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PILOT STUDY OF GROUND WATER RESOURCE MANAGEMENT IN SWIFT COUNTY, MINNESOTA REPORT TO THE LEGISLATIVE COMMITTEE ON MINNESOTA RESOURCES

MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS

PILOT STUDY OF GROUND WATER RESOURCE MANAGEMENT IN SWIFT COUNTY, MINNESOTA REPORT TO THE LEGISLATIVE COMMITTEE ON MINNESOTA RESOURCES

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ABSTRACT

This report summarizes the results of a study of the ground water resources of Swift County, Minnesota. Based on all available data, ground water supplies in Swift County and vicinity were determined to be adequate for current seasonal needs. Localized water shortages are likely under reasonable scenarios of possible future development. Impacts on the surface water resources of the area are projected. Management options to deal with potential water shortages were developed in cooperation with a Steering Committee of area residents. A key finding of the local Steering Committee was that emphasis needs to be placed on public education about ground water.

Procedures for defining an operational safe yield, expressed as protected levels, in surficial and buried aquifers have been developed. Although technically feasible, costs of actual implementation are prohibitive.

ACKNOWLEDGEMENTS

This study was funded by the Legislative Committee on Minnesota Resources. Cooperating agencies were the U. S. Geological Survey and the Minnesota Department of Natural Resources, the Swift County Steering Committee and the Irrigation Association of Minnesota.

Our apreciation is extended to Jerry Wright, Area Extension Engineer, for his assitance in organizing the Steering Committee.

SUMMARY AND CONCLUSIONS

This study is a pilot project to monitor and manage a critical aquifer system. All available data and techniques were used to determine if ground water supplies in Swift County and vicinity can meet seasonal and long-term needs. Irrigation dominates ground water use, which has increased seven-fold since 1976. Water use trends were examined and future water use projected.

The relationship between water use and supply was examined through the use of a ground water flow model which predicted water level changes due to drought and increased pumping. Ground water withdrawals from the system (1982 conditions) currently reduce evapotranspiration and ground water discharge to the Pomme de Terre and Chippewa rivers, and have lowered regional water levels 1 to 2 feet. Drought conditions and/or increased pumping will cause local water supply problems and streamflow depletion. On a regional basis the water supply is adequate to meet anticipated needs.

Ground water and surface water are closely linked in the Swift County area. In addition, mixing of water occurs between aquifers. Thus contamination or water quality degradation may become a problem in the future. Water quality currently meets drinking water standards except in isolated cases.

Ground water management options are discussed; the legal framework which applies in Minnesota sets safe yield as the management criteria. The use of protected levels as an indicator of safe yield is examined. Many of the more acceptable water use controls (e.g. pumping rotations, water allocations, water conservation programs) are very difficult to administer without local cooperation.

The observation well network is essential to the proper management of the ground water resource. The observation well network must be carefully expanded to efficiently monitor sensitive areas (those stressed by concentrations of wells, those connected to streams, those with water quality problems). Data from the observation well network must be received in a timely fashion. Observation well water levels as compared to the protected and historical levels for the wells should be a matter of public record.

Extensive aquifer studies are prohibitively costly. The results of this study may be used to guide preliminary analysis of other systems with the goal of setting conservative protected levels which will serve to alert the Department to the need for additional study.

GLOSSARY

Aquifer. Aquifers are rock strata or sediments which contain sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquiclude, aquitard, aquifuge. Rock strata or sediments, which although porous and capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for a well or spring. (Replaced by the term confining bed.)

Artesian. Artesian is synonymous with confined.

Buried aquifer. Buried aquifer is synonymous with confined aquifer.

Confined aquifer. An aquifer bounded above and below by confining beds. Ground water in a confined aquifer is under pressure and will rise in a well to a level above the bottom of the confining bed.

Confining bed. A layer of relatively impermeable material stratigraphically adjacent to one or more aquifers.

Drift. Drift is used to refer to all kinds of glacial deposits.

Evapotranspiration. The sum of all water evaporated from soil and water surfaces plus any water transpired by plants.

Gradient. Water moves in response to the force of gravity; rate of movement is proportional to the slope (gradient) of the water table (under confined conditions the gradient is determined by measureing water levels in wells which penetrate the confined zone, the difference is the potential gradient).

Hydraulic conductivity. Permeable rock transmits water under pressure. The hydraulic conductivity is a measure of the rate at which water is transmitted.

Hydrograph. Graphical representation of water levels over time.

Outwash. Glacial drift which has been stratified and sorted by the action of meltwater streams beyond the front of the glacier.

Permeability. The relative ease with which a porous medium can transmit a liquid under a potential gradient.

Porosity. Porosity expresses the volume of pore space in a substance. The pores contain water when the substance is saturated.

Saturated thickness.	That part of the aquifer where the pore spaces are full of water.
Storage coefficient.	The volume of water released from or taken into storage when the head in that aquifer changes. Values of the storage coefficient range from 0.30 to 0.00001.
Surficial aquifer.	The saturated layer between the water table and the first lower confining bed. The surficial aquifer is an unconfined aquifer.
Till.	Unstratified and unsorted glacial drift.
Transmissivity.	The rate at which water is transmitted through a width of aquifer under a gradient. The transmissivity is equal to the hydraulic conductivity of the aquifer times the saturated thickness of the aquifer.
Unconfined aquifer.	An aquifer that has a water table; this aquifer is between the water table and the first lower confining bed.
Water table.	The water table is the top of the saturated part of the soil or rock strata. Wells that penetrate the saturated zone just far enough to hold standing water are water table wells.

INTRODUCTION

The Swift County study was initiated as a pilot project to monitor and manage a critical aquifer system. The regulatory permits program of the Department of Natural Resources will become more effective and efficient if it can move from site-specific permit decisions to coordinated management of the aquifer system on a regional basis. A multifaceted effort was begun in 1983 to utilize all available data and techniques to determine if ground water supplies in Swift County and vicinity are adequate to meet seasonal and long-term needs. Ground water use in Swift County increased dramatically after the 1976-77 drought. Most of this increased ground water withdrawal is for agricultural irrigation. In 1984 Swift County had 197 permitted irrigators; prior to 1976 there had been only 38.

Results from two economic studies (Maki, *et al.*, 1978; Maxwell and Dorf, 1982) have documented the importance to Swift County of irrigation and agriculture in general. For each dollar of irrigated crop revenue, $2.20 were added to revenues in the community. For each irrigated acre in Swift county $309 are added to the economy; dryland acres contribute only $115. The future of irrigation depends on a reliable water supply.

A three-dimensional ground water flow model was developed by the U.S. Geological Survey. After calibration, this model predicted the effects of realistic future changes in ground water use. In cooperation with local interests, ground water management options were developed and implementation strategies suggested. One of the study objectives was to develop an operational definition of *safe yield* which could be used in managing the ground water resources of the State and applied in Swift County. The statutory definition implies an "operating definition" rather than a technical definition of *safe yield*, and implies that protected levels for an aquifer system could be set.

PURPOSE AND GOALS

The purpose of this report is to summarize the results of a study of the ground water resources of Swift County, Minnesota. The major objective is to plan for future management of ground water within the capability of the aquifer or aquifer system. Local participation in such resource management issues is encouraged in Minnesota; the mechanism for the creation of water appropriation and use management plans, which can be administered locally, is contained in Minnesota's Public Water Resources Rules 6115.0810. A local Steering Committee participated in this study.

Specfic study goals included:

1. quantify current water use.

2. quantify expected future development.

3. identify the type and extent of any potential water supply problems.

4. develop a plan for dealing with any water shortages in cooperation with the Steering Committee of area residents.

5. encourage the efficient use of water; disseminate information about the use of newer techniques and efficient equipment.

6. evaluate water quality in Swift County and assess the suitability of this water for various uses.

PREVIOUS INVESTIGATIONS

The current work is an extension of previous investigations in Swift County which include reconnaissance investigations (Bulletin 10 of the Division of Waters, 1959; Fax and Beissel, 1980); Hydrologic Atlases 213, 220, and 286; and U.S. Geological Survey studies (Larson, 1976; Soukoup, Gillies, and Myette, 1984).

LOCATION AND DESCRIPTION OF STUDY AREA

Swift County is in west-central Minnesota (Figure 1). The area of the county is 478,720 acres. The northeastern corner of the county is highest in elevation (maximum 1150 feet above mean sea level) and is steep and hilly. The topography of the rest of the county is generally flat and undulating. The confluence of the Minnesota and Pomme de Terre rivers has the lowest elevation in the county at 1075 feet (above mean sea level). Three fourths of the county drain to the Chippewa River, and, except for the extreme southwest corner, which drains to Big Stone Lake, the remainder is drained by the Pomme de Terre River (Fax and Beissel, 1980).

Glacial deposits of Quaternary age form the present land surface in Swift County. Till and outwash thicknesses range from 100 to 400 feet. These deposits overlie Cretaceous shales and sandstones and Precambrian basement rock (Cotter and Bidwell, 1966).

Glacial ice advances deposited tills; its melting formed meltwater streams which reworked and redeposited the glacial materials. The present day Pomme de Terre and Chippewa rivers occupy glacial drainageways which accumulated thick sand and gravel deposits, some of which are buried by till of subsequent glacial advances. Glacial Lake Benson existed for a time when drainage from part of Swift county was blocked. Alluvial fans were deposited by streams entering the lake, and finer materials were deposited on the lake bed (Wright, 1972).

