INJECTION WELLS

This continuing education unit introduces readers to “Injection Wells.”

INTRODUCTION TO INJECTION WELLS

Disposing of wastewater through underground wells began in the 1930s, when oil companies started pumping brine produced from oil and gas production into porous rock formations underground. This disposal method is more cost effective than treating and reusing wastewater.

What exactly is underground injection?

Underground injection is the placing of fluids underground, in porous formations of rocks, through wells or other similar conveyance systems. While rocks such as sandstone, shale, and limestone appear to be solid, they can contain significant voids or pores that allow water and other fluids to fill and move through them.

Man-made or produced fluids (liquids, gases or slurries) can move into the pores of rocks by the use of pumps or by gravity. The fluids may be water, wastewater or water mixed with chemicals.

Why are underground injection sites used for storage?

Americans generate large amounts of waste fluids.

More than 750 billion gallons of *hazardous and non-hazardous* fluids are disposed of safely through underground injection.

Over 9 billion gallons of *hazardous waste* is injected into wells each year in the US.

Facilities across the United States discharge a variety of hazardous and nonhazardous fluids into more than 500,000 injection wells. While treatment technologies exist, it would be very costly to treat and release to surface waters the billions and trillions of gallons of wastes that industries produce each year.

Agribusiness and the chemical and petroleum industries all make use of underground injection for waste disposal. When wells are properly sited, constructed, and operated, underground injection is an effective and environmentally safe method to dispose of wastes.

The Environmental Protection Agency (EPA) insures that these fluids are disposed of safely and cost effectively while fulfilling their mission to

protect underground sources of drinking water from contamination by regulating the location, construction, operation and closure of injection wells.

<u>What is the history of the regulation of underground injection wells in the United States?</u>

(Note: The abbreviation <u>USDW</u> is used often in this presentation. USDW is the abbreviation for "<u>underground source of drinking water</u>." It will be helpful to remember this abbreviation.)

First let's sum up the goal of any and all regulation in this area:

The goal of Federal regulations is to prevent contamination of "underground sources of drinking water" (USDW). A USDW is defined as an aquifer, or its portion, which serves as a source of drinking water for human consumption, or contains a sufficient quantity of water to supply a public water system, and contains fewer than 10,000 mg/liter of total dissolved solids.

The history of the U.S. federal government's role in achieving the above goal is summarized as follows:

- **In 1974, responding to concerns about underground injection practices, including failure of some wells, the U.S. Environmental Protection Agency (EPA) raised concerns that injected waste could contaminate underground drinking water.**
- **In December 1974, Congress enacted the Safe Drinking Water Act, which required the EPA to set requirements for protecting underground sources of drinking water (USDWs).**
- **EPA passed its Underground Injection Control regulations in 1980.**
- **In 1988 EPA made its UIC regulations stronger to comply with the newly upgraded waste disposal amendments of the Resource Conservation and Recovery Act.**

<u>Why Did Injection Wells Become so Strictly Regulated?</u>

Prior to EPA's regulation of injection wells, several cases of well failures occurred.

The Hammermill Paper Company in Erie, PA, and the Velsicol Chemical Corporation in Beaumont, TX, are two examples.

• In April 1968, corrosion caused the casing of Hammermill Paper Company's No. 1 well to rupture and spent pulping liquor flowed onto the land and entered Lake Erie.

Additionally, a noxious black liquid seeped from an abandoned gas well at Presque Isle State Park, 5 miles away. The Pennsylvania Department of Environmental Resources suspected (though never conclusively determined) that wastewaters from Hammermill's injection well migrated up the unplugged, abandoned well bore.

• In 1974 and 1975 the Velsicol Chemical Company noted lower than normal injection pressures in one of its two injection wells, which was designed without tubing.

In 1975, Velsicol shut down the well to determine the cause of the decreased injection pressures, and an inspection revealed numerous leaks in the well's casing. The company decided to plug the well and drill a new one.

During the course of the abandonment, Velsicol determined that contaminated wastewater had leaked to a USDW. The wastewater was pumped from the aquifer.

It was in response to events such as those described above, and the growing use of injection wells for waste storage that EPA issued a policy statement in 1974 stating that EPA opposed underground injection

> ***"without strict control and clear demonstration that such wastes will not interfere with present or potential use of subsurface water supplies, contaminate interconnected surface waters or otherwise damage the environment."***

It was this EPA action that resulted in the passage of the *Safe Drinking Water Act* by Congress in December of 1974 which granted EPA the power to regulate injection wells and otherwise protect our underground sources of drinking water (USDW). Later acts and regulations have added power to EPA's ability to protect our groundwater resources including stricter controls over injection wells.

How does the government define what an injection well is?

The EPA defines an injection well as any bored, drilled or a driven shaft or a dug hole, where the depth is greater than the largest surface dimension that is used to discharge fluids underground.

This definition covers a wide variety of injection practices that range from:

- **More than 100,000 technically sophisticated and highly monitored wells which pump fluids into isolated formations up to two miles below the Earth's surface,**
- **To the far more numerous on-site drainage systems, such as septic systems, cesspools, and storm water wells, that discharge fluids a few feet underground.**

Is their only one type of Injection Well?

No. The EPA classifies injection wells into 5 categories. We will describe all five types of injection wells and their uses. We will spend more time talking about Class I injection wells than about any of the other types.

Are All Injection Wells Waste Disposal Wells?

No, all injection wells are not waste disposal wells. Some Class V wells, for example, inject surface water to replenish depleted aquifers or to prevent salt-water intrusion. Some Class II wells inject fluids for enhanced recovery of oil and natural gas, and others inject liquid hydrocarbons that constitute our Nation's strategic fuel reserves in times of crisis.

