GROUNDWATER PROTECTION COUNCIL

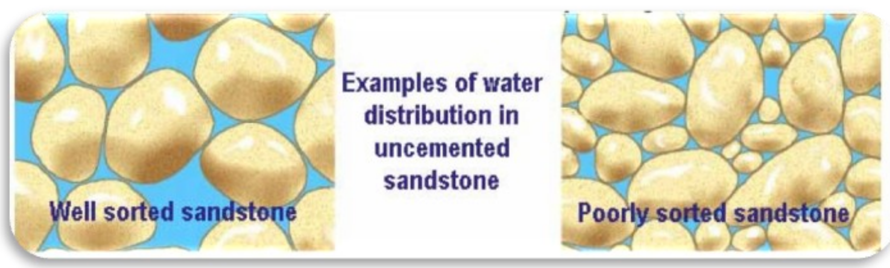
Injection Wells: An Introduction to Their Use, Operation & Regulation

GWPC UIC Underground Injection Control

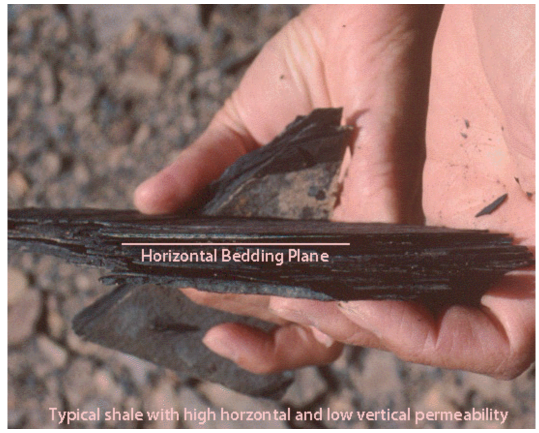
September 1, 2013

Groundwater Fundamentals

Water is essential to life. Whether your drinking water comes from a public water supply or a private well or spring, your very existence depends upon having safe, consumable water. The average American household uses approximately 146,000 gallons of fresh water annually. Americans drink 1 billion glasses of tap water per day. Many homes and businesses use groundwater. What is groundwater? Groundwater is stored beneath the land surface of our local communities in formations of saturated rock, sand, gravel, and soil. Unlike surface water, groundwater does not flow in a series of lakes and rivers. Instead, the precipitation that seeps into our soil continues its downward journey and eventually fills the pores of these subsurface formations (as shown in the diagram below). The amount of water that infiltrates the subsurface varies widely, depending on land use, the type of soil present, and the amount of precipitation that falls. Groundwater can also be replaced or recharged when rock formations come into contact with surface water bodies such as lakes and rivers. When these points of connection discharge groundwater to the surface, they are called springs. Formations that contain large enough amounts of water to feed springs (such as the one shown below) or wells are called aquifers.



The two factors which determine the amount of water that aquifers can provide are called porosity and permeability. Porosity is a measure of the amount of pore space, or holes and cracks, present in a rock. The more pores present, the greater the rock's ability to hold water. A rock with many pores has high porosity. Permeability refers to the degree to which the pores are connected, providing the groundwater a way to move within the rock.



Some rock formations, including many shale's have very low permeability perpendicular to their bedding planes (as shown at right). Other rock types such as sandstone can be highly permeable in multiple directions, allowing water to move through its pores easily regardless of flow direction. If you think of a sponge between two layers of children's clay you get a sense of an aquifer system that has a very porous layer bounded top and bottom by denser, less permeable layers.

Groundwater is found in rock, sand, gravel, and soil at a wide variety of depths. Groundwater is essential to our public water supply systems, economic growth, national agricultural production, and the overall quality of life that we all share whether or not we are personally dependent on it for drinking water. Fresh groundwater—that is, water with lower salinities and mineral content—is usually located nearer the earth's surface. Deeper rock formations contain water of limited quality or usability, with higher dissolved mineral content. Water with salinities greater than 10,000 parts per million of Total Dissolved Solids (TDS) is not considered a source of drinking water unless it can be cost effectively treated. That is why deep formations containing poor quality groundwater are used for disposal or injection of liquids.

Estimates place the volume of nationally-usable groundwater at 100 quadrillion gallons. However, a problem exists: the potential for groundwater contamination. Groundwater can be extremely susceptible to contamination from a variety of common sources, including

MOST AMERICANS ARE SURPRISED TO LEARN THAT:

83 billion gallons of groundwater are used in America each day, compared to 34 billion in 1950. *

40% of the nation's drinking water and 24% of our total fresh water supply comes from groundwater. *

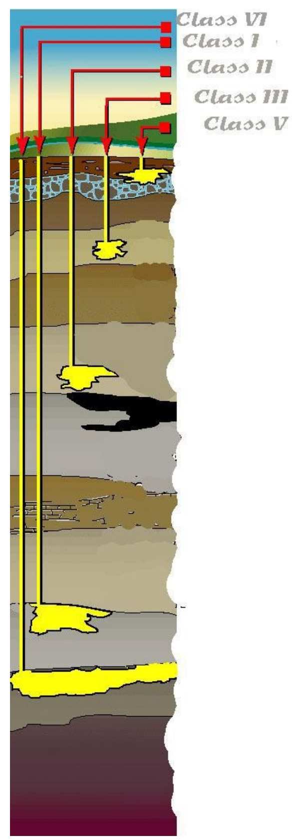
75% of our cities derive all or part of their water from underground sources. *

99% of the rural population supply their own water from their own wells, using groundwater.

***Source USGS Bulletin 1268, 2005**

septic tanks, feed lots, fertilizer, highway de-icing salt, industrial processes, landfills, oil and gas operations and underground storage tanks. Once a groundwater resource has been contaminated, cleaning it up to make it usable again can be extremely difficult, costly, and is sometimes not feasible at all. That is why it is important that these and other potential sources of contamination be handled in ways that protect groundwater. Some wastes are generated by industrial processes that are difficult or impossible to treat to levels that are safe for discharge at the surface. These materials may contaminate groundwater resources if not kept away from them. However, some of these wastes, in liquid form, can be pumped into formations deep below the earth's surface and permanently isolated from usable water resources. Safely managing this process is the purpose of the Underground Injection Control Program.

Underground Injection



Some waste is an unavoidable by-product of a myriad of manufacturing processes that create thousands of the products we use in the course of everyday living. Products such as steel, plastics, pharmaceuticals, and many others cannot be made without generating fluid wastes. Additionally, many millions of gallons of liquid wastes are generated in large municipalities from treated sewage. While industry continues to research and implement ways to reduce waste by recycling and improving manufacturing processes, generated wastes still require disposal. There are many acceptable ways to do this job, including incineration, biological or chemical treatment, and landfills in properly located and constructed sites. While some areas have rivers or other water bodies at the surface that can receive this treated water stream, others have very sensitive waters that make disposal of this wastewater unsafe and/or impractical. An environmentally acceptable way to deal with these wastes in many parts of the United States is disposal through injection wells. Injection wells penetrate thousands of feet below the earth's surface into rock formations where the waste is isolated from Underground Sources of Drinking Water (USDWs). But what exactly is underground injection?