WATER AVAILABILITY, QUALITY, AND SUITABILITY

Water availability in Swift County and vicinity is related primariliy to the distribution of aquifers in the glacial drift. The drift is underlain by older rock (Precambrain and Cretaceous Age), but these rocks are not significant sources of water (Delin, 1985b).

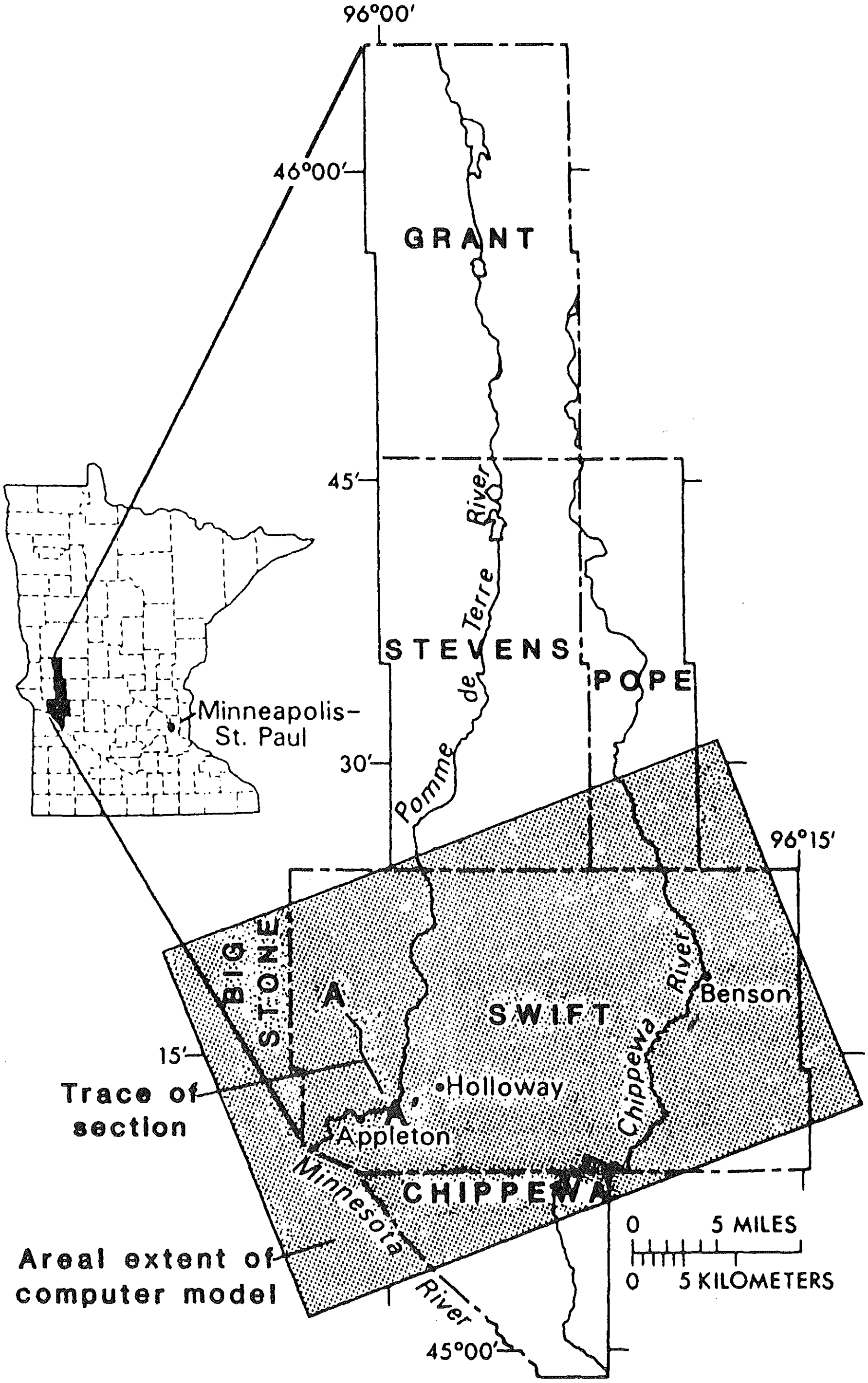

Figure 1: Location of study area, trace of section, and extent of computer model. From: Delin, G. 1985. Evaluation of availability of water from drift aquifers and effects of future development near the Pomme de Terre and Chippewa Rivers, western Minnesota. U. S. Geological Survey Water Resources Investigation Report in press.

The surficial aquifer consists of fine to medium sand and gravel deposited in a broad shallow basin. Thicknesses of the deposits range from zero at the boundaries to approximately 90 feet. The average saturated thickness is about 25 feet (Soukup, Gillies and Myette, 1984). Aquifer tests and analysis of samples from test holes were used to estimate transmissivities and storage coefficients. Transmissivities range from 9,600 ft/day to 25000 ft/day; storage coefficients range from 0.15 to 0.20.

Confined drift aquifers in the study area have been mapped and characterized. The major confined aquifers have been named for convenience. The aquifer names are derived from the relative positions of the aquifers and the proximity to larger towns. These aquifers have been described in detail by Delin (1985a); a condensed table of aquifer characteristics is presented here (Table 1).

Figure 2 is an example of the degree of continuity possible between surficial and confined aquifers in this area. The interconnections are significant because: 1) pumping from one aquifer may affect water levels in wells completed in another aquifer which is hydraulically connected to the pumped aquifer; 2) pumping of aquifers connected to the surficial sands may affect streamflow by reducing ground water flow to the rivers; and 3) contamination and lower quality water can move from one aquifer into another.

Ground water quality in the surficial and confined aquifers has been assessed in two U. S. Geological Survey studies (Soukup, Gillies, and Myette, 1984; Delin, 1985a). Several wells in Swift County are included in the ongoing ambient water quality network of the Minnesota Pollution Control Agency. Table 2 is a comparison of water quality data for confined and unconfined aquifers in the study area (Delin, 1985a).

The results, as reported by Delin (1985a), show that ground water in the study area is hard to very hard, generally suitable for domestic use, irrigation and most other uses. Concentrations of sulfate, iron, total dissolved solids, nitrate, and manganese locally exceed the Minnesota Pollution Control Agency's (MPCA) recommendations for domestic consumption; boron and specific conductance locally exceed recommended maximum levels for agricultural and wildlife use. Water quality in the confined and unconfined aquifers were very similar, indicating that mixing between the aquifers is probable (Delin, 1985a).

WATER USE TRENDS

Water use in Swift County was divided into five categories: irrigation; livestock watering; public and private; commercial and industrial; and rural domestic use. The amount of water consumed by users in each of these categories was quantified as follows:

Irrigation

Appropriation permits are required for agricultural irrigation; permit holders are required to report the amount of water used on an annual basis.

Table 1: Hydrologic characteristics of several confined aquifers supplying water for irrigation near the Pomme de Terre and Chippewa Rivers, western Minnesota.*

Aqufier name	Approx. areal extent (square miles)	Avg. depth below surface (feet)	Avg. thick-ness (feet)	Range of reported well discharges (gal/min)	Range of transmissivities (square feet/day)	Range in water level below land surface (feet)
Appleton	219	92	60	5 - 1500	1400 - 14000	0 - 65
Benson-middle	520	135	30	10 - 1600	1000 - 8000	0 - 80
Benson-upper	90	73	16	10 - 700	1000 - 5000	6 - 95
Erdahl	125	79	20	10 - 1140	1500 - 6000	6 - 98
Morris	435	80	16	8 - 1300	1800 - 10000	14 - 115

* Table excerpted from Delin, G., 1985. Hydrogeology of confined-drift aquifers near the Pomme de Terre and Chippewa Rivers, western Minnesota. U. S. Geological Survey, Water Resources Investigation in press.

