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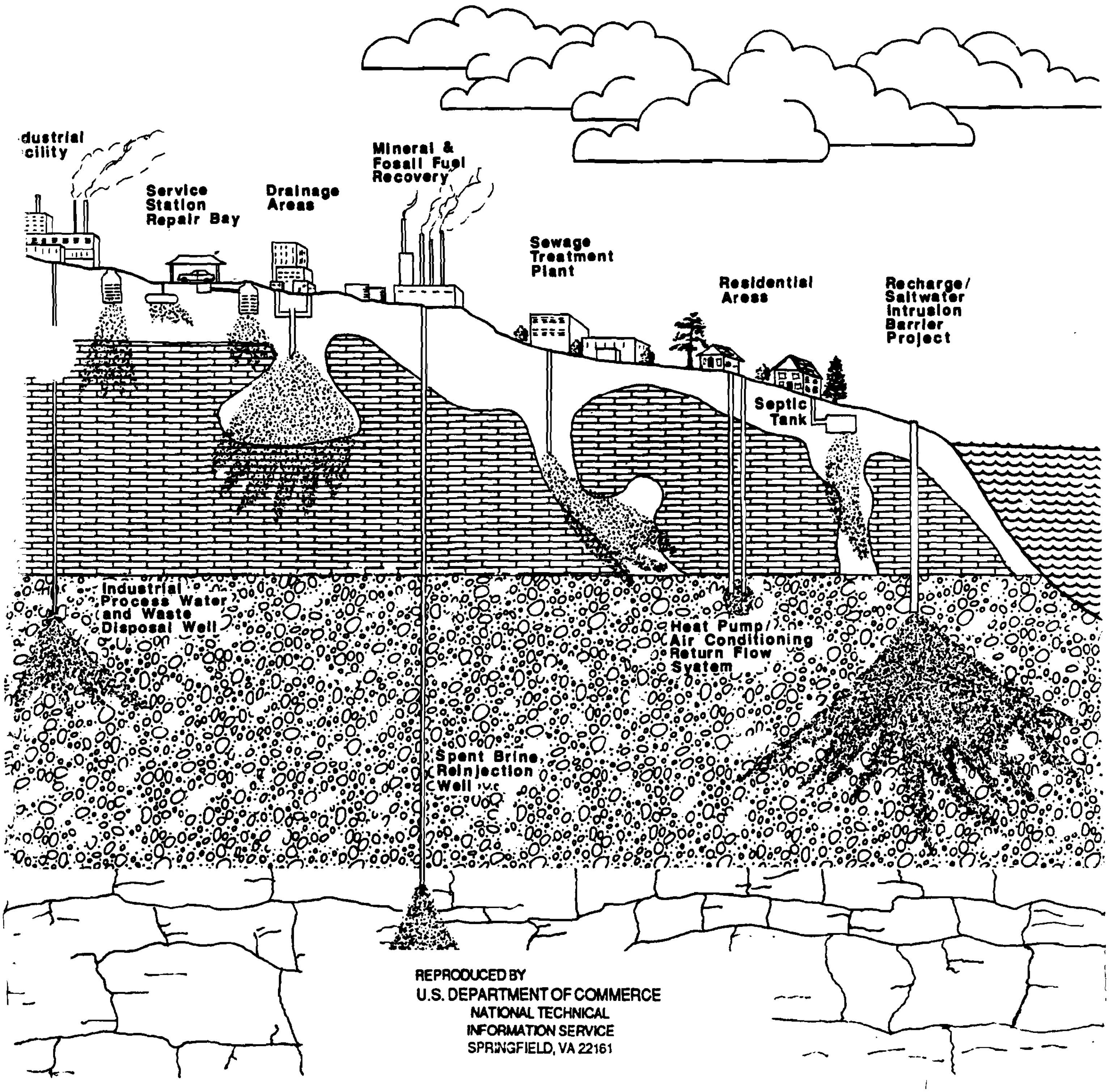
Water

Report To Congress

Class V Injection Wells

- Current Inventory
- Effects on Ground Water
- Technical Recommendations



Report To Congress
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REPORT TO CONGRESS

Foreword

This report was prepared by the Office of Water, Environmental Protection Agency, from data gathered by the States, Territories, and Possessions of the United States in fulfilling the regulatory requirement of 40 CFR 146.52(b) and with the support of the EPA Regional offices and the contractor, Engineering Enterprises, Inc. (EEI) under EPA Contract Number 68-03-3416. The EPA project manager was L. Lawrence Graham, and the EEI project officer was Lorraine C. Council. In addition, an EPA Work Group, comprised of representatives from the Office of Water, the Office of Solid Waste and Emergency Response, the Office of General Counsel, the Office of Policy, Planning and Evaluation, the Office of Research and Development, and the EPA Regions provided technical input and review.

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Executive Summary

This report to Congress, prepared by the United States Environmental Protection Agency (USEPA), summarizes the results of State surveys concerning Class V injection wells as defined by the 1986 Amendments to the Safe Drinking Water Act. In accordance with the Act, the report (1) identifies the categories and corresponding inventories of Class V wells in the United States and its Territories and Possessions, (2) describes primary contamination problems associated with different categories of these wells, and (3) summarizes recommendations for minimum design, construction, installation, and siting requirements that could be applied to protect underground sources of drinking water (USDW) from such contamination wherever necessary including corrective action and remedial action recommendations.

Reports addressing Class V well construction features, injectate chemical characteristics and volumes, contamination potentials, corrective alternatives, and recommendations for remedial actions and regulatory approaches were submitted by State Directors of 56 of the 57 States, Territories, and Possessions of the United States. The reports were reviewed, summarized, and collated in preparing this report to Congress on Class V injection wells.

There are seven general categories identified and over 170,000 Class V injection wells inventoried by the States. The general categories include drainage wells, geothermal wells, domestic (sewage) waste disposal wells, wells related to mineral and fossil fuel recovery, industrial/commercial/utility wells, recharge wells, and miscellaneous wells. Ninety-four percent of all Class V wells belong to only four of the general categories: drainage wells (58%), domestic waste disposal wells (25%), geothermal wells - mostly heat pump/air conditioning return flow wells - (6%), and wells related to mineral and fossil fuel recovery (5%).

Distribution of the inventoried wells among the ten USEPA Regions is varied. Thirty-seven percent of the wells reported are located in Region IX, seventeen percent in Region X, sixteen percent in Region IV, and ten percent in Region V. Regions VIII and II each reported five percent of the wells. Regions VII, III, and VI each reported between two and four percent of the total number of wells, and Region I reported less than one percent.

Ground-water contamination potentials for each of the thirty well types (subcategories of the seven general well types) were assessed based on information provided by the States and based on a rating system which incorporated the following criteria: potential useability and identification of USDW; typical construction, operation, and maintenance procedures; chemical and physical characteristics of the injectate; and contamination potential based, in part, on injectate volumes. Some well types exhibited a range of contamination potentials. Class V wells assessed to have <u>high</u> ground-water contamination potentials include agricultural drainage wells; improved sinkholes (high to moderate); raw sewage waste disposal wells and cesspools; septic systems; domestic wastewater treatment plant disposal wells (high to low); industrial process water and waste disposal wells; automobile service station waste disposal wells; and aquifer recharge wells (high to low).

Class V wells assessed to have <u>moderate</u> ground-water contamination potentials include storm water drainage and industrial drainage wells; improved sinkholes (high to moderate); special drainage wells (moderate to low); electric power and direct heat reinjection wells; aquaculture return flow wells; domestic wastewater treatment plant disposal wells; domestic wastewater treatment plant disposal wells; in-situ fossil fuel recovery wells; cooling water return flow wells (moderate to low); aquifer recharge wells (high to low); experimental technology wells (moderate to low); and abandoned drinking water/waste disposal wells.

Class V wells assessed to have <u>low</u> ground-water contamination potentials include special drainage wells (moderate to low); heat pump/air conditioning return flow wells; domestic wastewater treatment plant disposal wells (high to low); solution mining wells; spent brine return flow wells; cooling water return flow wells (moderate to low); aquifer recharge wells (high to low); saline water intrusion barrier wells; subsidence control wells; and experimental technology wells (moderate to low). Class V wells with <u>unknown</u> ground-water contamination potential include radioactive waste disposal wells and aquifer remediation wells.

The States recommended additional study in several areas. A primary concern of many States is that the existing inventory database is incomplete. Therefore, they recommend continuing efforts to locate uninventoried Class V facilities and upgrading the existing database of technical data for inventoried facilities. Regional and local hydrogeologic investigations may be necessary in order to more precisely define the potential impact of various Class V injection practices in areas containing sensitive aquifers.

The States also made several technical recommendations for adequate well siting, construction, operation, and maintenance to protect ground-water quality. The recommendations range from banning the use of cesspools and raw sewage waste disposal wells to developing appropriate mechanical integrity tests for geothermal electric power generation reinjection wells. Recommendations were also made to determine the ground-water contamination potentials of radioactive waste disposal wells and wells associated with aquifer remediation projects.

CLASS V REPORT TO CONGRESS

SECTION 1
INTRODUCTION

1.1 OBJECTIVE AND SCOPE

This report to Congress summarizes information and recommendations provided solely by the UIC programs of the States, Territories, and Possessions of the United States on Class V injection wells. Specifically, the report addresses the current inventory of Class V injection wells and their potential to affect ground water. Technical recommendations of the Directors of State Underground Injection Control Programs are presented. The U.S. Environmental Protection Agency recommendations are in the process of development.

1.2 BACKGROUND

On December 14, 1974, Congress enacted the Safe Drinking Water Act (PL 93-523) to protect the public health and welfare of persons and to protect existing and future underground sources of drinking water (USDW). In Part C of the Act, Congress directed the United States Environmental Protection Agency (USEPA) to develop regulations for the protection of underground source(s) of drinking water from contamination by the subsurface injection or emplacement of fluids through wells. In 1980, USEPA promulgated these regulations under 40 CFR Parts 144 through 146 and Part 124. The regulations specify minimum standards and technical requirements for the proper siting, construction, operation, monitoring, and plugging and abandonment of injection wells.

The Act also mandated the development of a Federally approved Underground Injection Control (UIC) program for each State, Possession, and Territory. Approval of a particular program is based on a finding that the program meets minimum standards and technical requirements of SDWA Section 1422 or Section 1425 and the applicable provisions set forth in 40 CFR Parts 124 and 144 through 146. States whose programs were submitted to and approved by USEPA are known as Primacy States. These states have primary enforcement responsibility for the regulation of injection wells in their States. In those instances where a State has opted not to submit a program for approval or where the submitted program does not meet the minimum standards and technical requirements, the program is promulgated and administered by USEPA. States with Federally administered programs are known as Direct Implementation (DI) States and are subject to the regulations set forth in 40 CFR Parts 124 and 144 through 146. There are 22 DI States, Possessions, and Territories at present. Reports on the Class V programs in the DI states and recommendations were prepared under the direction of the "Director" of that State program, i.e., the Regional Administrator. All underground injection is unlawful and subject to penalties unless authorized by a permit or rule.

The UIC regulations define and establish five classes or categories of injection wells. Class I wells inject hazardous and non-hazardous waste beneath the lowermost formation containing, within one-quarter mile of the well bore, an USDW. Class II wells are used in conjunction with oil and gas production. Class III injection wells are used in conjunction with the solution mining of minerals. Class IV wells inject hazardous or radioactive wastes into or above a formation which is within one-quarter mile of an USDW. (Class IV wells are prohibited by 40 CFR 144.13.) Class V wells include any wells that do not fall under Classes I through IV. Typically, Class V wells are used to inject non-hazardous fluids into or above underground sources of drinking water.

In 1980, USEPA chose to defer establishing technical requirements for Class V wells. Instead, these wells are authorized by rule. That is, injection into Class V wells is authorized until further requirements under future regulations are promulgated by USEPA. However, Class V wells are prohibited from contaminating any USDW or adversely affecting public health. Therefore, wells which are found to be violating this prohibition are subject to enforcement or closure. Some Primacy States require injection well permits while others currently implement authorization by rule or law.

The Agency has not established specific requirements for Class V wells for several reasons. By definition, the category of Class V encompasses a variety of well types ranging in complexity from radioactive waste disposal wells to storm water drainage wells. At the time of the original promulgation, little was known about the operation of these wells. The Agency reasoned that due to the large number and types of Class V wells in existence, the variability of injection fluids and volumes, the lack of knowledge concerning the extent of environmental damage caused by these wells, and the lack of knowledge concerning the consequences of bringing them under regulation, technical requirements could not be established that effectively would assure that operations of all Class V wells would not endanger USDW. Therefore, the Agency concluded that it was necessary to develop an assessment of Class V injection well activities prior to any regulatory development.

Under 40 CFR 146.52(a), USEPA requires owners and operators of Class V injection wells to notify the Director of the State or the Direct Implementation UIC program of the existence of all Class V wells under their control and to submit pertinent inventory information (as required under 40 CFR 144.26(a)). The Directors then are required, under 40 CFR 146.52(b), to complete and submit to USEPA a report containing the following:

1. Information on the construction features of Class V wells and the nature and volume of injected fluids;

2. An assessment of the contamination potential of Class V wells using hydrogeological data available to the State;

3. An assessment of the available corrective alternatives where appropriate and their environmental and economic consequences; and

4. Recommendations both for the most appropriate regulatory approaches and for remedial actions where appropriate.

The reports are required to be submitted no later than three years after the effective date of the State's UIC program approval. Several of the reports are not due until November 1987.

The 1986 Amendments to the Safe Drinking Water Act require USEPA to prepare and submit to Congress a report on Class V injection wells. The report is to summarize the results of the State reports and to note State recommendations for the design, siting, construction, operation, and monitoring of each Class V well type that has the potential to contaminate ground water. Specifically, Section 1426(b) of the Act states:

> The Administrator shall submit a report to Congress, no later than September 1987, summarizing the results of State surveys required by the Administrator under this section. The report shall include each of the following items of information:
>
> 1. The number of categories of Class V wells which discharge nonhazardous waste into or above an underground source of drinking water.
>
> 2. The primary contamination problems associated with different categories of these disposal wells.
>
> 3. Recommendations for minimum design, construction, installation, and siting requirements that should be applied to protect underground sources of drinking water from such contamination wherever necessary.

While the intent of Section 1426 is clear, it should be noted that the definition of Class V wells does not limit injection to only "into or above USDW" and does not limit Class V wells to only "disposal wells." Spent brine return flow wells (inventoried to date) and Class V radioactive waste disposal wells are examples of wells which inject below the lowermost USDW. Aquifer recharge wells and mineral and fossil fuel recovery wells are examples of wells which are not disposal wells.

Under 40 CFR Section 144.3, a "well" is defined as a bored, drilled, or driven shaft, or dug hole, whose depth is greater than its largest surface dimension. "Well injection" is defined as the subsurface emplacement of fluids through a bored, drilled, or driven well; or through a dug well where the depth of the dug well is greater than its largest surface dimension. A "fluid" is any material or substance which flows or moves, whether in semisolid, liquid, sludge, gas or any other form or state. The definitions of the five injection well classes are found in 40 CFR 144.6. A list of Class V well types recognized by USEPA for the purpose of this study is presented in Table 1-1.

As can be seen in Table 1-1, the Class V injection well category is large and diverse. This is due to the broad definition of Class V wells. If a well does not fit into one of the first four classes and meets the definition of an injection well, it is considered a Class V well.

Although included in Table 1-1 as Class V injection wells, air scrubber waste and water softener regeneration brine disposal wells, types 5X17 and 5X18, are not included in the inventory and assessment portion of this report. At the time the State Class V injection well reports were written, air scrubber waste and water softener regeneration brine disposal wells were categorized as Class V injection wells. As a result, however, of a July 31, 1987, USEPA policy decision, these well types, in certain situations, may fall under the Class II category rather than Class V. This was determined to be the case with those 5X17 and 5X18 wells inventoried in the State reports.

Class V injection wells can be divided into two general types of wells based on construction. "Low-tech" wells 1) have no casing designs or have simple casing designs and well head equipment and 2) inject into shallow formations by gravity flow or low volume pumps. In contrast, "high-tech" wells typically 1) have multiple casing strings, 2) have sophisticated well equipment to control and measure pressure and volume of injected fluid, and 3) inject high volumes into deep formations.

Low-tech well types include agricultural drainage wells (5F1), storm water and industrial drainage wells (5D2, 5D4), improved sinkholes (5D3), heat pump/air conditioning return flow wells (5A7), some aquaculture return flow wells (5A8), raw sewage disposal wells and cesspools (5W9, 5W10), septic systems (5W11, 5W31, 5W32), some mine backfill wells (5X13), some cooling water return flow wells (5A19), some industrial process water and waste disposal wells (5W20), automobile service station waste disposal wells (5X28), and abandoned water wells (5X29).