Underground injection is the placement of fluids into the subsurface through a well bore. Many of the wells used for injection are "high tech" in their construction, as discussed in this brochure. However, some are very simple, including dug wells, certain septic systems, and other shallow, simply constructed, subsurface fluid distribution systems. The practice of underground injection has become essential to many of today's industries, including the petroleum industry, chemical industry, food and product manufacturing industries, geothermal energy development, and many local small specialty plants and retail establishments. To dispose of fluids safely, the wells need to be in the right kind of geologic setting, properly constructed, operated, maintained, and checked through different kinds of monitoring. In the late 1960's, the realization that subsurface injection could contaminate groundwater if wells were not properly located and operated prompted many states to develop programs and methods to protect underground sources of usable water. Additionally, to increase groundwater protection, a federal Underground Injection Control or UIC program was created.

The UIC program was established under the authority and standards of the federal Safe Drinking Water Act (SDWA) of 1974. The goal of the program is the effective isolation of fluids from Underground Sources of Dinking Water (USDWs). There are approximately 169,000 wells in the United States that store or dispose of fluids in underground rock formations trapped by impermeable layers, keeping the fluids away from USDWs. Since the passage of several legislative acts in the 1970's regulating waste disposal into water, air, and landfills, underground injection has grown in importance. In the petroleum industry alone, about 21 billion bbl (barrels; 1 bbl = 42 U.S. gallons) of produced water are generated each year in the United States from nearly a million oil & gas wells. This represents about 57 million bbl/day, 2.4 billion gallons/day, or

913,000 m3/day(1). When disposed of at the surface, this water may pose a risk of contaminating surface waters or groundwater. Consequently, it is typically injected underground through an injection well constructed specifically for that purpose.

Since groundwater is a major source of drinking water in the United States, the UIC Program requirements were designed to prevent contamination of USDWs resulting from the operation of injection wells. A USDW is defined as an “aquifer or its portion which supplies any public water system or contains a sufficient quantity of groundwater to supply a public water system, and either currently supplies a public water system, or contains less than 10,000 milligrams per liter of total dissolved solids and is not an exempted aquifer.” Most groundwater used as drinking water today contains less than 3,000 milligrams per liter of total dissolved solids (TDS). However, the UIC Program protects waters with much higher mineral concentrations to ensure that water with the potential to be treated and used as drinking water in the future is protected now. Since the passage of the Safe Drinking Water Act, state and federal regulatory agencies have modified existing programs or developed new strategies to protect groundwater by establishing even more effective regulations to control the permitting, construction, operation, maintenance, monitoring, and closure of

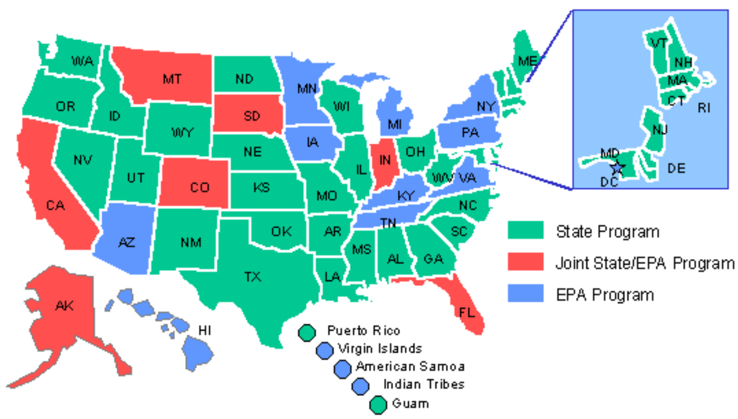
Underground Injection Control Well Classification Chart		
Well Class	Purpose	Active Wells*
I	Injection of hazardous, non-hazardous, and municipal wastes below the lowermost USDW	678
II	Injection of fluids associated with the production of oil and natural gas resources for the purposed of disposal or enhanced oil and gas recovery	168,000
III	Injection of fluids for the extraction of minerals	22,000
IV	Injection of hazardous or radioactive wastes into or above a USDW	33 Sites
V	Injection into wells not included in the other well classes but generally used to inject non-hazardous waste	469,000**
VI	Injection of supercritical carbon dioxide for storage	0***
* All numbers estimated from state agency surveys and USEPA publications		
** USEPA estimate of Class V wells (NOTE: 2005 state survey indicated between 650,000 and 1.5 Mil.)		
*** Existing commercial wells with permits issued under the Class VI program		

injection wells. As shown in the chart above, injection wells are divided into six different classes. The classes are generally based on the kind of fluid injected and the depth of the fluid injection compared with the depth of the lowermost USDW. Class I wells are used to inject industrial or municipal waste to a depth beneath the lowermost USDW. Class II wells are used to dispose of fluids associated with the production of oil and natural gas. Class III

1 Clark, C.E., and J.A. Veil, 2009, Produced Water Volumes and Management Practices in the United States [external site], ANL/EVS/R-09/1, prepared by the Environmental Science Division, Argonne National Laboratory for the U.S. Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory

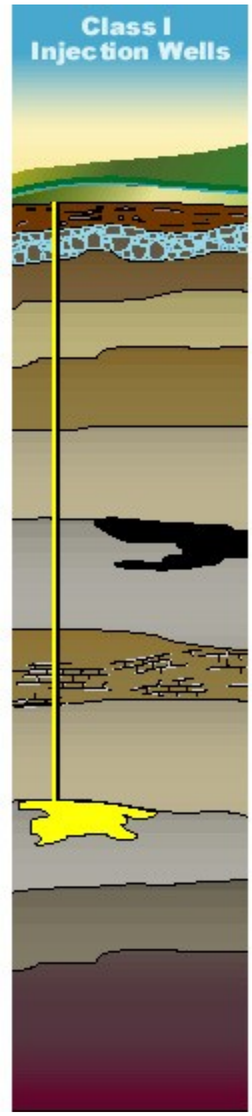
wells are used to inject fluids to aid in the extraction of minerals. Class IV wells were used to dispose of hazardous or radioactive wastes into or above a USDW, but have been banned in all 50 states, unless they are part of a contaminated site cleanup. Though Class IV hazardous and radioactive waste disposal wells have been banned for many years, some are still periodically discovered and must be cleaned up and closed. Class V wells are all wells not included in Classes I-IV that are used to inject or dispose of non-hazardous waste into or above a USDW. Class VI wells are used to dispose of the greenhouse gas carbon dioxide; a by-product of fossil fuel use, cement processing and other industrial processes.

The United States Environmental Protection Agency (USEPA) has given primary enforcement authority, called Primacy, over underground injection wells to those state agencies that have demonstrated an ability to implement a UIC Program meeting USEPA's legal requirements. These requirements are contained in Sections 1422 and 1425 of the SDWA, and the Federal Register (40 Code of Federal Regulations Parts 144 through 147), the publication that includes all of the federal regulations. The states that USEPA has determined have



regulations, laws, and resources in place that meet the federal requirements and are authorized to run the UIC Program are referred to as Primacy States. In many states, more than one state agency has Primacy for one or more classes of injection wells. For instance, one agency may have authority over Class II wells, and another agency have authority over Class I and Class V wells. In states that have not received primary responsibility for the UIC Program, USEPA remains the responsible regulatory agency. These states are referred to as Direct Implementation (or DI) States, because USEPA directly implements the federal UIC regulations in these states. Some states share responsibility with the USEPA, with authority over some well classes residing at the state level, and other well classes being regulated by USEPA. There are presently forty-one states and one tribe that have primacy over one or more well classes. In the following sections we will discuss each of the authorized classes of injection wells and how they fit into the national picture of underground injection.