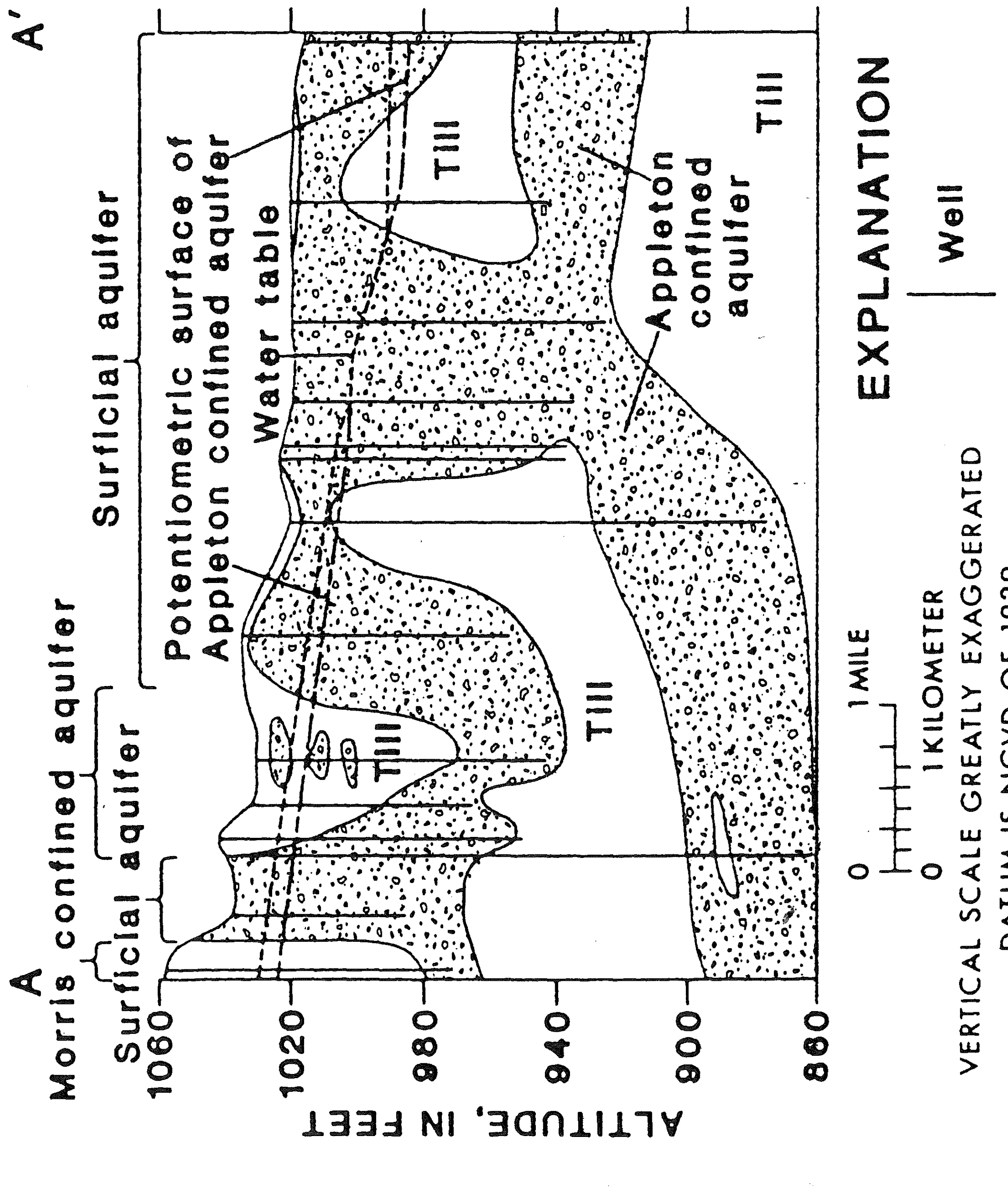

Figure 2: Hydrogeologic section A-A' north of Appleton showing interconnection of confined and unconfined drift aquifers. From Delin, G. 1985. Evaluation of availability of water from drift aquifers and effects of future development near the Pomme de Terre and Chippewa Rivers, western Minnesota. U. S. Geological Survey Water Resources Investigation Report in press.

Table 2: Comparison of water quality in confined and surficial aquifers near the Pomme de Terre and Chippewa Rivers, western Minnesota.

Chemical Constituent	Confined Aquifers				Surficial Aquifers			
	Number of analyses	Median	Range	Standard deviation	Number of analyses	Median	Range	Standard deviation
Specific conductance lab (umhos)	11	1,010	580-2,250	506	6	819	649-1,030	142
pH (standard units)	28	7.6	6.8-8.3	0.4	19	7.5	7.2-8.2	0.2
Temperature (Degrees C)	16	9.9	8.3-13	1.5	17	9.0	7.8-10	0.8
Hardness (mg/L as $CaCO_3$)	29	590	120-1,400	288	21	380	290-800	129
Hardness noncarbonate (mg/L as Ca)	29	304	0-1,030	296	13	119	78-351	89
Calcium, dissolved 8 (mg/L as Ca)	29	132	24-360	73	19	100	53-180	32
Magnesium, dissolved (mg/L as Mg)	29	57	14-137	29.5	18	36.5	25-64	11
Sodium, dissolved (mg/L as Na)	20	38.5	8.5-141	40.7	20	12.5	2.3-40	9

Table 2 cont.: Comparison of water quality in confined and surficial aquifers near the Pomme de Terre and Chippewa Rivers, western Minnesota.

Chemical Constituent	Confined Aquifers				Surficial Aquifers			
	Number of analyses	Median	Range	Standard deviation	Number of analyses	Median	Range	Standard deviation
Potassium, dissolved (mg/L as K)	20	5.2	2.7-9.6	2.1	20	3.9	1.7-6.6	1.2
Alkalinity lab (mg/L as $CaCO_3$)	11	329	214-469	79	6	255	250-310	80
Sulfate, dissolved (mg/L as SO_4)	29	270	1-1,080	320	21	150	37-374	80
Chloride, dissolved (mg/L as Cl)	29	4.0	1.4-80	14.3	17	5.7	0.5-46	14.8
Fluoride, dissolved (mg/L as Fl)	18	0.2	0.2-0.6	0.1	21	0.2	0.1-0.3	0.1
Silica, dissolved (mg/L as SiO_2)	18	27	12-33	5.5	18	26.5	23-29	1.5
Solids, residue at 180 C dissolved (mg/L)	29	770	388-1,960	467	15	510	366-970	142
Solids, sum of constituents, dissolved (mg/L)	17	700	380-1,800	468	13	520	340-880	146

Table 2 cont.: Comparison of water quality in confined and surficial aquifers near the Pomme de Terre and Chippewa Rivers, western Minnesota.*

Chemical Constituent	Confined Aquifers				Surficial Aquifers			
	Number of analyses	Median	Range	Standard deviation	Number of analyses	Median	Range	Standard deviation
Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	11	0.1	0.1-1	0.3	17	0.5	0.0-20	6
Phosphorus, ortho, dissolved (mg/L as P)	11	0.02	0.01-0.08	0.03	17	0.02	0.00-0.05	0.01
Boron, dissolved (ug/L as B)	18	210	0.2-1,600	407	18	105	0.2-240	59.8
Iron, dissolved (ug/L as Fe)	19	1,800	70-11,000	2,577	21	1,100	10-6,400	1,893
Manganese, dissolved (ug/L as Mn)	20	175	0-720	161	21	250	10-580	165
Carbon, organic total (mg/L as C)	11	3.1	2.3-7	1.4	--	--	--	--

* Delin, G., 1985. Hydrology of confined drift aquifers near the Pomme de Terre and Chippewa Rivers, western Minnesota. U. S. Geological Survey Water-Resources Investigation Report in press.

Pumping reports from Swift County were compiled. Missing pumping reports were estimated based on past reports, but where a pumping report had never been filed under a permit, that permit was not considered active.

Livestock Watering

Numbers of poultry, sheep, cattle, pigs and other farm animals were obtained from the Minnesota Department of Agriculture census. An appropriate water use multiplier (gallons per animal per day) was applied to determine total water use.

Public and other supply: small town residential

A per capita water use multiplier of 80 gallons per person per day was applied to the number of people who received their water from each public water supply or private well.

Commercial and Industrial

An informal survey was undertaken to determine how many commercial and industrial users existed in the county. There are currently no food processing plants, no dairies, no meat packers, nor any other high water use industries in Swift County. It was decided to consider total reported pumpage from public water supplies, less per capita water use, equal to commercial and industrial water use. Because there is no accounting of water leaks, this category contains the residual error and is overestimated.

Rural Domestic

A population figure for the rural population of Swift County was determined by subtracting the number of people who receive their water from public supplies from the county's total population. A multiplier of 80 gallons per person per day was applied.

The results of this analysis are presented in Figures 3 and 4. It is apparent that, while the use of water for domestic, commercial and industrial, and livestock watering has remained constant, irrigation has grown from an insignificant water use to overwhelmingdominance. Irrigated agriculture presently accounts for more than 80 percent of all ground water used in Swift County.

This rapid growth represents substantial investment and potential economic return to the population of Swift County and the State of Minnesota as a whole. The importance of ground water to the state of Minnesota is indicated by the statistics depicted in Figure 5. However, both actual water use and the rate of growth of irrigated agriculture have slowed due to the return of adequate precipitation in the 1980's and the weakening of the agricultural economy. This