High-tech well types include geothermal wells used for electric power or for direct heat (5A5, 5A6), some aquaculture return flow wells (5A8), domestic wastewater treatment disposal wells (5W12), mining, sand, or other backfill wells (5X13), solution mining wells (5X14), in-situ fossil fuel recovery wells (5X15), spent brine return flow wells (5A16), some cooling water return flow wells (5A19), some industrial process water and waste disposal wells (5W20), some aquifer recharge wells (5R21), salt water intrusion barrier wells (5B22), subsidence control wells (5S23), radioactive waste disposal wells (5N24), experimental technology wells (5X25), and aquifer remediation wells (5X26).

1.3 SUMMARY OF FINDINGS*

1.3.1 HYDROGEOLOGIC CONSIDERATIONS

Half of the population of the United States currently is served by ground water, and studies show that demand for this resource is increasing at a rate of 25 percent per decade. The use of ground water is increasing at a faster rate than is the use of surface water. The degree to which each State depends upon ground water varies from less than one percent of total water withdrawals (District of Columbia) to 85 percent (Kansas).

The largest single use for ground water is irrigation, and the major areas of usage are the southwestern, midwestern, and southern States. The second largest use for ground water in the United States is as a drinking water supply. Forty-eight percent of the population relies on ground water as a drinking water supply. Roughly two-thirds receive drinking water through public supplies, and the remainder are supplied through domestic wells.

Ground water aquifers are of two primary types, unconfined and confined. Unconfined, or water table, aquifers are the most common. Under unconfined conditions, the water table is exposed to the atmosphere such that the upper surface of the saturated zone is free to rise and decline through openings in the soil matrix. Available data suggest that most Class V injection is into or above unconfined aquifers. Confined, or artesian, aquifers are isolated from the atmosphere at the point of discharge by impermeable strata. The confined aquifer is subject to higher hydraulic pressure than atmospheric pressure, and certain high-tech Class V wells inject into these aquifers.

Waste disposal or other fluid emplacement through injection wells are potential causes of contamination to USDW. The distribution of contaminants within an aquifer can occur as discrete bodies, or "slugs," resulting from low volume or short term incidents of waste disposal/fluid injection. Cumulative effects of numerous slugs, or continual disposal of highly concentrated waste/injection fluid, or large volumes of waste/injection fluid from a single facility can cause widespread contamination. The degree of contamination ranges from slight deterioration in natural quality to the presence of toxic levels of heavy metals, organic compounds, inorganic contaminants, and radioactive materials.

* Findings are a compilation of data submitted by the States.

TABLE 1-1

CLASS V INJECTION WELL TYPES	
WELL CODE	**NAME OF WELL TYPE AND DESCRIPTION**
	DRAINAGE WELLS (a.k.a. DRY WELLS)
5F1	Agricultural Drainage Wells - receive irrigation tailwaters, other field drainage, animal yard, feedlot, or dairy runoff, etc.
5D2	Storm Water Drainage Wells - receive storm water runoff from paved areas, including parking lots, streets, residential subdivisions, building roofs, highways, etc.
5D3	Improved Sinkholes - receive storm water runoff from developments located in karst topographic areas.
5D4	Industrial Drainage Wells - include wells located in industrial areas which primarily receive storm water runoff but are susceptible to spills, leaks, or other chemical discharges.
5G30	Special Drainage Wells - are used for disposing water from sources other than direct precipitation. Examples of this well type include: landslide control drainage wells, potable water tank overflow drainage wells, swimming pool drainage wells, and lake level control drainage wells.
	GEOTHERMAL REINJECTION WELLS
5A5	Electric Power Reinjection Wells - reinject geothermal fluids used to generate electric power - deep wells.
5A6	Direct Heat Reinjection Wells - reinject geothermal fluids used to provide heat for large buildings or developments - deep wells.
5A7	Heat Pump/Air Conditioning Return Flow Wells - reinject groundwater used to heat or cool a building in a heat pump system - shallow wells.
5A8	Groundwater Aquaculture Return Flow Wells - reinject groundwater or geothermal fluids used to support aquaculture. Non-geothermal aquaculture disposal wells are also included in this category (e.g. Marine aquariums in Hawaii use relatively cool sea water).

TABLE 1-1

CLASS V INJECTION WELL TYPES

WELL CODE	NAME OF WELL TYPE AND DESCRIPTION
	DOMESTIC WASTEWATER DISPOSAL WELLS
5W9	Untreated Sewage Waste Disposal Wells - receive raw sewage wastes from pumping trucks or other vehicles which collect such wastes from single or multiple sources. (No treatment)
5W10	Cesspools - include multiple dwelling, community, or regional cesspools, or other devices that receive wastes and which must have an open bottom and sometimes have perforated sides. Must serve greater than 20 persons per day if receiving solely sanitary wastes. (Settling of solids)
5W11	Septic Systems (Undifferentiated disposal method) - are used to inject the waste or effluent from a multiple dwelling, business establishment, community, or regional business establishment septic tank. Must serve greater than 20 persons per day if receiving solely sanitary wastes. (Primary Treatment)
5W31	Septic Systems (Well Disposal Method) - are used to inject the waste or effluent from a multiple dwelling, business establishment, community, or regional business establishment septic tank. Examples of wells include actual wells, seepage pits, cavitettes, etc. The largest surface dimension is less than or equal to the depth dimension. Must serve greater than 20 persons per day if receiving solely sanitary wastes. (Less treatment per square area than 5W32)
5W32	Septic Systems (Drainfield Disposal Method) - are used to inject the waste or effluent from a multiple dwelling, business establishment, community, or regional business establishment septic tank. Examples of drainfields include drain or tile lines, and trenches. Must serve more than 20 persons per day if receiving solely sanitary wastes. (More treatment per square area than 5W31)
5W12	Domestic Wastewater Treatment Plant Effluent Disposal Wells - dispose of treated sewage or domestic effluent from facilities ranging from small package plants up to large municipal treatment plants. (Secondary or further treatment)

TABLE 1-1

CLASS V INJECTION WELL TYPES

WELL CODE	NAME OF WELL TYPE AND DESCRIPTION
	MINERAL AND FOSSIL FUEL RECOVERY RELATED WELLS
5X13	Mining, Sand, or Other Backfill Wells - are used to inject a mixture of fluid and sand, mill tailings, and other solids into mined out portions of subsurface mines whether what is injected is a radioactive waste or not. Also includes special wells used to control mine fires and acid mine drainage wells.
5X14	Solution Mining Wells - are used for in-situ solution mining in conventional mines, such as stopes leaching.
5X15	In-situ Fossil Fuel Recovery Wells - are used for in-situ recovery of coal, lignite, oil shale, and tar sands.
5X16	Spent-Brine Return Flow Wells - are used to reinject spent brine into the same formation from which it was withdrawn after extraction of halogens or their salts.
	OIL FIELD PRODUCTION WASTE DISPOSAL WELLS
5X17	Air Scrubber Waste Disposal Wells - inject wastes from air scrubbers used to remove sulfur from crude oil which is burned in steam generation for thermal oil recovery projects. (If injection is used directly for enhanced recovery and not just disposal it is a Class II well.)
5X18	Water Softener Regeneration Brine Disposal Wells - inject regeneration wastes from water softeners which are used to improve the quality of brines used for enhanced recovery. (If injection is used directly for enhanced recovery and not just disposal it is a Class II well.)
	INDUSTRIAL/COMMERCIAL/UTILITY DISPOSAL WELLS
5A19	Cooling Water Return Flow Wells - are used to inject water which was used in a cooling process, both open and closed loop processes.

TABLE 1-1

CLASS V INJECTION WELL TYPES

WELL CODE	NAME OF WELL TYPE AND DESCRIPTION
5W20	Industrial Process Water and Waste Disposal Wells - are used to dispose of a wide variety of wastes and waste-waters from industrial, commercial, or utility processes. Industries include refineries, chemical plants, smelters, pharmaceutical plants, laundromats and dry cleaners, tanneries, laboratories, petroleum storage facilities, electric power generation plants, car washes, electroplating industries, etc.
5X28	Automobile Service Station Disposal Wells - inject wastes from repair bay drains at service stations, garages, car dealerships, etc.
	RECHARGE WELLS
5R21	Aquifer Recharge Wells - are used to recharge depleted aquifers and may inject fluids from a variety of sources such as lakes, streams, domestic wastewater treatment plants, other aquifers, etc.
5B22	Saline Water Intrusion Barrier Wells - are used to inject water into fresh water aquifers to prevent intrusion of salt water into fresh water aquifers.
5S23	Subsidence Control Wells - are used to inject fluids into a non-oil or gas producing zone to reduce or eliminate subsidence associated with overdraft of fresh water and not used for the purpose of oil or natural gas production.
	MISCELLANEOUS WELLS
5N24	Radioactive Waste Disposal Wells - include all radioactive waste disposal wells other than Class IV wells.
5X25	Experimental Technology Wells - include wells used in experimental or unproven technologies such as pilot scale in-situ solution mining wells in previously unmined areas.
5X26	Aquifer Remediation Related Wells - include wells used to prevent, control, or remediate aquifer pollution, including but not limited to Superfund sites.

TABLE 1-1

CLASS V INJECTION WELL TYPES

WELL CODE	NAME OF WELL TYPE AND DESCRIPTION
5X29	Abandoned Drinking Water Wells - include those abandoned water wells which are used for disposal of waste.
5X27	Other Wells - include any other unspecified Class V wells.

Generally, Class V injection is into or above USDW. An USDW is defined as an aquifer or its portion which supplies any public water system or which contains a sufficient quantity of ground water to supply a public water system and currently supplies drinking water for human consumption or contains fewer than 10,000 mg/l total dissolved solids, and which is not an exempted aquifer. Certain special Class V facilities are known to inject fluids below USDW. Potential for contamination to USDW varies and is dependent upon where injection occurs relative to USDW; well construction, design, and operation; injectate quality; and injection volumes. Class V injection practices which discharge directly into USDW are potentially more harmful to USDW than Class V injection above or below USDW because some protection of USDW may be provided by injection above or below USDW.

1.3.2 CLASS V INJECTION WELL INVENTORY

As defined in this report, there are seven general categories of Class V injection wells containing a total of 30 well types. Based on State inventories, there are approximately 173,159 Class V wells in the United States and its associated Territories and Possessions. About 94 percent of all Class V wells belong to four main categories: drainage wells (58%), sewage related wells (25%), geothermal wells (6%), and mineral and fossil fuel recovery related wells (5%).

The numbers of Class V wells broken down by USEPA Regions are as follows:

Region IX:	64,214	37%
Region X:	29,826	17%
Region IV:	27,911	16%
Region V:	17,772	10%
Region VIII:	9,015	5%
Region II:	8,950	5%
Region VII:	6,675	4%
Region III:	4,589	3%
Region VI:	3,843	2%
Region I:	364	<1%

It should be noted that these numbers can be misleading, however, because inventories were not conducted with consistent levels of resources and guidance. There is a high probability that the distribution of wells and the resulting conclusions are not entirely accurate. Fifty-six States had submitted Class V inventory and assessment reports by August 1987 for incorporation into this Report to Congress.

Figure 1-1 is a map of the States and USEPA Regions. At the present time, there are 22 Direct Implementation States (or Possessions or Territories) and 35 Primacy States.

1.3.3 CONTAMINATION POTENTIAL ASSESSMENTS

Contamination potential has been assessed for each well type in this report, using all available data. Because inventory databases varied widely for different well types, a unified system was needed with which to assess each well type equivalently. The assessment incorporates the following parameters:

1. Identification and potential useability of USDW;
2. Typical construction, operation, and maintenance procedures;
3. Chemical and physical characterization of injection fluid; and
4. Typical injected volumes.

Based upon this rating scheme, well types have been assessed qualitatively for contamination potential as high, moderate, or low. Certain Class V well types exhibit such variation in design and injectate quality that a spectrum of ratings (e.g., moderate to low, high to moderate, high to low) resulted. A few well types have an unknown potential for contamination due to extremely limited information. Contamination potentials for Class V wells currently are assessed as follows:

High Contamination Potential

- Agricultural drainage wells, 5F1;
- Improved sinkholes, 5D3 (high to moderate);
- Raw sewage waste disposal wells, 5W9, and cesspools, 5W10;
- Septic systems, 5W11, 5W31, 5W32;

U.S. ENVIRONMENTAL PROTECTION AGENCY

REGIONS AND STATE UIC PROGRAM STATUS

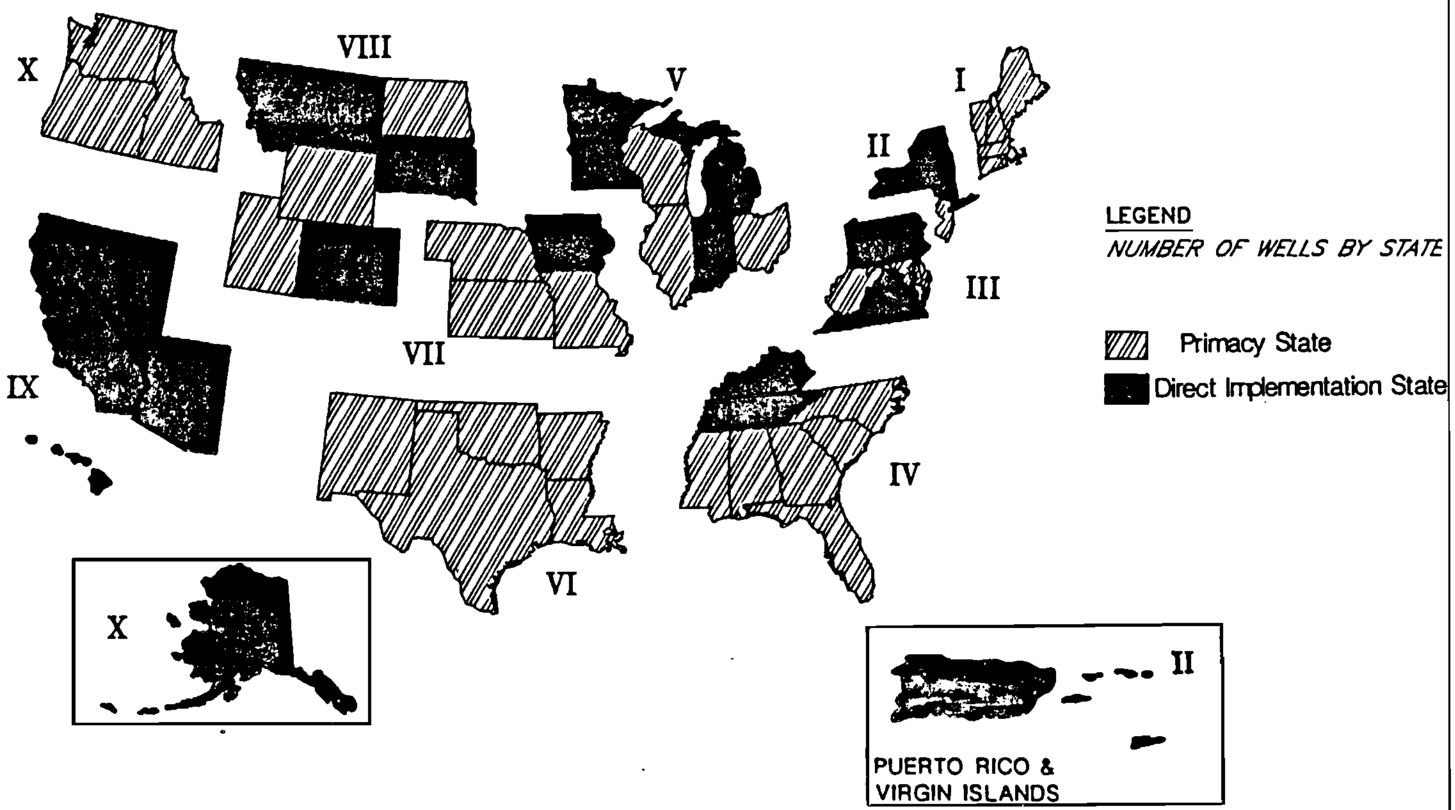


Figure 1-1

- Domestic wastewater treatment plant disposal wells, 5W12 (high to low);
- Industrial process water and waste disposal wells, 5W20;
- Automobile service station waste disposal wells, 5X28; and
- Aquifer recharge wells, 5R21 (high to low).

Moderate Contamination Potential

- Storm water drainage, 5D2, and industrial drainage wells, 5D4;
- Improved sinkholes, 5D3 (high to moderate);
- Special drainage wells, 5G30 (moderate to low);
- Electric power, 5A5, and direct heat reinjection wells, 5A6;
- Aquaculture return flow wells, 5A8;
- Domestic wastewater treatment plant disposal wells, 5W12 (high to low);
- Mining, sand, or other backfill wells, 5X13;
- In-situ fossil fuel recovery wells, 5X15;
- Cooling water return flow wells, 5A19 (moderate to low);
- Aquifer recharge wells, 5R21 (high to low);
- Experimental technology wells, 5X25 (moderate to low); and
- Abandoned drinking water/waste disposal wells, 5X29.