A more detailed description of each of the five classes of injection wells follows: (The wells are described in reverse order, beginning with Class V)

CLASS V INJECTION WELLS

These wells are those wells which are used for the shallow "injection" of non-hazardous fluids only. The EPA estimates there are between 500,000 to 685,000 Class V injection wells in the United States.

Class V wells are injection wells that are not included in the other classes.

Some Class V wells are technologically advanced wastewater disposal systems used by industry, but most are "low-tech" wells, such as septic systems and cesspools.

Generally, they are shallow and depend upon gravity to drain or "inject" liquid waste into the ground above or into underground sources of drinking water. Their simple construction provides little or no protection against

possible ground water contamination, so it is important to control what goes into them.

Class V wells "inject" *non-hazardous* fluids into or above a USDW and are typically shallow, on-site disposal systems, such as floor and sink drains which discharge directly or indirectly to ground water, dry wells, leach fields, and similar types of drainage wells.

The largest number of CLASS V injection wells are shallow wells that "inject" *non-hazardous* fluids into very shallow aquifers that are or can be used as sources of drinking water. Some of the wells in this category are:

- **Drainage wells in industrial setting that can receive surface runoff contaminated with a variety of pollutants;**
- **Septic tank systems and dry-wells used in automotive shops that receive fluids from repair and maintenance bays;**
- **Cesspools that receive sewage from a community;**
- **Agricultural drainage wells that may receive water contaminated with pesticides and fertilizers.**
- **Wastewater disposal – storm water runoff, incidental and process wastes from industry, car wash water, food processing wastes, treated sanitary wastes*, drainage from agricultural activities, and aquifer remediation.**
- **Beneficial uses – aquifer recharge, aquifer storage and recovery, subsidence control, saline intrusion barrier, and brine return from mineral recovery and energy production.**

For your information:

- ♦ **The majority of Class V well owners are small businesses and municipalities**
- ♦ **The two most numerous types of Class V wells are storm water drainage and large capacity septic systems.**

The government has established these guidelines for Class V Injection Wells:

• The well cannot endanger underground sources of drinking water (USDW's).
• Well owners must submit inventory information
• There are additional specific requirements for motor vehicle waste disposal wells and large capacity cesspools.

THIS PICTURE SHOWS 3 CLASS V WELLS

CLASS IV INJECTION WELLS

Class IV wells inject hazardous or radioactive wastes into or above underground sources of drinking water. There are 40 Class IV Injection Wells in the United States according to the EPA.

The use of Class IV wells to dispose of waste was banned in 1984.
These wells are banned under the Environmental Protection Agencies Underground Injection Control (UIC) program because they directly threaten public health.

However, these wells are authorized when operated to inject treated contaminated ground water back into the original aquifer as part of a clean-up effort and may only be operated with federal or state approval. Owners and operators of Class IV wells must still meet all Environmental Protection Agency requirements.

The remainder of this CEU deals with Class I, II, & III injection wells.

<u>GENERAL REQUIREMENTS FOR CLASS I, II, & III INJECTION WELLS</u>

In general, owners and operators of most new Class I, II and III injection wells are required to:

1. **Site the wells in a location that is free of faults and other adverse geological features;**

2. **Drill to a depth that allows the injection into formations that do not contain water that can potentially be used as a source of drinking water. These injection zones are confined from any formation that may contain water that may potentially be used as a source of drinking water;**

3. **Build to inject through an internal pipe (tubing) that is located inside another pipe (casing). This outer pipe has cement on the outside to fill any voids occurring between the outside pipe and the hole that was bored for the well (borehole). This allows for multiple layers of containment of the potentially contaminating injection fluids;**

4. **Test for integrity at the time of completion and every five years thereafter (more frequently for hazardous waste wells,**

5. **Monitor continuously to assure the integrity of the well.**

(Class I *Municipal* Injection Wells are a special case and do not have to meet all the requirements stated above. Class I Municipal Injection Wells are only presently found in Florida. They are discussed more fully below in the section discussing “Class I Injection Wells.)

CLASS III INJECTION WELLS

Class III injection wells are those wells used for the solution mining of minerals. The EPA estimates that there are 17,000 Class III injection wells in the United States.

Class III wells are wells that inject super-heated steam, water, or other fluids into formations in order to extract minerals. The injected fluids are then pumped to the surface and the minerals in solution are extracted. Generally, the fluid is treated and re-injected into the same formation.

- **50 percent of the salt used in America is extracted through Class III wells**
- **80 percent of the uranium is extracted using Class III wells**

Class III wells are regulated to minimize the environmental impacts from solution mining operations.

Examples of Fluids Used in the solution mining of various minerals:

- **Fresh water to extract salt (NaCl)**
- **Sodium bicarbonate to extract uranium salts**
- **Steam to extract sulfur**
- **Proprietary solutions to extract other minerals and metals**

Protective Regulations for Class III Injection Wells

Construction and siting

- **Cased and cemented to prevent movement of fluids into USDWs**
- **Tubing and packer appropriate for injected fluids**

Monitoring and testing

- **Nature of the injected fluid**
- **Injection pressure or injectate rate or volume**
- **Internal/external mechanical integrity test (MIT)**
- **Frequent testing of fluids in the injection zone**
- **Monitoring wells in adjacent USDWs**

Recordkeeping and Reporting

• Plan for safe plugging and abandoning of wells, including demonstration of financial responsibility

CLASS II INJECTION WELLS

Class II injection wells are those wells associated with the oil and gas industry. They include wells which inject brine and other fluids associated with oil and gas production. The EPA estimates there are 147,000 Class II Injection Wells in the United States. More than 700 million gallons of fluids are injected into Class II wells each year.

