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The Class V Underground Injection Control Study

Volume 20

Salt Water Intrusion Barrier Wells

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SALT WATER INTRUSION BARRIER WELLS

The U.S. Environmental Protection Agency (USEPA) conducted a study of Class V underground injection wells to develop background information the Agency can use to evaluate the risk that these wells pose to underground sources of drinking water (USDWs) and to determine whether additional federal regulation is warranted. The final report for this study, which is called the Class V Underground Injection Control (UIC) Study, consists of 23 volumes and five supporting appendices. Volume 1 provides an overview of the study methods, the USEPA UIC Program, and general findings. Volumes 2 through 23 present information summaries for each of the 23 categories of wells that were studied (Volume 21 covers 2 well categories). This volume, which is Volume 20, covers Class V salt water intrusion barrier wells.

1. SUMMARY

Salt water intrusion barrier wells are used to inject water into a fresh water aquifer to prevent the intrusion of salt water. Control of salt water intrusion through the use of these wells may be achieved by creating and maintaining a "fresh water ridge." This fresh water ridge may be achieved with a line of injection wells paralleling the coast. Another method used to control salt water intrusion is through the use of an injection-extraction system. Such a system may be used to inject fresh water inland, while salt water intruded into the aquifer is being extracted along the coast.

Waters of varying qualities are injected to create salt water intrusion barriers, including untreated surface water, treated drinking water, and mixtures of treated municipal wastewater and ground or surface water. Injectate typically meets primary and secondary drinking water standards. Ground water monitoring and toxicological, chemical, and epidemiological studies have found no measurable adverse effects on either ground water quality or the health of the population ingesting the water, when the injectate was treated wastewater effluent.

Salt water intrusion barrier wells are drilled to various depths depending on the depth of the aquifer being protected. They inject into fresh ground water aquifers used as drinking water supplies that are in hydraulic connection with an extensive salt water body, such as a sea, a salt lake, or an ocean.

No contamination incidents associated with the operation of salt water intrusion barrier wells have been reported.

Because protection of drinking water supplies is the major goal of a salt water intrusion barrier well and the injectate typically meets drinking water standards, salt water intrusion barrier wells are unlikely to receive spills or illicit discharges of potentially harmful substances.

According to the state and USEPA Regional survey conducted for this study, there are 315 salt water intrusion barrier wells documented in the United States. The number of salt water intrusion barrier wells in the nation is estimated to be greater than 609, but unlikely to be higher than 700. All documented salt water intrusion barrier wells are located in California (308),

Florida (1), and Washington (6). In addition, as many as 200 salt water intrusion barrier wells are believed to exist in New York. There also may be some wells in New Jersey, which indicated in its survey response that it has salt water intrusion barrier wells but did not provide any numbers.

The statutory and regulatory requirements differ significantly among California, Florida, Washington, and New York. In California and New York, USEPA Regions 9 and 2, respectively, directly implement the UIC program for Class V injection wells. However, both states have additional jurisdiction over salt water intrusion barrier wells through state regional water quality control boards in California and state pollutant discharge elimination system permits in New York. In contrast, Florida and Washington are UIC Primacy States for Class V wells. Both of these states require individual permits for the operation of salt water intrusion barrier wells.

2. INTRODUCTION

Salt water intrusion is a problem in some areas of the United States. It is a man-made problem caused by excessive drainage of low lying coastal areas or, in some cases, the over pumping of fresh ground water from aquifers that are in hydraulic connection with an extensive salt water body, such as a sea, a salt lake, or an ocean.[1] Other causes of salt water intrusion include the destruction of natural barriers that separate fresh and salt water (e.g., construction of salt water canals), which would enable salt water to advance inland and percolate into a fresh water aquifer, and commercial and urban development of recharge areas, which reduces the permeable land surface. The extent of intrusion depends on several factors, such as climatic conditions, the aquifer properties, changes in seaward natural flow, barometric changes, tidal effects, and human activities such as discharge and recharge wells (Kashef, 1986).

Figure 1 illustrates the situation that occurs when fresh water is withdrawn from an unconfined coastal ground water basin. The figure shows: (a) the natural equilibrium between fresh and sea water; and (b) salt water intrusion into an aquifer resulting from ground water withdrawal.

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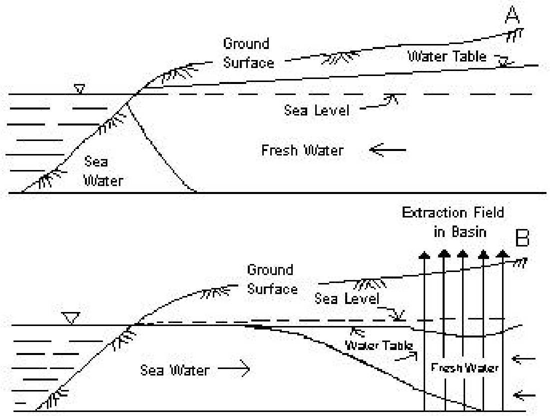
[1] Most of this summary discusses salt water intrusion in coastal areas, which is generally defined as a lateral movement of water. In non-coastal areas, most of the water quality deterioration is a result of vertical migration (Bloetscher, 1999). Vertical migration only occurs as a result of some type of withdrawal, generally pumping, and the solutions are very different to those employed to detain the salt water intrusion that results from the lateral movement of water (Bloetscher, 1999).

Figure 1. Hydrological Conditions in an Unconfined Coastal Ground Water Basin



Hydrological Conditions in an Unconfined Coastal Ground Water Basin:
A--Not subject to Sea-water Intrusion
B--Subject to Sea-water Intrusion

Source: based on Atkinson, 1986

One method used to control salt water intrusion is artificial recharge. In this context, artificial recharge refers to the injection of water into a low water quality or contaminated aquifer with no intent to withdraw the injected water. The injected water then produces a hydraulic barrier that has the effect of a physical barrier to sea water intrusion. The hydraulic barrier is created by raising the piezometric head of the fresh water aquifer and preventing the salt water from moving inland. Hydraulic barriers are created with either recharge basins or recharge wells.