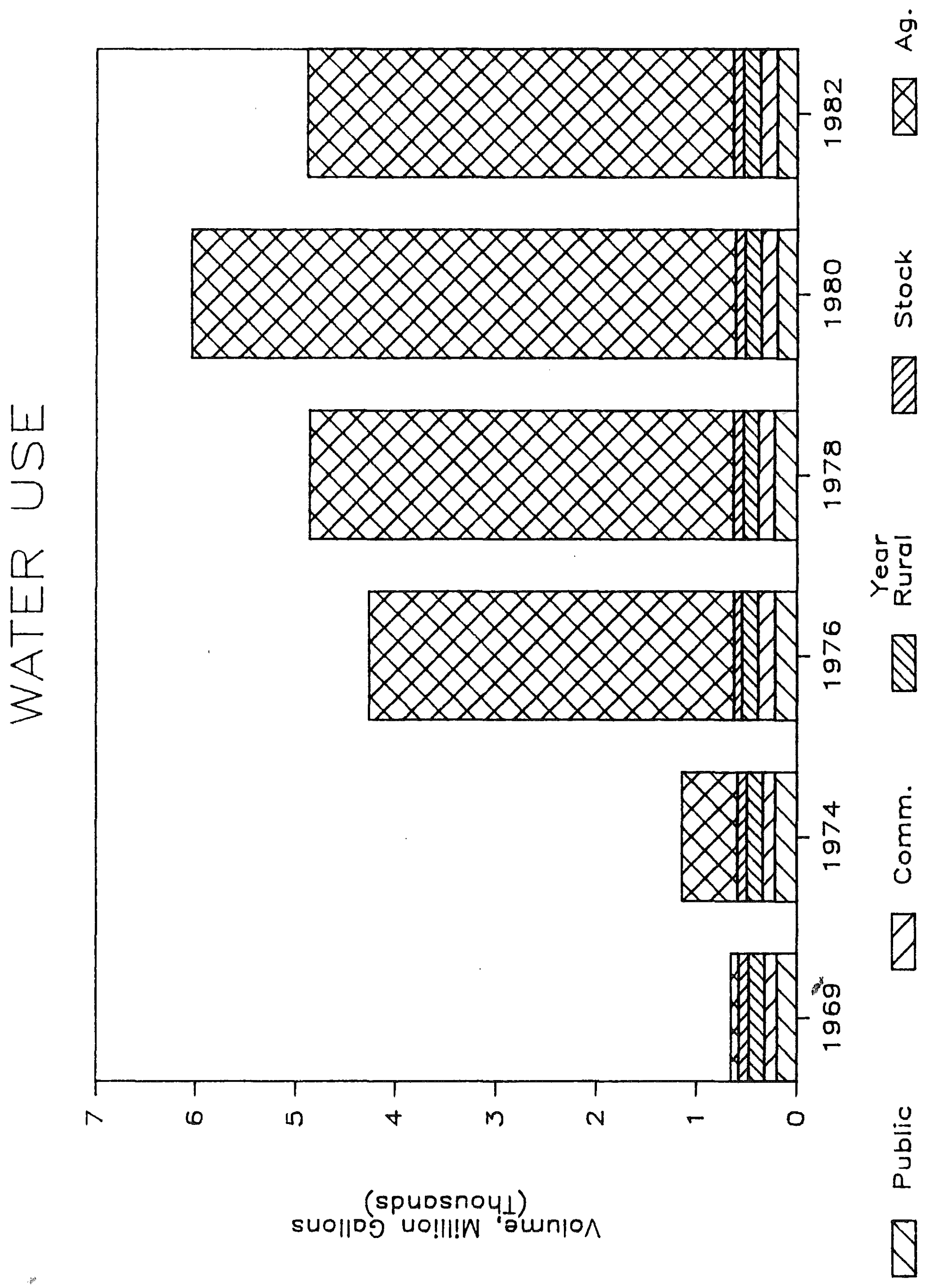

Figure 3: Historical Water Use in Swift County by Category (Volumes)

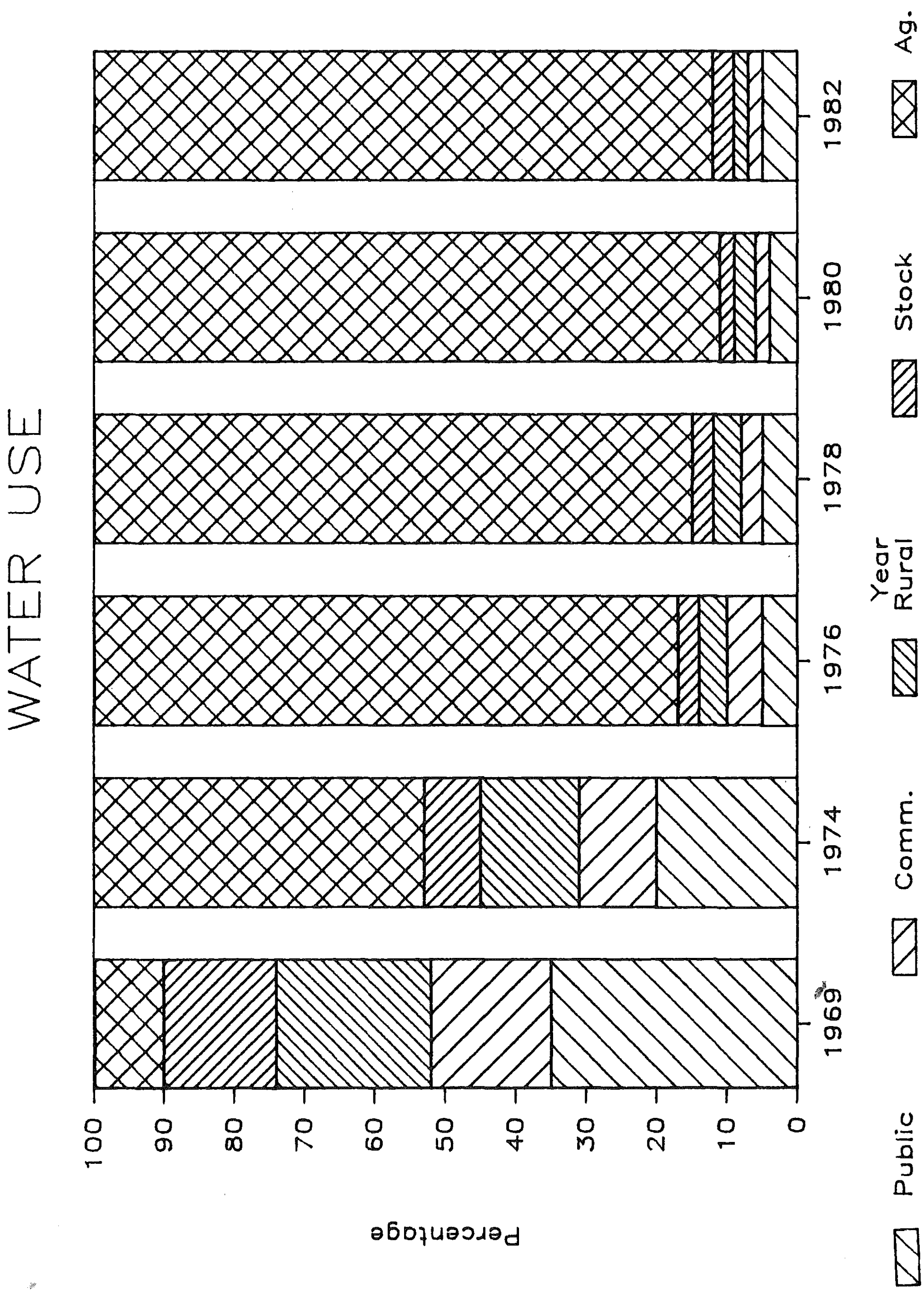

Figure 4: Historical Water Use in Swift County by Category (Percentage of Total)

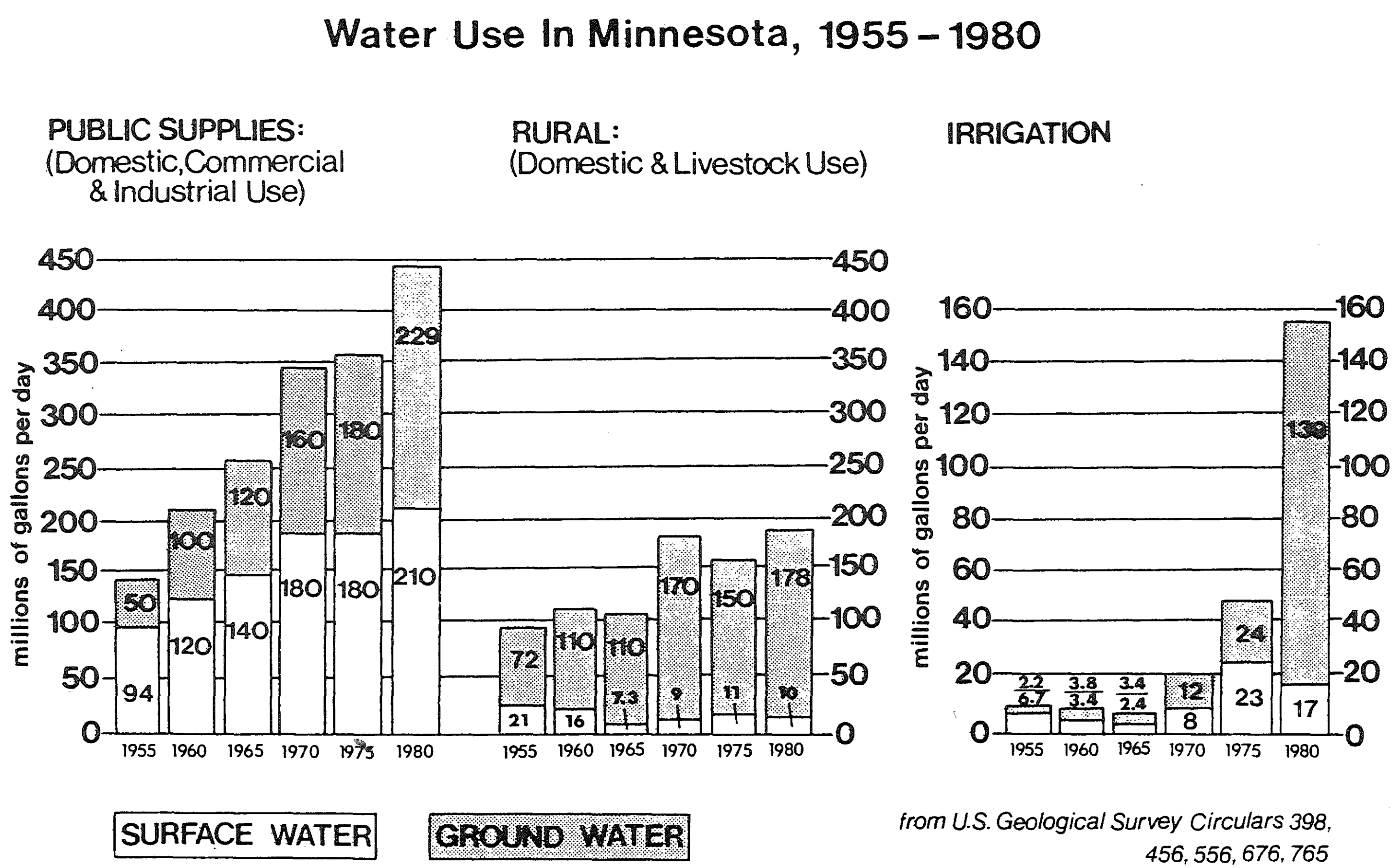

Figure 5: Changes in the use of surface and ground water supplies in Minnesota.

