strings must be cut off at least 6 feet below the ground level and capped by welding a steel plate on the casing stub. The surface area must be restored as specified by the site supervisor.

7.2 State and Local Programs

As discussed in Section 3 above, more than 85 percent of the documented wells and more than 90 percent of the estimated wells under either state or federal jurisdiction are located in six states: New Mexico, Utah, California, Nevada, Idaho, and Oregon. Attachment A of this volume describes how each of these states regulate direct heat return flow wells.

Individual permits are required for geothermal direct heat return flow wells in all states. The individual permit requirements are, in most cases, similar to those for Class II wells. The states' requirements include detailed siting and construction requirements, monitoring and other operating requirements, mandatory MIT, detailed requirements for plugging and abandonment, and financial responsibility requirements. In several of these states, the state agency responsible for regulating geothermal direct heat return flow wells also has jurisdiction over other natural resources, such as oil and gas, and is separate from the state’s Class V UIC program.

C In addition to the USEPA Regional oversight of Class V wells in this Direct Implementation state, California issues individual permits to geothermal direct heat return flow wells under the authority of its Public Resources Code and regulations governing geothermal resources. A detailed permit application allowing for case-by-case permitting decision is required. The state specifies, in regulations and permit conditions, requirements for well construction, operation, MIT, plugging and abandonment, and financial responsibility.

C Idaho is a Primary State for UIC Class V wells. The state issues individual permits for direct heat return flow wells under its UIC Class V program as well as its authority over geothermal resources. Permits are based on extensive background information, and specify well location and construction. Wells are required to supply information on the impact of injection on the geothermal reservoir and on other natural resources. Plugging and abandonment must be approved in advance.

C New Mexico is a Primacy State for UIC Class V wells, but has delegated authority over direct heat return flow wells to the Oil Conservation Division (OCD). The OCD, working with the State Engineer, issues individual permits for direct heat return flow wells under the authority of the state's Geothermal Resources Act, using a proposed rule as additional guidance on siting and construction, operating requirements, annual MIT, required plugging and abandonment plans, and financial responsibility.

C Nevada issues individual permits to direct heat return flow wells under its authority as a UIC Class V Primacy State. In addition, the State Engineer and Division of Minerals also permit direct heat return flow wells under their authority over geothermal resources. Detailed siting and construction standards, operating requirements, requirements for plugging and abandonment, and financial responsibility are found in both the UIC regulations and the regulations governing geothermal resources. Direct heat return flow wells in the state must satisfy both sets of standards.

C Oregon is a Primary State for UIC Class V wells. The state, through the Water Resources Department, regulates direct heat return flow wells under its water resource regulations pertaining to either low temperature or high temperature geothermal production and disposal. The state geologist within the Department of Geology and Mineral Industries also permits all geothermal wells. Such wells also must meet construction standards, operating requirements, MIT requirements every five years, and must follow specified plugging procedures.

C Utah is a Primary State for UIC Class V wells. Utah's Division of Water Rights (DWR) issues individual permits to direct heat return flow wells under its authority over geothermal energy production found in the state's water rights code. DWR's jurisdiction is intended to eliminate duplication of regulation, particularly with the state's Class V UIC program and Bureau of Pollution Control. The DWR applies detailed well siting and construction requirements; requires testing and monitoring of injection operations, individual MIT; sets stringent plugging and abandonment requirements; and requires bonds for financial responsibility.

ATTACHMENT A
STATE AND LOCAL PROGRAM DESCRIPTIONS

This attachment describes the control programs in the states in which direct heat return flow wells are most prevalent, namely California, Idaho, Nevada, New Mexico, Oregon, and Utah. In combination, these states have all but 4 of the 31 documented wells in the national inventory.

California

USEPA Region 9 directly implements the UIC program for Class V injection wells in California. At the state level, the California Department of Conservation, Division of Oil, Gas, and Geothermal Resources (CDOG) is the state agency with direct responsibility for geothermal direct heat return flow wells under Chapter 4 of Division 3 of the California Public Resources Code (PRC) (Sections 3700 - 3776). The Department has enacted state-wide geothermal regulations in Title 14, Chapter 4, Subchapter 4 of the California Code of Regulations (CCR). The PRC explicitly covers "any special well, converted producing well or reactivated or converted abandoned well employed for reinjecting geothermal resources or the residue thereof" (3703 PRC). The regulations define an injection well as "a service well drilled or converted for the purpose of injecting fluids" (1920.1(e) CCR). They also specify that injection wells may be used for the disposal of waste fluids, the augmentation of reservoir fluids, pressure maintenance of reservoirs or for any other purpose authorized by CDOG. New wells may be drilled and/or old wells may be converted for water injection or disposal service (1960 CCR).

Under California's Water Quality Control Act (WQCA), the state is divided into nine regions, and Regional Water Quality Control Boards, which are organizations separate from CDOG, are delegated responsibilities and authorities to coordinate and advance water quality (Chapter 4 Article 2 WQCA). A Regional Board can prescribe requirements for discharges (waste discharge requirements or WDRs) into the waters of the state, including ground water[6] (13263 WQCA). A WDR can pertain to injection wells (13263.5 and 13264(b)(3) WQCA) and at least one Regional Board has issued a WDR for geothermal wells.