Class I Wells



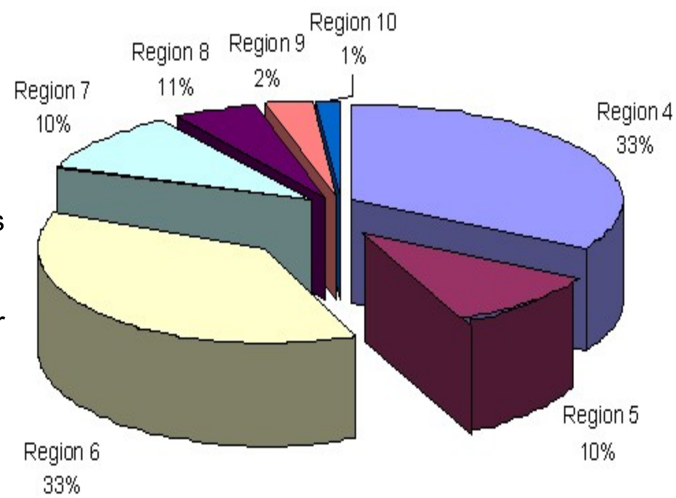
Class I wells typically inject anywhere from 1,700 to over 10,000 feet beneath the earth's surface. Most geologic formations containing potential drinking water sources are much shallower, often less than 1000 feet The suitability of this disposal method depends on the availability of appropriate underground rock formation combinations that have the natural ability to accept, yet confine, the wastes. It is this long term confinement that makes deep well disposal an environmentally sound waste disposal method. The ability of some rock formations to accept but confine liquids injected into them is the same characteristic that has held naturally occurring oil and gas deposits for millions of years without allowing them to escape.

Because these wells inject waste below the deepest USDW, there is little chance of any negative effects on potentially usable groundwater. In fact, in its March 2001 Study of Class I wells, the USEPA said that "the probability of loss of waste confinement due to Class I injection has been demonstrated to be low" and "existing Class I regulatory controls are strong, adequately protective, and provide an extremely low-risk option in managing the wastewaters of concern." In other words, the deep geologic formations that receive the waste (called the injection zone), the related confining layers above the injection zone, and the many layers of protection required in the construction, operating, and monitoring of wells, provide many safeguards against upward fluid movement, effectively protecting USDWs.

A facility owner is required to apply for and receive a permit from the state or USEPA before constructing or operating any type of Class I well.

Class I wells can be subdivided by the types of waste injected: hazardous, non–hazardous, and municipal waste water. Based on a 2007 survey by GWPC, there were 311 active Class I injection facilities in 19 states; which had a total of 523 wells. Of these, 114 wells were listed as hazardous, 305 were non-hazardous and 104 were municipal waste. (2) The greatest concentrations of Class I wells are located in the Gulf Coast, Great Lakes, and the Florida peninsular regions.

Hazardous wastes are those industrial wastes that are specifically defined as hazardous in federal law and rules (40 CFR Part 261.3 under Section 3001, of Subtitle C of the Solid Waste Disposal Act, as amended by the 1976 Resource Conservation and Recovery Act, or RCRA). Very few states have Hazardous Class I injection wells. Many of these wells are located along the Texas–Louisiana Gulf Coast. This area has a large number of waste generators such as refineries and chemical plants as well as deep geologic formations that are ideal for the injection of wastes. As shown in the chart (at right) USEPA Regions 4 and 6; which include many of the Gulf Coast states account for about 66% of all Class I wells.



Non–hazardous wastes are any other industrial wastes that do not meet the legal definition of hazardous wastes and can include a wide variety of fluids, such as those from food processing. Texas and Kansas have the greatest number of wells in this category because these states have specific industries that generate large quantities of non– hazardous, liquid

(2) Class I Inventory of the United States, GWPC, June, 2007

wastes. Municipal wastes, which are not specifically defined in federal regulations, are wastes associated with sewage effluent that has received treatment. With the exception of desalination wastes, disposal of municipal waste through injection wells is currently practiced only in Florida. In Florida, this waste disposal practice is often chosen due to a shortage of available land, strict surface water discharge limitations, extremely permeable injection zones, and cost effectiveness.

Site selection for a Class I disposal well is dependent upon geologic and hydrogeologic conditions, and only certain areas are suitable. Most of the favorable locations are generally in the mid–continent, Gulf Coast, and Great Lakes regions of the country, though some other areas are also safe for Class I well sites.

The process of selecting a site for a Class I disposal well involves evaluating many factors. Paramount in the consideration is the determination that the underground formations possess the natural ability to contain and isolate the injected waste. One important part of this determination is the evaluation of the history of earthquake activity. If a location shows this type of instability in the subsurface, it may mean that fluids will not stay contained in the injection zone, indicating the well should not be drilled in that particular location. A second important factor is determining if any improperly abandoned wells, mineral resources that provide economic reserves, or underground sources of drinking water are identified in the area. These resources are evaluated to ensure that the injection well will not cause negative impacts. Abandoned wells of any type—oil, gas, water, or injection that penetrate the proposed injection zone are investigated within a specified radius of the injection well to ensure that they were properly plugged. If they were not, they must be properly plugged to prevent them from becoming a means for the fluids injected into the Class I well to escape upward, potentially contaminating groundwater.

A detailed study is conducted to determine the suitability of the underground formations for disposal and confinement. The receiving formation must be far below any usable groundwater and be separated from them by confining layers of rock, which prevent fluid migration upward. The injection zone in the receiving formation must be of sufficient size (both over a large area and thickness) and have sufficient porosity and permeability to accept and contain the injected wastes. The region around the well should be geologically stable, and the injection zone should not contain recoverable mineral resources such as ores, oil, coal, or gas.

The primary concern in the construction of a Class I injection well is the protection of groundwater by assuring containment of the injected wastes through a multilayer protection system. A Class I injection well is constructed in stages, the first stage being the drilling of a hole to a depth below the lowermost USDW. A steel casing or surface pipe (usually between 6.5 and 15 inches outside diameter) is installed the full length of the bore hole and cement is placed outside of the casing from the bottom of the hole to the ground surface. This provides a barrier of steel and cement that protects the groundwater. The second phase is to continue drilling below the surface casing down through the intended injection zone. After drilling is complete, a second, smaller, (generally between 4.5 and 10 inches outside diameter) protective pipe called long string casing is installed from the surface down to the injection zone and is cemented in place from bottom to top. An injection packer, which is like a drain plug with a hole in the middle, is located inside the long string casing above the injection zone by placing it on an even smaller protective pipe (about 2.5 to 7 inches in diameter), known as injection tubing, which is placed inside the long string. The space between the long string and the injection tubing, called the annulus, is filled with a corrosion inhibiting fluid. When the seal on the outside of the injection packer is expanded tightly against the sides of the injection casing it forms a seal which keeps the annulus fluid in and the injection fluid out of the space above the packer. The pressure in this annular space is constantly monitored so that any change, indicating a failure of safety systems, would cause the well to be shut down for repairs before possible contamination of a USDW.

