HYDROLOGIC EFFECTS OF IMPOUNDMENTS IN

SHERBURNE NATIONAL WILDLIFE REFUGE, MINNESOTA

By R. G. Brown

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CONVERSION TABLE

Conversion factors for terms used in this report are listed below for readers who prefer to use metric units:

Multiply	By	To obtain
acre-foot (ac-ft)	1233	cubic meter (m^3)
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per square mile (ft^3/mi^2)	0.01093	cubic meter per kilometer (m^3/k)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
micromhos per centimeter at 25° Celsius (umho/cm at 25°C)	1.000	microsiemens per centimeter at 25° Celsius (uS/cm at 25°C)

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$^{o}F = 1.8^{o}C + 32$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, called NGVD of 1929, is referred to as sea level in this report.

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ABSTRACT

The hydrologic effects of proposed impoundments in Sherburne National Wildlife Refuge were found to be insignificant with respect to both ground- and surface-water flow patterns and water quality. Monitoring of water levels in 23 observation wells and of discharge in the St. Francis River during 1980 and 1981 has shown that ground water in the surficial aquifer responds quickly to areal recharge and subsequently discharges to the St. Francis River. The impoundment of surface water in the refuge was not found to affect water levels in the refuge significantly. The impoundments may affect ground-water-flow systems beneath and adjacent to the impoundments. Quality of ground and surface water was found to be similar except ground water contained higher concentrations of dissolved nitrite plus nitrate nitrogen than surface water. Phytoplankton removed dissolved nitrite plus nitrate nitrogen from surface water. The effects of impoundments on water quality are expected to be minor.

