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EVALUATION OF THE NATURAL FREEZE-THAW PROCESS FOR THE DESALINIZATION OF GROUNDWATER FROM THE NORTH DAKOTA AQUIFER TO PROVIDE WATER FOR GRAND FORKS, NORTH DAKOTA

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An effort was conducted to investigate, at the bench-scale, and feasibility of applying the Natural Freeze-Thaw Process to saline groundwater (greater than 5,000 mg/L total dissolved solids) from the Dakota Aquifer in Eastern North Dakota to provide usable quality water for the city of Grand Forks, North Dakota. The results of the study indicate that sufficient quantities of water can likely be extracted from the Dakota Aquifer, within close proximity to the city of Grand Forks. to augment the city's water supply by an estimated 1 million gallons per day or more. The bench-scale simulation of the natural freeze-thaw process demonstrated that the salinity of this water can be reduced significantly and that treated water of less than 500 mg/L total dissolved solids can be produced with the process. with greater than 72% yield. Economic analysis of the process indicates that a freeze-thaw desalinization plant could be installed and operated that would produce 1 million gallons per day of treated water at a total cost (including all installed capital and operations and maintenance costs) of $1.30 per thousand gallons

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EXECUTIVESUMMARY

The need for fresh potable water has become a significant concern in the United States in order to meet the demands of an ever-increasing population base. Water of varying qualities is needed for municipal, agricultural, and industrial development. The need for water is particularly critical in the arid regions of the western United States. The city of Grand Forks, North Dakota, and the United States Bureau of Reclamation have jointly funded a project entitled "Evaluation of the Natural Freeze-Thaw Process for the Desalinization of Groundwater from the Dakota Aquifer to Provide Water for Grand Forks, North Dakota."

The results of the evaluation indicate that sufficient quantities of water can likely be extracted from the Dakota Aquifer, within close proximity to Grand Forks, North Dakota, to augment the city's water supply by an estimated 1 million gallons per day, or more, with no adverse environmental impacts to a nearby wildlife refuge. However, the salinity of the water in the aquifer has precluded its suitability for use as a domestic and industrial supply to date. The natural freeze-thaw process, simulated at the bench scale, has demonstrated that the salinity of the water can be reduced significantly and that treated water of less than 500 mg/L total dissolved solids can be produced with the process, with greater than 72% yield.

Economic analysis of the process indicates that a freeze-thaw desalinization plant could be installed and operated in close proximity to Grand Forks that would produce 1 million gallons per day of treated water at a total cost (including all installed capital and operations and maintenance costs) of approximately $1.30 per thousand gallons.

It follows from the results of this project that a demonstration of this technology at a scale of 500,000 gallons per day or larger should be conducted as soon as possible in a climate like that of North Dakota, with water of similar quality to that of the Dakota Aquifer. A demonstration of this size would facilitate the utilization of this promising technology and potentially alleviate the anticipated shortages of usable-quality water in North Dakota, as well as in many regions of the western United States. The demonstration could also facilitate the export of U.S.-developed desalinization technology abroad.

EVALUATION OF THE NATURAL FREEZE-THAW PROCESS FOR THE DESALINIZATION OF GROUNDWATER FROM THE DAKOTA AQUIFER TO PROVIDE WATER FOR GRAND FORKS, NORTH DAKOTA

1 .O INTRODUCTION

The need for water has become a significant concern in the United States in order to meet the demands of an ever-increasing population base. Water of varying qualities is needed for municipal, agricultural, and industrial development. The need for water is particularly critical in the arid regions of the western United States. These regions have typically been sparsely populated, but recent trends have shown more and more urban dwellers relocating to these regions. However, the lack of usable water has severely limited growth and development. Many of these arid regions have abundant supplies of water, but the water is not of a quality suitable for use. Therefore, an economic means of treating these waters must be established in order to allow for continued growth and development in these regions.

Freeze crystallization processes are increasingly being recognized as a low-cost, energy-efficient means of treating water mat contains a wide variety of undesirable chemical constituents, including salts. Water purification using freeze crystallization processes has been shown to simultaneously and significantly remove salts, organics, and heavy metals from impure aqueous solutions. In addition, freeze crystallization processes have demonstrated the ability to produce significant quantities of water suitable for industrial, agricultural, and municipal uses. Although freeze crystallization is not a new technology, recent technical advances have made it an increasingly attractive option for the treatment of a wide variety of waters in order to produce water for beneficial uses.

1.1 The Natural Freeze-Thaw Process

Freezing is a crystallization process that can be used to purify water. When salts or other constituents are dissolved in water, the freezing point of the solution is lowered below 32°F, the freezing point of pure water. Partial freezing occurs when the solution is cooled to below 32°F, but not below the freezing point of the solution. Relatively pure ice crystals form, and an unfrozen solution, or brine, containing elevated concentrations of the chemical constituents is also formed. Because of the presence of these chemical constituents in the brine, it has a higher density than that of the purified ice and, therefore, readily flows from me ice. Thus, the purified ice and the brine are naturally separated.

The advantages of natural freezing for water purification are that the required refrigeration is provided at no cost and the ice pack is repeatedly subjected to freeze-thaw (FT) cycling. This repeated FT cycling promotes the formation of large ice crystals, which, in turn, increase the permeability of the ice pack. This increased permeability allows the brine to flow more readily through the purified ice pack.

It has also been found that if an ice pack is tightly frozen by ambient temperatures well below 0°F, pure ice is formed first. The remaining solution, which is initially unfrozen, again contains elevated concentrations of chemical constituents. As more of thii solution freezes, the concentrations of chemical constituents in the unfrozen solution continue to increase until the entire solution freezes. A tightly frozen ice pack, created by freezing under these types of atmospheric conditions, contains zones of ice with elevated concentrations of chemical constituents and zones of relatively pure ice. When this type of ice pack begins to melt during thawing periods, such as the spring or early summer, the concentrated zones in the ice melt first, and the initial runoff from the ice contains elevated concentrations of chemical constituents that were incorporated in the ice. Again, the concentrated brine and purified ice are naturally separated (Stinson, 1976).

1.2 Previous Natural FT Research

Heller (1939) investigated the purification of brackish groundwater in desert areas of the former Union of Soviet Socialist Republics (USSR). He used natural freezing to purify brackish groundwater and subsequently provided water for agricultural development. The salt content of the water tested was reduced from 15,000 to 400 ppm. Heller also found that as the brackish water was subjected to FT cycling, the salt content of the ice was significantly reduced.

Mitkin's (1963) research objectives were similar to those of Heller. In this work, a feed water salt content of 29,000 ppm was reduced to less than 1000 ppm. His results illustrated that natural freezing concentrated the salts in a brine and allowed a 70% conversion of the saline water to usable water, with the salt content reduced by 96%. Using a natural freezing process, he produced water that met USSR drinking water standards and created a brine with a salt concentration of 180,000 ppm.

Szekely (1964) of the Saskatchewan Research Council (SRC) also conducted natural freezing water purification research. Six waters with total dissolved solids (TDS) concentrations ranging from 4000 to 28,000 ppm were tested, and the salinity reductions ranged from 60% to 80%. Spyker (1974), also of the SRC, conducted natural freezing research on waters with TDS concentrations in the range of 2000 to 4000 ppm and was able to produce a brine with a TDS concentration in excess of 50,000 ppm.

Stinson (1968) received a Canadian patent on a process of natural freezing as a method for desalinating waters. Stinson's patent was based on spraying water to maximize ice production and minimize the space required for the ice. Stinson found that natural FT cycles improved the efficiency of water purification. He also confirmed that the FT process is effective in purifying saline waters and waters containing acids, bases, sugars, and organic materials. In addition, Stinson's results indicated that the purest ice is formed as a result of longer holding times, because repeated FT cycles allow more contaminants to drain from the ice.

Stinson's research was conducted at the University of Wyoming during the 1960s and 1970s. Ehnore (1968), a graduate student of Stinson's, conducted spray-freezing research during the winter of 1967-1968. Ehnore used lawn sprinklers to create 22-ft-high ice piles. The feed water had a TDS concentration of 2000 ppm and was purified by natural FT to produce 1.2 million gallons of potable water from me ice melt. The TDS concentrations of the purified water ranged from 60 to 400 ppm. Elmore estimated the cost of water purification by natural freezing to be $0.27 (1968 dollars) per 1000 gallons of water purified.

Stinson (1974) also conducted a large-scale experiment on the Big Sandy River in Wyoming to investigate the feasibility of using natural freezing to reduce the TDS content of the river. One of the ice piles he created had a TDS concentration of 30 ppm, which was lower than the TDS concentration of a nearby snowdrift.

1.3 Current Natural FT Research

Current natural FT water purification research has focused on an evaluation of the technical and economic feasibility of the process for the treatment of water produced in association with oil and natural gas production. This research was recently completed at the Energy & Environmental Research Center (EERC) and at B.C. Technologies (BCT) (formerly Resource Technology Corporation Process Division). Simulation results conclusively indicated that the natural FT process was effective in removing salts, organics, and heavy metals from the oil and gas produced waters. As part of this research, numerical process design and economic evaluation models were developed to provide the capability to estimate the equipment requirements, plant performance, and water treatment cost of a FT process for treating waters of various qualities at different locations and atmospheric conditions.

A separate project mat demonstrated the FT process on a large scale was conducted in conjunction with the above research. Evaluation of the demonstration plant project again indicated that the FT process is effective in removing salts, organics, and heavy metals from oil and gas produced water. This research also indicated that the FT process is an economic water treatment method on a large scale.

1.4 FT Process Design

Figure 1 is a simplified block flow diagram of the FT process. In the FT process, impure water (feed water) is pumped from a holding pond or groundwater well. When the ambient air temperature is below 32°F, the feed water is sprayed or dripped onto a freezing pad to create an ice pile. During subfreezing conditions, runoff from the ice pile will have high concentrations of chemical constituents. Thii runoff is automatically diverted to a brine storage pond or back to the feed water holding pond or well for recycle based upon the conductivity of the runoff. When temperatures promote melting or thawing, the runoff from the freezing pad will be highly purified water that is automatically diverted, based upon its conductivity, to a treated water storage pond for later beneficial uses or surface discharge.

A significant factor in the BCT-EERC FT process design which improves the effectiveness of the process compared to previous natural FT research is the addition of inexpensive control equipment that is used to automatically separate the FT process streams. Conductivity meters are

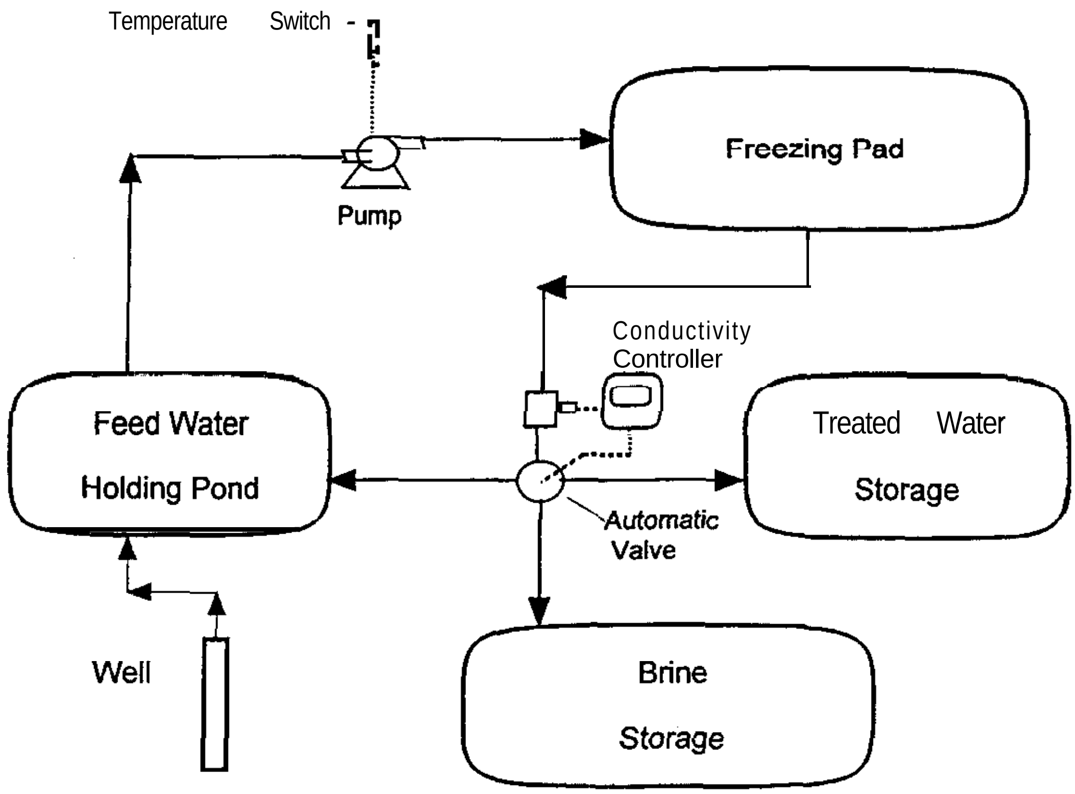


Figure 1. Block flow diagram of the natural FT water purification process.

used to estimate the TDS concentration of the process streams. Based upon the conductivity of the process stream, runoff is automatically diverted to either a treated water storage pond or a brine storage pond or recycled back to the feed water holding pond or well.

1.5 Benefits of the Research

As previously mentioned, the arid western United States has a distinct need for water. Water is needed before municipal, agricultural, and industrial development can provide the means for economic growth and stability. The state of North Dakota is an example of a region where economic growth is liited by the availability of usable water. The population of Grand Forks is increasing, but the amount of water available for municipal use is constant. Several Iarge industries have expressed interest in locating in eastern North Dakota, but the lack of water of a quality suitable for industrial development has prevented these companies from locating there. Had these companies been able to locate in Grand Forks, their presence could have had a tremendous positive economic impact on the city. Therefore, the city of Grand Forks was willing to investigate the use of unconventional sources of water to allow for future economic growth.

One potential source of water for Grand Forks is groundwater from the Dakota Aquifer. The Dakota Aquifer is confined by overlying lacustrine materials and glacial till sediments and underlying Ordovician limestones. It is one of the most extensive aquifers in the United States.

However, the water is saline and must be treated before it would be suitable for beneficial uses. Previous and current research has demonstrated that the FT process is effective in a great number of climates for treating water with a wide variety of chemical constituents. Therefore, this research was conducted to determine whether the FT process could be used to economically provide the city of Grand Forks, North Dakota, with an augmentation of their water supply for municipal and industrial growth. An additional benefit of this research is that the FT process, when commercialized, will be applicable for treating most impure groundwater and/or industrial wastewaters found in the arid Great Plains and Rocky Mountain regions of the western United States, where seasonal climatic conditions promote freezing.

1.6 Project Rationale

The FT process has been demonstrated to be an effective and efficient means of treating a variety of impure waters. The project research focuses on the use of this process to remove undesirable constituents, such as salts, from water in the Dakota Aquifer. Results of this research will determine whether the FT process is an effective and economic means of desalinating the Dakota Aquifer and providing water for beneficial uses.

2.0 WORK PERFORMED

This section describes the research conducted to complete all tasks of this project.

2.1 Task 1 - FT Bench-Scale Simulation

A bench-scale FT process simulation was conducted to demonstrate the technical feasibility of the FT process for treating water from the Dakota Aquifer system and to provide data regarding process performance and treated water and brine quality. Specific tasks completed are described below, with the exception of Subtask 4.2, which is the preparation of the final report.

2.1.1 Subtask 1.1 -Acquire Groundwater Samples from the Dakota Aquifer

Sufficient quantities of water for the research conducted were obtained from the Dakota Aquifer. A sample was collected for detailed analysis, and two S-gallon polyethylene drums were filled with Dakota Aquifer water, sealed, and shipped to BCT.

2.1.2 Subtask I.2 -Detailed Chemical Analysis of the Groundwater Sample from the Dakota Aquifer

The Dakota Aquifer water sample was subjected to the detailed suite of chemical analyses listed in Table 1.

2.1.3 *Subtask 1.3 - Conduct a Bench-Scale FT Process Simulation Using Groundwater from the Dakota Aquifer*

A bench-scale simulation of the FT process was conducted simulating the monthly average daily temperature cycles typical of months with subfreezing conditions in the Grand Forks, North Dakota, area. The atmospheric conditions for each month with subfreezing temperatures (November-April) were each simulated for 72 hours. Temperatures in the simulator were logged hourly, and on completion of the simulation, composite samples of treated water and brine were collected for analysis. Results of these analyses were used to perform a material balance on the simulation process streams.

Several disturbances of the system occurred during the simulation. Power outages occurred for short periods of time during the simulator start-up, which are reflected in the total hours of subfreezing temperature during the simulation. In addition, the simulator could not reach January low temperatures until all feed water in the simulator had frozen. The impact of these disturbances was a 5% reduction in the number of hours with freezing conditions actually obtained in the simulation versus hours with freezing conditions that were intended. Also, a slightly warmer temperature profile resulted than was intended. The effect of both of these impacts on the simulation results would be to reduce the efficiency of the process. Therefore, one might view the simulation results as conservative because of these disturbances. For simulation data illustrating the magnitude and impact of these disturbances on the intended simulation temperature profile, see Appendix A, Figure A-2.

2.1.4 Subtask 1.4 -Detailed Analysis of Treated Water and Brine Produced from the Bench-Scale Simulation

Composite samples of treated water and brine produced from the simulation were subjected to the detailed suite of chemical analyses listed in Table 1.

2.2 Task 2 - Selection of a Demonstration Site

Locations near the city of Grand Forks where the Dakota Aquifer quality and productivity are best suited to the FT process were determined, and the location for the FT demonstration was selected.

TABLE 1

Detailed Suite of Analyses for Simulation Samples

EPA Analytical or Standard Method No.	Parameter
SM 403	Alkalinity
EPA 200.7	Aluminum (Al)
EPA 350.2	Ammonia (NH_3-N)
SM 304	Antimony
EPA 206.2	Arsenic (As)
SM 507	Biological oxygen demand (BOD)
EPA 200.7	Barium (Ba)
EPA 200.7	Beryllium (Be)
EPA 200.7	Boron (B)
SM 508C	Chemical oxygen demand (COD)
EPA 200.7	Cadmium (Cd)
EPA 325.3	Chloride (Cl)
EPA 200.7	Chromium (Cr)
EPA 200.7	Cobalt (Co)
EPA 200.7	Copper (Cu)
EPA 335.3	Cyanide (CN)
EPA 340.2	Fluoride (F)
EPA 376.1	Hydrogen sulfide (H_2S)
EPA 200.7	Iron (Fe)
EPA 239.2	Lead (Pb)
EPA 200.7	Lithium (Li)
EPA 200.7	Manganese (Mn)
EPA 245.1	Mercury (Hg)
EPA 200.7	Nickel (Ni)
EPA 353.2	Nitrate (NO_3-N)
EPA 353.2	Nitrite (NO_2-N)
EPA 413.1	Oil and grease
EPA 420.2	Phenol
EPA 200.7	Phosphorus
EPA 270.2	Selenium (Se)
EPA 272.1	Silver (Ag)
EPA 375.4	Sulfate (SO,)
EPA 279.2	Thallium
EPA 160.1	Total dissolved solids (TDS)
SM 209C	Total suspended solids (TSS)
EPA 200.7	Vanadium (V)
EPA 200.7	Zinc (Zn)
EPA 150.1	pH
*	Total organic carbon (TOC)
*	Sodium absorption ratio (SAR)

* No EPA method applicable.

2.2.1 Subtask 2.1 -Review Existing Data Characterizing the Dakota Aquifer System in the Immediate Vicinity of Grand Forks, North Dakota

Existing data characterizing the Dakota Aquifer were reviewed for information regarding the local aquifer water quality, hydraulic heads, storage coefficients, and hydraulic conductivity. Locations near Grand Forks that were best suited for the FT demonstration were determined from this *review.*

2.2.2 Subtask 2.2 -Demonstration Site Selection

The locations near Grand Forks that were determined suitable for the FT demonstration in Subtask 2.1 were inspected to determine suitabiity of the topography and land availability. The locations were then ranked according to their proximity to existing water supplies. A location approximately 5 miles from Grand Forks was selected as the FT demonstration site. This location was chosen because it has more favorable water quality and productivity of the aquifer, the land is likely available for use, it has a suitable topography, and it is in reasonable proximity to Grand Forks.

2.3 Task 3 - Design of a Full-Scale FT Demonstration

Work performed in this task is delineated in the following sections.

2.3.1 Subtask 3.1 -Siting of the Demonstration

Based on previous information regarding water utilization by the city of Grand Forks, a desired capacity of the FT demonstration was determined. The size of the demonstration was based upon the productivity of the aquifer at the site, the anticipated need for future water supplies, and the funding required.

2.3.2 Subtask 3.2 -Assessment of the FT Demonstration Permitting/Approval Requirements

Contacts with the appropriate city, county, and state regulatory agencies were made, and the necessary steps and time required to obtain all regulatory approvals/permits necessary to conduct the demonstration were determined.

2.3.3 Subtask 3.3 -Design and Costing of the FT Demonstration

The results of the bench-scale simulation, including brine and treated water yields and water quality, and the numerical FT process and economic models previously developed were used to design me FT demonstration plant. Total economic requirements for the plant, including installed capital equipment costs, regulatory costs, operating expenses, and the *cost* of research support, were estimated.

2.4 Task 4 - Detailed Economic Analysis of the FT Process for Desalinization of Water for the City of Grand Forks, North Dakota

The results of all research conducted thus far, including simulation water yields and simulation water quality in addition to the numerical and economic models developed in previous research, were used to design a commercial-scale water treatment plant. Total economic requirements for the plant, including installed capital equipment costs, operating expenses, and the resulting water treatment costs, were determined. Based upon the resulting water treatment cost, the commercial economic feasibility of the process for desalinization of Dakota Aquifer water was determined.

3.0 RESULTS AND DISCUSSION

3.1 Task 1 - FT Bench-Scale Simulation

The bench-scale FT process simulation using water from the Dakota Aquifer was conducted in the BCT FT simulator. The results of subtasks required to complete thii task are delineated in the following sections.

3.1.1 Subtask 1.1 -Acquire Groundwater Samples from the Dakota Aquifer

Groundwater samples from the Dakota Aquifer were taken for detailed analyses and FT simulation. Two 55-gallon containers of Dakota Aquifer water were shipped to BCT for use in the FT simulation. Physical inspection of the water revealed a relatively clear, odorless water with minor amounts of fine sediment in the bottom of the drums.

3.1.2 Subtask I.2 - Detailed Chemical Analysis of the Groundwater Sample from the Dakota Aquifer

Water from the Dakota Aquifer was subjected to detailed chemical analysis (Table 1). The results of the analyses are presented in Table 2.

3.1.3 Subtask 1.3 - Conduct a Bench-Scale FT Process Simulation Using Groundwater from the Dakota Aquifer

A bench-scale FT process simulation was conducted using groundwater from the Dakota Aquifer and average daily temperature cycles typical of months with subfreezing conditions in the Grand Forks, North Dakota, area. The atmospheric conditions for each month with subfreezing temperatures (November-April) were simulated for 72 hours. Temperatures in the simulator were logged hourly, and on completion of the simulation, composite samples of treated water and brine were collected, weighed, and analyzed.

TABLE 2

Results of Detailed Chemical Analyses of Dakota Aquifer Water[a]

Parameter	Concentration
Alkalinity ($CaCO_3$)	187
Alkalinity (HCO,)	228
Aluminum (Al)	<0.7
Ammonia (NH_3)	1.80
Antimony (Sb)	<0.01
Arsenic (As)	<0.002
Barium (Ba)	co.1
BOD	4
Beryllium (Be)	<0.005
Boron (B)	4.5
Cadmium (Cd)	<0.0003
Calcium (Ca)	226
COD	30
Chloride (Cl)	1550
Chromium (Cr)	<0.001
Cobalt (Co)	<0.05
Copper (Cu)	<0.1
Cyanide (CN)	<0.1
Electrical Conductivity	6766 μS/cm
Fluoride (F)	3.8
Hydrogen Sulfide (H_2S)	<0.05
Iron (Fe)	1.7
Lead (Pb)	<0.002
Lithium (Li)	0.45
Magnesium (Mg)	92.8
Manganese (Mn)	<0.1
Mercury (Hg)	<0.0001
Nickel (Ni)	<0.07
Nitrate (NO,)	< 1
Nitrite (NO,)	< 1
Oil and Grease	1.9
pH	7.20
Phenols (total)	< 0.02
Potassium (K)	42.9
Selenium (Se)	<0.01
Silver (Ag)	<0.0003
Sodium (Na)	1180
Sodium Adsorption Ratio	16.7%
Sulfate (SO_4)	1730
Thallium (Tl)	<0.003
TDS	5040
TOC	<loo
TSS	<50
Vanadium (V)	10.04
Zinc (Zn)	<0.03

[a] All values are in mg/L, unless otherwise noted.

The material balance for the simulation yielded an acceptable mass balance closure of 101% The following normalized simulation product stream yields resulted: The brine stream collected and composited during the simulation consisted of all freezing pad runoff having an electrical conductivity (EC) of > 50,000 μS/cm. The brine stream represented 6.9% of the total simulation feed and had an EC of 50,800 μS/cm. The treated water stream collected and composited during the simulation consisted of all freezing pad runoff having an EC of < 1000 μS/cm. The treated water stream represented 72.6% of the total simulation feed and had an EC of 485 @/cm. Somewhat surprising was that during the simulation, a significant quantity of a moderately clean intermediate stream was produced from freezing pad runoff. This stream, collected and composited during the simulation, consisted of all freezing pad runoff having an EC of less than 50,000 but greater than 1000 μS/cm. The intermediate stream represented 20.5% of the total simulation feed and had an EC of 2500 μS/cm. This stream was not subjected to detailed analyses. However, this stream is significant and did require that modification be made to the design of the demonstration and commercial plants. The simulation product yields are summarized in Figure 2.

3.1.4 Subtask 1.4 -Detailed Analysis of Treated Water and Brine Produced from the Bench-Scale Simulation

At the conclusion of the FT simulation, composite samples of both the treated water and brine were subjected to detailed chemical analysis. The results of these analyses are presented with the results of the feed analyses in Table 3. The EC of the intermediate stream and the estimated TDS concentration for that stream are also presented in the table.

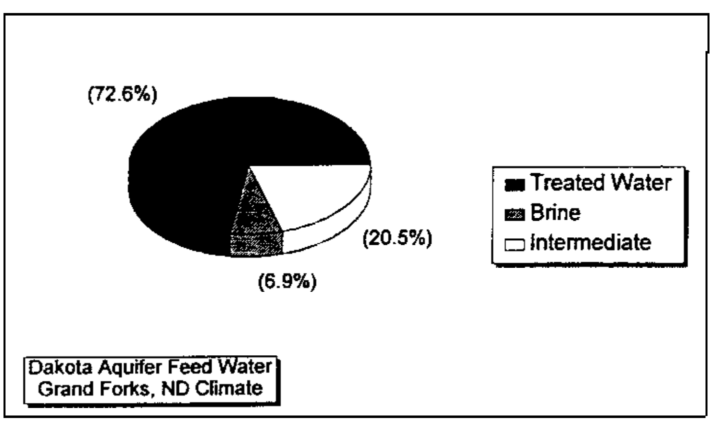


Figure 2. Simulation product yields.

TABLE 3
Results of Detailed Chemical Analysis of Simulation Process Streams

Process Stream: / Analyte	Produced Water Feed	Treated Water	Brine	Intermediate
Alkalinity (HCO_3), mg/L	228	33.8	1150	
Alkalinity (CO_3), mg/L	0	0	0	
Alkalinity (OH), mg/L	0	0	0	
Alkalinity ($CaCO_3$), mg/L	187	27.7	942	
Aluminum, mg/L	<0.7	<1	19.4	
Ammonia, mg/L	1.80	0.20	3.84	
Antimony, mg/L	<0.01	<0.01	co.01	
Arsenic, mg/L	<0.002	<0.004	<0.004	
Barium, mg/L	<0.1	<0.1	<0.2	
Beryllium, mg/L	co.005	<0.005	<0.03	
Biological Oxygen Demand, mg/L	4	20	200	
Boron, mg/L	4.5	<0.2	36	
Cadmium, mg/L	<0.0003	<0.0003	0.0070	
Calcium, mg/L	226	60.4	667	
Chemical Oxygen Demand, mg/L	30	40	860	
Chloride, mg/L	1550	32.9	17500	
Chromium, mg/L	<0.001	<0.001	0.0011	
Cobalt, mg/L	<0.05	<0.05	<0.05	
Conductivity (Electrical), j&cm	6766	485	50800	2467
Copper, mg/L	<0.1	<0.1	0.83	
Cyanide, mg/L	<0.1	<0.1	<0.1	
Fluoride, mg/L	3.8	<1	3.6	
Iron, mg/L	1.7	<0.08	<0.08	
Lead, mg/L	co.002	<0.002	<0.01	
Lithium, mg/L	0.45	co.2	6.6	
Magnesium, mg/L	92.8	2.6	1110	
Manganese, mg/L	<0.1	<0.01	0.95	
Mercury, #g/L	<0.1	<0.1	co.1	
Nickel, mg/L	<0.07	<0.07	<0.02	
Nitrate, mg/L	< 1	<1	11	
Nitrite, mg/L	< 1	<1	47	
Oil and Grease, mg/L	1.9	<1	a)	
pH	7.20	7.10	7.92	
Phenols, mg/L	<0.02	<0.02	<0.02	
Phosphorus, mg/L	<0.5	<0.3	<2	
Potassium, mg/L	42.9	1.3	484	
Selenium, mg/L	<0.01	<0.01	co.02	
Silver, μg/L	<0.3	<0.3	<6	
Sodium, mg/L	1180	35.9	13500	
Sodium Adsorption Ratio, %	16.7	1.23	74.3	
Sulfate, mg/L	1730	149	13000	
Sulfide, mg/L	<0.05	<0.05	co.05	
Thallium, mg/L	<0.003	<0.003	<0.03	
Total Dissolved Solids, mg/L	5040	292	47360	1838 b)
Total Organic Carbon, mg/L	<100	<100	140	
Total Suspended Solids, mg/L	<50	<10	2230	
Vanadium. mg/L	<0.04	co.04	<0.04	
Zinc, mod-	co.03	<0.03	<0.03	

Insufficient sample for analysis. b) E mated from ele cal conductivity the sample.

Using the data in Table 3 and Figure 2, a TDS balance for the simulation yields experimental salt losses to precipitation of approximately 23 % , which is consistent with the observations made during the simulation.

The data in the table confii the ability of the process to provide treated water of a quality suitable for municipal water supply. The TDS concentration of me treated water is 292 mg/L, which is well within the acceptable range for municipal and industrial water supply.

3.2 Task 2 - Selection of a Demonstration Site

The selection of a suitable FT process demonstration site involved completion of the following subtasks.

3.2.1 Subtask 2.1 -Review Existing Data Characterizing the Dakota Aquifer System in the Immediate Vicinity of Grand Forks, North Dakota

A review of the existing data characterizing the Dakota Aquifer revealed that limited research data were available on the use of the Dakota Aquifer as a production aquifer. However, the following information about the Dakota Aquifer near the targeted FT demonstration site was obtained: The saturated aquifer thickness at the selected site is 63 ft, and the thickness significantly increases to the west (Doering and Benz, 1972). The groundwater flows to the east, with an eastward hydraulic gradient of 5 ft per mile (Kelly and Paulson, 1970). The average TDS content of the Dakota Aquifer is 4400 ppm (Kelly and Paulson, 1970).

Data on the major hydraulic parameters of the Dakota Aquifer near the selected site were extracted from pumping tests conducted by the U.S. Department of Agriculture Agricultural Research Service from 1966 to 1968. The results of these pumping tests revealed that the aquifer has a transmissivity of 6000 ft^2/day, a hydraulic conductivity of 95 ft/day, a storage coefficient of 0.0004, and a porosity of 42.7% (Kelly, 1968).

3.2.2 *Subtask 2.2 - Demonstration Site Selection*

A site approximately 5 miles west of Grand Forks was selected for the FT demonstration (Figure 3). The site extends across the eastern liits of the Dakota Aquifer, and the suggested well field lies approximately 5 miles northwest of the Grand Forks water treatment plant. The FT demonstration site was selected because the productivity of the Dakota Aquifer is sufficient to demonstrate the FT process, the topography of the land is suitable, the land is likely available, and the land is close to Grand Forks.