An extension into the future of the growth shown in Figures 3 and 4 would predict alarming increases in water use. It is necessary to evaluate the probability of such future growth; and to make resonable predictions of growth of irrigated agriculture and future impacts on water use.

PROJECTION OF FUTURE WATER USE

Each of the water use categories discussed above was examined to determine the potential for future growth. The results of the study "Economic Impact of Irrigated Agriculture in West Minnesota" (Maki, *et al.*, 1978), Department of Agriculture census data and projections, soil survey maps, and hydrogeologic information were combined to arrive at reasonable estimates of future growth and thus future water use.

Table 3: Population of Swift County Minnesota [1]

Year	Population
1950	15837
1960	14936
1970	13177
1975	13336
1980	12920
1981	12918
1982	12812
1983	12776
1985*	12839
1990*	12792
1995*	12768
2000*	12652

*projected

[1]Estimates for 1950, 1960, 1970, and 1980 from U. S. Census of Population. Estimates for 1981, 1982, and 1983 and projected population series from: Office of State Demographer, State Planning Agency.

Population data for Swift County, both past and projected, are contained in Table 3. Projected numbers are estimates which consider migration, births and deaths. From this information it is evident that the population of Swift County has remained, and is projected to remain, relatively stable. It was concluded that water use in the rural domestic and public and private categories would remain constant.

Livestock numbers and production of livestock products are expected to increase due to the development of irrigation because of the increase in corn and other feed grain production (Maki, *et al.*, 1978). The determination of future water use in this category is thus linked to changes in irrigated agriculture and must be adjusted accordingly.

The commercial and industrial base of Swift County is linked to the agricultural economy of the area. The past history of the area suggests that the establishment of major new industry in the area is unlikely. There is the possibility that agriculture- related industry could move into the area, but the effect on water use is not quantifiable. However, it is logical to assume that any increases would be related to a strengthening of the agricultural economy.

Expected future development of the ground water resource is thus predominately dependent on future changes in irrigated agriculture. The problem of quantifying potential increases was approached by locating unirrigated land which could benefit from irrigation. Maps of the known extent of the buried aquifers were compared with maps of existing irrigation and irrigable soils. In this manner, the temporary delaying effect of economic difficulties has been factored out.

It was determined that most of the potential for development in Swift County had been realized by 1982. The maximum number of new irrigation systems (160 acres each) projected is as follows:

Appleton confined aquifer	30
surficial and Morris-confined aquifers	15
Benson middle confined aquifer	20

In 1983 only 150 additional acres were added to the acreage under irrigation. These conclusions were discussed with the Steering Committee, where there was general agreement that development had likely stabilized.

In addition, it is necessary to consider the effects of more efficient water use on total future water use in the county. Members of the Steering Committee expressed knowledge of irrigation techniques which reduce the quantity of water needed for a given crop yield. These techniques involve correct timing of irrigation, irrigation based on soil moisture content and the use of more efficient equipment. Rising energy costs rather than potential water shortages are providing the incentive for water conservation. It is possible that water use could thus remain stable in spite of slow growth in the actual number of acres irrigated.

MODELING RESULTS: INTERRELATIONSHIP BETWEEN WATER SUPPLY AND USE

The relationship between water supply and use was evaluated in two ways: changes in observation well water levels were compared to reported pumping of neighboring wells and precipitation; and a computer model of regional ground water flow was used to simulate the response of water levels to current pumping and hypothetical future development.

Hydrographs of observation well water levels were plotted and analyzed to determine seasonal recharge to the aquifer. Areal recharge as determined by this method ranged from 2.63 to 7.49 inches. Hydrographs of wells nearest the rivers were observed to be affected by additional recharge from the rivers. Areal recharge as determined by Delin (1985b) averaged 6 inches. Hydrographs from observation wells in the study area show deep troughs during the summer irrigation season, when water level declines as great as 30 feet have been observed. Hydrographs can only give information about one point in the aquifer system; to understand the response of the system over the region, it was necessary to create a computer model.

A three-dimensional ground water flow model was developed by the U. S. Geological Survey. A technical report of the results of the modeling effort is found in G. Delin's 1985 paper (Delin, 1985b). Figure 1 shows the areal extent of the model.

Many simplifying assumptions are necessary to construct a ground water flow model. The nature of this simplification is shown in Figure 6. Three layers were used to simulate the vertical relationships of the aquifers. Table 4 presents the major assumptions used in model construction. The model was calibrated using actual field measurements and included pumping (1982 volumes) as reported or estimated.

To approximate the effect current ground water withdrawals are having on water levels, a simulation of the steady state model without pumping was run. An apparent rise in water levels (recovery of the water levels from the stress caused by pumping through 1982) was observed. Current pumping has lowered water levels 1 to 2 feet in all aquifers and as much as 13 feet near Benson. The lowering of the water table has reduced losses to evapotranspiration, reducing the net loss to the ground water system (Delin, 1985b). The model thus delineates the area where pumping in the past has had the greatest impact.

The next step in calibration involved attempts to duplicate the aquifer's response to changing stresses. A comparison of observed water level hydrographs and model predictions of hydrographs revealed that the model was not duplicating the deep hydrograph troughs seen during summer pumping. This problem was partially resolved by simulating all pumping during one month instead of over three months (Delin, 1985b). The model could then adequately represent the regional effects of stress on the aquifer.

Based on water use and water use projections as discussed above, modeling of hypothetical development plans was carried out. These plans and the

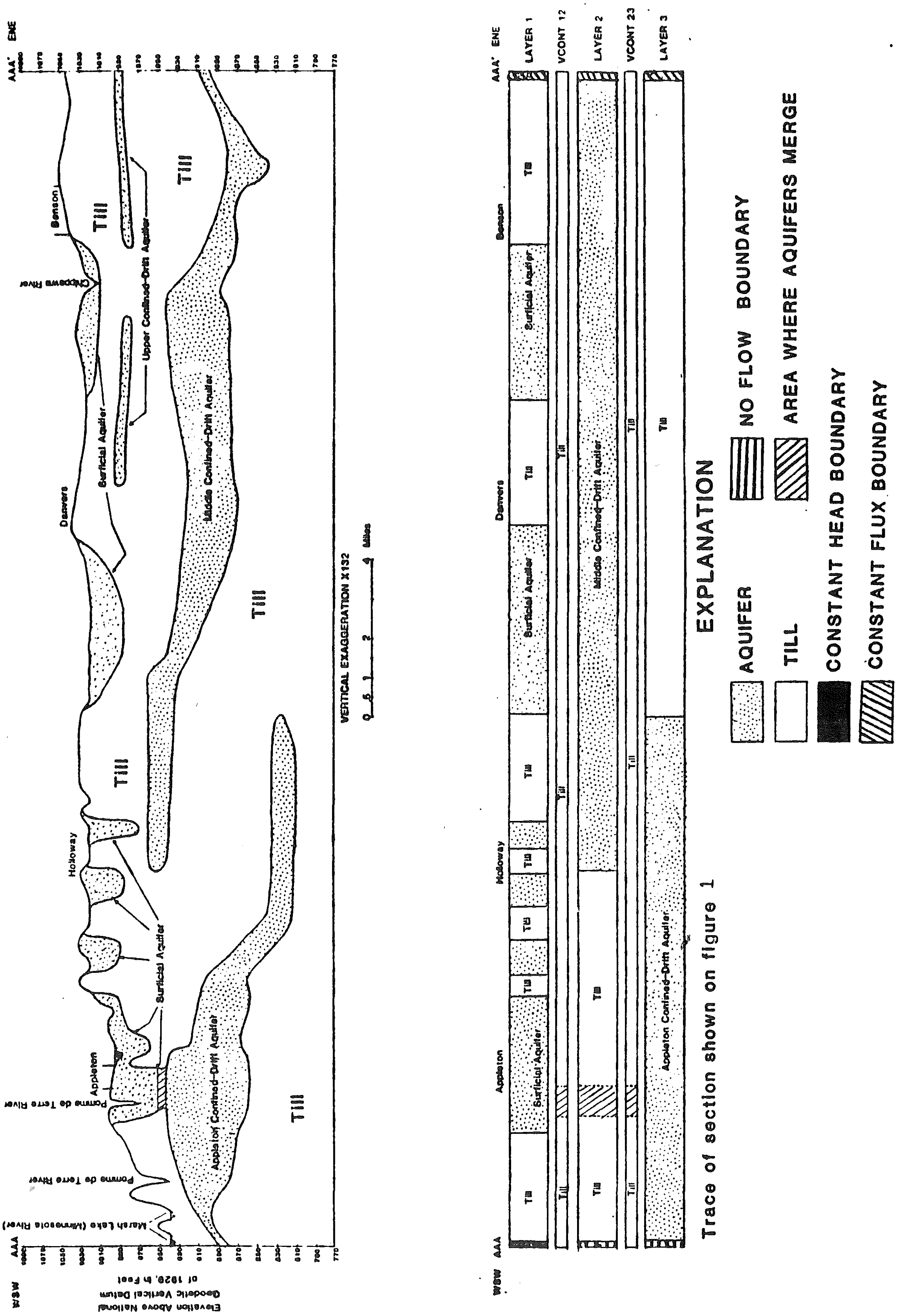

Figure 6: Hydrologic section showing drift lithology and representative layering scheme for the steady-state model. From: Delin, G. 1985. Evaluation of availability of water from drift aquifers and effects of future development near the Pomme de Terre and Chippewa Rivers, western Minnesota. U. S. Geological Survey Water Resources Investigation Report in press.