Permitting

Under the state geothermal regulations, injection well operators must file a Notice of Intent to Drill, post a bond or surety prior to injection operations, and pay an application fee (3724 PRC, 1931 CCR). Operations may not commence until the CDOG reviews and approves the application (3724.3 PRC; 1931 CCR). Applicants must provide a letter setting forth the entire plan of operations that includes analysis of reservoir conditions, method of injection (i.e., through casing, tubing, or tubing with a packer), source of injection fluid, and estimates of the daily amount of water to be injected. The application must include a map of the well field along

[6] The WQCA defines "waters of the state" as "any surface or ground water, including saline waters, within the boundaries of the state."

with one or more cross sections showing the wells involved and a copy of any environmental documents created in support of the operations. Notice is also required when operators convert an existing well to an injection or disposal well, even if there will be no change in mechanical condition as a result of the conversion. In addition, applicants must provide chemical analyses of injectate and injection zone fluids. Finally, the application must contain copies of the letter of notification sent to neighboring operators, if required by CDOG (3724, 3724.1 PRC). Officials set permit conditions on a case-by-case basis.

Regional Water Quality Control Boards can include special monitoring and reporting requirements in a Waste Discharge Requirement's monitoring and reporting program (3724 PRC).

Siting and Construction

The CDOG's geothermal regulations contain specifications for well construction. All wells must be cased in a manner that protects or minimizes damage to the environment, surface and ground waters, geothermal resources, life, health, and property (1935 CCR). Conductor pipe must be cemented with sufficient cement to fill the annular space from the shoe to the surface (1935.1 CCR). Surface casing must provide for control of formation fluids, protection of ground water, and prevention of blowouts. However, the specific requirements regarding length of casing and cementing point may be waived or modified for low-temperature geothermal wells (1935.2 CCR). Intermediate casing must be cemented solid to the surface whenever possible (1935.3 CCR). Similarly, production casing may be set above or through the injection zone and cemented above the objective zones (1935.4 CCR). The specific casing design criteria are determined on a case-by-case basis, depending on the hydrogeological conditions at each well field (3740 PRC).

State regulations also contain standards for blowout prevention. Each well must be equipped with blowout prevention equipment (BOPE) that includes high temperature-rated packing units and ram rubbers. This equipment must have a working-pressure rating equal to or greater than the lesser of (a) a pressure equal to the depth of the BOPE anchor string in meters multiplied by 0.2 bar per meter, (b) a pressure equal to the rated burst pressure of the BOPE anchor string, or (c) a pressure equal to 138 bars (2,000 psi). The state generally prohibits drilling in unstable geothermal areas, including areas with fumaroles, geysers, hot springs, and mud pots. However, if drilling in these areas is approved, drilling operations must be monitored by state officials until the surface casing has been cemented and the BOPE has been pressure-tested satisfactorily (1941-1942.2 CCR).

Operating Requirements

Completed and operating geothermal injection wells must be maintained and tested to prevent loss of or damage to life, health, property, and natural resources. All surface and wellhead equipment and pipeline, and subsurface casing and tubing must be examined periodically for corrosion. Operators must show "complete" casing integrity upon completion of a new injection well, when converting a production well to an injection well, or when reactivating an idle well. The geothermal regulations also require monitoring of injection well operations on a "continuing" basis to establish that all injectate is confined to the intended injection zone. CDOG staff (well supervisors) conducts onsite inspections periodically to note surface conditions and determine remedial action needed to address problems, if any. Operators must examine, document, and report injection pressures to CDOG, and CDOG may rescind injection approval if it appears damage is being done (1966 CCR).

Mechanical Integrity

Casing integrity tests must be performed within 30 days after injection starts and every two years thereafter, unless otherwise specified by CDOG. State regulations mandate the use of MITs to prevent damage to life, health, property, and natural resources; to protect geothermal reservoirs from damage; and to prevent the infiltration of detrimental substances into underground or surface water suitable for agricultural, industrial, municipal, or domestic use. Casing tests must be performed, which may include spinner surveys, wall thickness, pressure, and radioactive tracer tests. Cementing tests are also required, which may include tests on cementing of the casing, pumping of plugs, hardness of plugs, and depths of plugs. Finally, regulations require equipment testing of gauges, thermometers, surface facilities, lines, vessels, and BOPE. The CDOG well supervisor is delegated authority to require "such tests or remedial work as in his or her judgment are necessary" to prevent damage "or to prevent the infiltration of detrimental substances into underground or surface water ..." and therefore may determine the type and frequency of these tests on a case-by-case basis (1954 CCR).

Financial Responsibility

Operators must file an individual indemnity bond that secures the state against all losses, charges, and expenses incurred from assuring compliance with the state's geothermal resources regulations. The bond must be filed with CDOG at the time operators file the Notice of Intent to Drill. Bonds must be executed by the owner, as principal, and by an authorized surety company, as surety, on condition that the principal named in the bond will comply with all the provisions of the state's geothermal regulations. The bond's language must substantially conform to the language provided in California's Public Resources Code, Chapter 4, §3725. Operators may choose to file an individual indemnity bond of $25,000 for each well drilled, redrilled, deepened, maintained, or abandoned; or they may file a blanket bond of $100,000 to cover all operations statewide. Individual and blanket bonds may be terminated and canceled after the wells have been properly abandoned (3725.5 PRC). Liability for individual wells covered under a blanket bond may be terminated by consent of the CDOG supervisor (3725 and 3728 PRC).

