Survey of ReInjection Experience from Groundwater Cooling Applications

Prepared for Pacific Northwest Laboratory
Seasonal Thermal Energy Storage Program
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GROUNDWATER COOLING APPLICATIONS

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Approved for:

MIDWEST RESEARCH INSTITUTE

A handwritten signature in dark ink, appearing to read 'K. P. Ananth', with a long horizontal stroke extending to the right.

K. P. Ananth, Director
Energy and Materials Science

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1.0 SUMMARY AND CONCLUSIONS

The use of groundwater aquifers for thermal energy storage is an area under study in the Pacific Northwest Laboratory (PNL) Seasonal Thermal Energy Storage Program. However, the literature pertaining to reinjection of heated water is not well documented. To fulfill the need for more information, PNL contracted with Midwest Research Institute (MRI) to conduct a study to identify and document at least 30 sites where reinjection of groundwater from cooling applications was being (or had been) performed. The information obtained on each site was compiled and analyzed, the site described briefly and cooling and reinjection problems characterized. The end result of this study was to establish a data base of reinjection experience based on a variety of sites around the country with different hydrogeologic characteristics and cooling systems.

Due to the short duration of the study, it was not possible to obtain detailed cooling system information for each site. Therefore, efforts were aimed at identifying how groundwater was being used in the systems, including flow rates, injection temperatures, water quality data, and the type of reinjection problems that occur.

The approach used was to divide the continental United States into five geographic regions designated as follows: North, South, East, West, and Central. An effort was made to obtain as wide a diversity of aquifer types within each region as possible. However, the vast majority of sites were over sand and gravel aquifers. There were also a large number of sites over limestone aquifers. Other types of aquifers were sandstone and fractured shale.

The information on each site was collected from a number of sources: well drillers, consulting engineering firms, state regulatory agencies, heat pump manufacturers and distributors, the National Water Well Association, the site maintenance superintendents or engineers, the U.S. Geological Survey, state geological surveys, and local public works water quality labs. Initial contacts were by telephone; then survey forms were sent to those sources that seemed to have the most information. In general, the best sources turned out to be the well drillers and the site maintenance superintendents.

The response to our survey was slow in coming and required several follow-up calls. However, as a result of these efforts, MRI was able to obtain information on 45 sites. These sites, their basic characteristics, and major operating problems are identified in Table 1.

The major operating problems could be broadly categorized as plugging problems and thermal pollution problems. Plugging was caused by iron fouling due to the oxidation of ferrous iron and its precipitation as ferric hydroxide. Iron-using bacteria could also have caused plugging problems by becoming so abundant they clogged well screens or aquifer openings with slimy sludge. It is also possible for reduced manganese to oxidize, precipitate, and cause plugging problems.

TABLE 1

DOCUMENTED SITES

<u>Site</u>	<u>State</u>	<u>Aquifer</u>	<u>Reinjection Rate (gpm)</u>	<u>Reinjection Temp. (°F)</u>	<u>Comments</u>
<u>NORTH</u>					
1. C.F. Industries, Aurora	NE	Sand and gravel	150, 2 wells	60	Minor plugging problems
2. U.S. Meat Animal Research Center, Clay Center	NE	Sand and gravel	2,000, 2 wells	68	No problems
3. Private residence, Lake Poinsett	SD	Sand and gravel	8	64	New site
4. Idaho State University, Pocatello	ID	Sand and gravel	572	64	No problems
5. Southdale Shopping Center, Edina	MN	Sand and gravel		83	Plugging problems, rein- jection discontinued
6. Artistic Woven Labels, Holdrege	NE	Sand	240	67	Minor plugging problems
7. Private residence, Idaho Falls	ID	Shale	-	75	Do not reinject
<u>SOUTH</u>					
8. Lido Regency Condominium, Sarasota	FL	Limestone	350	90-100	Thermal problems
9. Beach Terrace Condominium, Sarasota	FL	Limestone	Not known	85	No problems
10. Manatee Junior College, Bradenton	FL	Limestone	1,250	95	Thermal problems
11. Florida State University, Tallahassee	FL	Limestone	Many wells	-	Thermal problems in the past
12. George Smith, Inc., Round Rock	TX	Limestone	7	84	Needs additional reinjec- tion well
13. Hercules, Inc., Savannah	GA	Limestone	820	92	Declining water table
14. General Services Administration, Savannah	GA	Limestone	1,000	80	No problems
15. Private residence, Indian Land	SC	Shale	8	92	No problems
<u>EAST</u>					
16. Edinboro State College, Edinboro	PA	Sand and gravel	50-100	60	No problems
17. General Electric Co., Johnson City	NY	Sand and gravel	125	95	No major problems
18. Long Island Lighting Co., Hicksville	NY	Sand and gravel	500	64	Thermal problems
19. We're Associates, Inc., Lake Success	NY	Sand and gravel	1,500-2,000, 3 wells	65	No problems
20. Lever Management, Garden City	NY	Sand and gravel	400, 2 wells	70	No problems
21. Intown Motor Lodge (old Frederick Hotel), Endicott	NY	Shale	50 est.	70-75	Bad fouling problems, re- injection discontinued

TABLE 1 (continued)

<u>Site</u>	<u>State</u>	<u>Aquifer</u>	<u>Reinjection Rate (gpm)</u>	<u>Reinjection Temp. (°F)</u>	<u>Comments</u>
<u>WEST</u>					
22. Utah Technical College, Orem	UT	Sand and gravel	1,500	68	No problems
23. Sandia Savings (Sims Building), Albuquerque	NM	Sand and gravel	500	88	No problems
24. Gig Harbor High School, Gig Harbor	WA	Sand and gravel	75	105	Potential fouling problems
25. New Mexico Junior College, Hobbs	NM	Sand and gravel	950	78	Thermal problems
26. Valcris, Inc., Turlock	CA	Sand and gravel	450-600	83	No problems
27. Turlock Refrigerating Co., Turlock	CA	Sand and gravel	1,500 est.	80-85	Discontinued due to state regulations
28. Shell Development Co., Salida	CA	Sand and gravel	Not available	95	Thermal problems, reinjec- tion discontinued
29. Brewster High School, Brewster	WA	Sand and gravel	64	-	No problems
30. Roswell High School, Roswell	NM	Sand and gravel	Not available	95	Plugging problems
31. Monterrey School, Roswell	NM	Sand and gravel	Not available	95	Plugging problems
32. Sierra Middle School, Roswell	NM	Shale and lime- stone	Not available	95	Plugging problems
33. Goddard High School, Roswell	NM	Limestone	Not available	95	Plugging problems
<u>CENTRAL</u>					
34. Private residence, Troy	OH	Sand and gravel	8	62	Plugging problems
35. Westover Retirement Residence, Hamilton	OH	Sand and gravel	60, 3 wells	75-95	Thermal and plugging problems
36. OK Elementary School, Wichita	KS	Sand and gravel	70, 2 wells	85	No problems
37. Cleveland Elementary School, Wichita	KS	Sand and gravel	200	-	Ground-water level too high
38. Aviation Education Center, Wichita	KS	Sand and gravel	Not available	95	High ground-water level
39. Certified Bakers, Wichita	KS	Sand and gravel	60-70, 2 wells	65	Plugging problems; rein- jection discontinued
40. University of Friends Church, Wichita	KS	Sand and gravel	50-60 est.	85	No problems
41. American Telephone and Telegraph Co., Norway	IL	Sandstone	400	80	No problems
42. Private residence, Bellevue	OH	Limestone	10	62	No problems
43. Private residence, Bellevue	OH	Limestone	10	62	Thermal intermixing problem
44. Rich Township High School, Olympia Fields	IL	Limestone	1,500, 2 wells	70	No reinjection problems
45. Commonwealth Edison-Unmanned Station, Goodings Grove	IL	Dolomite	860	94	Bad fouling problems

Recommended levels of Fe and Mn for relatively trouble-free well operation are 0.3 and 0.03 ppm, respectively. Even fairly high levels of these elements in groundwater can be handled if the water is not exposed to oxygen and if wells are regularly rehabilitated. Very hard water can cause scaling problems in a cooling system and occasionally in a reinjection well. Annual maintenance can solve this problem, however.

A number of sites had thermal pollution problems resulting from reinjection practices. In fact, several sites had discontinued groundwater usage because temperatures were too high. Some sites were forced to discontinue reinjection because of the implementation of stricter state injection standards which the site could not meet economically. In other states, reinjection of cooling water was prohibited or discouraged.

2.0 INTRODUCTION AND BACKGROUND INFORMATION

The use of groundwater for cooling applications is a common practice throughout the country wherever an adequate supply of water exists. However, the reinjection of the cooling water to water-bearing strata is not as widely practiced.

There are a number of advantages to reinjection of cooling or heating water. One is the preservation of the aquifer itself. In many areas of the country there is the possibility of decreasing groundwater levels through widespread pumping. Eventually, an aquifer can be destroyed if water is not returned to fill the voids. The Houston area is an example. Land subsidence caused by groundwater pumping has been a problem there for a number of years. Reinjection can protect an aquifer by returning good quality water to the water-bearing strata. This practice is particularly important in areas with aquifers of low yield. The life of an aquifer can be extended indefinitely through reinjection.

Economics is another reason reinjection is practiced. It is often cheaper to discharge cooling water to a reinjection well than to a storm or sanitary sewer. If a company discharges to a sewer, it must pay a user's fee to the city sewage treatment plant even if the water does not need to be treated.

Economics is an important factor in aquifer thermal energy storage, i.e., using groundwater as a heat sink. A practice that is becoming more common is the reversal of reinjection and supply well flows from the cooling to the heating seasons. In theory, the heated discharge water injected during the cooling season can be recovered for use during the heating season and vice versa. The type of aquifer (its transmissivity, depth, water quality, etc.) and the amount of cooling and heating required by the user will influence whether this practice can be successful.

2.1 GROUNDWATER COOLING SYSTEMS

In the course of identifying and documenting reinjection sites for the study, information was compiled on the type of cooling applications for which groundwater was being used. The simplest systems used groundwater for direct cooling. In one such system, groundwater is passed through a shell and tube heat exchanger where it cools a liquid. If the groundwater is cold enough (below 52°F), the liquid could be chilled water from the cooling system. Another direct cooling method is the use of a water-to-air heat exchanger or "fan and coil" system. Air is cooled by passing it over coils chilled by groundwater. Schematics of direct cooling systems are shown in Figure 1.

In some systems, groundwater serves two functions; it precools the air before the air passes over the air conditioning coil, and it condenses the refrigerant in a chiller or condenser. Figure 2 shows such a system. Figures 3 and 4 show how groundwater is used in heat pumps. In both the water-to-water and water-to-air heat pump systems, groundwater is

(A) Shell and Tube Heat Exchanger

(B) Water to Air Heat Exchanger

Figure 1 - Groundwater for Direct Cooling

Figure 2 - Groundwater for Precooling and Condensing

Figure 3 - Groundwater Condensing/Water-to-Water Heat Pump for a Chilled Water System

Figure 4 - Groundwater Condensing/Water-to-Air Heat Pump
for a Direct Expansion System

used for condensing. Figure 5 is an example of a closed loop heat pump. The circulating water is used as a heat source or sink depending on the season. The water is circulated through a heat exchanger located in the water well. Should some of the water in the circulating system be used for another purpose, the pump in the well would replenish the circulating water supply.

2.2 REINJECTION PROBLEMS

There are a number of factors that can cause reinjection practices to fail. One of the most common is thermal pollution. If groundwater is being used strictly for cooling, an increase in the groundwater temperature can cause a decrease in cooling efficiency. Increases in temperature are invariably caused by mixing heated reinjection water with supply water. The solution to this problem is to locate the reinjection well as far away as practical from the supply well. Another solution is to inject the heated water to a water bearing stratum not used by the supply well. Of course, without prior knowledge of the geohydrology of a region, it is difficult to know how far away to locate a discharge well and to what formation to reinject. Problems of thermal pollution may not become evident until several years after a system has been operating successfully.

Another factor influencing reinjection is plugging of the reinjection well. Plugging problems are most often caused by unfavorable groundwater chemistry. Sometimes, however, sand and silt are the cause. But iron dissolved in groundwater is the most troublesome constituent from the standpoint of reinjection practices. Soluble iron is normally present as ferrous iron, Fe(II) , but when exposed to oxygen will be oxidized to ferric iron, Fe(III) , which will precipitate as an insoluble gelatinous compound, ferric hydroxide, Fe(OH)_3 . When groundwater is circulated through a cooling system it can become oxygenated, and, if enough iron is present in the water, the precipitation of Fe(OH)_3 can eventually plug well screens or the aquifer voids. An additional problem is the existence in wells of bacteria which exert a catalytic effect that speeds oxidation of ferrous iron. Crenothrix and Leptothrix are genera that require oxygen and oxidize ferrous iron, producing ferric hydroxide. The oxidized iron is deposited on the surfaces of the water system, intermingling with the bacteria. This combination of iron oxide and bacteria can grow into large, slimy masses capable of blocking the water flow through pipes, pumps, well screens, and even the aquifer itself.

In the sites surveyed in this report, reinjection plugging problems could most often be traced to iron in the groundwater. Well drillers report that an iron concentration over 0.3 ppm can cause problems; therefore, they recommend annual rehabilitation of wells if iron is above this level. It is interesting to note that wells which yield water with a high iron concentration (1 to 10 ppm) appear to be erratically distributed throughout a region. Some of the wells will exhibit changes in the composition of their water with time that are difficult for hydrologists to explain.

Manganese is another constituent that can cause problems, but only one site of the 45 surveyed had a manganese problem. Levels of Mn above 0.03 ppm cause staining and taste problems. If Mn levels get too high, the Mn can precipitate like iron and cause plugging problems.

Note: System information was obtained from a private residence in Idaho Falls, Idaho. See description of Site No. 7 on p. 22.

Figure 5 - Closed Loop Groundwater Heat Pump

The total hardness of water can also influence reinjection practices, although this problem generally occurs in the cooling system in the form of scaling. The most common reaction is the deposition of calcium carbonate (CaCO_3) which results when CO_2 is lost from water containing calcium. In order for the carbonate reaction to stay in chemical equilibrium, CaCO_3 must precipitate out. Such deposition most often occurs in the cooling system where temperature is raised and CO_2 is driven off. However, it can also occur in the reinjection well if the discharge water is allowed to cascade down the well or if the injection tube is above the static water surface. Iron and manganese, if present, can also precipitate under these conditions.

Other compounds that sometimes cause cooling and reinjection problems are hydrogen sulfide (H_2S) and free carbon dioxide. Hydrogen sulfide is a vigorous corrosive agent; even small amounts can cause severe corrosion in pipes. Free carbon dioxide present in water as a weak acid, carbonic acid, is corrosive to both iron and copper. It prevents the formation of protective coatings on copper which normally form in waters free of carbon dioxide. Carbon dioxide also reacts with iron piping to form soluble ferrous bicarbonate. This corrosive attack may be very severe and cause early pipe failure.

One factor that could influence the success of reinjection practices but might be overlooked is air entrainment of the injection water. Air bubbles can become lodged in the interstices of an aquifer, e.g., in sand and gravel or sandstone aquifers. Forces that exceed the buoyancy of the air bubbles and the pressure of the injected water can prevent the movement of the bubbles towards the well or upward to the water table. These bubbles can have the same effect as clay particles and can effectively reduce the flow of water into the aquifer from the injection well. An experiment in Arkansas by the U.S. Geological Survey showed a 50% reduction in specific yield for a recharge well receiving air-entrained water. Redevelopment of the well required the use of sodium hexametaphosphate and surging and pumping before specific capacity was restored.

Important deterrents to reinjection are state regulations that prohibit or discourage reinjection or regulations that have recently become more stringent, thereby affecting old reinjection practices. During this study, several regulatory practices that influence the use of reinjection in groundwater cooling applications came to light in a number of states. In some states noncontact cooling water is classified as a wastewater, the same as sewage wastes, and is consequently subject to the same regulations. Reinjection may not be permitted in these states, or the permitting process may be so complicated as to discourage its practice. In some other states, the use of groundwater for cooling has been practiced for many years under lenient state regulations. Newer, tougher regulations on water quality have forced some sites to discontinue the use of old, poorly constructed reinjection wells. There is no state-to-state uniformity in regulations. What is acceptable in one state can be prohibited in a neighboring state.

2.3 ASSESSMENT OF THE CURRENT STATUS OF REINJECTION

One fact that became apparent early in our study was that there is no single body of information that provides all the information needed to characterize a cooling or reinjection site. Many sources were contacted in order to obtain a complete description of site practices and problems. For a typical industrial site using and reinjecting groundwater for cooling the following contacts were usually required: plant maintenance superintendent or engineer; well driller; cooling engineering consultant; U.S. Geological Survey and/or state geological survey; state environmental control agency (or agencies).

When a reinjection or cooling system operational problem could be identified at a particular site, we frequently obtained only a secondhand explanation of its cause. In a number of cases the well driller and the cooling system engineer had different explanations for reinjection and cooling system problems. We tended to trust well drillers for reinjection explanations and engineers for cooling system explanations. However, neither had water quality information, which is very important in assessing the magnitude of potential problems.

Sometimes we obtained a third opinion on site problems from a state regulatory agency. However, this was only possible in states that strictly control reinjection, such as in California.

One theme became apparent as we studied the 45 sites. A groundwater cooling or reinjection system was usually designed based on existent state regulations and hydrogeologic information. However, a few years later the site could develop problems because state regulations become more stringent, the hydrogeologic information is misleading, or the groundwater resource within the region changes hydrogeologic characteristics. In Florida, development of the groundwater resource has lowered the water table in some areas, raised groundwater temperature in some areas, and caused salt water intrusion in some other areas. Systems that worked successfully 10 years ago are currently having cooling or reinjection problems now.

One point was made clear by a groundwater cooling consulting engineer. Groundwater cooling and reinjection can be accomplished wherever there is an adequate groundwater supply as long as the system is designed properly. However, to design a system properly all site needs, state regulations, and aquifer characteristics must be thoroughly studied. If any one piece of information is overlooked, such as high iron content in the water, it could lead to future reinjection or cooling problems and possibly failure of the system.

Reinjection of cooling water is a relatively new practice; the successful, older sites are usually not more than 25 years old. The body of information on reinjection is still small but is growing rapidly. Often the newer sites employ practices that are more complex, but they exhibit a greater understanding of groundwater characteristics. Today, there is much more communication between well drillers, cooling system consultants, and regulatory agencies; and this has eliminated many of the design problems encountered in the old sites.

Details of study methodology, the problems encountered, and how the identified sites were analyzed are contained in Section 3.0, "Approach and Analysis." A definition of each site and an analysis of each site are presented in the following five sections by region. The appendix contains a summary of available data for each site.

3.0 APPROACH AND ANALYSIS

The first goal of this study was to identify at least 30 sites around the country that were reinjecting groundwater from cooling applications. In order to obtain a geographically representative sampling, we divided the country into five regions: North, South, East, West, and Central. The lines of division were arbitrarily chosen. The only criteria used were to keep most states in their traditional geographic regions and to use groundwater isotherms to help delineate boundaries. Preliminary contact with states revealed that many had no documentable reinjection sites. Therefore, any attempts to divide the country into greater detail (for instance by hydrogeologic characteristics) would have been useless. Figure 6 delineates the five regions and shows the groundwater isotherms. Also shown are states identified in our study that prohibit or discourage reinjection. The State of Minnesota prohibits reinjection but recently it has granted a permit for a DOE aquifer thermal energy storage demonstration program.

The next step was to contact heat pump distributors in each state and various state regulatory agencies so that we could identify reinjection sites within a particular state. A list of groundwater source heat pump manufacturers was obtained from the National Water Well Association (NWWA). Doug Bacon, Manager of Applied Research for NWWA, also gave us some leads on sources of information on groundwater reinjection and potential reinjection sites. NWWA is conducting its own field research study on reinjection of cooling water from a heat pump but has only just begun compiling data from the study.

From our early contacts, it was clear that in most cases the heat pump distributors and state agencies were not the best source of information. We obtained leads from many of these contacts but not many documentable sites. The distributors were often not familiar with the well system at a particular site. Often we were informed that a site was reinjecting cooling water, but further investigation showed that this was not true.

Many state agencies did not have their well permits organized in such a way as to facilitate the identification of cooling water injection wells. Some states have their well permits and driller's reports filed by industrial and residential classifications. In other words, one must have identified a site before it could be looked up in the file. However, many states are beginning to reorganize their permitting process and filing system so that they can begin identifying all reinjection wells in their state. This is the result of implementation by the EPA Office of Drinking Water Quality of its Underground Injection Control (UIC) program in April of 1980. Under this program, registration of all reinjecting wells is required, and registration of wells reinjecting cooling and heating water would begin within 1 to 2 years. Some states, Florida for example, have already begun the identification process because of the vast number of injection wells within their state.

Generally, the state agency providing the most information was the state geological survey or the state office of the U.S. Geological Survey.

Figure 6 - Region Delineation and Groundwater Isotherms

These offices not only had water quality information for the immediate area around an identified site, but they often had well logs or driller's reports for wells near the site or even for the site wells themselves. Usually, they were not aware of specific reinjection sites of the kind we were seeking. However, they often could provide us with the names of well drillers and consulting engineering firms that were known to be experienced in groundwater reinjection applications.

Other state agencies sometimes had information on particular sites or knew of sites that were having trouble meeting state regulations. Our contacts in these cases were usually geologists or hydrologists in agencies such as Department of Ecology, Department of Environmental Control, state Environmental Protection Agency, Department of Natural Resources, and Department of Water Resources.

By far the best source of information was well drillers. In fact, after contacting a few states, we changed our approach and contacted the large well drilling firms first. In most instances it was the Layne Company (Layne-Western, Layne-New York, Layne Atlantic, etc.). Layne has offices in almost every state, and their personnel usually knew if groundwater reinjection was being practiced in the state. If they had not drilled reinjection wells for cooling water, they often knew of other well drillers who had. They also could tell us what state agency could help us in our search. The small, independent well drillers were helpful in identifying sites and also in characterizing local problems encountered with reinjection applications.

Once a site had been identified, we contacted the site owner and obtained preliminary information such as:

- Are they reinjecting now?
- Do they have any problems?
- How many supply and disposal wells do they have?
- What type of cooling is being performed, e.g., process cooling, air conditioning, etc.?
- Do they have a well driller's report and well logs for their wells; if not, who does?
- Would they be willing to help us with our study by completing a one-page survey form?

Most of the sites lacked at least one of three important categories of information, either well system information, cooling system information, or water quality data. Water quality data were most often lacking, but many sites also lacked well data. Because of this missing information, it was often necessary to make three or more phone calls to obtain the missing data.

Once the site owners or well drillers agreed to cooperate, we mailed out our survey form. Some of the information requested on the cooling system form was: groundwater inlet and outlet temperature and flow rate; type of cooling system, manufacturer, and year installed; and information about cooling system problems or reinjection problems that had been encountered. The well system form was patterned after a well log and was used only for those sites with well information but no driller's report.

Many of the sites required three and four calls to ensure that the forms were completed and returned. A few times we found that sites that had originally said they were reinjecting their cooling water, were not. Sometimes the information returned to us was so extensive that it would require another study to adequately assess the cooling and reinjection applications. Other times we obtained just enough information to briefly describe the site. We have included both successful and unsuccessful applications in this report. Several sites had discontinued their groundwater cooling or reinjection practices many years ago.

During the 4-month study, we were able to document 45 sites. A few of the sites lacked water quality data or a well log. There were other sites that we were able to identify but were unable to document. Sometimes our contacts were unwilling to cooperate in the study, and sometimes sites reported the survey was "lost in the shuffle."

When we began to characterize the sites, we sometimes found ambiguous or missing information. Because follow-ups were not possible in every case, we limited our site characterization to a description of the site and an analysis of reinjection problems the site has had. With some sites we could identify potential problems based on the site's current cooling and reinjection practices. The goals of this study, however, were to identify, describe, and briefly analyze sites that are reinjecting cooling water. These sites were to be located in as many geographically and geologically different regions as possible. There is enough information available from 15 to 20 of the sites we contacted and from a few cooling system manufacturers to do a more in-depth study of reinjection practices in the future.

