ENGINEERING REPORT

DROUGHT-RELATED PROBLEMS

MINTO, NORTH DAKOTA

1977

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CHAPTER 1

SCOPE

The City of Minto has had persistent problems with their raw water supply. Their present supply consists of approximately 15,000 GPD from the Walsh County Rural Water Users and raw water from the Minto Dam on the Forest River. The storage capacity in the reservoir is sufficient during periods of adequate rainfall to maintain a dependable water supply. However, it should be noted that the dam is currently in structurally poor condition. With the dam at its present level, expansion of the city is limited by the amount of raw water available.

This report will present data to show Minto's water supply is totally dependent on rainfall. It will show what happens to the flow in nearby rivers during periods of drought like that encountered this year. The Report will also discuss forceable threats to health and safety if Minto does not develop a more drought-safe raw water source.

This Report is being prepared as a requirement of the Farmers Home Administration for a grant under the Comprehensive Drought Assistance Act of 1977, Federal Register Part 1933, Chapter 18, Title 7, Subchapter J.

CHAPTER II

BACKGROUND

On September 20, 1977 the City of Minto submitted three sets of a preapplication for a water supply project grant and loan to the Farmers Home Administration. There have been previous investigations concerning Minto's water supply. A study on the Forest River Basin conducted by the North Dakota State Water Commission in 1975 indicates several alternatives for a water supply for Minto. The surface water sources discussed are the Red River and the Forest River. The Red River is too far away to be an economical alternative. The Forest River, which is the current water supply , is not a dependable supply during periods of below normal rainfall. Ground water in the immediate area is unfit for drinking. The nearest potable ground water supply is approximately 21 miles away (Fordville Aquifer) and is uneconomically reachable. The City of Grafton, located 9 miles north of Minto is planning on implementing a new supply from the Red River of the North and have indicated that they would allow Minto to tie into their system. The following paragraphs will present background information on the Red River of the North and Forest River Basins.

The Red River of the North is formed by the confluence to the Ottertail and Bois de Sioux Rivers at the twin cities of Wahpeton, North Dakota and Breckenridge, Minnesota. It flows 400 miles in a tortuous northerly course, forming the boundary between North Dakota and Minnesota, to the International boundary between the United States and Canada. From the boundary, it flows generally northeast 155 miles in Canada to Lake Winnipeg. The drainage area of the Red River Basin in North Dakota is approximately 17,240 square miles. Table 1 shows the North Dakota tributaries.

TABLE 1

North Dakota Tributaries of the Red River Of the North in the United States

STREAM	River Miles From L. Winnipeg	Approximate Length in Miles	Drainage Area in Sq. Miles
West Side Tributaries in North Dakota			
Wild Rice River	470.1	243	2,020
Sheyenne River	428.2	500	7,140
Elm River	387.3	69	510
Goose River	357.4	186	1,280
Turtle River	----	----	730
Forest River	243.0	147	1,030
Park River	222.2	110	1,010
Pembina River	157.8	275	1,960
Minot Tributaries	----	----	1,560

Principal Minnesota tributaries entering the Red River between the confluence of the Bois de Sioux and Ottertail Rivers and the International boundary are the Buffalo, Wild Rice, Red Lake, Sanke, Tamarac, and Two Rivers. The Roseau River which drains a portion of the basin in Minnesota joins the Red River in Canada. Tributaries in North Dakota and Minnesota flow generally east or west into the Northward flowing Red River. Near the river, North Dakota tributaries tend to turn northward, flowing in some instances, nearly parallel with the mainstem for many miles before finally entering it. Longer tributaries have relatively steep slopes, particularly where they flow from the bordering highlands to the valley floor. In the lowlands, however, many tributaries have very flat slopes with poorly defined watershed boundaries.