Low Contamination Potential

- Special drainage wells, 5G30 (moderate to low);
- Heat pump/air conditioning return flow wells, 5A7;
- Domestic wastewater treatment plant disposal wells, 5W12 (high to low);
- Solution mining wells, 5X14;
- Spent brine return flow wells, 5X16;

- Cooling water return flow wells, 5A19 (moderate to low);
- Aquifer recharge wells, 5R21 (high to low);
- Saline water intrusion barrier wells, 5B22;
- Subsidence control wells, 5S23; and
- Experimental technology wells, 5X25 (moderate to low).

Unknown Contamination Potential

- Radioactive waste disposal wells, 5N24; and
- Aquifer remediation wells, 5X26 (including hydrocarbon recovery injection wells).

Additional study is necessary in a number of areas. A primary concern of many States is that the existing inventory database is incomplete. It is recommended by many States that efforts continue in attempting to locate uninventoried Class V facilities and to upgrade the existing database of technical data for inventoried facilities. Also, States recommended that hydrogeologic studies on both local and regional scales may need to be conducted for areas containing sensitive aquifers in order to define the potential impact of the various types of Class V injection practices. Table 1-2 presents a summary of available inventory data, types of fluids injected, and State recommendations.

1.4 CONTENT OF REPORT

Section Two of the report is an overview of the ground water resource and current and projected use of the resource. Several hydrogeologic considerations, important when examining injection well practices, are discussed to provide the reader with an appropriate background. A general understanding of our ground-water resource is essential, considering that over 95 percent of Class V injection wells discharge directly into, above, or between USDW.

The inventory information submitted by the State UIC programs is presented and summarized in Section Three of the report. Inventory numbers are given by well type and by USEPA Regions and States. The sources of the inventory data are primarily State reports; however, inventory information also was obtained from personal interviews, the FURS database (Federal UIC Reporting System), reports other than the State Class V reports, and published literature.

Section Four of the report is presented in two parts. The first part is a discussion of methods used to determine ground-water contamination potential and the criteria important in assessing an individual well type's potential. The second part of Section Four consists of the individual well type assessments for the Class V wells listed in Table 1-1. Each assessment addresses well purpose; inventory and location; construction, siting, and operation; nature of injected fluids and injection zone interactions; hydrogeology and water usage; contamination potential of well type; current regulatory approach; and State recommendations for siting, construction, operation, and corrective or remedial actions. As with the inventory information, most data used in the well type assessments came from States' Class V reports. Additional data were gathered from published literature, unpublished reports, inspection and investigation programs, and personal interviews.

The Summary and Conclusions Section, Section Five, provides an overview of the preceding sections on inventory and assessment and contains a summary table for quick reference. Section Six of the report presents recommendations both for the inventory database and for each Class V well type assessed in the report. The recommendations are a summary of those given by the State reports. The recommendations include consideration of the technical aspects of Class V injection, such as siting, construction, and operation.

Appendix A consists of State Report Summaries for each of the State Class V reports received and reviewed to date. Appendices B and C contain the glossary and list of acronyms and abbreviations used, respectively. Appendix D consists of a general bibliography and other well-type specific bibliographies. Appendix E is a listing of supporting data, mainly case studies, used (to augment State report data) in assessing well types.

TABLE 1-2

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Drainage Wells					
Agricultural Drainage Wells (5F1)	Nationwide: 1,338 wells New York: 150 wells Puerto Rico: no numbers West Virginia: no numbers Florida: no numbers Georgia: 43 wells Kentucky: no numbers Illinois: 6 wells Indiana: 72 wells Michigan: 15 wells Minnesota: 54 wells Oklahoma: no numbers Texas: 108 wells Iowa: 230 wells Missouri: no numbers Nebraska: 5 wells Colorado: no numbers North Dakota: 1 well Idaho: 572 wells Oregon: 16 wells Washington: 66 wells Potentially many times this figure in areas typified by irrigation.	Varies due to differing farming practices and soil types; potential agricultural contaminants include sediment, nutrients, pesticides, organics, salts, metals, and pathogens in some cases.	High	New York - SPDES Permit Florida - Permit Georgia - Banned Illinois - Rule Oklahoma - Rule Iowa - Diversion Permit Missouri - None Nebraska - Rule Utah - Rule Arizona - Permit Idaho - Permit if deeper than 18 feet Washington - Undecided	- Improvement of inventory efforts is essential. (PR, GA, IN, MI, MN, CO, OR) - Locate and properly plug all abandoned wells near Agricultural Drainage Wells. (IA) - Close surface inlets to allow infiltration through soil. (MO) - Raise the inlets above maximum ponding levels. (IA) - Require that injection fluids meet all or some drinking water standards. (NE, OR) - Require irrigation tailwater recovery and pumpback. (OR) - Use only necessary amounts of irrigation water and applied chemicals. (CA) - Require frequent monitoring of drinking water wells in surrounding areas. - Require detailed map with all well locations. (NE) - Require diagram of injection well construction. (NE) - Require siting of wells at least 2,000 ft. away from any stock, municipal, or domestic well. (NE) - Discourage use and encourage elimination of agricultural drainage wells by developing alternate methods. (IA)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Storm Water Drainage Wells (5D2)	Nationwide: 80,000-100,000 wells reported for 39 States	Herbicides, pesticides, fertilizers, deicing salts, asphaltic sediments, gasoline, grease oil, tar and residues from roofs and paving, rubber particulates, liquid wastes and industrial solvents, heavy metals and coliform bacteria.	Moderate	Information applies to both 5D2 and 5D4 unless otherwise specified. Connecticut-Permit (5D2) Massachusetts-Exempt (5D2) New Jersey-NJPDES Permit New York-Permit if injected volume exceeds 1,000 GPD Maryland-Permit (5D4) Alabama-Permit (5D2) Florida-Permit Georgia-Banned Kentucky-Local (5D2), Permit (5D4) South Carolina-Permit (5D2) Tennessee-Permit (5D2) Illinois-Rule Wisconsin-None (5D2) Rule (5D4) Louisiana-Class II Regulations (5D4), Registration of Class V wells not required New Mexico-Registration Oklahoma-Rule Nebraska-Rule Montana-Permit (5D2) Utah-Rule Wyoming-Permit (5D2) Arizona-Registration California-Rule Hawaii-Permit Guam-Permit (5D2) Alaska-Permit (5D2) Idaho-Permit if deeper than 18 feet (5D2) Washington-None	Apply to both storm water and industrial drainage wells: - New wells should be investigated and added to FURS. (KY, UT, WA) - Construction of new industrial drainage wells should be limited or discouraged; storm water sewers, detention ponds, or vegetative basins are preferred. (OR, IL, KY, TN, UT). - Sand and gravel filters should be added to wells. (KY, TN) - Stand pipes should be constructed at the openings of wells. (KY, TN) - Limit future construction to residential areas. (IL) - All spills should be diverted away from industrial drainage wells (OR, UT, WA) - New construction of wells in areas served by storm water sewers should be prohibited. (CA, AZ) - Drainage wells should not be constructed within 200 ft. of water supply wells which tap lower water-bearing aquifers. (CA) - Deep wells should be plugged or cemented to avoid mixing between aquifers. (KY, TN) - Depth to water data should be made available to well drillers. (AZ) - Additional studies including use of monitoring wells should be conducted to study possible pollution sources and prolonged effect of industrial drainage wells on ground water. (FL, WI, KS) - An assessment of the effects of storm drainage wells should be conducted prior to completing an inventory because the inventory would be time-consuming and costly. (MT, OR) - Sediments extracted from drainage wells, catch basins, or sediment traps should be disposed in an appropriate landfill. (AZ) - A public awareness program should be implemented. (AZ) - All drainage wells should be identified and plugged. (WV)
Industrial Drainage Wells (5D4)	Nationwide: 3,802 wells reported for 23 States.	Similar constituents to those found in Stormwater Drainage Wells, though generally present in higher concentrations. Heavy metals such as lead, iron, and manganese. Organic compounds.			

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Improved Sinkholes (5D3)	Nationwide: 479 wells New Hampshire: 3 wells Puerto Rico: 10 wells Kentucky: 76 wells Tennessee: 5 wells Indiana: 26 wells Michigan: 103 wells Minnesota: 6 wells Missouri: 250 wells Virginia, West Virginia, Florida, and Ohio: numbers not yet confirmed. Potentially in all areas with limestone and dolomite lithologies at relatively shallow depths.	Runoff, from paved areas, containing lead and petroleum products from automobiles, pesticides from horticulture and lawn care, nitrates from fertilizers, and fecal material from wild and domestic animals; normal fallout from air pollutants may also be present.	High to Moderate	Puerto Rico-Permit Florida-Permit Georgia-Banned Kentucky-Local Tennessee-Permit Indiana-None Michigan-None Minnesota-None Ohio-None Missouri-None	- Training should be required for engineers and drillers in the proper construction of wells with special emphasis on sanitary sealing and protection against corrosion. Training should be slanted toward construction in Karst or limestone formations. (PR) - Careful dye trace studies should be run on any existing or improved sinkhole drainage systems, and occasional monitoring of both entering and exiting fluids should be run after the system is in operation. (MO)
Special Drainage Wells (5G30)	Nationwide: 1,557 wells Florida: 1,385 wells Louisiana: 1 well Montana: 55 wells Hawaii: 1 well Idaho: 7 wells Washington: 108 wells. Potentially present in all Regions.	Highly variable, depending on system design; for landslide control, ground water is generally used; swimming pool drainage fluid may contain lithium hypochlorite, calcium hypochlorite, sodium bicarbonate, chlorine, bromine, iodine, cyanuric acid, aluminum sulfate, algaecides, fungicides, and muriatic acid.	Moderate to Low	Florida-Permit/Rule Louisiana-Class II Regulations, Registration of Class V wells not required Nebraska-Rule Montana-Permit Hawaii-Permit Idaho-Permit if deeper than 18 feet.	- Random sampling and analysis of swimming pool wastewater for possible contaminants should be required. (FL)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
<u>Geothermal Reinjection Wells</u>					
Electric Power Reinjection Wells (5A5)	Nationwide: 89 wells Texas: numbers not confirmed California: 65 wells Nevada: 16 wells Idaho: 4 wells Alaska: 4 wells	<u>Vapor-Dominated Resource</u> heavy metals (arsenic, boron, selenium), sulfates, and dissolved solids. <u>Hot Water-Dominated Resource</u> heavy metals (arsenic, boron, selenium), chlorides, dissolved solids, and acidic pH.	Moderate	Texas-Permit Nebraska-Rule Utah-Permit California-Permit Nevada-Permit Idaho-Permit	Apply to both electric power and direct heat reinjection wells: - Detailed study on the types of MIT available for geothermal systems and the resolution of each method. (NV) - Initial analysis of injectate and injection zone water conducted prior to full-scale injection operations; parameters of concern are temperature, inorganic constituents of Primary and Secondary Drinking Water Regulations, alkalinity, hardness, silica, boron, and ammonia nitrogen. (CA, NV) - Injection into non-thermal reservoirs if the thermal injection fluids meet drinking water requirements or if the receiving fluids are of equal or lesser quality. (ID)
Direct Heat Reinjection Wells (5A6)	Nationwide: 21 wells New York: no numbers New Mexico: 2 wells Texas: 1 well Colorado: 2 wells California: 1 well Nevada: 6 wells Idaho: 2 wells Oregon: 6 wells Utah: 1 well	Arsenic, boron, fluoride, dissolved solids, sulfates, chloride.	Moderate	New Mexico-Permit Texas-Permit Nebraska-Rule/Permit Utah-Permit California-Permit Nevada-Permit Idaho-Permit Oregon-Permit if injected volume exceeds 5,000 GPD	

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Heat Pump/Air Conditioning Return Flow Wells (5A7)	Nationwide: 10,028 wells. Potentially present in all regions; more expected in areas characterized by climatic extremes. Reported in all States except the following: Maine, Rhode Island, Vermont, Puerto Rico, Virgin Islands, West Virginia, Alabama, Arkansas, Hawaii, American Samoa, TTPI, Guam, CNMI.	Primarily thermally altered ground water; additives designed to inhibit scaling, corrosion and incrustation when water high in metals and salts, or demonstrating high or low pH, is used.	Low	Connecticut-Permit Massachusetts-Permit if injected volume is greater than 15,000 GPD New Jersey-Rule/Permit New York-Permit Delaware-Permit Maryland-Permit Florida-Permit Georgia-Banned North Carolina-Permit South Carolina-Rule Illinois-Rule Minnesota-Permit Wisconsin-Rule Louisiana-Permit New Mexico-Registration Oklahoma-Rule Texas-Rule Missouri-Registration Nebraska-Rule Montana-None North Dakota-Rule Utah-Permit Wyoming-Permit Arizona-None California-Permit Alaska-Permit Idaho-Permit Oregon-Permit if injected volume is greater than 5,000 GPD Washington-Permit	- More research is needed on the theoretical environmental effects of heat pumps. (MO, AZ, SC) - Authorization by rule is appropriate for properly spaced and operated systems. (SC) - New regulatory programs should be directed at large-scale systems rather than at systems for single-family dwellings. (LA, OK, TX) - Records should be maintained by counties and periodically up-loaded to State databases in order to monitor well densities. (WA) - The State permitting agency should set construction standards and ensure that wells are constructed and operated properly. (FL, KS, MO, NE, SC, WA) - Permits for commercial developments should include requirements for water quality characterizations of both source and receiving water. (WA) - Return wells should be cased through top of injection zone. (IA) - Annular space should be cemented or grouted. (IA, KS, NE, TN) - Adequate spacing between production wells should be practiced. (KS, NE, SC) - Discharge should be into or above the supply aquifer. (LA, IA, KS, SC) - Closed loop systems should be required. (UT, TN) - Discharge should be to the surface rather than to an injection well. (LA) - The waste product should contain no additives or only approved additives (LA, KS, NE) - Volumes and temperatures of injection fluids should be monitored. (NC) - Analyses of receiving fluids should be conducted periodically. (KS, WA) - A licensed water well driller should be employed to install, rework, and/or plug and seal the well. (LA, IL) - New well installation in known or suspected contaminated aquifers should be prohibited. (WA)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Ground-water Aquaculture Return Flow Wells (5A8)	Hawaii: 7 active wells 3 standby wells 15 proposed wells Potentially found wherever marine or fresh water organisms are cultured in large quantities.	Large volumes of wastewater composed of essentially salt water with added nutrients, bacteriological growth, perished animals, and animal detritus. Effluent typically contains nitrates, nitrites, ammonia, high BOD, and orthophosphate.	Moderate	Nebraska-Rule Utah-Permit Hawaii-Permit Oregon-Permit if injected volume exceeds 5,000 GPD	- Regular sampling and analysis of injection fluid and injection zone fluid should be required (semi-annually). (HI) - Water to be disposed should be filtered and appropriately treated prior to injection. (HI) - Return waters should be carefully monitored at a point before and after treatment to ensure the measures being employed are sufficient to allow the water to be injected. (HI)
<u>Domestic Wastewater Disposal Wells</u>					
Raw Sewage Disposal Wells (5W9)	Nationwide: 980 wells Puerto Rico: 5 wells Pennsylvania: no numbers Illinois: 916 wells Indiana: 22 wells Michigan: 11 wells Minnesota: 10 wells Texas: 10 wells Hawaii: 3 wells Alaska: 3 wells	Generally poor quality, including high fixed volatiles, BOD, COD, TOC, nitrogen (organic, and free ammonia), chloride, alkalinity and grease.	High	Illinois-Banned Nebraska-Rule Utah-Banned Hawaii-Permit Nevada-Banned Alaska-Permit or Rule Oregon-Rule	No recommendations concerning raw sewage disposal wells and cesspools were provided in State reports. However, the use of such disposal methods has been banned in several States.
Cesspools (5W10)	Nationwide: 6,622 wells New Jersey: 1 well New York: no numbers Puerto Rico: 67 wells Indiana: 22 wells Michigan: 18 wells Minnesota: 25 wells New Mexico: 14 wells Texas: 16 wells Nebraska: no numbers Wyoming: 3 wells Arizona: 17 wells California: 46 wells Hawaii: 57 wells Alaska: > 79 wells Oregon: 6,257 wells	Same as for Raw Sewage Disposal Wells.	High	New Jersey-NJPDES Permit New York-Permit if injected volume exceeds 1,000 GPD New Mexico-Banned Texas-Rule Nebraska-Rule Utah-Banned Wyoming-Permit Arizona-Permit California-Banned Hawaii-Permit Nevada-Banned Alaska-Permit or Rule Oregon-Rule	