INTRODUCTION

Construction of an impoundment system was proposed in the Sherburne National Wildlife Refuge, in northern Sherburne County, Minnesota, to improve waterfowl habitat by creating 25 pools, ranging in size from 4 to 1,600 acres (U.S. Fish and Wildlife Service, 1966). The proposed impoundment system will inundate approximately 6,300 of the 30,480 acres in the refuge and the pools will be maintained at depths from 0.5 to 5.0 feet, with a median pool depth of 4 feet. Fifteen of the impoundments were constructed in 1980; 2,264 acres were inundated by August 15, 1980, and an additional 2,707 acres by December 6, 1980 (fig. 1). The impoundments were built over existing wetlands, which comprise more than half the refuge area (fig. 2).

Purpose and Scope

A study of the effects of impoundments on hydrology in the Sherburne National Wildlife Refuge was made by the U.S. Geological Survey in cooperation with the U.S. Fish and Wildlife Service. The purpose of the study and of this report is to describe possible effects of the proposed impoundment system on ground- and surface-water movement and quality in and adjacent to the refuge.

Flow and water-quality data were collected for both ground and surface water from May 1980 to October 1981. The ground-water investigation was limited to the surficial aquifer because the impoundment effects would be most evident in this aquifer. Water-quality samples were analyzed for selected physical characteristics and concentrations of dissolved solids, sediment, nutrients, and bacteria.

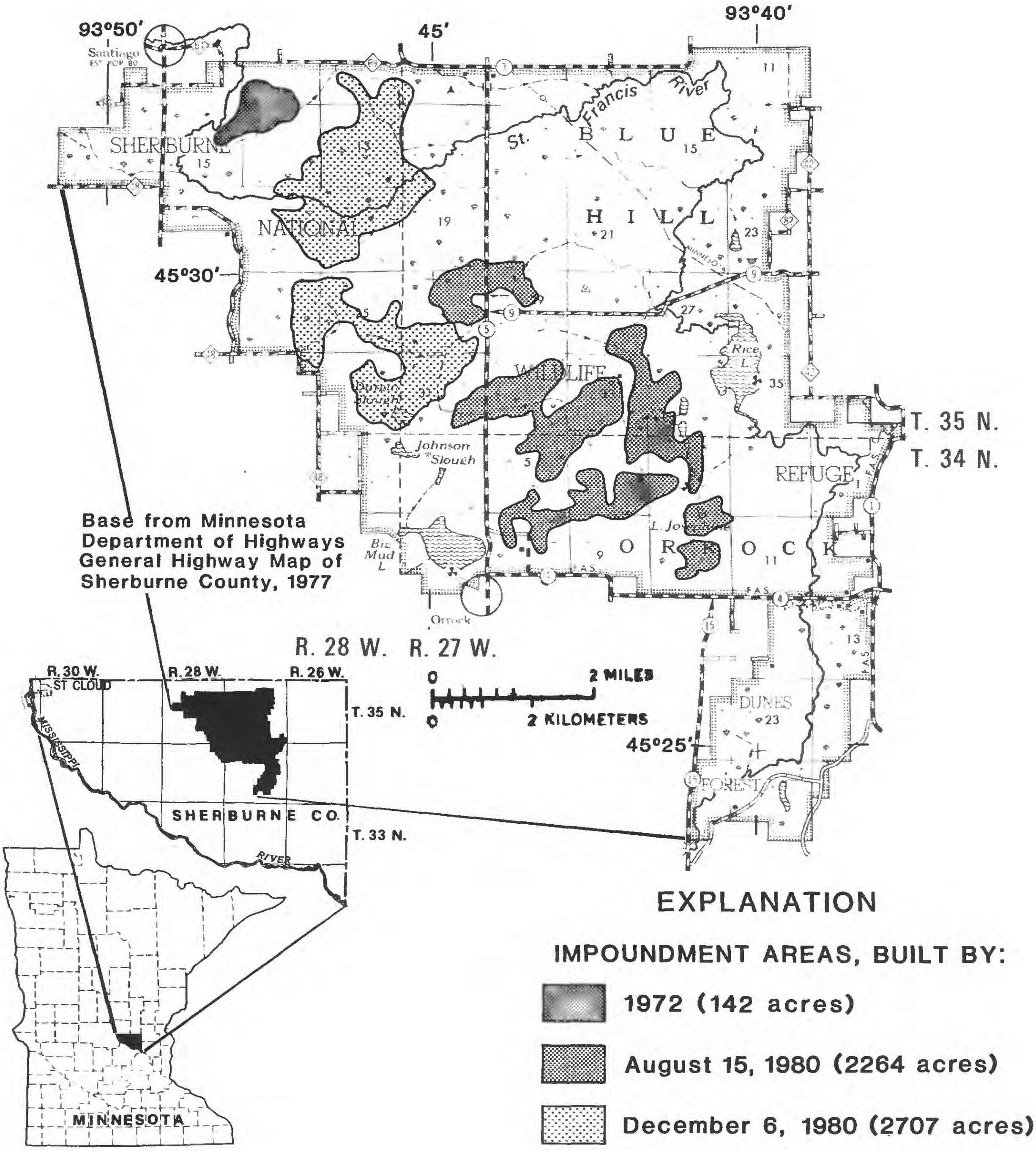
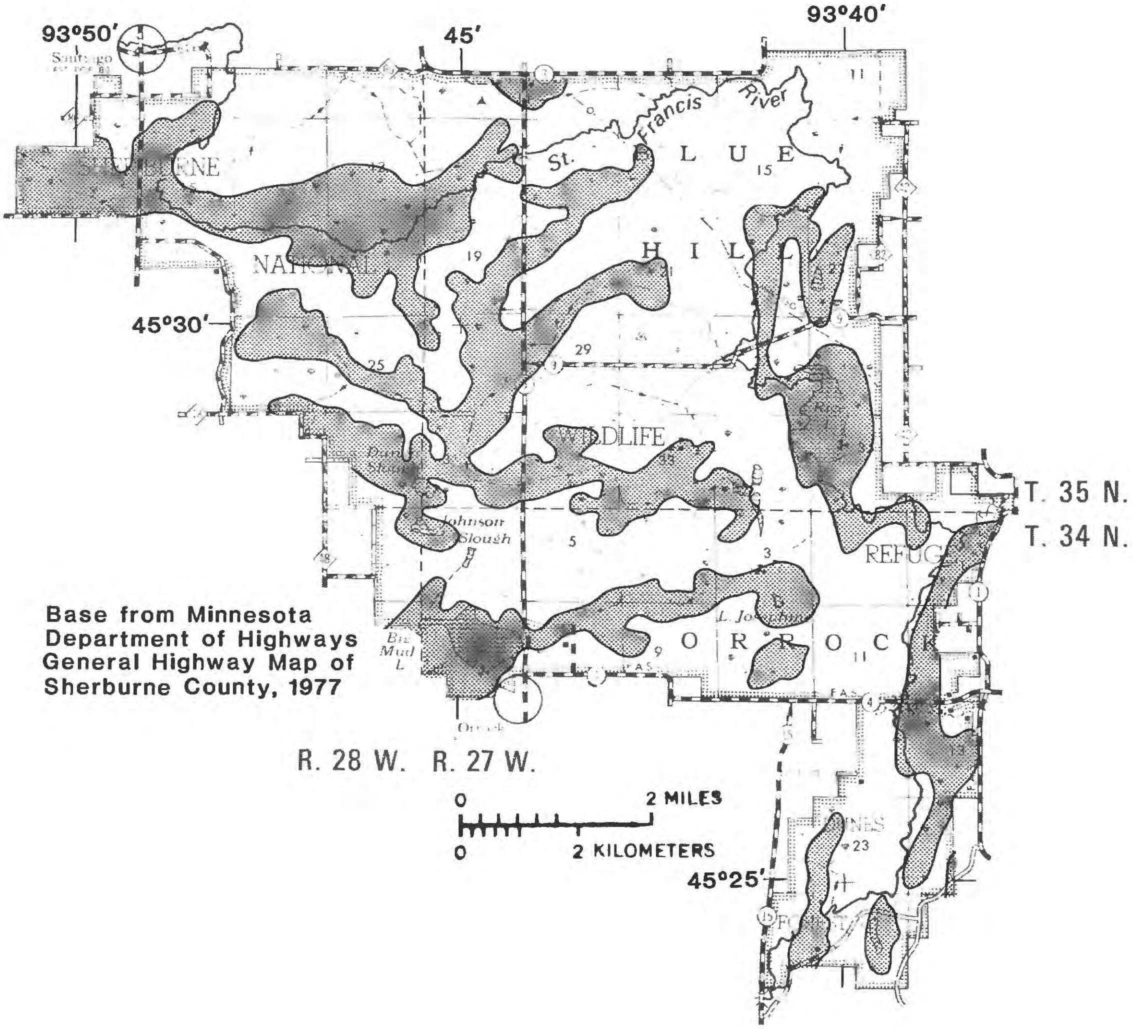