"Salt water intrusion wells used to inject water into a fresh water aquifer to prevent the intrusion of salt water into the fresh water" are considered Class V injection wells, according to the existing UIC regulations in 40 CFR 146.5(e)(7). For the purpose of this study, salt water intrusion barrier wells include those wells that inject mixtures of treated wastewater and ground or surface water. Wells that inject treated wastewater only are addressed separately in the sewage treatment effluent well summary, which is Volume 7 of the Class V UIC Study. In addition, aquifer recharge and aquifer storage and recovery (ASR) wells, whose primary objective is to replenish the water in an aquifer but may have salt water intrusion control as a secondary objective, are addressed separately in Volume 21 of the Class V UIC Study.

3. PREVALENCE OF WELLS

An estimated two-thirds of the continental United States is underlain by saline waters that can intrude into fresh water supplies as a result of excessive drainage or over pumping. Thus, salinity and salt water intrusion problems are not limited to coastal areas (Fairchild, 1985). Salt water intrusion problems have been reported in almost every state in the continental United States (Fairchild, 1985). Only three states, Colorado, Kentucky, and Tennessee, have not reported any current or expected future salt water intrusion problems.

Fairchild (1985) reviewed areas that were both suitable for aquifer recharge and in need of salt water intrusion prevention. Areas prone to salt water intrusion and areas with favorable conditions for injection well operation were mapped separately and then overlaid. The overlapping areas indicated that aquifer recharge has widespread applicability to solving both ground water demand and salt water intrusion problems in coastal areas and the Central Plains states. Coastal areas, which are more densely developed, tend to use injection wells. Because the Central Plains states have more available open land, they tend to use recharge basins and infiltration areas rather than injection wells. As open land area for recharge basins becomes more scarce, however, injection of wastewater or surface water may become a more desirable management option for creating salt water intrusion barriers (Fairchild, 1985).

For this study, data on the number of Class V salt water intrusion barrier 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 UIC Study. Table 1 lists the numbers of Class V salt water intrusion barrier 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 salt water intrusion barrier wells.

As shown in Table 1, there are currently a total of 315 salt water intrusion barrier wells known to exist in the United States (i.e., documented wells). However, the actual number of salt water intrusion barrier wells in the United States is estimated to be greater than 609. These estimates do not include any wells in New Jersey, which indicated in its survey response that it has salt water intrusion barrier wells but did not provide any numbers.

Table 1. Inventory of Salt Water Intrusion Barrier Wells in the United States

State	Documented Number of Wells	Estimated Number of Wells	
		Number	Source of Estimate and Methodology[1]
USEPA Region 1 -- None			
USEPA Region 2			
NJ	NR	NR	N/A
NY	0	200	Best professional judgement, based on the fact that salt water intrusion is a significant problem on Long Island.
USEPA Region 3 -- None			
USEPA Region 4			
FL	1 (testing phase)	> 1	Best professional judgement.
USEPA Region 5 -- None			
USEPA Region 6 -- None			
USEPA Region 7 -- None			
USEPA Region 8 -- None			
USEPA Region 9			
CA	308	308	Inventory submitted by injectors.
USEPA Region 10			
WA	6	50 to 100	Best professional judgement.
All USEPA Regions			
All States	315	> 609	N/A

[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.

4. INJECTATE CHARACTERISTICS AND INJECTION PRACTICES

4.1 Injectate Characteristics

Varying levels of water quality are injected to create salt water intrusion barriers, including untreated surface water, treated surface water, and mixtures of treated wastewaters and ground water or surface water. (For further discussion on sewage treatment effluent wells, which inject only sewage treatment effluent rather than mixtures of such wastewaters and other waters, refer to Volume 7 of the Class V UIC Study.)

Because protection of drinking water supplies is the major goal of a salt water intrusion barrier well, injectate is usually monitored, and injectate constituent concentrations typically meet primary and secondary drinking water standards (Crook et al., 1991). Two salt water intrusion barrier projects in California provide examples of the quality of water being injected into this type of Class V well. Injectate data for both projects are presented in Table 2, along with available drinking water standards for the purpose of comparison. These data represent 97 percent of the documented salt water intrusion barrier wells in the United States. A brief description of these projects follows.

The Los Angeles County Department of Public Works in California operates the West Coast, the Dominguez Gap, and the Alamitos Barrier Project systems. These systems include 229 injection wells that protect 15 miles of coastal Los Angeles County from salt water encroachment. The Los Angeles Metropolitan Water District (MWD) provides a treated blend of drinking and surface water imported from the California Aqueduct and the Colorado River. Secondary effluent is pumped from the City of Los Angeles Hyperion Treatment Plant to the West Basin Municipal Water District Water Recycling and Barrier Treatment Facility and subject to further advanced treatment prior to being blended with the MWD water and discharged through the salt water barrier intrusion system as injectate. During 1998, Los Angeles County injected approximately 8,287 million gallons of water into the wells. As seen in Table 2, analyses of the injected water show that it meets all primary and secondary drinking water standards.

Operated by the Orange County Water District (OCWD) in California, the Talbert Barrier Project is a series of 23 multi-point injection wells (81 injection points) that inject into four coastal aquifers (Talbert, Alpha, Beta, and Lambda aquifers). The source of injectate for the 23 wells is tertiary-treated wastewater effluent mixed with other water. As of 1991, OCWD was accepting up to 15 million gallons per day of secondary-treated municipal wastewater from the County Sanitation District of Orange County's Fountain Valley plant for advanced treatment at Water Factory 21 in the City of Fountain Valley. To produce high quality reclaimed water, Water Factory 21 utilizes lime clarification for removal of suspended solids, heavy metals, and dissolved minerals; carbonation for pH control; mixed-media filtration for removal of suspended solids; adsorption with granular activated carbon for removal of dissolved organics; reverse

Table 2. Water Quality Data for Two Salt Water Intrusion Barrier Projects in California