Plugging and Abandonment

Under the geothermal requirements of PRC, an operator must file for and obtain written approval to abandon, specifying the proposed method of abandonment. Furthermore, the operator must file the request at least 10 days before the proposed abandonment (3747 PRC). Unless otherwise approved, no person shall remove the casing from a geothermal injection well without first giving written notice to the state of the intention to do so. The notice shall be given at least 10 days before the proposed removal (3751 PRC). Within 60 days after the completion of abandonment of any well, the owner or operator of the well must provide a written report of completion. The CDOG well supervisor, in turn, must furnish the owner/operator with a written final approval of abandonment or disapproval (3748 PRC).

The regulations provide detailed requirements for plugging and abandonment. They include, for cased wells (including injection wells) a requirement that cement plugs must extend from the bottom of the geothermal zone or perforations to 30 meters over the top of the zone or perforations. Cement plugs must be placed from 15 meters below to 15 meters above liner tops. The requirements also address casing salvage, plugging of stubs and laps, shoe plugs, bridge plugs, surface plugs, and other specifications (1980 - 1981.2 CCR).

Idaho

Idaho is a UIC Primacy State for Class V wells and has promulgated regulations for all types of Class V wells. Geothermal wells used for direct heat are regulated in the Administrative Rules of the Idaho Water Resource Board (WRB), specifically, the Rules for the Construction and Use of Injection Wells (IDAPA 37 Title 03, Chapter 03) and Drilling for Geothermal Resources (IDAPA 37, Title 03, Chapter 04).

Permitting

Construction and use of deep injection wells (>18 feet) requires a permit (IDAPA 37.03.03.025.03(c)). Construction and use of shallow injection wells (<18 feet) is authorized by rule only if all required inventory information is submitted, and use of the well will not endanger USDWs or violate the state's water quality standards (IDAPA37.03.03.025.03(d)). Construction and use of geothermal production, exploration, or injection wells is authorized by permit (IDAPA 37.03.04.025.02).

Permit applications should include, but not be limited to, the following information: maps of the well area, locations of other drainage wells, construction information for the well, quantity and general character of the injected fluids, geologic and physical characteristics of the injection zone and confining beds, contingency plans to cope with well failures, and proof that the applicant is financially responsible, such as through a performance bond, to abandon the well properly (IDAPA 37.03.03.035).

Permits may be in effect for Class V wells for no longer than 10 years (IDAPA 37.03.03.040.07).

Siting and Construction

Class V wells requiring a permit may be required to be located at a minimum distance from a point of diversion for beneficial use that may be harmed from accidental or unauthorized injection, as determined by the Director. These requirements may be waived if the applicant can demonstrate that any springs or wells in the calculated perimeter of the perched water zone will not be contaminated by the applicant's well (IDAPA 37.03.03.050.03).

Owners or operators of a proposed injection well must submit the following information to the WRB: existing reservoir conditions, method of injection, source of injection fluid, estimate of daily amount of material to be injected, zones or formations affected, and analysis of fluid to be injected and of the fluid from the intended zone of injection (IDAPA 37.03.01.040).

Injection wells must be constructed to prevent the entrance of any fluids other than specified in the permit, as well as to prevent waste of fluids or movement of fluids from one aquifer to another (IDAPA 37.03.03.045.04.d).

Wells shall be located more than 100 feet from the boundary of the parcel of land on which the well is situated, or more than 100 feet from a public road. This requirement may be waived or modified by the WRB upon written request. Modifications may be made by giving consideration to factors such as topographic, geologic, hydrologic characteristics of the area, minimizing well interference, minimizing interference with multiple uses of the land, and protection of the environment (IDAPA 37.03.04.025.05).

Wells must be cased in a manner that protects or minimizes damage to the environment, usable ground waters, geothermal resources, life, health, and property. Specifications for casing strength may be determined by the WRB on a well-by-well basis. The permanent wellhead completion equipment must be attached to the production casing or to the intermediate casing if production casing does not reach the surface. All casing reaching the surface must provide adequate coverage for blow-out prevention equipment, hole protection control, and protection for natural resources. Sufficient casing must be run to reach a depth below all known and reasonably estimated ground water levels to prevent blow-outs or uncontrolled flows. Detailed requirements for conductor pipe, surface casing, production casing and intermediate casing are included in the regulations (IDAPA 37.03.04.025.06).

Operating requirements

For each well requiring a permit, the quality of injected fluids must either meet MCLs or other drinking water standards, or meet the concentration of chemical contaminants in receiving waters, whichever standard is less stringent. BMPs may be required to reduce coliform concentration in injectate. Monitoring for coliform may be required.

All injection wells authorized by rule must meet drinking water standards at the point of injection, and must not cause a violation of drinking water standards (IDAPA 37.03.03.050).