Reinjection sites under DOE's aquifer field test program were not investigated. Information on these sites, however, is being documented continuously under the program. Sites located around Seattle, Washington, and Portland, Oregon, which had been studied previously by PNL staff, were not pursued further.

4.0 NORTH REGION

States contacted in the North region were Montana, Idaho, Wyoming, North Dakota, South Dakota, Nebraska, Minnesota, Iowa, Wisconsin, and Michigan. Of these states, Minnesota and Wisconsin have stringent regulations regarding reinjection although Minnesota has recently granted a variance permit for a DOE demonstration program on aquifer thermal energy storage.

The reinjection of groundwater from cooling applications is not well developed in this region. There are a number of reasons for this. Some states do not have very extensive groundwater resources or have water of poor quality, such as South Dakota and Iowa. In other states, cooling is not as big a concern as is heating, and the use of 45°F water or colder for heating applications creates freezing or icing problems with many heat pumps.

Nebraska had by far the largest number of groundwater cooling systems in the region. All the sites identified were using water from Pleistocene alluvial deposits. Idaho has a number of sites; some in basalts, some in alluvial deposits. We were able to identify only two; one in alluvium, the other in broken shale. Idaho has an abundance of geothermal groundwater (over 67°F), and one of the documented sites is using 75°F water for cooling. We learned of other sites throughout the North region that were using groundwater for cooling, but upon investigation found that most were either in operation less than 9 months or were not reinjecting their cooling water. Most of these sites were not pursued further. One site in South Dakota was documented (a private residence) even though it was in operation for less than a year; this site reinjects into an aquifer consisting of fine sand, gravel, and clay.

A total of seven sites in the North region have been documented. These sites are categorized by three types of aquifers: sand and gravel, sand, and broken shale. The reinjection system of each site is discussed and analyzed below.

4.1 SANDS AND GRAVELS

Site No. 1: C. F. Industries, Aurora, Nebraska

Description: This is an industrial site in which the groundwater is supplied to two shell and tube heat exchangers for direct cooling (see Figure 1-A, p. 6). The rate of flow to each unit is 150 gpm at a temperature of 54°F. There are two source wells, but only one is used at a time. The discharge water from the heat exchangers is fed to each of the two reinjection wells at 150 gpm and 60°F. This is a gravity reinjection system. Depth to the reinjection zone is 90 ft; both reinjection wells are 185 ft deep and about 550 ft away from the source wells. The groundwater is not treated, and the water quality records from nearby wells show that the area groundwater is of high quality.

Analysis: Their response to our survey shows that since the heat exchanger was installed in 1964 the reinjection wells have had to be redeveloped twice in order to clean the well screens. The reason given for the clogged screens was air entrainment in the discharge water. The air entrained screen face either escapes to the surface of the water in the well or is carried into the aquifer. Once the air bubbles become lodged in the interstices of the aquifer, the flow through the aquifer is greatly decreased, possibly by as much as 50% in a sand and gravel aquifer. Special redevelopment procedures involving the use of sodium hexametaphosphate and surging and pumping are often necessary before the original specific capacity of the well can be restored.

Air entrainment can be occurring in the source well if the water level in the well drops below the top of the well screen. There is a good possibility that a significant amount of turbulence is occurring at the well screen due to the low percentage of open area in the screen, a characteristic of concrete well screens. This turbulence may be introducing air into the source well water. Another possible source of air or other gases comes from the release of dissolved gases when the groundwater is heated in the cooling system. This source would be very hard to control.

Other possible reasons for the clogging problem are encrustation and/or iron precipitation. Because this is a gravity reinjection system, the discharge water can be exposed to air, which can eventually lead to enough encrustation on the well screen to restrict water flow. Aeration could also precipitate any iron in the groundwater or injected water. Encrustation is only a minor problem with this system, however, because the water is of good quality (low iron, moderate hardness) and because discharge temperatures are only a few degrees (6°F) above groundwater temperatures.

Site No 2: Roman L. Hruska U. S. Meat Animal Research Center,
Clay Center, Nebraska

Description: This is an animal research facility that is using groundwater to cool four buildings. The cooling system is quite extensive. In general, the groundwater has been used for two different purposes: precooling and condensing. In precooling, the groundwater pre-cools the supply air of an air conditioning system via a precooling coil (water to air heat exchanger) before the unconditioned air passes through the cooling coil. In condensing, the groundwater is first cooled, then used for water-cooled condensers to condense the hot, gaseous refrigerant generated from compressors. A schematic of this system is represented by Figure 2, p. 7.

Two source wells provide water at a rate of 2,000 gpm to the cooling systems (500 gpm and 1,500 gpm from two wells). Water temperature is 57°F. The source wells are approximately 215 ft deep. The two reinjection wells are 500 and 1,300 ft from the nearest source well. The water leaving the cooling system is between 70 and 75°F, but by the time it reaches the discharge wells it has dropped to 68°F. The reinjection wells are screened from 115 and 145 ft in one well and from 95 to 125 ft and 145 to 155 ft in the second well. Static water level in the two wells is 89 and 94 ft. All cooling water is reinjected, and water quality is excellent.

Analysis: There have been no problems with this system. Part of it has been in operation 10 years; the rest has been in operation 4 years. Blueprints of the cooling system were received and are on file at MRI.

Site No. 3: Private Residence, Lake Poinsett, South Dakota

Description: This residence employs a groundwater heat pump system that has been in operation for less than a year. It is one of the few reinjection systems in South Dakota. The site is close to a lake, and the cooling system utilizes a Tetco heat exchanger. The source and reinjection wells are 16 and 22 ft deep, respectively. The source well is in a fine sand and is located 100 ft from the reinjection well. Water is supplied to the cooling system at a rate of 8 gpm and a temperature of 52°F. The reinjection rate is also 8 gpm, and the temperature is 64°F. The water is extremely hard (655 mg/liter as CaCO_3), and iron content is 0.38 ppm.

Analysis: There have been no cooling or reinjection problems in the short history of this site. The total hardness and iron values being what they are, problems could arise if the wells are not periodically rehabilitated.

Site No 4: Idaho State University, Pocatello, Idaho

Description: The university library is cooled with two water-to-water heat pumps installed in 1976. A schematic diagram of this cooling system is presented in Figure 3, p. 8. The cooling system flow rate averages 572 gpm at 59°F. Discharge water temperature is 64°F. Water is taken from and reinjected to a sand and gravel formation. Well logs from the region show that the stratigraphy of the area is highly variable from one site to the next. The source and reinjection wells are 270 ft apart; the depth to the producing zone is 180 ft in the source well and 130 ft in the reinjection well. The reinjection well can handle all of the water from the cooling system. Water quality data show that the water in this region is extremely hard (300 mg/liter hardness as CaCO_3), but otherwise the water is of good quality.

Analysis: This site has shown no operational problems during its history. Routine pump maintenance is performed every month; routine cooling system maintenance is performed every 6 months.

Site No. 5: Southdale Shopping Center, Edina, Minnesota

Description: This shopping mall has been using groundwater in its central cooling plant since 1956. Reinjection of the cooling water was discontinued in 1957 after the reinjection well became plugged and overflowed. Water is currently discharged to a stilling pond.

The 54°F groundwater first passes through fan and coil precooling units where it picks up about 10°F. It then passes through the central cooling plant, which consists of 6-16 cylinder York compressors where it gains 10°F more. The water is then pumped to the condensers of the "package units" in the individual stores in the shopping center where it picks up another 10°F. The water is then discharged to the stilling pond at about 83°F.

There were three wells in use in 1956, two source and one reinjection. The source wells are 442 and 452 ft deep and are taking water from the Jordan sandstone. The old reinjection well is 177 ft deep, and water was injected into glacial till gravels and sands.

Analysis: Because of serious plugging problems, the reinjection system is no longer used. It is speculated that the cause of the problems was iron precipitation. The Center's chief engineer said that during the time they were having problems with the injection operation, there was often a strong sulfurous odor in the mall. But quality analysis of the water does not show high iron or sulfate content in the groundwater (0.1 and 21 ppm, respectively). The chief engineer feels, however, that these analyses are suspect. The water is very hard (270 mg/liter as CaCO_3). After one year the reinjection operation was abandoned. Since that time the old reinjection well has been used as a supplemental supply of cooling water. According to the chief engineer, its yield has steadily improved through continued usage. This is to be expected as the plugged aquifer gradually opens up.

Site No. 6: Artistic Woven Labels, Inc., Holdrege, Nebraska

Description: This site is a private industry cooled by a 100-ton Trane Climate Exchanger cooling system (see Figure 3, p. 8). The site has one source well and one reinjection well 150 ft apart. The source well is providing water to the cooling system at 240 gpm and 58°F. Discharge water is injected at a rate of 240 gpm and a temperature of 67°F. The source well is 226 ft deep; depth to the producing zone is 165 ft. The aquifer type that is being used for reinjection was not identified but was deduced to be sand. Well rehabilitation and pump overhauls are required about every 5 years. Major cooling system maintenance is required a little more often, about every 4 years. The U.S. Geological Survey provided water quality information for an irrigation well near Holdrege that is pumping from the same depth and probably the same aquifer. However, this well is 3 miles from the identified site and may not be representative of the quality of the water used in Artistic Woven Label's cooling system. The analysis shows a very hard water (342 mg/liter as CaCO_3); total dissolved solids of 609 mg/liter and iron of 0.06 mg/liter.

Analysis: The company has had a problem with wear on the inside of the cooling coils and has had to have them replaced. The reinjection well has also plugged twice in 18 years of use. The reason given for both of these problems was sand in the cooling water. If this is so, it might indicate an improperly sized well screen or improper size distribution of the gravel pack (if this well has a gravel pack; no well log was available). Plugging could also be occurring as a result of encrustation. This system employs gravity injection; consequently, the discharge water could be exposed to air.

4.2 SHALE

Site No. 7: Private Residence; Idaho Falls, Idaho

Description: This site is included in our study because it is unique. The residence is heated and cooled with a heat pump that is fed by

75°F water at a flow rate ranging between 11 and 17 gpm. (U.S. Geological Survey in Idaho classifies this water as being "just barely" geothermal water, i.e., above 65°F). The water used in the cooling system is in a closed loop. Once the water leaves the heat pump, it passes back to the source well. Instead of being reinjected to an aquifer, it passes through a tube heat exchanger in the well, where it is cooled (or warmed). It is then pumped back to the heat pump. The depth to water in the well is 400 ft. A 10-hp, 50-gpm pump located below the heat exchanger pumps water through the system. When water pressure drops in the system, such as through irrigation or household water usage, the pump adds water from the well to the closed loop. The well is 470 ft deep and takes water from a 15-ft zone listed as "broken shale" on the well drillers report. U.S. Geological Survey says that this term may not be lithologically accurate. Water quality information was not available for this well or for the region. A schematic diagram of the system is presented in Figure 5, p. 11.

Analysis: This system has not been in use long enough to go through a cooling season; however, there should be no operational problems when it is switched to cooling. Reinjection is not performed with this system.

5.0 SOUTH REGION

States included in the South region are Texas, Oklahoma, Arkansas, Louisiana, Tennessee, Mississippi, Alabama, Georgia, North Carolina, South Carolina, and Florida. All of the above states were contacted except Oklahoma. Regulatory policy regarding reinjection in these states is not consistent. For example, Oklahoma does not normally permit reinjection, whereas in Louisiana, reinjection is not permitted if the injection zone is in or above a fresh water aquifer. Since there are many strata in Louisiana that bear fresh water, it is often difficult to determine if the intended injection zone is below all fresh water aquifers. Reinjection is, therefore, discouraged in Louisiana by the Water Resources Division, Office of Public Works. In North Carolina, reinjection is also discouraged. Prohibition of reinjection is under consideration.

Of the other states in the South region, use of groundwater for cooling is by far the most developed in Florida. Florida has a number of good limestone aquifers including the Floridan and lower Suwannee aquifers. Reinjection is very widespread although in the interior of the state, cooling water is most often discharged to lakes. The four sites selected for the study were chosen because the U.S. Geological Survey had information on them. Three are on the Gulf Coast. Two are condominiums; the third is a junior college. The fourth site is in Tallahassee at Florida State University (FSU). Groundwater is extensively used by FSU for cooling in many of the campus buildings.

Problems have occurred in some areas of Florida because of thermal pollution, declining groundwater levels, or salt water intrusion.

In Texas, the groundwater resource has been extensively developed for both irrigation and public water supply. Groundwater cooling does not appear to be widespread, and reinjection is even rarer. However, interest is growing in the use of groundwater heat pumps. One site identified in Texas was a cooling system distributor in Round Rock near Austin. There, groundwater is being pumped and injected to a limestone aquifer.

Most groundwater cooling in Georgia was being done on the coast in the Ocala limestone aquifer. Several sites were identified, but only two could be documented. Both were in Savannah. In South Carolina, the state neither encourages nor discourages groundwater reinjection. However, they are paying close attention to developments in North Carolina. Only one reinjection site was identified in South Carolina. It is a private residence on the South Carolina-North Carolina state line near Waxhaw, North Carolina. This was the only site in the South region that was not using water from a limestone formation; this water comes from a shale formation.

In the other states of the South region, problems of cost, iron content, too little water, or lack of interest in groundwater cooling and reinjection were reasons given the lack of sites that employ groundwater cooling and reinjection.

5.1 LIMESTONE

Site No. 8: Lido Regency Condominium, Sarasota, Florida

Description: The building's cooling system employs heat exchangers cooled by groundwater (Figure 3, p. 8). There are 85 separate apartments plus corridors that are cooled. No rated cooling capacity for the cooling system was available. Water flow rate to the exchangers is about 350 gpm at a temperature of 82°F. Discharge temperature ranges from 90°F to 100°F. The disposal and supply wells, one each, are rehabilitated annually. The source well is 456 ft deep and is located in a soft limestone aquifer known as the Suwannee formation. The reinjection well is about 150 ft from the source well and is 750 ft deep. Quality information for the source well was incomplete; hardness data were not available. Total hardness of the water from the disposal well was 1,000 mg/liter as CaCO₃.

Analysis: The condominium is changing from groundwater-cooled heat exchangers to an air conditioning system with a cooling tower. The reason for the change is the increase in the groundwater temperature since the cooling system was installed in 1970. Cooling efficiencies have decreased considerably since water temperature from the source well rose above 80°F. The increasing groundwater temperature is probably the result of reinjection in the area. The area has more than likely undergone extensive development the last 15 years, including development of groundwater aquifers. Reinjection will probably be practiced especially near coastal areas to ensure that salt water intrusion does not occur. There were no problems at this site.

Site No. 9: Beach Terrace Condominium, Sarasota, Florida

Description: This building's cooling system also employs groundwater-cooled heat exchangers (Figure 3, p. 8), but the rated cooling capacity was not known. Inlet and outlet temperatures are about 80°F and 85°F, respectively. No well log was available for the source well, but the well is about 400 ft deep and is in a soft limestone aquifer. The reinjection well was originally 877 ft deep but was later deepened to 1,348 ft. Water is injected at 800 and 1,300 ft into a fine grained limestone called the Floridan aquifer. Water quality was available only for the disposal well. Because this well is situated next to the Gulf of Mexico, total dissolved solids and chlorides are very high: 29,680 mg/liter and 15,400 mg/liter, respectively. Hardness is well over 2,000 mg/liter as CaCO₃. The wells are rehabilitated every 5 to 6 years.

Analysis: No cooling or reinjection problems were identified by the maintenance superintendent of the condominium.

Site No. 10: Manatee Junior College, Bradenton, Florida

Description: From 1965 to 1977, the college was cooled with three large centrifugal chillers. In November of 1977 the system was changed from well condenser cooling (Figure 3, p. 8) to a cooling tower. The condensers are a 170-ton Trane (370 gpm); a 235-ton Trane (450 gpm); and a 250-ton Chrysler

(428 gpm). Water was provided at a temperature of 80°F and discharged at 95°F. The groundwater wells still are used occasionally by the school for cooling. There are five supply wells and one reinjection well. The supply wells are all 6-in. diameter wells. The reinjection well is 12 in. in diameter down to a depth of 525 ft and 10 in. in diameter to a depth of 805 ft. The reinjection well was deepened in 1973 from 525 ft to 805 ft because of thermal problems in the nearby supply wells. The nearest supply well is 900 ft away. All wells are located in the Floridan limestone aquifer although the reinjection well may be into the Lower Suwannee limestone aquifer. No information was provided as to the volume of water discharged to the reinjection well. Total hardness for the cooling water was 1,582 mg/liter as CaCO₃; iron content was 0.10 ppm.

Analysis: The junior college had a number of problems with the reinjection and cooling systems which led to the installation in 1977 of a closed loop system with a cooling tower. A U.S. Geological Survey study in 1973 found that injection was occurring in the withdrawal zone of their two largest (450 and 430 gpm) and closest (900 and 1,150 ft) wells. The heated water was reaching the cone of depression caused by the withdrawal wells, which increased the supply water temperature from 80°F to 86°F. The increased temperature was decreasing the cooling efficiency of their centrifugal units. The college followed the U.S. Geological Survey recommendation of deepening the reinjection well from 525 ft to 805 ft. However, the problems continued. Not only were there thermal problems, but some of the source wells were pumping sand which was extremely abrasive in the condenser tubes. The sand probably resulted from the water level in a well being too low, which is a result of a declining water table in Manatee County. In addition, an increase in sulfur content of the water was found in 1976 and was blamed for some condenser-related problems. The declining water table and the thermal problems combined and caused the school to discontinue using most of their wells for cooling purposes and to install the closed loop cooling tower system.

Apparently, the dwindling of groundwater resources in the Manatee-Sarasota County area occurred at an alarming rate in 1976. In January 1977, new rules were implemented by the state. The rules restricted new ground water users to 1,000 gal/acre/day, that being the estimated annual average recharge at which nature replenishes groundwater. No information was received describing the effect this program has had on Manatee and Sarasota County groundwater levels.

Site No. 11: Florida State University, Tallahassee, Florida

Description: Many of the buildings on this campus have groundwater air conditioning systems (similar to that shown in Figure 3, p. 8). As of 1974, there were 20 chiller systems, ranging from 97 to 770 tons of rated cooling capacity, and 36 source and reinjection wells. Some of the reinjection wells have since been changed to supply wells; i.e., some of the cooling systems no longer reinject their discharge water. Total design discharge volume to reinjection wells is nearly 15,000 gpm, and total design inlet volume to all the chillers is nearly 33,000 gpm. Use of a few of the chillers has been discontinued; many of the older systems (10 to 12 years old) are

listed as standby. Depth of the various wells ranges from 180 ft (6-in. supply well) to 620 ft (18-in. discontinued reinjection well). The water-bearing formations are all limestone and are called the Floridan limestone aquifer. The City of Tallahassee gets its water from the same aquifer. Water quality data from the city show the water in this aquifer to be of good quality: iron, 0.01 ppm, and total hardness, 138 mg/liter as CaCO_3 indicates good recharge.

Analysis: There are too many different cooling systems on this site to describe and analyze them separately in this report. A more in-depth study of this site is needed. Groundwater usage for cooling by FSU is quite extensive. However, one concern of geohydrologists familiar with the area is the effect on the groundwater resource of elevated groundwater temperatures caused by reinjection of large volumes of cooling system water. There is little evidence at this time of any change in groundwater quality; however, the question apparently has not been studied in detail. The obvious effect of thermal pollution is to decrease the cooling value of the groundwater. Florida Geological Survey Bulletin 47 (1966) states, "As a result of the continued return of heated water to the aquifer, groundwater temperature is 5 to 6°F above normal in downtown Tallahassee and in the vicinity of Florida State University." During the early 1960's, Florida State University (FSU) experienced thermal pollution in several air conditioning supply wells on the campus. A very good explanation of the influence (rate of flow, direction of flow, etc.) of a reinjection well on four surrounding supply wells is given in the above Bulletin. Based upon the FSU study, it was determined that reinjection should occur in zones below the supply zones and be separated vertically from supply zone by a 50- to 100-ft thick zone of dolomite to retard recirculation. However, local thermal pollution problems still exist in the Tallahassee area.

Site No. 12: George Smith, Inc., Round Rock, Texas

Description: This building is cooled with two Carrier 35,000 BTUH groundwater source heat pumps (Figure 4, p. 9). The system's rated coefficient of performance (COP) is 2.84. Actual COP is 3.2 when water flow rate is 7 gpm and water temperature is 74°F. Discharge temperature for the system is 84°F. The disposal well is 100 yards from the source well; both are 420 ft deep and in a limestone aquifer. Water quality data from the City of Round Rock show total hardness of 315 mg/liter as CaCO_3 , TDS is 540 ppm, and iron is 0.04 ppm.

Analysis: The company does not always operate both Carrier units simultaneously. However, when they do, the reinjection well sometimes overflows. The company is exceeding the capacity of the reinjection well but could solve this problem by drilling another disposal well. This site will also be the site of a data-gathering effort by Texas Power and Light Company in the near future. The power company intends to install instruments to gather research data from this groundwater cooling system.

Site No. 13: Hercules, Inc., Savannah, Georgia

Description: This plant has employed three shell and tube heat exchangers (Figure 3, p. 8) since 1956. Combined rated cooling capacity of these Graham and Armstrong heat exchangers is 5.176×10^6 BTUH. Inlet water flow rate is 1,700 gpm, and temperature is 80°F. The injection flow rate and temperature are about 820 gpm and 92°F, respectively. The cooling system requires maintenance every 3 to 4 years. The supply well pump has had one major overhaul since 1956 (at a cost of \$25,000). From information provided for this study, it appears there is one supply well and one injection well. Neither well has needed rehabilitation since it was drilled. The supply well is 1,000 ft deep; the injection well, 750 ft deep. The water-bearing formation is the Ocala limestone, although there are layers of sand and clay that produce water. Depth to the static water level is 114 ft, which is also the depth to the producing zone. This system uses gravity reinjection. Water quality information from U.S. Geological Survey for the region shows that the water is of good quality. There is little or no iron, and total hardness ranges from 100 to 120 mg/liter as CaCO_3 .

Analysis: The only problems this site has had are well pump mechanical problems (necessitating the major overhaul) and a declining water table over the years. The pump problems were described as only normal wear and tear. The declining water table has been caused by increased water use in Chatham County, Georgia.

Site No. 14: General Services Administration, Federal Building, Savannah, Georgia

Description: The building is cooled with a 350 ton chiller (Figure 3, p. 8) which was installed in 1958 and is still in operation. Flow rate to the chiller is 1,000 gpm at a temperature of 72°F. All the cooling water is reinjected and injection temperature is around 80°F. The supply and injection wells are 300 ft apart and are both 750 ft deep. The water-bearing formation is the Ocala limestone. Water quality information is contained in the previous site description.

Analysis: No problems were identified with this site.

5.2 SHALE

Site No. 15: Private residence, Indian Lane, South Carolina

Description: This home is heated and cooled with an American Air Filter groundwater source heat pump (Figure 4, p. 9) with a 40,000 BTUH rated cooling capacity. The energy efficiency ratio is 10.3 with an inlet water temperature of 56°F and a flow rate of 8 gpm. The reinjection temperature, according to the homeowner, is 98°F; according to the heat pump distributor's technical representative, the temperature is 80°F. The site is using the same well for cooling and reinjection. Pumping rates are 8 to 12 gpm; reinjection rates range from 6 to 8 gpm. The well is 232 ft deep and passes through 185 ft of granite. Static water level is at 160 ft. Water quality

data were not available for the region. However, according to the Ground-water Protection Division, hardness is nearly 0 mg/liter as CaCO_3 ; iron and manganese are very low; and pH is around 6 to 6.5.

Analysis: The sytem has been operating since 1977 and no problems have occurred. The water from the supply well that is not reinjected is surface discharged. In summer the well temperature builds up to 76°F which makes discharge temperatures around 92°F. This explanation was provided by the NESCO technical representative. The 98°F discharge temperature provided by the homeowner may be an end-of-the-cooling-season temperature. This system uses gravity reinjection.