Most of the injected fluid is brine that is produced when oil and gas are extracted from the earth. Typically, 10 gallons of brine are produced for each gallon of oil. Fluids are injected into these wells to enhance oil recovery. Oil is also injected into these wells for the purposes of underground storage.

Examples of Fluids:

- **Produced high salinity brine**
- **Crude oil (for storage)**
- **Polymers and viscosifiers for enhanced recovery wells**
- **Drilling fluids and muds**

Protective Regulations for Class II Injection Wells

Construction and siting

• Cased and cemented to prevent movement of fluids into USDWs
• Construction and design of well (casing, tubing, and packer) varies

Monitoring and testing

• Internal/External mechanical integrity testing (MIT)
• Periodic monitoring and reporting

Record keeping and Reporting

• Plan for safe plugging and abandoning of wells, including demonstration of financial responsibility

CLASS I INJECTION WELLS

This CEU will focus more attention on Class I Injection Wells than on the other classes of injection wells. It is the Class I Injection Wells that most often receive public notoriety.

Public opinion is often polarized on the subject of injection wells, especially Class I injection wells because it is this class of injection well that may be permitted to inject hazardous waste into the earth (*what is defined as a hazardous waste is given below*). One benefit of this CEU may be to give the reader more accurate information on this current and often emotional topic.

Basic Definition of a Class I Injection Well

Class I wells are technologically sophisticated and inject hazardous and non-hazardous wastes below the lowermost underground source of drinking water (USDW). Injection occurs into deep, isolated rock formations that are separated from the lowermost underground source of drinking water (USDW) by layers of impermeable clay and rock. Class I Injection Wells are strictly regulated.

The Growth of Class I Injection Wells

In the 1950s, injection of hazardous chemical and steel industry wastes began. At that time, four Class I wells were reported; by 1963, there were 30 wells. In the mid 1960s and 1970s, Class I injection began to increase sharply, growing at a rate of more than 20 wells per year.

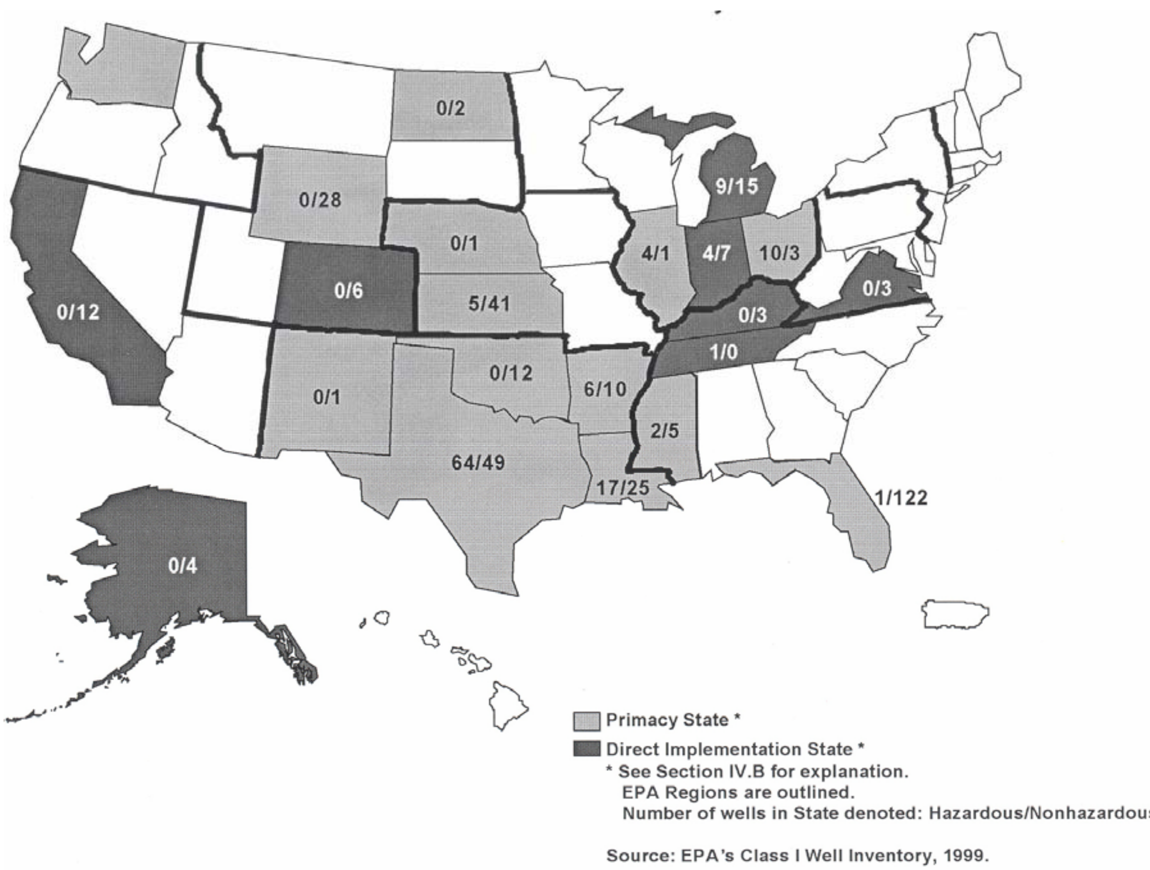
Class I Injection Wells includes the injection of hazardous and nonhazardous fluids (industrial and municipal wastes) into isolated formations beneath the lowermost USDW. Specifically, Class I Injection Wells:

- Inject <u>hazardous wastes</u> beneath the lowermost USDW
- Inject <u>industrial non-hazardous</u> liquid beneath the lowermost USDW
- Inject <u>municipal wastewater</u> (non-hazardous) beneath the lowermost USDW

There are 529 Class I Injection wells in the United States. The breakdown by state showing the distribution of Class I Injection Wells, categorized by whether they are Hazardous Waste Injection Wells, or Non-Hazardous Waste Injection Wells is shown below.