The owner/operator of a proposed injection well shall provide the WRB with information necessary for the evaluation of the impact of such injection on the geothermal reservoir and other natural resources. This information may include existing reservoir conditions, method of injection, source of injection fluid, estimates of daily amount of material to be injected, zones or formations affected, and analysis of fluid to be injected and of fluid from the intended zone of injection (IDAPA 37.03.04.040.01).

Mechanical Integrity

An owner or operator who proposes to drill or modify an injection well or convert a producing or idle well to an injection well must demonstrate by means of a test that casing has "complete" integrity (IDAPA method approved by the Director).

To establish integrity of annular cement above the shoe of the casing, the owner or operator must make sufficient surveys within 30 days after injection has started to prove that all injected fluid is confined to the intended zone of injection. Thereafter surveys shall be made at least every two years or more often if necessary. The WRB may grant a waiver from such tests (IDAPA 37.03.04.040).

The injection well owner/operator must develop approved procedures to detect constructional or operational failure in a timely fashion, and have contingency plans to cope with well failure (IDAPA 37.03.03.045.05(c)).

Financial Responsibility

The injection well owner/operator shall maintain financial responsibility to insure that the injection operation is abandoned as prescribed (IDAPA 37.03.03.045.06.(f)). Owners/operators must file with the Director a bond no less than $10,000 indemnifying the State of Idaho providing sufficient security conditioned upon the performance of the duties required by the regulations and the proper abandonment of the well (IDAPA 37.03.04.025.04).

Plugging and Abandonment

A notice of intent to abandon a geothermal resource well must be filed with the WRB five days prior to abandonment procedures (IDAPA 37.03.04.045.01). All wells shall be monumented with a four inch diameter pipe, ten feet in length of which four feet shall be above ground. The remainder shall be embedded in concrete. Good quality heavy drilling fluid shall be used to replace any water in the hole and to fill all portions of the hole not plugged with cement. All open annuli shall be filled solid with cement to the surface. A minimum of one hundred feet of cement shall be emplaced straddling the interface or transition zone at the base of the ground water aquifers (IDAPA 37.03.04.045.02). The state has prepared "General Guidelines for Abandonment of Injection Wells." The guidelines are not mandatory, and explain that because the final abandonment procedure must be specific to the well, it must be approved prior to abandonment.

- Casing should be pulled. If it cannot be pulled, the casing should be cut a minimum of two feet below the land surface, and a cement cap should be placed at the top of the casing after plugging the well, with at least two feet of soil covering the filled hole/cap.

- If the casing is left in place, it should be perforated and cement containing up to 5% bentonite may be pressure-grouted to fill the hole. Coarse bentonite chips or pellets may be used. A screen may be used if the well extends into the aquifer.

- If the well extends into the aquifer, a clean pit-run gravel or road mix can be used to fill the bore hole up to ten feet below the top of the saturated zone, or ten feet below the casing, whichever is deeper, and cement grout or bentonite clay used to the surface.

- The abandonment process must be witnessed by an IDWR representative.

Nevada

Nevada is a UIC Primacy State for Class V wells in which the Division of Environmental Protection (DEP) administers the UIC program. Direct heat return flow wells must satisfy Nevada's UIC program requirements. Geothermal wells also must satisfy special requirements pertaining to geothermal resources under the Division of Mineral's regulations.

UIC Statutes and Regulations

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 underground injection control 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 the USEPA does not disapprove the exemption within 45 days after notice of it (445A.850 NRS). The statute defines geothermal wells used in heating as Class V wells (445A.849 NRS).

Regulations, particularly Chapter 445A NAC, "Underground Injection Control," define and elaborate these statutory requirements. First, they provide that any federal, state, county, or municipal law or regulation that provides greater protection to the public welfare, safety, health, and to the ground water prevails within the jurisdiction of that governmental entity over the Chapter 445A requirements (445A.843 NAC).

<u>Permitting.</u> 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.

<u>Siting and Construction.</u> The state specifies, among other siting requirements, that the well must be sited in such a way that it injects into a formation separated from any USDW by a

confining zone 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 injection zone and cemented to prevent movement of fluids into or between USDWs (445A.908 NAC).

Operating Requirements. Monitoring frequency for injection pressure, pressure of the annular space, rate of flow, and volume of injected fluid is specified by the permit for Class V wells. Analysis of injected fluid must be conducted with sufficient frequency to yield representative data.

Mechanical Integrity. MIT is required once every 5 years, by a specified method.

Financial Responsibility. Class V geothermal injection wells are charged fees by DEP. Fees are lower if the wells discharge less than 250,000 gallons daily (445A.872 NAC). Class V geothermal injection wells also are specifically required to satisfy bonding requirements, and must be covered by a bond either equal to the estimated cost of plugging and abandonment of each well or, if approved by DEP, a sum not less than $50,000 to cover all injection wells of the permit applicant in the state. However, these bonding requirements may be waived or reduced by DEP upon receipt of adequate proof of financial responsibility (445A.872.3 NAC).

Plugging and Abandonment. A plugging and abandonment plan and cost estimate must be prepared for each well, 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 USDW (445A.923 NAC).