Constituents	Drinking Water Standard[a] (mg/l, unless otherwise indicated)	Health Advisory Level (mg/l, unless otherwise indicated)	Constituent Concentration (mg/l, unless otherwise indicated)	
			Los Angeles County, CA[1]	Orange County, CA[2]
Volatile Organic Compounds				
Bromoform	0.1 (F); 0.08 (P)	0.4 (D,C)	<MDL	<MDL - 0.0006
Chloroform	0.1 (F); 0.08 (P)	0.6 (D,C)	<MDL	0.0032 - 0.0067
Dibromochloromethane	N/A	N/A	<MDL	0.0006 - 0.0012
Dibromodichloromethane	N/A	N/A	<MDL	0.0017 - 0.0039
Dichloroacetic Acid	0.06 (P)	D	<MDL	<MDL - 0.007
Dichloromethane	0.005 (F)	0.5 (F,C)	<MDL	<MDL
Total Trihalomethanes	0.08 (P)	N/A	0.023 - 0.064	0.0039 - 0.0124
Trichloroacetic Acid	0.06 (P)	0.3 (D,N)	<MDL	<MDL - 0.0018
Inorganic Chemicals				
Aluminum	L	D	0.040 - 0.307	0.0014 - 0.02
Antimony	0.006 (F)	0.003 (F,N)	<MDL	<MDL
Arsenic	0.05 (R)	0.002 (D,C)	0.0017 - 0.0023	<MDL
Asbestos	7 MFL (F)	7 MFL (F,C)	<MDL	<MDL
Barium	2 (F)	2 (F,N)	0.033 - 0.112	0.002 - 0.0055
Beryllium	0.004 (F)	0.0008 (D,C)	<MDL	<MDL
Cadmium	0.005 (F)	0.005 (F,N)	<MDL	<MDL
Chromium	0.1 (F)	0.1 (F,N)	<MDL	<MDL - 0.0045
Cobalt	N/A	N/A	<MDL	<MDL
Copper	1.3 (F) (action level, at tap) Secondary MCL: 1 (F)	N/A	<MDL	0.0064 - 0.015
Cyanide	0.2 (F)	0.2 (F,N)	<MDL	<MDL
Fluoride	4 (F,R) Secondary MCL: 2 (F)	N/A	0.18 - 0.32	0.29 - 0.42
Iron	Secondary MCL: 0.3 (F)	N/A	<MDL	0.0083 - 0.024
Lead	0.015 (F) (action level, at tap)	N/A	<MDL	<MDL - 0.002
Manganese	L Secondary MCL: 0.05 (F)	N/A	<MDL	<MDL - 0.0031

Table 2. Water Quality Data for Two Salt Water Intrusion Barrier Projects in California (continued)

Constituents	Drinking Water Standard[a] (mg/l, unless otherwise indicated)	Health Advisory Level (mg/l, unless otherwise indicated)	Constituent Concentration (mg/l, unless otherwise indicated)	
			Los Angeles County, CA[1]	Orange County, CA[2]
Mercury	0.002 (F)	0.002 (F,N)	<MDL	<MDL
Nickel	0.1 (F)[b]	0.1 (F,N)	<MDL - 0.002	<MDL
Nitrate (as N)	10 (F)	N/A	0.05 - 0.49	<MDL
Nitrite (as N)	1 (F)	N/A	<MDL	Not reported
Nitrate plus Nitrite (as N)	10 (F)	N/A	0.05 - 0.19	0.14 - 0.83
Selenium	0.05 (F)	N/A	<MDL	<MDL - 0.0051
Silver	Secondary MCL: 0.1 (F)	0.1 (D,N)	<MDL	<MDL
Zinc	L Secondary MCL: 5 (F)	2 (D,N)	<MDL	<MDL
Radionuclides				
Gross Alpha	15 pCi/l (F)	15 pCi/l (C)	<MDL - 11.7 pCi/l	Not reported
Gross Beta	4 mrem/y (27.7 pCi/l) (F)	4 mrem/y (27.7 pCi/l) (C)	<MDL - 11.2 pCi/l	Not reported
Radium-226	Combined Radium 226 and 228: 5 pCi/l (F)	Combined Radium 226 and 228: 20 pCi/l (C)	<MDL - 1.2 pCi/l	Not reported
Radium-228			<MDL - 1.0 pCi/l	Not reported
Radon-222	300 pCi/l (P)	150 pCi/l (C)	<MDL - 91 pCi/l	Not reported
Strontium-90	N/A	N/A	<MDL - 2.0 pCi/l	Not reported
Tritium	N/A	N/A	<MDL	Not reported
Uranium	0.02 (P)	R	<MDL - 3.3 pCi/l	Not reported
Chemical Parameters				
Chloride	Secondary MCL: 250 (F)	N/A	48 - 96	8.6 - 60.8
Foaming Agents (MBAS)	Secondary MCL: 0.5 (F)	N/A	<MDL	<MDL - 0.07
pH	Secondary MCL: 6.5 - 8.5	N/A	7.98 - 8.16	6.8 - 7.9
Sulfate	500 (P) Secondary MCL: 250 (F)	D	57 - 148[c]	4.3 - 39.9
Total Dissolved Solids	Secondary MCL: 500 (F)	N/A	264 - 416[c]	44 - 258

Table 2. Water Quality Data for Two Salt Water Intrusion Barrier Projects in California (continued)

Constituents	Drinking Water Standard[a] (mg/l, unless otherwise indicated)	Health Advisory Level (mg/l, unless otherwise indicated)	Constituent Concentration (mg/l, unless otherwise indicated)	
			Los Angeles County, CA[1]	Orange County, CA[2]
Additional Parameters				
Calcium	N/A	N/A	36 - 67	Not reported
Magnesium	N/A	N/A	14 - 24	Not reported
Potassium	N/A	N/A	2.7 - 3.9	Not reported
Sodium	N/A	D	45 - 103	29.2 - 62.3
Total Organic Carbon	N/A	N/A	2.09 - 3.12	1.14 - 3.23

Data Sources:

[1] Metropolitan Water District, 1997 and West Basin Municipal Water District, 1997
[2] Orange County Water District, 1996

[a] Primary maximum contaminant level (MCL), unless otherwise noted.
[b] Being remanded.
[c] Constituent concentrations in blended water from the Los Angeles Metropolitan Water District and reclaimed water.

Regulatory Status:

D: Draft
F: Final
L: Listed
P: Proposed
R: Under Review
T: Tentative (not officially proposed)

Health Advisory:

C: 10^{-4} cancer risk
N: Noncancer lifetime

<MDL Less than method detection level.