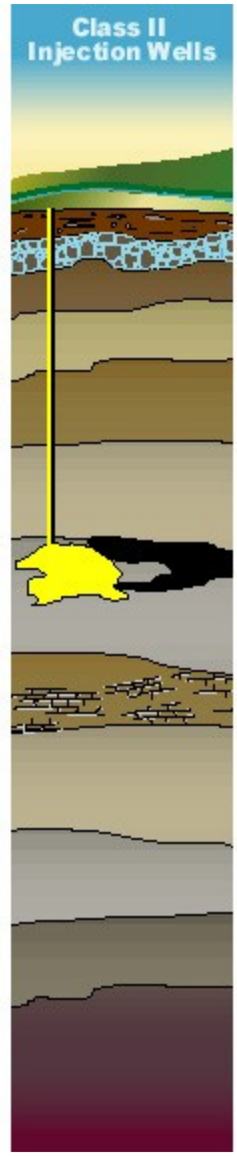
The operating conditions for the well are closely studied and are limited in the permit to make sure that the pressure at which the fluids will be pumped into the subsurface is safe, that the rock units can safely receive the volume of fluids to be disposed of, and that the waste stream is compatible with all the well construction components and the natural characteristics of the rocks into which the fluids will be injected.

Class I injection wells are continuously monitored and controlled, usually with sophisticated computers and digital equipment. Thousands of data points about the pumping pressure for fluid disposal, the pressure in the annulus between the injection tubing and the well casing (that shows there are no leaks in the well), and data on the fluid being disposed of, such as its temperature and flow rate, are monitored and recorded each day. Alarms are connected to sound if anything out of the ordinary happens, and if unusual pressures are sensed by the monitoring equipment, the well automatically shuts off. Disposal in the well does not resume until the cause of the unusual event is investigated, and the people responsible for operating the well and the regulatory agencies both are sure that no environmental harm has been or will be done by well operations. The wells are also tested regularly, using special tools that are inserted into the well to record data about the well and surrounding rock formations. These test results tell a geologist or engineer a great deal about conditions down in the well where we cannot otherwise see.

Regulators review all the data about the well operations, monitoring and testing frequently, and regularly inspecting the well site to make sure everything is operating according to the requirements put in place to protect drinking water sources.

When a Class I well is taken out of service, the injection tubing is removed and the well is plugged to prevent any waste movement. Often, a combination of mechanical plugs and cement are used to seal the wells, which are considered to be permanently secured—not abandoned. The large column of cement in the well ensures that nothing can move up or down in the well, protecting the groundwater resources that could otherwise be affected. Properly located, designed, constructed, operated, and monitored Class I wells have proven through years of use and many studies to be an environmentally and technically-sound method of permanent liquid waste disposal.

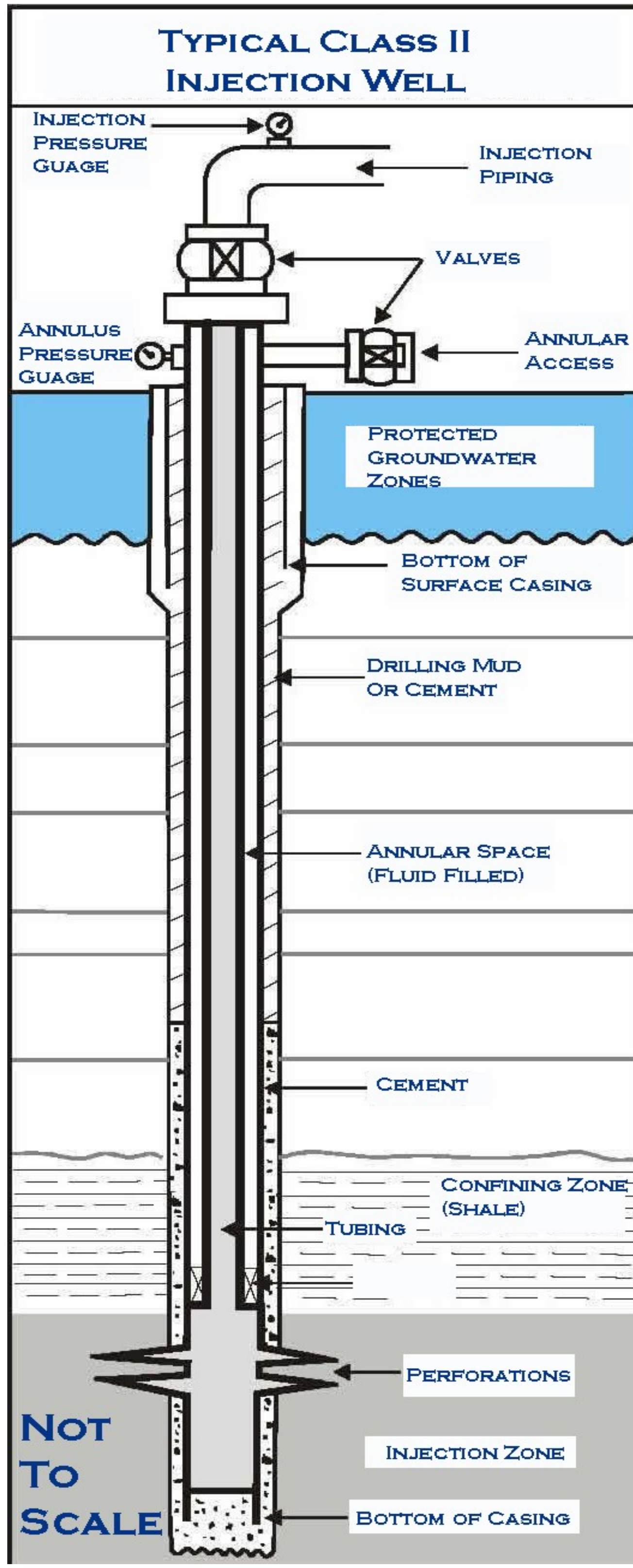
Class II Wells



Class II injection wells have been used in oil field related activities since the 1930's. Today there are approximately 168,000 Class II injection wells located in 31 states. All Class II injection wells are regulated by either a state agency which has been granted regulatory authority over the program, or by USEPA. Class II wells are subject to a regulatory process which requires a technical review to assure adequate protection of drinking water and an administrative review defining operational guidelines. The evaluation of the site suitability for a Class II injection well is very similar to that for a Class I nonhazardous waste injection well. The site's subsurface conditions are evaluated to make sure the formations will keep the fluids out of drinking water sources. The wells must be constructed to protect USDWs, and wells are tested and monitored periodically to ensure no drinking water is being negatively impacted by the operations.

Class II wells are categorized into three subclasses: salt water disposal wells, enhanced oil recovery (EOR) wells, and hydrocarbon storage wells.