Regulations on Geothermal Resources

In addition to Nevada's requirements pertaining to underground injection wells, geothermal wells used for direct heat also must satisfy regulations of the State Engineer and the Division of Minerals (DOM). These requirements are found in Chapter 534A NAC, "Geothermal Resources."

These regulations define a geothermal injection well as any well used to dispose of fluids derived from geothermal resources into an underground reservoir (534A.061 NAC). They further divide geothermal wells into three categories based on the use of the geothermal resource. A geothermal well is considered a commercial well if it is primarily used to provide geothermal resources on a commercial basis for purposes other than the generation of power (534A.170.2 NAC).

Permitting Requirements. The state requires a permit to drill or operate an individual geothermal well. Geothermal operators are required to file a Notice of Intention to Drill with the State Engineer, including descriptions of the purpose, location, estimated depth, casing, blowout protection, and drilling rig. The application must include information concerning well ownership, including the name of the land owner where the well will be sited, the name of the geothermal resource owner, and the name and address of the well operator and drilling contractor. Each permit application must include the appropriate financial assurance bond.

Finally, the permit must include a description of the location by the quarter section, section, township, and range. If the area has not been mapped, the application must state the location by distance and direction from an established landmark. Operators may also apply to permit wells for an entire project area, and must submit all the information required for individual permits (534A.190 and 534A.193 NAC).

In addition to geothermal well permit requirements that address production and injection wells alike, applications for geothermal injection wells must contain additional information for permit approval. This includes a description of the casings in the wells or proposed wells; the proposed method for testing the casings before injection; the estimated maximum injection pressure and temperature; and a description of the proposed pipelines, metering equipment, and safety devices used to prevent accidental pollution (534A.196 NAC).

Siting and Construction. Injection wells may not be drilled within 100 feet of the boundary of the land on which the well is sited (except for non-profit organizations) or a public road, street or highway. Exceptions to these regulations may be granted by DOM after considering such factors as the topographic, hydrologic and geologic characteristics of the area; characteristics of the reservoir; protection of the environment; and any existing rights. All wells must be cased in a manner that minimizes damage to the environment, ground and surface waters, geothermal resources, and property. Completion equipment for the well must be attached to the surface casing, and all casing reaching the surface must provide adequate anchorage for blowout protection equipment. Also, surface casing must provide for control of formation fluids and protection of fresh water. The annular space must be filled by circulating cement up the annulus to the surface. If the cement does not circulate or falls back, the casing must be cemented at the surface (534A.200, 534A.260, 534A.430 NAC) .

Operating Requirements. Unless otherwise approved, all geothermal fluids must be reinjected into the same reservoir from which they originated. Operators must take all necessary precautions to keep wells under control and operating safely at all times (534A.270, 534A.420 NAC).

Industrial geothermal well operators must complete monthly reports of production and temperature, based on continuous metering of rate of flow of water, steam, and pressure and temperature of fluids (534A.400, 534A.410, 534A.460 NAC). The injection of fluid for recharging, to maintain pressure, or for the disposal of water, must be reported in writing to DOM (534A.570 NAC). The owner or operator must notify DOM of the start date of injection before beginning injection, and notify DOM of discontinuation of injection within 10 days of discontinuation (534A.570 NAC).

Mechanical Integrity Testing. Nevada geothermal regulations do not specify MIT. However, the code states that all equipment used or purchased for development and production of geothermal resources must meet the minimum standards generally accepted for geothermal well equipment. DOM may require additional testing or repairs to prevent waste and damage to the environment.

Financial Responsibility. In addition to small annual fees, Nevada also requires operators to provide a sufficient bond of at least $10,000 per well to indemnify the state against costs of enforcing its geothermal regulations. Liability ceases upon proper well abandonment. Operators may also file blanket bonds of at least $50,000 to cover all wells to be operated statewide. Bonds must be in cash, issued by a surety authorized to do business in Nevada, or in the form of a savings or time certificate of deposit. If the certificate is used, it must be issued by a bank or savings and loan association operating in Nevada, and payable to the State of Nevada. Operators who deposited a surety bond guaranteeing performance with the federal government for wells drilled on federal land must file a copy of the bond with DOM (534A.250 NAC).

Plugging and Abandonment. Operators must file a request to abandon a well with DOM, including a detailed statement of the proposed abandonment activities. Cement used to plug the well, except for surface plugging, must be placed in the hole by pumping through drill pipe or tubing. The cement mix must be able to withstand high temperatures. Cement plugs must be placed in the uncased portion of wells to protect all subsurface resources. The plug must extend a minimum of 100 lineal feet above the producing formations and 100 lineal feet below the producing formations, or to the total depth drilled, whichever is less. Where there is an open borehole, a cement plug must be placed in the deepest casing string.

If there is a loss, or anticipated loss, of drilling fluids into the formation or if the well has been drilled with air or another gaseous substance, a permanent bridge plug must be set at the casing shoe and capped with a minimum of 200 lineal feet of cement. Cement plugs must also be placed across perforations, extending 100 lineal feet below, or to the total depth drilled, whichever is less, and 100 lineal feet above the perforations. If a cement retainer is used to plug perforations, it must be placed a minimum of 100 lineal feet above the perforations. DOM must approve cutting and recovering the casing. All annular spaces extending to the surface must be plugged with cement, and the innermost string of casing that reaches ground level must be cemented to a minimum depth of 50 feet below the top of the casing. Any interval not cemented must be filled with good quality heavy drilling fluids. Finally, the surface should be restored as near as practicable to its original condition, including cutting all casing strings below ground level, capping casing strings by welding a steel plate on the stub, and removing all structures and other facilities (534A.490 NAC).