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Septic Systems (5W11, 5W31, 5W32)	5W11: 26,769 inventoried wells in 31 States 5W31: 4,435 wells in 13 States 5W32: 3,783 wells in 8 States	Varies with type of system; fluids typically 99.9% water (by weight) and .03 suspended solids; major constituents include nitrates, chlorides, sulfates, sodium, calcium, and fecal coliform.	High	Connecticut-Permit if volume injected exceeds 5,000 GPD Massachusetts-Permit if volume injected exceeds 15,000 GPD New Jersey-NJPDES Permit New York-Permit if volume injected exceeds 1,000 GPD Maryland-Permit (5W31) Alabama-Permit Florida-Permit Kentucky-Rule (5W31) South Carolina-Permit (5W32) Minnesota-Rule Wisconsin-Rule (5W31) Louisiana-Rule New Mexico-Registration Oklahoma-Rule Texas-Local Missouri-Permit Nebraska-Rule Montana-Permit North Dakota-Rule Utah-Permit Wyoming-Permit Arizona-Permit California-Permit Hawaii-Permit (5W31) Nevada-Banned (5W31), Permit (5W32) CNMI-None Alaska-Permit or Rule Idaho-Permit if deeper than 18 feet Oregon-Permit if injected volume exceeds 5,000 GPD (5W32) Washington-Permit/Rule	- Further study is recommended. (FL, MT, OR) - Proper construction and installation guidelines should be developed. (MO) - Ongoing training programs for sanitarians is recommended; should include hydrogeology, ground-water flow, theory of septic system operation, and potential risks to human health. (PR, MD, MN) - Siting should be conducted so as not to endanger water wells. (KS, NE) - All systems should be sited and designed individually. (TX) - Local planning groups should be encouraged to establish septic tank density limits. (NE) - Sewage disposal wells for private facilities should be phased out and replaced by alternate methods of treatment and disposal. (TX) - Well constructions should be investigated. (KS) - Statewide monitoring systems should be established and should include inventory methodology and database updates. (WA)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Domestic Wastewater Treatment Plant Effluent Disposal Wells (5W12)	Potentially present in all Regions. 1,099 wells inventoried nationwide in 19 States.	Injected fluid, after secondary or tertiary waste treatment, believed to be generally compatible with receiving formation; may contain high nitrates and fecal coliform if improperly treated.	High to Low	Massachusetts-Permit if injected volume exceeds 15,000 GPD New York-Permit Puerto Rico-Permit Florida-Permit Kentucky-Eliminate Illinois-Rule Indiana-Permit Michigan-Permit Texas-Rule/Permit Nebraska-Rule Utah-Permit Arizona-Permit California-Permit Hawaii-Permit Nevada-Banned Alaska-Permit or Rule Idaho-Rule Washington-Rule	- Operation should ensure that injection is restricted to rates and pressures dictated by site-specific hydrogeologic conditions (should involve monitoring). (WY, AL, HI). - Alternative methods of disposal and feasibility of upgrading existing plants should be evaluated. (VA) - In some cases, wells should be plugged. (KY)
<u>Mineral and Fossil Fuel Recovery Related Wells</u>					
Mining, Sand or Other Backfill Wells (5X13)	Nationwide: 6,500 wells Maryland: 1 well Pennsylvania: 811 wells West Virginia: 258 wells Alabama: no numbers Kentucky: 61 wells Tennessee: no numbers Illinois: 5 wells New Mexico: 11 wells Texas: 65 wells Missouri: 4,326 wells Colorado: 2 wells Montana: 10 wells North Dakota: 300 wells Wyoming: 74 wells Nevada: 1 well Idaho: 575 wells	Hydraulic or pneumatic slurries - Solid portion of slurries may be sand, gravel, cement, mill tailings/refuse, or fly ash. - Slurry waters may be acid mine water or ore extraction process wastewater.	Moderate	Maryland-Permit Pennsylvania-Mine operation West Virginia-Mine operation Alabama-Permit Kentucky-Permit Illinois-Rule New Mexico-Unknown Texas-Rule Missouri-None Nebraska-Rule Colorado-Rule Montana-Permit North Dakota-Rule Utah-Rule Wyoming-Permit Idaho-Rule	- Siting, design, construction, and operation should be specified in permit requirements. (IL) - Slurry injection volumes should be monitored and compared to calculated mine volume to prevent catastrophic failure. (WV) - Ground-water monitoring in areas containing potable water. (MO) - Site-specific study is necessary to determine the nature and extent of degradation from mine backfill wells. (MT) - Authorization of mine backfill wells without permits should continue where tailings are injected into formations that are effectively isolated from USDW. (ID)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Solution Mining Wells (5X14)	Nationwide: 2,025 wells New York: 48 wells Michigan: 15 wells New Mexico: 1,073 wells Wyoming: 14 wells Arizona: 870 wells California: 5 wells Potentially in other mining districts.	Weak acid solutions (sulfuric and hydrochloric) Ammonium carbonate Sodium carbonate/bicarbonate Ferric cyanide	Low	New York-Permit New Mexico-Permit Nebraska-Permit Utah-Permit Wyoming-Permit Arizona-Permit California-Permit	- Network of injection wells should not extend beyond surface projection of ore body. (CA) - New types of mechanical integrity tests for implementation with this well type should be studied. (AZ) - Hydrologic monitoring should be conducted to determine a water budget. (AZ)
In Situ Fossil Fuel Recovery Wells (5X15)	Nationwide: 66 wells Colorado: 23 wells Indiana: 1 well Michigan: 1 well Wyoming: 41 wells Potentially in other areas wtih relatively shallow, organic rich sub strata.	Underground coal gasification: - air, oxygen, steam, water, igniting agents such as ammonium nitrate-fuel oil (ANFO) or propane. In situ oil shale retorting: - air, oxygen, steam, water, sand, explosives, igniting agents (generally propane) Purpose in both cases is to initiate and maintain combustion. Combustion products include polynuclear aromatics, cyanides, nitrites, phenols.	Moderate	Texas-Permit Nebraska-Rule Colorado-Rule Utah-Permit Wyoming-Permit	- Conduct complete geologic and hydrogeologic investigations prior to system implementation. (WY) - Remediate zone fluids to minimize future contamination. (WY)
Spent Brine Return Flow Wells (5X16)	Nationwide: 121 wells New York: no numbers West Virginia: 2 wells Indiana: 8 wells Michigan: 33 wells Arkansas: 70 wells Oklahoma: 7 wells North Dakota: 1 well Potentially in Regions having commercially recoverable halogen deposits.	Limited to brines from which halogens or salts have been extracted; Potential for addition of other undefined constituents into waste stream.	Low	New York-Permit Arkansas-Permit Oklahoma-Rule Nebraska-Rule Utah-Rule	- Technical requirements specified in permits should be similar to those for oilfield brine injection wells or solution mining wells. (WV, AR) - Construction requirements should be developed based upon well operating parameters. (AR) - Mechanical integrity tests should be required. (AR) - Semi-annual comprehensive sampling and analysis of fluid and comparison of produced vs. injected fluid should be required. (AR)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Industrial/Commercial Utility Disposal Wells (5A19)					
Cooling Water Return Flow Wells (5A19)	291 wells inventoried nationwide; potentially many times this number, and would be located in all Regions.	Dependent upon type of system, type of additives, and temperature of water; open pipe systems may expose ground water to accidental introduction of surface contaminants, industrial spills, or unauthorized disposal of wastes.	Moderate to Low	Massachusetts-Permit if injection volume exceeds 2,000 GPD New Jersey-NJPDES Permit Alabama-Permit Florida-Permit Georgia-Permit South Carolina-Rule Illinois-Rule Wisconsin-Rule Arkansas-None New Mexico-Registration Iowa-Permit Nebraska-Rule Utah-Permit California-Permit Hawaii-Permit Alaska-Permit Idaho-Permit Oregon-Permit if injected volumes exceed 5,000 GPD Washington-Permit	- Minimum locating requirements for the injection well relative to any nearby municipal supply wells should be established. (NE, SC) - Wells should be grouted from at least 20 feet below land surface to land surface or to the water table. (NE) - Wells should be cased from surface to the top of the uppermost supply and injection zone. (AR) - Cemented annulus from surface to supply/injection zone. (AR) - Require minimum of 2 wells: supply well and return well. (AR, SC) - Wells should be constructed such that spent fluids are injected into source aquifer. (AR) - Open loop return flow wells should be prohibited. (FL, AR, NE, UT) - Wells should be plugged with cement upon abandonment. (AR) - Permit specifications needed: Detailed map showing all area wells. Diagram of injection well design. Diagram of entire system. Type and volume of injectate. (AR, NE)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Industrial Process Water and Waste Disposal Wells (5W20)	1,989 inventoried wells in 33 States.	Potentially any fluid disposed by various industries; can have high dissolved solids, suspended solids, alkalinity, chloride, phosphate, sulfate, total volatiles.	High	Connecticut-Permit Massachusetts-Permit New Jersey-NJPDES Permit New York-Permit Maryland-Permit Pennsylvania-Permit Alabama-Permit Florida-Permit South Carolina-Permit Illinois-Rule Wisconsin-Permit Texas-Class I Regulations Nebraska-Rule Utah-Banned Wyoming-Permit Arizona-Permit California-Permit Hawaii-Permit Alaska-Permit Idaho-Permit if deeper than 18 feet Oregon-Permit	- Inventory efforts should continue with high priority on identifying industrial disposal facilities. (PR, IN, WI, AK, WY) - Assume all industrial waste disposal has a deleterious effect on USDW, warranting immediate action. (PA) - Extensive ground-water evaluation studies should be conducted to identify areas which would be vulnerable to contamination by industrial waste disposal. (PR, AL) - Drainage areas surrounding industrial facilities should be studied and all possible pollution sources noted. (KS) - Inspection of these facilities should be mandatory, and conducted by teams backed by chemical or industrial engineers. (PR) - Monitoring programs should be required and sampling specifications should be tightened. (PR, MD, FL, KS) - Ground-water monitoring should be conducted using a minimum of one upgradient and two downgradient wells. (AZ) - Practice of injecting industrial process water and waste should be discouraged, and wastes routed to on-site treatment facilities or municipal sanitary sewer systems. (FL) - Discharge of industrial process wastes to septic systems should be discouraged. (PR, NE) - These wells should be permitted only when injection is into ground water containing greater than ten-thousand mg/l TDS. (FL)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Automobile Service Station Waste Disposal Wells (5X28)	Nationwide: 99 wells Connecticut: 1 well Rhode Island: 3 wells Vermont: 10 wells New Jersey: 18 wells New York: 3 wells Virginia: 1 well Florida: no numbers Illinois: 5 wells Indiana: 2 wells Michigan: 27 wells New Mexico: no numbers Iowa: 1 well Missouri: 5 wells Utah: 2 wells Nevada: no numbers Idaho: 21 wells	Waste oil, antifreeze, floor washings (including detergents, organic, and inorganic sediment) and other petroleum products.	High	Connecticut-Permit New Jersey-NJPDES Permit New York-Permit Florida-Permit Illinois-Rule Nebraska-Rule Utah-Banned Idaho-Rule	- Inventory update is vital. Guidelines for construction, operation, and overall regulation of these wells need to be established. (NY, PR) - Permits should show construction features, a plan to utilize separators and holding tanks, and a plan to sample and analyze injected fluids. (IA) - Underground holding tanks should be required. (UT) - Local building code and sewer pretreatment inspection should identify areas where discharge to sewers is prohibited. (UT)
<u>Recharge Wells</u>					
Aquifer Recharge Wells (5R21)	Nationwide: 3,558 wells New Hampshire: 1 well New York: 3,000 wells Florida: 349 wells Illinois: 1 well Minnesota: 1 well New Mexico: 30 wells Texas: 44 wells Kansas: 4 wells Nebraska: 4 wells Wyoming: 32 wells Arizona: 51 wells California: 52 wells Idaho: 7 wells Washington: 7 wells Potentially found in areas characterized by large withdrawals for drinking water or irrigation far in excess of recharge.	Dependent upon source; water quality changes noted include adsorption, ion exchange, precipitation and dissolution, chemical oxidation, biological nitrification and denitrification, aerobic or anaerobic degradation, mechanical dispersion, and filtration.	High to Low	New Jersey-Rule/Permit Florida-Permit Illinois-Rule New Mexico-Registration Texas-Permit Nebraska-Rule Utah-Rule/Permit Wyoming-Permit Arizona-Permit California-Permit Idaho-Permit if deeper than 18 feet	- Injection fluid should be of generally equivalent or better quality than injection zone fluid. (NE) - Standards for injectate quality must be on a case by case basis. (AZ) - Regular injectate sampling should be conducted. (NE) - Use of proper design, construction and operation is essential. (FL, NE)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Saline Water Intrusion Barrier Wells (5B22)	California: 155 wells Florida: 2 wells Potentially found in coastal areas typified by abundant fresh water withdrawals for irrigation and/or drinking water.	Varies with type of source; examples include advanced treated sewage, surface urban and agricultural runoff, and imported surface waters.	Low	New Jersey-Rule/Permit Florida-Permit Nebraska-Rule Utah-Rule/Permit California-Permit Washington-Permit	- Pilot studies to define lithologic and hydrogeologic parameters influencing salt water intrusion should be conducted on site-specific basis. (CA) - Characterization of interaction of injectate and formation fluids is necessary. (CA)
Subsidence Control Wells (5S23)	4 wells inventoried for Wisconsin from state reports; it is believed inventory is incomplete; potentially present in desert and coastal areas typified by large, long-term ground-water withdrawals; areas having carbonate aquifers are particularly susceptible to subsidence.	See 'Aquifer Recharge Wells'	Low	Wisconsin-Permit Nebraska-Rule Utah-Rule/Permit	- Injectate quality should be monitored. (CA) - Proper well design, operation, and construction practices should be implemented. (CA) - For additional recommendations, see 'Aquifer Recharge Wells'
Miscellaneous Wells					
Radioactive Waste Disposal wells (5N24)	Unknown number, but existence confirmed for Tennessee, New Mexico, Idaho, and Washington in State reports.	Variety of radioactive materials, including Beryllium 7, Tritium, Strontium 90, Cesium 137, Potassium 40, Cobalt 60, beta particles, Plutonium, Americium, Uranium, and radionuclides.	Unknown	Illinois-Rule New Mexico-Banned Oklahoma-Rule Nebraska-Rule Utah-Rule/Permit Idaho-Permit if deeper than 18 feet Washington-Permit	- Discharges should satisfy all known, available, reasonable treatment and control methods. (WA) - Discharge to cribs and french drains should be pretreated prior to disposal. (WA) - Permits, permit compliance, and enforcement actions should be negotiated annually with EPA through the State/EPA Agreement Program. (WA)
Experimental Technology Wells (5X25)	225 wells in State reports; Potentially located in every Region.	Wide variety of injected constituents: highly acidic or basic compounds for solution mining; domestic wastewater containing high total suspended solids, fecal coliform, ammonia, BOD, pH; air is used in certain water recovery projects.	Moderate to Low	Alabama-Permit Florida-Permit Mississippi-Rule North Carolina-Permit Illinois-Rule New Mexico-Permit Nebraska-Rule Utah-Rule/Permit Wyoming-Permit Arizona-Permit California-Permit Hawaii-Permit Nevada-Permit	- Wells should not be sited and operated so as to permit injection into Class IIB aquifers. (CA) - Detailed hydrogeological studies should be conducted prior to any proposed injection. (CA) - Chemical analysis of waste stream periodically. (CA) - Mechanical integrity tests should be developed and conducted regularly. (CA, AZ)

TABLE 1-2, continued

SUMMARY OF CLASS V INJECTION WELL DATA AND RECOMMENDATIONS

TYPE OF INJECTION WELL	LOCATION & NUMBER OF WELLS OR POTENTIAL LOCATION	TYPES OF FLUIDS INJECTED	GROUND-WATER (USDW) CONTAMINATION POTENTIAL	STATE REGULATORY STRUCTURE	RECOMMENDATIONS
Aquifer Remediation Wells (Including Oil Recovery Injection Wells) (5X26)	Nationwide: 355 wells Rhode Island: 2 wells New Jersey: 9 wells Puerto Rico: 1 well Alabama: 1 well North Carolina: 12 wells Indiana: 4 wells Michigan: 59 wells Minnesota: 7 wells Wisconsin: 17 wells New Mexico: 50 wells Oklahoma: 60 wells Texas: 37 wells Kansas: 15 wells Missouri: no numbers Nebraska: no numbers Colorado: 81 wells	Dependent upon hydrogeologic regimen, parameters of the contamination plume, and design of the remediation program; for refinery projects, typical injectate constituents are oil/grease, phenols, toluene, benzene, lead, iron.	Unknown	New Jersey-NJPDES Permit Alabama-Permit North Carolina-Permit Wisconsin-Rule Oklahoma-Rule Nebraska-Permit Utah-Rule/Permit California-Permit	- Implementation of registering and monitoring programs. (KS) - Construction standards should be similar to those established for discharge wells. (OK) Cased from surface through the top of the injection zone. (OK) Screened intervals through sands and gravels. (OK) Annulus should be grouted. (OK) - Injected fluid quality should be better than that of the fluid in the contaminated aquifer but not necessarily of drinking water standards. (FL)
Abandoned Drinking Water/Waste Disposal Wells (5X29)	3,050 wells inventoried. Potentially present in all areas having shallow fresh water aquifers.	Potentially any kind of fluid, particularly brackish or saline water, hazardous chemicals and sewage; documentation of nitrate and coliform contamination documented in Nebraska (Exner and Spalding, 1985); Domestic sewage disposal via these wells documented for 75 homes in Minnesota; also documentation for disposal of pesticides within agricultural runoff (Jones, 1973; Exner and Spalding, 1985).	Moderate	Utah-Banned The following states have plugging and abandonment regulations for water wells: Rhode Island, New Jersey, Puerto Rico, Delaware, Maryland, Pennsylvania, Virginia, West Virginia, Alabama, Florida, Georgia, North Carolina, Tennessee, Illinois, Michigan, Minnesota, Ohio, Wisconsin, Arkansas, Louisiana, Oklahoma, Texas, Kansas, Missouri, Nebraska, Colorado, North Dakota, South Dakota, Wyoming, Arizona, California, Nevada, Alaska, Idaho, Oregon, and Washington	- Must establish a better inventory of wells. (PR, IN, MI, MN) - Wells should be properly plugged using cement. (MN)