A conceptual hydrogeologic model of the selected site was then used to determine the effects of pumping 2,000,000 and 4,000,000 gallons of water per day after 1, 5, and 10 years of pumping. This conceptual ***model,*** illustrated in Figure 4, is based on groundwater

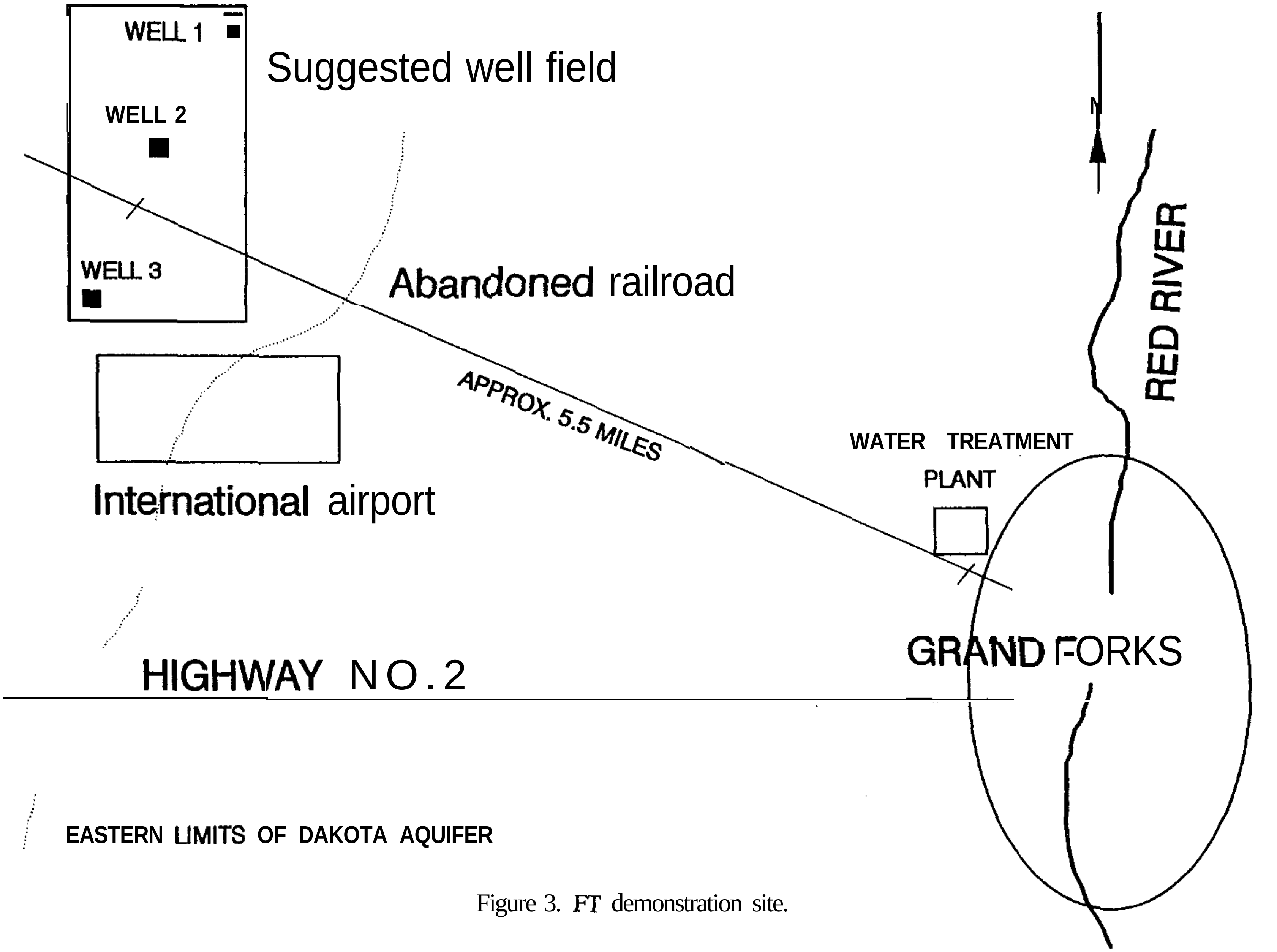
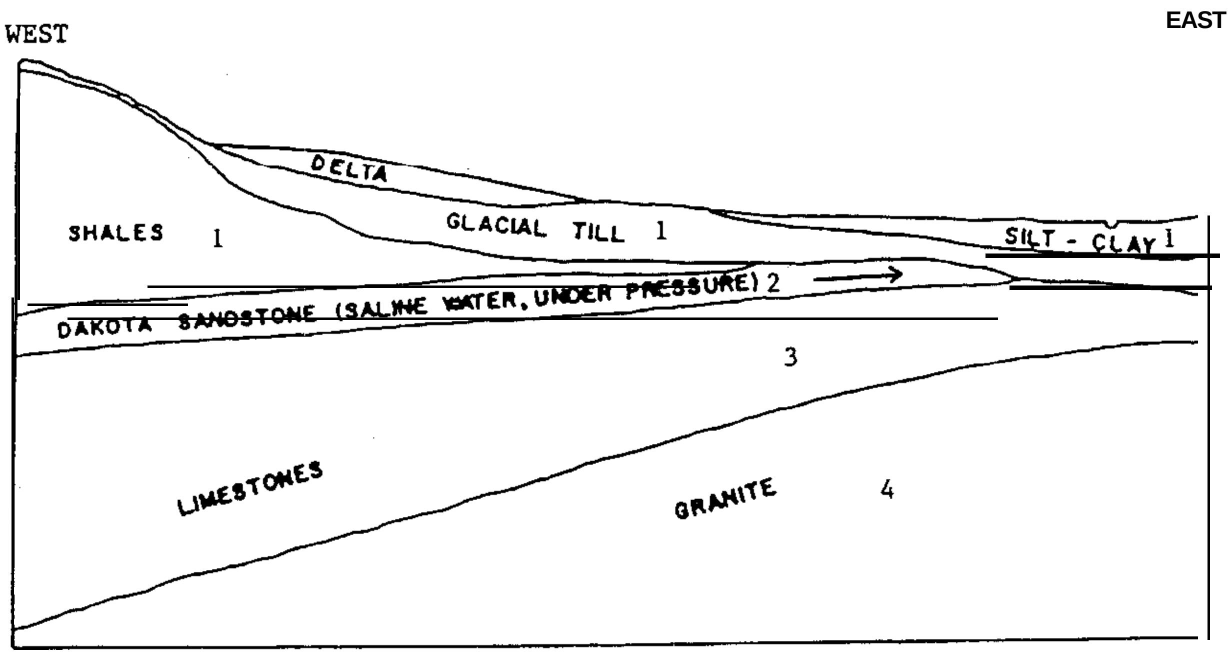


Figure 3. FT demonstration site.

Figure #2.- **CONCEPTUAL MODEL:** SKETCH OF GEOLOGIC CROSS-SECTION ON EAST WEST LINE THROUGH THE MIDDLE OF GRAND FORKS COUNTY, ND. (MODIFIED FROM DOERING AND BENZ, 1972)



EXPLANATION

Unit 1	**Cretaceous Shales, Glacial Till. Clay. Silt (unit 1)**
Unit 2	Dakota Sandstone (unit 2)
Unit 3	**Red River Formation: Paleozoic limestone (unit 3)**
Unit 4	Precambrian Granite Bedrock (unit 4)
↗	Ground Water Flow Direction

Figure 4. Conceptual hydrogeologic model.

flow through a confined, uniformly thick, homogeneous, and ***isotropic*** aquifer terminated by a hydraulic barrier. The hydraulic barrier consists of materials with the same hydraulic parameters as the overlying formation. Because of relatively large differences in the hydraulic parameters of the respective units (Figure 4), the hydraulic change caused by pumping spreads faster in the aquifer, thus allowing limited groundwater influx from the overlying and underlying formations.

A numeric modeling tool to support the conceptual model was used to optimize potential well field layouts and evaluate potential production rates. The model was specified for the selected site and applied to an area of approximately 1300 square miles. The purpose of the numerical model was to provide an effective way to observe changes in drawdown associated with modifications to the well field design. Using the numerical model, primary well field layouts were evaluated to estimate production potential. These layouts were then modified to produce the desired production rates while minimizing costs associated with the design of the well field.

The boundary conditions for the model consist of no-flow boundaries to the north, south, and east, with a constant-head boundary located to the west. Data collected in Subtask 2.1 were used to determine proper input data for the numerical model. However, owing to limited data, many parameters were estimated from the literature. These data and their sources are listed in Table 4. Note that the value for hydraulic conductivity used in the simulation is 40 ft/day, rather than the 95 ft/day found in the literature. This is to be conservative, in our estimation, and is also the result of an effort to match a steady-state simulation with the drawdowns achieved in a previous pumping test done on the aquifer.

The position of the constant-head boundary was estimated using an analytical computer model, THWELLS, designed to evaluate drawdown in confined aquifers. An appropriate constant-head boundary was determined for the desired production rates by calibrating the influence of drawdown after 200 days of pumping. The elevation head at the constant-head boundary was determined by assuming an eastward hydraulic gradient of 5 ft/mi or 505 ft (Kelly and Paulson, 1970). Calibration wells were then pumped under steady-state conditions to calibrate the model (Figure 5) to the hydraulic gradient in the modeled area. These data were imported into the existing model design as a preliminary VMODFLOW (Guigner and Franz, 1996) run to assign initial head levels to the model. The calibration of the numerical model was driven to simulate actual results of the ARS pumping tests and reported drawdowns.

The fully penetrating production wells are pumped intermittently, with a production cycle of 200 days on and 165 days off. The transient flow simulation was conducted at pumping rates of 2,000,000 and 4,000,000 gal/day. Two observation wells were added to the transient flow simulation near Kelly's Slough, ***a*** wildlife refuge approximately 5 miles from the site, to monitor any potential impacts on the area.

TABLE 4

Numeric Model Input Parameters

unit	Hydraulic Conductivity, ft/day	ss, 1/ft	Storage, Sy	Porosity	Recharge, in./yr
1	0.0008”	8E-5[d]	0.03[d]	0.2[d]	0
2	40	3E-6[b]	0.25’	0.427’	
3	0.001”	1E-6[d]	0.01[d]	0.1”	
4	0.0001’	5E-7[d]	0.01[d]	0.1[d]	

[a] Benz and Doering, 1973.

[b] Doering and Benz, 1972.

[c] Freeze and Cherry, 1979.

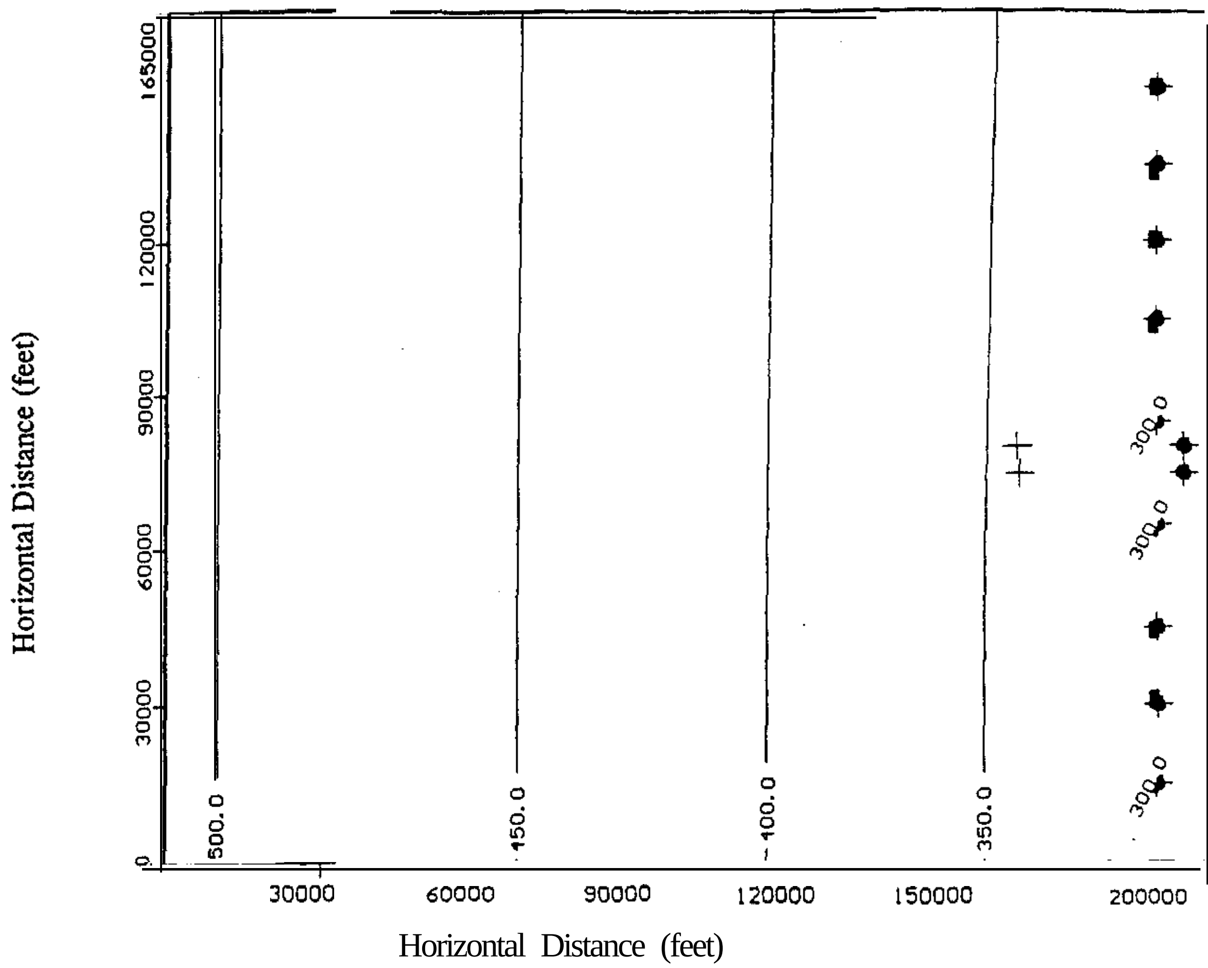
[d] Driscoll, 1986.

[e] Kelly, 1968.

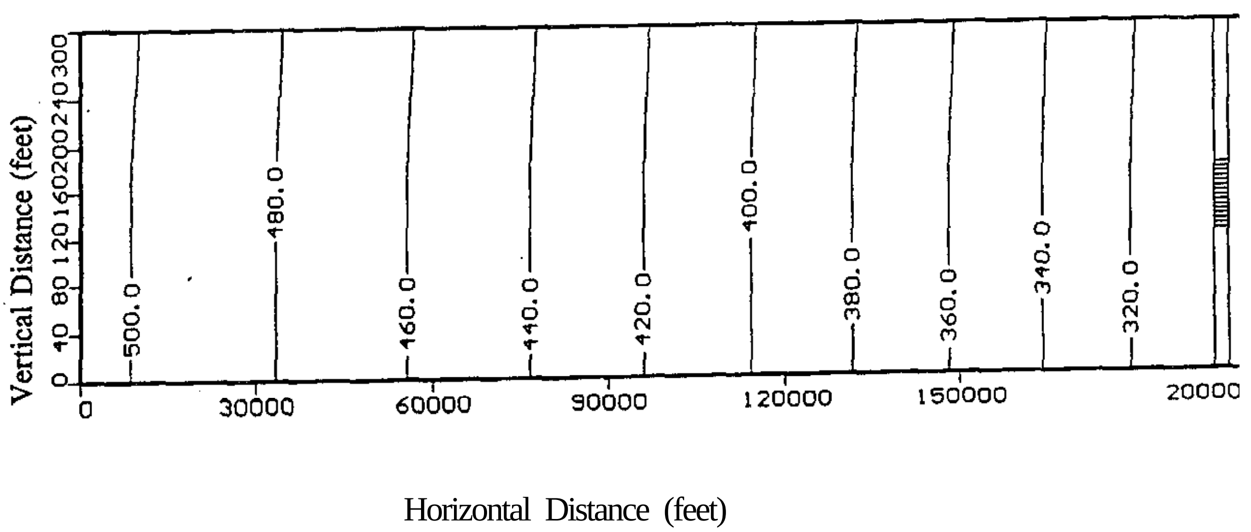
The 2,000,000-gal/day simulation produced 86 ft of drawdown in the production well after 10 years of pumping. The cross-sectional view given in Figure 6 shows projected drawdown illustrates the relationship between reduction of pressure head in the Dakota Aquifer and reduction curves after 1, 5, and 10 years of pumping. The head-versus-time graph of the observation wells of the piezometric surface in the overburden (Figure 7). The results indicate that after 10 years of intermittent pumping, the piezometric surface of the Dakota Aquifer would be reduced only by 5.3 ft near Kelly’s Slough and, thus, should not have any adverse impact on the water levels in the slough. This relationship is also shown in the drawdown-versus-time graph (Figure 8). Unfortunately, the elevation of the potentiometric surface at Kelly’s Slough is not known, and therefore, the model results and preliminary conclusions need to be confirmed with a detailed hydrogeologic investigation and aquifer test prior to a full-scale application of the FT process at this site.

The 4,000,000-gal/day simulation produced 119 ft of drawdown after 10 years of pumping. A cross-sectional view of projected drawdown curves after 1, 5, and 10 years of pumping is given in Figure 9. The head-versus-time graph shows that the reduction in the piezometric head near Kelly’s Slough is expected to be approximately 9.7 ft after 10 years of pumping (Figure 10). This relationship is also shown in the drawdown-versus-time graph (Figure 11). Data regarding anticipated drawdown for desired pumping rates are presented in Table 5. The same considerations regarding the need for a detailed hydrogeologic investigation and aquifer test are valid here.

The 10,000,000-gal/day simulation was not run at thii site. Based on estimations made following the previous two simulations, it was determined that the anticipated drawdowns for this simulation would have a significant impact on Kelly’s Slough.



(a)



(b)

Figure 5. Steady-state well calibration: a) areal view of model domain showing observation, calibration, and production wells and b) profile of model domain.

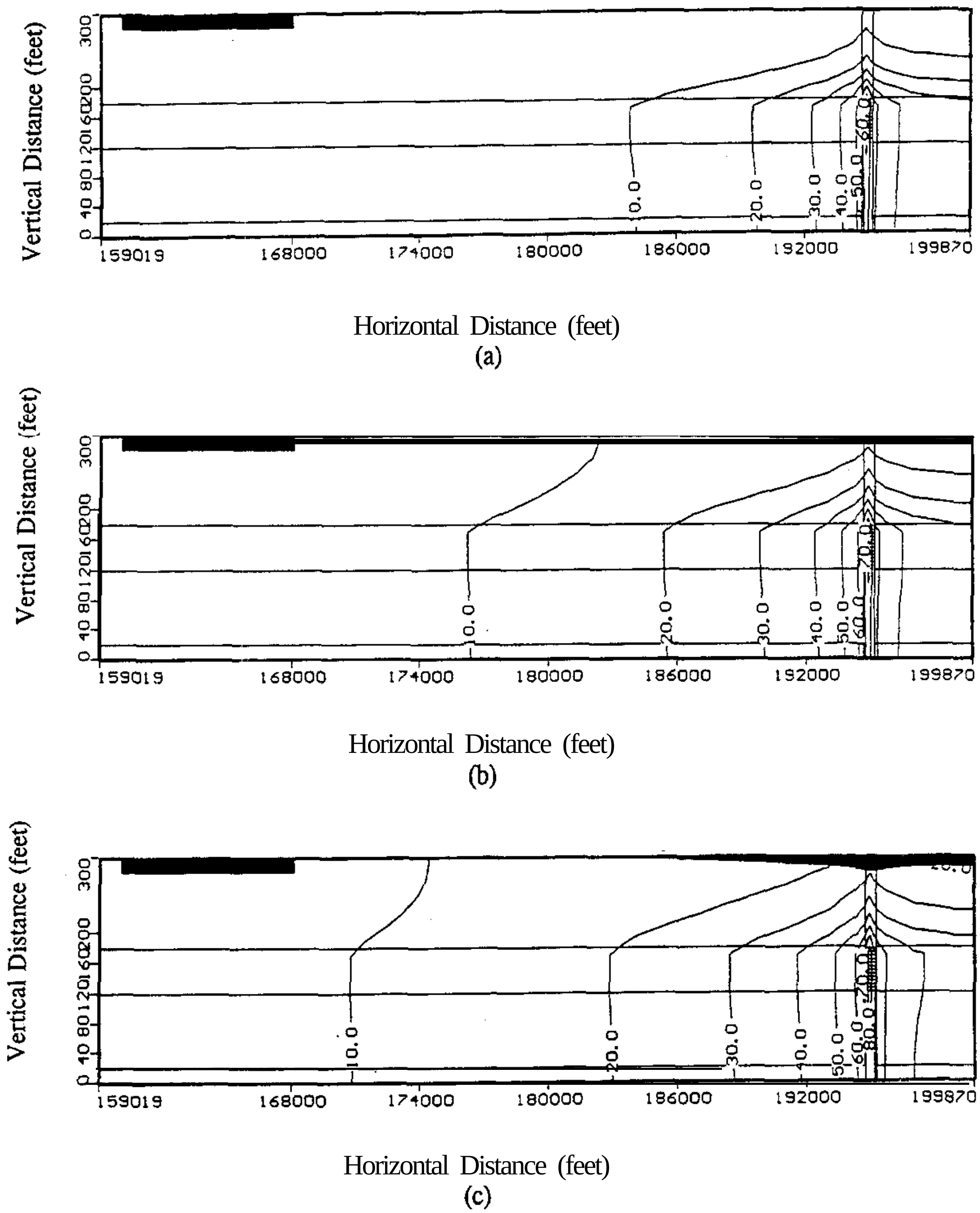


Figure 6. Cross section of drawdowns at 2,000,000 gal/day: a) after 1 year of pumping, b) after 5 years of pumping. and c) after 10 years of pumping.

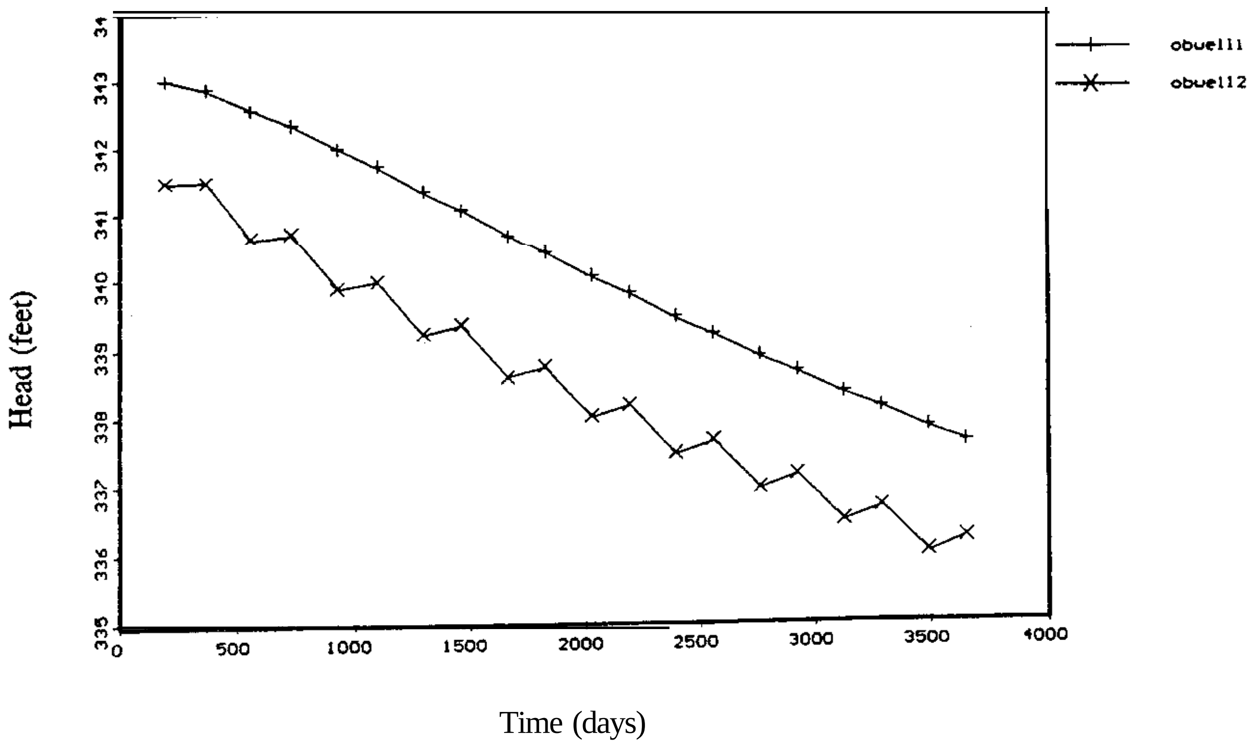


Figure 7. Head vs. time at 2,000,000 gal/day.

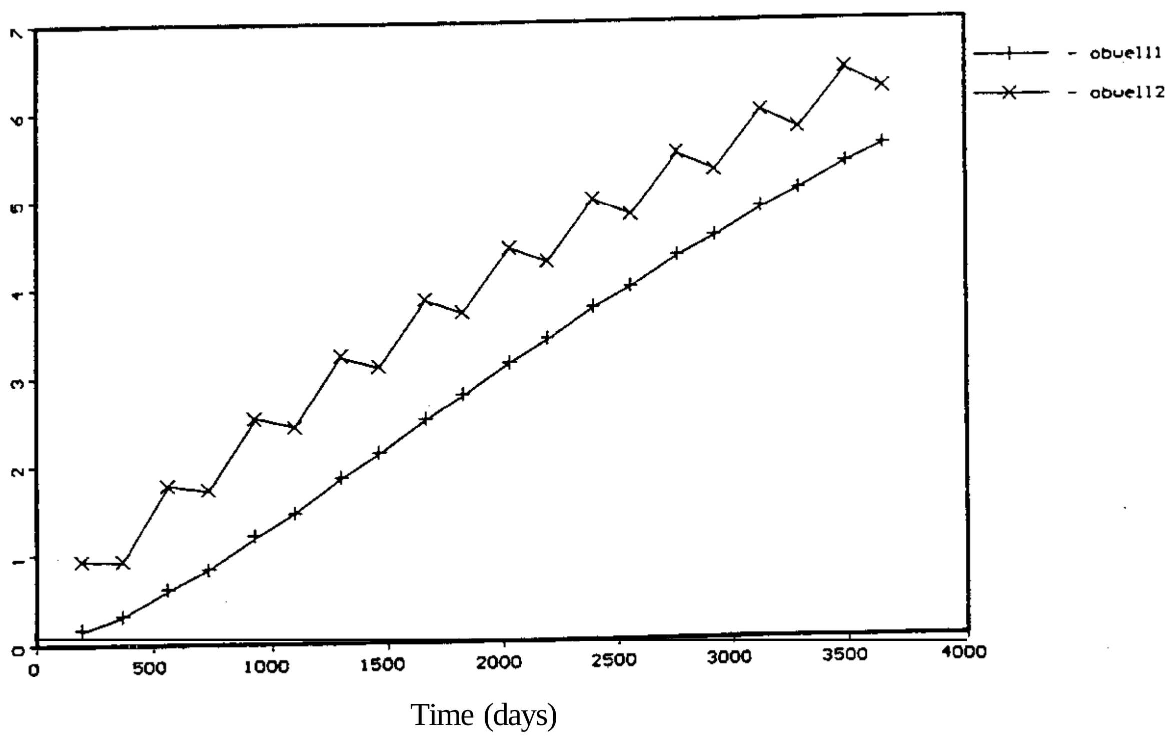


Figure 8. **Drawdown** vs. time at 2,000,000 gal/day.

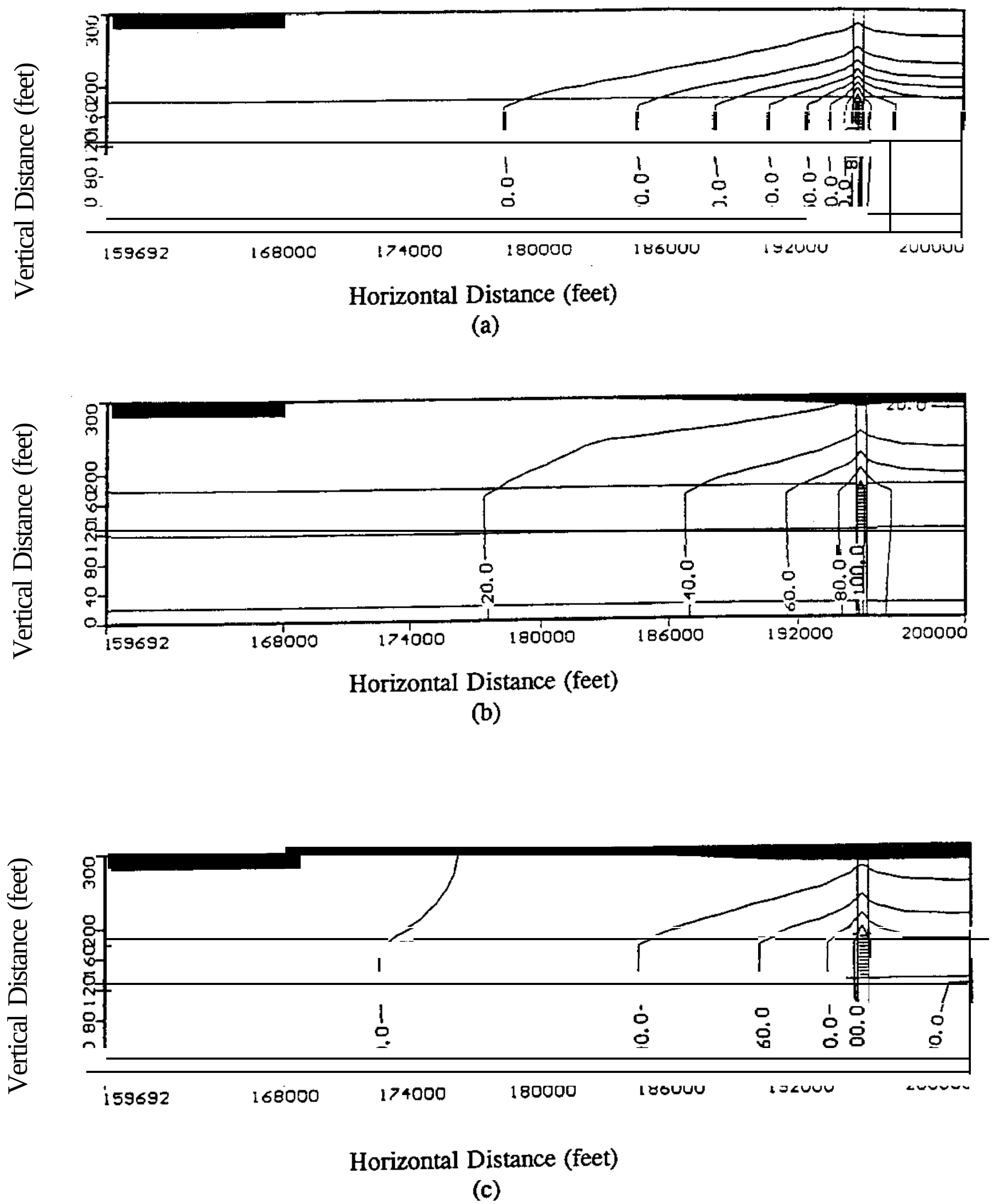


Figure 9. Cross section of drawdowns at 4,000,000 gal/day: a) after 1 year of pumping, b) after 5 years of pumping, and c) after 10 years of pumping.