New Mexico

New Mexico is a UIC Primacy State for Class V wells.[7] Direct heat return flow wells are principally regulated by OCD under a delegation of responsibility under the Geothermal Resources Act, rather than the UIC program. The OCD and the New Mexico State Engineer Office (SEO) acting jointly issue permits for direct heat return flow wells. OCD and SEO use Proposed Draft Rule 21 (PD 21), October 6, 1997 (which has not yet been finally promulgated) as guidance.

Permitting

Under PD 21, an approved discharge permit is required prior to injection. PD 21 specifies detailed information that must be included in support of the discharge permit application, including maps showing the location of the proposed wells; proposed maximum and average injection pressures, rates and injection volume; appropriate geological data (i.e., structure of the area; injection zone interval including lithologic detail, name, thickness and depth); proposed stimulation program; proposed injection procedure; proposed construction procedures, including a cementing and casing program; logging procedures; deviation checks; and a drilling, testing, and coring program; and a closure plan including a cost estimate sufficient to plug and abandon the well and close the facility in a manner that protects public health and the environment (PD 21.B).

Siting and Construction

Casing must be designed to prevent corrosion, loss of disposal fluids, and contamination of fresh water resources. A minimum of one casing string must be set below all fresh water bearing strata and cemented to the surface. All intermediate casing strings must be cemented to the surface. All cement tops and cement integrity must be verified by logging (PD 21.B.15). Appropriate logs must be kept and tests conducted during the drilling and construction of new wells and submitted to OCD for review prior to well injection. (PD 21.E.1.o)

Operating Requirements

There must be an approved discharge permit prior to injection. Specific operating requirements, which are separate from permit application requirements, such as boundary markings, injection pressure, flow rate, flow volume, and annulus pressure, are described in PD 21. The concentration of the injectate must be 10,000 mg/l or less TDS. The maximum injection pressure at the wellhead shall not initiate new fractures or propagate existing fractures in the confining zone, or cause the movement of injection or formation fluids into ground water

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[7] The state defines "ground water" as "interstitial water which occurs in saturated earth material and which is capable of entering a well in sufficient amounts to be utilized as a water supply" (20-6-2-I-1101.V NMAC). The state seeks to protect ground water "which has an existing concentration of 10,000 mg/1 or less TDS, for present and potential future use as domestic and agricultural water supply" (20-6-2-III-3101.A NMAC).

having 10,000 mg/l or less TDS. Injection between the outermost casing and the well bore is prohibited in a zone other than the injection zone (PD 21.E.1). Continuous monitoring and recording devices must be installed and mechanical charts made of injection pressure, flow rate, flow volume, and annular pressure. Continuous hydrogen sulfide monitoring devices also must be installed to protect public health. These devices must be checked and readings recorded daily (PD 21.F). Monthly and quarterly reports must be provided to OCD.

In addition to requirements under the Geothermal Resources Act, the New Mexico Environmental Department (NMED) requires the discharger to submit a contingency plan for NMED approval which addresses and outlines corrective action measures to be implemented should the system fail or the discharge result in ground water contamination.

Mechanical Integrity

Under PD 21, a well has mechanical integrity if there is no detectable leak in the casing, tubing, or packer while operating at maximum operating temperature and pressure; and no detectable conduit for fluid movement out of the injection zone through the well bore or vertical channels adjacent to the well bore (PD 21.D.1). Mechanical integrity tests are required prior to commencing injection and at least once yearly during operation (PD 21.D.2).

Financial Responsibility

Financial assurance in the form of a Plugging and Abandonment Bond and Safety Bond in the amount of the estimated closure cost described in the permit application must be submitted to OCD (PD 21.C).

Plugging and Abandonment

Notification to OCD is required 30 days prior to the cessation of operations. Closure shall be in accordance with the approved closure plan and any modifications or additional requirements made by OCD to protect public health and the environment. Prior to the release of the financial assurance covering the facility, OCD will inspect the site to determine that closure is complete (PD 21.H.1).

Oregon

Oregon is a UIC Primacy State for Class V wells. Under the statutory authority of Chapter 552 of the Oregon Revised Statutes, two state agencies have promulgated rules for geothermal wells used for direct heat. The Water Resources Department (WRD) has promulgated Division 210 of the Administrative Regulations (OAR) (690-210-0005 et seq.), which includes well construction standards and Division 230 (690-230-0005 et seq.), which includes standards and procedures for low-temperature geothermal production and injection wells and effluent disposal systems. The Department of Geology and Mineral Industries (DGMI) has promulgated Division 20 (632-020-0005 et seq.), which includes geothermal regulations covering re-injection of geothermal fluids into underground reservoirs to ensure that the re-injection will not be detrimental to the beneficial uses of waters of the state. However, compliance also is required with Water Resources Department rules (632-020-0005(1) and (3) OAR).