6.0 EAST REGION

States included in the East region are Virginia, West Virginia, Maryland, Pennsylvania, New Jersey, New York, Massachusetts, Connecticut, Vermont, New Hampshire, and Maine. Maine does not permit underground injection of any type; Virginia does not allow wastewater injections; however, the permitting process to allow cooling water reinjection is so complicated that reinjection is usually not performed in the state. In other states groundwater is used for cooling, but reinjection is not very common. On Long Island, however, reinjection is required. All sites, except one, were tapping and reinjecting to sand and gravel aquifers. One site was reinjecting to a fractured shale.

In New York three sites on Long Island were chosen for documentation. Groundwater cooling (and consequently reinjection) is quite extensive on Long Island. There have been problems with increased groundwater temperatures and pollution in the upper of the three aquifers on Long Island. Elsewhere in New York three sites were identified, but only two were documented at the time this report was written. One was in Endicott, and was the site reinjecting to a fractured shale. The other site was in Johnson City.

The only other site that could be documented in the East Region was in Edinboro, Pennsylvania, at Edinboro State College.

6.1 SANDS AND GRAVELS

Site No. 16: Edinboro State College, Edinboro, Pennsylvania

Description: The college science building was cooled and heated from 1964 to 1974 with a Worthington water-to-water heat pump with a maximum rated cooling capacity of 75 tons. The heat pump's 100-hp motor and compressor failed in 1974; and, rather than replace them, the system was changed so that the groundwater cooled the chill water directly in the heat exchanger. The groundwater temperature is about 52°F; discharge temperature before the compressor failed was about 60°F. Flow rate was probably between 50 and 100 gpm. Discharge temperature for the groundwater from the heat exchanger is not available. The source and injection wells are both about 60 ft deep; the static water level is about 3 ft, but there are 10 to 12 ft of clay just below the top foot of soil. The aquifer exhibits characteristics of a confined aquifer. Only incomplete water quality data were available. Hardness data from a city well showed average hardness was 175 mg/ liter as CaCO_3 .

Analysis: Since the system was changed in 1974 to utilize the groundwater to cool the chill water, no problems have occurred in the cooling system. The pump and compressor failures were due to wear and tear. The current cooling system has worked so well that the science building is sometimes too cool. No treatment of the groundwater is performed; the chill water (not the groundwater) is softened with Calgon.

Site No. 17: General Electric Co., Johnson City, New York

Description: Groundwater is supplied to a heat exchanger in the cooling system; total rated cooling capacity for the plant's cooling system is between 1,500 and 2,000 tons. The flow rate to the heat exchanger is between 250 and 275 gpm at a temperature of 57°F. Discharge temperature is about 95°F. The source well is 94 ft deep and in a sand and gravel aquifer. Pump rate is about 350 gpm. Not all the source water is used for cooling; about 75 gpm is softened and used in a quenching operation. This water is not reinjected. Of the water used for cooling, about 50% is discharged to the reinjection well and the rest is discharged to the sewer. The reinjection well is 300 ft from the source well and is also 94 ft deep. Water quality data show that hardness is 380 mg/liter as CaCO₃; iron is 0.10 ppm.

Analysis: The only problem the site has had was some sand and silt in the supply well stream. These problems were solved by redeveloping the well.

Site No. 18: Long Island Lighting Co., Hicksville, New York

Description: The building is using three 80-ton Worthington condensing/refrigeration units in their cooling system. Groundwater is used for condensing and also to provide precooling. The flow rate through the system is about 500 gpm; inlet and outlet temperatures are 54 and 64°F, respectively. There are two source wells and one diffusion well. The newer of the source wells (16 years old) is used continuously; the other is used intermittently. The older source well is 130 ft deep; the newer well is 202 ft deep. No depth information was available for the reinjection well. Well logs for all three wells had not yet been received as of the writing of this report. The wells are rehabilitated every 3 to 4 years. Both source wells are in what is known as the Magothy Aquifer, which ranges in depth from 100 to 300 ft. The aquifer at this site consists of glacial outwash gravels and sands. Water quality data for the Long Island area have not yet been received.

Analysis: Before the newer source well was drilled, the old well began pumping sand and fouling the tubes in the cooling system. Reinjection to the diffusion well had also increased the temperature in the source well from 70 to 75°F. Apparently, the old source well is fairly close to the diffusion well; reinjection might be occurring in the same water-bearing strata. The newer well has not had these problems; well water temperature is 54°F.

On Long Island, there is a Pleistocene aquifer called the Upper Glacial aquifer that is above the Magothy. It is of poorer quality and has been subject to the effects of years of pollution. It is approximately 100 ft thick, and its water has a higher temperature than water of the Magothy. It might be that the old well was tapping this aquifer.

The Magothy produces water of fairly good quality, but there are areas of contamination. Below it is an aquitard called Raritan clay. Below this is the Lloyd aquifer, which bears water of high quality. A special permit is needed to tap this aquifer.

Site No. 19: We're Associates, Inc., Lake Success, New York

Description: This site consists of three buildings located in an industrial park. Each building is cooled by a Carrier heat absorption unit with a rated cooling capacity of 350 tons. Total volume of water pumped to the three units ranges from 1,500 to 2,000 gpm at 58°F. The cooling water is pumped from two source wells. One well is a fixed flow rate of 1,100 gpm, the other well has a variable speed pump and a flow of 400 to 900 gpm. All the cooling water is pumped down three diffusion wells at a temperature of around 65°F. Well logs for the five wells were not available at the time this report was written. The wells are located in a glacier terminal moraine; the aquifer probably consists of gravels, boulders, and coarse sands.

Analysis: A variable speed pump was installed because too much water was passing through the cooling system; the high velocity of the water was eroding the coils. No other cooling system or reinjection problems have occurred.

Site No. 20: Lever Management, Garden City, New York

Description: Groundwater is being used in precoolers in the building. The flow rate through the system is about 400 gpm; inlet and outlet temperatures are 55 and 70°F, respectively. There is one supply well 290 ft deep and two diffusion wells 75 ft deep. Well logs were not available at the time this report was written, but the source well is located in the Magothy aquifer (sand and gravel), and the diffusion wells are probably in the Upper Glacial aquifer (sand and gravel). Rehabilitation of the wells is performed every 3 to 4 years; pump maintenance, every 6 to 7 years. No water quality data had been received at the time this report was written.

Analysis: No problems have occurred at this site.

6.2 SHALE

Site No. 21: Intown Motor Lodge (old Frederick Hotel), Endicott, New York

Description: The hotel has changed hands a couple of times, and the groundwater cooling system has long since been discontinued. The original system was probably like that in Figure 3 in Chapter 2. Groundwater flow rate to the condenser was estimated to be about 50 gpm at a temperature of 54°F; discharge temperature was between 70 and 75°F. The supply well and reinjection well are 150 ft apart. The supply well was 151 ft deep and was in a water-bearing sand (125 to 151 ft). The reinjection well was 166 ft deep and was in river mud from 30 to 156 ft before it entered a Devonian fractured shale. When the well was drilled, reinjection was attempted at 140 to 154 ft, but the mud (silt) would not take the water. So the well was drilled 10 ft into the rock, and reinjection was successful. Water quality data from a well 2,000 ft northeast show hardness is 386 mg/liter as CaCO₃; iron is 3 ppm.

Analysis: The cooling and reinjection systems were apparently beset by many problems. Severe liming inside the condensing unit caused frequent maintenance problems. The high iron content in the water also created problems with reinjection (a common problem in the area), and the well overflowed frequently. Indications are that the well system was not rehabilitated as often as was recommended by the well driller. The cooling system was also not cleaned as often as recommended by the cooling system contractor.

7.0 WEST REGION

States involved in the West region were Utah, New Mexico, California, Oregon, and Washington. As stated earlier, there is no uniform policy covering reinjection among the states. Arizona does not permit underground injection, and we found no sites in Oregon. But we did find a great deal of interest in the West region for the use of groundwater heat pumps.

In California, the use of the groundwater resource is quite extensive. However, reinjection controls have become more stringent, and many reinjection wells have had to be abandoned because they could not meet the stricter water quality standards for reinjection. Only three sites were found, and all three were in one county, Stanislaus. Two of the sites had discontinued reinjection operations within the last 6 months. The other site had not been affected by the more stringent controls.

In Washington, we were given leads on a number of sites using fractured basalt aquifers but found no one reinjecting. The two sites we identified were high schools; one in Brewster, the other near Tacoma.

Only one site was identified and documented in Utah, in Orem. However, six were identified in New Mexico. Four of those were in the Roswell School District, and information from the district office was not complete. The sites were fairly old (early 1960's), and no single person had enough information on any one site. There was also a considerable amount of time involved for the school district personnel to round up pertinent information. The other two sites were in Albuquerque (a bank) and Hobbs (a junior college).

Except for two of the schools in Roswell, the aquifer types of the identified sites were exclusively sands and gravels. The two schools in Roswell were in fractured limestone and fractured shale. The poorest water quality by far was in Roswell, New Mexico. Not only was it extremely hard, but it was very high in total dissolved solids. Water quality for the rest of the sites was good. Hard water was predominant, but there were no instances of iron fouling or manganese problems.

7.1 SANDS AND GRAVELS

Site No. 22: Utah Technical College, Orem, Utah

Description: This site is employing a water-to-water heat pump (Figure 3, p. 8) to heat and cool the college. There are apparently two Trane units (centrifugal chiller as described by their engineering consultant) with 500 tons of cooling capacity each and a rated COP of 4.5. Water (45 to 50°F) is pumped to each of these units at 750 gpm (or 1,500 gpm total) and an average temperature of 58°F. There are two wells from which water can either be pumped or used for reinjection. Because one well (No. 1) has a variable speed pump and is more energy efficient, it is used almost exclusively as a source well. The other well (No. 2) can be used as a source well if problems occur with the No. 1 well, a situation which happened last

year when a transformer failed. Once a week the flow is reversed for about 10 min, and water is pumped from No. 2 well and reinjected to the No. 1 well. The discharge cooling water has a temperature of about 68°F. There are two confined aquifers that are providing water for cooling (and heating). These are called the shallow Pleistocene and the deep Pleistocene. These aquifers consist of gravels and sands, with some strata containing clay. These aquifers are very high yielding. Water quality is good with very little or no iron and a total hardness of 146 mg/liter as CaCO₃.

Analysis: No problems have been identified with this site. The reason for periodically reversing the flow of the wells is to ensure the changeover valve does not become stuck. This operation might also help to ensure that the injection zone of No. 2 well stays clear and open.

Site No. 23: Sandia Savings (Sims Building), Albuquerque, New Mexico

Description: This site is being cooled with a large heat exchanger. No information on the unit was available except that the cooling water passes through 260 tubes in the exchanger; inlet temperature is about 70°F and outlet temperature is about 88°F. Both the pumping and reinjection rates are listed as being 500 gpm; indications are that this is also probably the rate of flow through the heat exchanger. The source well is 10 ft from the reinjection well and is tapping a confined aquifer at a depth of 108 to 260 ft. The aquifer consists of different strata of sand, gravel and sand, and sand with clay streaks. The reinjection well is 72 ft deep. The injection zone is at a depth of 20 to 72 ft, which is above the confining layer for the source well aquifer. The static water level in both wells is 17 ft. Water quality information from U.S. Geological Survey shows that the water is of good quality and is moderately hard (180 mg/liter as CaCO₃).

Analysis: The only problem that has occurred at this site is the collapse of the source well in 1976. This collapse filled the heat exchanger coils with gravel and also necessitated the rehabilitation of the well. This is an interesting site in that two different aquifers are used and there appear to be no intermixing between them. Temperature information for the shallow aquifer was not obtained. The well system information shows that this aquifer has an even greater potential yield than the deep aquifer (32 gpm per ft of drawdown vs 25 gpm per ft of drawdown). There appears to be no sign of chemical incompatibility between the two aquifer waters, and no loss of ability to inject.

Site No. 24: Gig Harbor High School, Gig Harbor, Washington

Description: The high school is cooled with a Trane water-to-water heat pump (Figure 3, p. 8) with 185-ton cooling capacity. Inlet water flow rate is 75 gpm at 50°F; reinjection rate is also 75 gpm, but water temperature is 105°F. The source well is 310 ft deep; depth to the water-producing zone is 265 ft. The zone consists of different strata of sands, gravels, and some clay. The reinjection well is 323 ft deep. The aquifer begins at a depth of 287 ft and also consists of different strata of gravels, sands, and some clay. Even though these two water-producing zones are similar, the geologic characteristics of the region are quite variable. For example,

the reinjection well was drilled 350 ft west of the source well and produced a good amount of water (500 gpm with 55 ft of drawdown after 4 hr). Before this well was drilled, a well had been drilled 325 ft east of the source well to a depth of 460 ft and it was a dry hole. The U.S. Geological Survey says this is typical of the region. Also typical is the variability of the water quality. Manganese and iron are unpredictable problems in the groundwater. Water quality analysis from the source well shows a fairly good quality water except for high iron and manganese content (0.44 ppm and 0.33 ppm, respectively).

Analysis: Well drillers in the area consider any water with over 0.3 ppm Fe or 0.1 ppm Mn to have the potential to cause fouling problems resulting from Fe and Mn precipitation. U.S. Public Health Service limits for these elements are 0.3 ppm and 0.05 ppm, respectively. (Washington State limits for potable water are 0.05 ppm and 0.03 ppm, respectively.) Because this water analysis was performed just after a relatively short pump test, it is possible that the sample might have come from a perched pool (not a flow-through stream) where the water has been in contact with an iron- and manganese-bearing formation for a very long time. The system has only been in operation since July 1979. Further pumping and use might decrease Fe and Mn values. It was speculated that an analysis of reinjection well water would show similar Fe and Mn content, although this would not necessarily be the case. Analysis of a nearby well shows 0.39 ppm Fe but only 0.05 ppm Mn.

The original plan for this cooling system was to reverse the flow of these two wells when the cooling season changed to the heating season. We do not know whether this practice is being performed now.

The only operational problem at this site is caused by an improperly developed reinjection well. The well water had a very high sand content. The result was that the well pump had to be repaired and the well redeveloped.

Site No. 25: New Mexico Junior College, Hobbs, New Mexico

Description: The junior college is using a Trane chiller with shell and tube heat exchanger with a rated cooling capacity of 300 tons. The schematic diagram of this system is similar to that shown in Figure 3, p. 8. Rate of flow through the unit is 950 gpm. The source well water temperature is about 65°F, however, information from the junior college shows an inlet temperature of 72°F to the heat exchanger. Discharge temperature is about 78°F. The source well may be some distance from the heat exchanger which may be why the inlet temperature is higher. The source and injection wells are tapping the Ogallala Formation, which is about 120 ft thick around Hobbs. The source well is 198 ft deep; the reinjection well is 177 ft deep. The Ogallala is a sand aquifer of good quality. Water quality information from the region shows that the water is very hard (250 to 300 mg/liter as CaCO₃) but low in iron. Manganese data were not available, but Mn has not been a problem in this water. Major maintenance on the well pump is performed every 2 years while the cooling system undergoes annual maintenance.

Analysis: Problems with this site arose from having the reinjection well too close to the source well. The water temperature in the source well was influenced by the water being reinjected. Because of the water cross-flow between the two wells, it was necessary to drill a new well further away from the source well (about 1,125 ft). However, this well could not take all of the flow from the source well, so another injection well had to be drilled.

The water is very hard, which may be why major maintenance is required annually on the cooling system.

The Ogallala Formation is a very extensive, deep aquifer beneath the High Plains region in New Mexico, Oklahoma, Texas, Colorado, Nebraska, and Kansas. It is thinnest in New Mexico, where it is 125 ft thick or less. It consists mostly of sandstone, shale, and gravel and has a maximum thickness of 300 ft. The Ogallala has been the center of controversy in the High Plains states because it has been so extensively developed that there is a danger of depleting and destroying a significant portion of the aquifer. The use of this aquifer for cooling and heating would not meet with controversy so long as the groundwater was reinjected to the Ogallala.

Site No. 26: Valcris, Inc., Turlock, California

Description: This is a commercial plant that is employing groundwater with a shell and tube heat exchanger for condensing the refrigerant gas. The schematic diagram is similar to that shown in Figure 3, p. 8. The combined total cooling capacity is 255 tons. Water flow to the condensers is estimated to be somewhere between 450 and 600 gpm at a temperature of 75°F. The source well is 515 ft deep; the bottom 250 ft of the well casing is perforated. The well log for this well shows alternating layers of sand and clay with a few layers of gravel. The reinjection well is not really a well but a buried sump. Water from the condenser (83°F) is taken by pipe to this "down well" and is injected (or "dumped") into a buried gravel sump. The depth to the sump was not known. Water quality data for the area show water of good quality, fairly hard (127 mg/liter as CaCO₃) with total dissolved solids about 300 ppm.

Analysis: No problems have been identified with this site. The implementation of stringent controls by California on reinjection practices have eliminated many reinjection operations. So far this site has been able to adapt and adjust to these controls. The confined aquifer being tapped by the source well is old alluvium beneath a thick lacustrine clay deposit (from 0 to 100 ft thick). This aquifer is widely used for irrigation in the region, which has lowered the head on the aquifer and water level often below the confining layer of clay.

Site No. 27: Turlock Refrigerating Co., Turlock, California

Description: This site is employing a York chiller with shell and tube heat exchangers for cooling. The schematic diagram is represented by Figure 3, p. 8. There are five condensers with a rated cooling capacity of 175 tons each. The source well is supplying 1,500 gpm of water at 68°F

to the condensers. Discharge temperatures are between 80 and 85°F. Well logs were not available to us, so the aquifer cannot be described. It is assumed that since this site is in the same area as Valcris, Inc., the hydrogeologic characteristics will be the same. Thus, two aquifers exist; one above the confining, lacustrine clay layer and one below it. We know that one, and probably both, wells (source and reinjection) penetrate both aquifers. Water quality data for the area were explained in the Valcris, Inc., description and are also in the appendix. The reinjection operation for this site has been discontinued.

Analysis: When the reinjection operation was functioning, there were no problems with the cooling system. There was a minor plugging problem with the reinjection well which was diagnosed as resulting from fine sand in the supply water. This could mean an improperly developed source well, need for a well screen or for smaller openings in an existing screen, or improper size distribution in the gravel pack (if the well has a gravel pack). The reason for discontinuing reinjection was pressure from state regulatory agencies. Apparently the injection well (and maybe the source well also) penetrates two separate aquifers and allows intermixing between the two. The water above the confining clay layer is of poor quality, and there was nothing to keep it from entering the reinjection well and mixing with good water from below. Promulgation of stricter reinjection statutes in California forced Turlock Refrigerating to either stop using the well or spend a lot of money correcting the problem. They chose to discontinue use of the well.

Our survey of California produced evidence to show that Turlock Refrigerating's experience is not unique. The enactment of stricter injection controls has resulted in abandonment of many reinjection wells. Concerns for public health and for protecting California's precious groundwater supply have become very strong in recent years. As a result, many uncased or inadequately cased wells no longer comply with state codes.

Site No. 28: Shell Development Company, Salida, California

Description: This is a research firm that had been reinjecting their groundwater and just recently discontinued the operation. The groundwater cooling system Shell employs is quite elaborate and cools a number of buildings. There are three supply wells and three reinjection wells (down wells). The original system was installed in 1957 and consisted of a Trane 169-ton chilled water unit. Chilled water is circulated from the Trane unit to chilled water coils located in the air handlers for the various buildings. The schematic diagram of this system is similar to that shown in Figure 3, p. 8.

The system was expanded through the years to include those units shown in Table 2. All condensing units were supplied by the three supply wells through a loop-type common piping system. Water was reinjected into the ground through an interconnected piping system from the condensers to the reinjection wells. The system was a closed pressurized system from the supply well to the reinjection point. The supply system was maintained at 50 to 65 psig. Pressure at the reinjection well was approximately atmospheric.

TABLE 2

SHELL DEVELOPMENT COMPANY CONDENSING WATER
SUMMARY FOR CHILLED WATER UNITS

<u>Unit</u>	Once Through Reinjection System (entering water temperature 75°F)				
	<u>Number of Condenser Passes</u>	<u>Cooling Capacity (Tons)</u>	<u>Pressure Drop (Ft.)</u>	<u>Flow Rate (GPM)</u>	<u>Exit Temperature (°F)</u>
York 230 ton	2	229	6.5	343	95
York 200 ton	3	205	12.5	300	95
York 100 ton	3	105	10.7	158	91
Trane 169 ton	4	169	16	242	95
Worth 60 ton		60.4	1.1	120	95
Carrier 70 ton	3	70	1.8	97	107
Trane 15 ton		17.5	7.5	30	100
Trane 10 ton		9.3	6.4	24	86
West 3 hp		3		7	95
West 3 hp		3		7	95
Total		871.2	132.8		

^a Information supplied to MRI by Shell Development Company.

Shell Development recently installed a closed loop cooling tower system the condenses water going to the chillers. Consequently, Shell is no longer using the reinjection wells. No water treatment of any kind was used.

The well logs for the six wells show that the water-producing zone consists of stratified layers of clay, sands, and gravels. Depths range from 135 to 350 ft. Water quality is very good although the water is fairly hard (ranges from 83 to 196 mg/liter as CaCO_3).

Analysis: In the 23 years of operating the once-through system, the site never encountered any significant reinjection or cooling problems. However, the temperature of the source well water did increase from 75 to 80°F, which was in violation of state regulations. The state contends that the temperature rise was caused by the injection of 95°F water. Without a detailed geohydrologic study it would be difficult for us to confirm or refute the state's contention. However, we can present the facts that we know.

The injection wells are 135, 170, and 226 ft deep. The supply wells are 147, 305, and 350 ft deep. There are a number of layers of slowly permeable clay layers (aquitards) between water-bearing strata. Thus, diffusion of water between different strata takes some time. Because the reinjection well sites are intermingled with the supply wells, and because reinjection has been occurring for as long as 23 years, it is very possible that the injection of 95°F water over time has raised groundwater temperature 5°F.

Site No. 29: Brewster High School, Brewster, Washington

Description: This high school is cooled with 12 American Air Filter water-to-air heat pumps (Figure 4, p. 9) ranging in capacity from 1-1/2 to 5 tons. Total cooling capacity is 330,000 BTUH. Total flow rate through the units is 64 gpm. All cooling water is reinjected. The source and reinjection wells are both very shallow (about 40 ft deep) and are 100 ft apart. The aquifer being tapped ranges from sand and gravel to sand and begins at a depth of 31 ft. This site uses a gravity reinjection system. The water is of good quality although very hard (307 mg/liter as CaCO_3). No inlet and outlet temperatures were available.

Analysis: The only problem the site has encountered is leaking pipes, which has been attributed to excessive water velocity. Because this site is using gravity reinjection, encrustation problems could arise fairly soon in the reinjection well. This would not be a major problem, however, and would only require acidizing the well.

Site No. 30: Roswell High School, Roswell, New Mexico

Description: The high school is cooled with a Trane Hermetical Reciprocating Compressor with a 60-ton rated cooling capacity. The schematic diagram of the system is very similar to Figure 3, p. 8. Temperature of the inlet water is listed at 78°. However, groundwater temperature for the region is around 65°F. Outlet water temperature is around 95°F. From

information we have received, it appears there is one source well and two diffusion wells. The wells are tapping a sand and gravel aquifer called the Basin Fill in the Pecos Valley. Well depths are 129, 150, and 208 ft. Groundwater quality for the region is generally poor. Total hardness as high as 1250 mg/liter as CaCO_3 is not uncommon in shallow wells. Iron concentration data are not available, but iron does not appear to be a big problem. High concentrations of chloride, sulfate, and total dissolved solids are a problem.

Analysis: This site has been in operation since 1961. In 1972, the existing input well had to be redrilled because it was severely plugged up. An additional injection well was drilled at that time also. Judging from the quality of the water in the region, well plugging problems would not be uncommon.

No treatment is applied to the cooling water, and no information was available as to the amount of maintenance required on the well and cooling systems. Also, no explanation is available for the difference between the groundwater temperature and the inlet water temperature.