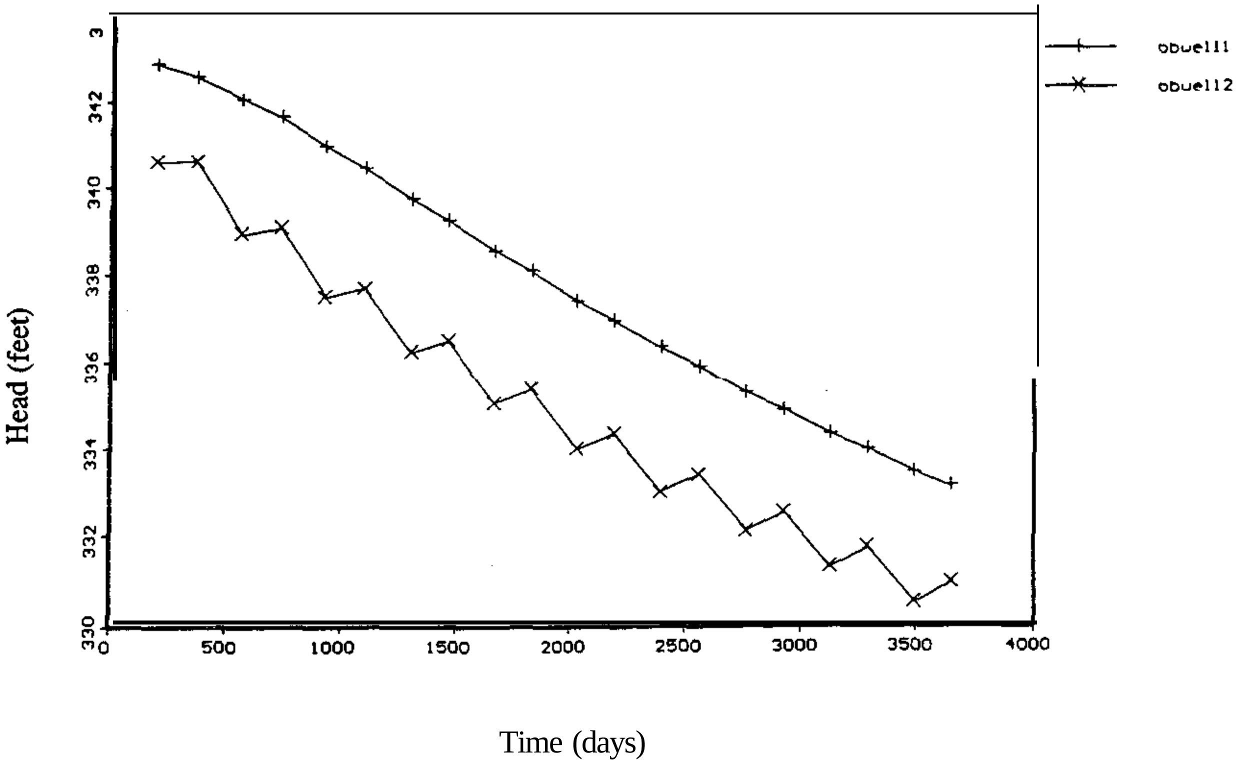


Figure 10. Head vs. time at 4,000,000 gal/day.

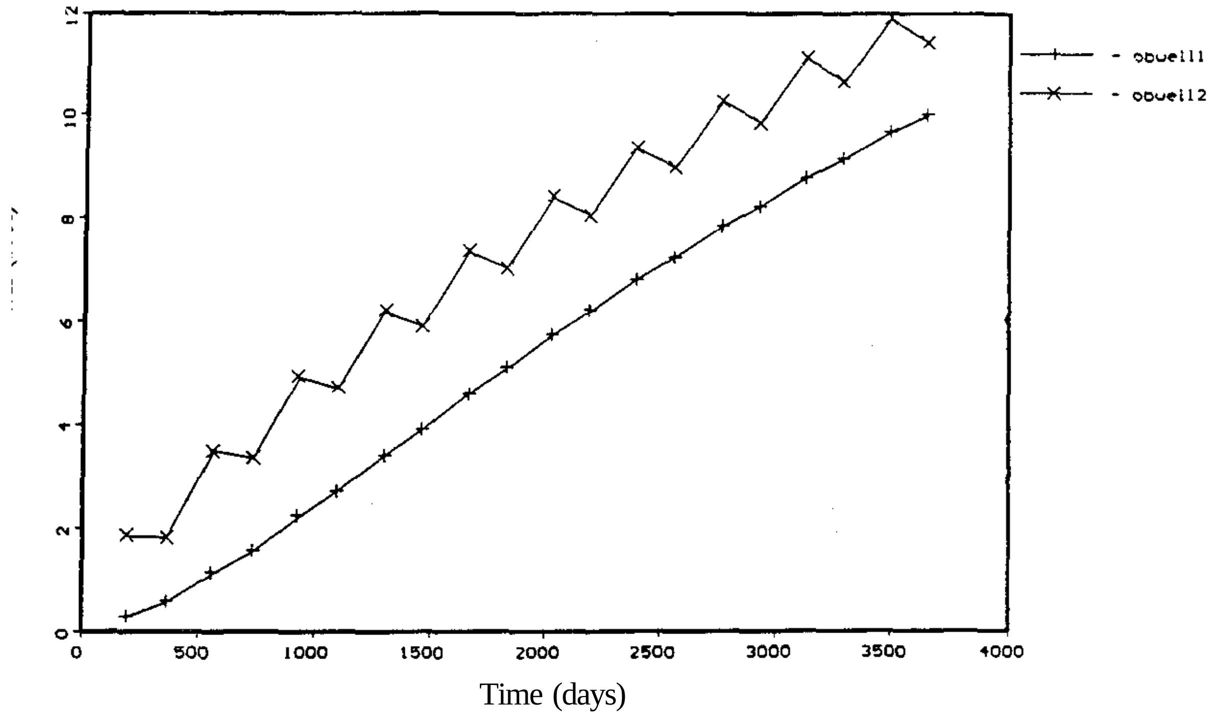


Figure 11. **Drawdown** vs. time at 4,000,000 gal/day.

TABLE 5

Anticipated Drawdowns for Desired Pumping Rates

Pumping Rate, gal/day	Time, days	Model Observed Drawdown, ft		
		Production Wells	Observation Well 1	Observation Well 2
2,000,000	200	72	0.2	0.9
	1660	82	2.5	3.8
	3485	86	5.3	6.4
4,000,000	200	94	0.3	1.9
	1660	112	4.7	7.4
	3485	119	9.7	11.9

The well field design and optimization were based on results of the numerical model. The drawdown was very sensitive to changes in pumping rates. Well spacing seemed to have no significant effect on anticipated drawdowns. The model outputs regarding this site are based on very limited data, and many parameters have been estimated from literature. The potential exists to move the site west for higher yield; however, increased costs and environmental concerns in regard to moving the site closer to Kelly's Slough require that these options be examined more carefully.

3.3 Task 3 - Design of a Full-Scale FT Demonstration

3.3.1 Subtask 3.1 - Sizing of the Demonstration

After an examination of water needs in eastern North Dakota, it was determined that any size of FT demonstration would be welcome, given the city's future need for water. For this reason, the size of the demonstration was based upon the results of the aquifer evaluation and the well field design. A demonstration plant sized to provide 183 million gal/yr (annualized 500,000 gal/day) of treated water was considered for the FT demonstration.

The demonstration plant would require 252 million gal/yr of feed to produce the desired rate of treated water. After the first year, 52 million gal/yr of feed would be provided from the intermediate FT process stream as indicated by the simulation results. This stream is approximately one half the salinity of the Dakota Aquifer water. The remaining 200 million gal/yr of feed would be provided by two 12-in.-diameter wells completed in the aquifer, each capable of providing 1 million gal/day of feed to the demonstration plant. These wells would operate 125 days/yr during the first year and 100 days/yr for the remaining years in order to provide the needed feed. This plant size and configuration provide limited contingency for the initial demonstration operation, are adequate for increasing the plant capacity should aquifer characteristics and FT operating efficiency allow, and can be economically scaled to a 365-million gal/yr (1-million gal/day) commercial plant by adding one additional well.

3.3.2 Subtask 3.2 -Assessment of the FT Demonstration Permitting/Approval Requirements

Contacts were made with the appropriate regulatory personnel to determine the permits/approvals necessary for the operation of a significant-scale FT plant in the Grand Forks area. It was determined through this effort that a conditional water use permit would be required from the North Dakota State Water Commission to remove and process water from the Dakota Aquifer. In addition, permits will be required from the North Dakota State Health Department, Division of Water Quality, for the construction and operation of each pond. Conversely, if the brine were to be reinjected for disposal, this would require a Class I Nonhazardous Injection Well Permit, also issued by the North Dakota State Health Department, Division of Water Quality. Similarly, if the intermediate process stream were to be reinjected into the Dakota Aquifer for storage until it is processed the following year, this would also require a Class I Nonhazardous Injection Well Permit.

3.3.2.1 Requirements for a Conditional Water Permit

The North Dakota State Water Commission was contacted to determine the steps necessary to obtain a conditional water permit. An application fee of $750.00 must accompany an application for industrial use in excess of 1 cubic ft/sec, or in excess of 724 acre-feet annually. If the application involves the storage of water, both the quantity of water which will be stored at the level of the principal spillway and the quantity which will be lost to evaporation must be reported on the application. Further details regarding the steps required to obtain this permit are provided in Appendix B.

3.3.2.2 Requirements for Construction and Operation of Storage/Evaporation Ponds

The requirements for permitting the construction and operation of storage ponds are provided by the North Dakota State Health Department, Division of Water Quality. Based upon discussion with personnel from this organization, it was determined that storage ponds for the feed water or intermediate water would not require impermeable synthetic liners. However, a brine evaporation pond would require an impermeable synthetic liner. Further details regarding the steps required to obtain this permit are provided in Appendix C.

3.3.2.3 Requirements for a Class I Nonhazardous Injection Well Permit

The North Dakota State Health Department, Division of Water Quality, was contacted to determine the steps necessary to obtain a Class I Nonhazardous Injection Well Permit. The application for the permit must be accompanied by a topographic map of the area extending at least 1 mile beyond property boundaries, a detailed engineering technical report, and a $50,000 surety bond or proof of equivalent performance to cover emergency plugging or remediation of the well or area affected by the well. It was determined that the engineering data required for these permits would have to be obtained during the demonstration operation, and for this reason, the demonstration design includes a storage pond for the intermediate process stream and a synthetically lined brine evaporation pond. Further details regarding the steps required to obtain this permit are provided in Appendix D.

3.3.3 Subtask 3.3 -Design and Costing of the FT Demonstration

The design and cost of a demonstration of the FT process for providing the city of Grand Forks, North Dakota, with additional water by treating saline water from the Dakota Aquifer were determined using the results of this and previous research. Based upon the results of Subtask 3.1, it was determined that a demonstration providing an annual average of 500,000 gal/day of treated water for use by the city would be a significant and reasonable size for the demonstration.

The results of Task 1 were used with newly modified versions of the existing BCT FT process and *economic* models to design the demonstration facility. The data developed in Task 1 that were used in this evaluation are summarized in Table 6.

TABLE 6

FT Process Yield and Water Quality Data Used in the FT Demonstration Design

Process Stream	TDS, mg/L	Yield, % of feed
Dakota Aquifer Feed Water	5040	
Treated Water	292	72.6
Intermediate Recycle	1838	20.5
Brine	47,360	6.9

Using the data in Table 6, the annual average demonstration plant performance was estimated (Table 7). The plant would require 251 million gal/yr of feed to the freezing pad. The demonstration would produce 183 million gal/yr of treated water suitable for use by the city of Grand Forks. The intermediate recycle stream would be 52 million gal/yr. The intermediate stream produced during the first year of operation would be stored in an earthen holding pond constructed of compacted clay/soil for processing the following year. Thus, 25 1 million gal of water would need to be- pumped from the Dakota Aquifer the first year; 52 million gal would be pumped and placed in the newly constructed holding pond prior to the onset of freezing; and the remaining 199 million gal would be pumped from the aquifer during the time period from November 1 through February 8.

TABLE 7

FT Demonstration Plant Annual Average Plant Performance

Process Stream	1000 gal/day	1000 gal/yr
Dakota Aquifer Feed Water		
First Year	689	251,500
Remaining Years	548	199,900
Treated Water	500	182,600
Intermediate Recycle	141	51,600
Brine	48	17,350

The well field designed to provide this water would consist of two 12-inch-diameter wells, each capable of providing 1 million gal/day of water from the aquifer. Only 199 million gal/yr would need to be pumped from the aquifer after the first year, if the demonstration plant were to be operated at the same rate (500,000 gal/day) for additional years, as the stored intermediate water would be available for processing. The well field design was based upon the results of Task 2.

The selection of a storage pond for the intermediate recycle stream was based upon a conservative review of the results of Subtask 3.2, which indicated that an earthen pond would be acceptable for storing this water and also indicated that additional hydrologic engineering data describing the aquifer would be required to permit reinjection of this water into the aquifer. Reinjecting the intermediate stream into the Dakota Aquifer for storage during the summer appears to be a safe and significantly less costly method for storing this relatively clean process output. However, the hydrologic characterization of the Dakota Aquifer was reliant on existing data in the literature, some of which was quite dated. Thereby, the design of the demonstration includes the storage pond and research and support funding to conduct a detailed aquifer characterization to determine the feasibility and environmental acceptability of storing the intermediate water produced in the aquifer during the warm months. Should this concept prove feasible, acceptable, and permissible, it would result in a reduction in the commercial FT plant cost discussed in the following section.

It was also decided, based upon the results of Subtask 3.2, that the freezing pad could be constructed of compacted clay/soil. However, the brine evaporation pond would require a single, synthetic, impermeable liner. Based upon these considerations, the designs and costs of the required ponds and pad were determined using the model, which was modified to include the intermediate water storage pond. Design and cost data for these items are summar ized in Table 8.

TABLE 8

Design and Installed Cost Data for Ponds and Pad for the FT Demonstration

Item	units	Storage Pond	Brine Pond	Freezing Pad
Base Dimension	ft	529	575	784
Surface Dimension	ft	685	651	808
Max. Fluid Depth	ft	20	7	1
Evaporative Area	ft^2	421,501	377,889	614,499
	acres	9.68	8.68	14.11
Max. Liquid Volume	ft^3	6,798,179	2,289,241	614,499
	M gal	50,857	17,126	4591
Max. Height of Ice	ft			80
Liner Required	ft^2		396,953	
Installed Liner Cost	$\$/ft^2$		0.73	
Excavation Required	yd^3	42,000	50,296	54,951
Total Installed Cost	$	108,150	419,499	141,230
Total Cost for Ponds and Pads	$			668,879

The process design model not only optimizes the size of the ponds required for the FT demonstration facility, but optimizes the cost of the ponds. In the cost optimization, soil excavated in the construction of the brine evaporation pond and freezing pad is used to construct above-ground berms for the construction of the storage pond for the intermediate recycle stream. This technique results in significant cost savings in the construction of the ponds. Appendix E provides details of the designs of each of the ponds and the individual excavation requirements for each pond. In determining the cost for each pond, a price of $\$2.57/yd^3$ was used for excavation and compaction. This price is the national average cost for large-scale excavation with required hauling of 1500 ft or less. The price was obtained from current literature ***(Mean's Construction Cost Data Book for*** 1996). The liner cost is $\$0.35/ft^2$, which is a current vendor quote from Reef Industries, Inc., of Houston, Texas, for a 30-mil HDPE liner with geotextile backing for added strength. This price does not include any discount for quantity purchased. The installed liner cost included the cost of the liner, the cost of liner installation, and estimated shipping costs. Excavation costs are broken down separately and not included in the liner cost. The cost of liner installation was estimated to be $\$0.35/ft^2$ by using a 2.0 installation factor, and shipping costs were conservatively estimated to be $\$0.03/ft^2$. Thus the total installed liner cost is $\$0.73/ft^2$.

Other demonstration facility requirements are summarized in Table 9. The cost of the well field and monitoring wells includes the hvo 12-in.-diameter pumping wells and monitoring wells to allow for detailed characterization of the Dakota Aquifer during the

TABLE 9

Installed Cost Data for Other Facility Requirements for the FT Demonstration

	Installed Cost, $
Well field and Monitor Wells	102,000
Transfer/Circulation Pumps	27,625
Pipe and Pipe Fittings	74,340
Controls and Control Valves	26,527
Facility, Services, and Fencing	30,000
Total Cost for Other Facility Requirements	260,492

demonstration. Also provided in the table are the cost of pumps, pipe and fittings, controls, facility, services, and fencing. The total installed capital costs for the demonstration are approximately $929,000.

Operating expenses for the first year of the demonstration were determined and are summarized in Table 10. During the first year of operation, permitting, research, and operating will be provided jointly by the EERC and BCT. Included in this cost are those anticipated to be necessary for all permitting required for the demonstration, detailed characterization of the Dakota Aquifer, and an assessment of the FT demonstration on the aquifer and related ecosystems, analysis of demonstration samples, operating and supervisory personnel for the demonstration, and engineering support for the demonstration, construction, and evaluation. Also included in the operating expenses are the cost of utilities required for plant operation, plant maintenance estimates, and insurance costs. The total operating expenses for the first year of operation are $1,077,000.

The total cost for the demonstration and first year of operation (including research support) is $2,006,000. This cost includes approximately $929,000 for installed capital, $950,000 for research and engineering support, and $127,000 for plant operating costs.

If the demonstration plant continued to operate beyond the first year, research and engineering support would not be needed. Instead, salaries and wages for plant operating personnel would be required, along with additional cost for sample analysis. The cost of salaries and wages beyond the first year is estimated to be $95,000/yr, and the cost of sample analysis is estimated to be $2500/yr. Subtracting the cost for research and engineering support during the first year from the annual expenses, and adding in the estimated cost of salaries, wages, and sample analyses, the expected annual expenses for plant operation would be approximately $224,000/yr. Operating the demonstration in this fashion, considering the economic basis described in Table 11, and considering amortization and recovery of installed capital costs over the plant life, the water treatment cost for continued commercial operation of the demonstration plant at the same rate (500,000 gal/day) would be $1.67/1000 gal of usable water produced, which is less than

TABLE 10

FT Demonstration Annual Operating Expenses for the First Year of Operation

Expense	$/yr
Staff and Research and Engineering Support	950,000
Utilities	80,358
Maintenance	27,881
Insurance	18,587
Total Annual Expenses	**1,076,826**

TABLE 11

Economic Basis for Determination of FT Water Treatment Cost Using the Demonstration Facility

Parameter	Value
Load Factor	1.0
Plant Life	20 yr
Bond	100%
Bond Interest	6%
Construction Period	Negligible
Salvage Value	$0

the current cost of domestic water in Grand Forks. A general layout of the FT demonstration facility is provided in Figure 12.

3.4 Task 4 - Detailed Economic Analysis of the FT Process for Desalinization of Water for the City of Grand Forks, North Dakota

Experimental research completed and discussed herein along with the preliminary hydrologic evaluation of the Dakota Aquifer have continued to confirm the technical feasibility of using the FT process to treat Dakota Aquifer water to provide water to the city of Grand Forks, North Dakota. However, the economics of commercial application of the FT process must be considered for development of the process for this application to continue. For this reason, the design requirements and cost of a commercial-scale FT plant to provide water to the city of Grand Forks were determined in a fashion similar to the analyses of the FT demonstration (Section 3.3.3). The estimated performance, installed capital costs, annual operating expenses, and resulting treated water cost are provided in the following section to determine whether the commercial economics of the FT process warrant continued development.

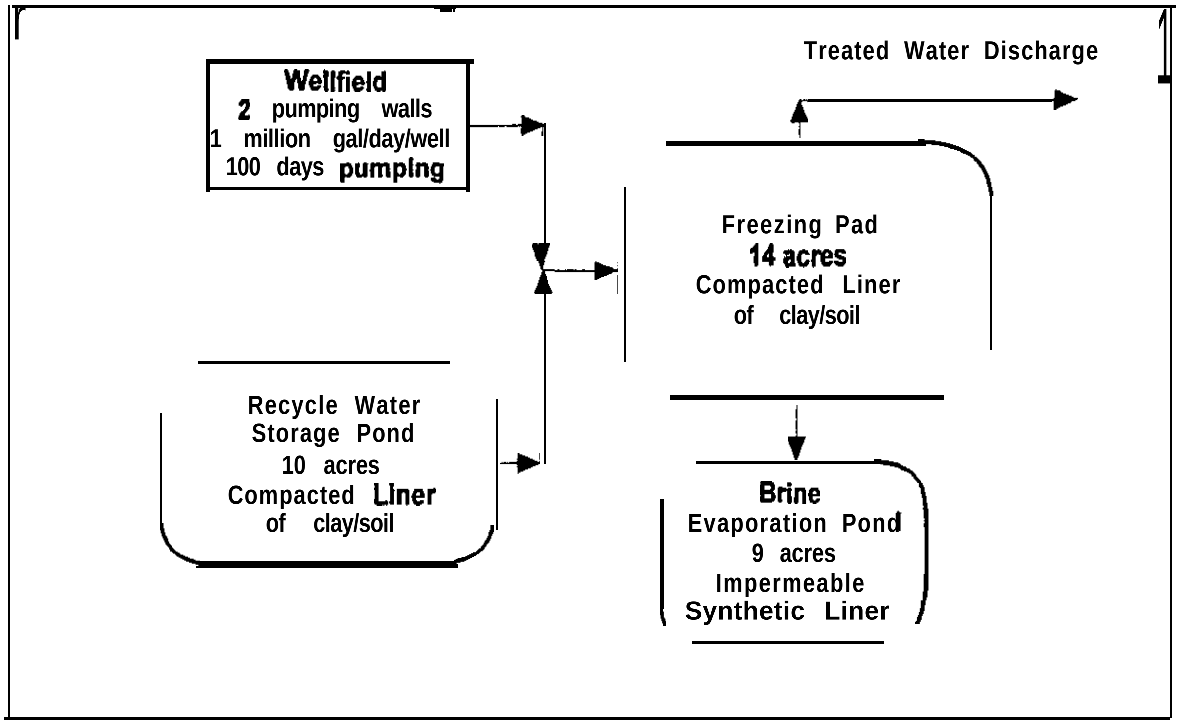


Figure 12. General site layout for FT demonstration facility for treating saline water from the Dakota Aquifer to provide water for the city of Grand Forks, North Dakota.

The experimentally determined FT process data derived in this research were used (Table 6) along with me modified process and economic models to determine the water treatment cost of the commercial FT facility. The design and economic evaluation assumptions are similar to those discussed in Section 3.3.3, with the exception of the treated water production rate and the well field.

The commercial facility is designed to provide an annual average of 1 million gal/day of water to the city. The design requires three pumping wells in the Dakota Aquifer that are constructed similarly to those previously discussed in Section 3.3.3. The 1 million gal/day size of the facility and the well field design both result from the preliminary aquifer evaluation completed in Task 2. It is expected that when a detailed characterization of the Dakota Aquifer is completed, it will be found that a greater amount of water can be removed from the aquifer in an environmentally safe fashion. However, based upon the preliminary aquifer evaluation, 1 million gal/day was viewed as a safe treated water production rate. This size facility would require that 4 million gal/day of water be removed from me aquifer after the first year of operation, (which would require that 5 million gal/day of water be removed), because after the first year of operation, reprocessing of the intermediate stream is possible.

Using the data in Table 6, the annual average commercial plant performance was estimated (Table 12). The designs and costs of me required ponds and pad are summarized in Table 13. The commercial facility requirements are summarized in Table 14. Additional data regarding the design of the ponds and the required excavation are found in Appendix E. Annual operating expenses for the commercial plant were determined and are summarized in Table 15.

TABLE 12

FT Commercial Plant Annual Average Plant Performance

	1000 gal/day	1000 gal/yr
Process Stream		
Fist Year	1377	502,800
Remaining Years	1095	400,000
Treated Water	1000	365,000
Intermediate Recycle	282	103,100
Brine	95	34,700

TABLE 13

Design and Installed Cost Data for Ponds and Pad for the FT Commercial Plant

Item	Units	Storage Pond	Brine Pond	Freezing Pad
Base Dimension	ft	778	823	1106
Surface Dimension	ft	933	898	1130
Max. Fluid Depth	ft	20	7	1
Evaporative Area	ft^2	814,150	742,982	1,223,990
	acres	18.46	17.06	28.10
Max. Liquid Volume	ft^3	13,666,760	4,559,840	1,223,990
	M gal	103.300	34.110	9157
Max. Height of Ice	ft			80
Liner Required	ft^2		769,860	
Installed Liner Cost	$\$/ft^2$		0.73	
Excavation Required	yd^3	64,195	99,845	87,533
Total Installed Cost	$	$165,000	815,810	225,000
Total Cost for Ponds and Pads	$			1,205,810

TABLE 14

Installed Cost Data for Other Facility Requirements for the FT Commercial Plant

	Installed Cost, $
Well Field and Monitor Wells	142,000
Transfer/Circulation Pumps	42,058
Pipe and Pipe Fittings	123,732
Controls and Control Valves	31,090
Facility, Services, and Fencing	45,000
Total Cost for Other Facility Requirements	383,880

TABLE 15

FT Commercial Plant Annual Operating Expenses

Expense	$/yr
Salaries and Wages	94,640
Utilities	160,060
Sample Analyses	2,500
Maintenance	47,690
Insurance	31,790
Total Annual Expenses	336,690

The commercial plant requires $1,589,690 for installed capital: $1,205,810 for ponds and pad and $383,880 for other facility requirements. The annual operating expenses for the commercial plant are $336,690. Constructing and operating the commercial plant in this fashion, considering the economic basis (Table 11) and amortization and recovery of installed capital costs over the plant life, the water treatment cost for the commercial FT operation is $1.30/1000 gal of usable water produced. This cost is approximately 33% less than the current cost of water in Grand Forks which is $1.97/1000 gal. However, additional treatment would likely be required to utilize this water as a potable water source. Likely treatment would include filtration and disinfection. A general layout of the FT commercial facility is provided in Figure 13.

4.0 CONCLUSIONS

This research has indicated the following:

- The FT process is technically feasible for treating water from the Dakota Aquifer to produce needed water for augmentation of the city of Grand Forks, North Dakora, municipal water supply. A significant yield (72.6%) of high-quality (292-mg/L TDS concentration) was produced in the process simulation, and detailed chemical analysis of this water indicated it to be of a quality suited for this application.

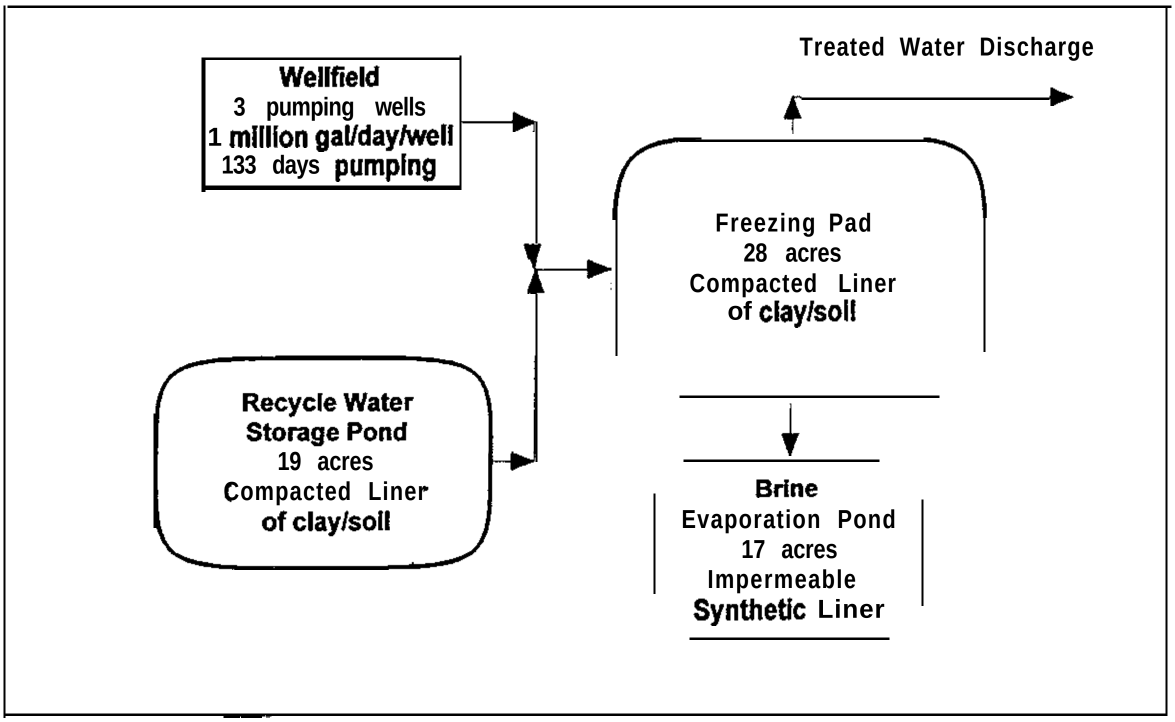


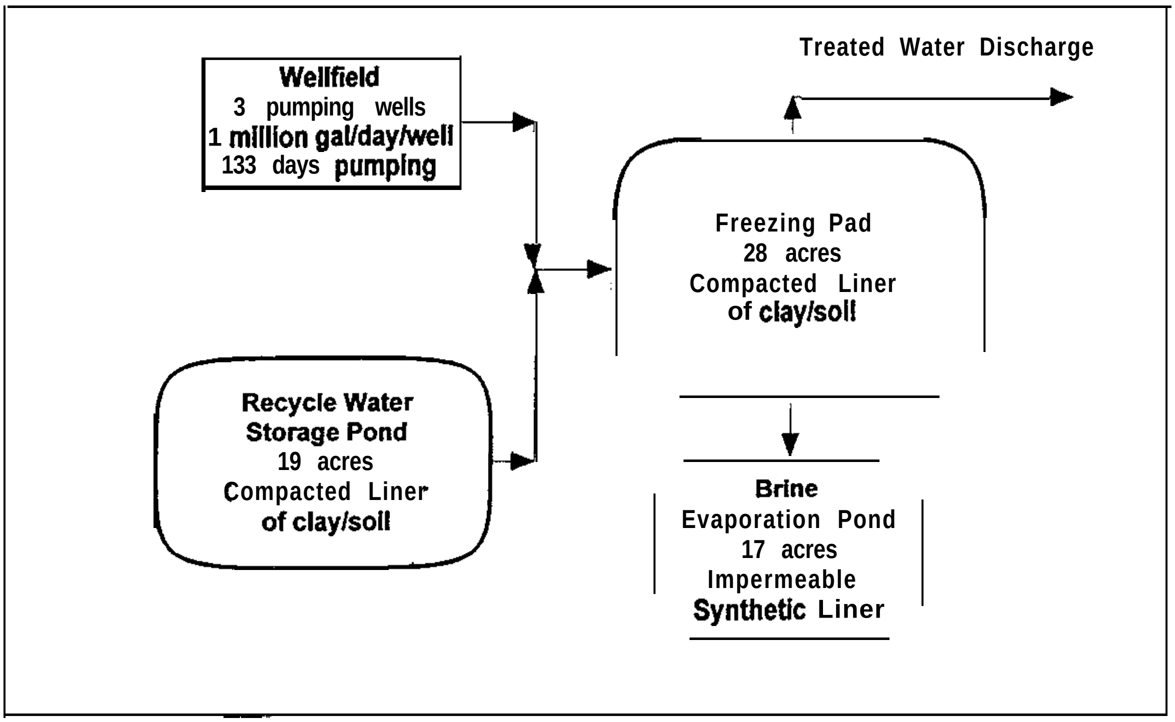
Figure 13. General site layout for FT commercial facility for treating saline water from the Dakota Aquifer to provide water for the city of Grand Forks, North Dakota.

- The Dakota Aquifer is capable of providing sufficient water for a l-million gal/day FT water treatment plant without adverse environmental impact.

- Considering a reasonable commercial FT plant operation, a reasonable economic basis (Table 1 1), and amortization and recovery of installed capital costs, the water treatment cost for the commercial plant operation is $1.30/1000 gal of usable water produced. This cost is approximately 33% less than the current cost of water in Grand Forks, which is $1.9711000 gal. However, additional treatment would likely be required to utilize this water as a potable water source. Likely treatment would include filtration and disinfection.

- Based upon the results of this research, this commercial application of the FT process provides an opportunity for the city of Grand Forks to ease its projected water shortage.

- The FT process should be demonstrated in this, or a similar, application as soon as possible, to ease projected water supply shortages in eastern North Dakota and permit the continuing economic growth of this region.



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- The FT process should be demonstrated in this, or a similar, application as soon as possible, to ease projected water supply shortages in eastern North Dakota and permit the continuing economic growth of this region.

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APPENDIX A

BENCH-SCALE FT SIMULATION

FT Bench-Scale Simulation Objectives

The objectives of the bench-scale FT process simulation are:

- to demonstrate the technical feasibility of the FT process for treating water from the Dakota aquifer system, and
- to provide data regarding process performance and treated water and brine quality.

FT Bench-Scale Simulation Design

The bench-scale FT process simulation was conducted in a 38" x 31" x 73" refrigeration unit. A personal computer interfaced programmable temperature controller was used to regulate hourly temperature cycles in the unit during the simulation.