SECTION 2
HYDROGEOLOGIC CONSIDERATIONS

2.1 IMPORTANCE AND USE OF THE GROUND-WATER RESOURCE

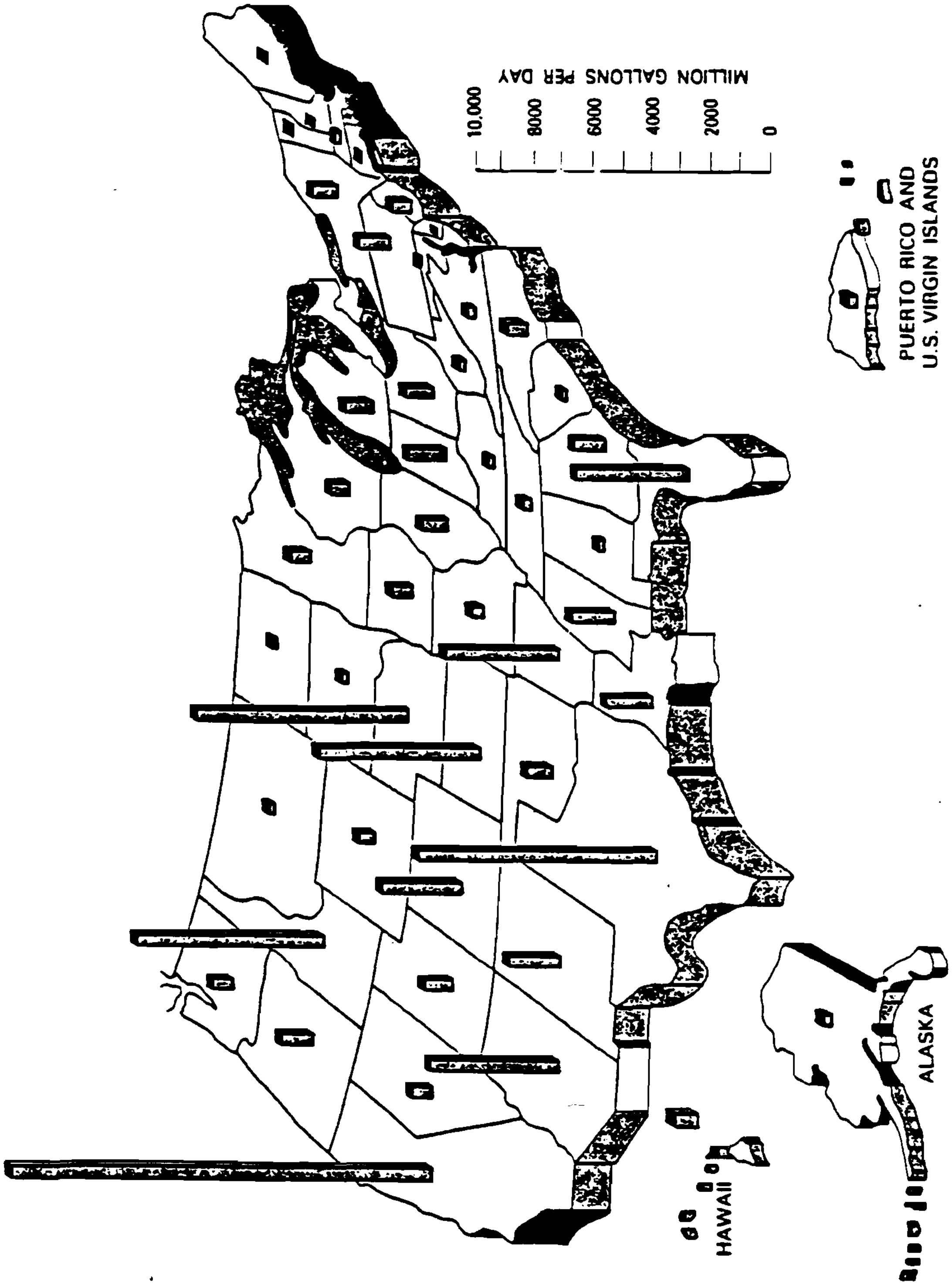
2.1.1 INTRODUCTION

Ground water is one of the most widely used natural resources and is available in at least small amounts at virtually every point on the Earth's surface (Heath, 1985). The availability of the resource is a significant issue in almost every State (Mann, 1985). Ground water serves as the dominant source of drinking water for most rural areas and is the largest source of water for irrigation in arid and semiarid regions of the midwestern and southwestern United States. In addition, ground water is an important source for industrial, urban, and irrigation purposes in humid areas (Heath, 1985). It is a relatively reliable resource and is not subject to the rapid or potentially large fluctuations in availability characteristic of surface water supplies (USEPA, 1977).

The development of ground water as a resource has led to declining ground-water levels in many areas of the country. These declines may lead to streamflow depletion, land subsidence, saltwater intrusion, and increased pumping costs for producers of water (Mann, 1985). The importance of ground water as a resource in the United States is represented in Figure 2-1. Half of the United States population is served by ground water, and studies show that ground-water use within this country is increasing at a rate of 25 percent per decade (USEPA, 1977). In many areas of the country, the ground-water resource is the only high quality economic source of water available.

Ground water contamination has been detected at sites in virtually all parts of the United States and regionally in some of the most heavily populated and industrialized areas. In almost all cases, ground-water contamination has been discovered only after a drinking water supply has been affected. Most of the time the level of contamination at the point of use does not exceed the health-based standards.

Consequences of ground-water contamination vary depending on 1) the potential hazard to health or the environment, 2) current use of the affected resource, 3) public concern, 4) regulatory requirements, and 5) funding available to study and mitigate the problem. In the most serious cases, water supply wells have been abandoned, uses of recreational areas have been altered, expensive remediation programs have been initiated, and new water supplies have been developed.



GROUNDWATER WITHDRAWALS IN 1980 FOR
THE UNITED STATES, PUERTO RICO AND
U.S. VIRGIN ISLANDS

(from Heath, 1985)

Figure 2-1

2.1.2 GROUND-WATER USE

Trends in water development during the last three decades demonstrate that the use of ground water for all purposes has been increasing at a faster rate than has the use of surface water (Heath, 1985). In 1980, nationwide ground water withdrawals ranged from less than one percent of total water withdrawal in the District of Columbia to 85 percent in Kansas (Heath, 1985). In addition, this survey demonstrated that in ten States, ground-water withdrawals represented more than half of the States' total water usage. The above figures are exclusive of thermoelectric power generation, for which surface water use still exceeds ground-water withdrawals.

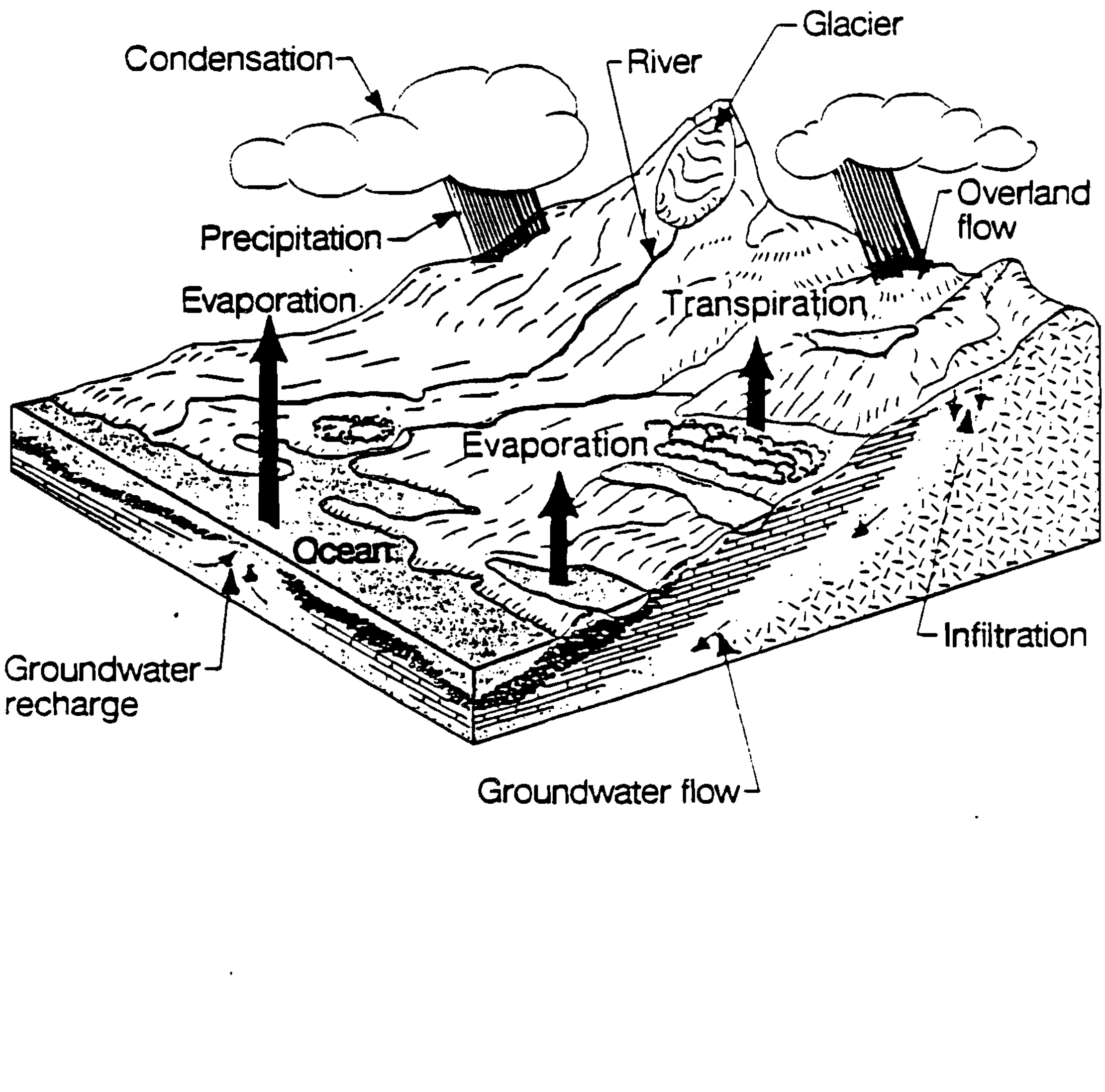
At this time, the largest use of ground water is for irrigation (Heath, 1985). States with the largest ground-water use for this purpose are California, Hawaii, Illinois, Indiana, Kansas, Minnesota, and Wisconsin. Other States in the southern United States that rely heavily upon ground water for irrigation practices are Arkansas, Florida, Louisiana, Mississippi, and Texas.

Forty-eight percent of the United States' population depends upon the ground-water resource as a drinking water supply. Thirty-nine percent of the ground-water-dependent population receive drinking water through public supplies and the other nine percent through individual domestic wells (USEPA, 1977). According to Heath (1985), the percentage of the United States population served by groundwater ranges from 30% in Maryland to 89% in New Mexico. Rural populations in the nation receive 94% of their drinking water from ground-water sources, whereas the populations served by public drinking water supplies get 35% of that supply from ground water (USEPA, 1977). Total withdrawal of ground water in 1984 was 8.8 billion gallons (27,000 acre-feet) per day of which 38% was used for drinking water (Heath, 1985).

2.2 PHYSICAL PROPERTIES OF GROUND-WATER AQUIFERS AND GROUND-WATER CONTAMINATION

2.2.1 PHYSICAL PROPERTIES

Under natural conditions, movement of ground water is from areas of recharge to areas of discharge. Ground water may be discharged to springs, ponds, lakes, or streams, lost by evapotranspiration to the atmosphere, or discharged directly into the ocean in coastal areas (Mann, 1985). This situation constitutes the hydrologic cycle, represented in Figure 2-2. In general, an equilibrium prevails in which long-term ground-water recharge is balanced by long-term discharge from the ground-water system (Mann, 1985).



HYDROLOGIC CYCLE

(from Driscoll, 1986)

Figure 2-2

Aquifers are of two primary types: unconfined and confined. Unconfined aquifers, also referred to as water table aquifers, are the most common. Under unconfined conditions, the water table is exposed to the atmosphere through openings in the overlying regolith (Driscoll, 1986). Water in unconfined aquifers, regardless of depth, is under the pressure exerted by the overlying water. The upper limit of the saturated zone in these aquifers is known as the water table. The pressure on fluids at the water table is equal to atmospheric pressure.

Ground water existing under confined or artesian conditions is isolated from the atmosphere at the point of discharge by impermeable strata (Driscoll, 1986). The confined aquifer generally is subject to pressures higher than atmospheric pressure, but it is possible for unconfined conditions to exist (laterally) in the recharge areas of confined aquifers. Unconfined and confined ground-water conditions are illustrated in Figure 2-3.

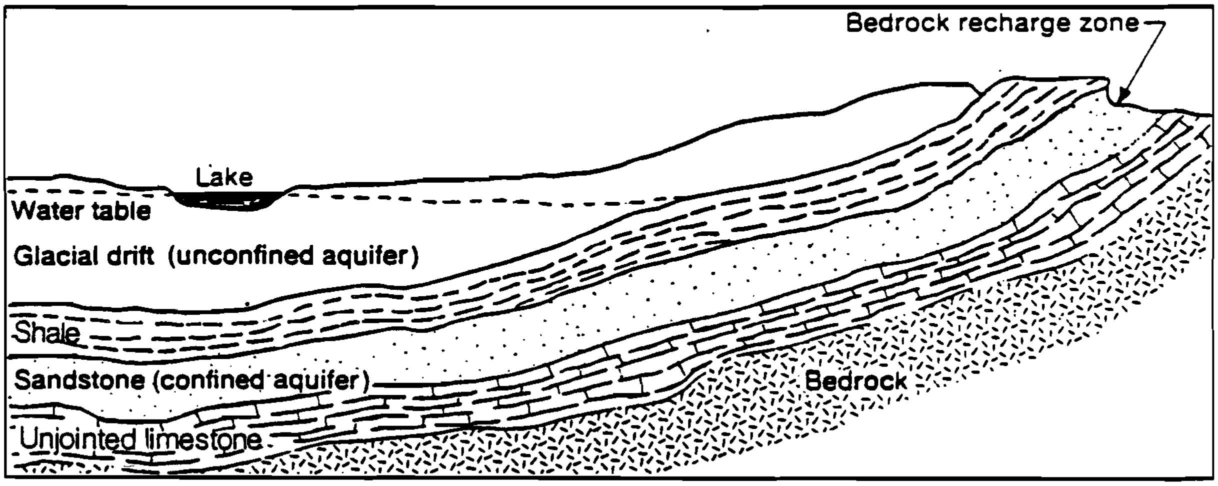
A third ground-water condition which can exist is due to variations in the ability of confining beds to retard water movement. Virtually all confining beds are capable of transmitting ground water if a sufficient hydraulic gradient and/or a total head differential exists between the aquifers. Beds that transmit measureable flows are termed "semi-confining," and the associated aquifers are considered to be semi-confined (Mann, 1985).

Intergranular pores, fractures, or openings resulting from solution in an unconfined aquifer are saturated with water below a free surface, known as the water table (Mann, 1985). As the volume of ground water in storage varies, the water table rises or falls accordingly. In confined aquifers, pores, fractures, and solution openings are completely filled with water. The water is confined under pressure by an overlying bed exhibiting low hydraulic conductivity (Mann, 1985). Changes in the amount of ground water stored under these conditions occur through elastic expansion and contraction of the porous material and of the water in response to pressure changes. In some instances, changes in ground-water storage can occur through the inelastic compaction of fine-grained sediments with associated subsidence of the land surface (Mann, 1985).

Five criteria have been proposed to differentiate between ground-water systems (Heath, 1982):

1. the aquifers and confining beds that make up the ground-water system;

2. the types of primary and secondary porosities, solution cavities, or fractures;



RELATIONSHIP OF SUBSURFACE STRATA TO OCCURRENCE OF CONFINED AND UNCONFINED AQUIFERS

(from Driscoll, 1986)

Figure 2-3

3. the composition of the dominant aquifer material, namely whether or not it is soluble, insoluble, or consists of both material types;

4. the storage coefficient and transmissivity of the dominant aquifer; and

5. the recharge and discharge conditions of the entire ground-water system.