As oil and natural gas are brought to the surface, they generally are mixed with salt water. On a national average, approximately 10 barrels of salt water are produced with every barrel of crude oil. Geologic formations are selected to receive the produced waters, which are re-injected through Enhanced Oil Recovery (EOR) injection wells are used to increase production and prolong the life of oil-producing fields. Secondary recovery is an EOR process commonly referred to as water–flooding. In this process, salt water that was co–produced with oil and gas is re-injected into the oil-producing formation to drive oil into pumping wells, resulting in the recovery of additional oil. Tertiary recovery is an EOR process that is used after secondary recovery methods become inefficient or uneconomical. Tertiary recovery methods include the injection of gas, water with special additives, and steam to maintain and extend oil production. These methods allow the maximum amount of the oil to be retrieved out of the subsurface. Approximately 60% of the salt water produced with oil and gas onshore in the United States is injected into EOR wells.



Hydrocarbon storage wells are generally used for the underground storage of crude oil and liquid hydrocarbons* in naturally occurring salt or rock formations. The wells are designed for both injection and removal of the stored hydrocarbons. The hydrocarbons are injected into the formation for storage and later pumped back out for processing and use.

* Hydrocarbons fit this classification if they are liquid at standard temperature and pressure (75 degrees Fahrenheit at 14.7 pounds per square inch).

As shown in the diagram (at right), construction of Class II injection wells is designed to adequately confine injected fluids to the authorized injection zone to prevent the migration of fluids into USDWs. Through the permitting process, site specific requirements are imposed to address any unusual circumstances. These injection wells are drilled and constructed using the same techniques as those for Class I wells, with steel pipe (called casing) cemented in place to prevent the migration of fluids into USDWs. Surface casing in conventionally constructed wells is cemented from below the lowermost USDW up to the surface to prevent fluid movement. Cement is also placed behind the long s injection casing at critical sections to confine injected fluids to the authorized zone of injection. A typical salt water injection well also has the injection tubing that was described earlier, through which the fluids are pumped from the surface down into the receiving geologic formations. As described in the section on Class I wells, a packer is commonly used to isolate the injection zone from the space between the tubing and injection casing above the packer, called the annulus. In some cases, multiple wells will be constructed under one permit, to manage the fluids in an entire oil or natural gas production field. The overall well system for injection is then evaluated by regulators to make sure all the components are properly constructed.

Typically, oil, gas, and salt water are separated at the oil and gas production facilities. The salt water is then either piped or trucked to the injection site for disposal or EOR operations. There, the salt water is transferred to holding tanks and pumped down the injection well. For EOR, the salt water may be treated or augmented with other fluids prior to injection. In some EOR cases, fresh water, or fresh water converted to steam, is injected to maximize oil recovery.

Injection well operations are regulated in ways designed to prevent the contamination of USDWs and to ensure fluid placement and confinement within the authorized injection zone. This includes limitations on factors such as the pressure that can be used to pump the water or steam into the well, or the volume of the injectate. Primacy states have adopted regulations which have been approved by USEPA as protective of USDWs for Class II injection well operations. These regulations address injection pressures, well testing, pressure monitoring, and reporting. Direct implementation states must meet operational guidelines developed directly by USEPA.

After placing Class II injection wells in service, groundwater protection is assured by testing and monitoring the wells. Injection pressures and volumes are monitored as a valuable indicator of well performance. Effective monitoring is important since it can identify problems below ground in the well so that corrective action can be taken quickly to prevent endangerment of USDWs. Tests that evaluate the conditions of the various well components and the formations in the subsurface are required prior to initial injection and no less than once every five years afterward. However, in some cases, more frequent testing may be required by regulatory authorities, if needed. All tests and test methods are rigorously reviewed by the State and/or USEPA. Test data, as well as data on the volume and characteristics of the fluids injected into the well, are regularly evaluated by regulatory agencies to make sure USDWs are protected by the operation and maintenance of the wells. Closure of Class II wells must be conducted in a manner protective of USDWs. Although regulations vary slightly from state to state, a cement plug is commonly required to be placed in the well across the injection zone, with additional plugs placed across the base of the lowermost USDW and near the surface.

Surface setup of a typical Class II injection well

Class III Wells

Class III injection wells are found in 18 states. Every Class III injection well, whether located in a Primacy or Direct Implementation state, must be permitted through the authorized regulatory agency. The operating permit requires that a well meet any regulations the state has adopted to ensure the protection of USDWs. The permits may include specific requirements for well construction, monitoring, mechanical integrity testing, maximum allowable injection pressure, and reporting. Proper closure or plugging of all Class III injection wells must be conducted in a manner to protect USDWs from potential contamination.

The techniques these wells use for mineral extraction may be divided into two basic categories: solution mining of salts and sulfur, and in situ leaching (in place leaching) for various minerals such as copper, gold, or uranium.

Solution mining techniques are used primarily for the extraction of salts and sulfur. For common salt, the solution mining process involves injection of relatively fresh water, which then dissolves the underground salt formation. The resulting brine solution is pumped to the surface, either through the space between the tubing and the casing in the injection well, or through separate production wells.

The technique for solution mining of sulfur is known as the Frasch process. This process consists of injecting superheated water down the space between the tubing and the casings of the injection well and into the sulfur–bearing formations to melt the sulfur. The molten sulfur is extracted from the subsurface through the tubing in the injection well, with the aid of compressed air, which mixes with the liquid sulfur and airlifts it to the surface.
In situ leaching is commonly used to extract copper, gold, and uranium. Uranium is the predominant mineral mined by this technique. The uranium in situ leaching process involves

injection of a neutral water solution containing nontoxic chemicals (e.g., oxygen and carbon dioxide) down the well. This fortified water is circulated through an underground ore body or mineral zone to dissolve the uranium particles that coat the sand grains of the ore body. The resulting uranium–rich solution is then pumped to the surface, where the uranium is extracted from the solution and the leaching solution is recycled back into the ore body through the injection well. This same general technology is employed for in situ leaching of other minerals, the only difference being the type of fluid used in the process. The typical life of an in situ leaching well is less than five years. At the end of the in situ leaching operations, State UIC regulations require restoration of the groundwater in the mined zone to its original quality. Given the purpose of Class III wells and their life span, Class III UIC projects often include many wells that are authorized through one permit, called an area permit. The standards in the permit apply to all of the wells in the project area.

Construction standards for Class III injection wells are designed to confine injected fluids to the authorized injection zone to prevent migration of these fluids into USDWs. Class III injection wells are drilled into mineralized rock formations and are cased with pipe which is cemented in place to prevent fluid migration into USDWs. Construction materials and techniques vary and depend upon the mineral extracted and the nature of the injected fluids. Tests are required before initial operation of Class III injection wells to evaluate conditions of the well construction materials and the rock formations. Several different tests have been approved for this purpose. The tests are required to determine that there are no leaks in the tubing, casing, or packer and that there is no fluid movement into a USDW. UIC regulations also require that the ore body be surrounded by monitoring wells to detect horizontal migration of the mining solutions. Additionally, overlying and underlying aquifers must be monitored to detect any vertical migration of these same fluids. This entire network closely monitors the mining activity performed through Class III wells to protect USDWs.