Figure 1.--Location of Sherburne National Wildlife Refuge and completed impoundment areas



EXPLANATION

Wetland area

Figure 2.--Location of wetland areas in refuge

Geologic Setting

Surficial deposits in the refuge are composed of highly permeable sandy soils underlain by red glacial till (Lindholm, 1980). The till retards downward movement of ground water, and the water in the sandy soils, or surficial aquifer, discharges to the St. Francis River. The till is underlain by undifferentiated sandstone and shale of Precambrian age. End moraines, which were formed during recession of the last glacier, are the most conspicuous geologic feature in the refuge. These moraines form an irregular, broken surface on the eastern edge of the refuge consisting of stratified drift covered with reworked glacial deposits composed of sand, gravel, and till.

Previous Investigations

Winchell and Upham (1888) first described the geology of central Minnesota, including the study area. Glaciation in the area has been described by Leverett (1932), Cooper (1935), and Wright (1956, 1972, and 1973).

Water resources of the study area were evaluated by Helgesen and others (1975). The most recent hydrologic study of the area (Lindholm, 1980), included development of a ground-water flow model of the surficial-aquifer system.

Methods of Investigation

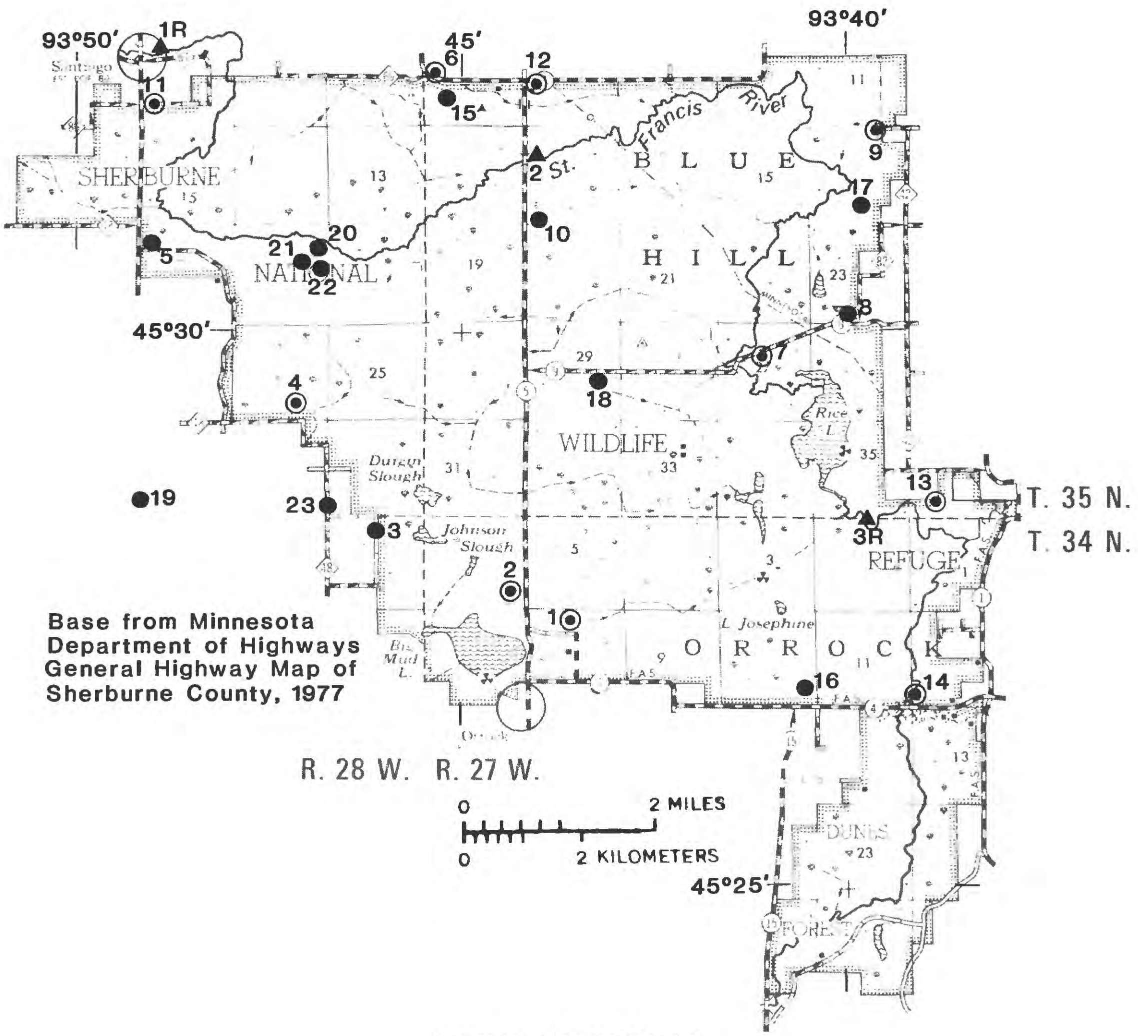
Ground Water

Water levels were measured monthly from June 1980 to June 1982 in 23 wells screened in the surficial aquifer. Samples for water-quality analyses were collected from 10 of the 23 wells in spring and fall of 1980 (fig. 3). The samples were analyzed for specific conductance and water temperature, and for concentrations of dissolved solids, dissolved ammonia nitrogen, and dissolved nitrite plus nitrate nitrogen. Samples were analyzed using the methods described by Skougstad and others (1978).

Surface Water

Water quality was measured from May 1980 to October 1981 at three locations (sites 1, 2, and 3) on the St. Francis River (fig. 3). Continuous- stage recorders were used at sites 1 and 3 for monitoring discharge from May 1980 to October 1981. Discharge volumes were determined from stage record by applying a rating curve developed from discharge measurements.

Water-quality samples were collected during periods of various discharge volumes to determine water-quality throughout the hydrograph. Samples of the river were analyzed for the same properties and constituents as the ground-water samples.



EXPLANATION

●5 Observation well and number

2 ◎ Observation well sampled for water quality, and number

▲2 Surface-water-quality site and number

1R ▲ Surface-water-quality site with stage recorder and number

Figure 3.--Location of wells in ground-water observation network and of surface-water gaging and water-quality sites

HYDROLOGY

Surficial Aquifer

The average hydraulic conductivity of the surficial aquifer is 210 feet per day (Lindholm, 1980). The aquifer thickness ranges from 20 feet in the northwestern edge of the refuge to more than 80 feet in the outwash-filled valley located in the southeastern part of the refuge (fig. 4). The underlying till has low hydraulic conductivity, (Lindholm, 1980) and is of sufficient areal extent that it restricts downward movement of ground water in the refuge.

The water-table map (fig. 5) shows that the general direction of ground-water flow in the surficial outwash in June 1980 was from the north to the east and south. Depth to the water table generally is less than 5 feet in the northern two-thirds of the refuge and from 5 to 20 feet in the southern third. Many of the lakes and wetlands are in direct hydraulic connection with the surficial aquifer and are, therefore, greatly influenced by fluctuations of the water table.

Recharge to the surficial aquifer generally is greatest in the spring. In late March and early April, water levels generally rise as a result of recharge from snowmelt. Water levels generally continue to rise during the remainder of April and May in response to spring rains. During the study, maximum water levels generally occurred in May and June (table 1). Minimum water levels occurred in February and early March.