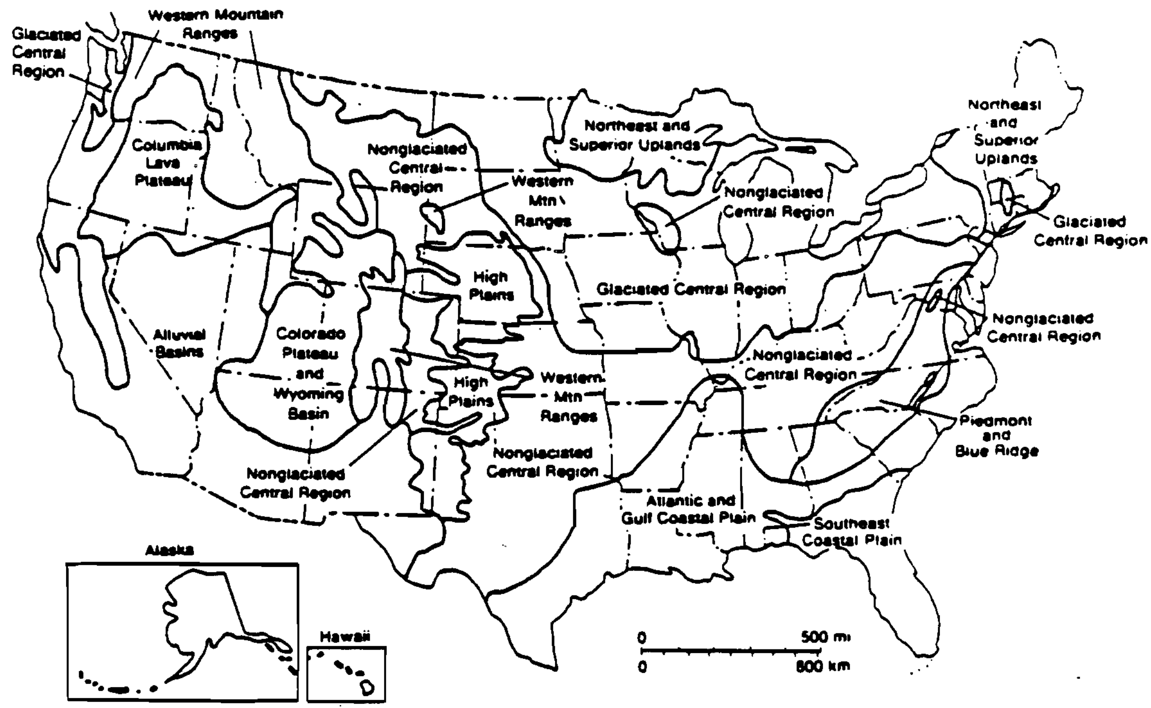
Based upon these criteria, the U.S. Geological Survey has proposed 13 ground-water regions for the conterminous United States. These regions are displayed in Figure 2-4. Note that Alaska and Hawaii are considered separate hydrogeologic regions. Geologic settings for aquifers and typical well yields for those aquifers are presented for each region in Table 2-1.

2.2.2 GROUND-WATER CONTAMINATION

For the purposes of this report, ground-water contamination is defined as the degradation of ground water's natural quality as the result of human activity (USEPA, 1977). The Safe Drinking Water Act defines a contaminant as "any physical, chemical, biological or radiological substance or matter in water."

Contamination processes begin with contaminant sources, namely waste disposal practices (USEPA, 1977). Leakage, percolation, or discharge of contaminants into water supply aquifers occur either intentionally or accidentally and can involve a variety of waste constituents. As the contaminant travels through the soil or rock media into the ground-water aquifer, it can be modified by various attenuation processes. These processes vary greatly in their effectiveness, and some toxic substances can be highly mobile. Attenuation of pollutants within the aquifer, like ground-water movement, can be extremely slow. Movement of these contaminants can occur as 1) individual bodies or "slugs," 2) local plumes caused by continual flow of leachate, and 3) masses of degraded water (USEPA, 1977).

The degree of contamination that can occur within ground-water aquifers ranges from a slight degradation in natural quality to the presence of toxic concentrations of heavy metals, organic compounds, and radioactive materials (USEPA, 1977). These constituents can be present in varying concentrations within certain Class V waste streams. It is important to note that simply removing the source of contamination does not clean up the aquifer once it has been contaminated. This contamination can result in portions of aquifers being condemned for use as drink-



GROUNDWATER REGIONS OF THE UNITED STATES

(from Driscoll, 1986)

Figure 2-4

TABLE 2-1. GEOLOGIC SETTING AND TYPICAL WELL YIELDS FOR PRINCIPLE AQUIFERS WITHIN MAJOR GROUND-WATER REGIONS (HEATH, 1982)

Region No.	Region	Geologic Situation	Well Yield (gpm)	Well Yield (m^3/day)
1	Western Mountain Ranges	Mountains with thin soils over fractured rocks, alternating with narrow alluvial and, in part, glaciated valleys	10-100	50-500
2	Alluvial Basins	Thick alluvial (locally glacial) deposits in basins and valleys bordered by mountains	100-5,000	500-30,000
3	Columbia Lava Plateau	Thick lava sequence inter-bedded with unconsolidated deposits and overlain by thin soils	100-20,000	500-100,000
4	Colorado Plateau & Wyoming Basin	Thin soils over fractured sedimentary rocks	10-1,000	50-5,000
5	High Plains	Thick alluvial deposits over fractured sedimentary rocks	100-3,000	500-20,000
6	Nonglaciated Central Region	Thin regolith over fractured sedimentary rocks	100-5,000	500-30,000
7	Glaciated Central Region	Thick glacial deposits over fractured sedimentary rocks	50-500	300-3,000
8	Piedmont & Blue Ridge	Thick regolith over fractured crystalline and metamorphosed sedimentary rocks	50-500	300-3,000
9	Northeast and Superior Uplands	Thick glacial deposits over fractured crystalline rocks	20-200	100-1,000
10	Atlantic & Gulf-Coastal Plain	Complexly interbedded sands, silts, & clays	100-5,000	500-30,000
11	Southeast Coastal Plain	Thick layers of sand & clay over semiconsolidated carbonate rocks	1,000-20,000	5,000-100,000

TABLE 2-1,
continued

12	Alluvial Valleys	Thick sand and gravel deposits beneath floodplains and terraces of streams	100-5,000	500-30,000
13	Hawaiian Islands	Lava flows segmented by dikes, interbedded with ash deposits and partly overlain by alluvium	100-5,000	500-30,000
14	Alaska	Glacial and alluvial deposits in part perennially frozen and overlying crystalline, metamorphic, and sedimentary rocks	10-1,000	50-5,000

ing water supplies. It is considerably more difficult to reclaim a polluted aquifer than to clean up a surface water supply (Canter and Knox, 1986; USEPA, 1977).

2.3 RELATIONSHIP OF CLASS V INJECTION TO UNDERGROUND SOURCES OF DRINKING WATER

2.3.1. GENERAL DISCUSSION

Underground sources of drinking water (USDW) have been targeted for protection under the Safe Drinking Water Act, and are bodies of water recoverable in "significant" quantities, having less than or equal to 10,000 mg/l Total Dissolved Solids (TDS). Typically, Class V wells are those that inject into or above USDW. However, certain Class V wells inject below USDW. Examples of such well types are geothermal reinjection wells, spent brine return flow wells, some of the mineral and fossil fuel recovery related wells, select radioactive waste disposal wells, and certain experimental technology wells. Potential for contamination by Class V injection can vary greatly and is largely dependent upon where injection occurs relative to USDW, construction and operation features of wells, and injectate quality and volumes.

2.3.2. RELATIONSHIP OF CLASS V INJECTION TO USDW

As discussed, certain Class V wells inject fluids below USDW. These wells often inject large fluid volumes. Depending on the compatibilities of the injectate and the USDW (i.e., physical and chemical characteristics), this could adversely impact (degrade) USDW if proper planning is not conducted. In many areas studied, USDW exist to depths of several thousand feet. Aquifers at these depths are confined, probably both above and below. Proper planning can assure that injection will occur below a lower confining layer. If proper construction and operation are practiced, including regular mechanical integrity testing, injection below USDW can pose minimal threat of contamination to USDW.

The inventory indicates that most Class V injection is above USDW. Wells of this type include many of the drainage wells and domestic waste water disposal wells. Attenuation of contaminants in shallow soils and unconsolidated sediments is the controlling parameter in shallow USDW contamination. If injection wells are sited and constructed properly, contaminants may be attenuated, thereby reducing the potential for harm to USDW.

Injection into USDW is the type of Class V activity potentially most harmful, and representatives of each Class V well type probably are presently injecting into USDW. Depending upon the nature of the injected fluids, injection directly into USDW could result in broadscale degradation within USDW.

SECTION 3
CLASS V INJECTION WELL INVENTORY

The Class V injection well inventory is characterized by extreme variations in database completeness. In general, inventories for "high-tech" Class V wells are more accurate than those for "low-tech" wells. A number of factors may be responsible for this disparity. High-tech Class V injection wells are typically associated with special industries or large scale remediation and disposal projects. They also tend to be small in number, localized, and easy for regulatory agencies to inventory and monitor. In addition, several agencies at the local, county, and state levels may be regulating these operations through drilling and waste discharge permits. Furthermore, owners/operators of high-tech wells generally are more informed about existing regulations, such as reporting requirements, than are owners/operators of some types of low-tech wells. As a result, files maintained by high-tech well operators tend to be more complete, whereas no such files may exist for many low-tech wells.

A number of inspection programs have been conducted that target high-tech Class V injection wells. These inspections have provided valuable inventory data for facilities inspected, as well as for other facilities owned by the same owner/operator. All these factors have resulted in a generally complete inventory database for high-tech wells and a generally poor to nonexistent one for low-tech wells.

The current regulations (40 CFR 144.24) state that injection into Class V wells is authorized by rule until future regulations are established. Owners or operators of Class V injection wells authorized by rule are required to submit specific inventory information within one year of the effective date of an applicable underground injection control program in their State. The inventory information required as specified in 40 CFR 144.26(a) includes the following:

1. facility name and location;

2. name and address of legal contact;

3. ownership of facility;

4. nature and type of injection well(s); and

5. operating status of injection well(s).

For programs administered by USEPA, owners/operators of the following types of Class V injection wells are required to supply additional inventory information [40 CFR 144.26(b)(1)(iii)]:

1. sand or other backfill wells;

2. radioactive waste disposal wells;

3. geothermal energy recovery wells;

4. brine return flow wells;

5. wells used in experimental technology;

6. municipal and industrial disposal wells other than Class I; and

7. any other Class V wells, at the discretion of the Regional Administrator.

The additional information to be provided by these owners/operators includes [40 CFR 144.26(b)(2)(ii-x)]:

1. location of each well or project by Township, Range, Section, and Quarter-Section; or by latitude and longitude to the nearest second, according to the conventional practice in the state;

2. date of completion of each well;

3. identification and depth of the formation(s) into which each well is injecting;

4. total depth of each well;

5. casing and cementing record, tubing size, and depth of packer;

6. nature of injected fluids;

7. average and maximum injection pressure at the well head;

8. average and maximum injection rate; and

9. date of the last mechanical integrity test, if any.

Per 40 CFR 146.52(b), within three years of approval of each UIC program, whether administered by the individual State or by the USEPA, a report must be submitted by the Director of the UIC Program to USEPA and must contain the following:

1. information on the construction features of Class V wells and the nature and volume of injected fluids;

2. an assessment of the contamination potential of Class V wells using available hydrogeological data;

3. an assessment of the available corrective alternatives where appropriate and their environmental and economic consequences; and

4. recommendations for both the most appropriate regulatory approaches and for remedial actions where appropriate.

Appendix A contains State Report Summaries on each report received to date. Summaries for each State report include:

1. status of the UIC program:

   a. primacy - implemented by the state

   b. direct implementation (DI) - implemented by the USEPA;

2. title, author, date, and status of the report;

3. hydrogeology and water usage;

4. number of injection wells by type, and their compatibility with numbers reported by Federal Underground Injection Control Reporting System (FURS);

5. assessed contamination potentials of each well type ("high," "moderate," or "low," where applicable);

6. applicable regulatory systems for each well type ("permit," "rule," or "none," where applicable);

7. inventory strategies;

8. availability of case studies and bibliographies; and

9. recommendations.

3.1 INVENTORY METHODS (STRATEGIES)

Several methods were used to gather inventory data. Strategies employed for different States and Territories are listed on the State Report Summaries in Appendix A. Some inventory methods were common to several states. For example, inventory efforts often were initialized by publishing notices about the UIC program in the local newspapers. Generally they requested information required by 40 CFR 144.26. Another commonly used method entailed mailing questionnaires to County Health Departments/Sanitarians, registered water well drillers, and public facilities such as schools, churches, etc. In addition, visits to various government agencies were made to question personnel who might be knowledgeable about current Class V activities and to search various files for existing Class V well registrations and permits. National Pollutant Discharge Elimination System (NPDES) permits generally were reviewed where available. Also, mailing lists and telephone contacts were compiled from local telephone directories and directories of related professional organizations (e.g., National Water Well Association).

The USEPA has instituted a computer database system for maintaining the inventory data of all classes of injection wells. The Federal UIC Reporting System (commonly referred to as FURS), contains general facility, well type, number, and status information for each inventoried injection facility. Generally, the FURS inventory data for Class V injection wells, on a national basis, are incomplete and dated. In preparing this report, well data provided in the State reports and additional correspondence were considered in addition to the FURS data.

3.2 INVENTORY RESULTS

According to the most recently submitted inventory figures, there are approximately 170,000 Class V injection wells in the United States, its Territories, and Possessions. Table 3-1 lists the number of wells reported to date for each State, Territory, and Possession. Also provided is the total for each well type and for each Region. Figure 3-1 illustrates the distribution of Class V wells by State. Table 3-2 is a summarized version which lists totals by Region and by general well type category. Figure 3-2 illustrates the distribution of Class V wells by Region. Please refer back to Table 1-1 for a list of well type subclassifications recognized by the USEPA for the purpose of this study. Figure 3-3 illustrates the distribution of inventoried Class V wells by general well type category.

At this time it is prudent to emphasize that the reported inventory figures should be interpreted cautiously. The inventory collection is an on-going process, and figures are subject to change frequently and dramatically. There are always questions about what practices are Class V as opposed to other classes of wells, and which practices are considered well injection. There is also, from time to time, confusion about what Class V subcategory to which a particular injection practice should be assigned.

Furthermore, it should be emphasized that many of the numbers included in the table are estimates and that records are not necessarily available for each well listed. For example, the estimated number of drainage wells (5D2 plus 5D4) in Arizona ranged from 25,000 to 100,000 wells. Based on verbal communication with various State agencies, the range was narrowed down to between 40,000 and 60,000 wells. For the sake of simplicity, the table indicates 50,000 wells.

In another case, the number of heat pump/air-conditioning return flow wells (5A7) in Oklahoma was reported to be "in the hundreds." Again for the sake of simplicity, the table lists "100" heat pump/air-conditioning return flow wells.

As a final example, the number of septic systems (5W11) in Florida was reported to be 19,000. This number was derived using a mathematical equation to estimate the "total" number of septic systems. Nineteen thousand represents one percent of the "total" number. This number was derived because only one percent of the total number of septic systems are believed to serve more than 20 persons. Florida has actual records on approximately 850 septic systems. The remaining estimated figures are too numerous to describe.