CONCENTRATION OF HAZARDOUS VS NONHAZARDOUS

INJECTION WELLS IN EACH STATE IN THE U.S.



Updated data to the map above:

163 HAZARDOUS CLASS I WELLS & 366+ NONHAZARDOUS CLASS I WELLS

- **There are 272 active Class I injection facilities nationwide. Of these, 51 are hazardous and 221 are non-hazardous. These 272 facilities maintain approximately 529 Class I injection wells that are scattered throughout the US in 19 states. The greatest concentration are located in the Gulf Coast, Great Lakes, and the Floridian peninsular geographical regions.**

- **Class I wells are mainly used in the following industries:**

  - **Petroleum Refining,**
  - **Metal Production,**
  - **Chemical Production,**
  - **Pharmaceutical Production,**
  - **Commercial Disposal,**
  - **Municipal Disposal and**
  - **Food Production.**

Class I wells are designated as hazardous or nonhazardous, depending on the characteristics of the wastewaters injected. Wastewaters are considered to be hazardous wastes if they demonstrate a hazardous characteristic of:

- **Ignitability,**
- **Corrosivity,**
- **Reactivity,**
- **Toxicity, or are**
- **A listed waste as determined by EPA**

This designation affects the stringency of the requirements imposed on operators of Class I wells.

Class I injection wells are sited such that they inject below the lowermost USDW and a confining zone above an injection zone. Injection zone reservoirs typically range in depth from 1,700 to over 10,000 feet below the surface.

CLASS I NONHAZARDOUS WASTE DISPOSAL INJECTION WELLS

These wells inject industrial, low radiation and municipal wastes.

There are 366 Class I non-hazardous injection wells nationwide. While these wells are scattered through 19 states, most of them are found in the states of Florida (112) and Texas (110).

CLASS I *MUNICIPAL* INJECTION WELLS-A SPECIAL TYPE OF NONHAZARDOUS WASTE DISPOSAL INJECTION WELL

Florida is the only state with Class I municipal nonhazardous waste disposal wells (104).

These wells are commonplace in Florida primarily due to:

- **A shortage of available land for waste disposal,**
- **Strict limitations on surface water discharges,**
- **The presence of highly permeable injection zones, and**
- **Cost considerations.**

Class I municipal wells inject sewage effluent that has been subject to at least secondary treatment. These wells have been constructed with well casings up to 30 inches in diameter to allow injection of large volumes of water (e.g., over 19 million gallons per day) at low pressures (e.g., about standard atmospheric pressure).

Class I municipal wells are not subject to the same strict requirements as other Class I wells.

CLASS I HAZARDOUS WASTE DISPOSAL INJECTION WELLS

Did you know?

- **89 percent of the hazardous waste that is land disposed is through Class I Wells**

- **Over 9 billion gallons of hazardous waste is injected into wells each year in the US.**

Injection of hazardous waste into deep wells began in the United States in the 1960s. At that time, the chemical industry was looking for a safe, relatively inexpensive method for disposing of high volumes of waste that could be considered toxic. Technology was borrowed from the oil and gas industry to develop this new form of disposal.

To repeat from the beginning of this CEU unit:

> ***While treatment technologies exist, it would be very costly to treat and release to surface waters the billions and trillions of gallons of wastes that industries produce each year.***
>
> ***Agribusiness and the chemical and petroleum industries all make use of underground injection for waste disposal. When wells are***

properly sited, constructed, and operated, underground injection is an effective and environmentally safe method to dispose of wastes.

There are 163 Class I hazardous waste injection wells located at 51 facilities. Most are found in Texas (78) and Louisiana (18). Eleven of the facilities are commercial hazardous waste injection facilities. These are the only facilities that can accept hazardous waste generated offsite for injection. Ten of them are located in the Gulf Coast region while one is located in the Great Lakes region.

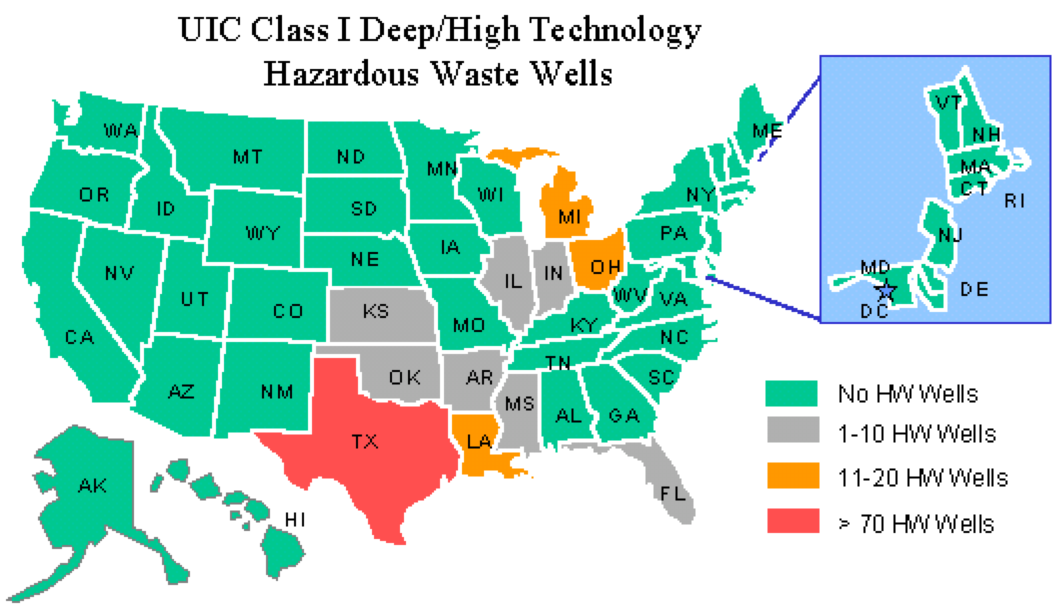
Current Regulations for Class I Hazardous Waste Injection Wells

In 1988 additional requirements were placed on Class I hazardous well operators. Simply stated,

> **Operators of Class I hazardous wells have to demonstrate that injected waste will not impact the biosphere (ground water or surface water) for 10,000 years.**

Operators who are not able to make this demonstration must treat their wastewater to acceptable levels, stop injecting, or implement pollution prevention measures, as specified by EPA in the regulations.