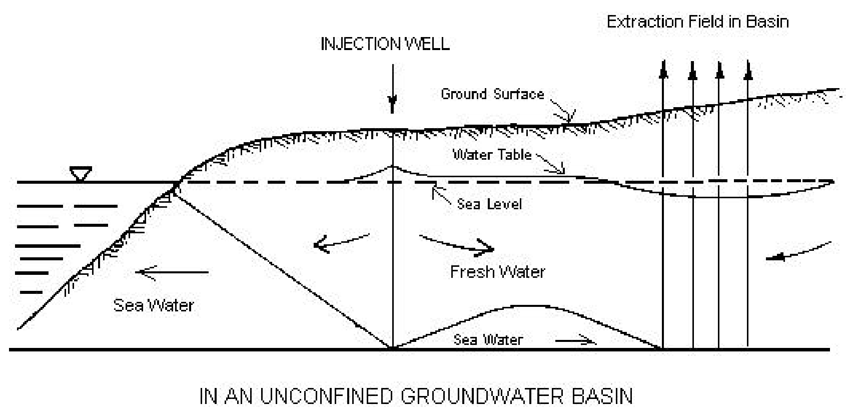
N/A Not available.

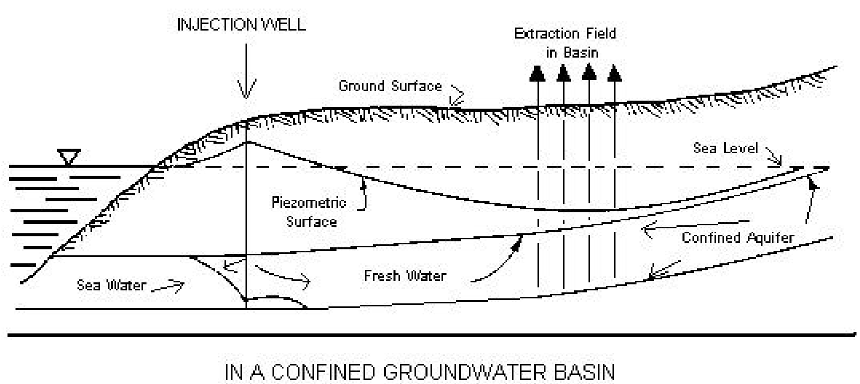
osmosis for demineralization; and chlorination for biological control and disinfection. This reclaimed water is then blended with ground water from deep wells for injection into the seawater barrier system. During 1996, OCWD injected 1,320 million gallons of water into its wells. Analyses of the injectate water show that it meets all primary and secondary drinking water standards (Table 2).

4.2 Well Characteristics

As stated earlier, salt water intrusion wells are used to inject water into fresh water aquifers to prevent the intrusion of salt water into the fresh water. Control of salt water intrusion through the use of these wells may be achieved by creating and maintaining a "fresh water ridge." This fresh water ridge may be achieved with a line of injection wells paralleling the coast. Figure 2 illustrates the use of injection wells to create a fresh water ridge to control salt water intrusion.

Figure 2. Use of Injection Wells to Create a Fresh Water Ridge to Control Salt Water Intrusion



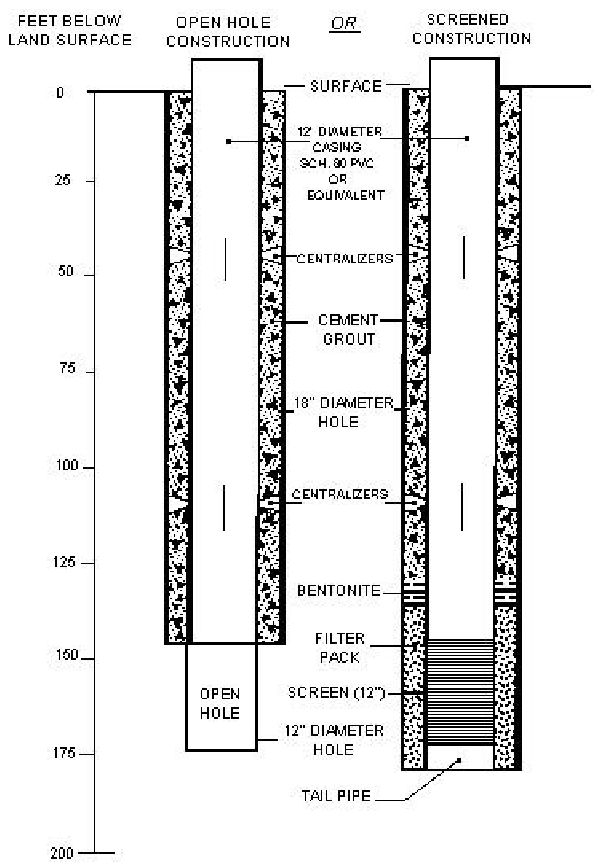


Source: USEPA, 1987

Although the design and construction of salt water intrusion barrier wells depend on site-specific conditions, the components of most salt water intrusion barrier wells are very similar. These include: (1) the well casing; (2) the well screen (except in rock and other open hole wells); (3) sand/gravel pack around the screen (except in rock and other open hole wells); (4) grout/cement around the casing; and (5) a pump.

Figure 3 shows a typical salt water intrusion barrier well. This design was used to construct two wells that will be part of the proposed Salinity Barrier System at the City of Hollywood Wastewater Treatment Plant in Broward County, Florida. The salt water intrusion barrier wells were constructed with twelve-inch outside diameter schedule 80 polyvinyl chloride (PVC) casing extending to a depth of approximately 136 feet below land surface.