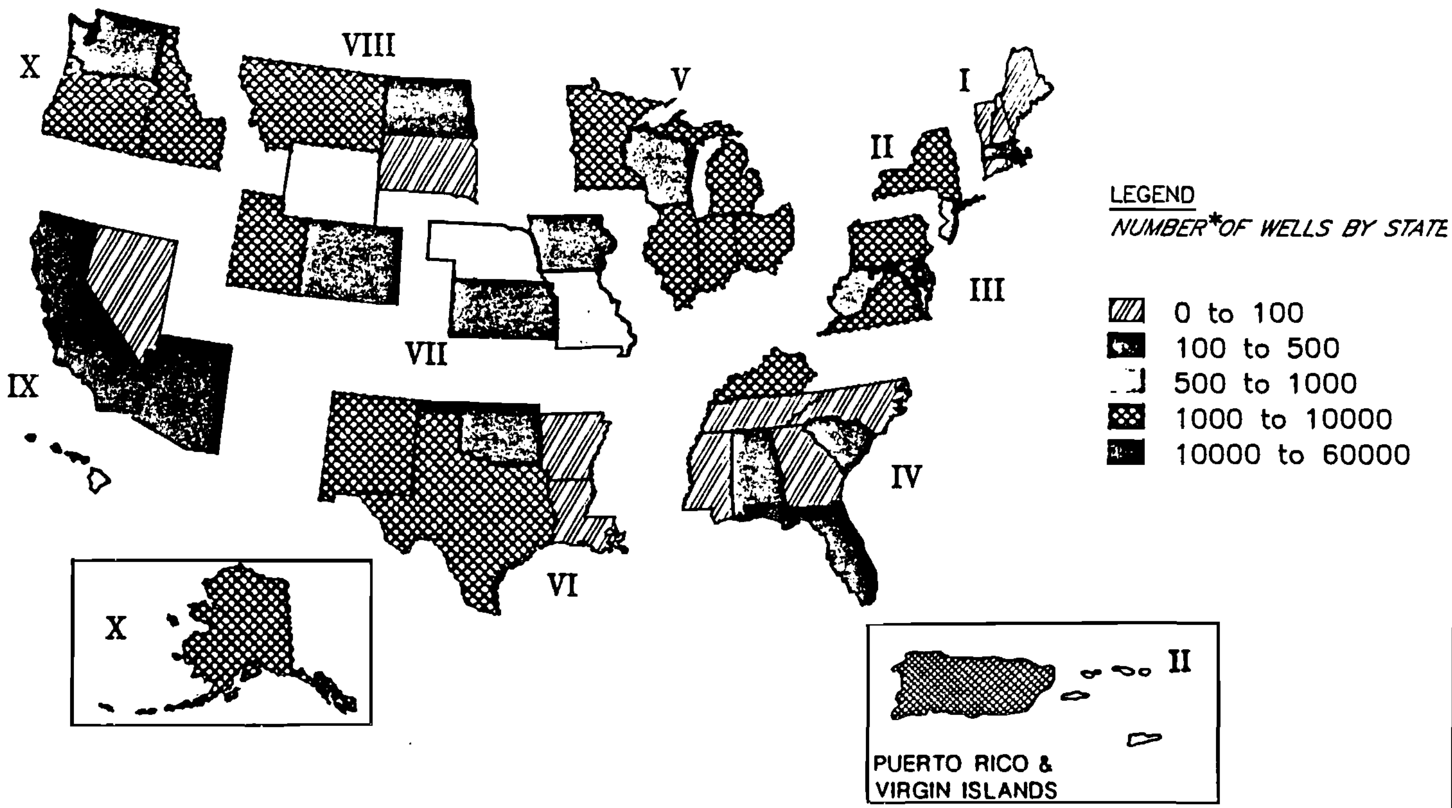
3.3 INVENTORY DISTRIBUTION

The geographical distribution of the wells inventoried to date is difficult to accurately describe for several reasons. First, efforts made to compile inventories differed significantly among States and Regions. While some States were successful at actually locating and keeping records on each reported well, other States made blanket estimates and had little to no documentation to support the estimates. In States where the USEPA was responsible for conducting the inventory, levels of effort varied significantly.

Second, record-keeping systems among States vary drastically. Inventories were easier to conduct and resulted in more accurate figures for States which require permits or registrations of injection wells. In many cases, file searches were quicker, and were likely to be more accurate than reliance on a network of contacts.

Third, the response rates differed significantly among various groups who were contacted for information. Whereas one State may have derived its most significant information from the Soil Conservation Service (SCS), for example, another State might have had less success with the SCS and found County Health Departments to be its most valuable source of information. It should be noted here that different groups have varying levels of interest in the different well types; therefore, the inventory figures provided by different groups vary accordingly. For example, the SCS may provide more information on agricultural drainage wells (5F1) while County Health Departments are likely to provide more information on septic systems (5W11). Table 3-3 illustrates the varying response rates of several groups which were contacted by mail in a portion of Region V.

TOTAL NUMBER OF CLASS V WELLS BY STATE



*Some numbers are estimates.

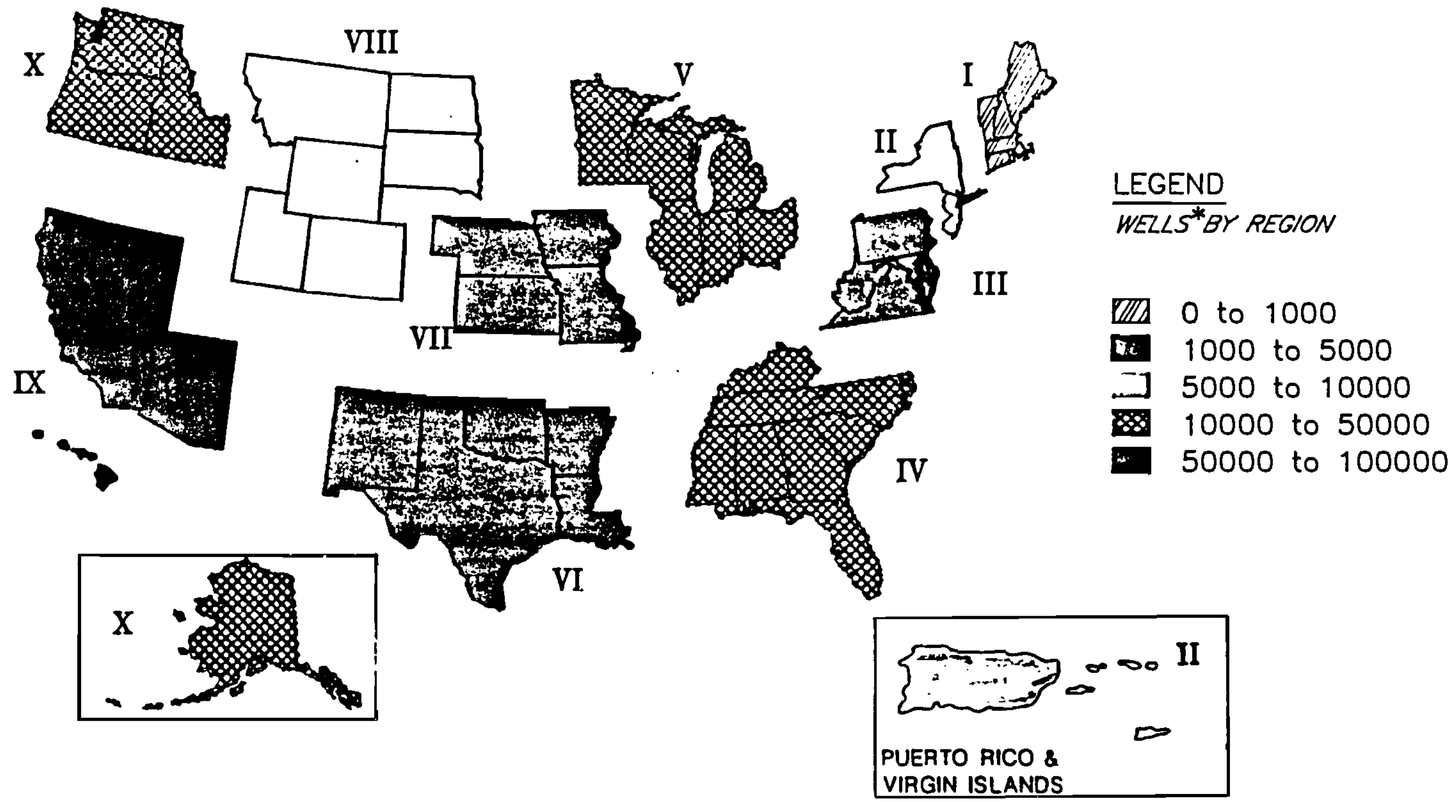
Figure 3-1

TABLE 3-2: CLASS V INJECTION WELL NATIONAL INVENTORY BY REGION & WELL CLASSIFICATION

EPA REGION	TOTAL #WELLS	DRAINAGE	GEOTHERMAL	DOMESTIC WASTEWATER	MINERALS & FOSSIL FUEL	INDUSTRIAL	RECHARGE	MISCELLANEOUS
I	364	41	24	169	0	127	1	2
II	8950	3780	181	1503	48	428	3000	10
III	4589	279	2291	916	1072	31	0	0
IV	27911	3583	2998	20493	61	393	351	32
V	17772	5460	1164	8237	63	651	6	2191
VI	3843	171	1149	106	1226	11	74	1106
VII	6675	495	1802	5	4326	22	8	17
VIII	9015	7627	222	425	465	44	7	225
IX	64214	59488	166	3146	876	235	258	45
X	29826	19820	166	8688	575	437	14	126
TOTAL	173159	100744	10163	43688	8712	2379	3719	3754

TOTAL NUMBER OF CLASS V WELLS

BY REGION



*Some numbers are estimates.

Figure 3-2

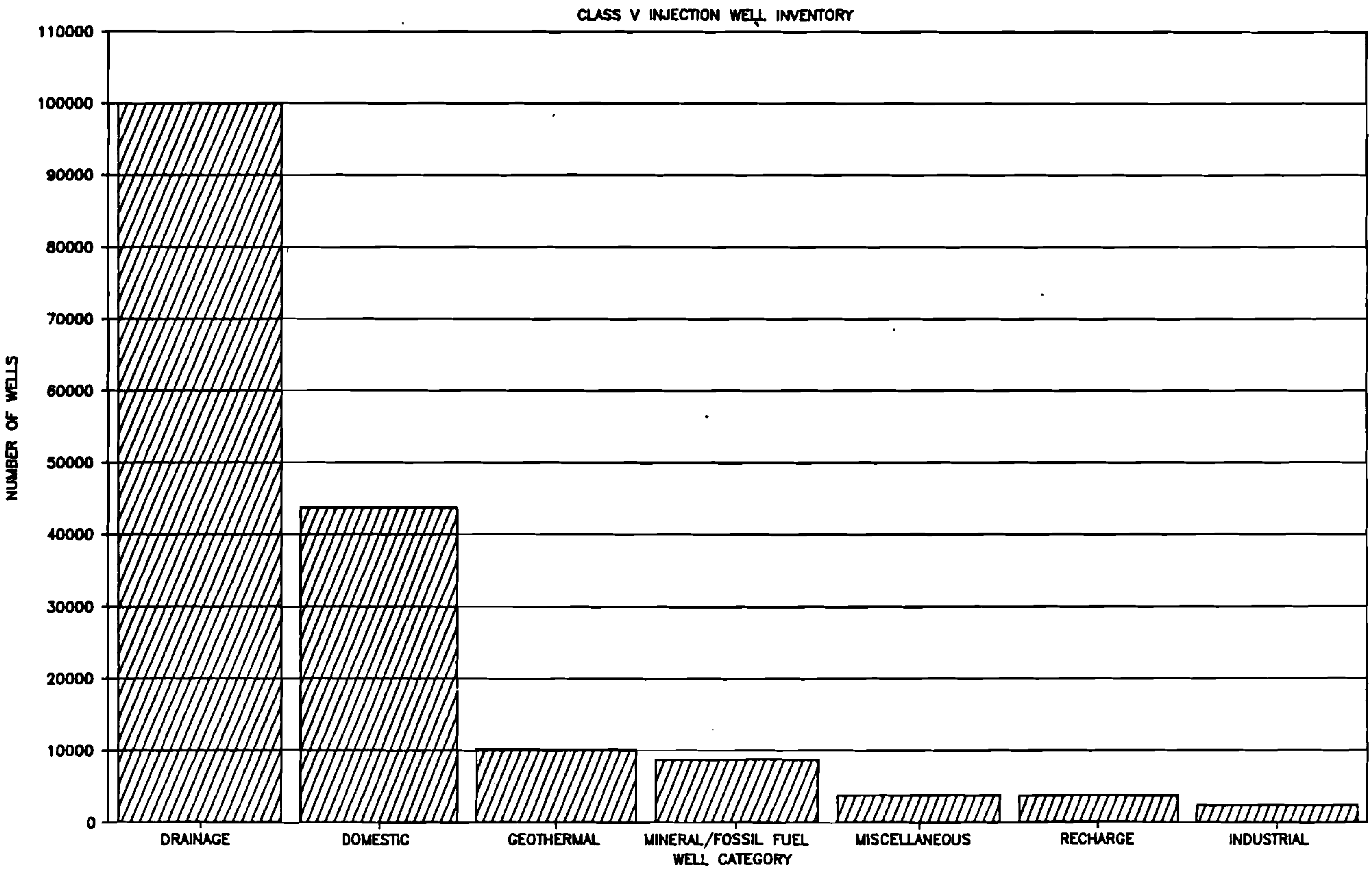


Figure 3-3

BAR GRAPH ILLUSTRATING
CLASS V INJECTION WELL INVENTORY
DISTRIBUTION BY WELL TYPE

TABLE 3-3

RESPONSE RATES OF VARIOUS GROUPS CONTACTED BY REGION V FOR INVENTORY INFORMATION

GROUP	RESPONSE RATE (%)		
	Indiana	Michigan	Minnesota
Agricultural extension agencies	39	35	23
City officials	25	29	48
County Health Departments	7	77	51
Drilling companies	17	11	9
Soil Conservation Service	31	48	59

Fourth, confusion about how to classify injection wells frequently was apparent. The most common error involved the distinction between heat pump/air-conditioning return flow wells (5A7) and cooling water return flow wells (5A19). Several inventories combined these two types based on the misconception that cooling water refers to air-conditioning return flow water. In actuality, "cooling water" is intended to describe fluids used to cool industrial products, industrial processes, and machines used by manufacturers, utilities, etc.

Another classification problem frequently encountered was distinguishing between sewage disposal systems (5W10, 11, 31, and 32) and industrial disposal wells (5W20). This problem is inherent to the classification system (Table 1-1) and is not easily resolved. In general, the classification system is based more on differing waste stream components rather than on differing well construction components. With this in mind, it is suggested that facilities which inject industrial waste into septic systems or cesspools be classified as industrial disposal facilities (5W20) rather than cesspool or septic system facilities (5W10, 5W11). Consequently, sewage disposal facilities would be limited to those facilities which inject solely sanitary wastes (and are multi-family, domestic, or public facilities serving more than 20 persons per day). Because this clarification was not provided prior to conducting the inventories, many industrial disposal facilities are included in the figures representing septic systems and cesspools under the heading, "Domestic Wastewater Disposal Wells."

Furthermore, confusion ensued when waste stream components included more than one of the described sub-classifications. For example, some facilities reported injecting both cooling water and industrial process wastewater. In Illinois, raw sewage, cooling water, and industrial process wastewater are all injected into abandoned coal mines. Mixed waste streams are difficult to inventory and even more difficult to assess. Facilities, injecting mixed waste streams were classified under the category of highest contamination potential. In the cases described above, the facilities were classified as industrial disposal facilities.

In summary, it is difficult to draw conclusions about the geographical distribution of Class V injection wells. The distribution would very likely change significantly if actual inventory figures were compiled under a study conducted to produce comparable data. "State" totals range from 0 wells in American Samoa and Trust Territories of the Pacific Islands (TTPI) to more than 25,000 wells in Florida and 50,000 wells in Arizona. To date, Region IX reports the largest inventory with over 64,000 wells. The bulk of Region IX's inventory, however, lies in the estimated number of drainage wells (5D2 plus 5D4) in Arizona: 50,000 wells. Approximate inventory figures by Region are shown on Table 3-4.

TABLE 3-4

TOTAL INVENTORY FIGURES BY REGION

Region	Total # of Wells
Region IX	64,214
Region IV	27,911
Region X	29,826
Region V	17,772
Region VIII	9,015
Region II	8,950
Region VII	6,675
Region III	4,589
Region VI	3,843
Region I	364

Although correlation between the number and distribution of wells is difficult, a few trends can be distinguished among well types.

3.3.1 DRAINAGE WELLS

The highest number of drainage wells is reported in Arizona (Region IX). Region X also reports a relatively high number of drainage wells. These high numbers are consistent with the hydrogeological conditions inherent to Regions IX and X. It is difficult to distinguish storm water drainage wells (5D2) from industrial drainage wells (5D4) within the current inventory, but industrial drainage wells might be expected to be located in highly populated (industrialized) areas with appropriate hydrogeological conditions. High numbers of improved sinkholes (5D3) are expected in areas with "karst" topography such as Region IV, Region V, Puerto Rico, and Missouri.

3.3.2 GEOTHERMAL REINJECTION WELLS

Relatively high numbers of geothermal reinjection wells were expected in areas with high geothermal gradients such as the West Coast of the United States. The reported inventory figures support this hypothesis as most electric power reinjection wells (5A5) and direct heat reinjection wells (5A6) are located in Regions IX and X.

Technology concerning heat pump/air-conditioning return flow wells (5A7) is available nationwide. Data indicate that heat pump/air-conditioning return flow wells are present in all Regions of the United States. It should be noted that high geothermal gradients are not required for efficient usage of groundwater source heat pumps.

3.3.3 DOMESTIC WASTEWATER DISPOSAL WELLS

Domestic wastewater disposal wells are prevalent in every Region of the United States. Generalizations beyond that fact are difficult to make. However, fewer domestic wastewater disposal wells are probably located in more highly populated areas because those areas are more likely to be served by sewer systems. An exception to this generalization may be older cities.