Distribution of Class I Hazardous Wells by State:

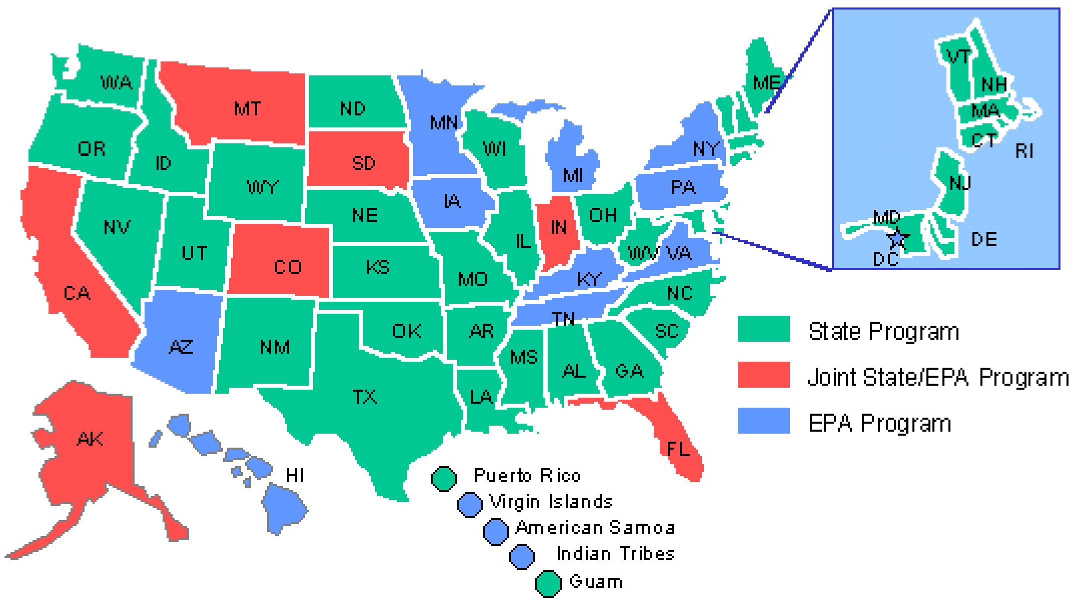


Who is responsible to controlling Class I Injection Wells (Hazardous and Nonhazardous), the federal government or the state governments?

The answer is: It depends! States have 3 choices when it comes to the enforcement of EPA regulations.

1. **States may petition the EPA to be allowed to be the enforcement agency in their state for EPA regulations (called primacy).**
2. **States may ask EPA to be allowed to jointly enforce EPA regulations in their state.**
3. **States may allow EPA to completely enforce the regulations in their states without the state's involvement.**

The map below shows which of the 3 choices have been made by the states:



CLASS I INJECTION WELL DESIGN AND CONSTRUCTION

The information that follows is a basic description of the design and construction features that are required for Class I injection wells to insure the safety of our underground sources of drinking water (USDW). The reader may remember that Class I, II, & III Injection Wells share certain general design requirements, which were stated previously.

Some design and construction features may be required for Class I hazardous waste injection wells and may not be required for Class I nonhazardous injection wells. Each Class I injection well is approved by EPA directly or through the state so each Class I injection well is approved for its design and construction on an individual basis. However, simply stated:

Note: ***(A useful diagram of the typical construction features of a Class I Injection Well follows this discussion)***

Class I wells are designed and constructed to prevent the movement of injected wastewaters into underground sources of drinking water (USDWs).

Wells typically consist of three or more concentric layers of pipe:

Surface casing, long string casing, and injection tubing. <u>All three layers are required in the case of class I hazardous injection wells.</u>

The well's casing prevents the borehole from caving in and contains the tubing. It typically is constructed of a corrosion-resistant material such as steel or fiberglass-reinforced plastic.

Surface casing is the outermost of the three protective layers; it extends from the surface to below the lowermost USDW.

The long string casing extends from the surface to or through the injection zone. The long string casing terminates in the injection zone with a screened, perforated, or open-hole completion, where injected fluids exit the tubing and enter the receiving formation.

The well casing design and materials vary based on the physical and chemical nature of injected and naturally occurring fluids in the rock formation, as well as the formation's characteristics. The wastewater must be compatible with the well materials that come into contact with it. Cement made of latex, mineral blends, or epoxy is used to seal and support the casing.