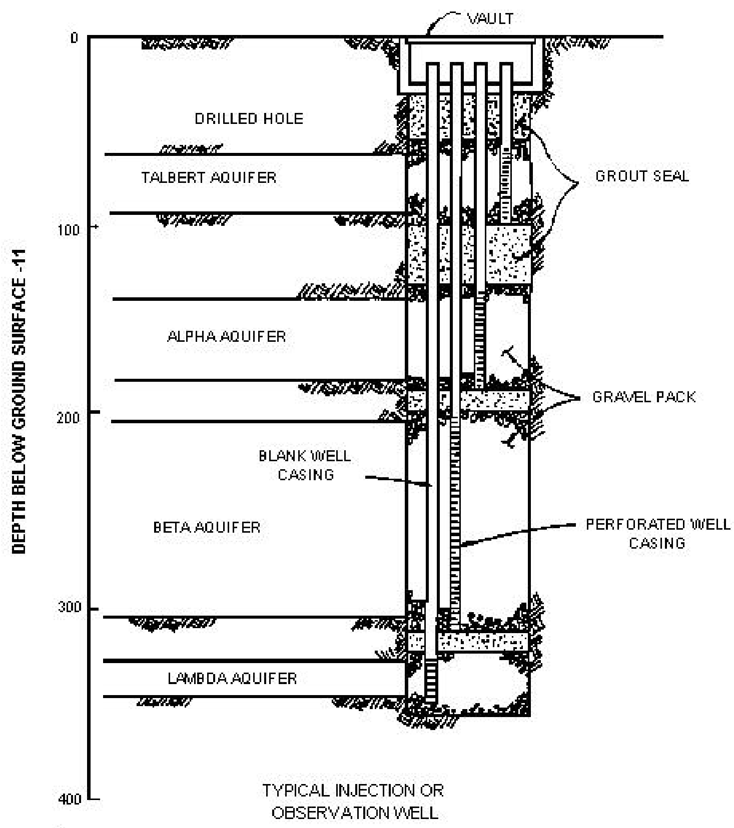
Figure 3. Design of a Typical Salt Water Intrusion Barrier Well



Source: City of Hollywood Wastewater Treatment Plant, 1998

Figure 4 shows the design of the salt water intrusion barrier wells being used in the Talbert Barrier Project, which is operated by OCWD in California.

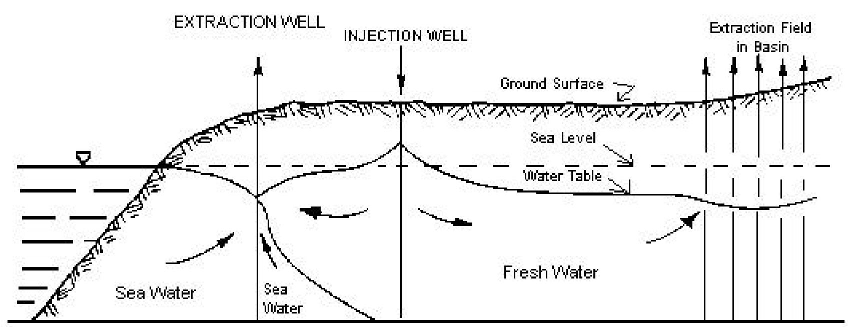
Figure 4. Design of Salt Water Intrusion Barrier Wells Used in the Talbert Barrier Project



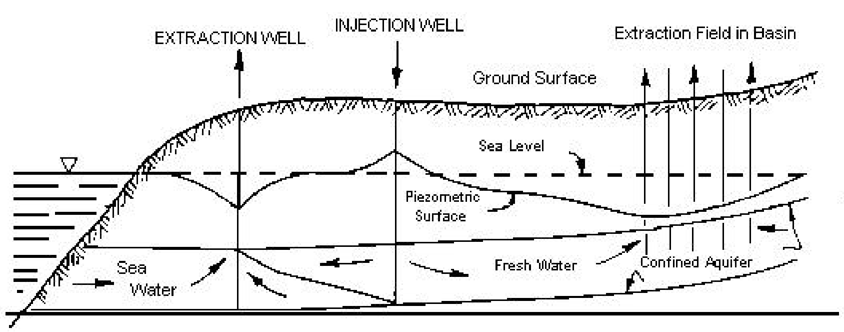
Source: California Regional Water Quality Control Board, Santa Ana Region, 1991

Another method used to control salt water intrusion through the use of injection wells is the use of an injection-extraction system. Such a system may be used to inject fresh water inland, while salt water intruded into the aquifer is being extracted along the coast. An illustration of an injection-extraction system is shown in Figure 5.

Figure 5. Use of an Injection-Extraction System to Control Salt Water Intrusion



IN AN UNCONFINED GROUNDWATER BASIN



IN A CONFINED GROUNDWATER BASIN

Source: USEPA, 1987

4.3 Operational Practices

Injecting high-quality water reduces the frequency of well clogging, increases the operating life of the well, and reduces cleaning costs. In addition, chlorination of the injected water helps to protect the well casing, prevents potential leaks, and reduces nearfield biofouling of the formations (Bloetscher, 1999). However, even when using high-quality water, clogging is inevitable.

When there is clogging and the injection head has increased above acceptable levels (approximately every three years when using high-quality injectate water), redevelopment of the injection wells is necessary (Bruington, 1968). Redevelopment of a well involves the removal of finer material from the natural formations surrounding the perforated sections of the casing. Periodic redevelopment of the well is used to restore its efficiency and specific capacity. Thorough initial development of the injection wells will delay the need for redevelopment and increase the initial specific capacity of the well, making it more efficient (Bruington, 1968).

Supply line pressure must be closely monitored and carefully controlled to prevent injection head fluctuations that could disrupt the well's gravel pack or even damage the injection well itself (Bruington, 1968). Injection wells should be supplied with pressure either individually or in small groups. This will prevent the complete collapse of the pressure ridge barrier in cases of shut down due to accidents, malfunctions, or strikes (Bruington, 1968).

Observation wells should be installed along the line of the injection barrier to monitor ground water levels. This allows operators to make an accurate, informed determination regarding the amount of water that should be injected to prevent salt water intrusion (Atkinson et al., 1986).

Abandoned salt water intrusion barrier wells should be thoroughly plugged to prevent the infiltration of contaminated surface waters into bodies of ground water. Wells are typically plugged with cement slurries; the exact composition of the slurry should be tailored to the specific geology of the well site (Atkinson et al., 1986).

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 salt water intrusion barrier wells to adversely affect USDWs are toxicity, persistence, and mobility. Appendices D and E of the Class V UIC Study provide information on these properties for constituents found above drinking water standards or health advisory levels in injectate of various types of Class V wells. As discussed in Section 3.1, water injected into salt water intrusion barrier wells is typically treated to meet primary and secondary drinking water standards. Thus, no further discussion of injectate constituent properties is provided here.

5.2 Observed Impacts

Based on information obtained from state and USEPA Regional offices, there are no documented contamination incidents associated with the use of salt water intrusion barrier wells. Ground water monitoring and toxicological, chemical, and epidemiological studies have found no measurable adverse effects on either ground water quality or the health of the population ingesting the water, when the injectate was treated wastewater effluent (Crook et al., 1991; Mills, 1991). Salt water intrusion barrier wells protect drinking water supplies from salt water contamination and augment the amount of fresh water available from a USDW.