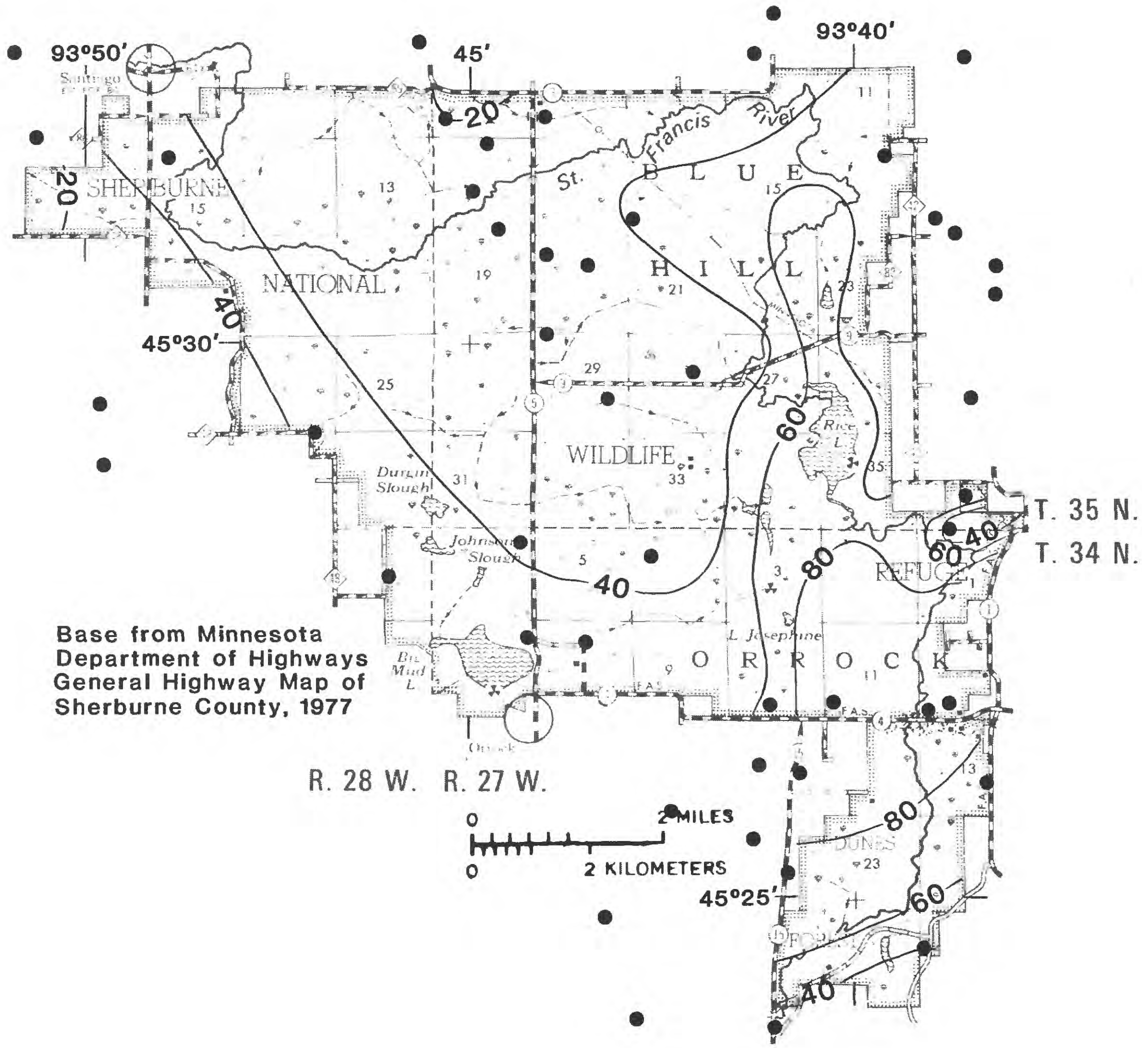
St. Francis River

Annual discharge of the St. Francis River reached annual maximums in June of both 1980 and 1981, then tapered off through the summer to annual minimums in January (fig. 6). Mean, maximum, and minimum monthly discharges all increased greatly between sites 1 and 3 during the study (table 2). The average increase in mean, maximum, and minimum monthly discharge between sites 1 and 3 for the study period was 290 percent, 170 percent, and 500 percent, respectively. The total volume for each month and the unit-area volume both increased between sites 1 and 3 by an average of 400 percent.

There is considerable discharge to the St. Francis River from the aquifer between sites 1 and 3. Assuming that unit-area volumes from surface drainage at sites 1 and 3 are similar, the discharge from the aquifer to the river is the difference between total unit-area volumes for the study period at sites 1 and 3, which is 4,660,000 cubic feet per square mile. This discharge from the aquifer to the river between sites 1 and 3 represents 55 percent of the total discharge at site 3.

Impoundment Areas

The impoundments as of 1982 contain approximately 11,255 acre-feet of water at full pool stage—approximately 1.4 times the amount of water coming into the refuge from the St. Francis River during the study, May 1980 to October 1981. The gate for the impoundment on the St. Francis River frequently is closed, which entirely cuts off the flow, but ground-water discharge to the river still yields a significant baseflow.

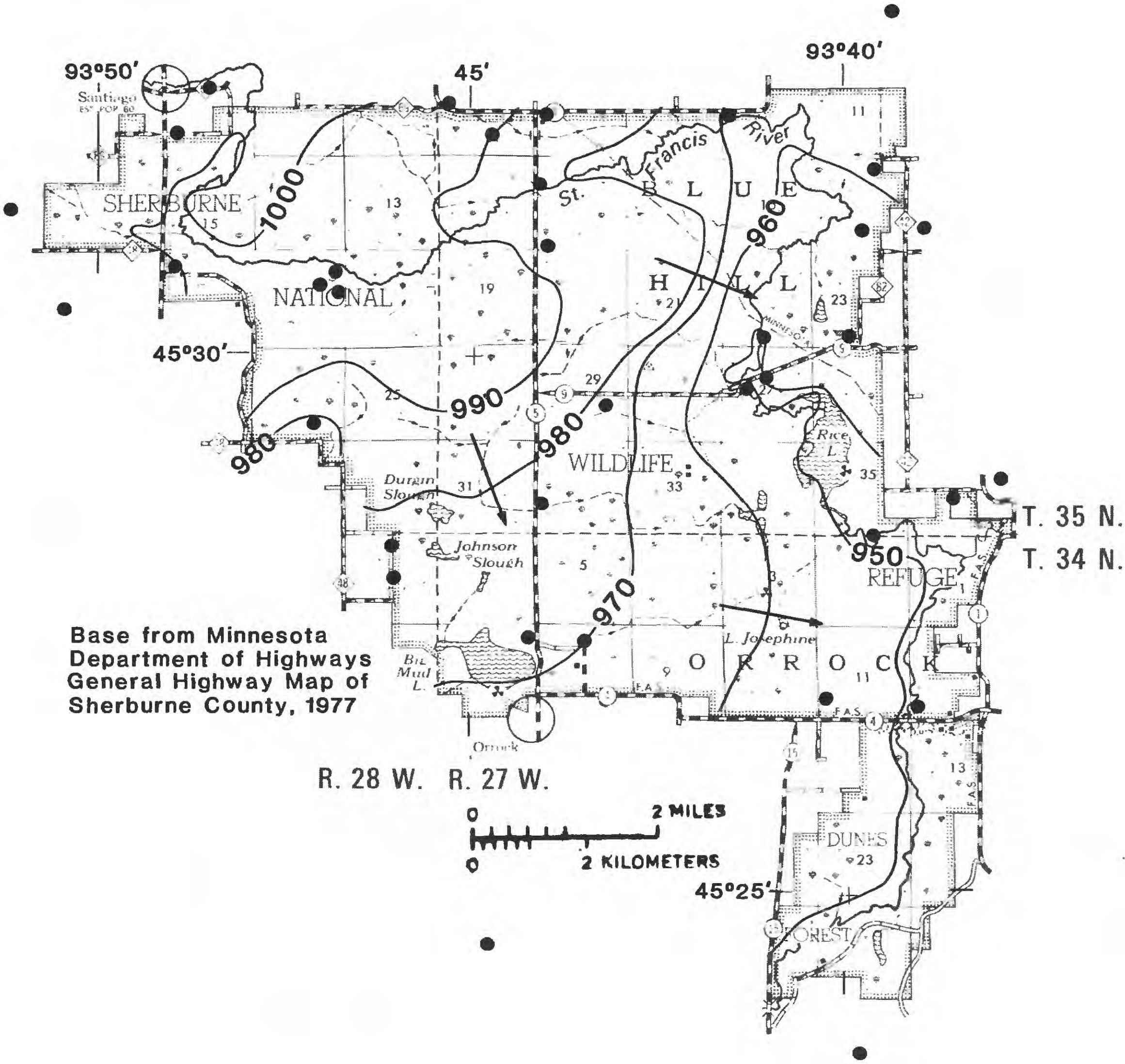


EXPLANATION

—40— Line of equal saturated thickness of surficial outwash. Interval 20 feet

● Auger hole

Figure 4.--Saturated thickness of surficial outwash in June 1980



EXPLANATION

—970— Water-table contour--altitude of water table, June 1980. Interval 10 feet

———► General direction of ground-water flow

● Observation well

Figure 5.--Water-table configuration and general direction of ground-water movement in June 1980

Table 1.—Maximum and minimum of water levels in observation wells from June 1980 to June 1982

[depth to water level from land surface]