The equipment configuration for the FT process simulator is illustrated in Figure A-l. The construction is as follows:

- The feed water holding tank is constructed of high density polyethylene (HDPE). The holding tank has an 11 gal. capacity with internal dimensions of 14.25" dia. x 17". The holding tank is insulated and the discharge piping from the holding tank flows by gravity into the top of the simulator. The feed rate is controlled by a manual valve. An electrically actuated stainless steel solenoid valve, operated by a temperature switching relay, turns the feed on when the simulator temperature is below 32°F and shuts the feed off when the temperature is above 32°F.
- The feed water entering the top of the simulator falls from 30" to 44", depending upon the height of the ice pile in the simulator, onto the freezing pad. The freezing pad is constructed of welded HDPE sheet stock and has internal dimensions of 20" x 29" x 18". The freezing pad has a 1" lateral slope so that runoff drains to the outlet which is 3/4" in diameter.
- Runoff from the freezing pad flows through two pipe tees each housing an electrical conductivity (EC) probe. The first EC probe is connected to a conductivity controller used to separate the brine. If the EC of the runoff is >50,000 uS/cm the runoff is automatically diverted, using an electrically actuated solenoid valve operated by the conductivity controller, to the brine collection vessel. The second EC probe is connected to another similar conductivity controller calibrated to operate at much lower EC values. This conductivity controller is used to separate the treatedwater. If the EC of the runoff is <1,000 uS/cm the runoff is diverted, using another similar solenoid valve operated by the conductivity controller, to the treated water collection vessel. If the EC of the runoff is <50,000 and >1,000 uS/cm, the water automatically flows into the transfer tank where it is recycled to the feed water holding tank.

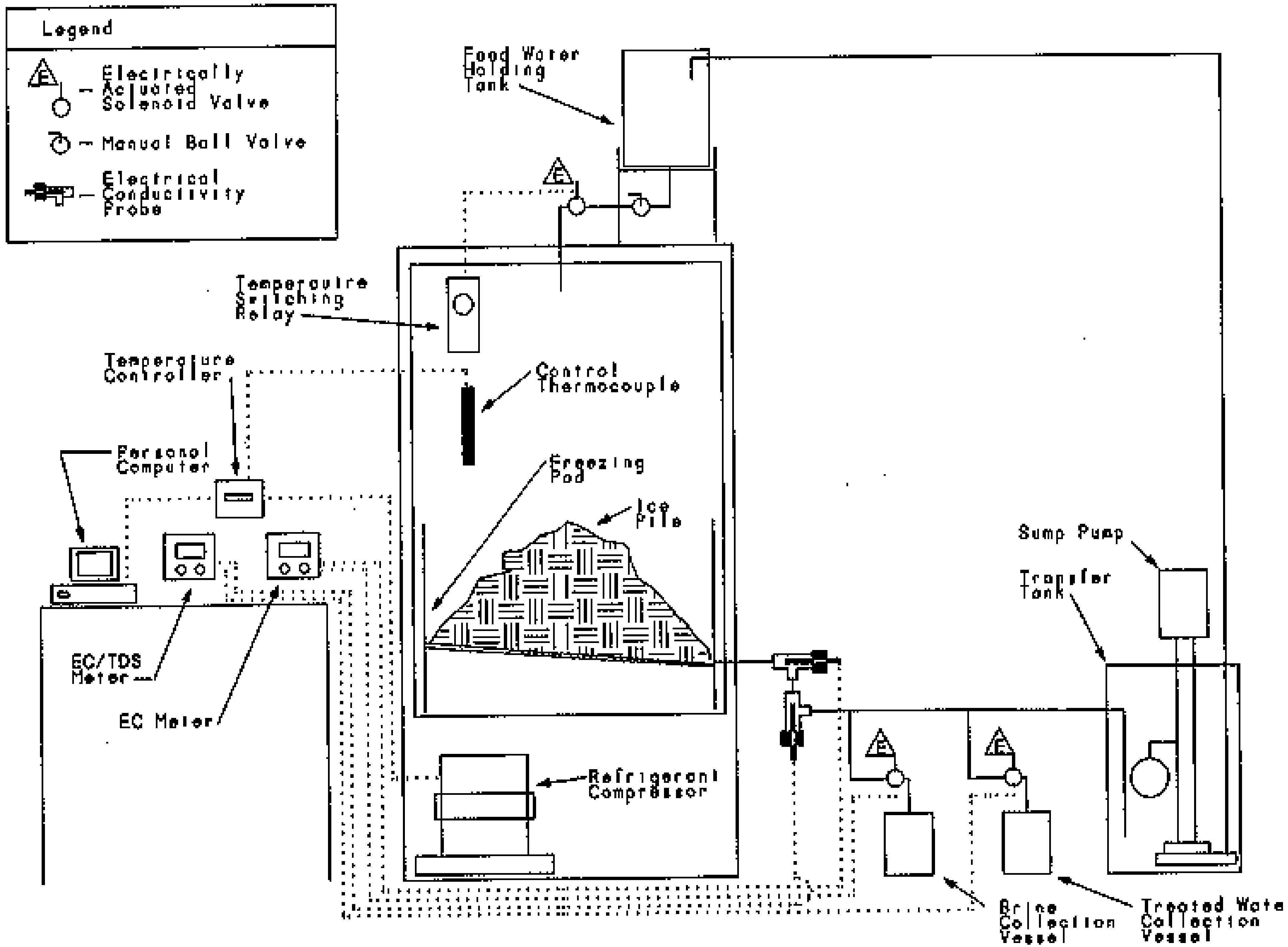


Figure A-1. Equipment Configuration for the Bench--Scale FTE Process Simulations.

- The transfer tank is a 10 gal HPDE vessel with internal dimensions of 10" x 13" x 18". The tank is equipped with a sump pump actuated by a liquid level switch which automatically transfers the recycle water to the feed tank.

FT Bench-Scale Simulation Procedure

The procedure used for the FT bench-scale simulation was as follows:

- Initially, the feed water holding tank was charged with a weighed mass of Dakota Aquifer water.
- The refrigeration unit temperature controller was programmed to simulate the monthly average daily temperature cycles typical of Grand Forks, ND. The temperature data used in the simulation is provided in Table A-l. During the simulation, the conditions for each month with sub-freezing temperatures were run three times consecutively, each on a twenty-four hour basis, for a seventy-two hour duration for each month. The average Grand Forks, ND climate has six months annually in which sub-freezing temperatures occur either continuously or intermittently (Table A-l). Thus, the total time required to complete the simulation was eighteen days.
- During the entire simulation, the temperature in the simulator was automatically logged on an hourly basis by the computer.
- The aquifer water was automatically fed from the feed water holding tank to the simulator when the temperature in the simulator was below 32°F. The simulator feed dropped on the freezing pad forming an ice pile.
- Run-off from the freezing pad was diverted to either the clean water collection vessel, the transfer tank or brine collection vessel, based upon the EC of the runoff.
- Additional feed water was added to the system, as needed to insure sufficient levels in the transfer and feed tanks for continued simulator operation.
- At the end of the simulation, the total masses of simulator feed, treated water generated, and heavy brine produced were recorded.
- Upon completion of the simulation, composite samples of the clean water and brine were prepared and submitted for analyses.

Table A-1. Daily Atmospheric Temperature Cycles for an eastern North Dakota location

Month	Hour	Average Temperature °C	°F
1	1	-19.6	-3.3
1	2	-20.4	-4.8
1	3	-20.9	-5.7
1	4	-21.1	-6.0
1	5	-20.9	-5.7
1	6	-20.4	-4.8
1	7	-19.6	-3.3
1	8	-18.6	-1.5
1	9	-17.4	.7
1	10	-16.1	3.0
1	11	-14.8	5.3
1	12	-13.6	7.4
1	13	-12.6	9.3
1	14	-11.9	10.7
1	15	-11.4	11.5
1	16	-11.2	11.8
1	17	-11.4	11.5
1	18	-11.9	10.7
1	19	-12.6	9.3
1	20	-13.7	7.4
1	21	-14.8	5.3
1	22	-16.1	3.0
1	23	-17.4	.7
1	24	-18.6	-1.5

Table A-l. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	°F
2	1	-15.9	3.3
2	2	-16.8	1.8
2	3	-17.3	.8
2	4	-17.5	.5
2	5	-17.3	.8
2	6	-16.8	1.8
2	7	-15.9	3.3
2	8	-14.8	5.3
2	9	-13.6	1.6
2	10	-12.2	10.0
2	11	-10.8	12.5
2	12	-9.5	14.8
2	13	-8.5	16.8
2	14	-7.6	18.3
2	15	-7.1	19.3
2	16	-6.9	19.6
2	17	-7.1	19.3
2	18	-7.6	18.3
2	19	-8.5	16.8
2	20	-9.6	14.8
2	21	-10.8	12.5
2	22	-12.2	10.0
2	23	-13.6	7.6
2	24	-14.9	5.3

Table A-1. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	°F
3	1	-8.7	16.3
3	2	-9.5	14.9
3	3	-10.0	14.0
3	4	-10.2	13.6
3	5	-10.0	14.0
3	6	-9.5	14.9
3	7	-8.7	16.3
3	8	-7.6	18.2
3	9	-6.4	20.4
3	10	-5.1	22.8
3	11	-3.8	25.2
3	12	-2.5	27.4
3	13	-1.5	29.3
3	14	-.7	30.8
3	15	-.2	31.7
3	16	.0	32.0
3	17	-.2	31.7
3	18	-.7	30.8
3	19	-1.5	29.3
3	20	-2.6	27.4
3	21	-3.8	25.2
3	22	-5.1	22.8
3	23	-6.4	20.4
3	24	-7.7	18.2

Table A-l. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	°F
4	1	1.4	34.5
4	2	.5	32.8
4	3	-.1	31.8
4	4	-.3	31.5
4	5	-.1	31.8
4	6	.5	32.8
4	7	1.4	34.5
4	8	2.6	36.6
4	9	3.9	39.1
4	10	5.4	41.1
4	11	6.9	44.4
4	12	8.3	46.9
4	13	9.4	49.0
4	14	10.3	50.6
4	15	10.9	51.6
4	16	11.1	52.0
4	17	10.9	51.6
4	18	10.3	50.6
4	19	9.4	49.0
4	20	8.2	46.8
4	21	6.9	44.4
4	22	5.4	41.7
4	23	3.9	39.1
4	24	2.5	36.6

Table A-1. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	Average Temperature °F
5	1	8.2	46.7
5	2	7.0	44.7
5	3	6.3	43.4
5	4	6.1	43.0
5	5	6.3	43.4
5	6	7.0	44.7
5	7	8.2	46.7
5	8	9.6	49.3
5	9	11.3	52.3
5	10	13.1	55.6
5	11	15.0	58.9
5	12	16.7	62.1
5	13	18.2	64.7
5	14	19.3	66.8
5	15	20.1	68.1
5	16	20.3	68.5
5	17	20.1	68.1
5	18	19.3	66.8
5	19	18.2	64.7
5	20	16.7	62.1
5	21	15.0	58.9
5	22	13.1	55.6
5	23	11.3	52.3
5	24	9.6	49.3

Table A-l. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	°F
6	1	13.7	56.6
6	2	12.6	54.7
6	3	11.9	53.5
6	4	11.7	53.1
6	5	11.9	53.5
6	6	12.6	54.7
6	7	13.7	56.6
6	8	15.1	59.1
6	9	16.7	62.0
6	10	18.4	65.1
6	11	20.1	68.2
6	12	21.7	71.1
6	13	23.1	73.5
6	14	24.1	75.4
6	15	24.0	76.6
6	16	25.0	77.0
6	17	24.8	76.6
6	18	24.1	75.4
	19	23.1	73.5
	20	21.7	71.1
6	21	20.1	68.2
6	22	18.4	65.1
6	23	16.7	62.0
6	24	15.0	59.1

Table A-1. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	Average Temperature °F
7	1	16.2	61.1
7	2	15.1	59.2
7	3	14.4	58.0
7	4	14.2	57.6
7	5	14.4	58.0
7	6	15.1	59.2
7	7	16.2	61.1
7	8	17.6	63.7
7	9	19.2	66.6
7	10	21.0	69.8
7	11	22.8	73.0
7	12	24.4	75.9
7	13	25.8	78.5
7	14	26.9	80.4
7	15	27.6	81.6
7	16	27.8	82.0
7	17	27.6	81.6
7	18	26.9	80.4
7	19	25.8	78.5
7	20	24.4	75.9
7	21	22.8	73.0
7	22	21.0	69.8
7	23	19.2	66.6
7	24	17.6	63.7

Table A-l. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	°F
8	1	15.0	59.0
8	2	13.9	56.9
8	3	13.1	55.7
8	4	12.9	55.2
8	5	13.1	55.7
8	6	13.9	56.9
8	7	15.0	59.0
8	8	16.5	61.6
8	9	18.2	64.7
8	10	20.0	68.0
8	11	21.8	71.3
8	12	23.6	74.4
8	13	25.0	77.0
8	14	26.1	79.1
8	15	26.9	80.3
8	16	27.1	80.8
8	17	26.9	80.3
8	18	26.1	79.1
8	19	25.0	77.0
8	20	23.5	14.4
8	21	21.8	71.3
8	22	20.0	68.0
8	23	18.2	64.7
8	24	16.4	61.6

Table A-1. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	°F
9	1	9.4	48.9
9	2	8.3	46.9
9	3	7.6	45.7
9	4	7.4	45.3
9	5	7.6	45.7
9	6	8.3	46.9
9	7	9.4	48.9
9	8	10.8	51.4
9	9	12.4	54.3
9	10	14.1	57.4
9	11	15.8	60.5
9	12	17.4	63.3
9	13	18.8	65.8
9	14	19.8	67.7
9	15	20.5	68.9
9	16	20.7	69.3
9	17	20.5	68.9
9	18	19.8	67.7
9	19	18.8	65.8
9	20	17.4	63.3
9	21	15.8	60.5
9	22	14.1	57.4
9	23	12.4	54.3
9	24	10.7	51.3

Table A-l. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average °C	Temperature °F
10	1	3.6	38.5
10	2	2.6	36.7
10	3	2.0	35.6
10	4	1.8	35.2
10	5	2.0	35.6
10	6	2.6	36.7
10	7	3.6	38.5
10	8	4.9	40.7
10	9	6.3	43.4
10	10	7.9	46.2
10	11	9.5	49.0
10	12	10.9	51.6
10	13	12.1	53.9
10	14	13.1	55.6
10	15	13.7	56.7
10	16	13.9	57.0
10	17	13.7	56.7
10	18	13.1	55.6
10	19	12.1	53.9
10	20	10.9	51.6
10	21	9.5	49.0
10	22	7.9	46.2
10	23	6.3	43.4
10	24	4.8	40.7

Table A-1. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	°F
11	1	-5.6	21.9
11	2	-6.3	20.6
11	3	-6.8	19.8
11	4	-6.9	19.6
11	5	-6.8	19.8
11	6	-6.3	20.6
11	7	-5.6	21.9
11	8	-4.7	23.5
11	9	-3.6	25.5
11	10	-2.5	27.5
11	11	-2.3	27.8
11	12	-2.2	28.0
11	13	-2.1	28.3
11	14	-2.0	28.4
11	15	-1.9	28.5
11	16	-1.9	28.6
11	17	-1.9	28.5
11	18	-2.0	28.4
11	19	-2.1	28.3
11	20	-2.2	28.0
11	21	-2.3	27.8
11	22	-2.5	27.5
11	23	-3.6	25.4
11	24	-4.7	23.5

Table A-l. Daily Atmospheric Temperature Cycles for an eastern North Dakota location (continued)

Month	Hour	Average Temperature °C	°F
12	1	-14.5	5.9
12	2	-15.2	4.6
12	3	-15.6	3.8
12	4	-15.8	3.6
12	5	-15.6	3.8
12	6	-15.2	4.6
12	7	-14.5	5.9
12	8	-13.5	7.6
12	9	-12.5	9.6
12	10	-11.3	11.7
12	11	-10.1	13.8
12	12	-9.0	15.8
12	13	-8.0	17.5
12	14	-7.3	18.8
12	15	-6.9	19.7
12	16	-6.7	19.9
12	17	-6.9	19.7
12	18	-7.3	18.8
12	19	-8.0	17.5
12	20	-9.0	15.8
12	21	-10.1	13.8
12	22	-11.3	11.7
12	23	-12.5	9.6
12	24	-13.6	7.6

Grand Forks Desalinization FT Bench-Scale Simulation Data

Simulation Temperature Profile

The temperatures actually achieved in the Grand Forks desalinization FT bench-scale simulation are presented in Figure A-2 along with the desired simulator temperatures (simulator set point). As the data in the figure illustrates, there were some departures from the desired simulation temperature profiles. These were primarily due to blown fuses in the refrigeration system. Some minor departures from the desired temperatures occurred as a result of the need to thaw the freezing pad outlet and the addition of heat tape to the outlet (December day 2). In addition, the simulator refrigeration system was not capable of cooling sufficiently to reach the severely cold temperatures typical of January evenings in eastern North Dakota. However, as the data in the figure illustrate, the desired temperature profiles were achieved for the vast majority of the eighteen day simulation. A total of 166 hours with sub-freezing were desired in the simulation. 157 hours were achieved. Further, since the departures primarily resulted in higher simulation temperatures than intended, one can reasonably conclude that, if these departures had any impact on the results of the simulation, the impact was to negatively effect the process treated water yields and quality and make the simulation somewhat conservative.

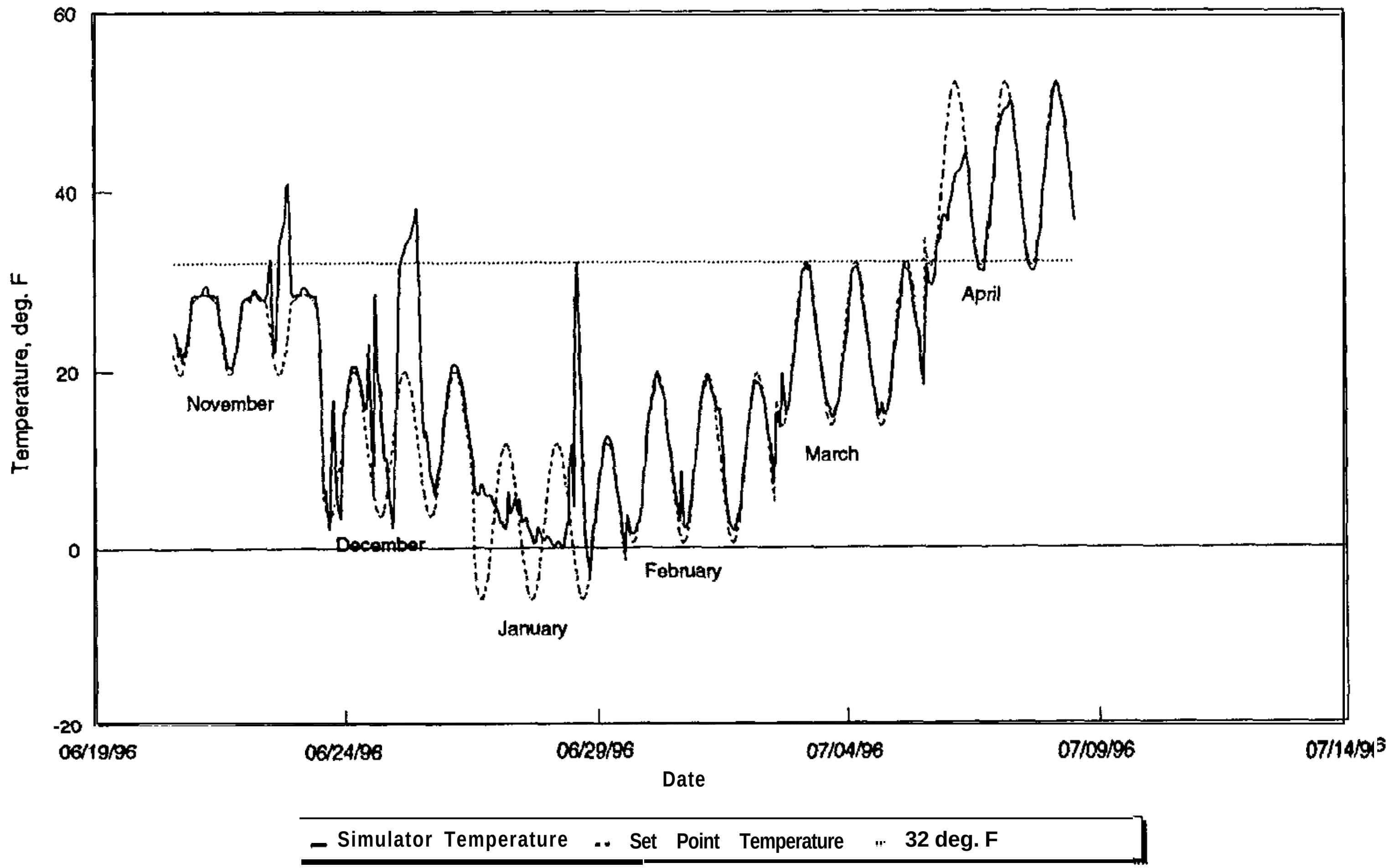
Simulation Log

Following Figure A-2, the simulation log is attached.

Simulation Yields and Results of Chemical Analyses

Simulation yield data and results of chemical analyses of the simulation process streams are provided in Section 3.1.2 and 3.1.4 in the body of this report.

Figure A-2. FTE Simulator Temperature vs Time
Grand Forks Desalinization Project



B.C. Technologies, Ltd.

Freeze-Thaw Bench-scale Simulation Log

Project: Grand Forks Desalinization

Feed: Dakota Aquifer Water

Month Simulated	Start Date	Start Time	Feed EC (mS)	Comments
None	06/19/96	17:10		EC meter/controller calibration
		17:10		Mix feed sample
		19:00		System Shakedown
None	06/20/96	05:55		EC meter/controller calibration
		05:55		Mix feed sample
		07:00	6.5	Feed Added - 17,160.9 grams
November Day 1		13:00		Started Simulation - Nov. Day 1
		15:00	6.5	Feed Added - 3,295.2 grams
		16:00		Fuse blown on ref. <15 min. downtime
November Day 2	06/21/96	13:00		Started Day 2 Simulation - Nov. Day 2
	06/22/96	10:30		Fuse blown on ref. <15 min. downtime
		10:30	6.6	Feed Added - 3,163.6 grams
		11:30		Recycle TDS = 4,200 ppm by EC/TDS meter.
		13:00		Fuse blown on ref. since about 12:00 - 1 hr. downtime
November Day 3		13:00		Started Day 3 Simulation - Nov. Day 3
		20:00		Fuse blown on ref. since about 14:00 - 6 hr. downtime
December Day 1	06/23/96	13:00		Started Day 4 Simulation - Dec. Day 1
		18:00		Freezing Pad (FP) outlet froze - Feed Tank empty (mt).
		18:00		Warmed up simulator a little thawing FP outlet.
December Day 2	06/24/96	13:00		Started Day 5 Simulation - Dec. Day 2
		15:00	6.6	Feed Added - 6,849.0 grams
		15:00		Freezing Pad (FP) outlet froze
		15:00		Warmed up simulator a little adding heat tape (HT).
	06/25/96	09:00		Freezing Pad (FP) outlet froze - HT on/fast fix.
		11:00		Fuse blown on ref. since about 03:00 - 8 hr. downtime.
December Day 3		13:00		Started Day 6 Simulation - Dec. Day 3
		15:12		Power Outage - Re-start CPU.
	06/26/96	09:00	6.5	Feed Added - 3295.7 grams
		10:00	7.0	Feed Added - 3477.9 grams
		11:00	7.0	Feed Added - 3396.8 grams
January Day 1		13:00		Started Day 7 Simulation - Jan. Day 1
		19:00		Refrig. unit cannot get temp down to set point value.
	06/27/96	08:00		Refrig. unit cannot get temp down to set point value.
January Day 2		13:00		Started Day 8 Simulation - Jan. Day 2
		19:00		Refrig. unit cannot get temp down to set point value.
		08:00		Refrig. unit cannot get temp down to set point value.
January Day 3	06/28/96	13:00		Started Day 9 Simulation - Jan. Day 3
		15:00		FP outlet frozen/thawed it - 1 hr. downtime
		19:00		Refrig. unit cannot get temp down to set point value.
	06/29/96	08:00		Sim. temp. got below zero last night/probably due to loss of feed.
		08:00		Feed tank "mt"/no FP runoff - will not add any more feed
February Day 1		13:00		Started Day 10 Simulation - Feb. Day 1
	06/30/96	10:00		We have a small amount of FP runoff.
February Day 2		13:00		Started Day 11 Simulation - Feb. Day 2
	07/01/96	07:30		Feed to ice frozen/ thawed it no downtime.
February Day 3		13:00		Started Day 12 Simulation - Feb. Day 3
	07/02/96	10:00		EC of FP runoff = 80,000 uS/cm
March Day 1		13:00		Started Day 13 Simulation - Mar. Day 1
	07/03/96	07:00		Unplugged FP heat tape/plugged it back in.
		09:30		Unplugged FP heat tape.

B.C. Technologies, Ltd.

Freeze-Thaw Bench-scale Simulation Log

Project: Grand Forks Desalinization

Feed: Dakota Aquifer Water

onth Simulatec	Start Date	Start Time	Feed EC (ms)	Comments
	07/03/96	09:30		Brine solenoid on - i.e. harvesting brine.
		10:00		Plugged in FP heat tape.
		11:30		Unplugged FP heat tape.
		11:30		Brine solenoid on - i.e. harvesting brine.
March Day 2		13:00		Started Day 14 Simulation - Mar. Day 2
		13:00		Plugged in FP heat tape.
	07/04/96	11:00		Brine solenoid on - i.e. harvesting brine.
March Day 3		13:00		Started Day 15 Simulation - Mar. Day 3
		13:00		Brine solenoid on - i.e. harvesting brine.
		16:00		Brine solenoid on - i.e. harvesting brine.
April Day 1	07/05/96	13:00		Started Day 16 Simulation - Apr. Day 1
		20:00		Plugged in FP heat tape/unplugged heat tape.
		21:50		Noticeable brine flow.
		22:40		Brine solenoid on - i.e. harvesting brine.
		23:05		Brine solenoid on - i.e. harvesting brine - EC 85K uS/cm
		23:15		Brine solenoid on - i.e. harvesting brine - EC 80K uS/cm
		23:45		Brine solenoid on - i.e. harvesting brine - EC 80K uS/cm
	07/06/96	00:15		Brine solenoid on - i.e. harvesting brine - EC 82K uS/cm
		00:45		Brine solenoid on - i.e. harvesting brine - EC 78K uS/cm
		01:00		Brine solenoid on - i.e. harvesting brine - EC 75K uS/cm
		01:20		Brine solenoid on - i.e. harvesting brine - EC 758K uS/cm
		02:30		Brine solenoid on - i.e. harvesting brine - EC 72K uS/cm
		03:30		Brine solenoid on - i.e. harvesting brine - EC 72K uS/cm
		04:30		Brine solenoid on - i.e. harvesting brine - EC 72K uS/cm
		05:30		Brine solenoid on - i.e. harvesting brine - EC 72K uS/cm
		06:30		Brine solenoid on - i.e. harvesting brine - EC 69K uS/cm
		07:30		Brine solenoid on - i.e. harvesting brine - EC 52K uS/cm
April Day 2		13:00		Started Day 17 Simulation - Apr. Day 2
		16:15		Brine solenoid on - i.e. harvesting brine - EC 45K uS/cm
		19:15		Brine solenoid on - i.e. harvesting brine - EC 40K uS/cm
	07/07/96	09:00		Brine solenoid on - i.e. harvesting brine - EC 15K uS/cm
		11:00		Brine solenoid on - i.e. harvesting brine - EC 12K uS/cm
		13:00		Brine solenoid on - i.e. harvesting brine - EC 8K uS/cm
April Day 3		13:00		Started Day 18 Simulation - Apr. Day 3
		15:00		Brine solenoid on - i.e. harvesting brine - EC/TDS 2500 ppm
		17:00		Brine solenoid on - i.e. harvesting brine - EC/TDS 2400 ppm
	07/08/96	09:30		Brine solenoid on - i.e. harvesting brine - EC/TDS 1200 ppm
		12:00		Brine solenoid on - i.e. harvesting brine - EC/TDS 1100 ppm
April Day 3		13:00		Started Day 18 Simulation - Apr. Day 3
		17:30		Brine solenoid on - i.e. harvesting brine - EC/TDS 1100 ppm
		19:00		Brine solenoid on - i.e. harvesting brine - EC/TDS 1100 ppm
	07/09/96	08:00		Treated water solenoid on some time during the AM - i.e. harvesting treated water - EC/TDS 800 ppm
End Simulation		13:00		Sim. Temp @ 40 F for remaining ice melt.
		18:00		Treated water EC/TDS currently 600 ppm
	07/11/96	12:00		End of melt last EC/TDS 35 ppm
		15:00		Drained residual from system piping and feed holding tank - 6111.92 EC 11.84 mS/cm

APPENDIX B

REQUIREMENTS FOR A CONDITIONAL WATER PERMIT

INSTRUCTIONS
for completion of

CONDITIONAL WATER PERMIT APPLICATION

Office of the State Engineer
North Dakota State Water Commission
900 East Boulevard Avenue
Bismarck, ND 58505-0850
Phone 701-224-2754

Application No. ________________

STATE OF NORTH DAKOTA
APPLICATION FOR CONDITIONAL WATER PERMIT

NOTE: Use one application for each type of source (ground water, surface water). Check all appropriate boxes and fill in each blank line. If the question is not applicable to your proposed development, enter NA (not applicable). If more space is necessary, attach additional sheets.

(PLEASE TYPE OR PRINT IN INK)

1. Name of Applicant ______________________________
   Mailing Address ______________________________
   City ____________________ State ____________ Zip ____________
   Home Phone ____________________ Other Phone ____________________

2. Source of water supply: ☐ ground water ☐ sulfate water
   If surface water: (a) stream ______________ a tributary of ______________
   ____
   (b) If new impoundment --1/4 ______ 1/4 sec. ______, Twp. ______, Rge. ______
   (c) If existing impoundment. *give name* ______________________________

3. (a) Point of diversion:
   (1) ______ 1/4 of Section ______ Township ______ N., Range ______ W., ______________ County
   Additional points of diversion, if any:
   (2) ______ 1/4 of Section - Township ______ N., Range - W., ______________ County
   (3) ______ 1/4 Of section - Township ______ N., *Range* - W., ______________ county

   (b) If water is not consumed. name the receiving body of water ______________________
   and describe location of discharge point: __ 1/4 ______ 1/4 Sec. . Twp. ______, Rge. ______

4. Amount of water requested:
   (a) If Impoundment: ____________ acre-feet storage out of which ____________ acre-feet will be used to offset evaporative losses.

   (b) Other annual uses from points listed in Item 3 above, rates of diversion. and periods of use.
   (1) ____________ (AMOUNT) acre-feet at ____________ (RATE) cfs gpm from ____________ (MONTH-DAY) to ____________ (MONTH-DAY) inclusive
   (2) ____________ (AMOUNT) acre-feet at ____________ (RATE) cfs gpm from ____________ (MONTH-DAY) to ____________ (MONTH-DAY) inclusive
   (3) ____________ acre-feet at ____________ (RATE) cfs gpm from ____________ (MONTH-DAY) to ____________ (MONTH-DAY) inclusive
   Total annual use requested (sum of 4b and evaporation from 4a):
   ____________ acre-feet maximum rate of g p m .

5. Proposed construction:
   Proposed starting date ______________________________
   Anticipated completion date ______________________________

(a) Irrigation (if applicable)

(1) Method of irrigation: ☐ gravity ☐ sprinkler ☐ waterspreading

(2) Project will involve new irrigated land: ☐ Yes ☐ No

(3) Project will involve supplemental water to existing irrigation: ☐ Yes ☐ No

(4) Description of land to be irrigated (show lot numbers where applicable):

SEC.	TWP	RGE.	NE1/4				NW1/4				SW1/4				SE1/4				TOTAL
			NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	
TOTAL NUMBER OF ACRES TO BE IRRIGATED:																			

(b) Non-irrigation use (if applicable):

Municipal ______________________ Recreation ______________________

Rural-Domestic ______________________ Fish and Wildlife ______________________

Industrial ______________________ Other (please specify) ______________________

7. Ownership:

(a) Property owner at the point of diversion. ______________________

(b) Property owner at the place of use: ______________________

(c) If either (a) or (b) above are other than the applicant, describe the arrangement enabling the applicant to make this filing: ______________________

____

____

8. State law requires that cities and landowners within a one-mile radius of the proposed point of diversion be advised of this application. A completed "Notice of Application" will be forwarded to you upon receipt of this application. Therefore, please indicate the number of landowners and cities which you must notify:

____

9. *THE APPLICANT CERTIFIES THAT THE STATEMENTS APPEARING HEREIN ARE TO THE BEST OF HIS KNOWLEDGE TRUE AND CORRECT:*

______________________ (SIGNATURE) ______________________ (DATE)

______________________ (SIGNATURE) ______________________ (DATE)

______________________ (SIGNATURE) ______________________ (DATE)

Signature of the applicant(s) must be exactly as in item 1. If more than one applicant is shown, all must sign.