Permitting

A permit to drill or operate any geothermal injection well is required from the State Geologist under the rules of the DGMI. The application for the permit must include an injection plan, map of the area, injection fluid characteristics, characteristics of the injection zone, hydrology of the area, estimated impacts of the injection, and proposed equipment and design (OAR 632-020-0155). WRD also permits on an ad hoc basis.

Siting and Construction

WRD applies general standards for well construction by rule (OAR 690-200-0005 to 0110) as well as special standards (OAR 690-230-0005 to 0140) on an ad hoc basis.

WRD requires wells to be constructed in a manner that protects ground water[8] from contamination, waste, loss of artesian pressure, and substantial thermal alteration (OAR 690-230-0030 (2)). Well construction standards include detailed requirements regarding materials used and methods for drilling and construction (OAR 690-210).

Low temperature geothermal production and injection wells must be constructed in conformance with WRD's rules in OAR 690-200-0005 to 690-225-0110 (Well Construction and Maintenance, Well Driller Licensing, Well Construction Standards, Abandonment of Wells) with specific modifications described in OAR 690-230-0005 to 690-230-0140.

No low temperature geothermal wells with an injection rate of less than 15,000 gpd can be located within 75 feet of any geothermal production well using the same ground water reservoir unless both wells are owned by the same person (OAR 690-230-0040).

The owner of any low-temperature injection well having an injection rate of greater than 15,000 gpd must have a separation distance between production and injection wells that is adequate to protect production wells from substantial thermal interference (OAR 690-230-0045).

An injection plan must be filed with WRD (OAR 690-230-0110 and 0115). Well “start card” and well logs must be filed by the well driller identifying the intended use of the well (OAR 690-230-0050). All wells may be inspected during and following construction.

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[8] The state's rules on ground water quality protection provide that all ground waters shall be protected from pollution that could impair existing or potential beneficial uses for which the natural quality of the ground water is adequate.

Operating Requirements

Adequate well-head protection equipment to insure public safety and the protection of ground water resources must be installed on any low-temperature injection or production well when the temperature of the fluid being withdrawn from the well bore exceeds 150 degrees F. Wells must be pump tested (<15,000 gpd for 1 hour, >15,000 gpd for 4 hours). Water well reports must include the temperature of fluid as measured at the discharge point at the beginning and end of the timed production test, as well as the maximum fluid temperature attained during the test (OAR 690-230-0070).

Procedures required to inject effluent into a low temperature 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.

Mechanical Integrity

All injection wells must be tested for mechanical integrity at least once every five years to determine there is no leak in the casing, and that there is no fluid movement into a USDW other than that from which the fluid was produced. The state must witness MITs (OAR 632-020-0157).

Financial Responsibility

There are no financial responsibility requirements.

Plugging and Abandonment

The owner/operator must give notice of at least 24 hours before the proposed date for commencement of abandonment procedures. Detailed plugging procedures are specified in the regulations at OAR 632-020-0125.

City of Klamath Falls, Oregon

An example of local regulation of direct heat return flow wells is provided by the City of Klamath Falls, one of the state's local communities that regulates geothermal wells and resources within and adjacent to the city. Klamath Falls' City Code provides for the conservation and beneficial management of geothermal resources and thermal ground waters, so as to assure their continued availability and productivity (8.250.1). Other sub-purposes include minimization of the potential for damage to or degradation of geothermal resources and thermal ground waters and protection of the subsurface environment during development and utilization of geothermal resources (8.250).

Prior to constructing, installing, or altering a well within the city limits, an application for a well permit must be submitted to the city's Geothermal Data Center. Permits will be granted based on several criteria, including, but not limited to, the estimated hydrological impacts of the proposed well's operation on the reservoir and surrounding wells, the adequacy of provisions for environmental protection and public safety, and the compliance of the proposed well and its use with all applicable city laws, ordinances, and regulations. The ordinance is also intended to be compatible with all pertinent state regulatory requirements (8.276).

The City Manager may attach conditions to the well permits as necessary to ensure the conservation and protection of geothermal resources, and/or their efficient utilization. Such conditions may include restrictions on hours of well operations, well design requirements above and beyond state requirements, restrictions on pumping, heat exchanging, storage and/or injection operations, or requirements for scientific sampling, testing or monitoring (8.280).

Once the well has been completed or altered, the owner/operator must provide a well completion inspection and report assuring compliance with the city ordinance and registration with the Geothermal Data Center (8.284).

Utah

Utah is a UIC Primacy State for Class V wells. Utah's DWR has primary regulatory authority among state agencies over wells used for geothermal energy production under Chapter R655 of the Utah Administrative Code (UAC), "Water Rights." Geothermal injection wells are defined as any special wells, converted producing wells, or reactivated abandoned wells used to maintain geothermal reservoir pressure, provide new material, or re-inject any material medium, residue, or by-product of geothermal resource exploration/development.