Table 4: Major elements of the model constructed by Delin (1985b)*

1	Ground water flow in the drift aquifers is primarily horizontal and flow in the till confining units separating them is primarily vertical.
2	The aquifers and confining units simulated are continuous, homogeneous, and isotropic.
3	The ratio of vertical to horizontal conductivity of the aquifers and confining units is 1 to 1.
4	Ground water flows regionally to the Minnesota River.
5	The Minnesota River stage does not fluctuate significantly in time and, therefore, can be simulated as a constant-head boundary.
6	Streambeds are 1 foot thick and composed of permeable material of lower hydraulic conductivity than the aquifer.
7	Minor streams and ditches are insignificant discharge points for the ground water system and can be ignored.
8	Areal recharge to the water table is from precipitation and occurs primarily in April - June and secondarily October - December.
9	Vertical leakage through till, where the surficial aquifer is absent, is at steady state and equals areal recharge.
10	The rate of evapotranspiration declines linearly to zero at a depth of 5 feet below land surface.
11	Ground water used for irrigation is consumed by evapotranspiration and return flow to the aquifer is negligible.

* From: Delin, G. 1985. Evaluation of availability of water from drift aquifers and effects of future development near the Pomme de Terre and Chippewa Rivers, western Minnesota. U. S. Geological Survey Water Resources Investigation Report in press.

modeling results are outlined in Table 5. Drought conditions were simulated by reducing average areal recharge by a factor of 30 percent and increasing pumping (over 1982 volumes) by 50 percent. New wells were added to the system in areas where additional irrigation would be feasible and economical; the wells were assumed to pump from the aquifer which could supply the water needed.

The ground water flow model revealed that essentially all (97%) of the available ground water is from precipitation over the area. Ground water leaves the area as evapotranspiration (36%), discharge into the rivers (46%), and pumping (17%; 1982 pumping assumed. Pumping reduces both evapotranspiration and ground water discharge to the rivers. During a drought the model predicts that discharge to the Pomme de Terre and Chippewa Rivers will be reduced by approximately 15 and 7 cfs, respectively. If maximum reasonable development occurs, ground water discharge to the river will be reduced by about 22 and 8 cfs, respectively (Delin, 1985b).

Ground water flow between the aquifers, as determined by the model, is considerable. Flows between aquifers range from 2 cfs between the surficial and Appleton confined aquifers (near Appleton the two merge) to 8 cfs from the surficial aquifer to the middle confined aquifer.

Parts of the surficial aquifer will be dewatered under drought conditions with maximum hypothetical development. Water levels would decline 2 to 6 feet regionally and as much as 13 feet in the area near Appleton where the surficial and Appleton confined aquifers merge. Water level declines estimated by the model represent an average over the block of land represented by an individual node. Actual water level declines will be different, and declines near pumped wells will be much greater.

GROUND WATER MANAGEMENT OPTIONS

Ground water management in Minnesota must conform to Minnesota Statutes (MS) and the Minnesota Public Water Resources Rules for the Appropriation and Use of Water (Rules). Minnesota is considered to be one of the most progressive states in the nation in terms of ground water management and protection (Steeler and Morandi, 1983).

Legal Framework

Users of ground water (users of small quantities and domestic use for less than 25 people are exempt) must obtain a permit before withdrawing water. The approval of an appropriation permit is subject to limits set up to safeguard aquifers and protect surface water supplies. As stated in the Public Water Resources Rules for the Appropriation and Use of Water (Rules) 6115.0670:

> 'C (1). The amounts and timing of water appropriated shall be limited to the *safe yield* of the aquifer to the maximum extent feasible and practical.'

Table 5.--Summary of the results of transient modeling, including hypothetical development.*

Experiment	Conditions of simulation	Model results: Layer 1	Layer 2	Layer 3
A	Predevelopment: 1982 pumping removed to determine effects of historical pumpage Average areal recharge	Water levels have declined 2 and 1 ft regionally in the Appleton and Benson areas, respectively, and as much as 4 ft near Appleton; ground-water discharge to rivers has decreased 18 percent since predevelopment.	Water levels have declined 1 ft regionally and as much as 13 ft locally in the Benson city wells.	Water levels have declined 2 ft regionally and as much as 4 ft north of Appleton and near Holloway.
B	Present well development (206 wells) Pumping stress: actual (1982) x 1.5 Drought: 30 percent less recharge	Water levels decline 4 and 2 ft regionally in the Appleton and Benson areas, respectively, and as much as 10 ft in some areas; ground-water discharge to rivers is 49 percent less than steady state; Pomme de Terre River discharge is reduced by 15.2 ft^3/sec.	Water levels decline 3 to 4 ft regionally and as much as 11 ft east of Benson and northwest of Lake Oliver.	Water levels decline 3 to 6 ft regionally and as much as 11 ft north of Appleton.

* From: Delin, G. 1985. Evaluation of availability of water from drift aquifers and effects of future development near the Pomme de Terre and Chippewa Rivers, western Minnesota. U. S. Geological Survey Water Resources Investigation Report in press.

Table 5 cont.--Summary of the results of transient modeling, including hypothetical development.*

Experiment	Conditions of simulation	Model results: Layer 1	Layer 2	Layer 3
C	Present + hypothetical well development: 14 in layer 1[a] 16 in layer 2[b] 28 in layer 3[c] (264 wells) Pumping stress: actual + estimated Average areal recharge	Water levels decline 1 and 0.5 ft regionally and as much as 5 and 1 ft locally in the Appleton and Benson areas, respectively; ground-water discharge to rivers is 13 percent less than for steady state.	Water levels decline 0.5 ft regionally and as much as 1 ft locally near Benson. Declines of as much as 2 ft occur near Holloway as a result of hypothetical pumping in layer 3.	Water levels decline 1 to 3 ft regionally ans as much as 5 ft in some areas.
D	Present + hypothetical well development: 14 in layer 1[a] 16 in later 2[b] 28 in layer 3[c] Pumping stress: (actual + estnated) x 1.5 Drought: 30 percent less recharge	Water levels decline 3 to 5 ft regionally and as much as 11 ft east of Benson and northwest of Lake Oliver.	Water levels decline 5 to 9 ft regionally ans as much as 13 ft southeast of Appleton.	

* From: Delin, G. 1985. Evaluation of availability of water from drift aquifers and effects of future development near the Pomme de Terre and Chippewa Rivers, western Minnesota. U. S. Geological Survey Water Resources Investigation Report in press.

> 'C (2). If the commissioner determines, based on substantial evidence, that a direct relationship of ground and surface waters exists such that there would be adverse impact on the surface waters through reduction of flows or levels below protected flows or protection elevations the amount and timing of the proposed appropriation from ground water shall be limited.'

> 'C (3). Appropriation of ground water shall not be approved or shall be issued on a conditional basis in those instances where sufficient hydrologic data are not available to allow the commissioner to adequately determine the effects of the proposed appropriation. If a conditional appropriation is allowed, the commissioner shall make further approval, modification, or denial when sufficient hydrologic data are available.

Definitions for *safe yield* are provided in the Rules (6115.0630):

> 'Subp. 15 *Safe yield for water table condition* means the amount of ground water that can be withdrawn from an aquifer system without degrading the quality of water in the aquifer and without allowing the long term average withdrawal to exceed the available long term average recharge to the aquifer system based on representative climatic conditions.'

> 'Subp. 16 *Safe yield for artesian condition* means the amount of ground water that can be withdrawn from an aquifer system without degrading the quality of water in the aquifer and without the progressive decline in water pressures and levels to a degree which will result in a change from artesian condition to water table condition.'

These definitions imply that a protected level may be determined for an aquifer which will act as an indicator for the *safe yield*. Aquifers are assumed to have certain idealized characteristics and are assumed to fall into one of two distinct categories, either artesian (confined) or water table (unconfined). Methods of estimating the protected level for a given aquifer system must be outlined and decisions must be made about the action to be taken when it is anticipated that withdrawals will soon cause water levels to drop below the protected level. The application of these principles must be regional in nature and is limited by existing hydrologic data.

Water Use Conflict

Minnesota's Public Water Resources Rules for the Appropriation and Use of Water define water use conflicts (Rules 6115.0740):

Subpart 1. 'For the purpose of these rules a conflict occurs where the available supply of waters of the state in a given area is limited to the extent that there are competing demands among existing and proposed users which exceed the reasonably available water. Existing and proposed appropriations could in this situation endanger the supply of waters of the state so that the public health, safety and welfare would be impaired.'

The evaluation of a conflict includes analyzing the following (Rules 6115.0740 Subpart 2):

'B(1). the reasonableness for use of water by the proposed and existing users;'

'B(2). the water use practices by the proposed and existing users to determine if the proposed and existing users are or would be using water in the most efficient manner in order to reduce the amount of water required.'

'B(3). the possible alternative sources of water supply available to determine if there are feasible and practical means to provide water to satisfy the reasonable needs of proposed and existing users.'

Priority System

If the conflict cannot be resolved by modifying the appropriations of the proposed and existing users, permits will be modified, issued or terminated on the basis of priorities (MS 105.41, Subd. 1a) established by the legislature:

'First priority. Domestic water supply, excluding industrial and commercial uses of municipal water supply.'