NOTE: Mail the completed application, along with the required map and application fee to:

STATE ENGINEER
State Office Building
900 East Boulevard
Bismarck, ND 58505-0850

INSTRUCTIONS FOR COMPLETING AN APPLICATION FOR A CONDITIONAL WATER PERMIT

A CONDITIONAL. WATER PERMIT APPLICATION MUST BE COMPLETED ON SWC FORM NO. 108: (SEE EXAMPLES ON PAGES 5, 8, 11, 14 & 17)

1. Complete all applicable blanks on the application form If the application is not satisfactorily completed it will be returned.

2. If an appropriation involves the storage of water, both the quantity of water which will be stored at the level of the principal spillway and the quantity which will be lost to evaporation from the corresponding surface area must be identified in item #4a on the application form. The mean net evaporative loss (gross evaporation less precipitation) can be determined from the SCS North Dakota Hydrology Manual, or upon request it will be provided by the State Engineer. If there are other uses involved in the proposed appropriation, they should be identified in item #4b. The total annual use will be the evaporation from item #4a and the otha annual uses identified in #4b. (see example page 17)

3. An individual may not hold undeveloped conditional water permits and pending applications for irrigation purposes that when totaled exceed 720 acre-feet of water. This does not appiy to applications for water permits to appropriate water from the Missouri River or applications submitted by irrigation districts.

4. An application will not be accepted that requests the appropriation ofwata from more than one water source. An appropriation from the main channel of a river and from a tributary to the river is an example of an appropriation from more than one water source.

5. The following application fee must accompany the application:

   a. For municipal use in municipalities of 2500 population or ova according to the latest federal census.......................... $500

   b. For municipal use in municipalities of less than 2500 population according to the latest federal census..................... $250

   c. For irrigation.. $200

   d. For industrial use of one c.f.s. or less, or seven hundred twenty four acre-feet annually, or less...................................... $250

   e. For industrial use in excess of one c.f.a., or in excess of seven hundred twenty four acre-feet annually.......................... $750

   f. For recreation, livestock, or fish and wildlife $100

   g. For commercial recreation . ..“... $200

   h. Water permit amendment .... $ 50

6. The date the application is received by the State Engineer will be the priority date assigned to the application, unless the applicant fails to complete the application process as prescribed by statute.

7. If the application is approved, a conditional water permit will be issued. The conditional water permit does not create a water right. Rather, it is an authorization for the permittee to construct facilities (such as a well and irrigation system) and to begin utilization of water. A water right will accrue to the permittee upon beneficial use of water.

8. A perfected permit will be issued after the permittee has put the water to beneficial use.

PREPARATION OF MAP: (SEE EXAMPLES ON PAGES 7, 10, 13, 16, & 19)

1. A map must accompany the application. It must be prepared from an actual survey, aerial photograph, or topographic map, and certified by a licensed surveyor unless another type of map is first approved by the State Engineer. The State Engineer may require additional information on the map if it is deemed necessary.

   a. The examples shown herein should be used as a guide in preparing the map.

   b. The map shall be drawn or generated by computer methods on a 8 1/2" x 11" sheet of tracing linen or polyester-mylar type film. Handwritten information will not be accepted.

   c. The map must show the following information:

      (1) Section, Township, Range and county designation to satisfactorily locate proposed works.

      (2) Points of diversion are to be shown by "o" at their proper location. (If system is portable, state "portable system" in the lower right hand portion of map.)

      (3) If use is for irrigation, irrigated tracts in each 40 acre subdivision must be indicated by cross hatching.

      (4) If use is for industrial purposes, show point of diversion and means of conveying water to place of use.

      (5) If use is for municipal purposes show point of diversion and the system to convey water to the central storage facility. Map may be drawn in reference to city blocks but also must show in what legal subdivision works are located. Show section, quarter section or one-sixteenth section lines as applicable.

      (6) If application proposes use of a dam and storage reservoir, show the outline of the reservoir with point of diversion marked at the point on the reservoir from which the diversion will be made.

      (7) If water wells are used, label wells with "o". Show the route of the pipeline or ditch to the point or area of use or central collection point.

(8) The watercourse from which water is diverted must be shown and named, and the direction of flow indicated.

(9) A north arrow must be shown.

(10) Scale of map must be shown (For example, 1" equals 1000' is a satisfactory scale for a one square mile tract of land.)

(11) The State Engineer may return the map to the applicant for correction if he desires additional information to properly evaluate the conditional water permit application.

(12) The title in the lower right hand corner of the map must indicate the name of the applicant and his post office address. (See examples on pages 7, 10, 13, 16, & 19)

(13) The Certificate of Surveyor, located in the lower left hand corner of the map, must be signed by a licensed surveyor and be in the following form:

CERTIFICATE OF SURVEYOR

STATE OF NORTH DAKOTA)
) SS
COUNTY OF ______________)

I, ______________________________ of ______________________________
Name Address
do hereby certify that this map was prepared from notes or information obtained from an ____
(actual survey, aerial photograph, or topographic map)
made by ______________________________ (or made under my direction
(person or firm who performed survey)
by ______________________________) on the ________ day of

______________________________,19 ______, for whose work I stand personally

responsible, and that it correctly represents the ______________________
(irrigation, municipal, industrial, fish & wildlife or recreation)
works for the accompanying application, together with a meander of streams, (and shows accurately the location and area of lands to be irrigated in each subdivision.)

____
Signature of Surveyor

NOTIFICATION AS REQUIRED BY STATUTE:

1. Upon receipt of a complete application, completed **Notice of Application** forms will be forwarded to the applicant along with a letter of instructions. Applicants are required by law to notify:

   a. each city located within a radius of one mile from the location of the proposed point of diversion;

   b. each record title owner of real estate within a radius of one mile from the location of the proposed point of diversion (excluding all landowners within the geographical boundary of a city). If the one-mile radius includes land within the geographical boundary of a rural subdivision where the lots are 10 acres or less, the notice must be given to the governing body of the township or other governing authority for the rural subdivision and no further notice need be given to the record title owners of real estate within the geographical boundary of the rural subdivision.

      If the one-mile radius includes a single tract of rural land which is owned by more than 10 individuals, the notice must be given to the governing body of the township or other governing authority for that tract of land and no further notice need be given to the record title owners of the tract.

      The record title owners shall be determined by an actual search of the records of the appropriate register of deeds office within 15 days of the mailing of the notice to landowners. The record title owners of land under contract for deed shall be deemed to include both grantor and grantee of the contract for deed.

   c. each person holding a water permit for the appropriation of water from points of diversion located within a radius of one mile from the location of the proposed point of diversion. The State Engineer will provide the applicant a list of permit holders who must be notified.

   d. all municipal or public use water facilities in the county in which the proposed point of diversion is located. The State Engineer will provide the applicant a list of all municipal or public use water facilities that must be notified.

2. After sending the completed **Notice of Application** forms, by certified mail, the applicant must immediately return the completed affidavit of notice along with the "white" certified mail receipts.

3. After the receipt of the completed affidavit of notice and the "white" certified mail receipts, a hearing date will be established. A minimum of 15 days must elapse from the date on which notice was mailed to the municipal or public use water facilities before a hearing date can be established. A **Notice of Hearing** will be published for two consecutive weeks in the official newspaper of the county in which the proposed point of diversion is located. The applicant is required to pay the publication fees for the **Notice of Hearing**.

4. Following the publication of the **Notice of Hearing** a hearing will be conducted on the application. All persons interested may present their views in person at the hearing or in writing.

EXAMPLE

Application No.____________

STATE OF NORTH DAKOTA
APPLICATION FOR CONDITIONAL WATER PERMIT

NOTE: Use one application for each type of source (ground water, surface water). Check all appropriate boxes and fill in each blank line. If the question is not applicable to your proposed development, enter NA (not applicable). If more space is necessary, attach additional sheets.

(PLEASE TYPE OR PRINT IN INK)

1. Name of Applicant John Q. Doe

   Mailing Address HC 2 Box 75

   City Breien State ND Zip 58525

   Home Phone 579-24 78 Other Phone ________

2. Source of water supply: ☐ ground water ☒ surface water

   If surface water: (a) stream Unnamed a tributary of ________ Missouri River

   (b) If new impoundment — ____ 1/4. ____ 1/4 Sec. ____ Twp. ____, Rge. ____

   (c) If existing impoundment, give name ________

3. (a) Point of diversion:

   (1) SE 1/4 of Section 24 Township 133 N., Range 55 W., Morton Cou

   Additional points of diversion, if any:

   (2) ____ 1/4 of section ____ Township ____ N., Range ____ W., ________ County

   (3) ____ 1/4 of Section ____ Township ____ N., Range ____ W., ________ County

   (b) If water is not consumed, name the receiving body of water ________,

   and describe location of discharge point ____ 1/4 ____ 1/4 Sec. ____ Twp. ____, Rge. ____

4. Amount of water requested:

   (a) If Impoundment: ________ acre-feet storage out of which ________ acre-feet will be used to offset evaporative losses.

   (b) Other annual uses from points listed in Item 3 above, rates of diversion, and periods of use:

   (1) 315.6 (AMOUNT) acre-feet at 1500 (RATE) ~~cfs~~ gpm from April 15 (MONTH-DAY) to Oct. 1 (MONTH-DAY) inclusive

   (2) ____ (AMOUNT) acre-feet at ____ (RATE) cfs gpm from ____ (MONTH-DAY) to ____ (MONTH-DAY) inclusive

   (3) ____ (AMOUNT) acre-feet at ____ (RATE) cfs gpm from ____ (MONTH-DAY) to ____ (MONTH-DAY) inclusive

   Total annual use requested (sum of 4b and evaporation from 4a):

   315.6 acre-feet maximum rate of 1500 gpm.

5. Proposed construction:

   Proposed starting date July 1, 1980

   Anticipated completion date Sept. 1, 1980

6. Description of proposed beneficial water uses:

(a) Irrigation (if applicable)

(1) Method of irrigation: ☐ gravity ☑ sprinkler ☐ waterspreading

(2) Project will involve new irrigated land: ☑ Yes ☐ No

(3) Project will involve supplemental water to existing irrigation: ☐ Yes ☑ No

(4) Description of land to be irrigated (show lot numbers where applicable):

			NE1/4				NW1/4				SW1/4				SE1/4				
SEC.	TWP.	RGE.	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	TOT
19	133	54									33.8	33.7	33.7	33.8					135
24	133	55													38.0	7.6		29.8	75

TOTAL NUMBER OF ACRES TO BE IRRIGATED: 210.

(b) Non-irrigation use (if applicable):

Municipal ______________ Recreation ______________

Rural-Domestic ______________ Fish and Wildlife ______________

Industrial ______________ Other (please specify) ______________

7. Ownership:

(a) Property owner at the point of diversion: John Q. Doe

(b) Property owner at the place of use: John Q. Doe

(c) If either (a) or (b) above are other than the applicant, describe the arrangement enabling the applicant to make this filing: ______________

8. State law requires that cities and landowners within a one-mile radius of the proposed point of diversion be advised of this application. A completed "Notice of Application" will be forwarded to you upon receipt of this application. Therefore, please indicate the number of landowners and cities which you must notify:

10 land owners

9. *THE APPLICANT CERTIFIES THAT THE STATEMENTS APPEARING HEREIN ARE TO THE BEST OF HIS KNOWLEDGE TRUE AND CORRECT:*

John Q. Doe — 8/20/79

SIGNATURE — DATE

SIGNATURE — DATE

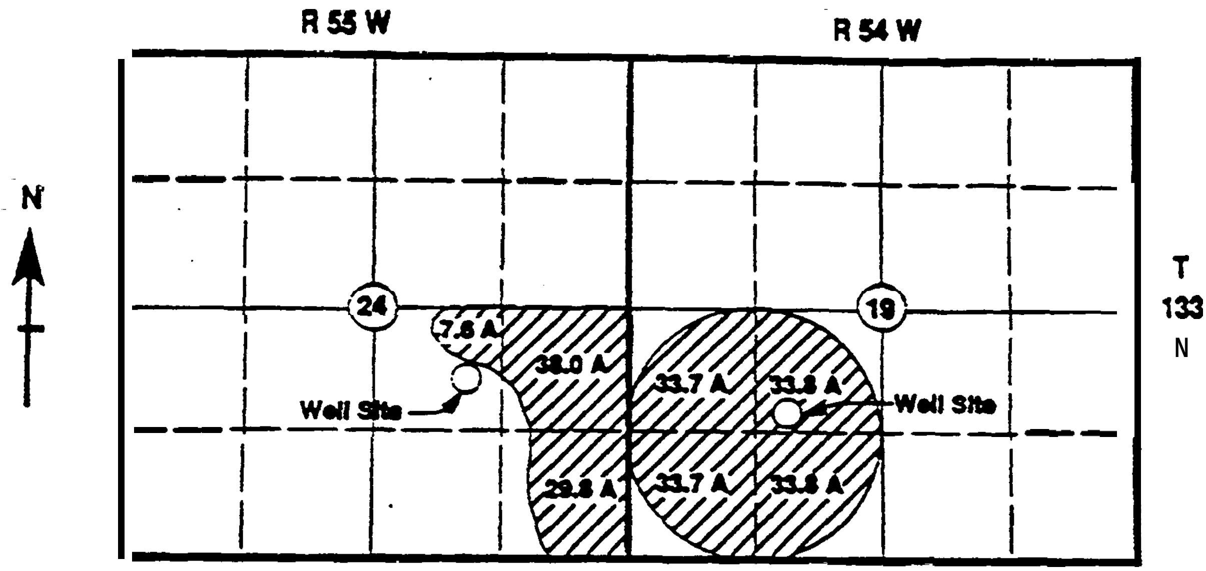
SIGNATURE — DATE

Signature of the applicant(s) must be exactly as in item 1. If more than one applicant is shown, all must sign

NOTE: Mail the completed application, along with the required map and application fee to:

STATE ENGINEER
State Office Building
900 East Boulevard

NOTE : EXAMPLE IRRIGATION
GROUND WATER SOURCE



Scale 1" = 2000'

○ Proposed Well Site

▨ Area To Be Irrigated

NOTE : Sprinkler System Will Be Used
To Distribute Water

APPROVED ____________________
State Engineer

STATE Of NORTH DAKOTA)
) SS
COUNTY OF GRANT)

I, George A. Fine of Odessa, ND do hereby certify that this map was made from notes taken during an actual survey made by me. (or made under my direction by Albert Mann for whose work I stand personally responsible) on June 16 19 79 and that it correctly represents the irrigation works described in the accompanying application, and shows accurately the location and area of the lands proposed to be irrigated in each subdivision.

George A. Fine
Surveyor

MAP

To accompany application

NO. __________ for

DOE IRRIGATION PROJECT

Morton County, ND

John Q. Doe

Braien, ND

APPLICANT

E X A M P L E

Application No.____________

STATE OF NORTH DAKOTA
APPLICATION FOR CONDITIONAL WATER PERMIT

NOTE: Use one application for each type of source (ground water, surface water). Check all appropriate boxes and fill in each blank line. If the question is not applicable to your proposed development, enter NA (not applicable). If more space is necessary, attach additional sheets.

(PLEASE TYPE OR PRINT IN INK)

1. Name of Applicant John Q. Doe

   Mailing Address HC 2 Box 76

   City Breien State ND Zip 58525

   Home Phone 579-2478 Other Phone ________

2. Source of water supply: ☒ ground water ☐ surface water

   If surface water: (a) stream ________ a tributary of ________

   (b) If new impoundment — ____ 1/4 ____ 1/4 Sec. ____, Twp. ____, Rge. ____

   (c) If existing impoundment, give name ________

3. (a) Point of diversion:

   (1) SW 1/4 of Section 19 Township 133 N., Range 54 W., Morton County

   Additional points of diversion, if any:

   (2) SE 1/4 of Section 24 Township 133 N., Range 55 W., Morton County

   (3) ____ 1/4 of Section ____ Township ____ N., Range ____ W., ________ County

   (b) If water is not consumed, name the receiving body of water ________

   and describe location of discharge point: ____ 1/4 ____ 1/4 Sec. ____, Twp. ____, Rge. ____.

4. Amount of water requested:

   (a) If Impoundment: ________ acre-feet storage out of which ________ acre-feet will be used to offset evaporative losses.

   (b) Other annual uses from points listed in item 3 above, rates of diversion, and periods of use:

   (1) 202.5 (AMOUNT) acre-feet at 900 (RATE) ~~cfs~~ gpm from April 15 (MONTH-DAY) to Oct. 1 (MONTH-DAY) inclusive

   (2) 113.1 (AMOUNT) acre-feet at 600 (RATE) ~~cfs~~ gpm from April 15 (MONTH-DAY) to Oct. 1 (MONTH-DAY) inclusive

   (3) ____ (AMOUNT) acre-feet at ____ (RATE) cfs gpm from ____ (MONTH-DAY) to ____ (MONTH-DAY) inclusive

   Total annual use requested (sum of 4b and evaporation from 4a):

   315.6 acre-feet maximum rate of 1500 gpm.

5. Proposed construction:

   Proposed starting date July 1, 1980

   Anticipated completion date Sept 1, 1980

6. Description of proposed beneficial water uses:

(a) Irrigation (if applicable)

(1) Method of irrigation: ☐ gravity ☑ sprinkler ☐ waterspreading

(2) Project will involve new irrigated land: ☑ Yes 0 No

(3) Project will involve supplemental water to existing irrigation: 0 Yes ☑ No

(4) Description of land to be irrigated (show lot numbers where applicable):

SEC.	TWP.	RGE.	NE1/4				NW1/4				SW1/4				SE1/4				TOTAL
			NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	
19	133	54									33.8	33.7	33.7	33.8					135.0
24	133	55													38.0	7.6		29.8	75.4
TOTAL NUMBER OF ACRES TO BE IRRIGATED:																			210.4

(b) Non-irrigation use (if applicable):

Municipal ____________ Recreation ____________

Rural-Domestic ____________ Fish and Wildlife ____________

Industrial ____________ Other (please specify) ____________

7. Ownership:

(a) Property owner at the point of diversion: John Q. Doe

(b) Property owner at the place of use: John Q. Doe

(c) If either (a) or (b) above are other than the applicant, describe the arrangement enabling the applicant to make this filing: ____________

8. State law requires that cities and landowners within a one-mile radius of the proposed point of diversion be advised of this application. A completed "Notice of Application" will be forwarded to you upon receipt of this application. Therefore, please indicate the number of landowners and cities which you must notify:

10 land owners

9. *THE APPLICANT CERTIFIES THAT THE STATEMENTS APPEARING HEREIN ARE TO THE BEST OF HIS KNOWLEDGE TRUE AND CORRECT:*

John Q. Doe 8/20/79
(SIGNATURE) (DATE)

(SIGNATURE) (DATE)

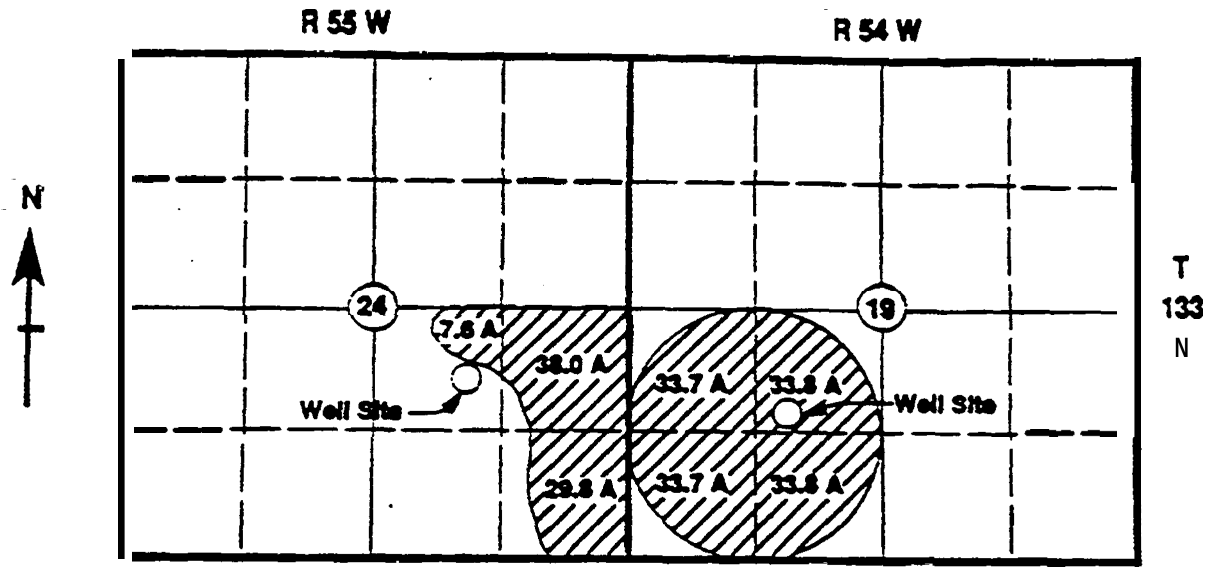
(SIGNATURE) (DATE)

Signature of the applicant(s) must be exactly as in Item 1. If more than one applicant is shown, all must sign.

NOTE: Mail the completed application, along with the required map and application fee to:

STATE ENGINEER
State Office Building
900 East Boulevard

NOTE : EXAMPLE IRRIGATION
GROUND WATER SOURCE



Scale 1" = 2000'

○ Proposed Well Site

Area To Be Irrigated

NOTE : Sprinkler System Will Be Used
To Distribute Water

APPROVED ______________________
State Engineer

STATE Of NORTH DAKOTA)
) SS
COUNTY OF GRANT)

I, George A. Fine of Odessa, ND do hereby certify that this map was made from notes taken during an actual survey made by me. (or made under my direction by Albert Mann for whose work I stand personally responsible) on June 16 19 79 and that it correctly represents the irrigation works described in the accompanying application, and shows accurately the location and area of the lands proposed to be irrigated in each subdivision.

George A. Fine
Surveyor

MAP

To accompany application

NO. __________ for

DOE IRRIGATION PROJECT

Morton County, ND

John Q. Doe

Breien, ND

APPLICANT

EXAMPLE

Application No.____________

STATE OF NORTH DAKOTA
APPLICATION FOR CONDITIONAL WATER PERMIT

NOTE: Use one application for each type of source (ground water, surface water). Check all appropriate boxes and fill in each blank line. If the question is not applicable to your proposed development, enter NA (not applicable). If more space is necessary, attach additional sheets.

(PLEASE TYPE OR PRINT IN INK)

1. Name of Applicant Passtime Golf Course

   Mailing Address P.O. Box 123

   City Hoveville State ND Zip 58765

   Home Phone ________ Other Phone 654 - 7611

2. Source of water supply: ☒ ground water ☐ surface water

   if surface water: (a) stream ________ a tributary of ________

   (b) If new impoundment ___1/4 ___1/4 Sec. ___, Twp. ___, Rge.

   (c) If existing impoundment, give name ________

3. (a) Point of diversion:

   (1) SE 1/4 of Section 7 Township 153 N., Range 64 W., Ramsey County

   Additional points of diversion, if any:

   (2) ___ 1/4 of Section ___ Township ___ N., Range ___ W., ______ County

   (3) ___ 1/4 of Section ___ Township ___ N., Range ___ W., ______ County

   (b) If water is not consumed, name the receiving body of water ________

   and describe location of discharge point: ___1/4 ___1/4 Sec. ___ Twp. ___, Rge.

4. Amount of water requested:

   (a) If impoundment: ______ acre-feet storage out of which ______ acre-feet will be used to offset evaporative losses.

   (b) Other annual uses from points listed in item 3 above, rates of diversion, and periods of use:

   (1) 66.2 (AMOUNT) acre-feet at 350 (RATE) cfs/gpm from May 1 (MONTH-DAY) to Oct. 1 (MONTH-DAY) inclusive

   (2) ___ (AMOUNT) acre-feet at ___ (RATE) cfs/gpm from ___ (MONTH-DAY) to ___ (MONTH-DAY) inclusive

   (3) ___ (AMOUNT) acre-feet at ___ (RATE) cfs/gpm from ___ (MONTH-DAY) to ___ (MONTH-DAY) inclusive

   Total annual use requested (sum of 4b and evaporation from 4a):

   66.2 acre-feet maximum rate of 350 gpm.

5. Proposed construction:

   Proposed starting date May 1, 1985

   Anticipated completion date Sept. 30, 1985

6. Description of proposed beneficial water uses:

(a) Irrigation (if applicable)

(7) Method of irrigation: ☐ gravity ☑ sprinkler ☐ waterspreading

(2) Project will involve new irrigated land: ☑ Yes a NO

(3) *Project* will involve supplemental water to existing irrigation: a Yes ☑ No

(4) Description of land to be irrigated (show lot numbers where applicable):

			NE1/4				NW1/4				SW1/4				SE1/4				
SEC.	TWP.	RGE.	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	TOTAL
7	153	64													11.0	11.0	7.9	3.2	33.1

TOTAL NUMBER OF ACRES TO BE IRRIGATED: 33.1

(b) Non-irrigation use (if applicable):

Municipal ____________ Recreation ____________

Rural-Domestic ____________ Fish and Wildlife ____________

Industrial ____________ Other (please specify) ____________

7. Ownership:

(a) Property owner at the point of diversion: Passtime Golf Course

(b) Property owner at the place of use: Passtime Golf Course

(c) If either (a) or (b) above are other than the applicant, describe the arrangement enabling the applicant to make this filing: ____________

8. State law requires that cities and landowners within a one-mile radius of the proposed point of diversion be advised of this application. A completed "Notice of Application" will be forwarded to you upon receipt of this application. Therefore, please indicate the number of landowners and cities which you must notify:

6 land owners

9. *THE APPLICANT CERTIFIES THAT THE STATEMENTS APPEARING HEREIN ARE TO THE BEST OF HIS KNOWLEDGE TRUE AND CORRECT:*

Curt A. Slice, President 1/24/85
(SIGNATURE) (DATE)

____________ (SIGNATURE) ____________ (DATE)

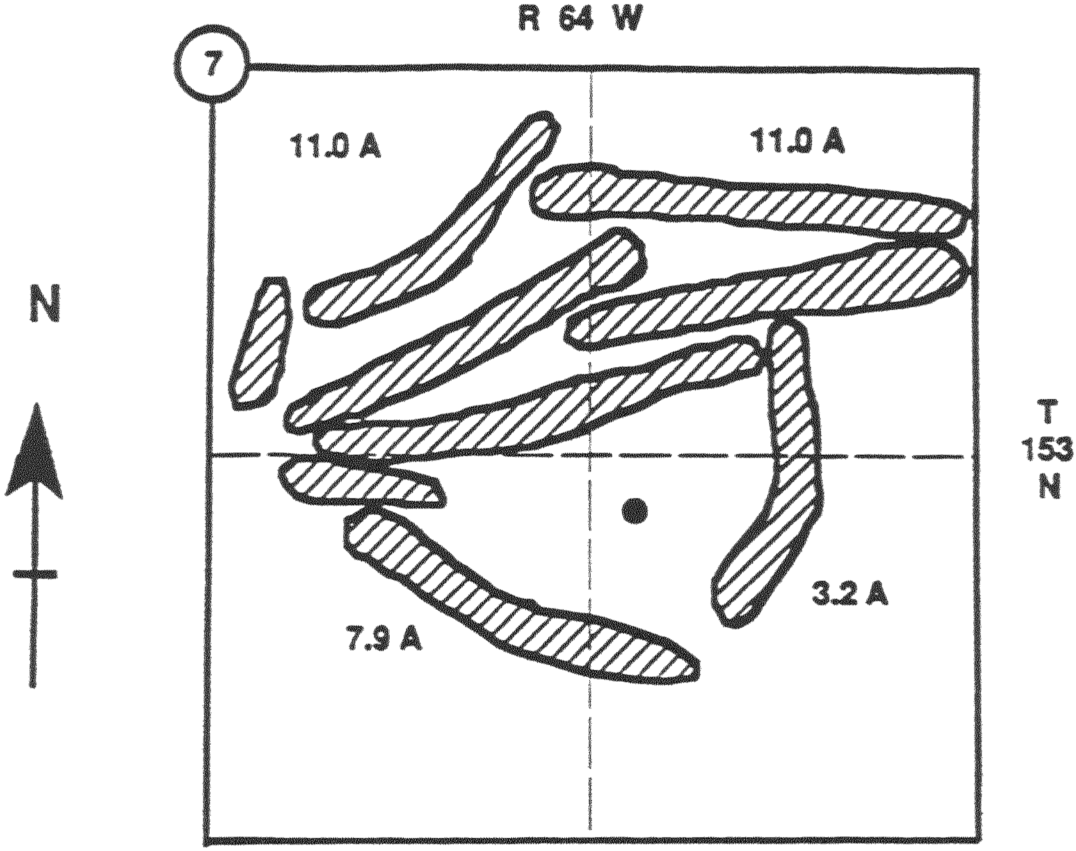
____________ (SIGNATURE) ____________ (DATE)

Signature of the applicant(s) must be exactly as in Item 1. If more than one applicant is shown, all must sign.

NOTE: Mail the completed application, along with the required map and application fee to:

STATE ENGINEER
State Office Building
900 East Boulevard

NOTE : EXAMPLE IRRIGATION (GOLF COURSE)
GROUND WATER SOURCE



Scale 1 " = 660'

● Well Location

Area To Be Irrigated

NOTE : Sprinkler System Will Be Used
To Distribute The Water

APPROVED ____________________
State Engineer

STATE OF NORTH DAKOTA)
) SS
COUNTY OF STARK)

I, George A. Fine of Dickinson, ND do hereby certify that this map was prepared from information obtained from field surveys and that it represents the area to be irrigated for the accompanying application.

George A. Fine
Surveyor

MAP

To accompany application

NO. __________ for

PASSTIME GOLF COURCE
Ramsey County, ND
Passtime Golf Cource
Hoveville, ND
APPLICANT

EXAMPLE

Application No.____________

STATE OF NORTH DAKOTA
APPLICATION FOR CONDITIONAL WATER PERMIT

NOTE: Use one application for each type of source (ground water, surface water). Check all appropriate boxes and fill in each blank line. If the question is not applicable to your proposed development, enter NA (not applicable). If more space is necessary, attach additional sheets.

(PLEASE TYPE OR PRINT IN INK)

1. Name of Applicant Slick Oil Co.
   Mailing Address Box SAE 1030
   City Dry Hole State TX Zip 77215
   Home Phone ________ Other Phone 713-249-1040

2 source of-water supply: ☒ ground water ☐ surface water

If surface water: (a) stream ________, a tributary of ________

(b) if new impoundment — ____ 1/4 ____ 1/4 Sec. ____, Twp. ____, Rge. ____

(c) If existing impoundment give name ________

3. (a) Point of diversion:

(1) 1/4 of Section 23 Township 152 N.. Range 102 W.. McKenzie County

Additional points of diversion, if any

(2) ____ 1/4 of Section ____ Township ____ N., Range ____ W.. ________ County

(3) ____ 1/4 of Section ____ Township ____ N., Range ____ W.. ________ County

(b) If water is not consumed, name the receiving body of water ________

and describe location of discharge point: ____ 1/4 ____ 1/4 Sec. ____ Twp. ____, Rge.

Amount of water requested:

(a) If impoundment: ________ acre-feet storage out of which ________ acre-feet will be used to offset evaporative losses.

(b) Other annual uses from points listed in item 3 above, rates of diversion, and periods of use:

(1) 20.0 (AMOUNT) acre-feet at 13.0 (RATE) cfs/gpm from Jan. 1 (MONTH-DAY) to Dec. 31 (MONTH-DAY) inclusive

(2) ____ (AMOUNT) acre-feet at ____ (RATE) cfs/gpm from ____ (MONTH-DAY) to ____ (MONTH-DAY) inclusive

(3) ____ (AMOUNT) acre-feet at ____ (RATE) cfs/gpm from ____ (MONTH-DAY) to ____ (MONTH-DAY) inclusive

Total annual use requested (sum of 4b and evaporation from 4a):

20.0 acre-feet maximum rate of 13.0 gpm.