6. BEST MANAGEMENT PRACTICES

6.1 Siting and Evaluation of Salt Water Intrusion Barrier Wells

Prior to establishing a salt water intrusion barrier, detailed hydrogeologic data should be collected and all sources of salt water intrusion should be identified. Once that is complete, an inventory of water supplies, water usage, existing pumping patterns, and surface development should be made. With these data in hand, intensive computer modeling should be conducted to determine the magnitude and extent of the salt water intrusion problem. Computer modeling is required for a successful salinity project to address technical issues and also to obtain information needed in the permitting process (Walker, 1999). Furthermore, computer modeling might be used to determine the siting and characteristics of the proposed salt water intrusion barrier wells and to evaluate the effects of the proposed recharge and monitoring programs on the USDW.

When using injection wells to control salt water intrusion, the hydraulic barrier injection point should be located near the toe of the salt water intrusion. Otherwise, the buoyancy effects that exert pressure on the salt front are not realized and salt water will continue to migrate inland (Bloetscher, 1999).

6.2 Alternatives to Salt Water Intrusion Barrier Wells

Control measures, other than salt water intrusion barrier wells, used to control salt water intrusion include: change in pumping patterns; use of extraction barriers; and use of subsurface barriers. These control measures are discussed briefly below.

6.2.1 <u>Change in Pumping Patterns</u>

A change in pumping patterns can be achieved by reducing pumping and relocating withdrawal wells to eliminate areas of intense pumping. Due to the difference in density between salt water and fresh water, these two methods will maintain the fresh water at a desirable piezometric head. According to the Department of Water Resources in California, water conservation is the best method to reduce pumping patterns. In other areas, like Florida, projects have been conducted to determine the most efficient arrangement of wells and rates of pumping to avoid salt water intrusion (Atkinson et al., 1986).

6.2.2 Extraction Barrier

This control program is a line of wells that are constructed adjacent to the coast and pumped to form a trough at the ground water level. The extraction barrier causes the sea water's piezometric head to be lower than the fresh water piezometric head, which protects the fresh water aquifer. The water pumped is brackish and normally is discharged into the sea (Todd, 1980).

6.2.3 Subsurface Barriers

Subsurface barriers are vertical walls that are placed inland to restrict the movement of sea water. There are three types of subsurface barrier walls: slurry walls, grout cutoffs, and steel sheet piles. Slurry wall construction involves pumping a slurry made of water and bentonite clay into a trench. Grout cutoffs are constructed by injecting a liquid, slurry, or emulsion under pressure into the soil. The injected fluid will occupy the pore spaces and will solidify to form an impermeable wall. Sheet piling involves driving lengths of steel that connect together into the ground to form a thin impermeable barrier to flow. These three types of barriers must be connected to an underlying impermeable geologic zone (Atkinson et al., 1986).

7. CURRENT REGULATORY REQUIREMENTS

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

Salt water intrusion barrier 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 salt water intrusion barrier 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 salt water intrusion barrier 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 salt water intrusion barrier 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.[2]

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

7.1.2 Other Federal Rules and Programs

As stated earlier, salt water intrusion barrier wells are used to protect USDWs from salt water contamination. Thus, salt water intrusion barrier well injectate is typically treated to drinking water standards, which are established under Section 1412 of the SDWA. This section requires USEPA to establish National Primary Drinking Water Regulations (NPDWRs) for a contaminant if (1) the contaminant may have an adverse public health effect; (2) it is known or likely to occur in public water systems with a frequency and at levels of public health concern; and (3) if regulation of such contaminant presents a meaningful opportunity for health risk reduction. A brief description of these regulations follows.

Total Trihalomethane Rule

In November 1979, USEPA set an interim MCL for total trihalomethanes (TTHMs) of 0.10 mg/l as an annual average (44 FR 68624). Compliance is defined on the basis of a running average of quarterly averages of all samples. The value for each sample is the sum of the measured concentrations of chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The interim TTHM standard only applies to community water systems using surface water and/or ground water serving at least 10,000 people that add a disinfectant to the drinking water during any part of the treatment process.

Surface Water Treatment Rule

In June 29, 1989, USEPA promulgated the final Surface Water Treatment Rule (SWTR) (54 FR 27486). Under the SWTR, USEPA set maximum contaminant level goals (MCLGs) of zero for *Giardia lamblia*, viruses, and *Legionella*; and promulgated NPDWRs for all public water systems using surface water sources or ground water sources under the direct influence of surface water. The SWTR includes treatment technique requirements for filtered and unfiltered systems that are intended to protect against the adverse health effects of exposure to *Giardia lamblia*, viruses, and *Legionella*, as well as many other pathogenic organisms. The rule became effective in June 1993.

Total Coliform Rule

In June 29, 1989, USEPA also promulgated the Total Coliform Rule, which applies to all public water systems (54 FR 27544). This regulation sets compliance with a MCL for total coliforms. If a system exceeds the MCL, it must notify the public using mandatory language developed by the USEPA.

Interim Enhanced Surface Water Treatment

On December 16, 1998, USEPA finalized the Interim Enhanced Surface Water Treatment Rule (IESWTR) (63 FR 69478). The purposes of the IESWTR are to: (1) improve control of microbial pathogens, including specifically protozoan *Cryptosporidium*, in drinking water; and (2) address risk trade-offs with disinfection products. The IESWTR applies to public water systems that use surface or ground water under the direct influence of surface water and serve 10,000 or more people. The regulation became effective on February 16, 1999.

Stage 1 Disinfection Byproducts Rule

In December 16, 1998, USEPA finalized: (1) maximum residual disinfectant level goals (MRDLGs) for chlorine, chloramines, and chlorine dioxide; (2) MCLGs for four trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform), two haloacetic acids (dichloroacetic acid and trichloroacetic acid), bromate, and chlorite; and (3) NPDWRs for three disinfectants (chlorine, chloramines, and chlorine dioxide), two groups of organic disinfection byproducts (TTHMs—a sum of chloroform, bromodichloromethane, dibromochloromethane, and bromoform—and haloacetic acids—a sum of dichloroacetic acid, trichloroacetic acid, monochloroacetic acid, and mono-and dibromoacetic acids), and two inorganic disinfection byproducts (chlorite and bromate) (63 FR 69389). The NPDWRs consist of maximum residual disinfectant levels or MCLs or treatment techniques for these disinfectants and their byproducts. The NPDWRs also include monitoring, reporting, and public notification requirements for these compounds.