One reason it is difficult to recognize any trends in the distribution of domestic wastewater injection wells is that they are exceedingly difficult to inventory. State and local regulations and record-keeping systems differ drastically. If records of individual systems are not kept by the State, it is difficult to identify these wells.

Another reason it is difficult to recognize trends is that some disposal systems were not included in some inventory efforts. For example, only septic systems with associated "wells" were inventoried in some States, while other States included both septic systems with "wells" and those with "drainfields." Both types will be included in the Class V inventories for this report. Without consistent inventories, it is impossible to make comparisons.

3.3.4 MINERAL AND FOSSIL FUEL RECOVERY WELLS

Inventory figures of these well types are believed to be relatively complete. These well types generally are limited to

States with related available natural resources. They seem to be well documented and regulated within their respective industry regulations.

3.3.5 INDUSTRIAL DISPOSAL

Problems with compiling inventories and recognizing usage trends of industrial disposal wells are similar to the problems associated with domestic wastewater disposal wells. Accurate records are not kept in many states. Furthermore, often there is reluctance on the part of owners/operators to report their industrial disposal wells for fear of "government interference." Also, injectate quality often is suspect, and recent public awareness campaigns concerning environmental protection may have made the owners/operators wary.

3.3.6 RECHARGE AND MISCELLANEOUS WELLS

Limited information was provided on recharge and miscellaneous wells. Presumably these well types will see increased usage in the future. Region V reports a relatively high number of abandoned drinking water wells (5X29); however, it should be noted that they are not necessarily used for the disposal of waste. The numbers reported indicate the number of abandoned drinking water wells on which they have records. There is no evidence to suggest that they are all being used to dispose of waste. Due to the difficulty in determining which wells actually are being used for disposal, the Agency is assuming a worst-case scenario and will include all abandoned drinking water wells in the inventory until data demonstrate otherwise. Where waste streams can be identified, well type classifications are revised to reflect the source of the waste streams.

3.4 EVALUATION OF THE DATABASE

Conducting an initial inventory search for Class V injection wells and then maintaining the inventory database with periodic updates is a complicated task. However, it is one that is essential to the program because a solid inventory is the basis for solid assessments. Some Class V wells were not regulated before the USEPA UIC program. Consequently, an unknown number of Class V injection wells probably remain "undiscovered" to this day since records of their existence either were not kept or were lost.

The inventory of Class V wells is considered to be poor to fair (i.e., incomplete). Many states were confident that most existing well types were identified even though the numbers of each type were thought to be low. Several factors contribute to the lack of detail and completeness (inventory vs. existing wells).

As described earlier, levels of effort among States and among Regions differed significantly. Second, the amount and type of information available for each well type differ among States, among Regions, and among well types. Third, different information sources responded to requests for information inconsistently. Fourth, several problems in classifying well types were evident.

It is essential to continue collecting inventory information and updating databases in order to reasonably assess the groundwater contamination potential of Class V injection wells.

3.5 RECOMMENDATIONS

The Class V injection well inventory continues to change. New wells continue to be constructed, and "undiscovered" existing wells continue to be identified. Several States recommended that additional resources and efforts be devoted to improving the Class V injection well database. All data should be computerized, including records of questionnaires, permit record files, and support documentation. Every effort should be made to establish a uniform classification and numbering system.

As a result of the States' efforts in inventorying Class V wells, several important lessons have been learned concerning strategies for obtaining a complete inventory on which to base assessments. Based on the inventory methods used by the States, the following recommendations for where and how to best find inventory information on both general and well specific levels are presented.

3.5.1 GENERAL

Currently there are at least 30 types of Class V injection wells, rather than only the 11 types that FURS recognizes. Not all States have all 30 types. However, because there are so many well types, States may have to employ more than one strategy when conducting and updating inventories.

The States in USEPA Region VIII recommend that the Agency make a request to Congress for funding to conduct an effort similar to the Surface Impoundment Assessment study. This study could be conducted with a more consistent approach and would provide a firm foundation for making regulatory changes.

When conducting mailed questionnaire surveys, some states found that telephone surveys used to ascertain appropriate "targets" enhanced mailed responses. Attachments to the questionnaires explaining the UIC program and follow-up telephone calls for data verification also have been useful in obtaining cooperation.

Some states recommended that every time an inventory search is conducted by State, Federal, local, or consultant entity, documentation of the strategy and date is essential so future inventory searches can build upon previous knowledge.

Current yellow pages, industry directories and association mailing lists, and agency and community listings were recommended for use by many states because they provide a good base of addresses and telephone numbers. Examples of directories include the Thomas Register and State Red Book of companies and industries; the Pennwell series of directories such as the Worldwide Refining and Gas Processing Directories; the telephone directory government blue pages; State association of governments or cities listings; and City, County, or State listings of business and commerce. Idaho reports that computerized directory systems, such as the Electronic Yellow Pages, allow statewide searches by specified categories and can provide addresses on printed mailing labels.

Some States have had good inventory results posting public notices in newspapers and various trade journals. Results are directly proportional to the notice's general content and ease of reading, location, and period of time the notice was posted.

Permits or other records needed during drilling and installation of a well may have been filed with the State agency which requires permits for water wells. However, the files may not be segregated by well type.

Many States require that all water well drillers be licensed with the State and that drillers register all completed wells and supply well logs. In these States, registration forms could be re-designed to indicate "well purpose." Well drillers should be better informed of the Class V UIC Program in order to identify specific injection well types.

Contamination potential assessments of the various Class V well types is, in part, dependent on 1) hydrogeologic characteristics and water usage in a given area, and 2) the population at risk. Numerous States recommended that efforts should be initiated to standardize the type and amount of information available on Class V injection wells.

3.5.2 SPECIFIC

In describing their inventory efforts, many States identified methods utilized to inventory specific well types. Recommendations based on these methods follow.

1. Agricultural Drainage Wells (5F1)

   Many States have entities which can be contacted concerning existence of agricultural drainage wells such as county extension services; irrigation, water, or drainage districts; septic tank and dry well installers and drillers; local or regional water quality or resource boards; county environmental health departments; local consultants and university groups, especially at the A & M universities; the USDA Soil Conservation Service offices; and USGS State offices or State geological surveys.

Often the farmer is the only person who really knows of the existence of agricultural drainage wells. If the farmer is informed of the potential contamination of USDW posed by these wells, he may volunteer information when asked. Iowa State University Cooperative Extension Service put together an information brochure, "Agricultural Drainage Wells in Iowa," for distribution to farmers and others to provide information on the effects of these wells on water supplies. Publications of this type may help to improve the inventory database by informing the public not only of their responsibility to report Class V wells but also the reason behind the requirements.

2. Storm Water and Industrial Drainage Wells (5D2, 5D4)

These wells are among the hardest types to effectively inventory if a State has not been registering them since the time of installation. Obviously, if a State has had no problems with drainage, then this type of well probably will not have been used. There are several potential places to search for storm drainage well records. These include the State or Federal highway department, city engineers, public works directors, architectural engineers - either private or public (certain areas may have been designed to be drained by these wells), drillers or "dry" well installers, State water resource divisions or boards, State health departments or environmental protection agencies, and USGS State offices or State geological surveys. Another key means of locating drainage wells is to check local zoning requirements for sewage and storm water control. Some local zoning departments also have records showing actual well locations. City zoning maps may be used to determine industrial sectors of the cities. A percentage of storm drainage wells located in industrial sectors may be "industrial drainage wells" (5D4) because the probability of chemical or hazardous substance spills and leaks is greater in industrial settings.

Public notices about storm drainage wells to the general population may be a good strategy to use. Fieldwork also may be necessary (in probable areas) when all other means fail.

3. Improved Sinkholes (5D3)

Sinkholes are found in areas of the United States underlain by karst limestone formations (approximately 20% of the

United States.). In many locations, naturally occurring sinkholes may have been improved to enhance acceptance rates of storm drainage or any fluids (e.g., sewage, industrial process water and waste products). Inventory strategies used for storm drainage wells also may be used to find improved sinkholes.

4. Electric Power Geothermal Reinjection Wells (5A5)

These wells are used in thermally active areas of the United States, notably the western states and in the Gulf Coast. Many geothermal electric power plants discharge to reinjection wells. Entities holding records on these wells include oil companies and other operators involved in geothermal electric power generation, the Geothermal Resources Council (based in San Francisco), State oil and gas divisions, energy or corporation commissions, departments of minerals (these are State level agencies), U.S. Bureau of Land Management (for developments on Federal leases), the U.S. Geological Survey, and the U.S. Department of Energy. States such as California and Nevada have permit programs for these wells.

5. Direct Heat Geothermal Reinjection Wells (5A6)

These wells also are used in thermally active areas of the United States but do not require as high groundwater temperatures as geothermal electric power operations. Many of these wells are shallower than electric power reinjection wells and may or may not reinject spent water.

In Oregon, wells which inject into a formation other than the source aquifer must apply for a permit with the Department of Environmental Quality. Other wells which reinject into the source aquifer or discharge to the surface do not need a permit. In California and Nevada, large direct heat operations file for permits with the California Department of Oil and Gas and the Nevada Department of Minerals. Public service commissions also may be involved if the direct heat operation is very large or serves as a public utility company. The Geothermal Resources Council and State and U.S. Geological Surveys are good information sources.

6. Heat Pump/Air Conditioning Return Flow Wells (5A7)

Historically, the best sources of information for heat pump/air conditioning return flow wells have been the State tax commissions since many States gave tax credits (or provided other incentives) for these systems. Idaho, Michigan, and Oregon offer such tax credits. Michigan and Ohio give property and sales tax incentives for groundwater heat pumps. In Massachusetts, heat pumps are exempted from State sales tax. Nevada has a program to reduce the valuation of alternative energy systems for property tax purposes.

In addition to State tax records, inventory information may be available through heat pump installers and distributors. The telephone yellow pages should list such companies. Also, the National Water Well Association, which is an advocate of ground-water heat pumps, has a plethora of information on heat pump companies, state laws, etc.

7. Aquaculture Return Flow Wells (5A8)

Aquaculture is the practice of rearing water animals or cultivating water plants in a controlled environment. Most operations are for profit, however, some aquaculture is experimental or for public interest (e.g. Marineland of the Pacific). The source of water may be ground water, wastewater from power plants or other industries, surface water or ocean water. Thus, only some aquaculture wastewater disposal wells are really return flow wells. Disposal wells are only one of the methods of wastewater discharge available. Sources of information for these wells include the State or local USDA office; the telephone yellow pages under Fish Hatcheries, Fish Farms, Seafood, Aquaculture; State listing of commerce, industry, or business; and research or public display aquariums.

8. Domestic Wastewater Disposal Wells (5W9, 5W10, 5W11, 5W31, 5W32, 5W12)

Historically, disposal of sewage wastes has been handled at the county and/or city level. Some States do maintain records of sewage disposal systems and almost all counties/cities maintain such records. In order to increase the inventory of these Class V injection wells, personal, telephone, and written queries (in decreasing order of effectiveness) should be made with the county/city sanitarians and public works directors. The nature and availability of sewage disposal well records vary from State to State and county to county. Experience has shown that often, records of these types of wells are extensive paper files and information is very difficult, if not almost impossible, to extract. Building a Class V inventory database of such wells may prove to be a long, tedious process which requires significant resources.

The city public works department director should be the person to contact for information on sewage treatment plant effluent disposal methods. Most plants discharge to surface waters; however, in some locations wells may be used (e.g. Hawaii, Florida). Some cities are using highly treated sewage wastewater (effluent) for aquifer recharge projects or saline water barrier projects (e.g., Palo Alto, California saline water intrusion barrier project).

9. Mineral and Fossil Fuel Related Wells (5X13, 5X14, 5X15, 5X16)

Records and other information on these wells related to energy and mineral recovery may be found by contacting the U.S. Bureau of Mines, U.S. Department of Energy, U.S. Geological Survey, State bureaus of mines, State departments of energy, corporation commissions, State departments of minerals and economic geology, State geological surveys, State water resources /protection boards, and the mining and energy industries themselves. For operations on Federal land, the U.S. Bureau of Land Management may hold records.

10. Cooling Water Return Flow Wells (5A19)

Most users of cooling water return flow wells are utilities (electric power generation) and industries. Often, the State water resources/protection boards or comparable agencies have records for such wells. If no State records are kept, then contact should be made with the utilities' and industries' process engineers or plant supervisors/ directors. The State public service commissions should have listings of all utilities in the States. Directories, such as the Thomas Register, California Red Book (other states may have similar directories), the Pennwell Oil and Gas Directory series, and others will give industry addresses, telephone numbers, and other pertinent information.

11. Industrial Process Water and Waste Disposal Wells (5W20)

It is difficult to obtain records for this grouping of wells. In addition to the large number and variety of industries, commercial ventures, and businesses, many industries may be reluctant to provide information on their waste disposal practices. The types of directories listed above for 5A19 wells and the telephone yellow pages can be consulted for information on locations of industries.

The State water resources agencies or environmental health/protection agencies may have a permit program or keep records on these wells, especially if they are "high technology" wells. Additionally, industries which were denied NPDES (surface water) discharge permits may be disposing of waste through injection wells.

12. Automobile Service Station Waste Disposal Wells (5X28)

The wells referred to in this Class V category inject a variety of wastes from car dealer and gasoline service stations including waste oil, engine cleaning solvents, brake fluid, transmission fluid, antifreeze, and other fluids from the repair bays; car wash effluent (detergent, oil and grease, sediments, heavy metals); and minor spills of gasoline and oils. Many automobile service stations participate in waste oil and other recycling programs and are connected to the city sewer lines. Sometimes oil and grease interceptors - separators are required by a State plumbing code. But many other stations may be using private waste and wastewater discharge systems such as "dry" wells and septic systems (which may receive wastes other than domestic wastes).

Finding the stations which inject their wastes and wastewaters is difficult because (1) the number of automobile service stations is great, and (2) city or county officials will have to be contacted to determine which stations are on the sewer system and if they are allowed to dispose of <u>all</u> their wastes in the sewer system. Many service stations could be contacted and queried on their waste disposal systems through the oil companies. A significant number of stations are privately owned and would have to be contacted individually. Furthermore, many stations may be reluctant to provide information about their waste disposal practices or may not have detailed information on wells and septic systems they use. Information on automobile service stations may be available now through the Underground Storage Tank (UST) Programs initiated by the Hazardous and Solid Waste Amendments of 1986, (HWSA), and Superfund Amendments and Reauthorization Act (SARA) amendments (e.g., UST owner operation inventory surveys).

13. Recharge Wells (5R21, 5B22, 5S23)

Most recharge projects are under the direction of or directly report information to the State, regional, or local water resources agency or similar agency. Permits and extensive monitoring/testing programs usually are required since important USDW are directly affected by recharge projects.

14. Radioactive Waste Disposal Wells (5N24)

The Nuclear Regulatory Commission (NRC) licenses and regulates commercial nuclear facilities under the Energy Reorganization Act of 1974. In the past, facilities managed by The Department of Energy (DOE) may have used wells to dispose of some low-level radioactive waste. Some States may regulate these wells through water resources boards, health departments, or environmental protection agencies.

Radioactive waste disposal wells may be used by national and private nuclear research laboratories, national and private processing and manufacturing plants, nuclear power plants, the military, and various smaller entities using nuclear materials such as hospitals, oil and service companies, mining and energy companies, etc.

15. Experimental Technology Wells (5X25)

Many of the wells falling into this category are used in pilot scale solution mining operations. Inventory information for these wells should be available through the same entities named for 5X14 wells.

Other types of experimental technology wells include thermal storage project wells, air injection wells for water table recharge, tracer study wells, aquifer remediation wells, and oil shale and coal gasification related wells. The State water resources or protection boards, research or academic institutes, or mining boards may have inventory data for the various facilities.

16. Aquifer Remediation Related Wells (5X26)

Aquifer remediation related wells have been increasing in number in the last 10 to 20 years, especially since the inception of federal programs such as RCRA and CERCLA. Many contaminant spills, leaks, and other discharges are being remediated in part by injection-extraction well systems. For example, this type of clean-up technology is being used near Denver, Colorado, at the Rocky Mountain Arsenal. Additionally, several companies are remediating long-term oil leaks from refineries, terminals, storage areas, and pipelines using extraction-injection systems. Contacting appropriate State or Federal water protection agencies which may be involved in or have initiated several of these clean-ups may help to improve inventories. Many industries whose sites have experienced contamination are starting aquifer and soil contamination remediation programs on their own initiative. Contacting their environmental staffs and private consulting firms (employed to clean-up their facilities) may result in better inventories.

17. Abandoned Drinking Water Wells Used for Waste Disposal (5X29)

These wells are very difficult to obtain information on for the Class V inventory. State water well laws on reporting new wells and on plugging and abandonment may be used to inventory these wells. Most information on these wells may come from individuals reporting specific waste disposal operations. Wells installed and abandoned before regulation programs began may remain unknown.