Site No. 31: Monterrey School, Roswell, New Mexico

Description: This school is cooled with 60-ton Trane and 50-ton Bell and Gossett reciprocating compressors. Schematic diagrams of these two systems are similar to the diagram in Figure 3, p. 8. Like Roswell High School, inlet and outlet water temperatures are listed as 78°F and 95°F, respectively. Also, the Basin Fill is the source of water. Well depth is about 135 ft, and the aquifer materials consist of sands, gravels, and "concrete rock," which is probably consolidated, cemented sands and gravels. Water quality problems are the same as those listed for Roswell High School.

Analysis: The reinjection well plugged 7 or 8 years ago, and a new one had to be drilled. See Roswell High School for other comments.

7.2 SHALE AND LIMESTONE

Site No. 32: Sierra Middle School, Roswell, New Mexico

Description: The school is cooled with three Trane reciprocating shell and compressor/tube heat exchanger systems (schematic diagram similar to Figure 3, p. 8). Total rated cooling capacity is 120 tons. Again, inlet and outlet temperatures are 78°F and 95°F, respectively. Both the supply and reinjection wells are about 174 ft deep. The aquifer materials appear to be broken shale and fractured limestone. Water quality is similar to that described for Roswell High School.

Analysis: No major problems have occurred at this site. For other comments see Analysis for Roswell High School.

Site No. 33: Goddard High School, Roswell, New Mexico

Description: This is the fourth Roswell site. The school is cooled with a 240-ton Tonrac centrifugal compressor and shell and tube heat exchanger. The schematic diagram is the same as that shown in Figure 3, p. 8. Inlet and outlet water temperatures are listed as 78°F and 95°F. The source and reinjection wells are 329 ft and 346 ft deep, respectively. The formation being tapped is called the San Andreas Limestone of Monzano and is a fractured limestone. Water from this formation is still of poor quality. Total hardness, chlorides, and total dissolved solids are very high.

Analysis: The reinjection well plugged and a new one had to be drilled in 1974. See Analysis for Roswell High School for further comments.

8.0 CENTRAL REGION

We designated seven states as being in the Central region: Colorado, Kansas, Missouri, Illinois, Indiana, Ohio and Kentucky. The states fall primarily between the 52 and 57° isotherms (see Figure 6, p. 16). All states except Indiana were contacted. Missouri prohibits reinjection, but this prohibition is currently under review by various state agencies and the state legislature.

In the Central region, Kansas, by far, has the most developed use of groundwater for cooling and heating. All five sites that were identified in Kansas are in the Wichita area where use of groundwater and reinjection are common. Other sites are in the Hutchinson and Great Bend areas and are in similar geologic deposits (Pleistocene sands and gravels).

In Colorado, the use of groundwater for cooling is not common, and no one with U.S. Geological Survey, Colorado Geological Survey, or Layne-Western knew of any sites in the state. In Kentucky, the situation was similar. The groundwater is often not of good enough quality to use or is not in sufficient quantities for use in cooling. Interest in groundwater heat pumps is increasing in Kentucky, however. The main office for American Air Filter, one of the largest heat pump manufacturers, is in Louisville, Kentucky.

In Illinois, use of groundwater for cooling is apparently limited to the northern part of the state around Chicago. There are very good deep dolomitic limestone and sandstone aquifers in the northern part of the state. Three large sites were identified for us by the Illinois Water Survey. All three had been in operation at least 15 years although one, Commonwealth Edison, had discontinued use of groundwater for cooling at its unmanned station in Goodings Grove.

Four sites were identified in Ohio. Two were in sand and gravel aquifers in southeast Ohio, and the other two were in Bellevue in northern Ohio, where the aquifer was limestone. These two sites were using the same wells for supply and reinjection.

On the whole, the water quality in this region is good with only a couple of instances of iron problems (greater than 0.3 ppm). The water is very hard throughout the region; total hardness over 300 mg/liter as CaCO_3 is common.

8.1 SANDS AND GRAVELS

Site No. 34: Private residence, Troy, Ohio

Description: The residence is cooled with a Tetco Geothermal Water-to-Air Heat Extractor having a rated cooling capacity of 3 tons (Figure 4, p. 9). Inlet water temperature averages around 55°F; outlet temperature was 62°F when measured, but no information on outside ambient temperature was available. Flow rate averages 8 gpm. This system has been in operation less than a year so we do not have an average outlet temperature that is representative of an entire cooling season.

The source well is 60 ft from the injection well and is 82 ft deep. Static water level is about 35 ft. The reinjection well is 73 ft deep; static water level is 48 ft. Both wells are tapping a Pleistocene sand and gravel aquifer. A water quality analysis showed that the water has a total hardness of 340 mg/liter as CaCO_3 and an iron content of 2 ppm.

Analysis: Although this site has been in operation less than a year, they are having problems with reinjection. The reinjection well, drilled in fall of 1979, took water for only 2 months before it began to overflow. The well was then treated with NU Well and surged with air for 4 hr but with very little improvement. The plugging problems occurred during the winter while the heat exchanger was heating the residence and discharge temperatures were below the 55° groundwater temperature. The high iron content (2 ppm) can create plugging problems very easily. However, the reinjection well plugged up even though discharge water temperature was not elevated and discharge water was not being exposed to air (i.e., pumped reinjection vs. gravity reinjection). No explanation for reinjection failure can be offered other than iron fouling.

Site No. 35: Westover Retirement Residence, Hamilton Ohio

Description: This retirement residence was being heated and cooled by a unique system until this year. A new cooling tower has just been installed. The original system was put into operation around 1965. A similar system is in operation in the Vaughn Building Company in Hamilton. The late president of the company, Charles Beeler, designed both systems. It is the Vaughn system that we will describe here although we understand that there are a few differences between it and the system at Westover. (Westover was also using groundwater as condenser cooling water.)

The cooling system of the Vaughn building is very similar to the direct cooling system using a water-to-air heat exchanger (Figure 1-B, p. 6) with two exceptions: (a) two sets of groundwater coils are used to control only the fresh air temperatures and (b) the coils are used both for precooling in summer and preheating in winter. Under this design, the regular air conditioner becomes a standby unit for extremely hot or high humidity weather.

The groundwater was supplied by three wells about 100 ft deep. The flow rate through the entire system was 60 gpm. Groundwater temperatures at the beginning of the cooling season were 55°F; by the end of the season they were 65 to 70°F. Reinjection temperatures were about 75°F at the beginning of the cooling season but about 90°F by the end of the season. The discharge water was put into three reinjection wells approximately 150 ft from the supply wells. The aquifer being tapped was described by a well driller as a "buried valley" under a thick clay overburden. The aquifer consists of coarse gravel to sand and gravel. Water quality analysis of this aquifer shows high iron (1.23 ppm), high Mn (0.31 ppm), and a very hard water (330 mg/liter as CaCO_3). The wells at Westover are on the fringe of this buried valley.

Analysis: This site had two problems: (a) groundwater temperature became too high to use the water for cooling and (b) high manganese content in the water caused plugging problems in the coils. Apparently, the Mn content of Westover's water is even higher than the analysis from other wells using water from the same aquifer.

Because Westover was situated above the fringe of this aquifer and because the aquifer is not extensive in size, the situation was similar to a perched water table. Westover was reinjecting heated water at a rate faster than the aquifer could cool the water. Consequently, by the end of each cooling season the groundwater temperature was 10 to 15°F higher than it was at the start of the season. The cooling system was designed to use 55° water for its operation and apparently was not operating properly on the warmer water.

In the winter, the use of the groundwater for heating would change the supply water from 65°F down to 48°F by the end of the heating season. This temperature cycling would seem ideal for a groundwater heat pump; i.e., warm water in the winter, cold water in the summer. It appears that the cooling and heating system was not equipped to efficiently take advantage of the temperature range (48 to 70°F) of the groundwater. However, the most important factor in the demise of this cooling system may have been the poor water quality (high Fe and Mn). The high temperatures in the cooling system water (around 90°F late in the summer) created severe manganese (and possibly iron) precipitation problems in the coils of the system. If the reinjection wells had been located further away from the supply wells, the temperature fluctuation probably would not have been evident. Manganese problems also may not have been as severe although this is only speculation.

Site No. 36: OK Elementary School, Wichita, Kansas

Description: The school is cooled and heated with nine American Air Filter Ener-Con Units, which are water to air heat pumps (Figure 4, p. 9). Total rated cooling capacity for the system is 32-1/2 tons. The inlet water temperature is 59°F, and the discharge temperature is 85°F. Water flow rate through the system is 70 gpm at 40 psi. The water is subjected to electrostatic water treatment, which successfully eliminates scaling and keeps any iron in the water in suspension.

The source well is 200 ft from the two reinjection wells and all wells are 50 ft deep. Depth to the Pleistocene sand and gravel aquifer is 30 ft; static water level is 12 ft. Water quality data for the region show some wells with high iron content, although information we have from well drillers is that this site is in an area of low iron. Water quality data from a well 1-1/2 miles away show hardness is 150 mg/liter as CaCO₃.

Analysis: During the past 4 years of operation, no problems have occurred with either the cooling system or the well system.

Site No. 37: Cleveland Elementary School, Wichita, Kansas

Description: The school is cooled directly by groundwater using Trane Air Handling Units which contain water coils (Figure 1-B, p. 6). The groundwater is supplied from a 55-ft deep well at a rate of 200 gpm and temperature of 62°F. The disposal well is 34 ft deep; depth to water fluctuates between 4 and 8 ft. The aquifer consists of Pleistocene sands and gravels. Water quality data from another shallow well 3/4 mile away show the shallow water is high in iron (2.4 ppm); however, this may only be a very local problem. Data from a 91-ft well 1/2 mile away showed a total hardness of 115 mg/liter as CaCO₃. The water used in the school's cooling system also undergoes electrostatic water treatment.

Analysis: The reinjection well for this site had to be abandoned because groundwater levels were so high (4 to 8 ft) that the well could not take the discharge water. However, Layne-Western Company said that a ratio of two or three disposal wells to one supply well is a common practice in the high water table areas. An additional disposal well or two might have solved the reinjection problem.

Site No. 38: Aviation Education Center, Wichita, Kansas

Description: This is a vocational school which is cooled by 11 Friedrich Climate Master water-to-air heat pumps (Figure 4, p. 9) ranging in rated cooling capacity from 3.5 to 16.5 tons. Total rated cooling capacity is 60 tons for the entire center. Total flow rate for cooling water was not available, but individual unit rates range from 7 to 26 gpm. Inlet temperature is about 75°F, and discharge temperature is about 95°F. The source and reinjection wells are 200 ft apart. The source well is 78 ft deep, and the reinjection well is 48 ft deep. Both wells are in Pleistocene sands and gravels. There are several clay layers between the surface and bottom of the wells. Iron content of the water is not available but is probably not a problem. Water quality will probably be similar to that of OK Elementary School.

Analysis: The only problem this site has had is similar to that of Cleveland Elementary School, a high static water level. They have one supply disposal well and only one disposal well. They capped the vent on the disposal well and forced the water into the aquifer. Additional disposal wells might solve the reinjection problem. However, there is a drainage ditch nearby that keeps the static water level high, and there does not appear to be anywhere for the water to go.

Site No. 39: Certified Bakers, Wichita, Kansas

Description: The bakery was using a fan-coil unit to cool the building from 1966 to 1968. Groundwater was supplied to the coils at a temperature of 60°F and a rate of 60 to 70 gpm. Discharge temperature was about 65°F. The schematic diagram is represented by Figure 1-B, p. 6. There was one supply well and two disposal wells. All wells are around 42 ft deep and are in Pleistocene sand and gravels. The disposal wells were redeveloped in the second year of operation because of plugging problems. It was

found that the water was probably high in iron, and a recommendation was made to treat the wells annually. After they were redeveloped, the wells could take 60 gpm each. No water quality data are available for the area, but it appears iron content is high, at least locally.

Analysis: This site discontinued groundwater cooling the same year the wells were redeveloped. The reason given by the bakery was that flour dust was caking on the cooling coils because of the condensation on the coils. Therefore, they were not getting any cooling. An additional problem with the site, according to a consulting engineer for the bakery, was iron precipitation in the disposal wells which caused them to overflow. There appears to be a question as to whether the discharge tubes in the re-injection wells were above or below the static water level. If they were above, then iron fouling problems were very likely to occur.

Site No. 40: University of Friends Church, Wichita, Kansas

Description: Cooling information was not complete for the site, but it appears that groundwater is used in cooling a condenser of an old Trane unit and is also circulated to a new Carrier heat pump with a 65- to 70-ton capacity (Figure 3, p. 8). Water temperature from the supply well is 60°F; discharge temperature is 85°F. Flow rate is estimated to be between 50 and 65 gpm. There is one supply and one disposal well, both in the same sand and gravel aquifer from 12 to 35 ft deep. Water quality data from the area show that iron is a problem. One well in the next section had a Fe concentration of 4.8 ppm. Layne-Western thought a value of 0.3 ppm Fe might be more realistic for this site.

Analysis: This site has had no problems with their cooling system or the reinjection well. They must acidize the well annually, however, to ensure that they do not have problems with iron fouling.

8.2 SANDSTONE

Site No. 41: American Telephone and Telegraph Co., Norway, Illinois

Description: The groundwater in this installation first pre-cools the air for 12 parallel air handling units and is then used for condensing the cooling system's hot gaseous refrigerant in a condenser. A schematic diagram of the system is very similar to that shown in Figure 2 (p. 7) except that this system has more than one duct and fan arrangement using groundwater. Groundwater is being pumped at a rate of 400 gpm and a temperature of 61°F to the cooling system. Discharge temperature is about 80°F. There are two supply wells, and both are tapping water-bearing sandstone formations that are located at various depths, as indicated in the well log. These wells are about 1,350 ft deep. Distance to water when not pumping is 244 ft. One well is used all the time; the second well has a larger, more inefficient pump and is used only as a backup. There is only one disposal well, but it can take a vast amount of water. The well is 608 ft deep and passes through three sandstone layers. Water level when not pumping is 205 ft. This well takes water so fast that a vacuum is created on the discharge

line. Water quality data for the well show a total hardness around 450 mg/liter as CaCO_3 and only a trace of iron.

Analysis: The cooling system was changed in 1976 from a steam absorption chiller to reciprocating type chillers due to increased fuel costs. With this change, no water treatment is required because the cooling system water is circulated at a lower temperature. Apparently, scaling problems were occurring with the old system. However, no information was provided as to the type of water treatment, if any, performed prior to 1976.

8.3 LIMESTONE AND DOLOMITE

Site No. 42: Private residence, Bellevue, Ohio

Description: This site and site No. 43 are very much the same. Both sites are heated and cooled with a Tetco water-to-air heat pump (Figure 4, p. 9). Flow rate through the system is 10 gpm, and water temperature is 54°F. Discharge temperature is around 62°F.

These sites are unique in that they are discharging to the supply well. The well for this site is 100 ft deep and located in "hard limestone with direct openings," as the well driller described it. The top 8 ft of the well is in clay, and the rest is in limestone. Depths to the producing zones are about 70 and 100 ft. Static water level in the well is about 50 ft. The 6-in. well has a 4-in. plastic liner running the length of the well (100 ft). A packer has been placed between the well wall and the 4-in. liner at a depth of 70 ft. Water is pumped from the 100-ft level and returned (outside the 4-in. liner) to the 70-ft level. The system appears to be working very well but is less than a year old. Water quality data for the area are incomplete and variable. The entire limestone aquifer in this region of Ohio was used for waste disposal for many years. Therefore, there are localized water quality problems. From the well driller's information, total hardness is probably over 400 mg/liter as CaCO_3 and iron concentration is very low for this site as well as for site No. 43.

Analysis: See site No. 43.

Site No. 43: Private residence, Bellevue, Ohio

Description: This site is almost identical to site No. 42 except that instead of hard limestone, this well is in soft, fractured limestone. The well is 163 ft deep; the static water level is 110 ft. Depths to the producing zones are 125 and 160 ft. The packer in this well was placed at 125 ft. Water is pumped from 160 ft and reinjected just above 125 ft. Water quality information is incomplete and variable. (See Description for site No. 42.)

Analysis: Both sites are new (less than a year old), but the principle upon which they are operating is sound. The original intention for reinjecting above the supply zone was to have warm water (or cool water depending on the season) slowly migrate from the injection zone down to the supply zone and eventually raise (or lower) the temperature in the supply zone. Thus, the supply water formation could be used as a heat sink.

The theory is fairly sound, but each site had a problem that kept the theory from working. At site No. 42, the water injection rate was too slow to make any change in temperature. At high injection rates, the well driller thinks, there would eventually be a temperature change in the lower zone. At site No. 43, the water from the injection zone was intermixing too rapidly with the supply zone. One speculation was that water intermixing was occurring within the well and that if the well were grouted between the two zones, it would eliminate the problem. Neither situation has influenced the operation of the cooling systems.

One question that has not been answered is the means by which the warmer, less dense injected water will migrate through the limestone to the supply zone of colder, denser water.

Site No. 44: Rich Township High School, Olympia Fields, Illinois

Description: This cooling system is 16 years old. Within the system is a groundwater cooled Bell and Gossett shell and tube heat exchanger (Figure 4, p. 9). Flow rate of water supplied to the exchanger is 1,500 gpm at a temperature of 55°F, and discharge temperature is 70°F. There are two supply wells and two discharge wells. The supply and discharge wells are about 240 ft apart. All four wells are about 300 to 310 ft deep and are in a dolomitic limestone formation. Water quality information show that the groundwater is extremely hard (539 mg/liter as CaCO₃). Iron is moderately high at 0.3 ppm.

Analysis: The school is having plumbing problems described as the rusting of pipes caused by the quality of the well water. The extremely hard water is probably causing the problems in the galvanized pipes. There has apparently been no problem with reinjection, however.

Site No. 45: Commonwealth Edison - Unmanned Substation, Goodings Grove, Illinois

Description: This unmanned substation was using groundwater to cool condenser water through a shell and tube heat exchanger. A total of 860 gpm of condenser water from two condensers was entering the shell side at 104°F and leaving at 85°F. The groundwater, however, was entering the tube side at a flow rate of 420 gpm and a temperature of 55°F, and leaving at 93.9°F. In this application, groundwater was used for direct cooling. A schematic diagram would be very similar to Figure 1-A (p. 6) in Chapter 2, except that the water to be cooled is on the shell side and the groundwater is on the tube side. The condenser system and, therefore, the groundwater cooling system, was discontinued in 1972 after being in operation since 1959. The equipment requiring this system was replaced with more advanced equipment.

Prior to 1959, the groundwater was pumped directly through the condensers to provide cooling. However, because of extensive water chemistry problems, the condenser cooling water circuit was made a closed system in 1959. It was then that the heat exchanger was installed to use groundwater to cool the condenser water.

There were two supply wells supplying groundwater, but only one well was used at a time. Supply well No. 2 is 300 ft deep; the bottom 143 ft are in the Niagaran dolomite formation. Depth to static water was 105 ft in 1958. Supply well No. 1 is 485 ft deep and is also in dolomite. Depth to static water was 82 ft in 1958. There is only one recharge well, and it is 350 ft from supply well No. 1 and 815 ft from supply well No. 2. It was initially 202 ft deep but was deepened to 495 ft in 1957. Depth to static water level in the recharge well was 92 ft in 1958. Water quality analysis by the Illinois State Water Survey Division shows that in 1957 total hardness was 720 mg/liter as CaCO_3 ; iron concentration was 1.0 ppm. No hydrogen sulfide was detected. However, in 1959, iron concentration was 3 ppm; H_2S concentration ranged from 0.1 to 1.2 ppm, and free carbon dioxide concentration was fairly high. Thus, the water had become corrosive.

Analysis: From the start, this site was beset with many corrosion, plugging, and scaling problems in the wells and condensing system. The corrosion problem became apparent in 1959 when a considerable amount of black sediment consisting principally of iron and copper sulfides was found in the discharge water. In a water analysis, hydrogen sulfide was found in the supply well waters. Subsequently, the presence of free carbon dioxide in the well water also became a serious corrosion problem. Visual inspection of a section of pipe which had been removed from a discharge line showed that rapid corrosion had taken place. The inside of the pipe was covered with a thick scale which consisted of iron oxide and iron sulfide.

Another problem in the substation well system was the presence of the iron bacteria, Crenothrix. The presence of this bacteria combined with the insoluble gelatinous, ferric hydroxide precipitate caused the recharge well to plug up shortly after it was put into operation in 1957. The well was drilled deeper at that time.

In June 1959, chemical treatment of the supply water was started. Solutions of sodium hypochlorite to control hydrogen sulfide corrosion and sodium citrate, an iron sequestering reagent, were injected simultaneously into supply well No. 1. After about 5 weeks of continuous treatment it became apparent that much of the sodium hypochlorite was being consumed by bacterial deposits in the piping and condenser cooling coils. So for 4 days the sodium citrate feed was discontinued and a heavy dosage of sodium hypochlorite was fed to remove the bacterial growths. The original hypochlorite-citrate treatment was then resumed. It was continued until mid-August when sodium hydroxide additions also were begun to increase the pH of the water.

The sodium citrate treatment was effective in retaining iron in solution for at least 16 hr, which, according to the Illinois State Geological Survey, is adequate to prevent plugging of underground formations of recharge wells. The strong chlorination (sodium hypochlorite treatment) for removing the Crenothrix growths from piping and tubing was effective, and the continuous chlorination eliminated hydrogen sulfide and prevented recurrence of bacterial growths. However, when this was accomplished it was found by weighing copper and steel corrosion test coils that corrosion had increased because of the absence of the protective scales and films.

The sodium hydroxide additions were an attempt to decrease the corrosiveness of the water by neutralizing part of the free CO₂ and increasing the pH of the water. A feed of 2 gal. of 50% sodium hydroxide per day was only slightly effective in increasing the pH, and the rate of corrosion on steel was not reduced.

Theoretical calculations showed that to neutralize the free carbon dioxide to a level which would mitigate corrosion of steel would require about 300 lb of sodium hydroxide per day and would cost about \$15. The total chemical cost was projected to be about \$25 per day at a water flow of 5 million pounds per day.

An experimental decarbonator was designed, and field tests showed that it was effective in reducing the free carbon dioxide content of the water, thereby increasing its pH from 7.1 to 7.8. Although no corrosion rates were determined during this test, it is probable that decarbonation would have reduced corrosion appreciably.

However, because of the cost which would be entailed in the adequate chemical treatment of the Goodings Grove water, or in the alternate cost of installing a full-scale decarbonator, it was decided that the condenser cooling water circuit should be made a closed system. In 1959, the system was changed, and the closed loop water was cooled by groundwater in a heat exchanger with stainless steel tubes. In addition the existing well supply piping was replaced with plastic lines and other corrosion-resistant piping.