Class IV Wells

Class IV wells have been identified by USEPA as a significant threat to human health and the environment since these wells introduce very dangerous wastes into or above a potential drinking water source. USEPA has banned the use of these wells for many years. However, due to both accidents and illegal intentional acts, Class IV wells are still periodically found at various locations. As these wells are identified by state and federal UIC regulatory agencies, their closure is a high priority for the UIC Program. Regulators evaluate site conditions, determine what actions need to be taken to clean up the well and surrounding area, and permanently close the well so additional hazardous wastes cannot enter the subsurface through the well. This well class may include storm drains where spills of hazardous wastes enter the ground or septic systems where hazardous waste streams are combined with sanitary waste. When these wells are found, the UIC Program staff usually coordinates with the state or USEPA hazardous waste program staff to oversee actions required at the site to remove the contamination and protect USDWs.

Although otherwise banned, there is one instance where Class IV wells are allowed. In these cases the wells are used to help clean up existing contamination. Sites exist across the United States where hazardous wastes have entered aquifers due to spills, leaks or similar releases into the subsurface. Under two separate federal laws, the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), regulators require and oversee the clean up of these contaminated sites. Some remediation technologies require the contaminated groundwater to be pumped out of the subsurface, treated at the surface to remove certain contaminants, then pumped back into the contaminated formation. The process essentially creates a big treatment loop for the groundwater. However, the water can still have contaminants at levels that meet the definition of hazardous waste when it is injected back into the subsurface, until the treatment process has time to remove more contaminants. Thus, these wells that are treating and cleaning up groundwater technically are still Class IV wells. USEPA recognized that these site clean ups need to occur, and that the ban of Class IV wells was hindering the process. Since these wells are helping the environment, the agency changed the regulations to allow these wells to be used, as long as they are part of an approved regulatory clean up of the site. This is the only exemption to the ban on Class IV wells.

Class V Wells

If a well does not fit into one of the first four classes of injection wells, but still meets the definition of an injection well, it is considered a Class V well. Class V injection practices recognized by USEPA include several individual types of wells, which range in complexity from simple cesspools that are barely deeper than they are wide, to sophisticated geothermal reinjection wells that may be thousands of feet deep. However, the number of shallow, relatively simple Class V wells is large, and the sophisticated, deep Class V wells are quite rare in comparison. Remember that injection wells are classified based on the type of waste disposed of and the depth of the disposal zone compared with the deepest USDW. In some parts of the country, USDWs are found at great depths. When injection above a USDW does not meet the definition of a Class I well or the injection fluid definitions below, such wells are defined as Class V wells.

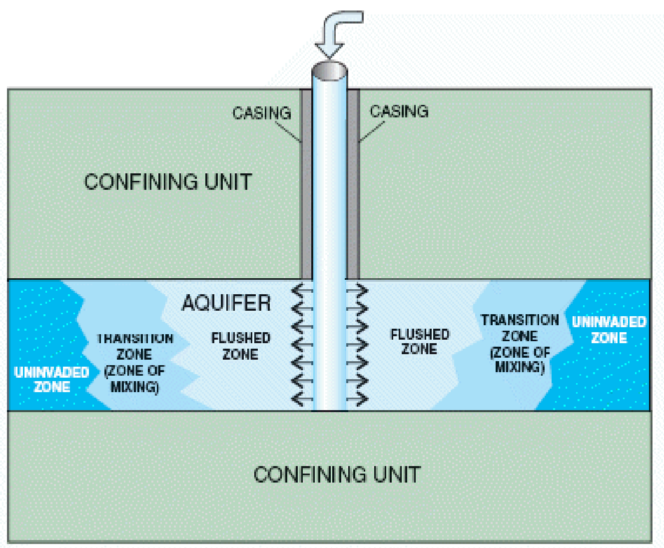
1. Class I: Hazardous waste and non hazardous industrial or municipal waste injected below the lowermost USDW; or
2. Class II: Fluids produced from oil and natural gas activities; or
3. Class III: Fluids generated in mineral production; or
4. Class IV: Hazardous or radioactive wastes injected into or above a USDW, the well defaults to the Class V category.

Class V injection wells can be located anywhere, but they are especially likely to exist in areas that do not have organized wastewater collection and treatment. Unfortunately, these areas are often the same areas where people are most likely to depend on groundwater for their drinking water source, typically from private wells that do not undergo treatment or disinfection at a public water supply system. There are over 20 different Class V well types. The variety of Class V wells includes but is not limited to agricultural drainage wells, storm water drainage wells, large capacity septic systems, mine backfill wells, aquifer remediation wells, heat pump/air conditioning return flow wells, aquifer recharge wells, aquifer storage and recovery, saltwater intrusion barrier wells, subsidence control wells, and nonhazardous industrial disposal wells such as those associated with carwashes and laundromats.

Not all Class V wells are used for disposal. Examples of Class V practices which are not strictly disposal include: aquifer recharge, aquifer storage and recovery, and saltwater intrusion control. With the increasing need to manage water both at the surface and underground and to develop additional water sources to meet increased demand for drinking water, these wells, along with treated sewage effluent wells and stormwater drainage wells, emplace water underground and are considered to be important tools for water managers.

Aquifer recharge wells are typically used to prevent land surface subsidence and to maintain pressure and volume in an aquifer.

Aquifer storage and recovery (ASR) wells are used to store water underground for future use. (The diagram at right shows a typical ASR system.) Advantages of using ASR to provide for water storage include flexibility, projects are both scalable and adjustable—wells can be added as needed to provide for additional storage. The use of ASR can also avoid the potential political, environmental, and economic impacts



from the construction and flooding of new surface water reservoirs. Water stored underground is not as susceptible to contamination from surface sources or evaporation as surface reservoirs.

Fluids injected into aquifer recharge and ASR wells include potable drinking water (from a drinking water treatment plant), groundwater (treated or untreated), and/or surface water (treated or untreated), according to EPA's Class V Fact Sheets. However, EPA also notes that the major goal of aquifer recharge and ASR wells is to replenish water in aquifers for subsequent use and that the injection fluids typically meet drinking water standards.

Class V Wells that inject sanitary wastewater that has received secondary or tertiary treatment, are considered sewage treatment effluent wells. In areas suffering from water scarcity and in areas where rainfall is predicted to decrease, wastewater reuse can stretch existing surface and groundwater supplies. Injection of treated wastewater increases groundwater pressure and volume, enhancing contributions to surface water and providing water for later recovery for potable and non-potable uses. An example of sophisticated water reuse with ASR or aquifer recharge wells for a large municipality would start with high quality effluent from a wastewater treatment plant subjected to more advanced water treatment in a specialized drinking water treatment facility before delivery for injection and underground storage.

Many municipalities use stormwater drainage wells to prevent sanitary sewer overflows and to meet municipal stormwater discharge permit requirements and construction permitting requirements for new land development. According to EPA, stormwater drainage wells are Class V wells used to remove stormwater or urban runoff from impervious surfaces such as roadways, roofs, and paved surfaces to prevent flooding and related problems including infiltration into basements. Many water resource managers are looking at holistically managing the hydrologic cycle (including stormwater harvesting) to address competing and increased demands from agriculture, environmental flows, municipalities, and industry.