Proposed construction:

Proposed starting date Jan. 7, 1984

Anticipated completion date Feb. 1, 1984

6. Description of proposed beneficial water uses:

(a) Irrigation (if applicable) *N/A*

(1) Method of irrigation: ☐ gravity ☐ sprinkler ☐ waterspreading

(2) Project will involve new irrigated land: ☐ Yes ☐ No

(3) Project will involve supplemental water to existing irrigation: ☐ Yes ☐ No

(4) Description of land to be irrigated (show lot numbers where applicable):

SEC.	TWP.	RGE.	NE1/4				NW1/4				SW1/4				SE1/4				TOTAL
			NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	
TOTAL NUMBER OF ACRES TO BE IRRIGATED:																			

(b) Non-irrigation use (if applicable):

Municipal ______ Recreation ______

Rural-Domestic ______ Fish and Wildlife ______

Industrial ✓ Other (please specify) ______

7. Ownership:

(a) Property owner at the point of diversion: *John Q. Public*

(b) Property owner at the place of use: *John Q. Public*

(c) If either (a) or (b) above are other than the applicant, describe the arrangement enabling the applicant to make this filing: ______

8. State law requires that cities and landowners within a one-mile radius of the proposed point of diversion be advised of this application. A completed "Notice of Application" will be forwarded to you upon receipt of this application. Therefore, please indicate the number of landowners and cities which you must notify:

8 land owners

9. *THE APPLICANT CERTIFIES THAT THE STATEMENTS APPEARING HEREIN ARE TO THE BEST OF HIS KNOWLEDGE TRUE AND CORRECT:*

Ima Roughneck, President (SIGNATURE) *1/2/84* (DATE)

______ (SIGNATURE) ______ (DATE)

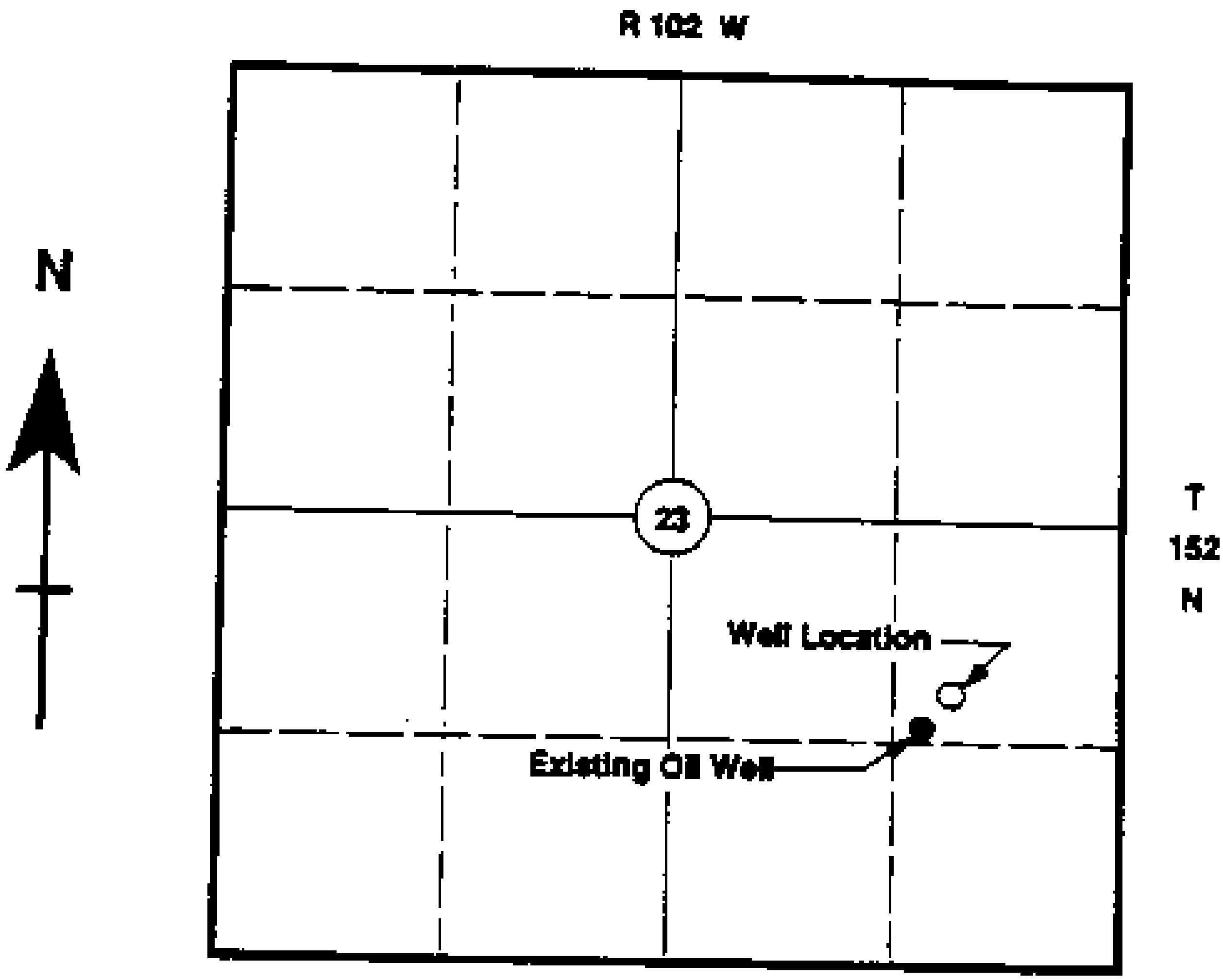
______ (SIGNATURE) ______ (DATE)

Signature of the applicant(s) must be exactly as in item 1. If more than one applicant is shown, all must sign.

NOTE: Mail the completed application, along with the required map and application fee to:

STATE ENGINEER
State Office Building
900 East Boulevard

NOTE : EXAMPLE INDUSTRIAL USE
GROUND WATER SOURCE



Scale 1 " = 1320 '

○ Proposed Well Site
● Existing Oil Well

APPROVED ______________________
State Engineer

STATE OF NORTH DAKOTA } SS
COUNTY OF GRANT

I, George A. Fine of Odessa, ND do hereby certify that this map was prepared from information obtained from field surveys and that it represents the well location for the accompanying application.

George A. Fine
Surveyor

MAP

To accompany application

NO. ______________ for

SLICK OIL CO.

McKenzie County, ND

Slick Oil Co.

Dry Hole, TX

APPLICANT

E X A M P L E

Application No.______________

STATE Of NORTH DAKOTA
APPLICATION FOR CONDITIONAL WATER PERMIT

NOTE: Use one application for each type of source (ground water, surface water). Check all appropriate boxes and fill in each blank line. If the question is not applicable to your proposed development, enter NA (not applicable). If more space is necessary, attach additional sheets.

(PLEASE TYPE OR PRINT IN INK)

1. Name of Applicant Ima Rancher
   Mailing Address HC 2 Box 48
   City Ranger State ND Zip 58001
   Home Phone 783-2478 Other Phone __________

2. Source of water supply: ☐ ground water ☑ surface water
   If surface water: (a) stream Unnamed a tributary of Little Missouri River
   (b) If new impoundment — ____ 1/4 NW 1/4 Sec. 23, Twp. 136 N, Rge. 102 W
   (c) If existing impoundment, give name __________

3. (a) Point of diversion:
   (1) NW 1/4 of Section 23 Township 136 N., Range 102 W., Slope County
   Additional points of diversion, if any:
   (2) ____ 1/4 of Section ____ Township ____ N., Range ____ W., ____ County
   (3) ____ 1/4 of Section ____ Township ____ N., Range ____ W., ____ County
   (b) If water is not consumed, name the receiving body of water __________
   and describe location of discharge point: ____ 1/4 ____ 1/4 Sec. ____ Twp. ____, Rge. ____

4. Amount of water requested:
   (a) If impoundment: 180.0 acre-feet storage out of which 52.0 acre-feet will be used to offset evaporative losses.
   (b) Other annual uses from points listed in item 3 above, rates of diversion, and periods of use:
   (1) ____ (AMOUNT) acre-feet at ____ (RATE) cfs/gpm from ____ (MONTH-DAY) to ____ (MONTH-DAY) inclusive
   (2) ____ (AMOUNT) acre-feet at ____ (RATE) cfs/gpm from ____ (MONTH-DAY) to ____ (MONTH-DAY) inclusive
   (3) ____ (AMOUNT) acre-feet at ____ (RATE) cfs/gpm from ____ (MONTH-DAY) to ____ (MONTH-DAY) inclusive
   Total annual use requested (sum of 4b and evaporation from 4a):
   52.0 acre-feet maximum rate of N/A gpm.

5. Proposed construction:
   Proposed starting date June 1, 1990
   Anticipated completion date Sept. 1, 1990

6. Description of proposed beneficial water uses:

(a) Irrigation (if applicable)

(1) Method of irrigation: ☐ gravity a sprinkler a waterspreading

(2) Project will involve new irrigated land: a Yes a No

(3) Project will involve supplemental water to existing irrigation: a Yes ☐ No

(4) Description of land to be irrigated (show lot numbers where applicable):

SEC.	TWP.	RGE.	NE1/4				NW1/4				SW1/4				SE1/4			
			NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4	NE1/4	NW1/4	SW1/4	SE1/4

TOTAL NUMBER OF ACRES TO BE IRRIGATED: ______

(b) Non-irrigation use (if applicable):

Municipal ______ Recreation ______

Rural-Domestic ______ Fish and Wildlife ______

Industrial ______ Other (please specify) livestock

7. Ownership:

(a) Property owner at the point of diversion: Ima Rancher

(b) Property owner at the place of use: Ima Rancher

(c) If either (a) or (b) above are other than the applicant, describe the arrangement enabling the applicant to make this filing: ______

8. State law requires that cities and landowners within a one-mile radius of the proposed point of diversion be advised of this application. A completed "Notice of Application" will be forwarded to you upon receipt of this application. Therefore, please indicate the number of landowners and cities which you must notify:

5 land owners

9. *THE APPLICANT CERTIFIES THAT THE STATEMENTS APPEARING HEREIN ARE TO THE BEST OF HIS KNOWLEDGE TRUE AND CORRECT:*

Ima Rancher (SIGNATURE) 1/5/90 (DATE)

______ (SIGNATURE) ______ (DATE)

______ (SIGNATURE) ______ (DATE)

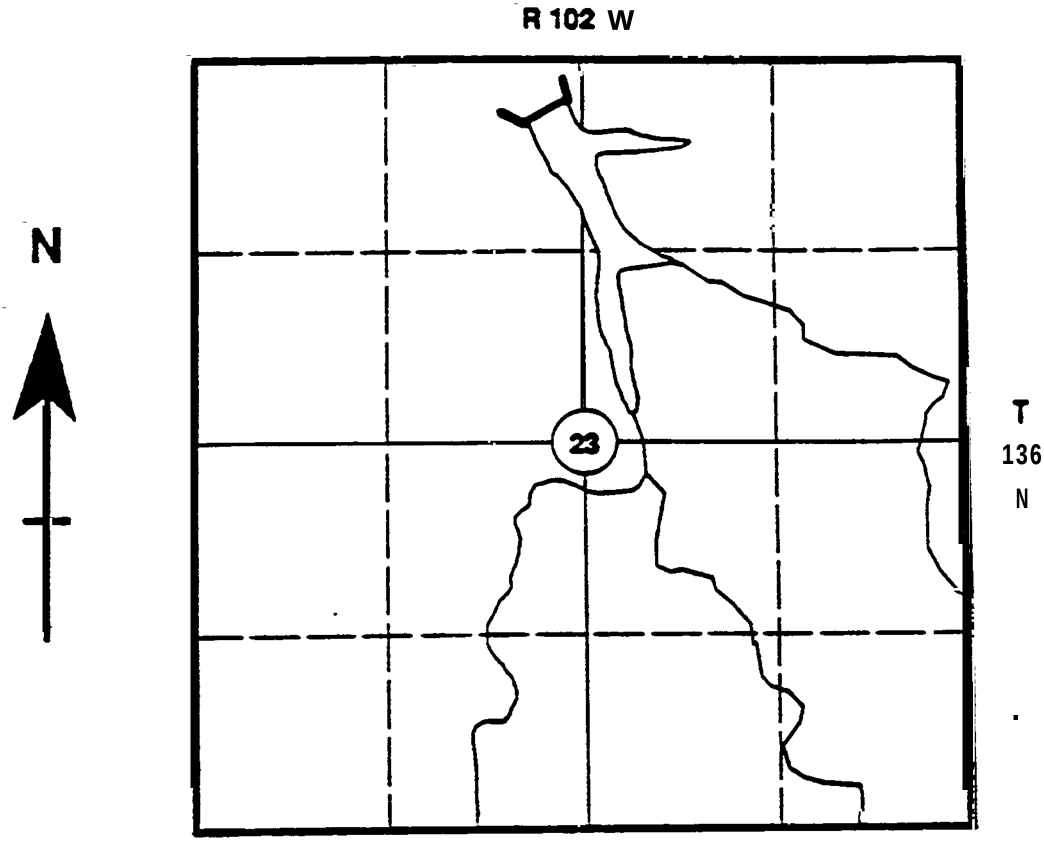
Signature of the applicant(s) must be exactly as in Item 1. If more than one applicant is shown, all must sign.

NOTE: Mail the completed application, along with the required map and application fee to:

STATE ENGINEER
State Office Building
900 East Boulevard

SWC FORM NO. 102

NOTE: EXAMPLE LIVESTOCK USE
SURFACE WATER SOURCE



Scale 1" = 1320'

APPROVED ____________________
State Engineer

STATE OF NORTH DAKOTA)
) SS
COUNTY OF STARK)

I, John W. Ray of Dickinson, ND do hereby certify that this map was prepared from information obtained from field surveys and that it correctly represents the dam described in the accompanying application, together with a meander of streams.

John W. Ray
Surveyor

MAP

To accompany application

NO. __________ for

RANCHER DAM

Slope County, ND

Ima Rancher

Ranger, ND

APPLICANT

APPENDIX C

REQUIREMENTS FOR CONSTRUCTION AND OPERATION OF STORAGE/EVAPORATION PONDS

NORTHDAKOTA
DEPARTMENT OF HEALTH

ENVIRONMENTAL HEALTH SECTION

1200 Missouri Avenue
P.O. Box 5520
Bismarck, North Dakota 58506-5520
Fax #701-328-5200

July 9, 1996

Chris Rousseau
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street
Grand Forks, ND 55203

RE: Brine Storage Ponds
Devils Lake, North Dakota

Dear Mr. Rousseau:

Reference is made to our recent phone conversation in which you requested a copy of our design requirements for wastewater storage ponds. Enclosed is a copy of Chapter 90 of the Ten States Standards, which are used as the standard for design of wastewater storage ponds in North Dakota.

Because of the concentration of solids in the brine, an exception will be made to the percolation requirements of section 96.24. The proposed brine ponds must have impermeable synthetic liners to prevent migration of contaminants into the groundwater.

Should you have any questions, please contact me at (701) 328-5212.

Sincerely,

David L. Bergsagel

David L. Bergsagel
Environmental Engineer
Division of Municipal Facilities

Chapter 90

Waste Stabilization Ponds (Lagoons)

91. Supplement To Engineer's Report

The engineer's report shall contain pertinent information on location, geology, access, flood hazard, soil conditions, area for expansion, and any other factors that will affect the feasibility and acceptability of the proposed facilities. The following information must be submitted in addition to that required in Section 11, engineer's report.

91.1 Supplementary Field Survey Data

91.11 The location and direction of all residences, roads, buildings, commercial development, water courses, and water supplies within ½ mile of the proposed facility.

91.12 Soil boring to determine surface and subsurface soil characteristics of the immediate area and their effect on the construction and operation of the proposed facility.

91.13 Data demonstrating the percolation rates to be anticipated at the elevation of the prosed pond bottom.

91.14 A layout of the facility showing suitable area for expansion with complete contours of the site and adjacent area and other pertinent information.

91.15 Sulfate content of the basic water supply.

92. Basis of Design

92.1 Area and Loadings

The maximum design loading on the primary cell or cells shall be 30 pounds per acre per day of 5-day 20 C BOD and the primary cell or cells shall be designed to satisfy the total design organic loading.

At least three cells designed for series operation shall be provided and the area in the primary cell or cells shall be approximately one-half (½) of the total surface acreage of the ponds. The surface area of the ponds shall be determined by the computation requiring the largest surface area based upon organic and hydraulic loading. The total organic loading for the total surface area shall be less than 20 pounds of 5-pounds 20° BOD per acre per day. The total hydraulic loading, including infiltration and inflow, shall be used to determine the volume required to provide a minimum storage capacity of 180 days. The 180-day storage shall be provided between the 2- and 5-foot liquid levels. The Department may consider and allow deviations where hardship **cases** can be documented and proved to the satisfaction of the Department. Higher design loadings may be permitted where mechanical aeration is utilized. Such designs may be approved by the Department after all the required information is reviewed. Due consideration shall be given to possible future municipal expansion and/or additional sources of wastes when the original land acquisition is made. Suitable land should be available at the site for increasing the size of the original construction. The facility shall be designed and operated to retain all wintertime flows.

92.2 Industrial Wastes

Due consideration will be given to the type and effects of industrial wastes on the treatment process.

92.3 Multiple Units

Multiple cells are required and the design may include facilities for series and parallel operation for additional flexibility. However, series

operation is required to meet effluent standards and to provide for better nutrient reduction.
Flexibility is desirable if one cell must be taken out of use for repair, enlargement or for some other reason.
Where a greater degree of treatment is necessary or desirable, or when population growth required additional treatment, more cells can be added as primary or secondary cells. The required surface area and loadings shall be as set.

92.4 Pretreatment

When ponds are used to provide additional treatment for effluents from existing or new primary or secondary sewage treatment works, the reviewing authority will, upon request, establish BOD loadings for the pond after due consideration of the efficiencies of the preceding treatment units.

92.5 Pond Shape

The shape of all cells should be such that there are no narrow or elongated portions. Round, square, or rectangular ponds with a length not exceeding 3 times the width are considered most desirable. Other shapes will be considered by the reviewing authority. No islands, peninsulas, or coves should be permitted. Dikes should be rounded at corners to minimize accumulations of floating materials.

93. Location

93.1 Distance From Habitation

A pond site should be as far as practicable from human habitation or any area which may be developed within the reasonable future. A distance of at least 1/4 miles is recommended whenever possible.

93.2 Prevailing Winds

If practicable, ponds should be located so that local prevailing winds will be in the direction of uninhabited areas.

93.3 Surface Runoff

The facility shall be designed to exclude surface run-off and shall not interfere with the natural drainage system unless adequate drainage is incorporated into the design.

93.4 Ground Water Pollution

The site of waste stabilization shall be critically evaluated with regard to locations in areas of porous soils and fissured rock formations, as well as location of water supplies and other facilities subject to contamination to avoid creation of health hazards or other undesirable conditions. The possibility of chemical pollution shall be considered.

94. <u>Pond Construction Details</u>

94.1 Embankments and Dikes

94.11 Material

Embankments and dikes shall be constructed of relatively impervious materials and compacted sufficiently to form a stable structure. The minimum compaction shall be 90 percent of Proctor Density, however, 95 percent Proctor Density is recommended. Vegetation should be removed from the area upon which the embankment is the be placed.

94.12 Top Width

The maximum embankment top width shall be 8 feet to permit access of maintenance vehicles.

94.13 Maximum Slopes

Embankment slopes should not be steeper than:

94.131 Inner

3 horizontal to 1 vertical.

91.132 Outer

3 horizontal to 1 vertical.

94.14 Minimum slopes

Embankment slopes should not be flatter than:

94.141 Inner

5 horizontal to 1 vertical.

Flatter slopes are sometimes specified for larger installations because of wave action but have the disadvantage of added shallow areas conducive to emergent vegetation which also is conducive to producing **mosquitos** breeding habitation.

94.142 Outer

Not applicable.

94.15 Freeboard

Minimum freeboard shall be 3 feet.

94.16 Minimum Depth'

The minimum normal liquid depth in a primary cell should be 2 feet.

94.17 Maximum Depth'

Maximum normal liquid depth in a primary cell should be 5 feet. The reviewing authority may consider depths over 5 feet in the secondary or multiple cell facilities for special considerations.

94.18 Seeding

Embankment shall be seeded from the outside toe to the high water line on the insider slope of the dikes. Perennial type, low growing, **spreading grasses that withstand erosion and can be kept mowed are most**

'Not applicable for facilities with mechanical aeration.

satisfactory for seeding of embankments. In general, alfalfa and other long-rooted crops should be used in seeding, since the roots of this type plant are apt to impair the water holding efficiency of the dikes. Th County Agricultural Extension Agent can usually advise as to hardy, locally suited permanent grasses which would be satisfactory for embankment seeding. Additional protection for embankments (riprap) may be necessary where the dikes are subject to erosion due to severe flooding of an adjacent watercourse or severe wave action.

94.19 Vegetation Control

A method shall be specified which will prevent growth of vegetation on the bottom of the ponds and to the high water line on the dikes.

94.2 Pond Bottom

94.21 Uniformity

The pond bottom should be as level as possible at all points. Finished elevations shall be within 2 inches of average elevation of the bottom. Shallow or feathering fringe areas usually result in locally unsatisfactory conditions.

94.22 Vegetation

The bottom shall be cleared of vegetation and other debris. Organic material thus removed shall not be used in the dike core construction. However, suitable topsoil relatively free of debris may be used as cover material on the outer slopes of the embankment.

94.23 Soil Formation

The soil formation or structure of the bottom shall be relatively tight to avoid excessive liquid loss due to percolation or seepage. Soil boring and tests to determine the characteristics of surface soil and subsurface soil shall be made a part of preliminary surveys to select ponds sites. Gravel limestone areas must be avoided.

94.24 Percolation

The ability to maintain a satisfactory water level in the ponds is one of the most important aspects of design. Removal of porous topsoil and proper compaction of subsoil improves the water holding characteristics of the bottom. Compacted clay, bentonite, or other approved material shall be used to adequately seal areas containing sand, gravel, or other porous material, and these areas shall be indicated on the plans. Where excessive percolation is anticipated, sealing of the bottom with a clay blanket, bentonite, or other sealing material should be given consideration. Percolation from the facility should be limited to 1/8 inch per day.

94.3 Influent Lines

94.31 Material

Any generally accepted material for underground sewer construction will be given consideration for the influent line to the pond. The material selected should be adapted to local conditions. Special consideration must be given to the character of the wastes, possibility of septicity, exceptionally heavy external loadings, abrasion, the necessity of reducing the number of joints, soft foundations, and similar problems. Surcharging of the sewer upstream from the inlet manhole is not permitted.

94.32 Manholes

A manhole shall be installed at the terminus of the gravity outline and shall be located as close to the dike as topography permits and it invert should be at least 6 inches above the maximum operating level of out surcharging the manhole.

94.33 Influent Lines

Influent lines should be located below the bottom of the pond and shall terminate in accordance with Section 94.35. This line can be placed at zero grade. The use of an unexposed dike to carry the influent line to the discharge points is prohibited, as such a structure will impede circulation. A gate valve and blow off are recommended in a gravity influent line to allow cleaning of the line.

94.34 Points of Discharge

The influent line to the primary cell or cells should be essentially center discharging. Influent lines or interconnecting piping to secondary cells of multiple celled ponds operated in series shall consist of pipes through the separating dikes (Section 94.43). Influent lines should be located to minimize short-circuiting within the pond.

94.35 Inlets

The inlet line for gravity influent shall discharge horizontally into a shallow, saucer-shaped depression which should extend below the pond bottom ***not*** more then the diameter of the influent pipe plus 1 foot. Force main inlet lines may discharge vertically through a 90° bend. The line should not extend more than 12 inches above the lagoon floor elevation.

94.36 Discharge Apron

The end of the discharge line should terminate with a concrete apron which a minimum area of 6 feet square.

94.4 Discharge and Interconnecting Piping

94.41 Material

Discharge and interconnection piping should be of adequate size and shall be manufactured in conformity with the latest standards issue by the American Water Works Association or applicable Commercial Standards. All discharge or interconnecting pipe lines shall be valved with gate valves rated for use with the piping specified. Structures which allow constant overflow shall not be permitted.

94.42 Discharge Piping

Discharge piping shall be installed complete with gate valve and valve box. The invert of the piping shall be 6 inches or more above the pond bottom to avoid pick-up of bottom deposits. Erosion protection should be provided at the discharge end of piping. The end of the discharge pipe should be screened or valved to prevent entrance of small animals. When possible, the discharge piping should be located to prevent short-circuiting. Consideration must be given in the design of all piping to protect against freezing or ice damage under winter conditions.

94.43 Interconnecting Piping.

Interconnecting piping shall be installed complete with gate valve and valve box. The invert or the pipe shall be 6 inches or more above the pond bottom to avoid pick-up of deposits. Erosion protection should be provided at the discharge end of piping. When possible, the discharge piping should be located to prevent short-circuiting. Consideration must be given in the design of all piping to protect against freezing or ice damage under winter conditions.

95. <u>Miscellaneous</u>

95.1 Fencing

The complete waste stabilization pond site shall be enclosed with a suitable fence to preclude entrance of livestock and discourage trespassing. A vehicle access gate of sufficient width to accommodate mowing equipment should be provided. All access gates should be provided with a lock. Fences shall be located away from the outside tow of the dike to facilitate dike mowing and maintenance operations.

95.2 Warning Signs

Appropriate signs should be provided along the fence around the pond to designate the nature of the facility and advise against trespassing.

95.3 Liquid Depth Operation

Optimum liquid depth in the primary cell is influenced to some extent by lagoon area since circulation is larger installations permit greater liquid depth. The basic plan of operation may also influence depth. Normal operating depths are to be controlled by the interconnecting or discharge piping and should range between 2 and 5 feet. For winter storage the operating level should be lowered before ice formation and gradually increased to 5 feet by the retention of winter flows. In the spring, the level in the secondary cell can be lowered to any desired depth providing the liquid meets effluent standards, and approval to discharge has been obtained. Shallow operation can be maintained following discharge with generally increased depths to discourage emergent vegetation, In the fa 11, the levels can be lowered, provided effluent standards are met, to prepare for winter storage.

95.4 Laboratory Equipment

See Section 46.4

APPENDIX D

REQUIREMENTS FOR A CLASS I NONHAZARDOUS INJECTION WELL PERMIT

NORTH DAKOTA
DEPARTMENT OF HEALTH

ENVIRONMENTAL HEALTH SECTION

1200 Missouri Avenue
P.O. Box 5520
Bismarck, North Dakota 58506-5520
Fax #701-328-5200

July 16, 1996

Chris Rousseau
EERC, University of North Dakota
15 N 23rd Street
Grand Forks, ND 58203

Re: Class I injection well permit

Dear Mr. Rousseau:

Enclosed are a Class I permit application, a summary of the technical requirements for UIC permits, and *Article* 33-25 of the North Dakota Century Code dealing with the UIC program. The state rules reference several sections of the Code of Federal Regulations, 40 CFR, Part 144. Additional technical specifications and guidance can be found in these sections of the CFR. The summary of technical requirements for UIC permits is still considered to be in draft form because North Dakota has not received final EPA approval for some modifications made in the program.

Also required to obtain 8 Class I UIC permit is a $50,000 surety bond, or proof of equivalent financial performance, to wver emergency plugging or remediation of the well or area affected by the well. I will supply you those forms when you are sure of your plans.

If you have any further questions please call me at 701-328-5233.

Sincerely,

Scott Radig

Scott Radig
Environmental Engineer

encl.

NORTH DAKOTA DEPARTMENT OF HEALTH
DIVISION OF WATER QUALITY
Underground Injection Control Program

Class I Permit Application

I. Name of Facility:

____

II. Facility Contact:

____

III. Facility Mailing Address:

____
(Street or P.O. Box)

______________________ ____________ ____________
(City or Town) (State) (Zip Code)

IV. Facility Location:

____
(Street, Route No., or Legal Description)

____
(County)

______________________ ____________ ____________
(City or Town) (State) (Zip Code)

V. SIC Codes:

List, in descending order of significance, the four 4-digit standard industrial classification (SIC) codes found in the 'Standard Industrial Classification Manual which best describe your facility in terms of the principal products or services you produce or provide. Also, specify each classification in words.

First: No. ________ Name ______________________________

Second: No. ________ Name ______________________________

Third: No. ________ Name ______________________________

Fourth. No. ________ Name ______________________________

VI. Operator Information:

____
(Name)

Status of Operator.

F = Federal M = Public (Other than Federal or State)
S = State 0 = Other (Specify) ________________
P = Private

________________________ ______________
(Street or P.O. Box) (Telephone No.)

_______________ _______ ________
(City or Town) (State) (Zip Code)

VII. Indian Land:

Is this facilii located on Indian Lands? Yes or No

VIII. Existing Environmental Pen-nits:

NDPDES (Discharge to Surface Water)
No. ____________________

RCRA (Hazardous Waste)
No. ____________________

PSD (Air Emissions from Proposed Sources)
No. ____________________

Other (Specify) ___________________________________

No. ____________________

IX. Map:

Attach to this application a topographic map of the area extending to at least one mile beyond property boundaries. The map must show the outline of the facility, the location of each of its existing and proposed intake and discharge structures, each of its hazardous waste treatment, storage, or disposal facilities, and each well where it injects fluids underground. Include all springs, rivers, and other surface water bodies in the map area.

X. Nature of Business (provide a brief description]:

____
____
____
____
____
____

XI. The Following Information Shall be Submitted in an Engineering Report:

1. Maps showing the injection wells for which a permit is sought and the applicable area of review. The map must show the number or name and location of all producing wells, injection wells, abandoned wells, dry holes, surface bodies of water, springs, mines, quarries, water wells, and other pertinent surface features, including residences and roads.

2. A tabulation of data on all wells within the area of review which penetrate into the proposed injection zone.

3. Maps and cross sections indicating the general vertical and lateral limits of all underground sources of drinking water within the area of review, their position relative to the injection formation, and the direction of water movement, where known, in each USDW which may be affected by the proposed injection.

4. Maps and cross sections detailing the geologic structure of the local area.

5. Generalized maps and cross sections illustrating the regional geologic setting.

6. Proposed operating data which should include average and maximum daily rate and volume of fluid to be injected, average and maximum injection pressure, and source and analysis of chemical, physical, radiological, and biological characteristics of injection fluids.

7. Proposed formation testing program to obtain analysis of chemical, physical, radiological, and other characteristics of the receiving formation,. including the estimated formation fracture pressure.

6. Proposed stimulation program.

9. Proposed injection procedure.

10. Engineering drawings of the surface and subsurface construction details of the system.

11. Contingency plans to cope with all shut-ins or well failures so as to prevent migration of fluids into any underground source of drinking water.

12. Corrective action proposed to be taken for wells within the area of review which penetrate the injection zone and are not properly completed or plugged.

13. Construction procedures, including the cementing and casing program, logging procedures, deviation checks, and a drilling testing and coring program.

14. Expected changes in pressure, native fluid displacement, and direction of movement of injection fluid.

15. Discussion of the qualifications and training of injection operations supervisory personnel.

16. A certificate that the applicant has assured, through a performance bond or other appropriate means, the resources necessary to close, plug, or abandon the well.

17. Any other information required to properly evaluate the application, such as proposed observation wells, etc.

XII. Certification:

I certify, under a penalty of law, that I have personally examined and am familiar with the information submitted in this application and all attachments, and that, based on my inquiry of those persons immediately responsible for obtaining the information contained in the application, I believe that the information is true, accurate, and complete. I ***am*** aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

____

(Name & Official **Title** - Type or Print)

________________________ __________________

(Signature) (Date Signed)

OPINION

ATTORNEY GENERAL
STATE OF NORTH DAKOTA
State Capitol
Bismarck, North Dakota 58505

701-224-2210

Nicholas J. Spaeth
ATTORNEY GENERAL

Capitol Offices
Consumer Fraud and Antitrust Division
701-224-3404
800-472-2600
Toll Free in ND

Criminal Justice Training and Statistics Division
701-224-2594

Fire Marshal
701-224-2434

Gaming Division
701-224-4848

Licensing Division
701-224-2219

Division Offices
Bismarck, ND 58502

Bureau of Criminal Investigation
P.O. Box 1054
701-221-6180
800-472-2185
Toll Free in ND

Drug Enforcement Unit
P.O. Box 993
701-221-5156
800-472-2183
Toll Free in ND

August 29, 1989

Mr. William J. Delmore
Assistant Attorney General
North Dakota state Department of
Health and Consolidated Laboratories
1200 Missouri Avenue
P.O. BOX 5520
Bismarck, ND 58502-5520

Dear Mr. Delmore:

I have examined the proposed amendments to article 33-25 of the North Dakota Administrative Code concerning underground injection control.

These administrative rules are in compliance with N.D.C.C. § 28-32-02 and axe hereby approved as to their legality. Upon final adoption. these rules may be filed with Legislative Council.