APPENDIX

SUMMARIZED SITE DATA

WELL SYSTEM INFORMATION

Site No. 1

Well location: Business or residence name CF Industries

Street West Highway 34 City, State, Zip Aurora, Nebraska 68818

	Source Wells #1 & #2	Reinjection Wells #1 & #2
Year well drilled	<u>1944</u>	<u>1944</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>185 ft</u>	<u>185 ft</u>
Depth to producing zone	<u>90 ft</u>	<u>90 ft</u>
Static water level	<u>112 ft</u>	<u>112 ft</u>
Water level when pumping	<u>117 ft @ 850 gpm</u>	<u></u>
Potential well yield	<u>170 gpm/ft</u>	<u></u>
Initial well yield	<u>850 GPM</u>	<u></u>
Typical pumping and reinjection rates	<u>300 GPM</u>	<u>150 GPM</u>
Casing depth	<u>185 ft</u>	<u>185 ft</u>
Casing size	<u>18</u>	<u>#1 #2 18; 16 in</u>
Type of casing material	<u>concrete</u>	<u>#2 concrete, steel</u>
Screened interval	<u>60 ft</u>	<u>ft</u>
Type of screen used	<u>concrete</u>	<u>#2 concrete, steel</u>
Gravity or pumped reinjection?		<u>gravity</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>160 ft</u>	<u>ft</u>
Permit required? <u>yes</u> If so, by whom? <u>State</u>		
Distance from source well to reinjection well <u>550</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>gravel & sand</u>	<u>gravel & sand</u>

WATER QUALITY DATA AND WELL LOG

Site No. 1 C.F. Industries, Aurora, Nebraska

Water Quality (Ave. of wells in region)

	Mg/l		Mg/l
Calcium (Ca)	<u>53</u>	Dissolved Solids	<u>250</u>
Magnesium (Mg)	<u>8</u>	Hardness as CaCO ₃	<u>164</u>
Iron (Fe)	<u>0.014</u>	Noncarbonate	<u></u>
Manganese (Mn)	<u>0.008</u>	Bicarbonate (HCO ₃)	<u>190</u>
Chloride (Cl)	<u>9</u>	Alkalinity as CaCO ₃	<u>156</u>
Sulfate (SO ₄)	<u>40</u>	pH	<u>7.3</u>

Well Log (depths in feet)

No well log received

WELL SYSTEM INFORMATION

Site No. 2

Well location: Business or residence name U.S. Meat Animal Research Center

Street P. O. Box 166 City, State, Zip Clay Center, NE 68933

	Source Wells #1	Reinjection Wells #4
Year well drilled	<u>1969</u>	<u>1969</u>
Type of well construction	<u>gravel pack</u>	<u>gravel pack</u>
Depth of well	<u>220 ft</u>	<u>145 ft</u>
Depth to producing zone	<u>158 ft</u>	<u>115 ft</u>
Static water level	<u>89 ft</u>	<u>89 ft</u>
Water level when pumping	<u>102 ft @ 600 gpm</u>	<u>98 ft @ 500 gpm</u>
Potential well yield	<u>46 gpm @ 24 hr</u>	<u>55 gpm/ft @ 3 hr</u>
Initial well yield	<u>600 gpm @ 24 hr</u>	<u>500 gpm @ 3 hr</u>
Typical pumping and reinjection rates	<u>200-600 GPM</u>	<u>300-600 GPM</u>
Casing depth	<u>193 ft</u>	<u>115 ft</u>
Casing size	<u>10 in</u>	<u>12 in</u>
Type of casing material	<u>steel</u>	<u>steel</u>
Screened interval	<u>190-220 ft</u>	<u>113-145 ft</u>
Type of screen used	<u>cook-bronze</u>	<u>cook-bronze</u>
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake		
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well _____		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>gravel</u>	<u>gravel</u>

WELL SYSTEM INFORMATION

Site No. 2

Well location: Business or residence name U.S. Meat Animal Research Center

Street P. O. Box 166 City, State, Zip Clay Center, NE 68933

	Source Wells #5	Reinjection Wells #6
Year well drilled	<u>1976</u>	<u>1976</u>
Type of well construction	<u>gravel pack</u>	<u>gravel pack</u>
Depth of well	<u>215 ft</u>	<u>155 ft</u>
Depth to producing zone	<u>175 ft</u>	<u>63 ft</u>
Static water level	<u>94 ft</u>	<u>94 ft</u>
Water level when pumping	<u>120 ft @ 6 hr</u>	<u>107 ft @ 1032 gpm</u>
Potential well yield	<u>56 gpm/ft @ 6 hr</u>	<u>79 gpm/ft @ 6 hr</u>
Initial well yield	<u>1400 gpm @ 6 hr</u>	<u>1032 gpm @ 6 hr</u>
Typical pumping and reinjection rates	<u>1400-1800 GPM</u>	<u>1400-1700 GPM</u>
Casing depth	<u>175 ft</u>	<u>116 ft</u>
Casing size	<u>16 in</u>	<u>16 in</u>
Type of casing material	<u>steel</u>	<u>steel</u>
Screened interval	<u>175-215 ft</u>	<u>95-125 ft</u>
Type of screen used	<u>Mustang</u> <u>(stainless steel)</u>	<u>Mustang</u> <u>(stainless steel)</u>
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake		
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well _____		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>gravel</u>	<u>gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 2 U.S. Meat Animal Research Center

Water Quality

	Mg/l		Mg/l
Calcium (Ca)	<u>59</u>	Dissolved Solids	<u></u>
Magnesium (Mg)	<u>13</u>	Hardness as CaCO ₃	<u>200</u>
Iron (Fe)	<u>0.15</u>	Noncarbonate	<u>0</u>
Manganese (Mn)	<u><0.04</u>	Bicarbonate (HCO ₃)	<u></u>
Chloride (Cl)	<u>10</u>	Alkalinity as CaCO ₃	<u>216</u>
Sulfate (SO ₄)	<u>43</u>	pH	<u>7.1</u>

Well Log (depths in feet) (Supply Well #5)

0	-	1	Top Soil
1	-	20	Gray Clay
20	-	56	Brown-gray Clay
56	-	58	Fine Sand
58	-	61	Gray Clay
61	-	79	Fine Coarse Sand-Clay Streaks
79	-	84	Gray Clay
84	-	114	Coarse Fine Sand & Gravel
114	-	120	Gray Clay
120	-	122	Fine Sand
122	-	129	Gray Clay
129	-	135	Coarse Fine Sand & Gravel
135	-	152	Gravel Coarse Sand
155	-	160	Brown Clay
160	-	175	Coarse-Fine Sand-Gravel
175	-	215	Gravel - Coarse Fine Sand

WELL SYSTEM INFORMATION

Site No. 3

Well location: Business or residence name Private Residence

Street _____ City, State, Zip Lake Poinsett, South Dakota

	Source Wells	Reinjection Wells
Year well drilled	<u>1966</u>	<u>1979</u>
Type of well construction	<u>Open end</u>	
Depth of well	<u>16 ft</u>	<u>16 ft</u>
Depth to producing zone	<u>ft</u>	<u>10 ft</u>
Static water level	<u>13 ft</u>	<u>7 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>30 GPM/ft</u>	<u>GPM</u>
Initial well yield	<u>30 GPM</u>	<u>13 GPM</u>
Typical pumping and reinjection rates	<u>8 GPM</u>	<u>8 GPM</u>
Casing depth	<u>16 ft</u>	<u>22 ft</u>
Casing size	<u>24 in</u>	<u>12 in</u>
Type of casing material	<u>concrete</u>	<u>PVC</u>
Screened interval	<u>ft</u>	<u>13-18 ft</u>
Type of screen used		<u>slotted plastic</u>
Gravity or pumped reinjection?		<u>pumped</u>
Type of pump	<u>Jet pump</u>	
Depth of pump intake	<u>13 ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well <u>100 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u>fine sand</u>		<u>gravel and fine sand</u>

WATER QUALITY DATA AND WELL LOG

Site No. 3 Private Residence, Lake Poinsett, South Dakota

Water Quality (Supply Well)

	Mg/l		Mg/l
Calcium (Ca)	<u>144</u>	Dissolved Solids	<u> </u>
Magnesium (Mg)	<u>72</u>	Hardness as CaCO ₃	<u>655</u>
Iron (Fe)	<u>0.38</u>	Noncarbonate	<u>464</u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>380</u>
Chloride (Cl)	<u> </u>	Alkalinity as CaCO ₃	<u>78</u>
Sulfate (SO ₄)	<u> </u>	pH	<u> </u>

Well Log (depths in feet)

No well log received

WELL SYSTEM INFORMATION

Site No. 4

Well location: Business or residence name Idaho State University

Street 1000 East Lovejoy City, State, Zip Pocatello, Idaho 83209

	Source Wells	Reinjection Wells
Year well drilled	<u>1976</u>	<u>1976</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>280 ft</u>	<u>230 ft</u>
Depth to producing zone	<u>180 ft</u>	<u>130 ft</u>
Static water level	<u>ft</u>	<u>ft</u>
Water level when pumping	<u>100 ft</u>	<u>95 ft</u>
Potential well yield	<u>500 GPM</u>	<u>500 GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>572 GPM</u>	<u>572 GPM</u>
Casing depth	<u>200 ft</u>	<u>150 ft</u>
Casing size	<u>12 in</u>	<u>12 in</u>
Type of casing material	<u>steel</u>	<u>steel</u>
Screened interval	<u>30 ft</u>	<u>30 ft</u>
Type of screen used	<u>Brass perforated</u>	<u>Brass perforated</u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u>Layne & Bowler</u>	<u>Layne & Bowler</u>
Depth of pump intake	<u>180 ft</u>	<u>130 ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Idaho Water Resource Board</u>		
Distance from source well to reinjection well <u>270 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>sand & gravel</u>	<u>sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 4 Idaho State University Library, Pocatello, Idaho

Water Quality (Ave. of two nearby city wells in Pocatello)

	Mg/l		Mg/l
Calcium (Ca)	<u>74</u>	Dissolved Solids	<u>409</u>
Magnesium (Mg)	<u>27</u>	Hardness as CaCO ₃	<u>296</u>
Iron (Fe)	<u>0.02</u>	Noncarbonate	<u></u>
Manganese (Mn)	<u>0.01</u>	Bicarbonate (HCO ₃)	<u>438</u>
Chloride (Cl)	<u>41</u>	Alkalinity as CaCO ₃	<u></u>
Sulfate (SO ₄)	<u>36</u>	pH	<u>7.6</u>

Well Log (depths in feet)

Well log not received

WELL SYSTEM INFORMATION

Site No. 5

Well location: Business or residence name Southdale Shopping Center

Street 66th St. & France Avenue City, State, Zip Edina, Minnesota

	Source Wells #3	Reinjection Wells #2
Year well drilled	<u>1956</u>	<u>1956</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>452 ft</u>	<u>177 ft</u>
Depth to producing zone	<u>ft</u>	<u>128 ft</u>
Static water level	<u>73 ft</u>	<u>ft</u>
Water level when pumping	<u>73-76 ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>737-1000 GPM</u>	<u>GPM</u>
Casing depth	<u>233 ft</u>	<u>140 ft</u>
Casing size	<u>12 in</u>	<u>12 in</u>
Type of casing material	<u>steel</u>	<u>steel</u>
Screened interval	<u>ft</u>	<u>20 ft</u>
Type of screen used	<u></u>	<u>stainless steel</u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u></u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Jordan sandstone</u>	<u>sand & gravel</u>

WELL SYSTEM INFORMATION

Site No. 5

Well location: Business or residence name Southdale Shopping Center

Street 66th St. & France Avenue City, State, Zip Edina, Minnesota

	Source Wells #1	Reinjection Wells
Year well drilled	<u>1956</u>	<u></u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>442 ft</u>	<u>ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>70 ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>800-1400 GPM</u>	<u>GPM</u>
Casing depth	<u>247 ft</u>	<u>ft</u>
Casing size	<u>12 in</u>	<u>in</u>
Type of casing material	<u>steel pipe</u>	<u></u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u>ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u>Jordan sandstone</u>		

WATER QUALITY DATA AND WELL LOG

Site No. 5 Southdale Shopping Center, Edina, Minnesota

Water Quality

	Mg/l		Mg/l
Calcium (Ca)	<u>56</u>	Dissolved Solids	<u>291</u>
Magnesium (Mg)	<u>14</u>	Hardness as CaCO ₃	<u>199</u>
Iron (Fe)	<u>0.1</u>	Noncarbonate	<u></u>
Manganese (Mn)	<u></u>	Bicarbonate (HCO ₃)	<u>336</u>
Chloride (Cl)	<u>19</u>	Alkalinity as CaCO ₃	<u>275</u>
Sulfate (SO ₄)	<u>21</u>	pH	<u>7.4</u>

Well Log (depths in feet) (Supply Well #3)

0- 82 Drift
82-129 Sandy Clay
129-177 Sand, Gravel, Boulders
177-185 Hard Clay/Rock
185-210 Sand, Gravel, Streaks of Clay
210-233 Limestone
233-247 Gravel/Sand
247-380 Limestone
380-452 Jordan Sandstone

WELL SYSTEM INFORMATION

Site No. 6

Well location: Business or residence name Artistic Woven Labels Inc.

Street West Highway 6 City, State, Zip Holdrege, Nebraska 68949

	Source Wells	Reinjection Wells
Year well drilled	<u>1962</u>	<u>1962</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>226 ft</u>	<u>180 ft</u>
Depth to producing zone	<u>165 ft</u>	<u>ft</u>
Static water level	<u>ft</u>	<u>ft</u>
Water level when pumping	<u>185 ft</u>	<u>ft</u>
Potential well yield	<u>270 GPM</u>	<u>GPM</u>
Initial well yield	<u>400 GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>240 GPM</u>	<u>240 GPM</u>
Casing depth	<u>226 ft</u>	<u>180 ft</u>
Casing size	<u>9-7/8 in</u>	<u>8 in</u>
Type of casing material	<u>cast iron</u>	<u></u>
Screened interval	<u>15 ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u>Gravity</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u>150 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u>Sand</u>		

WATER QUALITY DATA AND WELL LOG

Site No. 6 Artistic Woven Labels, Holdrege, Nebraska

Water Quality

	Mg/l		Mg/l
Calcium (Ca)	<u>115</u>	Dissolved Solids	<u>609</u>
Magnesium (Mg)	<u>14</u>	Hardness as CaCO ₃	<u>342</u>
Iron (Fe)	<u>0.06</u>	Noncarbonate	<u>121</u>
Manganese (Mn)	<u>-</u>	Bicarbonate (HCO ₃)	<u>270</u>
Chloride (Cl)	<u>34</u>	Alkalinity as CaCO ₃	<u>221</u>
Sulfate (SO ₄)	<u>201</u>	pH	<u>7.6</u>
Sodium (Na)	<u>56</u>		

Well Log (depths in feet)

No well log received

WELL SYSTEM INFORMATION

Site No. 7

Well location: Business or residence name Eric Gerstenberger

Street 1355 Rimline Road City, State, Zip Idaho Falls, Idaho

	Source Wells	No ReInjection
Year well drilled	<u>1979</u>	<u></u>
Type of well construction	<u>Open end</u>	<u></u>
Depth of well	<u>470 ft</u>	<u></u>
Depth to producing zone	<u>455 ft</u>	<u></u>
Static water level	<u>410 ft</u>	<u></u>
Water level when pumping	<u>ft</u>	<u></u>
Potential well yield	<u>GPM</u>	<u></u>
Initial well yield	<u>GPM</u>	<u></u>
Typical pumping and reinjection rates	<u>GPM</u>	<u></u>
Casing depth	<u>450 ft</u>	<u></u>
Casing size	<u>8 in</u>	<u></u>
Type of casing material	<u>steel</u>	<u></u>
Screened interval	<u>ft</u>	<u></u>
Type of screen used	<u>none</u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u></u>	<u></u>
Permit required? <u></u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u></u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u>Broken shale</u>		

WATER QUALITY DATA AND WELL LOG

Site No. 7 Private Residence, Idaho Falls, Idaho

Water Quality (None available)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	_____
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	_____

Well Log (depths in feet)

<u>From</u>	<u>To</u>	<u>Material</u>
0	10	Soil
10	20	Soil and Gravel
20	25	Clay
25	40	Broken Shale
40	65	Firm Shale
65	80	White Pumice
80	90	Broken Shale
90	115	Soft White Pumice
115	195	Soft Brown Pumice
195	320	Firm Brown Pumice
320	335	Broken Brown Shale
335	355	Firm Shale
355	375	Broken Brown Shale
375	380	Firm Brown Shale
380	400	Brown Clay
400	410	Broken Shale
410	455	Hard Brown Shale
455	465	Broken Shale
465	470	Broken Shale-some Cinders

WELL SYSTEM INFORMATION

Site No. 8

Well location: Business or residence name Lido Regency Condominium

Street _____ City, State, Zip Sarasota, Florida

	Source Wells	Reinjection Wells
Year well drilled	<u>1967</u>	<u>1972</u>
Type of well construction	<u>Natural</u>	<u>Natural</u>
Depth of well	<u>457 ft</u>	<u>750 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>1640 GPM</u>
Typical pumping and reinjection rates	<u>350 GPM</u>	<u>350 GPM</u>
Casing depth	<u>350 ft</u>	<u>492 ft</u>
Casing size	<u>8 in</u>	<u>10 ft</u>
Type of casing material	<u>Black Iron</u>	<u>Black Iron</u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u>none</u>	<u>none</u>
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Sarasota County Health Department</u>		
Distance from source well to reinjection well _____		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Soft Limestone</u>	<u>Soft Limestone</u>

WATER QUALITY DATA AND WELL LOG

Site No. 8 Lido Regency Condominium, Sarasota, Florida

Water Quality (Reinjection Well)

	Mg/l		Mg/l
Calcium (Ca)	<u> </u>	Dissolved Solids	<u>1463</u>
Magnesium (Mg)	<u> </u>	Hardness as CaCO ₃	<u>1000</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>164</u>
Chloride (Cl)	<u>161</u>	Alkalinity as CaCO ₃	<u>135</u>
Sulfate (SO ₄)	<u>820</u>	pH	<u>8.3</u>

Well Log (depths in feet) (Reinjection Well)

0	-	15	Sand
15	-	40	Brown Clay
40	-	42	Gray Rock
42	-	63	Gray Sandy Clay
63	-	65	Rock
65	-	175	Soft Sandy Gray Clay
175	-	190	Medium Hard Lime Rock
190	-	250	Soft Gray Clay
250	-	271	Soft White Gray
271	-	280	Very Hard Chirt Rock
280	-	303	Very Hard Brown Limestone
303	-	330	Soft Sandy Limestone
330	-	334	Hard Lime Rock
334	-	435	Soft Sandy Clay
435	-	530	Brown Limestone
530	-	750	SoftLime & Water

WELL SYSTEM INFORMATION

Site No. 9

Well location: Business or residence name Beach Terrace Condominium

Street Ocean Boulevard City, State, Zip Sarasota, Florida

	Source Wells	Reinjection Wells
Year well drilled	<u>(Not Available)</u>	<u>1970</u>
Type of well construction	<u></u>	<u>Natural</u>
Depth of well	<u></u>	<u>1348</u> ft
Depth to producing zone	<u></u>	<u></u> ft
Static water level	<u></u>	<u></u> ft
Water level when pumping	<u></u>	<u></u> ft
Potential well yield	<u></u>	<u>20 GPM/ft after 1/2 hr</u>
Initial well yield	<u></u>	<u>300 GPM after 1/2 hr</u>
Typical pumping and reinjection rates	<u></u>	<u></u> GPM
Casing depth	<u></u>	<u>562</u> ft
Casing size	<u></u>	<u>6</u> in
Type of casing material	<u></u>	<u>Black Iron</u>
Screened interval	<u></u>	<u></u> ft
Type of screen used	<u></u>	<u>none</u>
Gravity or pumped reinjection?	<u></u>	<u>pumped</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u></u> ft	<u></u> ft
Permit required? <u></u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u></u> ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u></u>		<u>Floridan Limestone</u>

WATER QUALITY DATA AND WELL LOG

Site No. 9 Beach Terrace Condominium, Sarasota, Florida

Water Quality (Reinjection Well)

	Mg/l		Mg/l
Calcium (Ca)	<u>810</u>	Dissolved Solids	<u>29,680</u>
Magnesium (Mg)	<u>970</u>	Hardness as CaCO ₃	<u>6,000</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>196</u>
Chloride (Cl)	<u>15,400</u>	Alkalinity as CaCO ₃	<u> </u>
Sulfate (SO ₄)	<u>3,000</u>	pH	<u> </u>
Sodium (Na)	<u>8,800</u>		

Well Log (depths in feet) (Reinjection Well)

0	-	30	Sand
30	-	140	Marl with some limestone
140	-	280	Limestone
280	-	310	Dolomite
310	-	330	Marl
330	-	430	Limestone
430	-	450	Sand
450	-	470	Conglomerate (Limestone, Chert, Sand)
470	-	530	Sand
530	-	815	Limestone
815	-	1005	Dolomite
1005	-	1270	Limestone
1270	-	1348	Dolomite

WELL SYSTEM INFORMATION

Site No. 10

Well location: Business or residence name Manatee Junior College

Street 5840 26th Street, West City, State, Zip Bradenton, Florida 33507

	Source Wells #1	Reinjection Wells #4
Year well drilled	<u>1972</u>	<u></u>
Type of well construction	<u>Natural</u>	<u>Natural</u>
Depth of well	<u>520 ft</u>	<u>250 ft</u>
Depth to producing zone	<u>440 ft</u>	<u>ft</u>
Static water level	<u>ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>50 GPM/ft</u>	<u>GPM</u>
Initial well yield	<u>500 GPM</u>	<u>141 GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>44 ft, 44-149ft</u>	<u>80 ft</u>
Casing size	<u>8 in, 6 in</u>	<u>6 in</u>
Type of casing material	<u>Black Steel</u>	<u>Black Steel</u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u>none</u>	<u>none</u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>80 ft</u>	<u>ft</u>
Permit required? <u></u> If so, by whom? <u></u>		
Distance from source well to reinjection well (#1) <u>900</u> ft; (#4) <u>1425</u> ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Limestone</u>	<u>Limestone</u>

WELL SYSTEM INFORMATION

Site No. 10

Well location: Business or residence name Manatee Junior College

Street 5840 26th Street, West City, State, Zip Bradenton, Florida 33507

	<u>Source Wells</u> <u>#2</u>	<u>Reinjection Wells</u>
Year well drilled	<u>1967</u>	<u>1972; deepened in 1973</u>
Type of well construction	<u>Natural</u>	<u>Natural</u>
Depth of well	<u>480 ft</u>	<u>805 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>4 ft</u>	<u>5 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>66 GPM/ft</u>	<u>133 GPM/ft</u>
Initial well yield	<u>525 GPM</u>	<u>613 GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>69 ft; 155-294ft</u>	<u>351 ft, 213 ft</u>
Casing size	<u>8 in, 6 in</u>	<u>12 in, 10 in</u>
Type of casing material	<u>Black Steel</u>	<u>Black Steel</u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u>none</u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u>pumped</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Fla.Dept. of Pollution Control</u>		
Distance from source well to reinjection well <u>#2, 1150 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Limestone</u>	<u>Limestone</u>

WELL SYSTEM INFORMATION

Site No. 10

Well location: Business or residence name Manatee Junior College

Street 5840 26th Street, West City, State, Zip Bradenton, Florida 33507

	Source Wells #3	Source Wells #5
Year well drilled		
Type of well construction	Natural	Natural
Depth of well	250 ft	250 ft
Depth to producing zone	ft	ft
Static water level	ft	ft
Water level when pumping	ft	ft
Potential well yield	GPM	GPM
Initial well yield	300 GPM	300 GPM
Typical pumping and reinjection rates	GPM	GPM
Casing depth	80 ft	80 ft
Casing size	6 in	6 in
Type of casing material	Black Steel	Black Steel
Screened interval	ft	ft
Type of screen used		
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake	ft	ft
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well #3, 1175 ft #5, 1625 ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	Limestone	Limestone

WATER QUALITY DATA AND WELL LOG

Site No. 10 Manatee Junior College, Bradenton, Florida

Water Quality

	Mg/l		Mg/l
Calcium (Ca)	<u>354</u>	Dissolved Solids	<u>640</u>
Magnesium (Mg)	<u>170</u>	Hardness as CaCO ₃	<u>1582</u>
Iron (Fe)	<u>0.1</u>	Noncarbonate	<u>196</u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>400</u>
Chloride (Cl)	<u>114</u>	Alkalinity as CaCO ₃	<u>328</u>
Sulfate (SO ₄)	<u>295</u>	pH	<u>7.2</u>

Well Log (depths in feet) (Reinjection Well)

0 - 40	Brown Sand	450 - 510	White Lime
40 - 42	Rock	510 - 515	White Lime Rock
42 - 50	Light Gray Clay	515 - 520	Water
50 - 120	Light Gray Clay	525 - 550	Limestone
120 - 121	Rock	550 - 560	Limestone & Water
121 - 155	Sandy Clay	560 - 565	Hard Limestone
155 - 157	Rock	565 - 575	Limestone & Water
157 - 180	Sandy Clay	575 - 580	Hard Limestone
180 - 240	Sandy Clay	580 - 625	Limestone & Water
240 - 260	Green Clay & Rock	625 - 655	Limestone
260 - 280	Green Clay	655 - 690	Hard Yellow Limestone
280 - 330	Sandy Clay	690 - 700	Limestone & Water
330 - 400	White Lime Rock	700 - 720	Hard Limestone
400 - 440	White Lime	720 - 805	Yellow Limestone & Water
440 - 450	White Lime Rock (Water)		

WELL SYSTEM INFORMATION

Site No. 11

Well location: Business or residence name Florida State University

Street _____ City, State, Zip Tallahassee, Florida 32306

	Source Wells 21	Reinjection Wells 15
Year well drilled	(Too Many to List)	
Type of well construction		
Depth of well		
Depth to producing zone		
Static water level		
Water level when pumping		
Potential well yield		
Initial well yield		
Typical pumping and reinjection rates		
Casing depth		
Casing size		
Type of casing material		
Screened interval		
Type of screen used		
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake		
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well _____		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Limestone</u>	<u>Limestone</u>

WATER QUALITY DATA AND WELL LOG

Site No. 11 Florida State University, Tallahassee, Florida

Water Quality (City of Tallahassee - ave. of 3 wells)

	Mg/l		Mg/l
Calcium (Ca)	<u>39</u>	Dissolved Solids	<u>169</u>
Magnesium (Mg)	<u>11</u>	Hardness as CaCO ₃	<u>138</u>
Iron (Fe)	<u>0.01</u>	Noncarbonate	<u></u>
Manganese (Mn)	<u>0</u>	Bicarbonate (HCO ₃)	<u>167</u>
Chloride (Cl)	<u>4</u>	Alkalinity as CaCO ₃	<u>137</u>
Sulfate (SO ₄)	<u>6</u>	pH	<u>7.6</u>

Well Log (depths in feet)

Not available

WELL SYSTEM INFORMATION

Site No. 12

Well location: Business or residence name George Smith, Inc.