Saltwater intrusion control wells are used to increase or maintain aquifer pressure in a fresh water aquifer as a barrier to prevent saltwater from flowing into and contaminating the aquifer.

Class V wells injecting below the lowermost USDW have the least potential for contaminating groundwater. Class V injection directly into USDWs has a greater potential to cause harm to water quality than discharges above the water table. Discharges above the water table may allow some contaminants to be removed from the waste through various chemical and microbial processes in soils and the vadose zone. However, some rock formations and soil types, such as sand, can allow fluids injected above USDWs to move very quickly without very much change. In these cases, the effect can be similar to injecting directly into the USDW.

Based on numbers obtained through a 2006 survey of the states, it is estimated that there may be more than 1,500,000 Class V injection wells in the United States and its territories. The survey also suggests that about 49 percent of all Class V wells belong to three categories: drainage wells (approx. 23 percent), sewage-related wells (approx. 17 percent) and industrial waste (approx. 9 percent) (3)

USEPA has developed rules and a strategy for regulating Class V injection wells. Involvement by state and local government and the public in implementing the strategy is essential to its success. Many states have adopted regulations and ordinances for oversight of certain Class V wells. USEPA targeted those Class V wells which pose the greatest environmental risks as candidates for regulatory development, education and outreach, and enforcement when necessary.

Two subclasses of particular concern are large capacity cesspools and automotive waste disposal wells. Large capacity cesspools are any residential cesspools used by multiple dwellings, businesses, or other facilities that are not individual homes (such as schools and churches). The specific definition of a large capacity cesspool can vary slightly from state to state, and environmental regulators can help a facility determine if their cesspool is “large

(3) Class V Survey of State UIC Agencies, GWPC, 2006

capacity." Large capacity cesspools dispose of untreated sewage into or above a drinking water source, creating significant risk for bacteria and viruses being introduced into drinking water. Automotive waste disposal wells (such as the one shown below left) are used by motor vehicle repair or maintenance shops, car dealers, or any operation that disposes of fluids from vehicles (including trucks, boats, trains, planes, tractors, snowmobiles, and similar types of vehicles). Motor vehicle waste disposal wells have a high potential to receive drops and spills of vehicle fluids, such as oil, transmission fluid, antifreeze, solvents and degreasers, and other toxic materials. As these fluids enter groundwater, they can create a serious health risk in USDWs.

Motor vehicle waste disposal well

In 1999, USEPA adopted the Underground Injection Control Regulations for Class V Injection Wells., Revisions, known as the Class V Rule, Phase I, established minimum federal standards for these two kinds of Class V wells. Some of the protective requirements of the Class V Rule, Phase I include a ban on new large capacity cesspools (like the one shown below right) and the closure of all existing large capacity cesspools by 2005. New motor vehicle waste disposal wells were also banned, while existing disposal wells in groundwater protection areas and other designated sensitive groundwater areas must either be permanently closed or permitted by the primacy state or USEPA to continue operating under the ban. Some UIC primacy states have made the requirements for existing motor vehicle waste disposal wells apply in the entire state, rather than limiting them to specific sensitive groundwater areas. The owner or operator of a large capacity cesspool or motor vehicle waste disposal well is required to send a notice to the state or USEPA at least 30 days before beginning to close one of these wells. USEPA developed a special guide for owners and operators of motor vehicle waste disposal wells, to provide additional information about how the rule affects them. The document, entitled Small Entity Compliance Guide: How the New

Large capacity cesspool well

Motor Vehicle Waste Disposal Well Rule Affects Your Business, is USEPA publication number 816-R-00-018, November 2000, and is available by contacting USEPA's Small Business Division. Additional information about large capacity cesspools, motor vehicle waste disposal wells, and other Class V wells is also available on the Internet at www.epa.gov/safewater/uic/. A video describing the regulation and closure of motor vehicle waste disposal wells is available through the GWPC website at www.gwpc.org.

Fluids injected by Stormwater Drainage and Large Capacity Septic System (LCSS) wells can also degrade groundwater quality. LCSS wells discharge partially treated sewage and Stormwater Drainage wells accept and inject waters that may contain contaminants from roadways and other sources of runoff. EPA's Phase I Rules also added and modified several Class V definitions including definitions related to these two Class V well types, which increase the numbers and types of facilities requiring Class V regulation. The rules add new definitions including *improved sinkhole*, *point of injection* and *subsurface fluid distribution system*. Importantly the definition of *subsurface fluid distribution system* and *well* expands the "deeper than wide" well definition to include perforated piping and tiles intended to distribute fluids below the surface of the ground.

In June 2002, USEPA published its Notice of Final Determination for Class V Wells; that, at that time, additional federal requirements were not needed for the remaining types of Class V wells (other than the motor vehicle waste disposal wells and large capacity cesspools). The determination also noted that the use and enforcement of existing federal UIC regulations are adequate to prevent Class V wells from endangering USDWs. This determination was made after completion of a national Class V study, a proposed determination, receipt of public comments and additional information received in response to the proposed determination, and a final assessment of all the data and information provided by the public and by various state UIC programs.

This determination certainly does not mean that Class V wells are not regulated. In fact, the only Class V wells that are operating legally are those whose owners have submitted inventory information to the State or USEPA as required by regulation and are operating their wells in a way that does not endanger USDWs. The required inventory information is simple to prepare and submit, and each Regional USEPA office or primacy state has a form that an owner or operator of a Class V well should complete. The well would be required to obtain a permit with more stringent protection measures or required to be permanently closed. If the state or USEPA office decides that additional information is necessary to ensure USDWs are not threatened by the operation of a well, the owner or operator will be asked for that information. There are cases in which a well that is not a large capacity cesspool or motor vehicle disposal well may require permitting or closure, if data indicate the well poses a risk of contamination to nearby USDW's..

The June 2002 Class V Final Determination by USEPA included a discussion of how the agency will continue to prioritize Class V program actions to ensure that these wells are constructed, operated, and maintained to protect USDWs. These actions include continuing to implement the long standing UIC regulations and the 1999 Class V, Phase I Rule, educating and assisting Class V well operators on best management practices and compliance tools, exploring non-regulatory approaches for voluntary Class V well standards and practices, and coordinating with other USEPA programs to educate the public and determine the maximum possible number of UIC well facilities. An important result of these coordination efforts is the development and publication of two guidance documents addressing decentralized on-site wastewater facilities, which include Class V Large Capacity Septic Systems. These documents are entitled Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems, EPA 832-B-03-001 and Handbook for Managing Onsite and Clustered (Decentralized) Wastewater Treatment Systems, EPA 832-B-05-001. USEPA also will evaluate new information as it becomes available, and if new information illustrates additional needs in the Class V UIC Program, the agency will be able to take additional steps, including developing additional federal regulations.

Class VI Wells

Class VI wells are designed to inject supercritical carbon dioxide (CO_2) into abandoned oil and gas zones, deep saline aquifers and other potential formations for the purpose of storage or disposal. Wells injecting CO_2 into active oil and gas formations for the purpose of enhanced recovery remain in the Class II program.