The Stage 1 Disinfection Byproducts Rule applies to public water systems that are community water systems and nontransient, noncommunity water systems that treat their water with a chemical disinfectant for either primary or residual treatment. In addition, certain requirements for chlorine dioxide apply to transient noncommunity water systems.

Radon Rule

On July 18, 1991, USEPA proposed a MCLG, a MCL, monitoring, reporting, and public notification requirements for radon and a number of other radionuclides in public water supplies (systems serving 25 or more individuals or with 15 or more connections) (56 FR 33050). USEPA proposed to regulate radon at 300 pCi/l.

On August 6, 1996, Congress passed amendments to the SDWA. Section 1412(b)(13)(A) of the SDWA, as amended, directs USEPA to withdraw the proposed national primary drinking water regulation for radon. Thus, as directed by Congress, on August 6, 1997 (62 FR 42221), USEPA withdrew the 1991 proposed MCLG, MCL, monitoring, reporting, and public notification requirements for radon.

USEPA expects to publish a final MCLG and national primary drinking water regulation for radon by August, 2000.

Ground Water Rule

Currently, USEPA is developing a Ground Water Rule that will specify appropriate use of disinfection and encourage the use of alternative approaches, including best management practices and control of contamination at its source. The rule will be designed to protect against pathogenic bacteria and viruses in source water, against growth of opportunistic pathogenic bacteria in ground water distribution systems, and to mitigate against any failure in the engineered systems, such as cross-connections or sewage infiltration into distribution systems. The Ground Water Rule will apply to systems using only ground water, which are not regulated under the 1989 SWTR.

USEPA expects to publish the Final Ground Water Rule by November 2000. The statutory deadline, under the SDWA (Section 1412(b)(8)), for the Ground Water Rule is May 2002.

7.2 State and Local Programs

As discussed in Section 3, the four states for which documented or estimated numbers of salt water intrusion barrier wells were provided by the states or USEPA Regional offices are: California, Florida, New York, and Washington. California, New York, and Washington each contain a significant number, while Florida is testing a single well. The statutory and regulatory requirements differ significantly among these states, as described in Attachment A of this volume and summarized below.

In California, USEPA Region 9 directly implements the UIC program for Class V injection wells. Salt water intrusion barrier wells in the state are authorized by rule in accordance with the existing federal requirements. However, the state has additional jurisdiction over salt water intrusion barrier wells through state regional water quality control boards. If treated wastewater is planned to be used for artificial recharge, regional water quality control boards issue site-specific discharge requirements. In addition, the Department of Health Services must review and approve the application. In these instances, the injectate must meet drinking water standards at the point of injection. County water districts and/or county health departments may supplement the requirements. If potable water is planned to be used for aquifer recharge, the projects are reviewed and regulated by local health departments.

Florida is a UIC Primacy State for Class V wells. In this state, owners or operators of salt water intrusion barrier wells are required to obtain a Construction/Clearance Permit from the Department of Environmental Protection before receiving permission to construct. In order to use the well, the applicant is required to submit information needed to demonstrate that well operation will not adversely affect a USDW. Once such a demonstration is made, the Department will issue an authorization to use the well subject to certain operating and reporting requirements, including the requirement to meet drinking water standards at the point of injection. Injection of fluids that exceed the drinking water standards is allowed only if it is not into a USDW and if it is controlled in accordance with a site-specific operating permit.

In New York, USEPA Region 2 directly implements the UIC program for Class V injection wells. However, the state has promulgated additional regulations in the state's Code of Rules and Regulations to establish water quality standards, effluent limitations, and monitoring requirements; and create a state pollutant discharge elimination system requiring permits for discharges into the waters of the state. The Environmental Conservation Law (§17-0105) defines "pollutant" to include water, waters of the state to include ground water, and point source to include a well.

Washington is a UIC Primacy State for Class V wells. In this state, an individual permit is required to operate a salt water intrusion barrier well. In addition, Washington has set standards for direct ground water recharge projects using reclaimed water. These rules primarily address the standards and treatment requirements for the reclaimed water, when injected into potable and non-potable ground water.

ATTACHMENT A
STATE AND LOCAL PROGRAM DESCRIPTIONS

This attachment does not describe every state's program controls; instead, it focuses on the four states where salt water intrusion barrier wells are known or believed to exist: California, Florida, New York, and Washington. Altogether, these four states have a total of 315 documented and more than 409 estimated salt water intrusion barrier wells. These estimates represent approximately 99 percent and 67 percent of the documented and estimated salt water intrusion barrier wells, respectively.

California

USEPA Region 9 directly implements the UIC program for Class V injection wells in California. The California Water Quality Control Act (WQCA), however, establishes broad requirements for the coordination and control of water quality in the state, sets up a State Water Quality Control Board, and divides the state into nine regions, with a Regional Water Quality Control Board (RWQCB) that is delegated responsibilities and authorities to coordinate and advance water quality in each region (Chapter 4 Article 2 WQCA). A RWQCB can prescribe requirements for discharges (waste discharge requirements, or WDRs) into the waters of the state (13263 WQCA). These WDRs can apply to injection wells (13263.5 and 13264(b)(3) WQCA).

Permitting

Although the RWQCBs do not permit injection wells, the WQCA provides that any person operating, or proposing to operate, an injection well (as defined in §13051 WQCA) must file a report of the discharge, containing the information required by the Regional Board, with the appropriate Regional Board (13260(a)(3) WQCA). Furthermore, the RWQCB, after any necessary hearing, may prescribe requirements concerning the nature of any proposed discharge, existing discharge, or material change in an existing discharge to implement any relevant regional water quality control plans. The requirements also must take into account the beneficial uses to be protected, the water quality objectives reasonably required for that purpose, other waste discharges, and the factors that the WQCA requires the Regional Boards to take into account in developing water quality objectives, which are specified in §13241 of the WQCA (13263(a) WQCA). However, a RWQCB may waive the requirements in 13260(a) and 13253(a) as to a specific discharge or a specific type of discharge where the waiver is not against the public interest (13269(a) WQCA).