Sincerely,

Nicholas J. Spaeth

dfm
cc: Katherine Chester Vet Weyst
Legislative Council

RECEIVED
AUG 1989
Env. Enforce & Legal Services

ARTICLE 33-25

UNDERGROUND INJECTION CONTROL

Chapter 33-25-01
UNDERGROUND INJECTION CONTROL PROGRAM

33-25-01-01. Definitions.

1. "Abandoned well" means a well whose use has been permanently discontinued or which is in a state of disrepair such that it cannot be used for its Intended purpose or for observation purposes.

2. "Area of review" means the area of review surrounding an injection well described according to the criteria in 40 CFR 146.6 and 146.63.

3. “Casing” means a pipe or tubing of appropriate material, of varying diameter and weight, lowered into a borehole during or after drilling in order to support the sides of the hole end thus prevent the wells from caving to prevent loss of drilling mud into porous ground or to prevent water, gas, or other fluid from entering or leaving the hole.

4. “Catastrophic collapse” means the sudden and utter failure of overlying strata caused by removal of underlying materials.

5. “CFR” means Code of Federal Regulations as of August 27, 1987.

6. “Director” means the director of the division of water supply and pollution control of the state department of health and consolidated laboratories.

7. “Exempted aquifer” means an aquifer or its portion that meets the criteria in the definition of “underground source of drinking water” but which has been exempted according to the procedures of subsection 2 of section 33-25-01-05.

8. “Fluid” means material or substance which flows or moves whether in a semisolid, liquid, sludge, gas, or any other form or state.

9. “Formation” means a body of rock characterized by a degree of lithologic homogeneity which is prevailing, but not necessarily, tabular and is mappable on the earth’s surface or traceable in the subsurface.

10. “Hazardous Waste” means a hazardous waste as defined in 40 CFR 261.3.

11. “Injection zone” means a geological formation, group of formations, or part of a formation receiving fluids through a well.

12. “Packer” means a device lowered into a well to produce a fluidtight seal.

13. “Plugging” means the act or process of stopping the flow of water oil or gas into and out of a formation through a borehole or well penetrating that formation.

14. “Radioactive waste” means any waste which contains hazardous material in concentrations which exceed those listed in 10 CFR part 20, appendix B, table II, column 2.

15 “Well” means a bored drilled or driver shaft or a dug hole, whose depth is greater than the largest surface dimension.

History: Effective June 1 1983; amended effective November 1, 1989.
General Authority: NDCC 61-28-04
Law Implemented: NDCC 61-28-04

33-25-01-02. Classification of injection wells. Injection wells are classified as follows:

1. Class I. Wells used to inject hazardous waste and other industrial and municipal disposal wells which inject fluids beneath the lowermost formation containing, within one quarter mile 1402.34 meters] of the well bore, an underground source of drinking water.

2. Class II. Wells which Inject fluids:

a. Which are brought to the surface in connection with conventional oil or natural gas production and may be commingled with wastewaters from gas plants which arc an integral part of production operations unless those waters are classified as a hazardous waste at the time of injection.

b. For enhanced recovery of oil or natural gas; and

c. For storage of hydrocarbons which are liquid at standard temperature and pressure

3. Class III. Wells which inject for extraction of minerals or energy.

4. Class IV. Wells used to dispose of hazardous wastes or radioactive wastes into or above a formation which within one quarter mile [402.34 meters] of the well, contains an underground source of drinking water and wells used to dispose of hazardous wastes which cannot be classified under Class I wells, e.g., wells used to dispose of hazardous wastes into or above a formation which contains an exempted aquifer.

5. Class V Injection wells not included in Class I, II, III, or IV.

History: Effective June 1, 1983; amended effective November 1, 1989.
General Authority: NDCC 23-20.3, 61-28-04, 61-28.1-03
Law Implemented: NDCC 23-20.3, 61-28-04, 61-28.1-03

33-25-01-03. Prohibition of unauthorized injection. Any underground injection (except Class II and III) is prohibited except as authorized by permit or rule issued under this section. Also the construction of any well required to have a permit under this section is prohibited until the permit has been issued.

History: Effective June 1, 1983.
General Authority: NDCC 61-28-04
Law Implemented: NDCC 61-28-04, 61-28-06

33-25-01-04. Prohibition of movement of fluid into underground sources of drinking water.

1. No owner or operator shall construct, operate, maintain, convert, plug, abandon, or conduct any other underground injection activity in a manner which causes or allows movement of fluid containing any contaminant into an underground source of drinking water if the presence of that contaminant may cause a violation of any maximum contaminant level under chapter 33-17-01 or which may adversely effect the health of persons. The applicant for a permit shall have the burden of showing that the requirements of this section are met.

2. The director shall prescribe additional requirements in accordance to 40 CFR 144.12(b) through (e) for all injection wells which may cause a violation of a maximum contaminant level under chapter 33-17-01 or which may adversely affect the health of persons.

History: Effective June 1, 1983; amended effective November 1, 1989.
General Authority: NDCC 61-28-04, 61-28. I-03
Law Implemented: NDCC 61-28-04, 61-28. I-03

33-25-01-05. Identification of underground sources of drinking water and exempted aquifers.

1. The director may identify and shall protect as an underground source of drinking water all aquifers or parts of aquifers which:

   a. Supply any public water system; or

   b. Contain a sufficient quantity of ground water to supply public water system and:

      (1) Currently supply drinking water for human consumption; or

      (2) Contain fewer than ten thousand milligrams per liter total dissolved solids; and

      (3) Are not exempted aquifers.

2. After notice and opportunity for a public hearing the director may designate, identify, and describe in geographic or geometric terms, or

both, which are clear and definite exempted aquifers or parts thereof using the following criteria.

a. It does not currently serve as a source of drinking water; and

b. (1) It cannot now and will not in the future serve as source of drinking water because

(a) It is mineral, hydrocarbon, or geothermal energy producing;

(b) It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical;

© It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or

(d) It is located over a Class III wall mining area subject to subsidence or catastrophic collapse; or

(2) the total dissolved solids content of the ground water is more than three thousand and less than ten thousand milligrams per liter and it is not reasonably expected to supply a public water system

History: Effective June 1, 1983; amended effective November I, 1989
General Authority: NDCC 61-28-04, 61-28.1-03
Law Implemented: NDCC 61-28-04, 61-28. I-03

33-25-01-06. Permitting

1. Application for a permit.

a. Any person who is required to have a permit shall complete, sign, and submit an application to the director.

b. When the owner and operator are different, it is the operator's duty to obtain a permit.

c. The application must be complete before the permit is issued.

d. All applicants of Class I wells shall provide information specified in 40 CFR 144.31 (e) and 146.14(a) and © (for Class I nonhazardous waste injection wells) or 40 CFR 146.10(a), 146.71(~), and 146~72(a) (for Class I hazardous waste injection wells).

e. Applicants shall keep records of all data used to complete permit applications and supplemental information for at least three years from the date the application is signed.

f. Operators of new injection wells, unless covered by an existing ere. permit, shell submit an application within a reasonable time before construction is expected to begin.

2. Signatories to permit applications.

a. All permits shall be signed as follows:

(1) For a corporation: by a principal executive officer of at least the level of vice president.

(2) For a partnership or sole proprietor: by a general partner or proprietor.

(3) For a municipality, state, federal, or other public agency: by either a principal officer or authorized representative.

b. A person is a duly authorized representative if the authorization:

(1) Is made in writing by the legal signatory;

(2) Specifies an individual or position having responsibility for the overall operation; and

(3) Is submitted to the director either prior to or along with documents signed by the authorized representative.

Changes in authorization must be in writing and submitted to the director.

3. Duration of permits. Underground injection control permits for Class I and II wells shall be effective for a fixed term of not more then ten years.

4. Transfer of permits.

a. Any Class V permit may be automatically transferred to a new permittee if:

(1) The current permittee notifies the director at least thirty days prior to the proposed transfer date; and

(2) The notice includes a written agreement between the existing and new permittee containing:

(a) A specific date for transfer of permit responsibility, coverage, and liability; and

(b) a demonstration that the new permittee meets the financial responsibility requirements.

b. Permits for Class I wells may be transferred only if the permit has been modified or revoked and reissued.

5. Modification, revocation and reissuance, or termination of permits.

a. Permits may be modified, revoked and reissued, or terminated at the request of any affected person or at the director's initiative if cause exists as specified in 40 CFR 144.39. All requests shall be in writing and shall contain facts or reasons supporting the request.

b. If the director tentatively decides to modify or revoke and reissue a permit, the director shell prepare a draft permit incorporating the proposed changes. The director may request additional information and, in the case of a modified permit, may require the submission of an updated permit application. In the case of revoked and reissued permits, the director shall require the submission of a new application.

c. The following are causes for terminating a permit during its term or for denying a permit renewal application:

(1) Noncompliance by the permittee with any permit condition;

(2) Failure by the permittee to fully disclose all relevant facts or misrepresentation of relevant facts; or

(3) A determination that the permitted activity endangers human health or the environment.

d. If the director tentatively decides to terminate a permit, the director shall issue notice of intent to terminate.

History: Effective June I, 1983; amended effective November 1, 1989.
General Authority: NDCC 61-28-04
Law Implemented: NDCC 61-28-04, 61-28-06

33-25-01-07. Area permits.

1. The director may issue a permit on an area basis, rather than for each well individually; provided, that the permit is for injection wells:

   a. Described and identified by location in permit applications, if they are existing wells;

   b. Within the same well field, facility site, reservoir project, or similar unit in the same state;

   c. Of similar construction;

   d. Of the same class;

   e. Operated by a single owner or operator; and

   f. Used to inject other than hazardous waste.

2. Area permits shall specify:

   a. The area within which underground injections are authorized; and

   b. The requirements for construction, monitoring, reporting, operation, and abandonment for all wells authorized by the permit.

3. The area permit may authorize the permittee to construct and operate, convert, or plug and abandon wells within the permit area, provided:

   a. The permittee notifies the director at such time as the permit requires;

   b. The additional well meets the area permit criteria; and

   c. The cumulative effects of drilling and operation of additional injection wells are acceptable to the director.

4. If the director determines that any additional well does not meet the area permit requirements, the director may modify or terminate the permit or take enforcement action.

5. If the director determines the cumulative effects are unacceptable, the permit may be modified.

History: Effective June 1, 1983.
General Authority: NDCC 61-28-04
Law Implemented: NDCC 61-28-04, 61-28-06

33-25-01-08. Draft permits and fact sheets.

1. Draft permits.

   a. When the application is complete, the director shall tentatively decide either to prepare a draft permit or deny the application.

   b. If the director decides to prepare the draft permit, it shall contain the following information:

      (1) All required permit conditions;

      (2) All compliance schedule requirements;

      (3) All monitoring requirements; and

      (4) All specific requirements for construction corrective action, operation, hazardous waste management, reporting, plugging and abandonment, financial responsibility, mechanical integrity, and any other conditions the director may impose.

2. Feet sheets.

   a. A feet sheet shall be prepared for:

      (1) Every draft permit for a major facility or activity.

      (2) Every draft permit which the director finds is the subject of widespread public interest or raises major issues.

   b. If a fact sheet is required, it:

      (1) Shall be sent to the applicant and, on request, to any other

person.

(2) Shall include:

(a) A brief description of the type of facility or activity.

(b) The type and quantity of wastes, fluids, or pollutants which are proposed to be or are being injected.

(c) A brief summary of the basis for the draft permit condition.

(d) The reasons why any requested variances or alternatives to required standards do or do not appear justified.

(e) A description of the procedure for reaching a final decision, including:

[1] Beginning and ending dates of comment period;

[2] Address where comments will be received;

[3] Procedures for requesting a hearing and the nature of the hearing; and

[4] Any other procedures by which the public may participate.

(f) The name and telephone number of a person to contact for additional information.

History: Effective June 1, 1983.
General Authority: NDCC 61-28-04
Law Implemented: NDCC 61-28-04

33-25-01-09. Public notice and comment - Requests for hearings - Public hearings - Response to comments.

1. Public notice.

a. The director shall give public notice that the following actions have occurred.

(1) A draft permit has been prepared.

(2) A hearing has been scheduled.

(3) Intent to deny a permit application.

b. Public notice shall be given to allow thirty days for public comment on the draft permit.

c. Public notice of a public hearing shall be given at least thirty days before the hearing.

d. Public notice shall be given by the methods specified in 40 CFR 124.1 O(c).

e. Public notices and public notices for hearings shall at a minimum contain the information specified in 40 CFR 124.10(d).

2. Public comment.

a. During the public comment period, any interested person may submit written or oral comments and, if no public hearing is scheduled, request a public hearing in writing stating the nature of the issues.

b. All comments shall be considered in making the final decision and shall be answered when the final permit decision is made.

3. Public hearing. The director shall hold a public hearing whenever there is a significant degree of public interest in a draft permit. The director also may hold a public hearing at the director's discretion.

4. Response to comments.

a. The director shall issue a response to comments when final permit decision is made. The response shall:

(1) Specify which provisions if any of the draft permit have been changed in the final permit decision and the reasons for the change; and

(2) Briefly describe and respond to all significant comments on the draft permit raised during the public comment period or during any hearing.

b. The response to comments shall be available to the public.

History: Effective June 1, 1983.
General Authority: NDCC 61-28-04
Law Implemented: NDCC 61-28-04

33-25-01-I 0. Conditions applicable to all permits.

1. The general conditions contained in 40 CFR 144.51 apply to Class I and V underground injection control permits. All conditions shall be incorporated into the permits either expressly or by reference.

2. A permittee may not commence injection into a new injection well until:

   a. Construction is complete;

   b. The permittee has submitted notice to the director that construction is complete; and

   c. The director has inspected or reviewed the new injection well and finds it in compliance with the permit, or the permittee has not received notice from the director of intent to inspect within thirteen days of the permittee's completion notice.

3. The director shall impose on a case-by-case basis such additional conditions as are necessary to prevent the migration of fluids into underground sources of drinking water.

4. The permit shall require the permittee to maintain financial responsibility and resources to close, plug, and abandon the underground injection operation in a manner prescribed by the director. The permittee must show evidence of financial responsibility to the director by the submission of surety bond, or other adequate assurance, such as financial statements or other materials acceptable to the director. Operators of Class I hazardous waste injection wells must maintain the resources to close, plug, or abandon the well and for postclosure care pursuant to 40 CFR 144 subpart F and 40 CFR 146.71 and 146.72.

5. The permittee shall retain all records concerning the nature and composition of injected fluids until three years after completion of

plugging and abandonment of the well.

6. The following information shall be reported within twenty-four hours:

   a. Any monitoring or other information which indicates that any contaminant may cause an endangerment to an underground source of drinking water.

   b. Any noncompliance with a permit condition or malfunction of the injection system which may cause fluid migration into or between underground sources of drinking water.

History: Effective June I, 1983; amended effective November 1, 1989.
General Authority: NDCC 23-20.3-03, 61-28-04, 61-28.1-03
Law Implemented: NDCC 23-20.3-03, 61-28-04, 61-28.1-03

33-25-01-I 1. Technical requirements.

1. Construction requirements

   a. (1) Existing wells shall achieve compliance with construction requirements prior to permitting or according to a compliance schedule established as a permit condition.

      (2) New injection wells shall submit plans for testing, drilling, and construction as part of the permit application.

      (3) New injection wells shall be in compliance with construction requirements prior to commencing injection operations.

      (4) Changes in construction plans require approval of the director.

   b. Class I well construction shall conform to the requirements contained in 40 CFR 146.12 (nonhazardous waste injection wells) or 40 CFR 146.65 (hazardous waste injection wells).

2. Corrective action.

a. Applicants for Class I nonhazardous waste injection well permits shall identify all known wells which penetrate the injection zone within the area of review.

b. Applicants for Class I hazardous waste injection well permits are subject to the corrective action requirements of 40 CFR 146.64 and shall as part of the permit application submit a plan to the director outlining the protocol used to:

(1) Identify all wells penetrating the confining zone or injection zone within the area of review; and

(2) Determine whether walls are adequately completed or plugged.

c. All Class I injection wells are subject to the following:

(1) For wells in the area of review which are improperly sealed completed or abandoned, the applicant shall also submit a corrective action plan consisting of such steps or modifications as are necessary to prevent movement of fluid into an underground source of drinking water.

(2) The director's review of the corrective action plan shall consider all of the following criteria and factors:

(a) Toxicity and volume of the injected fluid.

(b) Toxicity of native fluids or byproducts of injection.

(c) Potentially affected population.

(d) Geology.

(e) Hydrology.

(f) History of the injection operation.

(g) Completion and plugging records.

(h) Abandonment procedures in effect at the time the wall was abandoned.

(i) Hydraulic connections with an underground source of drinking water.

(3) Where the corrective action plan is adequate, the director shall incorporate the plan into the permit as a condition.

(4) Where the corrective action plan is inadequate, the director shall:

(a) Require the applicant to revise the plan;

(b) Prescribe a corrective action plan as a permit condition; or

(c) Deny the permit.

(5) Permits for existing injection wells that require corrective action shall include a compliance schedule requiring corrective action as soon as possible.

(6) New injection wells may not be permitted until all required corrective action has been taken.

(7) The director may require as a permit condition that injection pressure be so limited that pressure in the injection zone does not exceed hydrostatic pressure at the site of an improperly competed or abandoned well within the area of review. This pressure limitation shall satisfy the corrective action requirement. Alternatively, such injection pressure limitation can be part of a compliance schedule and last until all other required corrective action has been taken.

3. All Class I hazardous waste injection wells must be sited in accordance with 40 CFR 146.62.

4. operating, monitoring, and reporting requirements for Class I wells shall at a minimum include the items contained in 40 CFR 146.13 (for nonhazardous waste injection wells) or 40 CFR 146.67, 146.68, and 146.69 (for hazardous waste injection wells).

5. In authorizing a new Class I well, the director shall require the submission of all the information specified in 40 CFR 144.31 and 146.14 (for nonhazardous waste injection wells) or 40 CFR 144.31, 146.70(a), 146.71 (a), and 146.72(a) (for hazardous waste injection wells).

6. Prior to granting approval for the operation of a Class I well, the operator shall submit for review by the director information listed in 40 CFR 146.14(b) (for nonhazardous waste injection wells) or 40 CFR 146.66 and 146.70(b) (for hazardous waste injection walls)

History: Effective June I 1983; amended effective November 1, 1989
General Authority: NDCC 23-20.3-03, 61-28-04, 61-28. I-03
Law Implemented: NDCC 23-20.3-03, 61-28-04, 61-28.1-03

33-25-01-I 2. Plugging and abandonment

1. Any Class I permit shall include, and any Class V permit may include, a plan for plugging and abandonment which shall be incorporated into the permit as a condition to ensure that movement of fluids either into an underground source of drinking water or between underground sources of drinking water is not allowed.

2. Temporary intermittent cessation of injection operations is not abandonment.

3. The permittee shall notify the director at such times as the permit requires before conversion or abandonment of the well or in the case of area permits before closure of the project.

4. Prior to granting approval for plugging and abandonment of a Class I well, the director shall consider the plan submitted by the operator which contains the information listed in 40 CFR 146 14(c) (for nonhazardous waste injection wells) or 40 CFR 146 71 (a)(4) and 146 72(a) (for hazardous waste injection wells)

History: Effective June 1, 1983
General Authority: NDCC 23-20.3-03, 61-28-04, 61-28. I-03
Law implemented: NDCC 23-20.3-03, 61-28-04, 61-28.1-03

33-25-01-I 3 Mechanical integrity.

1. A permit for any Class I well shall include, and for any Class V well may include, a condition prohibiting injection operations until the permittee shows to the satisfaction of the director that the well has mechanical integrity.

2. An injection well has mechanical integrity if

   a. There is no significant leak in the casing, tubing, or packer; and

   b. There is no significant fluid movement into an underground source of drinking water through vertical channels adjacent to the injection well bore.

3. The mechanical integrity of a Class I non hazardous waste well must be demonstrated using the methods listed in 40 CFR 146(b), (c), (d), and (e). The director may also allow the use of radioactive tracer survey (timed run method) for detecting leaks in the tubing, casing, or packer and for demonstrating the absence of fluid movement behind the casing (where the injection zone immediately underlies the lowermost underground source of drinking water on a case-by-case basis).

4. The mechanical integrity of a Class I hazardous waste injection as defined by 40 CFR 146.8 must be demonstrated as established by 40 CFR 146.68(d).

5. The mechanical integrity of a Class I nonhazardous waste injection well must be demonstrated at least once every five years and whenever there has been a well workover.

History: Effective June 1, 1983; amended effective November 1, 1989.
General Authority: NDCC 23-20.3-03, 61-28-04, 61-28.1-03
Law Implemented: NDCC 23-20.3-03, 61-28-04, 61-28. I-03

33-25-01-I 4. Area of review. The area of review for each injection well or each field, project, or area of the state shall be determined according to 40 CFR 146.6 (for nonhazardous waste injection wells) or 40 CFR 146.63 (for hazardous waste injection wells).

History: Effective June I, 1983; amended effective November 1, 1989.
General Authority: NDCC 23-20.3-03, 61-28-04

Law Implemented: NDCC 23-20.3-03, 61-28-04

33-25-01-I 5. Schedules of compliance.

1. The compliance schedule of a Class I nonhazardous waste injection well or a Class V injection well must require compliance as soon as possible, and not later than three years after the effective date of the permit.

2. If the schedule of compliance is for more than one year, then interim requirements and completion dates (not to exceed one year) must be incorporated into the compliance schedule and permit.

3. No later than thirty days following each interim and final date, the permittee shall submit progress reports to the director.

4. No owner or operator of a Class I hazardous waste injection well may begin injection until all corrective action as required in 40 CFR 146.64 has been taken.

History: Effective June I 1983; amended effective November 1, 1989
General Authority: NDCC 23-20.3-03, 61-28-04, 61-28.I-03
Law Implemented: NDCC 23-20.3-03, 61-28-04, 61-28. I-03

33-25-01-I 6. Authorization of Class V underground injection wells.

1. Authorization of injection into a Class V well is authorized indefinitely subject to the requirements of subsections 4, 5, and 6 of section 33-25-01 -10 and subsection 3 of section 33-25-01-I 2.

2. The owner or operator of any existing Class V well shall within one year of the effective date of an underground injection control program notify the director of the existence of any well meeting the definitions of Class V under the owner's or operator's control, and submit the following inventory information:

   a. Name of owner or operator of the well and legal contact;

   b. Number of wells and location by township, range and section;

   c. Nature and volume of injected fluids;

d. Construction features of the well including well depth screened interval and casing size and type; and

e. Any other information which the director requests.

3. All new Class V wells shall be in compliance with article 43-35 and submit to the director a log of formations penetrated and the inventory information requested in subsection 2.

4. a. The director may require the operator of a Class V well authorized by rule to apply for and obtain an individual or area permit. Cases where permits may be required include:

(1) The injection well is not in compliance with the applicable rule

(2) The injection well is not *or* no longer is within the category of wells and types of well operations authorized by rule.

(3) Protection of an underground source of drinking water requires the injection operation be regulated by requirements not contained in the rules.

b. Any owner/operator authorized by rule may request and be granted a permit and hence be excluded from coverage by rule.

c. All injection wells regulated by rule shall submit inventory information to the director.

d. Upon program approval, the director shall notify owner/operators of injection wells of their duty to submit inventory information.

e. Failure to submit required inventory information for a Class V well within one year of program approval will result in authorization removal for that well.

History: Effective June 1, 1983.
General Authority: NDCC 61-28-04, 61-28.1-03
Law Implemented: NDCC 61-28-04, 61-28.1-03

33-25-01-l 7. Requirements for hazardous waste injection wells. The owner or operator of all wells injecting hazardous waste shall comply with the requirements for hazardous waste management facilities as specified in 40 CFR 144.14, 146 subpart G, and 148.

History: Effective June 1, 1983; amended effective November 1, 1989.
General Authority: NDCC 23-20.3-04, 23-20.3-05, 61-28-04
Law Implemented: NDCC 23-20.3-04, 23-20.3-05, 61-28-04

33-25-01-l 8. Class IV wells. All Class IV wells are prohibited except wells used to inject contaminated ground water that has been treated and is being injected into the same formation from which it was drawn if such injection is approved by the director in accordance with 40 CFR 144.13(c).

History: Effective June 1, 1983; amended effective November 1, 1989
General Authority: NDCC 61-28-04
Law Implemented: NDCC 61-28-04, 61-28-06

TECHNICAL REQUIREMENTS FOR UIC PERMITS

A. Construction Requirements

1. General

The state UIC program will evaluate all aspects of proposed construction of Class I nonhazardous, Class I hazardous, and Class III injection wells, and will maintain construction standards that protect USDWs. The evaluation will include supervision and witnessing of many phases of well construction and testing.

The suitability of a proposed site for underground injection is evaluated by the appropriate staff prior to issuing a permit. In determining the suitability of a proposed site, the permitting agency will review information submitted in the technical report accompanying the application and any information developed in the pre-application conference. The following factors are among those considered.

a. Site location relative to population distribution,

b. Location relative to fresh water resources, water wells, and areas of groundwater withdrawal.

c. Local use of groundwater.

d. Site topography for evaluation of flood hazard, drainage problems, etc

e. Ownership and use of adjacent land

f. Details of surficial geology, including locations of known or suspected faults.

g. Details of subsurface geology, including presence of an adequate injection reservoir and confining strata, or presence of a suitable ore body, and locations of all known or suspected faults.

h. Locations of all known wells in the area and the probability of the presence of unknown abandoned well holes.

In addition, the staff will perform site inspections prior to construction to verify information submitted with the application and to determine the accessibility of the proposed site for drilling and other construction equipment.

2. Mechanical Integrity Testing

Chapters 43-02-02.1 and 33-25-01 of the North Dakota Administrative Code require that the permittee demonstrate mechanical integrity before any Class I or III injection well is put into operation and issued a permit. Mechanical integrity must also be demonstrated at least once every five years and whenever there has been a well work over.

An injection well has mechanical integrity if it meets the following criteria:

a. There is no significant leak in the casing, tubing, or packer. One of the following methods must be used to evaluate the absence or significant leaks:

   (1) Monitoring of annulus pressure after an initial pressure test

   (2) Pressure test with liquid or gas.

   (3) Radioactive tracer survey (under approved conditions)

b. There is no significant fluid movement into an underground source of drinking water through vertical channels adjacent to the injection well bore. One of the following methods must be used to determine the absence of significant fluid movement:

   (1) The result of a temperature, noise log, or radioactive tracer survey in certain cases.

   (2) The cementing records or cementing evaluation logs which show the existence of adequate cement to prevent fluid migration (only for and Class III).

   (3) Radioactive tracer survey (under approved conditions).

c. The permitting agency may allow the use of a test to demonstrate mechanical integrity other than those listed above. Any alternate mechanical integrity test must receive written approval from the permitting agency and agreed on the EPA prior to implementation and be consistent with the requirements of 40 CFR 146.8(d).

As a permit condition, the permitting agency will require that mechanical integrity be demonstrated before an injection well is put into operation, Thereafter, Class I non hazardous and Class Ill injection wells must demonstrate mechanical integrity at least once every five years, and whenever there has be a well worked over.

d. Mechanical Integrity Testing of Class I Hazardous Waste Wells

Class I hazardous waste injection wells are required to perform additional mechanical integrity testing as follows:

(1) The long string casing, injection tube and annular seal will be tested by means of an approved pressure test with liquid or gas annually and whenever there has been a well work over.

(2) The bottom hole cement will be tested annually be means of an approved radioactive tracer survey.

(3) An approved temperature, noise survey, or other approved log will be conducted at least once every five years to test movement of fluid along the borehole.

(4) A casing inspection log will be complete every five years.

(5) Any other test approved by the Division of Water Quality in accordance with 40 CFR 146.8(d) will be conducted.

In conducting and evaluating the tests enumerated in this section and other tests to be allowed by the Department of Health, the owner or operator and the Department Health, the owner and operator and the Department of Health will apply methods and standards generally accepted in the industry. Then the owner or operator reports the results of mechanical integrity test to the Department of Health, he will include a description of the test(s) and the method(s) used. In making the evaluation, the Department of Health will review monitoring and other test data submitted since the previous evaluation.

3. Class I Nonhazardous Well Construction Requirements

a. All Class I nonhazardous wells will be sited to inject into a formation which is beneath the lowermost formation containing a USDW within one-quarter mile of the well bore. All class I nonhazardous wells will be ceased and cemented to prevent the movement of fluids into or between underground sources of drinking water. The casing and cement used in the construction of each newly drilled well will be designed for the life expectancy of the well. In determining and specifying casing and cementing requirements, the following factors will be considered:

(1) The depth of the injection zone

(2) Injection pressure, external pressure, internal pressure, and axial loading.

(3) Hole size.

(4) Size and grade of all casing strings (wall thickness, diameter,

nominal weight, length, joint specification, and construction material).

(5) Corrosiveness of injection fluid, formation fluids, and temperature.

(6) Lithology of injection and confining intervals

(7) Type or grade of cement

b. All Class I nonhazardous injection wells, except those municipal wells injecting non- corrosive wastes, will inject fluids through tubing, with a packer set immediately above the injection zone, or tubing with an approved fluid seal as an alternative. The tubing, packer, and fluid seal will be designed for the expected service.

(1) The use of other alternatives to a packer may be allowed with the written approval of the Department of Health. To obtain approval, the operator will submit a written request to the Department of Health which will set forth the proposed alternative and all technical data supporting its use. The Department of Health will approve the request if the alternative method will reliably provide a comparable level of protection to the USDW. The Department of Health may approve an alternative method solely for an individual well or for general use.

(2) In determining and specifying requirements for tubing, packer, or alternatives, the following factors will be considered:

(a) Depth of setting

(b) Characteristics of injected fluid (chemical content, corrosiveness, and density).

(c) Injection pressure.

(d) Annular pressure.

(e) Rate, temperature, and volume of injected fluid

(f) Size of casing

(3) Appropriate logs and other tests will be conducted during the drilling and construction of all new Class I nonhazardous wells. A description report interpreting the results of such logs and tests will be prepared by a quality log analyst and submitted to the

Department of Health. At a minimum, such logs will include:

(a) Deviation checks on all holes constructed by first drilling a pilot hole, and then enlarging the pilot hole by reaming or another method. Such checks will be at sufficiently frequent intervals to assure that vertical avenues for fluid migration in the form of diverging holes are not created during drilling.

(b) Such other logs and tests as may be needed after taking into account the availability of similar data in the area of the drilling site, the construction plan and the need for additional information, that may arise from time to time as the construction of the well progresses. In determining which logs and tests will be required, the following logs will be considered for use in the following situations:

i. For surface casings intended to protect underground sources of drinking water:

a) Resistivity, spontaneous potential, and caliper logs before casing is installed.

b) A cement bond, temperature, or density log after the casing is set and cemented.

ii. For the immediate and long strings of casing intended to facilitate injection:

a) Resistivity, spontaneous potential, porosity, and gamma ray logs before the casing is installed.

b) Fracture-finding logs.

c) A cement bond, temperature, or density log after the casing is set and cemented.

(4) At a minimum, the following information concerning the injection formation will be determined or calculated for new Class I nonhazardous wells:

(a) Fluid pressure,

(b) Temperature.

(c) Fracture pressure.

(d) Other physical and chemical characteristics of the injection matrix.

(e) Physical and chemical characteristics of the formation fluids.

4. Class III Construction Requirements

Requirements for Class III wells include:

a. All new Class III wells will be cased and cemented to prevent the migration of fluids into or between USDW. The North Dakota Geological Survey may waive the cementing requirements for new wells in existing projects or portions of existing projects where he has substantial evidence that no contamination of the USDW would result. The casing and cement used in the construction of each newly drilled well will be designed for the life expectancy of the well. In determining and specifying cement and cementing requirements, the following factors will be considered.

(1) Depth to injection zone.

(2) Depth to bottom of all USDWs.

(3) Estimated maximum and average injection pressures.

(4) The nature of injection and formation fluids.

(5) Lithology of injection and confining zones.

(6) External pressure, internal pressure, and axial loading.

(7) Hole size.

(8) Size and grade of all casing strings (wall thickness, diameter, nominal weight, length, joint specification, and construction material).

(9) Type or grade of cement.

b. Appropriate logs and other tests will be conducted during the drilling and construction of all new Class III wells. A descriptive report interpreting the results of such logs and tests will be prepared by a qualified log analyst and submitted to the North Dakota Geological Survey. The logs and tests appropriate to each type of Class III well will be determined based on the intended function, depth, construction, and other characteristics of the well, availability of similar data in area of the drilling site, and the need for additional information that may arise from time to time as the construction of the well progresses. Deviation checks will be conducted on all holes where pilot holes and reaming are used, unless the hole will be cased and cemented by circulating cement to the surface. Where deviation checks are necessary, they will be conducted at sufficiently frequent intervals to assure that vertical avenues for fluid migration in the form of diverging holes are not created during drilling.

c. Where the injection zone is a formation which is naturally water-bearing, the following information concerning the injection zone will be determined or calculated for new Class III wells or projects:

(1) Fluid pressure.