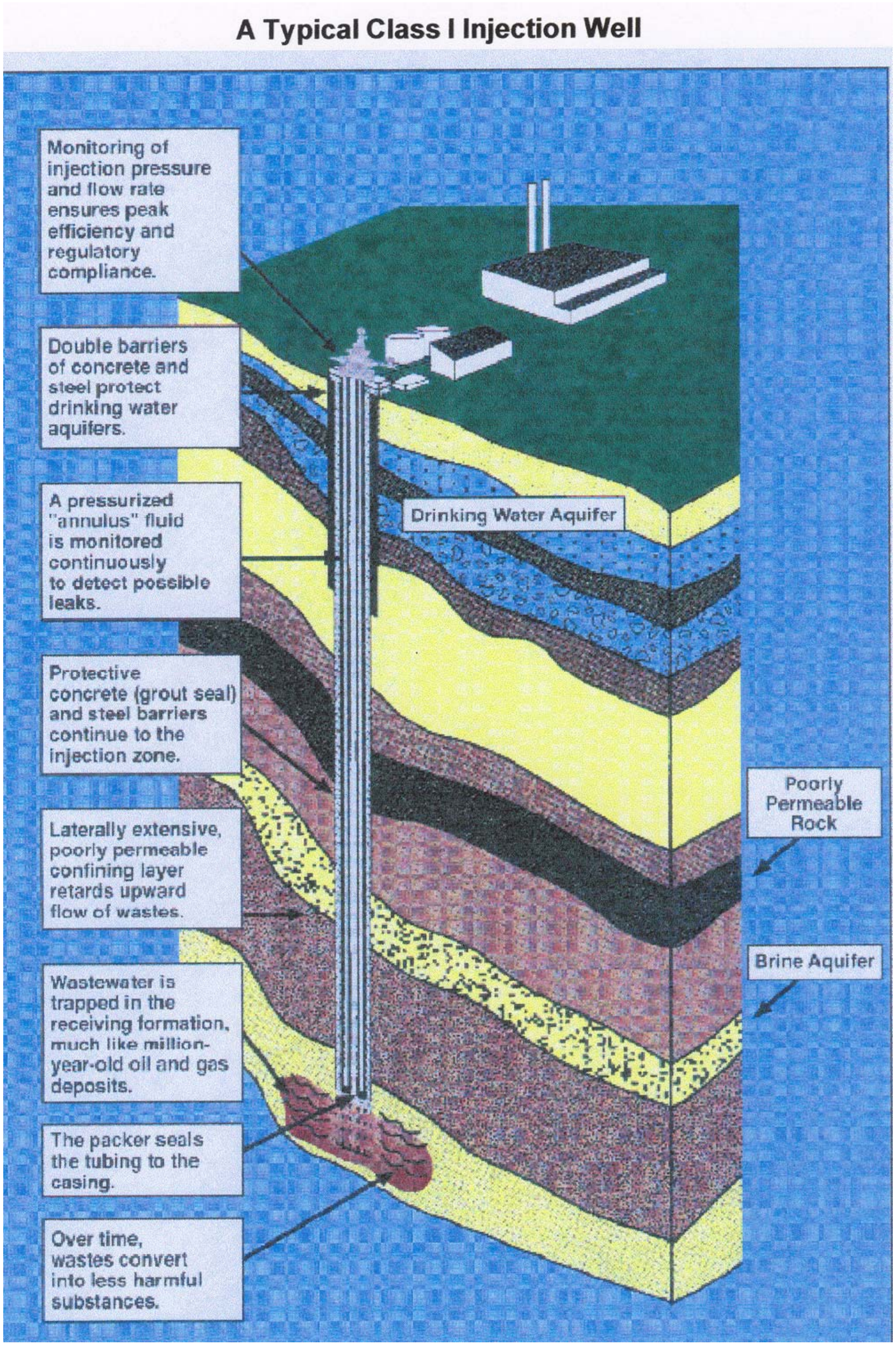
The characteristics of the receiving formation determine the appropriate well completion assembly—a perforated or screen assembly is appropriate for unconsolidated formations such as sand and gravel, while an open-hole completion is used in wells that inject into consolidated sandstones or limestone.

The innermost layer of the well, the injection tubing, conducts injected wastewater from the surface to the injection zone. Because it is in continuous contact with wastewater, the tubing is constructed of corrosion-resistant material (e.g., steel and high-nickel alloys, fiberglass reinforced plastic, coated or lined alloy steel, or more exotic elements such as zirconium, tantalum, or titanium).

The annular space between the tubing and the long string casing, sealed at the bottom by a packer and at the top by the wellhead, isolates the casing from injected wastewater and creates a fluid-tight seal.

The packer is a mechanical device set immediately above the injection zone that seals the outside of the tubing to the inside of the long string casing. The packer may be a simple mechanically set rubber device or a complex concentric seal assembly.

Constant pressure is maintained in the annular space; this pressure is continuously monitored to verify the well's mechanical integrity and proper operational conditions.



LOCATION SELECTION FOR A CLASS I INJECTION WELL

The geologic properties of the subsurface around the well offer a final safeguard against the movement of injected wastewaters to a USDW. Class I wells are sited so that, should any of their components fail, the injected fluids would be confined to the intended subsurface layer.

Class I wells inject into zones with the proper configuration of rock types to ensure that they can safely receive injected fluids. The geological formation into which the wastewaters are injected is known as the injection zone.

Extensive pre-siting geological tests confirm that the injection zone is of sufficient lateral extent and thickness and is sufficiently porous and permeable so that the fluids injected through the well can enter the rock formation without an excessive build up of pressure and possible displacement of injected fluids outside of the intended zone.

The injection zone is overlain by one or more layers of relatively impermeable rock that will hold injected fluids in place and not allow them to move vertically toward a USDW; this rock layer(s) defines the confining zone. Confining zones are typically composed of shales, which are "plastic," meaning they are less likely to be fractured than more brittle rocks, such as sandstones.

Class I fluids are injected deep into the earth into brine-saturated formations or nonfreshwater zones. The typical Class I well injects wastewaters into geologic formations thousands of feet below the land surface.

In the Great Lakes region, injection well depths typically range from 1,700 to 6,000 feet; in the Gulf Coast, depths range from 2,200 to 12,000 feet or more. Fluids at these depths move very slowly, on the order of a few feet per hundred or even thousand years, meaning that fluids injected into the deep subsurface are likely to remain confined for a long time.