Well number	Project well name	Altitude of land surface (feet above sea level)	Maximum water level (feet)	Date (mo-day-yr)	Minimum water level (feet)	Date (mo-day-yr)	Difference between maximum and minimum (feet)
1	SR-01	979	5.44	06-17-81	7.38	02-19-81	1.94
2	SR-02	985	9.14	05-27-82	11.31	02-19-81	2.17
3	SR-03	983	4.18	05-27-82	6.51	02-19-81	2.33
4	SR-04	988	7.54	07-21-81	9.11	06-23-80	1.57
5	SR-05	1,008	6.13	03-27-81	8.80	01-23-81	2.67
6	SR-06	999	3.44	11-18-81	5.47	02-19-81	2.03
7	SR-07	965	11.28	06-17-82	14.71	03-12-81	3.43
8	SR-08	987	28.33	05-27-82	30.94	04-15-81	2.61
9	SR-09	967	1.79	06-17-81	3.53	02-05-81	1.74
10	SR-10	990	2.79	05-27-82	6.27	01-23-81	3.48
11	SR-11	1,012	2.26	03-25-82	4.69	02-19-81	2.43
12	SR-12	991	4.60	10-31-80	6.12	03-25-82	1.52
13	SR-13	976	24.55	08-19-81	25.89	04-15-81	1.34
14	SR-14	961	14.92	05-27-82	17.01	07-23-80	2.09
15	SHOP, REFUGE	995	4.11	6-17-81	7.43	02-05-81	3.32
16	USGS NIKKO	981	24.75	11-26-80	26.40	06-02-81	1.65
17	USGS FURMAN	995	15.70	05-13-82	17.95	06-07-81	2.25
18	RECORDER	987	4.20	04-21-82	7.49	02-19-81	3.29
19	USGS KOB	996	4.13	06-17-80	6.99	03-03-82	2.86
20	SAV A	993	0.43	06-17-81	1.75	07-23-80	1.32
21	SAV B	1,001	7.90	11-26-80	8.58	04-15-81	0.68
22	SAV C	1,005	12.77	12-26-80	13.99	08-20-80	1.22
23	BARTHEL	981	3.94	06-17-81	5.75	08-20-80	1.81

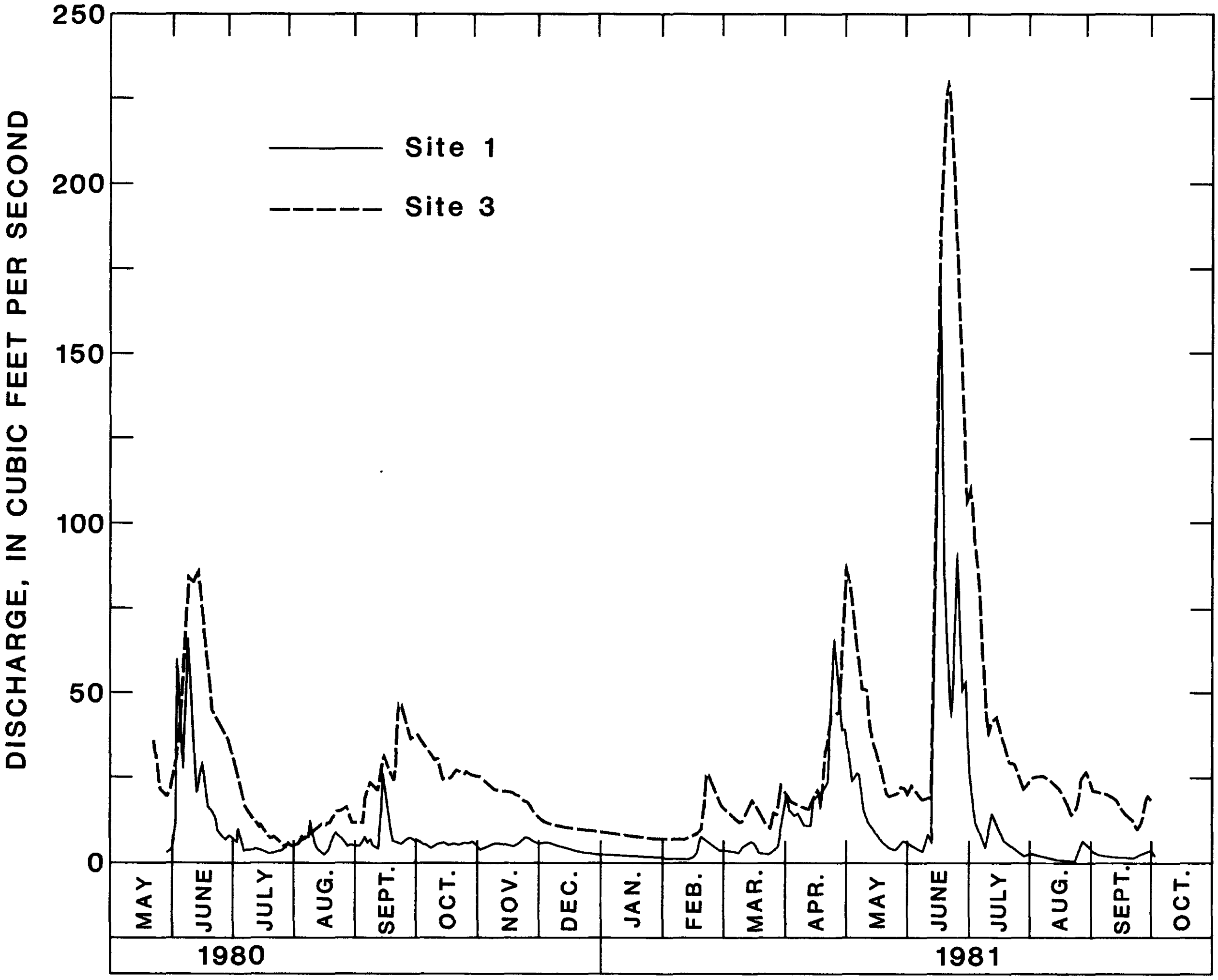


Figure 6.--Discharge of the St. Francis River at sites 1 and 3 between May 1980 and October 1981

Table 2.--Streamflow characteristics of the St. Francis River at sites 1 and 3

Date	Discharge Mean	Discharge Maximum	Discharge Minimum	Total volume (cubic feet)	Unit-area volume[1] (cubic feet per square mile)
	(cubic feet per second)				
ST. FRANCIS RIVER AT SITE 1 (drainage area 87.4 square miles)					
June 1980	25	65	6.7	65,000,000	740,000
July	4.5	9.3	3.1	12,000,000	140,000
Aug.	6.0	12	2.1	16,000,000	180,000
Sept.	8.5	26	3.9	22,000,000	250,000
Oct.	5.7	7.3	4.3	15,000,000	180,000
Nov.	6.0	8.3	4.4	16,000,000	180,000
Dec.	4.4	6.2	2.7	12,000,000	140,000
Jan. 1982	2.2	2.7	2.0	5,900,000	70,000
Feb.	3.6	8.5	1.9	8,700,000	100,000
Mar.	4.8	16	2.9	13,000,000	150,000
Apr.	27	67	11	70,000,000	800,000
May	13	38	4.5	35,000,000	400,000
June	52	183	3.3	14,000,000	150,000
July	9.2	38	2.1	25,000,000	280,000
Aug.	2.2	6.8	.42	5,900,000	70,000
Sept.	2.0	3.6	1.3	5,200,000	60,000
ST.FRANCIS RIVER AT SITE 3 (drainage area 149.9 square miles)					
June 1980	55	85	28	142,000,000	940,000
July	12	30	4.6	32,000,000	210,000
Aug.	11	17	4.8	30,000,000	200,000
Sept.	29	48	12	75,000,000	500,000
Oct.	28	39	24	75,000,000	500,000
Nov.	20	25	13	52,000,000	350,000
Dec.	10	13	8.9	27,000,000	180,000
Jan. 1981	8.0	8	7.5	27,000,000	140,000
Feb.	13	28	7.5	31,000,000	210,000
Mar.	15	23	10	40,000,000	270,000
Apr.	57	80	14	148,000,000	990,000
May	40	87	18	107,000,000	710,000
June	107	230	18	277,000,000	1,800,000
July	49	112	22	131,000,000	870,000
Aug.	22	27	14	59,000,000	390,000
Sept.	17	21	9.9	44,000,000	290,000

[1] Unit-area volume is the total volume, in cubic feet, for the month divided by the drainage area in square miles.