'Second priority. Any use of water that involves consumption of less than 10,000 gallons of water per day. For purposes of this section "consumption" shall mean water withdrawn from a supply which is lost for immediate further use in the area.'

'Third priority. Agricultural irrigation, involving consumption in excess of 10,000 gallons per day, and processing of agricultural products.'

'Fourth priority. Power production, involving consumption in excess of 10,000 gallons per day.'

'Fifth priority. Other uses, involving consumption in excess of 10,000 gallons per day.'

Within priority groups, users shall be treated as equals. The requirements of higher priority users are satisfied first. If any water remains, it is apportioned to users within the lower priority group.

Well Interference

The priority system provides varying degrees of protection from interference to domestic well users and the domestic use portion of public water supplies; interference (as distinguished from water use conflict) is related directly to well construction, proximity to other user, or lack of reasonable capture rather than to overuse of the water resource. Well interference problems are investigated and mediated by the Department accori'ding to Rules 6115.0730.

Ground Water Management in Other States

Management of the ground water resource in other states has been investigated. The results are summarized in this section. The legal framework within which each state's water resource managers operate dictates the options open to them; however, Minnesota hopes to learn from the successes and avoid the failures of others.

Many states, particularly in the western part of the country, have considered or implemented ground water management controls to deal with declining water levels and increased development, and to avoid land subsidence and increased numbers of conflicts between ground water users. The legal framework in which the ground water resource is to be managed will determine the controls exercised. The tolerance of the users for the negative effects of management and of overuse and misuse of the resource will also influence management decisions.

Eastern states are relatively water-rich. These states have traditionally defined ground water rights based on common law, with the reasonable use doctrine currently most widespread. This doctrine allows any traditional beneficial use of water on the overlying land without regard to impacts on adjacent landowners. Due to the general abundance of water, conflicts are more likely to arise over water quality issues. Many states have replaced or augmented the common law system with some form of permitting, but in the absence of conflict over water use, permitting may become a mere formality rather than a management tool.

States with permit systems may impose limits on water use: how water is used, how much water is used, how long water can be used. Connecticut, Delaware, Florida, Georgia, Iowa, Kentucky, Maryland, New Jersey, North Carolina, New Jersey, Oklahoma, South Carolina, Virginia, and Wisconsin are among the States which have adopted some form of ground water use permitting program (Cox and Shabman, 1982; Miller and Powers, 1984).

Specific areas which face problems needing more intensive management may be designated and administered differently than the rest of the state. Such areas may be called critical areas, capacity use areas, aquifer protection areas, restricted use areas, or ground water management areas (Miller and Powers, 1984). Ground water management districts have been formed in most Western and Midwestern states (as well as some Eastern states) to manage the specific problems and concerns unique to the area managed. Management plans can be initiated on a local level or state level; administration and funding may also be local, state or joint.

One problem common to all ground water management policies stems from the current unreliability of drought forecasting. Many of the proposed temporary restrictions must be imposed very early in a drought period to prevent water scarcity and to allow the available water to be allocated optimally. Forewarned, farmers can plan to plant less water-demanding or early maturing plants or opt to let part of their land lie fallow. Industry can plan production to coincide with water availability and power companies can plan purchases from utilities in areas not experiencing drought.

Water Conservation

Wise use of the water resource is a necessary part of any rational water management program. The amount of sacrifice the water users can tolerate will limit the conservation effort to relatively convenient measures during times of abundant precipitation; only during drought periods can widespread compliance be expected. New equipment purchases can be made with water conservation in mind; old equipment can be modified to waste less water. Tax incentives can encourage water conservation in the same ways they encourage energy conservation.

Minnesota's Rules require that conservation be a part of conflict resolution and emergency and contigency planning.

Well Spacing

Well spacing requirements determine the minimum spacing between new high capacity wells and existing wells. This distance may be dependent on the proposed pumping rate or diameter of the new well, the aquifer in which the well is screened, the priority of the existing well, or some combination of these factors. Well spacing can control high capacity well development and may prevent direct interference with surrounding wells. Spacing criteria are relatively easy to administer. However, only new wells are controlled; existing conflicts and excessive withdrawals will still exist. Individuals who have not yet developed a water supply are at a disadvantage and may incur higher water access costs due to forced locations of new wells. Well spacing requirements may pose possible constitutional challenges where the right to water is considered a property right (Aiken and Supalla, 1979).

Well spacing restrictions are too arbitrary to be useful in glacial terrain. In Minnesota the site of a well must be determined by the geology; test holes sometimes reveal very good producing wells and 'dry holes' in close proximity.

Pumping Rotations

Pumping rotation is a method for timing withdrawals from the aquifer. The timing of permissible pumping may be on a daily, weekly, monthly, or yearly interval, or some combination thereof. The rotation may be instituted over the entire area of interest or only in localized areas of overdevelopment. This approach may be effective in maintaining artesian pressures. Depending on the interval, there may be an indirect control on the amount of water withdrawn. If the timing of permissible pumping does not coincide with crop and soil needs, water will be inefficiently used. Administration of rotation schedules is problematic and compliance is difficult to monitor (Aiken and Supalla, 1979).

Pumping rotations could be used in Minnesota to resolve water use conflicts. Under Minnesota's Rules (6115.0810), local water use management plans may be formulated. Such a plan could make administration of pumping rotations possible and could increase compliance because of local input to the plan.

Well Drilling Moratoria

Temporary well drilling moratoria may be useful as a means of gaining time to develop more equitable and feasible methods of control. It is inequitable to individuals who have not developed systems prior to the moratorium and does nothing to control current withdrawals. Well drilling moratoria are very unpopular because they give water to the current users who caused the problem to begin with.

Well drilling restrictions have been imposed by Minnesota counties in the past. The Governor or Legislature could impose statewide restrictions in an emergency.

Water Allocation and Rationing

Limits on the total annual withdrawal from a ground water system may be imposed. These limits may be temporary, may be limited in scope (new wells only, for example), and may be allocated in a number of ways; all allocations may be reduced by the same amount or they may be reduced by a proportionate amount dependent on the acres irrigated or on the amount of water used in the past.

These limitations may also be used to reduce the amount of ground water withdrawals during periods of extreme climatic conditions. The reductions could be enforced for a set period of time or until the stress on the ground water resource is relieved.

Allocation techniques are feasible in Minnesota; in fact allocation has been used to resolve a surface water use conflict on the Clearwater River. The success of allocation and rationing plans will be enhanced by improved drught forecasting and the use of local administration bodies which could be created under Rules 6115.0810.

Mining

Ground water mining depletes ground water in storage in excess of ground water recharge. Mining is in direct opposition to conservation of the resource or *safe yield* concept and cannot be considered for ground water management in Minnesota. In other states it is used to support economic development over a period of years.

Renewable Resource Concept - Basin Yield

Under the renewable resource concept, that portion of the ground water resource which can be renewed on an annual basis (on the average) is available for use. This management principle falters unless the capture of natural discharge is considered. It is not possible to maintain the natural system unaltered while withdrawing water for use because the stable natural system required a balance between natural discharge and natural recharge.

The principle behind the determination of a basin yield is the water budget. The amount of water entering the basin must equal the amount of water leaving the basin, plus or minus the change in storage. This is directly applicable to the establishment of *safe yields* under water table conditions because the long term annual recharge, discharge to or recharge from surface waters, and net changes in storage (water levels) are considered. One potential drawback to this approach is the lack of any site specific determination of predicted conditions; there is no direct field measurement which can be used as a flag for potential problems.

Water Quality Thresholds

The intrusion of low quality water into an aquifer is slow; the speed with which the contaminant or undesirable substance travels is at most as fast as the speed of the water itself. Travel of the low quality water is in response to established gradients and will not stop immediately when pumping is stopped, but will continue until the new equilibrium is established. Monitoring of water quality must be done in close proximity to potential sources of contaminants and at levels which allow detection before substantial contamination has occurred. In prinicple the monitoring of water quality is straightforward, yet administration of such a program will require the cooperation of several state agencies, in particular the Departments of Natural Resources and Health and the Pollution Control Agency. Minnesota has groundwater quality problems near landfills, hazardous waste sites, under some agricultural lands, and in the western part of the state.

Protected Levels

Management based on protected levels determined for individual observation wells in each aquifer or aquifer system allows consideration of regional differences. The flexibility inherent in this approach is necessary due to differences in hydrogeology, climate, water requirements, economic structure, and social factors between regions. Initially, protected levels may have to be set based on relatively little information and a limited understanding of the aquifer system.

The administration of a ground water management program based on protected levels requires the monitoring of water levels in a well-designed network of observation wells at regular intervals. The more critical the aquifer system, the more closely spaced the monitored water levels must be, in both space and time. A drawback of this approach that critical conditions could develop on a local basis before the protected level in the nearest observation well is reached.

Minnesota's statutory definitions of *safe yield* imply that a "protected level" may be determined for an aquifer that will act as an indicator for the *safe yield*. The goal under confined conditions must be to keep the water levels above the bottom of the confining layer. The protected level may be determined to allow leeway before the water level reaches the bottom of the aquitard. The established level would then act as a warning flag, equivalent to the cutoff level used in surface water management. When it is approached, closer scrutiny of the aquifer system could be initiated, the public could be notified to begin executing voluntary conservation plans, while there is still time to avoid problems.

The objective of such a study may be to determine if the decline of water levels is due to overdevelopment of the aquifer, i.e. withdrawals exceed recharge, or if the decline is due to a discrete climatological condition. If water levels are not expected to recover, appropriate measures will then be taken to protect the resource.