Class I hazardous wells are located in geologically stable areas. The operator of a well must demonstrate that there are no transmissive fractures or faults in the confining rock layer(s) through which injected fluids could travel to drinking water sources. Well operators also must show that there are no wells or other artificial pathways between the injection zone and USDWs through which fluids can travel.

EPA regulations prevent Class I hazardous wells from being sited in areas where earthquakes could occur and compromise the ability of the injection zone and confining zone to contain injected fluids.

RISKS ASSOCIATED WITH CLASS I INJECTION WELLS

There are two potential pathways through which injected fluids can migrate to USDWs:

(1) Failure of the well or
(2) Improperly plugged or completed wells or other pathways near the well.

EPA's extensive technical requirements for Class I wells are designed to prevent contamination of USDWs via these pathways.

Well Failure

Contamination due to well failure is caused by leaks in the well tubing and casing or when injected fluid is forced upward between the well's outer casing and the well bore should the well lose mechanical integrity.

Internal mechanical integrity is the absence of significant leakage in the injection tubing, casing, or packer. An internal mechanical integrity failure can result from corrosion or mechanical failure of the tubular and casing materials.

External mechanical integrity is the absence of significant flow along the outside of the casing. Failure of the well's external mechanical integrity occurs when fluid moves up the outside of the well due to failure or improper installation of the cement.

To reduce the potential threat of well failures, operators must demonstrate that there is no significant leak or fluid movement through channels adjacent to the well bore before the well is issued a permit and allowed to operate.

In addition, operators must conduct appropriate mechanical integrity tests every year (for hazardous wells) and every 5 years (for nonhazardous wells) thereafter to ensure the wells have internal and external mechanical integrity and are fit for operation. It is important to note that failure of a mechanical integrity test, or even a loss of mechanical integrity, does not necessarily mean that wastewater will escape the injection zone.

Class I wells have redundant safety systems to guard against loss of waste confinement.

Pathways for Fluid Movement

The *zone of concern* is the radius around the injection well where there could potentially be migration into an underground source of drinking water (USDW). This migration could be caused by the pressure of injection of the waste into the well and/or formation fluid migrating into a USDW.

Improperly plugged or completed wells that penetrate the confining zone near the injection well can provide a pathway for fluids to travel from the injection zone to USDWs. These potential pathways are most common in areas of oil and gas exploration.

Because the geologic requirements for Class I hazardous injection activities are similar to those for oil and gas exploration, these activities often take place in the same areas. EPA estimates that there may be as many as 300,000 abandoned wells and 100,000 producing wells potentially in the zones of concern of Class I injection wells.

To protect against migration through this pathway, wells that penetrate the zone affected by injection pressure must be properly constructed or plugged. Before injecting, operators must identify all wells within the zone of concern that penetrate the injection or confining zone, and repair all wells that are improperly completed or plugged before a permit is issued.

Fluids could potentially be forced upward from the injection zone through transmissive faults or fractures in the confining beds which, like abandoned wells, can act as pathways for waste migration to USDWs. Faults or fractures may have formed naturally prior to injection or may be created by the waste dissolving the rocks of the confining zone. Artificial fractures may also be created by injecting wastewater at excessive pressures.

To reduce this risk, injection wells are sited such that they inject below a confining bed that is free of known transmissive faults or fractures. In addition, during well operation, operators must monitor injection pressures to ensure that fractures are not propagated in the injection zone or initiated in the confining zone.

A SUMMARY OF THE: LOCATION (SITING), CONSTRUCTION, OPERATING, MONITORING & TESTING, REPORTING & RECORD KEEPING, AND CLOSURE REQUIREMENTS FOR CLASS I INJECTION WELLS

LOCATION REQUREMENTS

(*AoR means the zone of concern around the well)*

Summary of Siting Requirements[13]	
Hazardous Wells	Nonhazardous Wells
• 2-mile AoR study performed. • No-migration petition demonstration required. • Sited in demonstrated geologically-stable areas. • Additional geologic structural and seismicity studies performed.	• ¼-mile AoR study performed (a larger AoR study may be conducted if required by state regulations). • Sited in demonstrated geologically-stable areas.

CONSTRUCTION REQUREMENTS

Summary of Construction Requirements	
Hazardous Wells	Nonhazardous Wells
• Well is cased and cemented to prevent movement of fluids into USDWs. • Detailed requirements for appropriate tubing and packer. • UIC Program director must approve casing, cement, tubing and packer design prior to construction.	• Well is cased and cemented to prevent movement of fluids into USDWs. • Constructed with tubing and packer appropriate for injected wastewater.

OPERATING REQUIREMENTS

Summary of Operating Requirements	
Hazardous Wells	Nonhazardous Wells
• Continuously monitor injection pressure, flow rate, and volume. • Install alarms and devices that shut-in the well if approved injection parameters are exceeded. • Maintain injection at pressures that will not initiate new fractures or propagate existing fractures.	• Continuously monitor injection pressure, flow rate, and volume. • Maintain injection at pressures that will not initiate new fractures or propagate existing fractures.

MONITORING AND TESTING REQUIREMENTS

Summary of Monitoring and Testing Requirements	
Hazardous Wells	Nonhazardous Wells
• Follow approved waste analysis plan. • Conduct internal MIT every year and external MIT every five years. • Monitoring wells to supplement required monitoring are authorized.	• Conduct internal and external MITs every 5 years. • Monitoring wells to supplement required monitoring are authorized.