Impoundment of surface water may have caused an increase in evapotranspiration because the surface area of open water was increased. The increased evapotranspiration would represent an increased loss or output of water from the hydrologic system because of the impoundments. The loss would have to be balanced by increased inflow from surface or ground water if the pool level is to be maintained.

WATER QUALITY

Concentrations of dissolved solids, specific conductance, and dissolved ammonia nitrogen in samples of water taken from the river and from wells located near the river were found to be similar. Discharge of water from the aquifer to the river causes the concentrations to be similar.

Total dissolved solids in water from the surficial aquifer (table 3) ranged from 83 to 294 mg/L (milligrams per liter) and had an average concentration of 164 mg/L. Water in the aquifer at locations away from the river, such as from wells 1, 2, 4, and 6, has lower dissolved-solids concentrations compared to near the river (wells 7, 9, 11, and 14). Dissolved-solids concentrations of water from the St. Francis River (table 4) ranged from 148 to 278 mg/L and had an average concentration of 217 mg/L at site 1, 225 mg/L at site 2, and 210 mg/L at site 3.

Average specific conductance of water from the surficial aquifer was 246 umhos/cm (microhms per centimeter), whereas average specific conductance in the St. Francis River was 314 umhos/cm at site 1, 322 umhos/cm at site 2, and 330 umhos/cm at site 3. Specific conductance in water from wells close to the river was high compared to specific conductance of water from wells farther from the river.

Concentrations of dissolved ammonia nitrogen generally were the same in water from the surficial aquifer and the St. Francis River. Average concentration of ammonia in ground water was 0.05 mg/L whereas the average concentration in the river was 0.03 mg/L at site 1, 0.08 mg/L at site 2, and 0.07 mg/L at site 3.

Concentrations of dissolved nitrite plus nitrate nitrogen varied in water from the surficial aquifer and the St. Francis River. Nitrite plus nitrate in ground water ranged from 0.00 to 7.5 mg/L, with an average concentration of 1.5 mg/L. Average concentration of nitrite plus nitrate in the river was 0.87 mg/L at site 1, 0.04 mg/L at site 2, and 0.08 mg/L at site 3. Low concentrations of nitrite plus nitrate in the river most likely result from consumption by phytoplankton. Eutrophic conditions exist in the river and, as a result, there are extensive populations of phytoplankton. Nitrite plus nitrate nitrogen concentrations are higher upstream from site 1 where the river is faster flowing and not suitable for phytoplankton growth.

Table 3.—Quality of water from selected wells

[microhms per centimeter (μmhos/cm), milligrams per liter (mg/L)]

Well number	Date of sample	Time	Specific conductance (μmhos/cm at 25°C)	Temperature (°C)	Solids, residue at 180°C dissolved (mg/L as N)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)
1	80-05-22	1030	228	8.5	157	0.98	0.00
	80-09-03	1800	244	13.0	171	.98	.00
	80-11-24	1640	—	7.0	—	—	—
2	80-05-22	1200	157	9.5	120	3.6	.05
	80-09-04	1130	159	11.0	120	4.7	.03
	80-11-24	1700	—	6.0	—	—	—
4	80-06-23	1420	189	15.0	119	.48	.16
	80-09-04	1030	152	11.5	110	1.6	.01
	80-11-24	1615	—	7.0	—	—	—
6	80-06-06	1000	140	15.0	83	.08	—
	80-09-03	0945	149	15.5	84	.03	.05
	80-11-24	1545	—	6.5	—	—	—
7	80-05-22	1400	313	9.0	206	1.2	.08
	80-09-03	1430	293	12.0	199	1.3	.01
	80-11-24	1335	—	9.5	—	—	—
9	80-06-23	1040	237	18.0	160	2.2	.13
	80-09-03	1530	270	13.0	186	2.4	.00
	80-11-24	1500	—	7.0	—	—	—
11	80-06-06	0910	303	13.0	169	.01	—
	80-09-03	1130	413	11.0	294	.00	.14
	80-11-24	1600	—	6.0	—	—	—
12	80-06-06	0830	—	14.0	277	.04	.06
	80-09-03	1330	444	14.0	272	.00	.00
	80-11-24	1530	—	7.0	—	—	—
13	80-06-23	1552	—	—	100	.03	—
	80-11-24	1430	—	7.5	—	—	—
14	80-06-05	2130	292	13.0	142	2.0	—
	80-06-23	1300	167	17.0	120	1.0	—
	80-09-04	1300	279	11.5	195	7.5	.07
	80-11-24	1620	—	7.0	—	—	—

Table 4.--Quality of water from the St. Francis River at sites 1, 2, and 3

[cubic feet per second (ft^3/s) microhmos per centimeter (μmhos/cm), milligrams per liter (mg/L)]

Site number	Date of sample	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (μmhos/cm at 25°C)	Temperature (°C)	Solids, residue at 180°C dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)
1	80-05-21	1600	6.8	282	19.5	205	0.42	0.02
	80-06-23	1515	8.6	170	22.0	211	.68	.00
	80-07-09	1045	3.4	315	21.0	201	.56	.01
	80-07-29	1212	6.1	280	23.0	208	.62	.03
	80-10-02	1500	6.7	375	12.0	228	1.3	.01
	80-12-02	0950	6.2	340	.0	251	1.2	.03
	81-02-04	1230	1.9	339	.0	216	1.7	.05
	81-04-08	1030	5.0	320	9.5	218	.34	.04
	81-05-01	1044	38	380	12.5	—	—	—
	81-07-20	1253	6.5	340	23.0	—	—	—
	81-08-27	1033	5.4	—	18.0	—	—	—
2	80-05-21	1130	17	222	16.5	210	.00	.05
	80-06-23	1510	27	354	22.0	232	.08	.13
	80-07-09	1305	5.7	330	19.0	201	.02	.05
	80-07-29	1055	16	305	20.5	226	.00	.01
	80-10-02	1230	14	300	11.5	200	.06	.03
	80-12-02	1130	6.7	360	1.0	252	.10	.04
	81-02-04	1424	4.1	393	.0	255	.03	.10
	81-04-08	1215	65	304	10.0	228	.02	.16
	81-07-20	1434	7.9	320	20.5	—	—	—
	81-08-27	1233	8.3	340	16.0	—	—	—
3	80-05-21	1830	36	266	27.0	192	.00	.01
	80-06-23	1227	41	293	26.0	205	.11	.02
	80-07-09	1545	15	330	31.0	188	.16	.00
	80-07-29	0913	25	—	22.5	148	.01	.02
	80-10-02	0930	38	330	11.5	208	.00	.13
	80-12-02	1440	12	466	1.0	278	.09	.01
	81-02-04	1733	7.5	419	.0	260	.20	.21
	81-04-08	1445	14	295	15.0	198	.09	.21
	81-05-01	1044	89	270	13.0	—	—	—
	81-07-20	1253	14	310	29.0	—	—	—
	81-08-27	1445	16	320	20.5	—	—	—