Street 16,316 Interstate 35 City, State, Zip Round Rock, Texas 75664

	Source Wells	Reinjection Wells
Year well drilled	<u>1978</u>	<u>1978</u>
Type of well construction	<u>Natural</u>	<u>Natural</u>
Depth of well	<u>420 ft</u>	<u>420 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>18 GPM</u>	<u>18 GPM</u>
Casing depth	<u>ft</u>	<u>ft</u>
Casing size	<u>4 in</u>	<u>4 in</u>
Type of casing material	<u>PVC</u>	<u>PVC</u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?		<u>pumped</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>400 ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u>300 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Limestone</u>	<u>Limestone</u>

WATER QUALITY DATA AND WELL LOG

Site No. 12

George Smith Inc., Round Rock, Texas

Water Quality (City of Round Rock)

	Mg/l		Mg/l
Calcium (Ca)	<u>99</u>	Dissolved Solids	<u>540</u>
Magnesium (Mg)	<u>17</u>	Hardness as CaCO ₃	<u>315</u>
Iron (Fe)	<u>0.04</u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u>< 0.02</u>	Bicarbonate (HCO ₃)	<u>327</u>
Chloride (Cl)	<u>23</u>	Alkalinity as CaCO ₃	<u>268</u>
Sulfate (SO ₄)	<u>49</u>	pH	<u>7.7</u>

Well Log (depths in feet)

Not available

WELL SYSTEM INFORMATION

Site No. 13

Well location: Business or residence name Hercules, Inc.

Street P. O. Box 2249 City, State, Zip Savannah, Georgia 31498

	Source Wells	Reinjection Wells
Year well drilled	<u>1956</u>	<u>1956</u>
Type of well construction	<u>Natural</u>	<u>Natural</u>
Depth of well	<u>1000 ft</u>	<u>750 ft</u>
Depth to producing zone	<u>114 ft</u>	<u>ft</u>
Static water level	<u>114 ft</u>	<u>114 ft</u>
Water level when pumping	<u>100 ft</u>	<u>ft</u>
Potential well yield	<u>1700 GPM</u>	<u>820 GPM</u>
Initial well yield	<u>1700 GPM</u>	<u>820 GPM</u>
Typical pumping and reinjection rates	<u>1700 GPM</u>	<u>820 GPM</u>
Casing depth	<u>270 ft</u>	<u>244 ft</u>
Casing size	<u>12 in</u>	<u>8 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>None</u>	<u>None</u>
Type of screen used	<u>None</u>	<u>None</u>
Gravity or pumped reinjection?		<u>Gravity</u>
Type of pump	<u>Layne & Bowler</u>	<u>-</u>
Depth of pump intake	<u>270 ft</u>	<u>- ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Georgia EPA</u>		
Distance from source well to reinjection well <u>1000 ft</u>		
Type aquifer materials (e.g., sandstone, Limestone, gravel, sand, etc.) <u>some sand</u>		<u>Limestone, some sand</u>

WELL SYSTEM INFORMATION

Site No. 14

Well location: Business or residence name General Services Administration

Street Federal Building City, State, Zip Savannah, Georgia 31412

	<u>Source Wells</u>	<u>Reinjection Wells</u>
Year well drilled	<u>1958</u>	<u>1958</u>
Type of well construction	<u>Natural</u>	<u>Natural</u>
Depth of well	<u>750 ft</u>	<u>750 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>1000 GPM</u>	<u>1000 GPM</u>
Casing depth	<u>750 ft</u>	<u>750 ft</u>
Casing size	<u>6 in</u>	<u>6 in</u>
Type of casing material	<u>Steel</u>	
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used		
Gravity or pumped reinjection?		
Type of pump	<u>50 hp Centrifugal</u>	
Depth of pump intake	<u>300 ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well <u>300 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Limestone</u>	<u>Limestone</u>

WATER QUALITY DATA AND WELL LOG

Site No. 13 & 14 Hercules Inc., and GSA, Federal Building, Savannah, Georgia

Water Quality (Savannah City Wells)

	Mg/l		Mg/l
Calcium (Ca)	<u>26</u>	Dissolved Solids	<u>170</u>
Magnesium (Mg)	<u>10</u>	Hardness as CaCO ₃	<u>106</u>
Iron (Fe)	<u>0.02</u>	Noncarbonate	<u>0</u>
Manganese (Mn)	<u></u>	Bicarbonate (HCO ₃)	<u>134</u>
Chloride (Cl)	<u>7</u>	Alkalinity as CaCO ₃	<u></u>
Sulfate (SO ₄)	<u>6</u>	pH	<u>7.6</u>

Well Log (depths in feet)

Not received for either site

WELL SYSTEM INFORMATION

Site No. 15

Well location: Business or residence name Private Residence

Street _____ City, State, Zip Indian Land, S. C.

	Rejection and Source Well	Reinjection Wells
Year well drilled	<u>1975</u>	_____
Type of well construction	<u>Natural</u>	_____
Depth of well	<u>232 ft</u>	<u>ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>160 ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>pump 12 GPM, inject 6-8 GPM</u>	<u>GPM</u>
Casing depth	<u>6 ft</u>	<u>ft</u>
Casing size	<u>6 in</u>	<u>in</u>
Type of casing material	_____	_____
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u>none</u>	_____
Gravity or pumped reinjection?	<u>gravity</u>	_____
Type of pump	<u>jet pump</u>	_____
Depth of pump intake	<u>190 ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well <u>(Same well)</u>		
Type aquifer materials (e.g., sandstone, On Gold Hill Fault, gravel, sand, etc.) <u>in shale</u>		

WATER QUALITY DATA AND WELL LOG

Site No. 15 Private Residence, Indian Land, South Carolina

Water Quality (Regional water quality)

	Mg/l		Mg/l
Calcium (Ca)	<u> </u>	Dissolved Solids	<u>50</u>
Magnesium (Mg)	<u> </u>	Hardness as CaCO ₃	<u>0</u>
Iron (Fe)	<u>trace</u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u>trace</u>	Bicarbonate (HCO ₃)	<u> </u>
Chloride (Cl)	<u> </u>	Alkalinity as CaCO ₃	<u> </u>
Sulfate (SO ₄)	<u> </u>	pH	<u>6-6.5</u>

Well Log (depths in feet)

Not received

WELL SYSTEM INFORMATION

Site No. 16

Well location: Business or residence name Edinboro State College

Street _____ City, State, Zip Edinboro, Pennsylvania

	<u>Source Wells</u>	<u>Reinjection Wells</u>
Year well drilled	<u>1963</u>	<u>1963</u>
Type of well construction	<u>Gravel pack</u>	<u>Gravel pack</u>
Depth of well	<u>58 ft</u>	<u>62 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>3-1/2 ft</u>	<u>9 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield (gpm/ft dd)	<u>74 @ 8 days</u>	<u>110 @ 24 hr</u>
Initial well yield (gpm)	<u>302 @ 8 days</u>	<u>302 @ 24 hr</u>
Typical pumping and reinjection rates	<u>100 GPM</u>	<u>100 GPM</u>
Casing depth	<u>0- 0- 0- 20; 58; 38 ft</u>	<u>0- 0- 0- 20; 62; 22 ft</u>
Casing size	<u>30; 24; 18 in</u>	<u>30; 24; 18 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>38-58 ft</u>	<u>22-62 ft</u>
Type of screen used	<u>Everdur</u>	<u>Everdur</u>
Gravity or pumped reinjection?		<u>pumped</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well _____	<u>ft</u>	
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 16 Edinboro State College, Edinboro, Pennsylvania

Water Quality (Supply Well)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	<u>175*</u>
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	<u>98</u>
Chloride (Cl)	<u>6</u>	Alkalinity as CaCO ₃	<u>100</u>
Sulfate (SO ₄)	<u>12</u>	pH	_____

* From a city well, 38 ft deep.

Well Log (depths in feet) (Reinjection Well)

0	-	1	Topsoil
1	-	11	Clay
11	-	25	Coarse to Fine Gravel and Sand
25	-	62	Medium to Fine Gravel and Sand

WELL SYSTEM INFORMATION

Site No. 17

Well location: Business or residence name General Electric Company

Street 600 Main Street City, State, Zip Johnson City, N.Y. 13790

	Source Wells	Reinjection Wells
Year well drilled	<u>1974</u>	<u>1974</u>
Type of well construction	<u>Natural</u>	
Depth of well	<u>94.5 ft</u>	<u>94.0 ft</u>
Depth to producing zone	<u>65 ft</u>	<u>65 ft</u>
Static water level	<u>15 ft</u>	<u>15 ft</u>
Water level when pumping	<u>275 ft</u>	<u>ft</u>
Potential well yield	<u>12.5 gpm/ft</u>	<u>1.85 gpm/ft</u>
Initial well yield	<u>560 @ 24 hrs</u>	<u>120 @ 2 hrs</u>
Typical pumping and reinjection rates	<u>350 GPM</u>	<u>125 GPM</u>
Casing depth	<u>75 ft</u>	<u>81 ft</u>
Casing size	<u>14 in</u>	<u>14 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>74-94.5 ft</u>	<u>74-94 ft</u>
Type of screen used	<u>Stainless Steel</u>	<u>Stainless Steel</u>
Gravity or pumped reinjection?		<u>Pumped</u>
Type of pump	<u>Vert. w/Rt Angle Drive</u>	<u>Centrifugal</u>
Depth of pump intake	<u>74.5 ft</u>	<u>75 ft</u>
Permit required? <u>Yes</u> If so, by whom?	<u>New York State Dept. of Environmental Conservation</u>	
Distance from source well to reinjection well	<u>300</u>	<u>ft</u>
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 17 General Electric Company, Johnson City, New York

Water Quality (Supply Well)

	Mg/l		Mg/l
Calcium (Ca)	<u>113</u>	Dissolved Solids	<u>499</u>
Magnesium (Mg)	<u>24</u>	Hardness as CaCO ₃	<u>380</u>
Iron (Fe)	<u>0.1</u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u>0.01</u>	Bicarbonate (HCO ₃)	<u> </u>
Chloride (Cl)	<u>33</u>	Alkalinity as CaCO ₃	<u>265</u>
Sulfate (SO ₄)	<u>140</u>	pH	<u>7.3</u>
Carbon Dioxide (CO ₂)	<u>2</u>		

Well Log (depths in feet) (Reinjection Well)

0 - 1 Blacktop and Soil
1 - 21 Sand & Gravel (dry)
21 - 28 Sand & Gravel w/large stones (dry)
28 - 60 Clay & Gravels (dry)
60 - 65 Gravel w/some clay (some water)
65 - 94 Clean Water Bearing Sand, Fine Gravel
94 Shale Bed Rock

WELL SYSTEM INFORMATION

Site No. 18

Well location: Business or residence name Long Island Lighting Company

Street 175 E. Old Country Road City, State, Zip Hicksville, New York

	<u>Source Wells</u>	<u>Reinjection Wells</u>
Year well drilled	<u>1964</u>	<u>(Not Received)</u>
Type of well construction		
Depth of well	<u>187 ft</u>	<u>ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>62-1/2 ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield (GPM/ft)	<u>59 @ 8 days</u>	
Initial well yield (GPM)	<u>654 @ 8 days</u>	
Typical pumping and reinjection rates	<u>500 GPM</u>	<u>500 GPM</u>
Casing depth	<u>145 ft</u>	<u>ft</u>
Casing size	<u>12 in</u>	<u>in</u>
Type of casing material		
Screened interval	<u>145-187 ft</u>	<u>ft</u>
Type of screen used	<u>Cook-Everdur</u>	
Gravity or pumped reinjection?		
Type of pump	<u>Peerless DWT</u>	
Depth of pump intake	<u>187 ft</u>	<u>ft</u>
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well _____	<u>ft</u>	
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 18 Long Island Lighting Company, Hicksville, New York

Water Quality (Not Received)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	_____
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	_____

Well Log (depths in feet) ("New" supply well)

0	-	1	Top Soil
1	-	3	Loam
3	-	10	Coarse Sand & Gravel
10	-	11	Coarse Sand & Some Grits
11	-	73	Coarse Sand & Very Heavy Gravel
73	-	79	Med. Sand & Grits
79	-	87	Fine Sand & Streaks of Clay
87	-	107	Fine Sand
107	-	110	Fine Sand & Chunks of Clay
110	-	132	Coarse Sand
132	-	138	Coarse Sand & Clay Chunks
138	-	140	Solid White Clay
140	-	147	Fine Sand & Streaks of Clay
147	-	165	Fine Sand
165	-	178	Fine Sand & Some Chunks of Clay
178	-	180	Brown & White Clay
180	-	194	Fine White Sand

WATER QUALITY DATA AND WELL LOG

Site No. 19 We're Associates, Lake Success, New York

Water Quality (Not Received)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	_____
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	_____

Well Log (depths in feet)

Drillers reports and well logs not received

WATER QUALITY DATA AND WELL LOG

Site No. 20 Lever Management, Garden City, New York

Water Quality (Not Received)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	_____
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	_____

Well Log (depths in feet)

Drillers reports and well logs not received

WELL SYSTEM INFORMATION

Site No. 21

Well location: Business or residence name Intown Motor Lodge

Street _____ City, State, Zip Endicott, New York

	Source Wells	Reinjection Wells
Year well drilled	<u>1961</u>	<u>1961</u>
Type of well construction	<u>Open End</u>	<u>Open Hole</u>
Depth of well	<u>151 ft</u>	<u>166 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>35 ft</u>	<u>35 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>76 GPM</u>	<u>150 GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>151 ft</u>	<u>156 ft</u>
Casing size	<u>6 in</u>	<u>6 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well	<u>2000 ft</u>	
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand and Gravel</u>	<u>Fractured Shale</u>

WATER QUALITY DATA AND WELL LOG

Site No. 21 Intown Motor Lodge (old Frederick Hotel), Endicott, New York

Water Quality (From well 2000 ft away)

	Mg/l		Mg/l
Calcium (Ca)	<u>103</u>	Dissolved Solids	<u>558</u>
Magnesium (Mg)	<u>31</u>	Hardness as CaCO ₃	<u>386</u>
Iron (Fe)	<u>3</u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>225</u>
Chloride (Cl)	<u>65</u>	Alkalinity as CaCO ₃	<u>188</u>
Sulfate (SO ₄)	<u>180</u>	pH	<u>7.0</u>
Carbon dioxide (CO ₂)	<u>24</u>		

Well Log (depths in feet) (Supply Well)

0 - 30 Sand & Gravel
30 - 125 River Mud (Fine Sand and Silt)
125 - 150 Water-Bearing Sand
150 - 151 Water-Bearing Sand and Gravel

(Reinjection Well)

0 - 30 Gravel
30 - 154 River Mud (Fine Sand and Silt)
154 - 156 Not reported
156 - 166 Fractured Shale

WELL SYSTEM INFORMATION

Site No. 22

Well location: Business or residence name Utah Technical College

Street 1200 South 800 West City, State, Zip Orem, Utah

	Source Wells	Reinjection Wells
Year well drilled	<u>1976</u>	<u>1976</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>550 ft</u>	<u>537 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>55 ft</u>	<u>56 ft</u>
Water level when pumping	<u>253 ft</u>	<u>163 ft</u>
Potential well yield	<u>110 GPM/ft after 12 hr</u>	<u>161 GPM/ft after 54 hr</u>
Initial well yield	<u>2089 GPM after 19 hr</u>	<u>2089 GPM after 54 hr</u>
Typical pumping and reinjection rates	<u>1500 GPM</u>	<u>1500 GPM</u>
Casing depth	<u>189 ft; 189-599 ft</u>	<u>270 ft; 260-537 ft</u>
Casing size	<u>20 in; 24 in</u>	<u>20 in; 24 in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>285-417; 533-546 ft</u>	<u>309-525 ft</u>
Type of screen used	<u>Perforated Pipe</u>	<u>Perforated Pipe</u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom?	<u></u>	<u></u>
Distance from source well to reinjection well	<u>920 ft</u>	<u></u>
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Gravel & Sand</u>	<u>Gravel & Sand</u>

WATER QUALITY DATA AND WELL LOG

Site No. 22 Utah Technical College, Orem, Utah

Water Quality (Well 4,100 ft away)

	Mg/l		Mg/l
Calcium (Ca)	<u>36</u>	Dissolved Solids	<u>206</u>
Magnesium (Mg)	<u>14</u>	Hardness as CaCO ₃	<u>146</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u>2</u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>176</u>
Chloride (Cl)	<u>12</u>	Alkalinity as CaCO ₃	<u>144</u>
Sulfate (SO ₄)	<u>21</u>	pH	<u>7.8</u>

Well Log (depths in feet) (Supply Well)

0	-	47	Sandy Brown Clay
47	-	49	Pea Gravel
49	-	85	Sandy Brown Clay
85	-	144	Sandy Blue Clay
144	-	184	Sandy Gravel
184	-	217	Coarse Gravel
217	-	241	Yellow Clay
241	-	279	Blue Clay and Gravel
279	-	402	Gravel to 3" and Sand
402	-	408	Pea Gravel With Clay
408	-	417	Gravel
417	-	442	Brown Clay
442	-	464	Blue Clay
464	-	474	Gray Clay, Some Gravel
474	-	489	Clay and Gravel
489	-	490	Hard Clay
490	-	518	Clay and Gravel
518	-	531	Brown Clay
531	-	550	Gravel

WELL SYSTEM INFORMATION

Site No. 23

Well location: Business or residence name Sandia Saving Building

Street 2615 Isleta Blvd., S.W. City, State, Zip Albuquerque, N.M. 87105

	<u>Source Wells</u>	<u>Reinjection Wells</u>
Year well drilled	<u>1954</u>	<u>1954</u>
Type of well construction	<u>Gravel packed</u>	<u>Gravel packed</u>
Depth of well	<u>260 ft</u>	<u>72 ft</u>
Depth to producing zone	<u>108-206 ft</u>	<u>20-72 ft</u>
Static water level	<u>17 ft</u>	<u>17 ft</u>
Water level when pumping	<u>39 ft</u>	<u>2 ft</u>
Potential well yield	<u>25 GPM/ft</u>	<u>32 GPM/ft</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>500 GPM</u>	<u>500 GPM</u>
Casing depth	<u>260 ft</u>	<u>72 ft</u>
Casing size	<u>14 in</u>	<u>14 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>108-260 ft</u>	<u>20 ft</u>
Type of screen used	<u>Perforated Pipe</u>	<u>Perforated Pipe</u>
Gravity or pumped reinjection?		<u>Gravity</u>
Type of pump	<u>Turbine</u>	
Depth of pump intake	<u>70 ft</u>	<u>40 ft</u>
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well <u>10 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Gravel & Sand</u>	<u>Gravel & Sand</u>

WATER QUALITY DATA AND WELL LOG

Site No. 23 Sandia Savings (Sims Building) Albuquerque, New Mexico

Water Quality (From well 2 blocks away)

	Mg/l		Mg/l
Calcium (Ca)	<u>46</u>	Dissolved Solids	<u>406</u>
Magnesium (Mg)	<u>16</u>	Hardness as CaCO ₃	<u>180</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u>41</u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>170</u>
Chloride (Cl)	<u>32</u>	Alkalinity as CaCO ₃	<u>140</u>
Sulfate (SO ₄)	<u>99</u>	pH	<u>7.6</u>

Well Log (depths in feet) (Supply Well)

0	-	5	Top soil and fill material
5	-	29	Sand
29	-	32	Sand and Gravel
32	-	35	Sand
35	-	53	Gravel and Boulders
53	-	56	Sand and Gravel
56	-	71	Gravel
71	-	74	Clay and Boulders
74	-	77	Shale and Clay - very hard
77	-	83	Shale and Clay - lime hard
83	-	92	Shale and Clay
92	-	98	Rock
98	-	116	Lime Shale and Sand Stone
116	-	131	Sand
131	-	134	Sand and Clay Streaks
134	-	137	Sand
137	-	165	Gravel and Sand
165	-	170	Sand and Clay Streaks
170	-	193	Sand and Gravel
193	-	260	Sand
260	-	265	Sandy Clay

WELL SYSTEM INFORMATION

Site No. 24

Well location: Business or residence name Gig Harbor High School

Street _____ City, State, Zip Gig Harbor, Washington

	Source Wells	Reinjection Wells
Year well drilled	<u>1977</u>	<u>1978</u>
Type of well construction	_____	_____
Depth of well	<u>310 ft</u>	<u>320 ft</u>
Depth to producing zone	<u>265 ft</u>	<u>287 ft</u>
Static water level	<u>180 ft</u>	<u>162 ft</u>
Water level when pumping	<u>280 ft</u>	<u>ft</u>
Potential well yield	<u>5 GPM/ft after 8 hr</u>	<u>9 GPM/ft after 4 hr</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>75 GPM</u>	<u>75 GPM</u>
Casing depth	<u>289 ft</u>	<u>293 ft</u>
Casing size	<u>10 in</u>	<u>10 in</u>
Type of casing material	_____	_____
Screened interval	<u>287-307 ft</u>	<u>295-315 ft</u>
Type of screen used	<u>Stainless Steel</u>	<u>Stainless Steel</u>
Gravity or pumped reinjection?	_____	_____
Type of pump	_____	_____
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Department of Energy</u>		
Distance from source well to reinjection well <u>350 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u>Sand & Gravel</u>		

WATER QUALITY DATA AND WELL LOG

Site No. 24 Gig Harbor High School, Gig Harbor, Washington

Water Quality

	Mg/l		Mg/l
Calcium (Ca)	<u> </u>	Dissolved Solids	<u>103</u>
Magnesium (Mg)	<u> </u>	Hardness as CaCO ₃	<u>165</u>
Iron (Fe)	<u>0.44</u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u>0.33</u>	Bicarbonate (HCO ₃)	<u>227</u>
Chloride (Cl)	<u>3</u>	Alkalinity as CaCO ₃	<u>186</u>
Sulfate (SO ₄)	<u> </u>	pH	<u>7.7</u>

Well Log (depths in feet) (Reinjection Well)

0	-	1	Fill
1	-	3	Sand & Gravel
3	-	6	Sand
6	-	28	Yellow hardpan
28	-	44	Sand & Gravel
44	-	72	Gray hardpan
72	-	84	Blue Clay & Some Gravel
84	-	87	Gray Hardpan
87	-	91	Gray Clay & Gravel
91	-	113	Gray hardpan
113	-	118	Yellow hardpan
118	-	176	Sand, Gravel & Clay
176	-	185	Gravel, Sand & Clay
185	-	191	Gray hardpan
191	-	193	A little Water, Clay & Gravel
193	-	208	Gray Clay & Gravel
208	-	218	Hard packed Sand, Gravel & Clay
218	-	287	Gray Sand, Clay & Gravel
287	-	291	Water, Gravel & Sand
291	-	294	Water, Gravel & Sand
294	-	299	Water, Gravel & Fine Sand
299	-	301	Water, coarse & fine sand-gravel
301	-	311	Water, sand, gravel & pea gravel
311	-	315	Water & Gravel
315	-	318	Water, Gravel, sand & clay
318	-	323	Water, Clay & Gravel

WELL SYSTEM INFORMATION

Site No. 25

Well location: Business or residence name New Mexico Junior College

Street Lovington Highway City, State, Zip Hobbs, N. M. 88240

	Source Wells	Reinjection Wells
Year well drilled	<u>1970</u>	<u>1971</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>198 ft</u>	<u>177 ft</u>
Depth to producing zone	<u>40 ft</u>	<u>20 ft</u>
Static water level	<u>ft</u>	<u>ft</u>
Water level when pumping	<u>GPM</u>	<u>GPM</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>950 GPM</u>	<u>950 GPM</u>
Typical pumping and reinjection rates	<u>198 ft</u>	<u>177 ft</u>
Casing depth	<u>14 in</u>	<u>14 in</u>
Casing size	<u></u>	<u></u>
Type of casing material	<u>60-190 ft</u>	<u>88-165 ft</u>
Screened interval	<u>Perforated pipe</u>	<u>Perforated pipe</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>State of New Mexico</u>		
Distance from source well to reinjection well <u>1125 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand</u>	<u>Sand</u>

WATER QUALITY DATA AND WELL LOG

Site No. 25 New Mexico Junior College, Hobbs, New Mexico

Water Quality (Well in region in the Ogallala)

	Mg/l		Mg/l
Calcium (Ca)	<u>76</u>	Dissolved Solids	<u>495</u>
Magnesium (Mg)	<u>19</u>	Hardness as CaCO ₃	<u>268</u>
Iron (Fe)	<u>0.10</u>	Noncarbonate	<u>91</u>
Manganese (Mn)	<u></u>	Bicarbonate (HCO ₃)	<u>216</u>
Chloride (Cl)	<u>48</u>	Alkalinity as CaCO ₃	<u>177</u>
Sulfate (SO ₄)	<u>112</u>	pH	<u>7.5</u>

Well Log (depths in feet) (Reinjection Well)

1	-	20	Rock
20	-	30	Caliche Rock
30	-	165	Sand
165	-	172	Yellow Clay
172	-	177	Red Bed

WELL SYSTEM INFORMATION

Site No. 26

Well location: Business or residence name Valcris, Inc.