Ground Water Management in Swift County

Localized ground water shortages and pumping induced stream flow depletion are projected for Swift County under drought conditions and under increased pumping stress. It should be pointed out that the most recent drought (1976 - 1977) occurred prior to most of the development in the area (the drought was the impetus behind the development). This means that no actual observations of the system under the double stress of drought and large ground water withdrawals have been made. A ground water model was used to predict the response of this aquifer system to these severe conditions.

Should drought conditions recur, well interference problems are predicted, especially involving shallow wells and wells constructed in the surficial aquifer. Procedures have been deveoped to deal with well interference; costs are shared between responsible parties, which may include the complainant in cases where the well was of substandard construction. The construction of new domestic wells should take these findings into account. The Steering Committee suggested a public information campaign emphasizing proper well construction and the fact that the surficial aquifer may not provide a reliable water supply under all conditions.

The potential for water use conflict is present on a local basis; conflicts must be dealt with as set forth in the Rules. A conflict exists when the aquifer cannot supply the needs of all users without exceeding its *safe yield*. The establishment of protected levels related to the *safe yield* of the aquifer for observation wells in the aquifer system will provide a warning system. Voluntary water conservation, pumping rotations, or water allocations will then provide flexible means to avoid permit terminations of the lower priority (mostly irrigation in this case) users in order to protect public and domestic water supplies.

The goal of ground water management based on protected levels can be realized only if the observation well network is expanded to cover potential problem areas (based on model predictions). Once the network is augmented, protected levels can be set for this aquifer system. Timely reporting of water levels is important when ground water management is based on protected levels. A local ground water mangement district could administer the program on a day to day and implement any pumping rotations, allocations, or water conservation programs.

The issue of the interrelationship between ground water pumping and streamflow depletion is more complex. When a stream is running out of water, surface water appropriations can be stopped immediately. Ground water recharge, however, will continue as long as the gradient for flow exists. In order for a given stream discharge to be maintained, the system must be understood well enough to allow prediction of impending gradient reversal (the change from ground water discharge to the stream to ground water recharge from the stream). A well-planned network of observation wells must exist between pumping wells and the stream, in the same aquifer, and near enough to the stream to detect gradient changes which will affect flow to or from the stream. Further work is needed to determine the parameters of a technmical investigation of the ground water-surface water relationship.

It will not be possbile to study all aquifer systems at the level of detail used in this study. It is anticipated that studies in most areas will stop short of creating a detailed computer model, rather a conceptual model of the system will be compared to better known aquifer systems and protected levels set by inference. Such protected levels must be conservative and serve as a warning that further study is needed.

Even if all aquifer systems could be thoroughly studied, the time and personnel necessary to manage the established monitoring systems do not exist at the state level. In recognition of the need for local participation, a Steering Committee participated in this study.

STEERING COMMITTEE

The formation of a Steering Committee was based on the idea that such a committee could collect and disseminate information to individual irrigators, municipalities, and other water users. The Committee exists to define and identify local concerns, discuss the constraints of a realistic ground water management strategy.

The County Agricultural Extension Agent and staff of the Department of Natural Resources identified interest groups functioning within the community and developed a list of potential candidates for the Steering Committee. Committee members were selected to represent irrigation and agriculture; domestic water use;

commercial and industrial water use; municipal water suppliers; county officials; members of the Minnesota legislature; recreational users; and the Soil and Water Conservation District. Because Swift County is a rural area, members typically represented more than one category. Candidates received a letter explaining the project and asking for their participation. A list of contacts for the Steering Committee is found in the appendix.

Even though the official intent is to create a core group to facilitate information transfer, interested and concerned individuals are also welcome at Steering Committee meetings. The initial meeting set a primary objective of development of policies which are accepted locally and which conform to the rules and regulations which govern policies of the Department of Natural Resources. The Steering Committee is to provide local input to any water management plans for the area. This encompasses representing the local opinion on many issues: the extent of potential future development, economic impacts of irrigated agriculture, present and potential use of water conservation, and water use control measures including management options such as scheduling or rationing. It also encompasses carrying back some of the ideas to the local community through press releases and personal contacts. As such, the Steering Committee has an educational function.

The usefulness of the Steering Committee becomes clear when local compliance with water use control measures is estimated: only an informed and concerned local population can make any such measures effective. A working group for a response effort is created which has the mandate to plan for a water shortage and to look at options before any crisis begins. The concerns and conflicts of different users are reconciled as well as possible in an effort to assure that the cost of weathering a water shortage is shared.

The committee felt that the level of awareness of ground water resource issues could be raised if water levels in local observation wells were regularly reported in the newspapers in the context of their past readings. County newspapers, the Soil and Water Conservation Districts and the DNR could cooperate to produce news releases for this purpose. Preparation of the materials for such news releases has begun. Past observation well water levels have been plotted and accompanying text for publication has been drafted. It was recommended that water levels from observation wells in the surficial sands, the lower confined aquifer (near Appleton) and the middle confined aquifer (around Benson) be published.

The Steering Committee provided input on the possible extent of future development (or increases in water use estimates). Members reviewed soils maps, aquifer maps and maps of present irrigated acreage. Their consensus was that the largest increase in development had already occurred. The majority of irrigation is on the sandy soils near the river where moisture availability is low. The wetter soils would not produce sufficient economic return on the capital investment for the irrigation system. To produce a given yield these wetter soils do not require large amounts of additional water as sandy soils do. Excessively dry periods and higher crop prices may make new irrigation systems cost effective; this would be incentive for additional development.

Rural Minnesota is currently facing economic problems. Crop prices are low, interest rates on loans have been high, resulting in farm foreclosures and sales. Large increases in irrigated agriculture are unlikely in the short term as long as these factors remain unchanged. Increases may occur related to expansion of existing systems or to acquisitions of tracts by corporate investors.

Methods of meeting the objectives set before the Steering Committee include meetings, discussions, and papers. Scenarios were developed as an attempt to describe somewhat realistic situations for the committee to comment on, respond to and plan for:

Scenario I: After a winter of below normal snowfall and spring precipitation the following summer is hot and dry. Because of the is an increased demand for ground water, lowered water levels are observed in wells. Although no one is yet out of water, a number of citizens want to explore possible solutions before conditions become severe. This implies a degree of cooperation between residents and early recognition of a possible problem; consequences of severe conditions need to be identified.

Scenario II: After a 2 year history of fairly dry conditions the region is experiencing a dry fall. Water levels in observation wells have not recovered to the same extent as in previous years during this season (late fall). If these conditions persist there may be limited water available and some residents may be out of water.

Scenario III: Although there has been a history of normal conditions in terms of temperature and precipitation, and high capacity use of water has not increased significantly, water levels in observation wells have not shown seasonal recovery for the past 5 years. This distinct downward trend may be evidence of stress on the aquifer(s). Even though i'development and use of water has not increased, citizens wish to stabilize the declining water levels in order to preserve the ground water resource.

Scenario IV: The same conditions exist as in scenario III, except that high capacity use of water has been increasing at the rate of 10 percent per year. This trend is seen both in the amount of water reported withdrawn and in the number of applications submitted for use. It is desired to stabilize this trend.

The primary response of the committee to the scenarios was that public education was needed. Proper construction of new domestic wells and the benefits derived from irrigation should be emphasized. Better communication between all parties (irrigators, non-irrigators, state legislature, etc.) is desired.

Examples of ground water management controls under discussion or in use in other states were presented to the Committee. Irrigators want a ground water management plan they feel they can live with; they would prefer to have restrictions expressed as a volume of water (although the objection was raised that this could not be accurately measured) and they want any restrictions for the upcoming season to be imposed well in advance of the planting season. This assumes a capability to forecast drought. Observation well water levels were suggested as a drought warning because they are an expression of overall stress on the aquifer system.

If restrictions on water use are to be implemented, fairness and reasonableness are the prime concerns of the Steering Committee members. They feel water conservation represents a financial burden for irrigators, if the purchase of new equipment is necessary, and that the responsibility for water conservation should not fall solely upon the irrigators, but also on municipal water supplies and rural domestic and livestock use.

The Steering Committee indicated a general level of awareness of potential water quality problems stemming from the use of fertilizers and other agricultural chemicals on irrigated sands. At present no hazard to the ground water is seen in Swift County, and the use of these compounds is considered necessary to produce desirably high crop yields.

The following is a summary of the conclusions reached in discussions of the Steering Committee:

1. Development of the ground water resource in Swift County has peaked; future development will occur at a much slower rate.

2. Some of the ground water management options were very unfavorably received (a well drilling moratorium, for example) by local residents because of the perception that an unfair advantage would be given to some individuals.

3. Management strategies which were equitable to all were more favorably received (rationing or allocation of given volumes among all users, for example). The Steering Committee indicated that cooperation was likely, especially if prior notification were to be given. Early notification of any upcoming (or possible) reduction of appropriation volume is imperative, before seed, herbicide, pesticide and fertilizer are purchased.

4. The quality of water from aquifers in Swift County is suitable for all anticipated uses. The committee does not feel that any restrictions in the use of agricultural chemicals are warranted.

5. Water conservation techniques should be emphasized and used by all water users. The Steering Committee felt that a combination of different controls or techniques should be used to reduce water use.

6. Area residents must be educated about the ground water resource - what it is, how it responds to use, and its importance to the community.

7. The committee felt that the benefits of irrigated agriculture to the community should be emphasized.

8. Because a water shortage would affect the entire community there must be good cooperation and communication between parties.

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