On December 10, 2010 the USEPA finalized the UIC Class VI Rule. The publication of this rule followed a nearly 3 year process of discussions, meetings and hearings with a broad array of stakeholder groups including GWPC and its state members. Special meetings were held on topics including mechanical integrity, well construction, and monitoring, measuring and verification. The Class VI rule was developed using an iterative process that relied very heavily on stakeholder input and feedback. While the Class VI program most closely resembles the Class I program with respect to its requirements in areas such as well construction, monitoring and area of review, it is more similar to the Class II program for well mechanical integrity and well closure. However, unlike other well classes it has unique characteristics in areas like financial assurance, permitting, operations and post closure monitoring. Also like the Class I, III and V programs it comes under Section 1422 of the SDWA. This means that states seeking primacy for the program must have requirements that meet or exceed the federal requirements. Unlike other 1422 programs, however, primacy for the Class VI program may be granted to a state without a requirement that wells in Classes I, III and V be included in the primacy request.

States had 270 days from the date of the publication of the Class VI rule to apply for primacy. While several states expressed an interest in obtaining primacy for the Class VI program, as of July 2012 deadline no state had officially requested or been granted primacy. This means that since September 7, 2011 the program for the entire U.S. has been run by the USEPA.

Whether or not the implementation of the Class VI program will become a substantial effort depends upon several factors including:

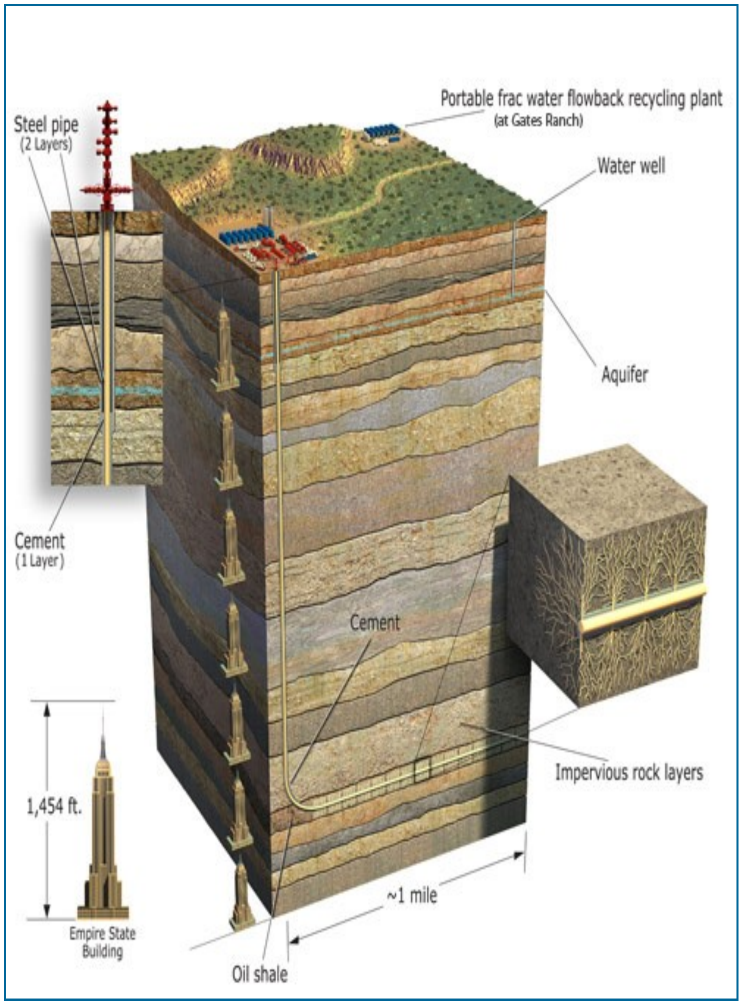
1. The availability of adequate federal/ state funding to implement the program;
2. The ability to find, hire and train technical staff; and
3. The passage of federal carbon legislation to drive the process of establishing a cost for carbon and thus the need for carbon sequestration

While the likelihood of mass implementation of commercial geologic sequestration of CO_2 is unknown, there is no question it was necessary to develop the Class VI program to ensure that a mechanism was in place should the need for large scale CO_2 sequestration become a reality.

Hydraulic Fracturing and the UIC Program

In the past decade an issue regarding the use of hydraulic fracturing as a means of enhancing oil and gas production has arisen. The question was often posed as "Should hydraulic fracturing be considered underground injection"? While there was no mention of hydraulic fracturing in the original SDWA or its subsequent updates, the question lingered. In 1998 a group called the Legal Environmental Assistance Fund (LEAF) filed a lawsuit in federal court attempting to force the USEPA to withdraw the Class II UIC program from the State of Alabama because it did not regulate the hydraulic fracturing of coalbed methane zones as a Class II UIC activity. The case was adjudicated up through the 11th Circuit Court of Appeals. The court decided that for the purposes of hydraulic fracturing of coalbed methane zones the SDWA UIC Class II provisions applied. Subsequent to the courts determination, the State of Alabama revised its Section 1425 Class II UIC program to include this activity. However, since the court's decision addressed only the Alabama UIC program and then only as it related to hydraulic fracturing of coalbed methane wells, the issue of whether or not hydraulic fracturing, in general, was covered by the UIC program remained unanswered.

In 2005 the U.S. Congress passed the Energy Policy Act. In the act, Congress clarified its original intent under the SDWA with respect to hydraulic fracturing. The act stated that underground injection "excludes (i) the underground injection of natural gas for purposes of storage; and (ii) the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities" Subsequent to the passage of the act, the USEPA began the process of developing an official guidance document regarding the use of diesel in hydraulic fracturing. A draft of the guidance document was released on May 4, 2012. As of the writing of this brochure, the draft guidance was awaiting review from the Office of Management and Budget. Based on the text of the draft guidance, it is expected the USEPA will classify hydraulic fracturing using diesel fuel as a UIC activity for which a permit is required. The question of how states will respond to the final guidance is unclear although adjustments to delegated programs in some states are likely to occur.



Graphic courtesy of the Texas Oil & Gas Association

Final Thoughts

Over the years some have questioned the advisability and safety of injecting fluids underground. While there are risks associated with any method of waste disposal it is important to recognize that the alternatives to underground injection carry much greater inherent risk because of their proximity to the near surface environment. For example, fluid storage in unlined pits (such as the one shown at right) and disposal via surface discharge are far more likely to cause contamination of both surface and groundwater resources than is deep underground injection.

While new technologies like on-site treatment systems such as those being developed at Texas A&M University (below left courtesy of John Veil, Veil Environmental) carry the promise of lowering the volumes of fluid that must be injected underground; in the near term underground injection is still the safest and most effective means of isolating wastes from the near surface environment and most importantly from groundwater.

In the final analysis, it could be said that if the success of a regulatory program is measured by the prevention of environmental harm, the UIC program is a candidate for the most successful environmental protection program in history.

Mission Statement

The Groundwater Protection Council is a national association of state groundwater and underground injection control agencies whose mission is to promote the protection and conservation of groundwater resources for all beneficial uses, recognizing groundwater as a critical component of the ecosystem.

The Groundwater Protection Council provides a forum for stakeholder communication and research in order to improve governments' role in the protection and conservation of groundwater.

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