REPORTING AND RECORD KEEPING REQUIREMENTS

Summary of Reporting and Record Keeping Requirements	
Hazardous Wells	Nonhazardous Wells
• Report quarterly on injection and injected fluids and monitoring of USDWs in the AoR; results from the waste analysis program; and geochemical compatibility. • Report on internal MIT every year and external MIT every 5 years. • Report any changes to the facility, progress in meeting the milestones of a compliance schedule, loss of MI, or noncompliance with permit conditions.	• Report quarterly on injection and injected fluids and monitoring of USDWs in the AoR. • Report every 5 years on internal and external MITs. • Report any changes to the facility, progress in meeting the milestones of a compliance schedule, loss of MI, or noncompliance with permit conditions.

CLOSURE REQUIRMENTS

Summary of Closure Requirements	
Hazardous Wells	Nonhazardous Wells
• Flush well with a non-reactive fluid; tag and test each cement plug. • Conduct pressure fall-off test and MIT. • Submit plugging and abandonment report. • Complete outstanding clean-up actions; continue groundwater monitoring until injection zone pressure can not influence USDW. • Inform authorities of the well, its location, and zone of influence.	• Flush well with a non-reactive fluid; tag and test each cement plug. • Submit plugging and abandonment report.

HISTORY OF FAILURE FOR CLASS I INJECTION WELLS

Early failures associated with Class I injection such as those at Hammermill Paper Company and Velsicol Chemical Company (described earlier in this CEU), illustrated the potential threats of wastewater injection and the need for and importance of the EPA regulations.

The 1980 EPA regulations address many of these risks. Since passage of the regulations, EPA and other organizations have conducted numerous studies of hazardous and nonhazardous Class I wells which demonstrate that such failures are unlikely to occur.

In early studies done on Class I Injection Wells that had failed, it was found the wells had been constructed and injection had begun before the EPA introduced its 1980 *Underground Injection Control Standards*. Most of the malfunctions reported in the studies were related to design, construction, or operating practices that are no longer allowed under EPA regulations.

Six specific findings from the early safety studies of Class I Injection Wells:

<u>Leaks in the injection well casing</u> caused movement of wastewaters into a USDW at four facilities. The leaks were detected either through annular monitoring or separate monitoring wells.

<u>Excessive injection pressure or hydraulic surges</u> causing a blowout at the wellhead or surface piping, leading to contamination at the surface.

The presence of improperly abandoned wells was cited as a factor in contamination at the surface in one study.

Leaking packer assemblies were the most likely cause of leakage into an non-drinking water zone. This was the most commonly documented malfunction, at 17 facilities involving 29 wells. Such leaks allow wastewater to come into contact with the protective well casing, causing corrosion.

Corrosion of the casing or tubing was suspected as the cause of leakage of injected fluids in one case. Corrosion caused the tubing to separate, resulting in a blowout and waste spillage at the surface.

Injection directly through the casing, without packer and tubing, was the primary cause of two cases of drinking water contamination from Class I wells.

Each of the six causes of well failure noted above would not have occurred had the failed wells been sited, constructed and operated under current EPA requirements for Class I Injection Wells.

All of the failed wells noted above were removed from service. The wells were repaired and returned to service, plugged, or converted into monitoring wells.

Further EPA studies were done between 1988 & 1991 to analyze causes of mechanical integrity failures. No underground sources of drinking water (USDW) were affected by any of these mechanical integrity failures.

From 1988 to 1991, 130 cases of internal mechanical integrity failures (leakage in the injection tubing that can result from corrosion or mechanical failure of the tubular materials) were reported.

All of these internal mechanical integrity failures were detected during well operation by the continuous annulus monitoring systems or by mechanical integrity tests. The wells were shut-in until they were repaired. Of these mechanical integrity failures, 42 percent occurred in the tubing and 23 percent involved the long string casing.

One external mechanical integrity failure (flow along the outside of the casing) occurred. It was detected by a routine external mechanical integrity test and did not involve wastewater migration.

Only four cases of significant nonhazardous wastewater migration were detected. Three of the cases were detected by monitoring wells. The fourth potential wastewater migration case was discovered when a Class I well was drilled into the same formation.

None of these failures affected a USDW.

SUMMARY OF SAFETY CONCERNS ABOUT CLASS I INJECTION WELLS

The probability of Class I well failures, both nonhazardous and hazardous, has been demonstrated to be low. Many early Class I failures were a result of historic practices that are no longer permissible under the EPA regulations.

Class I wells have redundant safety systems and several protective layers; an injection well would fail only when multiple systems fail in sequence without detection. In the unlikely event that a well would fail, the geology of the injection and confining zones serves as a final safety net against movement of wastewaters to USDWs.

Injection well operators invest millions of dollars in the permitting, construction, and operation of wells, and even in the absence of EPA regulations would carefully monitor the integrity of the injection operation to safeguard their investments.

Failures of Class I wells are rare. Most failures of mechanical integrity are internal failures, detected by continuous annulus monitoring systems or mechanical integrity tests, and the wells are shut-in until they are repaired.

EPA's study of more than 500 Class I nonhazardous and hazardous wells showed that loss of mechanical integrity contributed to only 4 cases of significant wastewater migration (none of which affected a drinking water source) over several decades of operation. Even as injection wells are entering "middle age," their mechanical integrity remains intact. This can be attributed to the rigorous requirements for monitoring and for ensuring that the well materials are compatible with the wastewater injected.

In 1988 EPA upgraded regulations for injection well safety to offer additional protection. These 1988 regulations require operators of Class I hazardous wells to demonstrate that the hazardous constituents of the wastewater will not migrate from the injection zone for 10,000 years, or as long as the wastewater remains hazardous.

CONCLUDING COMMENTS TO THE INJECTION WELLS CEU

The International School of Well Drilling has prepared this CEU from a variety of sources. The consensus of the experts is that current regulation and control of injection wells provide strong protection and an extremely low-risk option for the management of the waste products injected into underground wells.

END OF TEXT

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