The WQCA specifies that no provision of the Act or ruling of the State Board or a Regional Board is a limitation on the power of a city or county to adopt and enforce additional regulations imposing further conditions, restrictions, or limitations with respect to the disposal of waste or any other activity which might degrade the quality of the waters of the state (13002 WQCA).

Siting and Construction Requirements

Construction standards from Bulletin 74-90 of the Department of Water Resources generally apply. In addition, RWQCBs have jurisdiction over injection barrier wells. The Santa Ana RWQCB has jurisdiction over the Orange County Seawater Intrusion Barrier Project. The Los Angeles RWQCB has jurisdiction over the Los Angeles County injection barriers (Alamitos Barrier, Dominguez Gap, and West Coast Basin barriers). Requirements established by the RWQCBs pertain to injection wells injecting reclaimed water. No such requirements pertain to injection wells injecting solely potable water.

The following requirements are established by Order No. 91-121 issued by the Santa Ana RWQCB for the Orange County Project, whose seawater barrier consists of 23 specially designed multiple casing wells. The limitations in the Order are intended to maintain ground water quality in the underlying ground water subbasin and to protect beneficial use of the ground water subbasin. The Order requires the county to adopt an ordinance or resolution that prevents construction of new domestic water supply wells within 2,000 feet of the injection wells.

Operating Requirements

Order No. 91-121, which applies only to the Orange County Project, requires compliance with a Monitoring and Reporting Program and submission and approval of a draft operating plan and a final operating plan. It requires monitoring of domestic water supply wells in the vicinity of the injection barrier, and provision of an alternate safe water supply if necessary if a domestic water supply well is adversely affected by the discharges.

The RWQCB discharge specifications in Order No. 91-121 include 4-sample average and daily maximum concentration limits for specified constituents; pH limits for the injection water; a requirement that the injection water shall not cause taste, odor, foam or color in the ground water; a requirement that neither the treatment nor injection shall cause a nuisance or pollution as defined by the California Code; prohibition of injection of any substance in concentrations toxic to human, animal, plant, or aquatic life; prohibition of injection of saline wastes; a requirement that the injection water at all times must meet all the California primary drinking water standards; a requirement that all reclaimed water injected shall at all times be adequately disinfected, oxidized, coagulated, clarified, filtered wastewater meeting the requirements specified in the California Wastewater Reclamation Criteria; a requirement that all reclaimed water injected shall receive organics removal treatment such that the total organic carbon concentration does not exceed 2.0 mg/l; a requirement that total nitrogen concentration shall not exceed 10 mg/l; and a limit on the amount of water injected in the Talbert Barrier project shall not exceed 25 million gallons per day (mgd), of which the maximum amount of reclaimed water shall not exceed 18 mgd based on the quarterly average flow. Monthly and quarterly monitoring of the results of all weekly analyses, results of monthly analyses, and total flow of all injection water by source must be collected and reported to the RWQCB (Order No. 91-121).

Monitoring Requirements

Not specified by statute or regulations.

Plugging and Abandonment

A closure plan must be submitted to the RWQCB and financial assurance for closure must be provided.

Florida

Florida is a UIC Primacy State for Class V wells. Chapter 62-528 of the Florida Administrative Code (FAC), effective June 24, 1997, establishes the state's UIC program, and Part V of Chapter 62-528 (62-528.600 to 62-528.900) addresses criteria and standards for Class V wells. Class V wells are grouped for purposes of permitting into 8 categories. Group 2 includes salt water intrusion barrier wells.

Permitting

Underground injection through a Group 2 Class V well is prohibited except as authorized by permit. Owners and operators are required to obtain a Construction/Clearance Permit before receiving permission to construct. The applicant is required to submit detailed information, including well location and depth, description of the injection system and of the proposed injectate, and any proposed pretreatment. When site-specific conditions indicate a threat to a USDW, additional information must be submitted. If a Group 2 well applicant demonstrates that the operation of the well will not adversely impact a USDW, the Department will issue a non-renewable and non-expiring authorization to use the well. The authorization will contain operating and reporting requirements. The fluids injected must meet the primary and secondary drinking water quality standards in Chapter 62-500 FAC. A Group 2 well that does not inject fluids meeting the primary and secondary drinking water requirements must obtain an operating permit. Finally, all Class V wells are required to obtain a plugging and abandonment permit.

Siting and Construction Requirements

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

Class V wells are required to be constructed so that their intended use does not violate the water quality standards in Chapter 62-520 FAC at the point of discharge, provided that the drinking water standards of 40 CFR Part 142 (1994) are met at the point of discharge.

Operating Requirements

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

Monitoring Requirements

Monitoring generally will be required for Group 2 wells, unless the wells inject fluids that meet the primary and secondary drinking water standards in 62-550 FAC and the minimum criteria in Rule 62-520, and that have been processed through a permitted drinking water treatment facility. Monitoring frequency will be based on well location and the nature of the injectant and will be addressed in the permit. The Department will determine the frequency of monitoring based on the location of the well, the nature of the injected fluid, and, where applicable, water quality criteria for the receiving waters.

Plugging and Abandonment

The proposed plugging method will be approved as a condition of the permit.

New York

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

Permitting

New York's SPDES prohibits the discharge of any pollutant into the waters of the state without an SPDES permit. The Environmental Conservation Law (§17-0105) defines "pollutant" to include water, waters of the state to include ground water; and point source to include a well.

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

Siting and Construction Requirements

New York law requires all well drillers on Long Island to be licensed (Chapter 338).

Operating Requirements

Effluent limits (Part 703) in the SPDES permit must be met. Monitoring and reporting requirements in the SPDES permit must be met.

Monitoring Requirements

Not specified by statute or regulations.

Plugging and Abandonment

Not specified by statute or regulations.

Washington

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

Permitting

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

Siting and Construction Requirements

The state has promulgated minimum standards for construction and maintenance of wells (173-160-010 through -560 WAC). However, injection wells regulated under Chapter 173-218 are specifically exempted from these constructions standards (173-160-010(3)(e) WAC).

Operating Requirements

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

Monitoring Requirements

Not specified by statute or regulations.

Plugging and Abandonment

All wells not in use must be securely capped so that no contamination can enter the well (173-160-085 WAC).

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