Street Lander & B Street City, State, Zip Turlock, California 95380

	Source Wells	Reinjection Wells
Year well drilled	<u>1962</u>	<u></u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>515 ft</u>	<u>ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>60 ft</u>	<u>ft</u>
Water level when pumping	<u>165 ft</u>	<u>ft</u>
Potential well yield	<u>14 GPM/ft @ 32 hrs</u>	<u>GPM</u>
Initial well yield	<u>1500 @ 32 hrs</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>1500 GPM</u>	<u>GPM</u>
Casing depth	<u>250 ft</u>	<u>ft</u>
Casing size	<u>8, 10, 12, 14 in</u>	<u>in</u>
Type of casing material	<u>Steel</u>	<u></u>
Screened interval	<u>250-515 ft</u>	<u>ft</u>
Type of screen used	<u>Perforated pipe</u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Water Quality Control Board</u>		
Distance from source well to reinjection well <u>ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u>Gravel & Sand</u>		

WATER QUALITY DATA AND WELL LOG

Site No. 26 Valcris, Inc., Turlock, California

Water Quality (From a well in Turlock)

	Mg/l		Mg/l
Calcium (Ca)	<u>35</u>	Dissolved Solids	<u>305</u>
Magnesium (Mg)	<u>10</u>	Hardness as CaCO ₃	<u>127</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>117</u>
Chloride (Cl)	<u>91</u>	Alkalinity as CaCO ₃	<u>96</u>
Sulfate (SO ₄)	<u>12</u>	pH	<u>7.8</u>

Well Log (depths in feet) (Supply Well)

0 - 4	Top Soil	340 - 390	Clay
4 - 6	Hard Pan	390 - 398	Sand
6 - 8	Sand	398 - 420	Clay
8 - 22	Clay	420 - 430	Gravel
22 - 30	S. Clay	430 - 508	Clay
30 - 40	Sand	508 - 509	Sand
40 - 48	Clay	509 - 515	Clay
48 - 51	Sand	515	Sand
51 - 60	Set Sand		
60 - 64	Clay		
64 - 65	Sand		
65 - 72	Set Sand		
72 - 152	Clay		
152 - 190	Sand		
190 - 196	Clay		
196 - 224	Sand		
224 - 265	Sand Clay		
265 - 270	Sand		
270 - 295	Clay		
295 - 296	Sand		
296 - 298	Clay		
298 - 308	Sand		
308 - 339	Clay		
339 - 340	Gravel		

WELL SYSTEM INFORMATION

Site No. 27

Well location: Business or residence name Turlock Refrigerating Company

Street 660 5th Street City, State, Zip Turlock, California 95380

	Source Wells	Reinjection Wells
Year well drilled	<u>(Driller's reports not available)</u>	
Type of well construction	<u></u>	<u></u>
Depth of well	<u>ft</u>	<u>ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>1500 GPM</u>	<u>1500 GPM</u>
Casing depth	<u>ft</u>	<u>ft</u>
Casing size	<u>in</u>	<u>in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Water Quality Control Board</u>		
Distance from source well to reinjection well <u>1300</u> <u>ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u></u>	<u></u>

WATER QUALITY DATA AND WELL LOG

Site No. 27 Turlock Refrigerating Company, Turlock, California

Water Quality (From a well in Turlock)

	Mg/l		Mg/l
Calcium (Ca)	<u>35</u>	Dissolved Solids	<u>305</u>
Magnesium (Mg)	<u>10</u>	Hardness as CaCO ₃	<u>127</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>117</u>
Chloride (Cl)	<u>91</u>	Alkalinity as CaCO ₃	<u>96</u>
Sulfate (SO ₄)	<u>12</u>	pH	<u>7.8</u>

Well Log (depths in feet)

Well logs not available

WELL SYSTEM INFORMATION

Site No. 28

Well location: Business or residence name Shell Development Company

Street _____ City, State, Zip Salida, California

	Source Wells #1	Reinjection Wells #1
Year well drilled	<u>1945</u>	<u>1957</u>
Type of well construction	_____	_____
Depth of well	<u>147</u> ft	<u>135</u> ft
Depth to producing zone	_____ ft	_____ ft
Static water level	_____ ft	<u>22</u> ft
Water level when pumping	_____ GPM	_____ GPM
Potential well yield	_____ GPM	_____ GPM
Initial well yield	_____ GPM	_____ GPM
Typical pumping and reinjection rates	<u>102</u> ft	<u>112</u> ft
Casing depth	<u>12</u> in	<u>12</u> in
Casing size	_____	<u>Steel</u>
Type of casing material	_____ ft	_____ ft
Screened interval	_____	<u>None</u>
Type of screen used	_____	_____
Gravity or pumped reinjection?	_____	_____
Type of pump	_____	_____
Depth of pump intake	_____ ft	_____ ft
Permit required? <u>Yes</u> If so, by whom? <u>Water Quality Control Board</u>		
Distance from source well to reinjection well _____ ft		
Type aquifer materials (e.g., sandstone, Sand, Clay, gravel, sand, etc.) _____ and Gravel		<u>Sand, Clay, and Gravel</u>

WELL SYSTEM INFORMATION

Site No. 28

Well location: Business or residence name Shell Development Company

Street _____ City, State, Zip Salida, California

	Source Wells #2	Reinjection Wells #2
Year well drilled	<u>1967</u>	<u>1957</u>
Type of well construction	_____	_____
Depth of well	<u>305 ft</u>	<u>226 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>ft</u>	<u>22 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>300 ft</u>	<u>180 ft</u>
Casing size	<u>14 in</u>	<u>12 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>160-300 ft</u>	<u>ft</u>
Type of screen used	_____	<u>None</u>
Gravity or pumped reinjection?	_____	_____
Type of pump	_____	_____
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Water Quality Control Board</u>		
Distance from source well to reinjection well _____ ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand, Clay and Gravel</u>	<u>Sand, Clay and Gravel</u>

WELL SYSTEM INFORMATION

Site No. 28

Well location: Business or residence name Shell Development Company

Street _____ City, State, Zip Salida, California

	Source Wells #3	Reinjection Wells #3
Year well drilled	<u>1964</u>	<u>1967</u>
Type of well construction	<u>Gravel pack</u>	
Depth of well	<u>300 ft</u>	<u>170 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>36 ft</u>	<u>22 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>300 ft</u>	<u>153 ft</u>
Casing size	<u>14 in</u>	<u>12 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>151-187; 209-297 ft</u>	<u>54-152 ft</u>
Type of screen used		
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Water Quality Control Board</u>		
Distance from source well to reinjection well <u>ft</u>		
Type aquifer materials (e.g., sandstone, Sand, Clay, gravel, sand, etc.) <u>and Gravel</u>	<u>Sand, Clay and Gravel</u>	

WATER QUALITY DATA AND WELL LOG

Site No. 28 Shell Development Company, Salida, California

Water Quality (Average of the 3 supply wells)

	Mg/l		Mg/l
Calcium (Ca)	<u>32</u>	Dissolved Solids	<u>239</u>
Magnesium (Mg)	<u>16</u>	Hardness as CaCO ₃	<u>147</u>
Iron (Fe)	<u>< 0.05</u>	Noncarbonate	<u></u>
Manganese (Mn)	<u>< 0.01</u>	Bicarbonate (HCO ₃)	<u>171</u>
Chloride (Cl)	<u>28</u>	Alkalinity as CaCO ₃	<u>140</u>
Sulfate (SO ₄)	<u>5</u>	pH	<u>7.7</u>

Well Log (depths in feet) (Supply Well #2)

0	-	5	Top Soil
5	-	7	Hard Pan
7	-	20	Clay & Sand Stks.
20	-	41	Clay, Hard Pan & Sand Stks.
41	-	44	Clay
44	-	76	Sand & Small Gravel
76	-	78	Clay
78	-	95	Fine Sand-Hard Pan & Small Clay Stks.
95	-	120	Hard Pan & Small Fine and Sand Stks.
120	-	128	Sand
128	-	137	Clay & Hard Gravel Stks.
137	-	142	Sand
142	-	160	Clay
160	-	192	Sand & Small Gravel
192	-	203	Hard Crumbly Clay & Small Sand Stks.
203	-	217	Sand
217	-	234	Clay & Small Sand Stks.
234	-	248	Sand
248	-	260	Hard Clay & Sand Stks.
260	-	265	Fine Sand
265	-	273	Crumbly Clay
273	-	275	Fine Sand
275	-	296	Sand & Hard Clay Stks.
296	-	305	Hard Crumbly Clay

WELL SYSTEM INFORMATION

Site No. 29

Well location: Business or residence name Brewster High School

Street _____ City, State, Zip Brewster, Washington

	Source Wells	Reinjection Wells
Year well drilled	<u>1977</u>	<u>1977</u>
Type of well construction	_____	_____
Depth of well	<u>40 ft</u>	<u>40 ft</u>
Depth to producing zone	<u>31 ft</u>	<u>31 ft</u>
Static water level	<u>12 ft</u>	<u>11 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>110 GPM, no dd</u>	<u>GPM</u>
Initial well yield	<u>110 GPM @ 2 hrs</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>64 GPM</u>	<u>64 GPM</u>
Casing depth	<u>31 ft</u>	<u>32 ft</u>
Casing size	<u>6 in</u>	<u>6 in</u>
Type of casing material	<u>Welded Steel</u>	<u>Welded Steel</u>
Screened interval	<u>30-40 ft</u>	<u>31-41 ft</u>
Type of screen used	<u>Johnson SS</u>	<u>Johnson SS</u>
Gravity or pumped reinjection?		<u>Gravity</u>
Type of pump	_____	_____
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well	<u>100 ft</u>	
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 29 Brewster High School, Brewster, Washington

Water Quality

	Mg/l		Mg/l
Calcium (Ca)	<u>90</u>	Dissolved Solids	<u> </u>
Magnesium (Mg)	<u>20</u>	Hardness as CaCO ₃	<u>307</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>298</u>
Chloride (Cl)	<u>9</u>	Alkalinity as CaCO ₃	<u>289</u>
Sulfate (SO ₄)	<u>54</u>	pH	<u>8.6</u>
Carbon dioxide (CO ₂)	<u>1</u>		

Well Log (depths in feet) (Supply Well)

0 - 4 Top Soil

4 - 34 Gravel & Sand (coarse)

34 - 37 Gravel & Sand (fine)

37 - 40 Gravel & Sand (medium)

WELL SYSTEM INFORMATION

Site No. 30

Well location: Business or residence name Roswell High School

Street 400 West Hobbs Street City, State, Zip Roswell, N. M. 88201

	Source Wells	Reinjection Wells
Year well drilled	<u>1960</u>	<u>1972</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>150 ft</u>	<u>208 ft</u>
Depth to producing zone	<u>115 ft</u>	<u>150 ft</u>
Static water level	<u>70 ft</u>	<u>90 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>100 ft</u>	<u>208 ft</u>
Casing size	<u>7 in</u>	<u>5-1/2 in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>100-150 ft</u>	<u>163-203 ft</u>
Type of screen used	<u>Perforated pipe</u>	<u>Perforated pipe</u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u></u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u>ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Gravel</u>	<u>Gravel & Sand</u>

WELL SYSTEM INFORMATION

Site No. 30

Well location: Business or residence name Roswell High School

Street 400 West Hobbs Street City, State, Zip Roswell, N. M. 88201

	Source Wells	Reinjection Wells
Year well drilled		1972
Type of well construction		
Depth of well	ft	129 ft
Depth to producing zone	ft	119 ft
Static water level	ft	91 ft
Water level when pumping	ft	ft
Potential well yield	GPM	GPM
Initial well yield	GPM	GPM
Typical pumping and reinjection rates	GPM	GPM
Casing depth	ft	129 ft
Casing size	in	in
Type of casing material		Steel
Screened interval		80-90
		120-127 ft
Type of screen used		Perforated pipe
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake	ft	ft
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well _____ ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) _____		Gravel

WATER QUALITY DATA AND WELL LOG

Site No. 30 Roswell High School, Roswell, New Mexico

Water Quality (City Well #7 of Roswell)

	Mg/l		Mg/l
Calcium (Ca)	<u>185</u>	Dissolved Solids	<u>1370</u>
Magnesium (Mg)	<u>153</u>	Hardness as CaCO ₃	<u>680</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>203</u>
Chloride (Cl)	<u>325</u>	Alkalinity as CaCO ₃	<u> </u>
Sulfate (SO ₄)	<u>457</u>	pH	<u>7.7</u>

Well Log (depths in feet) (Reinjection Well)

0	-	3	Surface
3	-	25	Clay
25	-	31	Gravel
31	-	38	White Clay & Gravel
38	-	45	White Clay
45	-	56	Brown Clay
56	-	78	Yellow Clay and Gravel
119	-	127	Gravel
127	-	129	Brown and Blue Clay

WELL SYSTEM INFORMATION

Site No. 31

Well location: Business or residence name Monterrey School

Street South Union Avenue & Gayle City, State, Zip Roswell, N. M. 88201

	Source Wells	Reinjection Wells
Year well drilled	<u>1960</u>	<u>1960</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>148 ft</u>	<u>138 ft</u>
Depth to producing zone	<u>110 ft</u>	<u>105 ft</u>
Static water level	<u>90 ft</u>	<u>90 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>148 ft</u>	<u>138 ft</u>
Casing size	<u>7 in</u>	<u>7 in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>100-148 ft</u>	<u>100-138 ft</u>
Type of screen used	<u>Perforated pipe</u>	<u>Perforated pipe</u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u></u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u>ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 31 Monterrey School, Roswell, New Mexico

Water Quality (See Site No. 30)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	_____
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	_____

Well Log (depths in feet) (Supply Well)

0	-	3	Top Soil
3	-	18	Yellow Clay
18	-	30	Grey Gravel
30	-	45	Brown Clay
45	-	50	Concrete & Gravel
50	-	75	Clay & Gravel
75	-	110	Concrete & Gravel
110	-	120	Sand & Gravel
120	-	133	Concrete
133	-	136	Porous Rock
136	-	148	Hard Rock

WELL SYSTEM INFORMATION

Site No. 32

Well location: Business or residence name Sierra Middle School

Street 601 South Sycamore City, State, Zip Roswell, N. M. 88201

	Source Wells	Reinjection Wells
Year well drilled	<u>1962</u>	<u>1962</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>177 ft</u>	<u>173 ft</u>
Depth to producing zone	<u>89 ft</u>	<u>93 ft</u>
Static water level	<u>80 ft</u>	<u>80 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>103 ft</u>	<u>93 ft</u>
Casing size	<u>7 in</u>	<u>7 in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u>ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u></u>		

WATER QUALITY DATA AND WELL LOG

Site No. 32 Sierra Middle School, Roswell, New Mexico

Water Quality (See Site No. 30)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	_____
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	_____

Well Log (depths in feet) (Supply Well)

0	-	4	Brown soil
4	-	19	Light grey caleche
19	-	30	Grey gravel
30	-	34	Light red clay
34	-	37	Grey concrete rock
37	-	70	Brown clay
70	-	74	Red clay
74	-	83	Red rock and clay
83	-	86	Red clay
86	-	102	Red grey pourous rock
102	-	166	Grey lime, a little water
166	-	174	Grey water crevices, broken shale
174	-	177	Grey hard lime

WELL SYSTEM INFORMATION

Site No. 33

Well location: Business or residence name Goddard High School

Street W. Country Club & Garden Ave. City, State, Zip Roswell, N. M. 88201

	<u>Source Wells</u>	<u>Reinjection Wells</u>
Year well drilled	<u>1964</u>	<u>1974</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>329 ft</u>	<u>346 ft</u>
Depth to producing zone	<u>261 ft</u>	<u>300 ft</u>
Static water level	<u>54 ft</u>	<u>66 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>1500 GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>175 ft</u>	<u>228 ft</u>
Casing size	<u>10.75 in</u>	<u>7 in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u> </u> If so, by whom? <u> </u>		
Distance from source well to reinjection well <u> </u> ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Porous Limestone</u>	<u>Porous Limestone</u>

WATER QUALITY DATA AND WELL LOG

Site No. 33 Goddard High School, Roswell, New Mexico

Water Quality (Well 1 mile away)

	Mg/l		Mg/l
Calcium (Ca)	<u>194</u>	Dissolved Solids	<u>2440</u>
Magnesium (Mg)	<u>70</u>	Hardness as CaCO ₃	<u>770</u>
Iron (Fe)	<u> </u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>88</u>
Chloride (Cl)	<u>945</u>	Alkalinity as CaCO ₃	<u> </u>
Sulfate (SO ₄)	<u>600</u>	pH	<u>7.5</u>

Well Log (depths in feet)

(Reinjection Well)

0	-	3	Brown surface
3	-	11	Brown clay
11	-	33	White clay
33	-	57	Brown sand and gravel
57	-	61	Grey clay
61	-	138	Brown clay and gravel
138	-	157	Blue and brown clay
157	-	206	Red clay and limestone streaks
206	-	212	Limestone and clay streaks
212	-	233	Grey limestone
233	-	237	Red and gray limestone - water
237	-	256	Red and gray limestone and streaks of red clay
256	-	276	Red and grey limestone
276	-	294	Grey and black limestone
294	-	346	Grey limestone and water breaks (no samples recovered between 300 and 325)

WELL SYSTEM INFORMATION

Site No. 34

Well location: Business or residence name Private Residence

Street _____ City, State, Zip Troy, Ohio 45373

	Source Wells	Reinjection Wells
Year well drilled	<u>1972</u>	<u>1979</u>
Type of well construction		<u>Cable tool</u>
Depth of well	<u>82 ft</u>	<u>74 ft</u>
Depth to producing zone	<u>73 ft</u>	<u>68 ft</u>
Static water level	<u>35 ft</u>	<u>48 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>0.75 GPM/ft after 1-1/2 hrs</u>	<u>5 GPM/ft after 3 hrs</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>8 GPM</u>	<u>8 GPM</u>
Casing depth	<u>82 ft</u>	<u>69 ft</u>
Casing size	<u>5-5/8 in</u>	<u>5-5/8 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>None</u>	<u>69-74 ft</u>
Type of screen used		<u>Johnson, PVC</u>
Gravity or pumped reinjection?		<u>Pumped</u>
Type of pump	<u>Starite</u>	
Depth of pump intake	<u>75 ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well <u>60 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 34 Private Residence, Troy, Ohio

Water Quality (Supply Well)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	<u>340</u>
Magnesium (Mg)	_____	Hardness as CaCO ₃	_____
Iron (Fe)	<u>2</u>	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	<u>7.0</u>

Well Log (depths in feet) (Supply Well)

0 - 23 Clay

23 - 39 Sand and Gravel

39 - 73 Clay

73 - 82 Water bearing Sand and Gravel

WELL SYSTEM INFORMATION

Site No. 35

Well location: Business or residence name Westover Retirement Residence

Street 855 Stahlheber City, State, Zip Hamilton, Ohio 45013

	3 Source Wells	3 Reinjection Wells
Year well drilled	<u>1966</u>	<u>(Not Received)</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>100 ft</u>	<u>ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>71 ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>79 ft</u>	<u>ft</u>
Casing size	<u>6 in</u>	<u>in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>79-86 ft</u>	<u>ft</u>
Type of screen used	<u>Cook Brass #80</u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u></u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u>~ 150</u> ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u></u>		

WATER QUALITY DATA AND WELL LOG

Site No. 35 Westover Retirement Residence, Hamilton, Ohio

Water Quality (From well 2 blocks away)

	Mg/l		Mg/l
Calcium (Ca)	<u>90</u>	Dissolved Solids	<u>536</u>
Magnesium (Mg)	<u>39</u>	Hardness as CaCO ₃	<u>339</u>
Iron (Fe)	<u>1.23</u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u>0.3</u>	Bicarbonate (HCO ₃)	<u> </u>
Chloride (Cl)	<u> </u>	Alkalinity as CaCO ₃	<u>277</u>
Sulfate (SO ₄)	<u> </u>	pH	<u>7.3</u>

Well Log (depths in feet) (one of the supply wells)

0	-	1	Top Soil
1	-	14	Yellow Clay
14	-	65	Blue Clay
65	-	71	Blue Clay and Gravel
71	-	86	Coarse Gravel
86	-	100	Blue Clay

WELL SYSTEM INFORMATION

Site No. 36

Well location: Business or residence name OK Elementary School

Street 1607 North West Street City, State, Zip Wichita, Kansas 67203

	Source Wells	2 Reinjection Wells
Year well drilled	<u>1975</u>	<u>1975</u>
Type of well construction	<u>Gravel pack</u>	<u>Gravel pack</u>
Depth of well	<u>50 ft</u>	<u>50 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>12 ft</u>	<u>12 ft</u>
Water level when pumping	<u>12 ft</u>	<u>12 ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>500 GPM</u>	<u>500 GPM</u>
Typical pumping and reinjection rates	<u>70 GPM</u>	<u>70 GPM</u>
Casing depth	<u>50 ft</u>	<u>50 ft</u>
Casing size	<u>8 in</u>	<u>8 in</u>
Type of casing material	<u>PVC</u>	<u>PVC</u>
Screened interval	<u>25-50 ft</u>	<u>25-50 ft</u>
Type of screen used	<u>PVC</u>	<u>PVC</u>
Gravity or pumped reinjection?		<u>pumped</u>
Type of pump	<u>Turbine</u>	<u>Turbine</u>
Depth of pump intake	<u>30 ft</u>	<u>30 ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Division of Water Resources</u>		
Distance from source well to reinjection well <u>200 ft</u>		
Type aquifer materials (e.g., sandstone, Coarse gravel, sand, etc.) <u>Sand & Gravel</u>		<u>Coarse Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 36 OK Elementary School, Wichita, Kansas