POSSIBLE EFFECTS OF IMPOUNDMENT AREAS

Hydrology

Impoundment of surface water in the refuge area has caused levels in water-table-observation wells located near the impoundments to rise (table 5). The rise in water levels from 0.18 to 0.50 foot near the impoundments increased the water-table slope between a given pool and the major ground-water discharge area, the St. Francis River. This does not include impoundments built on the river. The increase in water-table slope (hydraulic gradient), however, is insignificant in its effect on ground-water discharge to the St. Francis River. An increase in water-level near an impoundment may, however, affect the local and regional flow systems near the impoundment. Possible effects were investigated by considering two hypothetical settings that involve interaction between impoundments and the ground-water system.

In the first hypothetical setting, the water level in a wetland is increased 5 feet, the maximum increase that has occurred in construction of the present impoundments. Figure 7(A) illustrates a hypothetical setting of a realistic cross section between a wetland and St. Francis River in the refuge. In this setting, there are no water-table mounds between the wetland and the river. The water-table slope is the difference between altitudes of the water table at the wetland (996) and the river (990), 6 feet, divided by the distance between points, 1,040 feet, or 0.0058. Ground-water flows both into and out of the wetland within the local flow system (figure 7A). In the regional system, flow is to the St. Francis River. When the water level in the wetland is raised (fig. 7B) by an impoundment, (1) the water-table slope between the wetland area and river increases, but not significantly; (2) the local flow system is altered so that ground water will not flow into the wetland area, (3) seepage out of the wetland area is increased; and (4) the regional flow system becomes in contact with the wetland area.

The ground-water flow system shown in figure 7 is a realistic setting for many wetland and proposed impoundment areas in the refuge. Other areas in the refuge are believed to have water-table mounds between the wetlands and the river. In the second hypothetical setting, a downgradient water-table mound 8 feet higher than the St. Francis River is between the wetland and the river; the slope of the water-table shown is 0.0077 (figure 8A). The theoretical flow system shows that in this setting the wetland has ground-water inflow but no ground-water outflow. The wetland does not have outflow because there is a point of least hydraulic head, or stagnation point, beneath the wetland. This hydraulic head, shown as 996.4 feet, is greater than the hydraulic head of the wetland (996 feet) and, therefore, ground water moves towards the wetland. The stagnation point also is a boundary between two local flow systems; one system involves flow to the wetland and the other involves flow to the river. The resulting hydrologic boundary prevents flow between the wetland and the river.

Winter (1981) found that if a flow system similar to the one shown in figure 8(A) is changed in a way that increases the slope of the water-table from less than 0.01 to more than 0.01, the stagnation point probably would

Table 5.--Average levels in water-table observation wells located near impoundments before (1980) and after (1981) construction

Well Number	Average water level 1980 (altitude in feet above sea level)	Average water level 1981 (altitude in feet above sea level)	Difference between 1980 and 1981 (feet)
1	971.90	972.12	0.22
2	974.81	975.18	.37
3	977.40	977.90	.50
4	979.85	980.20	.35
15	990.10	990.28	.18
18	980.76	981.22	.46
20	991.72	992.13	.41
21	992.68	992.93	.25
22	992.47	992.65	.18
23	975.85	976.19	.35
Precipitation (inches)	26.34	25.16	-1.18