(2) Fracture pressure

d. Physical and chemical characteristics of the formation fluids.

e. There the injection zone is not a water-bearing formation, only the fracture pressure must be submitted.

f. Where the injection is into a formation which contains water with less than 10,000 milligrams per liter total dissolved solids, monitoring wells will be completed into the injection zone and into any USDW above the injection zone.

g. Where injection is into a formation which does *not* contain water with less than 10,000 milligrams per liter total dissolved solids, no monitoring wells are necessary in the injection strata.

h. Where injection wells penetrate a USDW in an area subject to subsidence or catastrophic collapse, an adequate number of monitoring wells will be complete into the USDW outside the physical influence of the subsidence or catastrophic collapse.

5. Class I Hazardous Waste Well Construction Requirements

All existing and new Class I hazardous waste injection wells will be constructed and completed to:

a. Prevent the movement of fluids into or between USDWs, or into any unauthorized zones.

b. Permit the use of appropriate testing devices and work over tools.

c. Permit continuous monitoring of injection tubing and long string casing by installing and using continuous recording devices to monitor the injection pressure, the flow rate, volume, and temperature of injected fluids, and the pressure on the annulus between the tubing and the long string casing. Automatic alarm and automatic shutoff systems will be designed to sound and shut-in the well when pressures and flow rates or other parameters approved by the Department of Health exceed a range and/or gradient specified in the permit. The automatic alarm will also be designed to sound when the pressure and flow rates or other parameters approved by the Department of Health exceed a rate and/or gradient specified in the permit.

All well materials must be compatible with fluids with which the materials may be expected to come into contact. A well will be deemed to have compatibility as long as the materials used in the construction of the well meet or exceed standards developed for such materials by the American Petroleum Institute, the American Society for Testing Materials, or comparable standards acceptable to the Department of Health.

d. Casing and cementing used in the construction of each newly drilled well will be designed for the life expectancy of the well, including the post-closure care period. The casing and cementing program will be designed to prevent the movement of fluids into or between USDWs, and to prevent potential leaks from fluids from the well. In determining and specifying casing and cementing requirements, the Department of Health will consider the following information:

(1) Depth of injection zone.

(2) Injection pressure, external pressure, internal pressure, and axial loading.

(3) Hole size.

(4) Size and grade of all casing strings (well thickness, diameter, nominal weight, length, joint specifications, and construction material).

(5) Corrosiveness of injected fluid, formation fluids, and temperature.

(6) Lithology of injection and confining zones.

(7) Type or grade of cement

(8) Quantity of chemical composition of injected fluid

One surface casing string will, at maximum, extend into the confining bed below the lowest formation that contains s USDW and may be cemented by circulating cement from the base of the casing to the surface, using a minimum of 120 percent of the calculated annual volume. The Department of Health may require other than 120 percent when the geology or other circumstances warrant it.

e. At least one long string casing, using sufficient number of centralizers, will extend into the injection zone and will be cemented by circulating cement to the surface in one or more of the following stages:

(1) Of sufficient quantity and quality to withstand the maximum operating pressure.

(2) In a quantity no less than 120 percent of the calculated volume necessary to fill the annular space. The Department of Health may require more than 120 percent when the geology or other circumstances warrant it.

Circulation of cement may be accomplished by staging. The Department of Health may approve an alternative method of cementing in cases where the cement cannot be recirculated to the surface, provided that it can be demonstrated by using logs that the cement is continuous and does not allow fluid movement behind the well bore.

f. Casing, including any casing connections, must be rated to have sufficient structural strength to withstand, for the design life of the well:

(1) The maximum burst and collapse pressures which may be experienced during the construction, operation, and closure of the well.

(2) The maximum tensile stress which may be experienced at any point along the length of the casing during the construction, operation, and closure of the well.

At a minimum, cement and cement additives must be of sufficient quality and quantity to maintain integrity over the design life of the well.

g. All Class I hazardous waste injection wells will inject fluids through tubing, with a packer set at a point by the Department of Health. In determining and specifying requirements for tubing and packer, the following factors will be considered:

(1) Depth of setting.

(2) Characteristics of injection fluid (chemical contents, corrosiveness, temperature, and density).

(3) Injection pressure.

(4) Annular pressure.

(5) Rate (intermittent or continuous), temperature, and volume of injected fluid.

(6) Size of casing.

(7) Tubing tensile, burst, and collapse strengths.

h. The Department of Health may approve the use of a fluid seal if the following conditions are met:

(1) It is demonstrated that the seal will provide a level of protection comparable to a packer.

(2) It is demonstrated that the staff is and will remain adequately trained to operate and maintain the well and to identify and interpret variations in parameters of concern.

(3) The permit contains specific limitations on variations in annular pressure and loss of annular fluid.

(4) The design contains specific limitations on variations in annular pressure and loss of annular fluid.

(5) A secondary system is used to monitor the interface between the annulus fluid and the injection fluid, and the permit contains requirements for testing the system every three months and recording the results.

B. Corrective Action

The state may require that corrective action be taken when any well within the area III injection operation is inadvertently constructed, plugged, or abandoned so as to pose a hazard to a USDW.

The area of review is the area surrounding an injection well or group of injection wells, for which pressure data are collected and artificial penetrations are evaluated for possible corrective action.

The area of review for Class I nonhazardous and Class V injection wells will be determined as follows:

1. Zone of endangering influence. The zone of endangering influence will be that area, the radius of which is the lateral distance from an injection well, field of project, in which the pressure in the injection zone may cause the migration of the injection zone may cause the migration of the injection and/or formation fluid into a USDW.

2. Fixed radius. A fixed radius around the well, field, or project of one-quarter mile minimum.

If the area of review is determined by a mathematical model for the zone of endangering influence, the permissible radius is the result of the calculation or measurement, even if it is less than one-quarter mile.

The area for review for a Class I hazardous waste well will be a two-mile radius around the well bore. The Department of Health may specify a larger area of review based on the calculated zone influence of the well.

The area of review for each Class III injection well will have a radius of not less than one-quarter mile around each well or fields as may be determined by the North Dakota Geological Survey.

The Departmant of Health may modify the area of review for any Class I or III injection well application after appropriate review. Justification for modifying area of review requirements may include favorable geological conditions, great depth to injection zone, small anticipated injection pressures and fluid

In general, the staff reviews data submitted by the applicant, evaluates the proposed corrective action plan and, if the plan is approved, may incorporate it as a permit provision. The following are requirements for corrective action:

1. Applications for Class I nonhazardous and hazardous injection well permits will identify all known wells which penetrate the injection zone within the area of review.

2. For wells in area of review which are improperly sealed, completed, or abandoned the applicant will also submit a plan consisting of such steps or modifications, are necessary to prevent movement of fluid into a USDW.

3. The permit agency's review of the plan for corrective action will consider the following criteria and factors.

   a. Toxicity and volume of the injected fluid.

   b. Toxicity of native fluids or by-products of injection.

   c. Potential affected population.

   d. Geology.

   e. Hydrology.

   f. History of the injection operation.

   g. Completion and plugging records.

   h. Abandonment procedures in effect at the time the well was abandoned

   i. Hydrologic connections with a USDW.

4. Where the corrective action plan is adequate, the plan will be incorporated into the permit as a condition.

5. Where the corrective action plan is inadequate, the permuting agency will:

   a. Require the applicant to revise the plan.

   b. Provide a corrective plan as a permit condition.

   c. Deny the permit.

6. Permits for existing injection wells that require corrective action will include a compliance schedule requiring corrective action as soon as possible.

7. New injection wells may not be permitted until all required corrective action has been taken.

8. The permitting agency may require as a permit condition that injection pressure be so limited that pressure in the injection zone does not exceed hydrostatic pressure at the site of any improperly completed or abandoned well within the area of review. This pressure limitation will satisfy the corrective action requirement.

   Alternatively, such injection pressure limitation can be part of a compliance schedule and last until all other required corrective action has been taken.

C. Operating, Monitoring and Reporting Requirements

State UIC regulations provide specific operating, monitoring, and reporting requirements for Class I nonhazardous, Class I hazardous, and Class III injection operations. Class V wells will operation under general rules prohibiting pollution of USDWs and requiring submission of inventory data.

1. Operating Requirements

For Class I nonhazardous, Class I hazardous, and Class III wells, the permit will establish that:

a. The injection pressure at the well head will not exceed a maximum which will be calculated so as to assure that the pressure in the injection zone during injection does not initiate new fractures or propagate existing fractures in the injection zone, initiate fractures in the confining zone, or cause the movement of injection or formation fluids into a USDW.

b. Injection between the outermost casing protecting USDWs and the well bore is prohibited.

For Class I nonhazardous wells, unless an alternative to tubing and packer has written approval from the Department of Health, the annulus between the tubing and the long string casing will be filled with a fluid and a pressure will be maintained on the annulus.

For Class I hazardous waste wells, the surface facilities must comply with the Department of Health's rules and standards for hazardous waste management facilities.

Additional operating requirements for Class I hazardous wells are:

a. An annulus pressure that exceeds the operating injection pressure will be maintained unless the Department of Health determines that such a requirement might harm the integrity of the well. The fluid in the annulus will be noncorrosive or will contain a corrosive inhibitor.

b. Mechanical integrity of the injection well will be maintained at all times.

c. Permit requirements for hazardous waste wells which inject waste which have potential to react with the injection formation to generate gases will include:

(1) Conditions limiting the temperature, pH, or acidity of the injected waste.

(2) Procedures necessary to assure that pressure inbalances which might cause a backflow or blowout do not occur.

d. Continuous recording devices will be installed and used to monitor the injection pressure; flow rate, volume and temperature of the injected fluids; and the pressure on the annulus between the tubing and the long string casing. The following will also be installed and used:

(1) Automatic alarm and automatic shutoff systems designed to sound and shut in the well when pressures and flow rates or other parameters approved by the Department of Health exceed a range ***and/or*** gradient specified in the permit.

(2) Automatic alarms designed to sound when the pressure and flow rates or other parameters approved by the director exceed a. rate and/or gradient specified in the permit, in cases where a certified, trained operator will be on-site at all times when the well is operating.

e. In an automatic alarm or shutdown is triggered, an investigation will begin immediately to investigate and identify as expediently as possible the cause of the alarm or shutdown. If, upon such investigation, the well appears to be lacking mechanical integrity or if the required monitoring listed above other indicates that the well may be lacking mechanical integrity, the following actions will be taken:

(1) Cease injection of waste fluids unless authorized by the Department of Health to continue or resume injection.

(2) Take all necessary steps to determine the presence or absence of a leak

(3) Notify the Department of Health within 24 hours after the alarm or shutdown

f. If a loss of mechanical integrity is discovered before an automatic alarm or shutdown is triggered, or during periodic mechanical integrity testing, the following actions will be taken:

(1) Immediate cease injection of waste fluids.

(2) Take all steps reasonably necessary to determine whether there may

have been a release of hazardous wastes or hazardous waste constituents into any unauthorized zone.

(3) Notify the Department of Health within 24 hours after the loss of mechanical integrity is discovered.

(4) Notify the Department of Health when injection can be expected to resume.

(5) Restore and demonstrate mechanical integrity to the satisfaction of the Department of Health prior to resuming injection of waste fluids.

g. Whenever evidence is obtained that indicates there may have been a release of injected wastes into an unauthorized zone, injection of waste fluids will immediately cease and:

(1) Notify the Department of Health within 24 hours of obtaining such evidence.

(2) Take all necessary steps to identify and characterize the extent of any release.

(3) Comply with any remediation plans specified by the Department of Health.

(4) Implement any remediation plan approved by Department of Health.

(5) When such release is into a USDW currently serving as a water supply, placed a notice in a newspaper of general circulation.

The Departnment of Health may allow the injection to resume prior to completing cleanup action if it can be determined that the injection operation will not endanger USDWs.

h. The Department of Health will be notified and approval obtained prior to conducting any well work over.

2. Monitoring Requirements

Each UIC permit will establish monitoring requirements as follows:

a. Class I nonhazardous monitoring wells will, at a minimum, include:

(1) The analysis of injected fluids with sufficient frequency to yield

representative data of their characteristics.

(2) Installation and use of continuous recording devices to monitor injection pressure, flow rate and volume, and the pressure on the annulus between tubing and the long string of casing.

(3) The demonstration of mechanical integrity at least once every five years during the life of the well.

(4) The type, number and location of wells within the area of review to be used to monitor any migration of fluids into and pressure in the USDW, the parameters to be measured, and the frequency of monitoring.

b. Ambient monitoring requirements are also required for Class I nonhazardous wells. Ambient monitoring is based on a site-specific assessment of the potential for fluid movement for the well or injection zone and on the potential value of monitoring wells to detect such movement. Department of Health requires a monitoring program to be developed. At a minimum, the program will:

(1) Monitoring the pressure buildup in the injection zone annually including, at a minimum, a shutdown of the well for a time sufficient to conduct a valid observation of the pressure fall-off curve.

(2) The Department of Health may also require continuous monitoring for pressure changes in the first aquifer overlaying the confining zone. When such a well is installed, the aquifer will be sampled and analyzed on a quarterly basis for constituents specified by the Department of Health.

(3) The use of indirect, geophysical techniques to determine the position of the waste front, the water quality in the information designed by the Department of Health, or to provide other site-specific information.

(4) Periodic monitoring of the groundwater quality in the first aquifer overflying the injection zone.

(5) Periodic monitoring of the groundwater quality in the Iowermost USDW.

(6) An additional monitoring necessary to determine whether fluids are moving into or between USDWs.

C. Class III monitoring wells will, at a minimum, include:

(1) The analysis of the physical and chemical characteristics of the injected fluid with sufficient frequency to yield representative data on its characteristics.

(2) Monitoring of injection pressure and wither flow rate or volume semimonthly, or metering and daily recording of injected and produced fluid volumes as appropriated.

(3) Demonstration of mechanical integrity at least once every five years during the life of the well for salt solution mining.

(4) Monitoring of the fluid level in he injection zone semimonthly, where appropriate, and monitoring of parameters chosen to measure water quality in monitoring wells semimonthly.

(5) Quarterly monitoring of wells adjacent to the injection site to detect any migration from the injection zone into a USDW.

(6) All Class III wells may be monitored on a field or project basis rather than an individual well basis by manifold monitoring. Manifold monitoring may be used in cases of facilities consisting of more than one injection well operating with a common manifold. Separate monitoring systems for each well are not required provided the owner/operator demonstrates that manifold monitoring is comparable to the individual well monitoring.

(7) In determining the number, location, construction, and frequency of the monitoring well, the following criteria will be considered:

(a) The population relying on the USDW affected or potentially affected by the injection operation.

(b) The proximity of the injection operation to points of withdrawal of drinking water.

(c) The local geology and hydrology.

(d) The operating pressure and whether negative pressure grading is being maintained.

(e) The toxicity and volume of the injected fluid, the formation water, and the process of by-products.

(f) The injection well density

d. Class I hazardous waste well testing and monitoring requirements will, at a minimum. include:

(1) Monitoring of Injected Wastes

(a) An approved written waste analysis plan will be developed and followed that describes the procedures to be carried out to obtain a detailed chemical and physical analysis of a representative sample of the waste, including the quality assurance procedures used. At a minimum, the plan will specify:

i. The parameters for which the waste will be analyzed and the rationale for the selection of these parameters.

ii. The test methods that will be used to test for parameters.

(b) The sampling methods that will be used to obtain a representative sample of the waste to be analyzed.

(2) The analysis of the injected wastes will be repeated as described in the waste analysis plan at frequencies specified in the waste analysis plan, and when processes or operating changes occur that may significantly alter the characteristics of the waste stream.

(3) Continuous or periodic monitoring will be conducted of selected parameters as required by the Department of Health.

(4) The waste analysis plan will remain accurate and the analysis remain representative.

e. Hydro-geologic Compatibility Determination

Information will be submitted that demonstrates to the satisfaction of the Department of Health the waste stream and its anticipated reaction products will not alter the permeability, thickness, or other relevant characteristics of the confining or injection zones such that they would no longer meet the minimum criteria for siting a Class I hazardous waste well

f. Compatibility of Well Materials

The waste stream must be compatible with the well materials with which the waste is expected to come into contact, and submit to the Department of Health a description of the lithology used to make that determination. Compatibility for purposes of this requirement is established if contact with injected fluids will not cause the well materials to fail to satisfy any design requirements imposed under the construction requirements for a Class I hazardous waste well.

(1) The Department of Health will require continuous corrosion monitoring of the construction materials used in the well or wells injecting corrosive wastes, and may require such monitoring for other wastes by:

(a) Placing coupons of the well construction material in contact with the waste stream.

(b) Routing the waste stream through a loop construction with the material used in the well.

(c) Using an alternate method approved by the Department of Health.

(2) If a corrosion monitoring program is required:

(a) The test will use materials identical to those used in the construction of the well, and such materials must continuously be exposed to the operating pressures and temperatures (measured at the wellhead) and flow rates of the injection.

(b) The materials will be monitoring for loss of mass, thickness, cracking, pitting, and other signs of corrosion on a quarterly basis to ensure that the well components meet the minimum standards for material strength and performance set forth in the construction requirements.

3. Periodic Mechanical Integrity Testing

The requirements for periodic mechanical integrity testing will consist of the following:

a. The long string casing, injection tube, and annular seal will be tested by means of an approved pressure test with a liquid or gas annually and whenever there has been a well work over.

b. The bottom-hole cement will be tested by means of an approved radioactive tracer survey annually.

c. An approved temperature, noise, or other approved log will be run at least once every five years to test for movement of fluid along the bore hole. The Department of Health may require such tests whenever the well is worked over.

d. Casing inspection logs will be run at least once every five years unless the director waives this requirement due to well construction or other factors worked which limit the test's reliability.

e. Any other test deemed necessary by the Department of Health,

4. Ambient Monitoring

a. The Department of Health requires a monitoring program a monitor program to be developed based on a site-specific assessment of the potential for fluid movement for the well or injection zone, and on the potential value or monitoring wells to detect such movement: at a minimum, the Department of Health will require monitoring of the pressure buildup in the injection zone annually including, at a minimum, a shutdown of the well for a sufficient time to conduct a valid observation of the pressure fall-off curve.

b. The Department of Health may also require a monitoring system consisting of

(1) Continuous monitoring for pressure changes in the first aquifer overlaying the confining zone. When such a well is installed, the aquifer will be sampled and analyzed quarterly for constituents specified by the Department of Health.

(2) The use of indirect, geophysical techniques to determine the position of the waste front, the waster quality in a formation designated by the Department of Health, or to provide other site-specific data.

(3) Periodic monitoring of the groundwater quality in the first aquifer overlaying the injection zone.

(4) Periodic monitoring of the groundwater quality in the lowermost USDW.

(5) Any additional monitoring necessary to determine whether fluids

are moving into or between USDWs

(6) The Department of Health may require seismicity monitoring when there is reason to believe that the injection activity may have the capacity to cause seismic disturbances.

5. Reporting Requirements

a. For Class I nonhazardous injection wells, reporting requirements will, at a minimum, include:

Quarterly reports to the Division of Water Quality on:

(1) The physical, chemical, and other relevant characteristics of injection fluids.

(2) Monthly average, maximum, and minimum values for injection pressure, flow rate and volume, and annular pressure.

(3) The result of monitoring of wells in the area of review.

b. Reporting the results with the first quarterly report after the completion of:

(1) Periodic tests of mechanical integrity

(2) Any other tests of the injection well conducted by the permittee if required by the Department of Health.

(3) Any well work over.

c. For Class III injection wells, reporting requirements will, at a minimum include:

(1) Quarterly reporting to the North Dakota Geological Survey on required monitoring.

(2) Results of mechanical integrity and any other periodic tests required by the North Dakota Geological Survey reported with the first regular quarterly report after the completion of the test.

(3) Monitoring may be reported *on* a project or field basis rather than individual well basis where manifold monitoring is used.

d. For Class I hazardous waste injection wells, reporting requirements will, at a minimum, include:

(1) Quarterly reporting to the Department of Health on the following:

(a) The maximum injection pressure.

(b) The description of any event that exceeds operating parameters for annulus pressure as specific in the permit.

(c) A description of any event which triggers an alarm or shutdown device and the response taking.

(d) The total volume of fluid injected.

(e) Any change in the annular fluid volume.

(f) The physical, chemical, and other relevant characteristics of injected fluids.

(g) The result of the required monitoring.

(2) Reporting within 30 days or with the next quarterly report, whichever come later, the results of

(a) Periodic tests of mechanical integrity.

(b) Any other tests of the injection required by the director

(c) Any well work over.

D. Plugging and Abandonment

Each permit application submits a proposed plugging and abandonment plan for the permitting agency's review. The proposed plan includes such information as:

1. The type of plugging method
2. Grades and anticipated volumes of cement.
3. Size and placement depth of cement plugs.
4. A discussion of the procedures for pre-plugging hole conditioning.
5. Type and density of mud or other fluid left in the hole.
6. The sequence of steps involved in the plugging operation.

Prior to abandoning Class I and III injection wells, the wells will be plugged with cement in a manner which will not allow movement of fluid either into or between USDWs. The North Dakota Geological Survey may allow Class III wells to use other plugging materials if there is satisfaction that such materials will prevent movement of fluids into or between USDWs.

7. The placement of cement plugs will be accomplished by one of the following:

   a. The balance method

   b. The dump bailer method.

   c. The two-plug method

   d. An approved methods which will reliable provide a comparable level of protection to USDWs.

The well to be abandoned will be in a state of static equilibrium, with the mud weight equalized top to bottom, either by circulating the mud in the well at least once or by a comparable method prescribed by the permitting agency prior to the placement of the cement plugs.

For individually permitted wells, the information listed above may be specific and quantitative. However, for area permits, the procedures, materials, etc. may be generalized and applied to all plugging operations performed within the permit area. In the case of Class III well field which are in or underlying exempted aquifers, t he plan will demonstrate that contaminants from the mine zone will not move into USDWs. There it is necessary, the permitting agency may prescribe aquifer cleanup and restoration to ensure that such contaminant migration will not occur. In addition to the plan, each applicant must also provide a certification of financial responsibility as a guarantee that the injection operation will be plugged and abandoned in a manner prescribed by the appropriate division. The Division of Water Quality (all Class I injection wells) and the North Dakota Geological Survey (Class III injection wells) must be notified in writing at least 90 days prior to commencement of plugging operations.

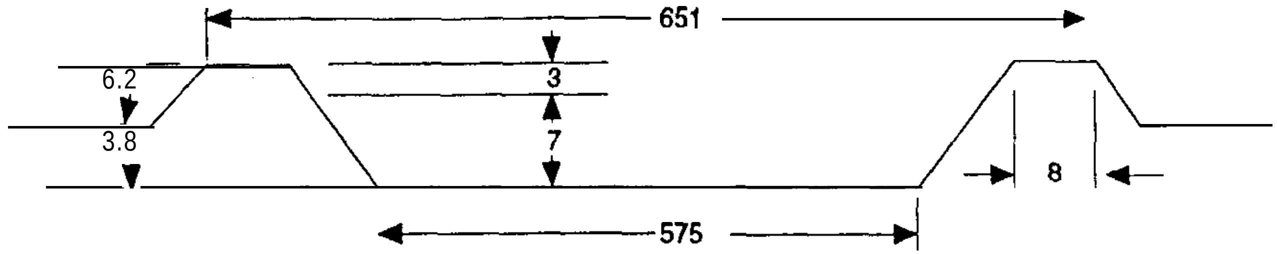
Additional requirements pertaining to closure activities for Class I hazardous waste well 146.71 (closure), 146.72 (post-closure care), and 146.73 (financial responsibility for post-closure care).

APPENDIX E

DESIGNS AND EXCAVATION REQUIREMENTS FOR FT DEMONSTRATION AND COMMERCIAL PONDS

Figure E-l. Demonstration Plant Brine Evaporation Pond Design and Excavation Requirements

Brine Evaporation Pond



Above Surface Elevation:

Surface dimension, (ft)	651
Berm width, (ft)	8
Height above surface, (ff)	6.2
Width of slope, (ft)	18.6
Soil req. for berm, (cuyd)	15906

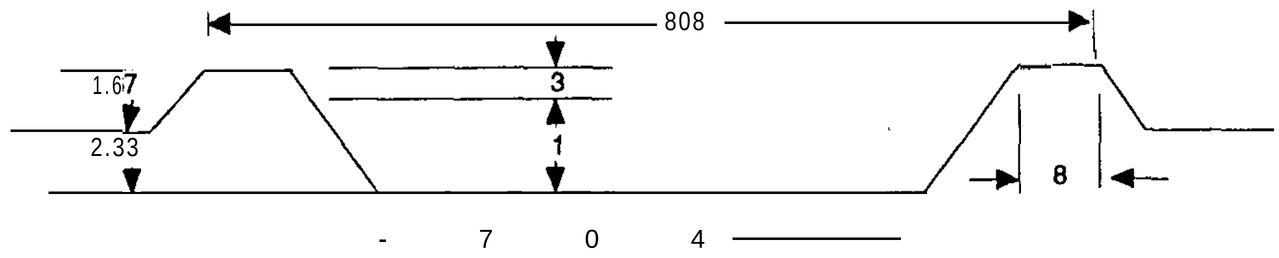
Below Surface Elevation:

Base dimension. (ft)	575
Depfh below grade, (ft)	3.8
Width of slope, (ft)	11.4
Excavation req., (cuyd)	50296

Excess soil available lor Intermediate storage pond, (cuyd) = 34390

Figure E-2. Demonstration Plant Freezing Pad Design and Excavation Requirements

Freezing Pad



Above Surface Elevation:

Surface dimension, (ft)	808
Berm width, (it)	6
Height above surface, (ft)	1.67
Width of slope, (ft)	5.01
Soil req. for berm, (cuyd)	2601

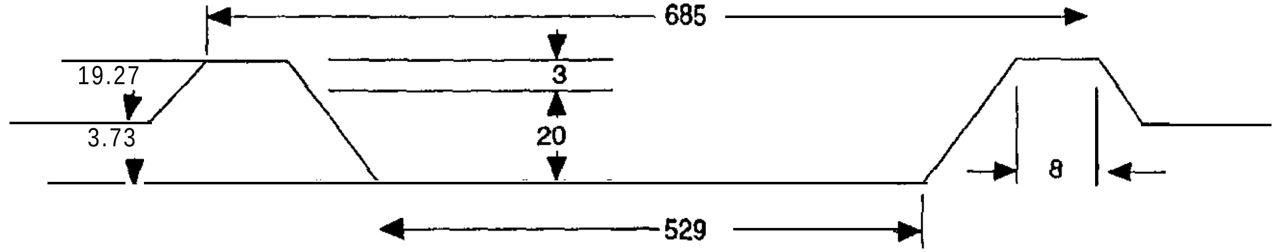
Below Surface Elevation:

Base dimension, (ft)	784
Depth below grade, (It)	2.33
Width of slope, (ft)	6.99
Excavation req., (cuyd)	54951

Excess soil available for Intermediate storage pond, (cuyd) = 52350

Figure E-3. Demonstration Plant Intermediate Storage Pond Design and Excavation Requirements

Intermediate Storage Pond



Above Surface Elevation:

Surface dimension, (ft)	665
Berm width, (fl)	6
Height above surface. (ft)	19.27
Width of slope, (ft)	57.61
Soil req. for berm, (cuyd)	128695

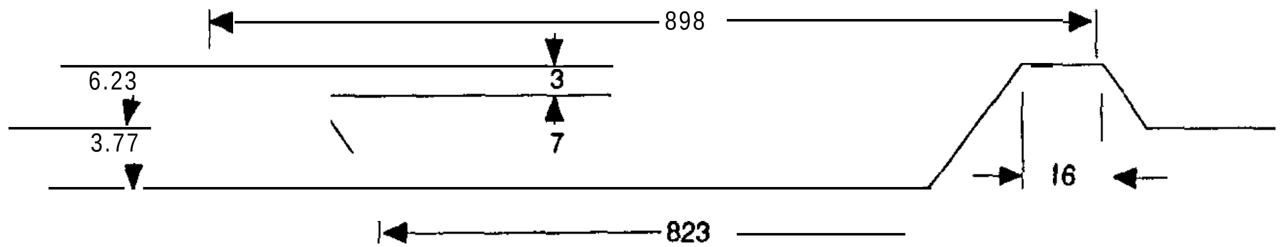
Below Surface Elevation:

Base dimension, (ft)	529
Depth below grade, (ft)	3.73
Width of slope, (ft)	11.19
Excavation req., (cuyd)	42000

Additional soil available from brine evap. pond and freezing pad, (cuyd) = 86695

Figure E-4. Commercial **Plant Brine Evaporation Pond Design and Excavation Requirements**

Brine Evaporation Pond



Above Surface Elevation:

Surface dimension, (ft) 696
Berm width, (ft) 16
Height above surface, (ft) 6.23
Width of slope, (ft) 16.69
Soil req. for berm, (cuyd) 28752

Below Surface Elevation:

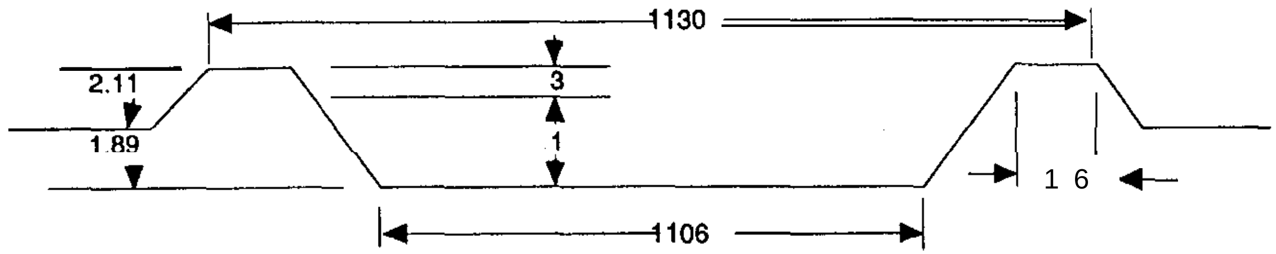
Base dimension, (ft) 623
Depth below grade, (ft) 3.77
Width of slope, (ft) 11.31

Excavation req., (cuyd) 99845

Excess soil available for Intermediate storage pond, (cuyd) = 71094

Figure E-5. Commercial Plant Freezing Pad Design and Excavation Requirements

Freezing Pad



Above Surface Elevation:

Surface dimension, (ft)	1130
Berm width, (ft)	16
Height above surface, (ft)	2.11
Width of slope, (ft)	6.32
Soil req. for berm, (cuyd)	7873

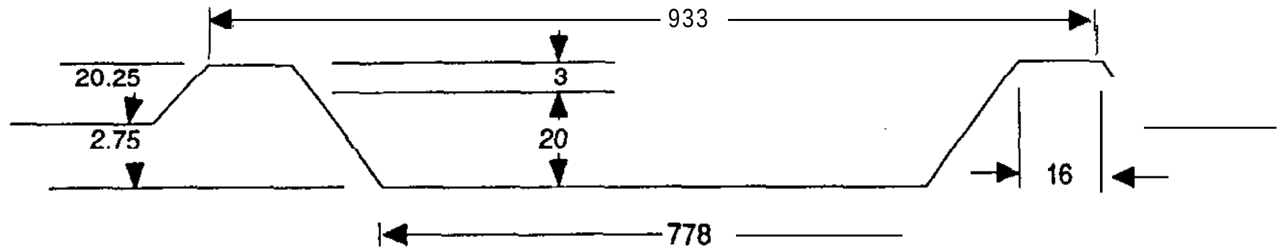
Below Surface Elevation:

Base dimension, (ft)	1106
Depth below grade, (ft)	1.693
Width of slope, (ft)	5.679
Excavation req.. (cuyd)	87533

Excess soil available for Intermediate storage pond, (cuyd) = 79660

Figure E-6. Commercial Plant Intermediate Storage Pond Design and Excavation Requirements

Intermediate Storage Pond



Above Surface Elevation:

Surface dimension, (ft)	933
Berm width, (ff)	16
Height above surface, (ft)	20.25
Width of slope, (ft)	60.76
Soil req. for berm, (cuyd)	214699

Below Surface Elevation:

Base dimension, (ff)	776
Depth below grade, (ff)	2.746
Width of slope, (ff)	6.236
Excavation req., (cuyd)	64195

Additional soil available from brine evap. pond and freezing pad, (cuyd) = 150705