Water Quality (From well 8,000 ft away)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	<u>150</u>
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	<u>174</u>	Alkalinity as CaCO ₃	<u>267</u>
Sulfate (SO ₄)	<u>69</u>	pH	_____

Well Log (depths in feet)

No well log was received

WELL SYSTEM INFORMATION

Site No. 37

Well location: Business or residence name Cleveland Elementary School

Street 3345 W. 33rd Street, South City, State, Zip Wichita, Kansas 67217

	Source Wells	Reinjection Wells
Year well drilled	<u>1962</u>	<u>1962</u>
Type of well construction	<u>Gravel pack</u>	<u>Gravel pack</u>
Depth of well	<u>34 ft</u>	<u>34 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>4 ft</u>	<u>6 ft</u>
Water level when pumping	<u>14 ft</u>	<u>19 ft</u>
Potential well yield	<u>22 GPM/ft after 3 hr</u>	<u>15 GPM/ft after 3 hr</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>200 GPM</u>	<u>200 GPM</u>
Casing depth	<u>39 ft</u>	<u>22 ft</u>
Casing size	<u>12 in</u>	<u>12 in</u>
Type of casing material	<u>Steel</u>	<u>Wrought Steel</u>
Screened interval	<u>39-51 ft</u>	<u>22-34 ft</u>
Type of screen used	<u>Stainless steel</u>	<u>Stainless steel</u>
Gravity or pumped reinjection?		<u>pumped</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u></u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 37 Cleveland Elementary School, Wichita, Kansas

Water Quality (from well 4,000 ft away)

	Mg/l		Mg/l
Calcium (Ca)	<u>130</u>	Dissolved Solids	<u>1150</u>
Magnesium (Mg)	<u>25</u>	Hardness as CaCO ₃	<u>288</u>
Iron (Fe)	<u>2.4</u>	Noncarbonate	<u>140</u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u>351</u>
Chloride (Cl)	<u>396</u>	Alkalinity as CaCO ₃	<u> </u>
Sulfate (SO ₄)	<u>149</u>	pH	<u> </u>
Sodium (Na)	<u>265</u>		

Well Log (depths in feet) (Supply Well)

0 - 1 Brown Clay
1 - 5 Fine to Medium Sand
5 - 12 Fine to Coarse Sand, Some Gravel
12 - 13 Blue Clay
13 - 21 Medium to Coarse Sand and Gravel
21 - 24 Blue Gray Clay
24 - 51 Medium to Coarse Sand and Gravel, some clay lenses

WELL SYSTEM INFORMATION

Site No. 38

Well location: Business or residence name Aviation Education Center

Street 2021 South Eisenhower City, State, Zip Wichita, Kansas 67209

	<u>Source Wells</u>	<u>Reinjection Wells</u>
Year well drilled	<u>1977</u>	<u>1977</u>
Type of well construction	<u>Gravel pack</u>	<u>Gravel pack</u>
Depth of well	<u>78 ft</u>	<u>~ 52 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>10 ft</u>	<u>5 ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>68 ft</u>	<u>~ 42 ft</u>
Casing size	<u>10 in</u>	<u>10 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>68-78 ft</u>	<u>42-52 ft</u>
Type of screen used	<u>Stainless steel</u>	<u>Stainless steel</u>
Gravity or pumped reinjection?		<u>Pumped</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>Yes</u> If so, by whom? <u>Division of Water Resources</u>		
Distance from source well to reinjection well <u>200 ft</u>		
Type aquifer materials (e.g., sandstone, Coarse gravel, sand, etc.) <u>Sand & Gravel</u>		<u>Coarse Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 38 Aviation Education Center, Wichita, Kansas

Water Quality (From well 3,000 ft away)

	Mg/l		Mg/l
Calcium (Ca)	<u>29</u>	Dissolved Solids	<u>391</u>
Magnesium (Mg)	<u>6</u>	Hardness as CaCO ₃	<u>96</u>
Iron (Fe)	<u>0.05</u>	Noncarbonate	<u>0</u>
Manganese (Mn)	<u>-</u>	Bicarbonate (HCO ₃)	<u>294</u>
Chloride (Cl)	<u>48</u>	Alkalinity as CaCO ₃	<u> </u>
Sulfate (SO ₄)	<u>26</u>	pH	<u> </u>
Sodium (Na)	<u>113</u>		

Well Log (depths in feet) (Supply Well)

0 - 2 Top Soil

2 - 11 Brown Clay

11 - 15 Fine to Medium Sand & Gravel

15 - 19 Gray-Brown Clay

19 - 47 Medium to Coarse Sand & Gravel

47 - 51 Tan Clay

51 - 55 Fine to Medium Sand & Gravel & Tan Clay

55 - 60 Fine to Medium Sand & Gravel

60 - 66 Tan Clay

66 - 78 Medium to Coarse Sand and Gravel

WELL SYSTEM INFORMATION

Site No. 39

Well location: Business or residence name Certified Bakers

Street 3500 N. Santa Fe City, State, Zip Wichita, Kansas 67211

	Source Wells	Reinjection Wells #1
Year well drilled	<u>1966</u>	<u>1966</u>
Type of well construction	<u>Gravel pack</u>	<u>Gravel pack</u>
Depth of well	<u>45 ft</u>	<u>40 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>13 ft</u>	<u>11 ft</u>
Water level when pumping	<u>~ 17 ft</u>	<u>15 ft</u>
Potential well yield	<u>71 GPM/ft after 4 hr</u>	<u>63 GPM/ft after 4 hr</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>60-70 GPM</u>	<u>30-35 GPM</u>
Casing depth	<u>35 ft</u>	<u>25 ft</u>
Casing size	<u>12 in</u>	<u>12 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>35-45 ft</u>	<u>25-40 ft</u>
Type of screen used	<u>Stainless steel</u>	<u>Stainless steel</u>
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well _____ ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WELL SYSTEM INFORMATION

Site No. 39

Well location: Business or residence name Certified Bakers

Street 3500 N. Santa Fe City, State, Zip Wichita, Kansas 67211

	Source Wells	Reinjection Wells
		#2
Year well drilled		1966
Type of well construction		Gravel pack
Depth of well	ft	43 ft
Depth to producing zone	ft	ft
Static water level	ft	13 ft
Water level when pumping	ft	17 ft
Potential well yield	GPM	63 GPM/ft after 4 hr
Initial well yield	GPM	GPM
Typical pumping and reinjection rates	GPM	30-35 GPM
Casing depth	ft	28 ft
Casing size	in	12 in
Type of casing material		Steel
Screened interval		28-43 ft
Type of screen used		Stainless steel
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake	ft	ft
Permit required? <u>Yes</u> If so, by whom?		
Distance from source well to reinjection well	<u>~200</u> ft	
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)		Sand & Gravel

WATER QUALITY DATA AND WELL LOG

Site No. 39 Certified Bakers, Wichita, Kansas

Water Quality (None Available)

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	_____
Iron (Fe)	_____	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	_____

Well Log (depths in feet)

(Reinjection Well #1)

0 - 6 Clay

6 - 8 Sandy Clay

8 - 15 Fine to Medium Sand & Gravel

15 - 37 Fine to Very Coarse Sand & Gravel

37 - 38 Clay

38 - 40 Medium to Coarse Sand and Gravel

WELL SYSTEM INFORMATION

Site No. 40

Well location: Business or residence name University of Friends Church

Street 1840 University City, State, Zip Wichita, Kansas

	<u>Source Wells</u>	<u>Reinjection Wells</u>
Year well drilled	<u>1961</u>	<u>1961</u>
Type of well construction	<u>Gravel pack</u>	<u>Gravel pack</u>
Depth of well	<u>40 ft</u>	<u>31 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>12 ft</u>	<u>11 ft</u>
Water level when pumping	<u>13 ft</u>	<u>ft</u>
Potential well yield	<u>55 GPM/ft after 3 hrs</u>	<u>50 GPM/ft after 2-1/2 hr</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>~ 50 GPM</u>	<u>~ 50 GPM</u>
Casing depth	<u>22 ft</u>	<u>19 ft</u>
Casing size	<u>10 in</u>	<u>10 in</u>
Type of casing material	<u>Steel</u>	<u>Steel</u>
Screened interval	<u>22-35 ft</u>	<u>19-31 ft</u>
Type of screen used	<u>Cast iron</u>	<u>Cast iron</u>
Gravity or pumped reinjection?		<u>pumped</u>
Type of pump	<u></u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u>ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sand & Gravel</u>	<u>Sand & Gravel</u>

WATER QUALITY DATA AND WELL LOG

Site No. 40 University of Friends Church, Wichita, Kansas

Water Quality (From well 4,000 ft away)

	Mg/l		Mg/l
Calcium (Ca)	<u>41</u>	Dissolved Solids	<u>371</u>
Magnesium (Mg)	<u>3.8</u>	Hardness as CaCO ₃	<u>104</u>
Iron (Fe)	<u>4.8</u>	Noncarbonate	<u>14</u>
Manganese (Mn)	<u></u>	Bicarbonate (HCO ₃)	<u>127</u>
Chloride (Cl)	<u>63</u>	Alkalinity as CaCO ₃	<u></u>
Sulfate (SO ₄)	<u>105</u>	pH	<u></u>
Sodium (Na)	<u>86</u>		

Well Log (depths in feet) (Supply Well)

0	-	2	Soil
2	-	5	Brown Clay
5	-	12	Fine to Medium Sand (some coarse sand)
12	-	21	Coarse Sand and Gravel
21	-	26	Fine to Coarse Sand & Gravel (dirty yellow)
26	-	36	Fine to Coarse Sand & Gravel
36	-	40	Green and Blue Shale

WELL SYSTEM INFORMATION

Site No. 41

Well location: Business or residence name American Telephone & Telegraph Co.

Street _____ City, State, Zip Norway, Illinois

	Source Wells #2	Reinjection Wells
Year well drilled	<u>1961</u>	<u>1960</u>
Type of well construction	_____	_____
Depth of well	<u>1353</u> ft	<u>608</u> ft
Depth to producing zone	_____ ft	_____ ft
Static water level	<u>244</u> ft	<u>205</u> ft
Water level when pumping	<u>382</u> ft	_____ ft
Potential well yield	<u>9 GPM/ft after 8 hrs</u>	<u>12 GPM/ft after 8 hrs</u>
Initial well yield	_____ GPM	_____ GPM
Typical pumping and reinjection rates	<u>1288</u> GPM	<u>825</u> gpm
Casing depth	<u>639</u> ft	<u>244</u> ft
Casing size	<u>20-12</u> in	<u>20</u> in
Type of casing material	_____	_____
Screened interval	_____ ft	_____ ft
Type of screen used	_____	_____
Gravity or pumped reinjection?	_____	_____
Type of pump	<u>Layne Turbine</u>	_____
Depth of pump intake	<u>440</u> ft	_____ ft
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well _____ ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sandstone</u>	<u>Sandstone</u>

WELL SYSTEM INFORMATION

Site No. 41

Well location: Business or residence name American Telephone & Telegraph Co.

Street _____ City, State, Zip Norway, Illinois

	Source Wells #1	Reinjection Wells
Year well drilled	<u>1960</u>	_____
Type of well construction	_____	_____
Depth of well	<u>1348</u> ft	_____
Depth to producing zone	_____ ft	_____
Static water level	_____ ft	_____
Water level when pumping	_____ ft	_____
Potential well yield	_____ GPM	_____
Initial well yield	_____ GPM	_____
Typical pumping and reinjection rates	<u>585</u> GPM	_____
Casing depth	<u>632</u> ft	_____
Casing size	<u>20 to 12</u> in	_____
Type of casing material	<u>Concrete</u>	_____
Screened interval	_____ ft	_____
Type of screen used	_____	_____
Gravity or pumped reinjection?	_____	_____
Type of pump	<u>Layne Turbine</u>	_____
Depth of pump intake	<u>440</u> ft	_____
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well _____ ft		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Sandstone</u>	<u>Sandstone</u>

WATER QUALITY DATA AND WELL LOG

Site No. 41 American Telephone and Telegraph Co., Norway, Illinois

Water Quality (Supply Well #2)

	Mg/l		Mg/l
Calcium (Ca)	<u>108</u>	Dissolved Solids	<u>606</u>
Magnesium (Mg)	<u>44</u>	Hardness as CaCO ₃	<u>452</u>
Iron (Fe)	<u>trace</u>	Noncarbonate	<u></u>
Manganese (Mn)	<u>0</u>	Bicarbonate (HCO ₃)	<u></u>
Chloride (Cl)	<u>24</u>	Alkalinity as CaCO ₃	<u>292</u>
Sulfate (SO ₄)	<u>210</u>	pH	<u></u>
Sodium (Na)	<u>43</u>		

Well Log (depths in feet)

0 - 20	Yellow clay	955 - 960	Red rock
20 - 195	Clay, some sand & gravel	900 - 1128	Limestone (some shale)
195 - 244	Sand & clay	1128 - 1138	Sandstone
244 - 485	Sandstone	1138 - 1152	Limestone
485 - 494	Shale	1152 - 1180	Sandstone
494 - 535	Sandstone	1180 - 1191	Limestone, some sand
535 - 540	Shale	1191 - 1340	Sandstone
540 - 585	Sandstone	1340 - 1345	Sandy limestone
585 - 590	Shale	1345 - 1348	Shale
590 - 780	Limestone		
780 - 785	Sandstone		
785 - 955	Limestone		

WELL SYSTEM INFORMATION

Site No. 42

Well location: Business or residence name Private Residence

Street _____ City, State, Zip Bellevue, Ohio

	Source and Reinjection Well	
Year well drilled	<u>1979</u>	
Type of well construction		
Depth of well	<u>100 ft</u>	<u>ft</u>
Depth to producing zone	<u>70 & 100 ft</u>	<u>ft</u>
Static water level	<u>50 ft</u>	<u>ft</u>
Water level when pumping	<u>ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>30 GPM @ 70 ft; 50 GPM @ 100 ft</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>10 GPM</u>	<u>GPM</u>
Casing depth	<u>8 ft, 100 ft</u>	<u>ft</u>
Casing size	<u>6 in, 4 in</u>	<u>in</u>
Type of casing material	<u>plastic</u>	
Screened interval	<u>none</u>	
Type of screen used		
Gravity or pumped reinjection?		
Type of pump		
Depth of pump intake	<u>95 ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? _____		
Distance from source well to reinjection well <u>0 ft</u>		
Type aquifer materials (e.g., sandstone, gravel, sand, etc.) <u>Hard limestone with direct openings</u>		

WATER QUALITY DATA AND WELL LOG

Site No. 42 & 43

Water Quality

	Mg/l		Mg/l
Calcium (Ca)	_____	Dissolved Solids	_____
Magnesium (Mg)	_____	Hardness as CaCO ₃	<u>~ 425</u>
Iron (Fe)	<u>trace</u>	Noncarbonate	_____
Manganese (Mn)	_____	Bicarbonate (HCO ₃)	_____
Chloride (Cl)	_____	Alkalinity as CaCO ₃	_____
Sulfate (SO ₄)	_____	pH	<u>7.6</u>

Well Log (depths in feet) (Site No. 42)

0 - 8 Yellow Clay
8 - 100 Limestone

WELL SYSTEM INFORMATION

Site No. 43

Well location: Business or residence name Private Residence

Street _____ City, State, Zip Bellevue, Ohio

	Source and Reinjection Well	
Year well drilled	<u>1979</u>	_____
Type of well construction	_____	_____
Depth of well	<u>163</u> ft	_____ ft
Depth to producing zone	<u>125 & 160</u> ft	_____ ft
Static water level	<u>110</u> ft	_____ ft
Water level when pumping	_____ ft	_____ ft
Potential well yield	_____ GPM	_____ GPM
Initial well yield	<u>100</u> GPM	_____ GPM
Typical pumping and reinjection rates	<u>10</u> GPM	_____ GPM
Casing depth	<u>25 ft, 125</u> ft	_____ ft
Casing size	<u>6 in, 4</u> in	_____ in
Type of casing material	<u>plastic</u>	_____
Screened interval	<u>none</u>	_____
Type of screen used	_____	_____
Gravity or pumped reinjection?	_____	_____
Type of pump	_____	_____
Depth of pump intake	<u>160</u> ft	_____ ft
Permit required? <u>No</u> If so, by whom?	_____	_____
Distance from source well to reinjection well	<u>0</u> ft	_____
Type aquifer materials (e.g., sandstone, Soft Fractured gravel, sand, etc.)	<u>Limestone</u>	_____

WELL SYSTEM INFORMATION

Site No. 44

Well location: Business or residence name Rich Township High School

Street 203rd & Route 54 City, State, Zip Olympia Fields, IL 60461

	Source Wells #1	Reinjection Wells #1
Year well drilled	<u>1960</u>	<u>1960</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>302 ft</u>	<u>300 ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>40 ft</u>	<u>40 ft</u>
Water level when pumping	<u>134 ft</u>	<u>120 ft</u>
Potential well yield	<u>5 GPM/ft after 9-1/2 hrs</u>	<u>10 GPM/ft after 8 hrs</u>
Initial well yield	<u>457 after 9 hrs</u>	<u>820 after 8 hrs</u>
Typical pumping and reinjection rates	<u>GPM</u>	<u>GPM</u>
Casing depth	<u>99 ft</u>	<u>104 ft</u>
Casing size	<u>12 in</u>	<u>12 in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u>Turbine</u>	<u></u>
Depth of pump intake	<u>ft</u>	<u>ft</u>
Permit required? <u>No</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u></u>		
Type aquifer materials (e.g., sandstone, dolomitic gravel, sand, etc.) <u>limestone</u>	<u>dolomitic limestone</u>	

WELL SYSTEM INFORMATION

Site No. 44

Well location: Business or residence name Rich Township High School

Street 203rd & Route 54 City, State, Zip Olympia Fields, IL 60461

	Source Wells	Reinjection Wells
	<u>#2</u>	<u>#2</u>
Year well drilled	<u>1960</u>	<u>1968</u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>304</u> ft	<u>310</u> ft
Depth to producing zone	<u></u> ft	<u>118</u> ft
Static water level	<u>46</u> ft	<u>54</u> ft
Water level when pumping	<u>119</u> ft	<u>65</u> ft
Potential well yield	<u>10 GPM/ft after 8 hr</u>	<u>75 GPM/ft after 1-1/3 hr</u>
Initial well yield	<u>748 GPM after 8 hr</u>	<u>820 after 1-1/3 hr</u>
Typical pumping and reinjection rates	<u></u> GPM	<u></u> GPM
Casing depth	<u></u> ft	<u>94</u> ft
Casing size	<u></u> in	<u>12</u> in
Type of casing material	<u></u>	<u></u>
Screened interval	<u></u> ft	<u>None</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u>Turbine</u>	<u></u>
Depth of pump intake	<u></u> ft	<u></u> ft
Permit required? <u>No</u> If so, by whom? <u></u>		
Distance from source well to reinjection well <u></u> ft		
Type aquifer materials (e.g., sandstone, dolomitic gravel, sand, etc.)	<u>limestone</u>	<u>dolomitic limestone</u>

WATER QUALITY DATA AND WELL LOG

Site No. 44 Rich Township High School, Olympia Fields, Illinois

Water Quality (Supply Well #1)

	Mg/l		Mg/l
Calcium (Ca)	<u> </u>	Dissolved Solids	<u>691</u>
Magnesium (Mg)	<u>0.0</u>	Hardness as CaCO ₃	<u>539</u>
Iron (Fe)	<u>0.3</u>	Noncarbonate	<u> </u>
Manganese (Mn)	<u> </u>	Bicarbonate (HCO ₃)	<u> </u>
Chloride (Cl)	<u>2</u>	Alkalinity as CaCO ₃	<u>336</u>
Sulfate (SO ₄)	<u> </u>	pH	<u> </u>

Well Log (depths in feet) (Reinjection Well #2)

0 - 1	Topsoil
1 - 3-1/2	Brown silty clay
3-1/2 - 8	Brown & gray clay
8 - 43	Gray fine silty sand with clay layers
43 - 54	Gray sandy clay
54 - 88	Silty sand, boulder at 60 ft
88 - 93	Gray shale, and Limestone
93 - 118	Gray limestone, some small layers of shale
118 - 120	Brown limestone
120 - 310	Gray limestone

WELL SYSTEM INFORMATION

Site No. 45

Well location: Business or residence name Commonwealth Edison-unmanned substation

Street _____ City, State, Zip Goodings Grove, Illinois

	Source Wells #1	Reinjection Wells
Year well drilled	<u>1957</u>	<u>1957</u>
Type of well construction	_____	_____
Depth of well	<u>485</u> ft	<u>495</u> ft
Depth to producing zone	_____ ft	_____ ft
Static water level	<u>82</u> ft	<u>92</u> ft
Water level when pumping	<u>90</u> ft	_____ ft
Potential well yield	_____ GPM	_____ GPM
Initial well yield	_____ GPM	_____ GPM
Typical pumping and reinjection rates	<u>420</u> GPM	<u>420</u> GPM
Casing depth	_____ ft	<u>152</u> ft
Casing size	<u>12</u> in	<u>8</u> in
Type of casing material	_____	_____
Screened interval	_____ ft	_____ ft
Type of screen used	_____	_____
Gravity or pumped reinjection?		<u>pumped</u>
Type of pump	<u>B-J Submersible</u>	_____
Depth of pump intake	<u>200</u> ft	_____
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well	<u>350</u> ft	
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Dolomite and Shale</u>	<u>Dolomite and Shale</u>

WELL SYSTEM INFORMATION

Site No. 45

Well location: Business or residence name Commonwealth Edison-unmanned substation

Street _____ City, State, Zip Goodings Grove, Illinois

	Source Wells	Reinjection Wells
	<u>#2</u>	<u></u>
Year well drilled	<u>1957</u>	<u></u>
Type of well construction	<u></u>	<u></u>
Depth of well	<u>300 ft</u>	<u>ft</u>
Depth to producing zone	<u>ft</u>	<u>ft</u>
Static water level	<u>105 ft</u>	<u>ft</u>
Water level when pumping	<u>153 ft</u>	<u>ft</u>
Potential well yield	<u>GPM</u>	<u>GPM</u>
Initial well yield	<u>GPM</u>	<u>GPM</u>
Typical pumping and reinjection rates	<u>350 GPM</u>	<u>GPM</u>
Casing depth	<u>152 ft</u>	<u>ft</u>
Casing size	<u>8 in</u>	<u>in</u>
Type of casing material	<u></u>	<u></u>
Screened interval	<u>ft</u>	<u>ft</u>
Type of screen used	<u></u>	<u></u>
Gravity or pumped reinjection?	<u></u>	<u></u>
Type of pump	<u>B-J Submersible</u>	<u></u>
Depth of pump intake	<u>200 ft</u>	<u>ft</u>
Permit required? _____ If so, by whom? _____		
Distance from source well to reinjection well	<u>815 ft</u>	<u></u>
Type aquifer materials (e.g., sandstone, gravel, sand, etc.)	<u>Dolomite</u>	<u></u>

WATER QUALITY DATA AND WELL LOG

Site No. 45 Commonwealth Edison-Unmanned substation, Goodings Grove, Illinois

Water Quality

	Mg/l		Mg/l
Calcium (Ca)	<u>150</u>	Dissolved Solids	<u>863</u>
Magnesium (Mg)	<u>64</u>	Hardness as CaCO ₃	<u>636</u>
Iron (Fe)	<u>3</u>	Noncarbonate	<u></u>
Manganese (Mn)	<u></u>	Bicarbonate (HCO ₃)	<u></u>
Chloride (Cl)	<u>5.0</u>	Alkalinity as CaCO ₃	<u>293</u>
Sulfate (SO ₄)	<u>378</u>	pH	<u>7.1</u>
Carbon dioxide (CO ₂)	<u>35-60</u>	Hydrogen sulfide (H ₂ S)	<u>0.1-1.2</u>

Well Log (depths in feet)

(Reinjection Well)

0	-	142	till
142	-	300	Niagaran dolomite
300	-	410	alexandrian dolomite
410	-	485	Maquoketa Shale & Dolomite

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