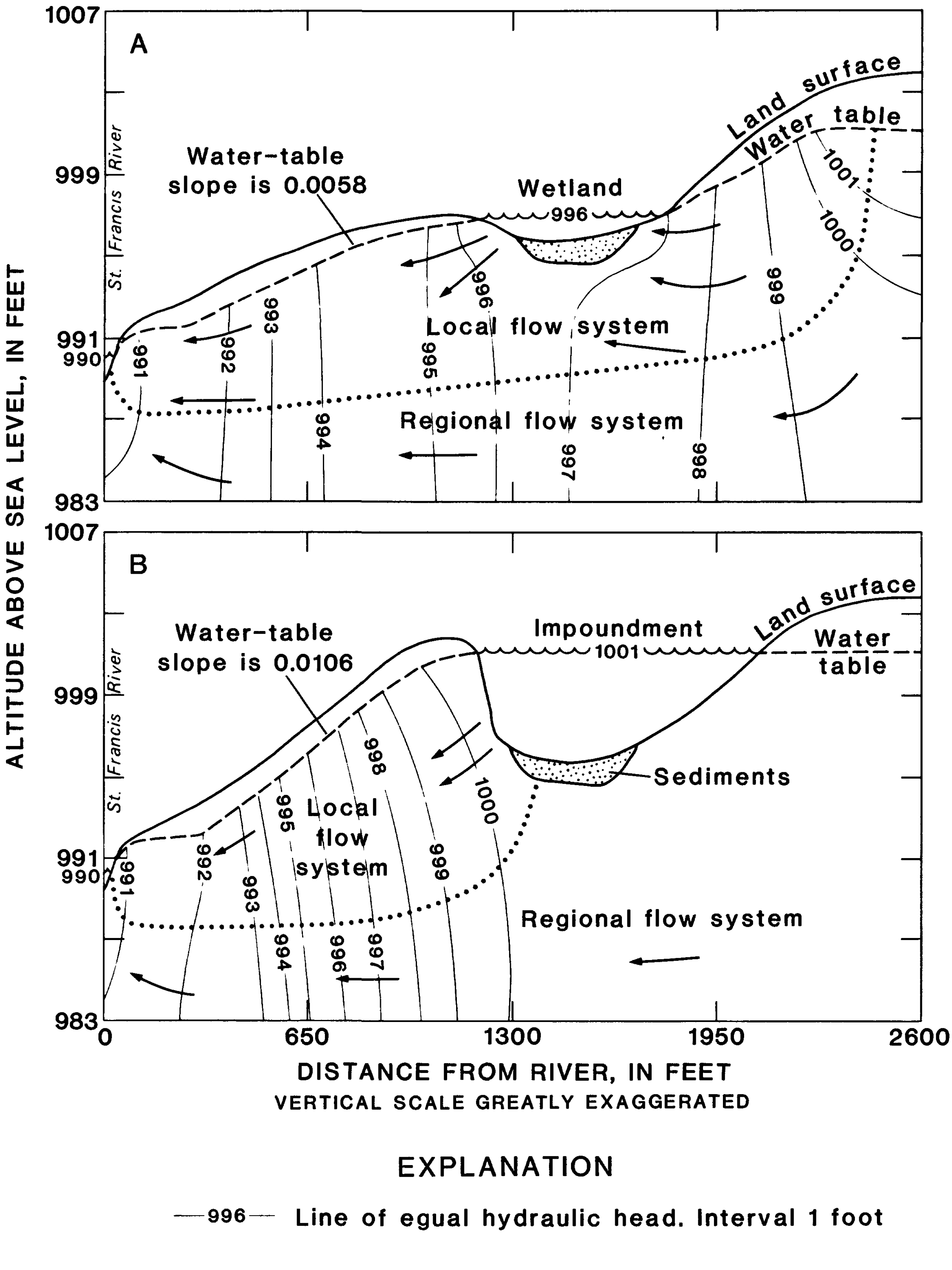
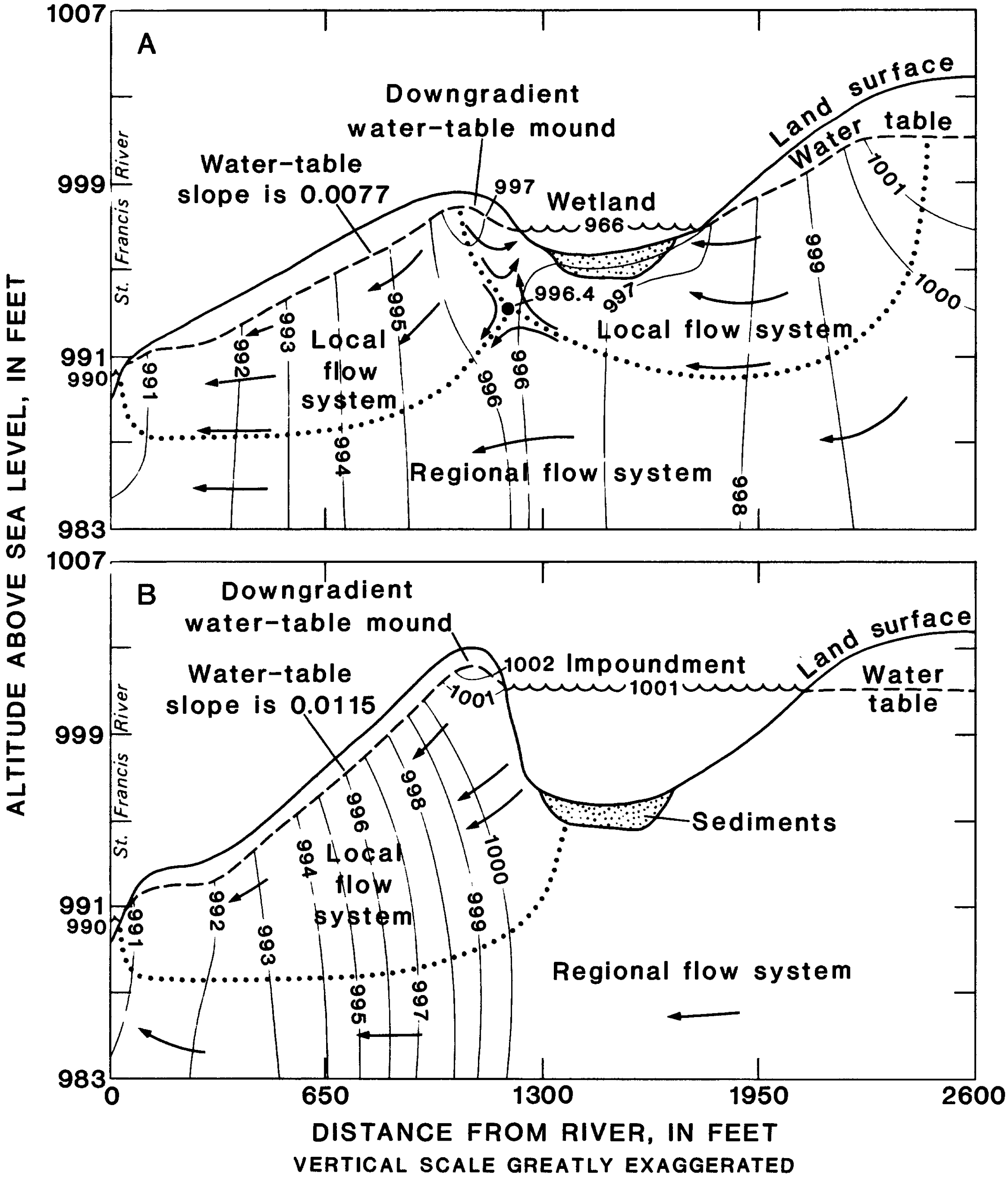


Figure 7.--Hydrogeologic sections showing theoretical ground-water-flow system in the refuge between a wetland (A) or impoundment (B) and the St. Francis River (adapted from Winter, 1981)



EXPLANATION

—996— Line of equal hydraulic head. Interval 1 foot

Figure 8.--Hydrogeologic sections showing theoretical ground-water-flow system in the refuge when a water-table mound is between a wetland (A) or impoundment (B) and the St. Francis River (adapted from Winter, 1981)

disappear. In figure 8(B), the water-table slope has changed because the water level in the wetland was raised 5 feet by constructing an impoundment. As a result, there is seepage from the impoundment to the river.

The possible changes in both types of hypothetical settings (figs. 7 and 8) illustrate that impoundment of surface water probably will affect localized flow systems but will not significantly affect discharge to the river. The two settings given are extreme cases. The most common setting would be when the pools are 60-percent full, the normal pool stage, and the river is at normal or low flow, in which case the effects on local flow systems would be minor.

Water Quality

Impoundment of surface water will increase mixing of surface water and ground water. The only chemical constituent determined in this study that would be affected when water from the impoundment moves through the surficial aquifer to the river is dissolved nitrite plus nitrate nitrogen. The concentrations of nitrite plus nitrate nitrogen are higher in ground water than surface water; therefore, nitrite plus nitrate nitrogen concentrations may increase in the river as a result of the impoundments. However, the increased input of nitrite plus nitrate nitrogen to the river from ground-water discharge could be offset by increased consumption of nitrite plus nitrate by phytoplankton in the river. The overall effects of the impoundments on quality of ground water will probably be minor, although there could be an increase in phytoplankton growth in the river.

SUMMARY AND CONCLUSIONS

Construction of impoundments in the Sherburne National Wildlife Refuge to improve waterfowl habitat are expected to have only minor effects on the hydrology and water quality of ground and surface water. Impoundment of surface water may increase ground-water discharge to the river slightly by affecting ground-water-flow systems adjacent to the impoundments.

The quality of surface and ground water is similar; it differs only in concentrations of nitrite plus nitrate nitrogen. Ground water contains higher concentrations of dissolved nitrite plus nitrate nitrogen than does river water. The lower concentration of nitrite plus nitrate nitrogen in the river probably is the result of uptake by phytoplankton. Effects of the impoundments on ground-water quality should be minor, but the greater input of dissolved nitrite plus nitrate to the river, owing to increased ground-water discharge, may cause an increase in growth of phytoplankton in the river.

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