Permitting Requirements

Any person or operator who wishes to construct an injection well must submit an application form to DWR. This requirement extends to modifying an existing injection well and converting another well type to an injection well (even in cases where mechanical condition does not change). The application must contain information detailing location, elevation, and layout; lease identification and well number; a list of tools and equipment to be used; expected depth and geologic characteristics; drilling, mud, casing, and cementing plans; logging, coring, and testing plans; waste disposal plans; environmental considerations; and emergency procedures. Information contained in permit applications may be shared with other state agencies having interest in or jurisdiction over injection issues. To the extent possible, DWR will eliminate duplicative application efforts with other interested agencies, including the Bureau of Pollution Control. DWR conditions permits on a case-by-case basis (UAC R317-7-6 thru R317-7-9).

Siting and Construction

Injection wells used in geothermal operations must be located more than 100 feet from the boundary of the parcel on which the well is situated. In addition, injection wells must be more than 100 feet from a public road, street, or highway dedicated prior to the commencement of drilling. The State Engineer must approve all well spacing proposals, giving consideration to topographic characteristics of the area, hydrogeological characteristics, well interference, economic considerations, and environmental protection. Regulations also allow DWR to approve directional drilling for parcels of one acre or more whose surface is unavailable for drilling. In such cases, the surface well location may be on another property that may or may not be contiguous to the property containing the geothermal resource (UAC R655-1-2.4.1 through 2.4.5).

Regulations governing well construction require that all wells be cased in a manner that protects or minimizes damage to the environment, usable ground waters, geothermal resources, life, health, and property. Permanent wellhead completion equipment must be attached to the production casing or to the intermediate casing if production casing does not reach the surface. Casing strength specification is determined on a case-by-case basis. All casing reaching the surface should provide adequate anchorage for blowout protection equipment, hole pressure control, and protection of natural resources. In addition, casing should reach below all known or reasonably estimated ground water levels to prevent blowouts or uncontrolled flows (UAC R655-1-2.7).

Operating Requirements

Operators must conduct MIT upon completion of a new well or before converting a production well to injection, showing that the casing has "complete" integrity (UAC R655-1-5.2.1). Testing must be completed within 30 days after injection operations commence, and thereafter every two years. The test must prove that all injected fluid is confined to the intended injection zone. Operators must notify DWR 48 hours prior to testing. In addition, operators must test for corrosion of well materials. Other regulations require operators to provide reports of injection operations by the tenth day of each month (UAC R655-1-5.2).

Mechanical Integrity Testing

Testing is required at the discretion of DWR to prevent damage to life, health, property, and natural resources; to protect geothermal reservoirs; or to prevent the infiltration of detrimental substances into underground or surface waters suitable for beneficial uses. The regulations list the various tests that are required, including casing tests, cementing tests, and equipment tests (UAC R655-1-7.3).

Operators must conduct casing integrity testing upon completion of a new well or before converting a production well to injection, showing that the casing has "complete" integrity (UAC R655-5.2.1). Testing must be completed within 30 days after injection operations commence, and thereafter every two years. The test must "prove that all injected fluid is confined to the intended zone of injection." Operators must notify DWR 48 hours prior to testing should the department wish to observe the testing. In addition, operators must test for corrosion of well materials. Other regulations require operators to provide monthly reports of injection operations (UAC R655-1-5.2.2).

Financial Responsibility

Utah requires owners to file a bond with DWR indemnifying the state against costs of enforcing its geothermal regulations and the improper abandonment of any permitted wells. The amount of the bond will not be less than $10,000 for each individual well, or $50,000 for statewide operations. These bonds remain in force for the life of the well(s) and will not be released until properly abandoned or substituted by another bond. Any person who acquires ownership or operation of any well is subject to the bonding requirements and must tender his own bond, or assume responsibility under an existing blanket bond (UAC R655-1-2.3).

Plugging and Abandonment

Utah's regulations pertaining to plugging and abandonment of injection wells specify that the actions taken must block interzonal migration of fluids that may contaminate fresh water and other natural resources; prevent damage to geothermal resources; prevent reservoir energy loss; and protect life, health, the environment, and property (UAC R655-1-6.1). Written notification is required 5 days before abandonment efforts commence, as well as a history of well operations within 60 days of abandonment completion (UAC R655-1-6.2 (b) and (n)). All abandoned wells must be monumented by 4-inch diameter pipe 10 feet in length, of which 4 feet are above ground. Name, number, and location of the well shall appear on the monument. When filling the wells, operators should use good quality heavy drilling fluid to replace any water in the hole and to fill all portions of the hole not plugged with cement (UAC R655-1-6.2 (d)). All cement plugs should be pumped into the hole through drill pipe or tubing, and all open annuli should be filled solid with cement to the surface. A minimum of 100 feet of cement should be emplaced straddling the interface or transition zone at the base of ground water aquifers (UAC R655-1-6.2(g)). In addition, 100 feet of cement should straddle the placement of the shoe plug on all casings, including conductor pipe. Other requirements include a surface plug of neat cement or concrete mix in place from the top of the casing to at least 50 feet below the top of the casing (UAC R655-1-6.2(i)). All casing should be cut off at least 5 feet below land surface and cement plugs should extend 50 feet over the top of any liner installed in the well (UAC R655-1-6.2(j),(k)); (UAC R655-1-6.1-- R655-1-6.2).

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