During the last glacial period, the entire watershed of the Red River of the North was covered by a continental glacier which altered topography and resulted in the formation of the soils of the basin. Prior to the glacial period, the surface was rough and the drainage clearly defined. When the glacier moved southward over the region, it wore down the divides and ridges and filled the valleys, thus producing the rolling surface of a portion of the watershed. As the glacier melted and receded northward, a heterogeneous mass of clay, sand, gravel and boulders, termed "drift" was deposited over the basin to depths of up to 400 feet. A series of recessional morines were formed, roughly concentric with one another, each representing a halt in the general retreat of the ice sheet. These moraines, varying in size, give greater relief to the area bounding the Red River drainage basin than is characteristic of the drift plain in general.

After the ice front had retreated within the Red River drainage basin, water from the melting glacier was ponded between the surrounding highlands and the ice front that blocked the northern outlet, thus forming glacial Lake Agassiz. This lake at first, drained southward through the Lake Traverse-Bigstone Lake depression into the Minnesota River Valley, later by an eastern outlet into northern Minnesota, and finally northward through Lake Winnipeg into Hudson Bay. During the time Lake Agassiz was in existence, sediments transported by rivers were spread over the bottom to a depth of 20 to 50 feet, covering the drift in most places. In addition, deltas formed by the rivers flowing into the lake cover large areas of the old lake bed.

Several beach ridges were formed at successively lower elevations as the level of the lake dropped and as the outlet changed. These beaches tell the story of the lakes demise. As Lake Agassiz drained, it left a very level dry lake bed with a fall averaging two to three feet per mile towards the river and less than one foot per mile to the north.

The Pembina Escarpment forms the western edge of this plain in the north. The escarpment rises as much as 50 feet per mile for a distance of three or four miles where it meets the more gently sloping drift prairie. South of the escarpment, the boundary between the lake plain and the uplands becomes less pronounced until, in the Wild Rice subbasin, it is almost obliterated by a terminal moraine.

Most of the major tributaries of the Red River in North Dakota have their headwaters in the drift prairie or in the Pembina Escarpment. In the upper reaches of these tributary courses, valleys are narrow, steep sides and relatively deep. As the tributaries leave the drift prairie or escarpment and enter the lake plain, their valleys continue to be narrow. The depth of the valleys decreases generally, however, as the rivers become more winding.

The Minto-Forest River areas are in southeastern Walsh County in northeastern North Dakota. They are a part of the Western young Drift section of the Central Lowland Province of Fenneman (1938, p. 559) and are in the Red River Valley area as designated by Simpson (1929, p. 4). The areas of investigations total about 7½ square miles.

The average annual precipitation recorded at the United States Weather Bureau station at Grafton, about 10 miles north of Minto, is 21.06 inches based upon data gathered during the period 1891 to 1959. The mean annual temperature for the same period as 37.5 degrees.

The areas covered in this investigation lie entirely within the basin of glacial Lake Agassiz which covered the Red River Valley. Upham (1896) mapped the extent of glacial Lake Agassiz in the United States and southern Manitoba. His monograph includes maps and descriptions of the physiographic and geologic features in the vicinity of Minto and Forest River. The areas have little relief and the major topographic features are the youthful stream valleys cut in the glacial Lake Agassiz sediments. Clay and silt are the predominant constituents of the lake deposits; they overlie glacial till throughout the areas. The till is a hetrogeneous mixture of clay, silt, sand and gravel; clay is the major constituent. Under the till are much older sandstones and shales of Cretaceous or Paleozoic age.

Small quantities of ground water are obtained from dug or bored wells in the sediments of glacial Lake Agassiz and somewhat larger amounts are obtained from wells penetrating the sand and gravel lenses in the glacial drift. Very highly mineralized water may be obtained from wells penetrating the older sandstones under the glacial drift.

Thirteen test holes were drilled near Minto and nine near Forest River in an attempt to find an aquifer that would be suitable for a municipal supply for the city of Grafton. Some sand and gravel were present in each section; however, they did not form a large enough aquifer to yield a municipal water supply.

The iron content was much in excess of the recommended maximum for drinking water in all of the samples analyzed and the water was very hard. These samples were all obtained from wells penetrating alluvial deposits.

Agriculture and agricultural products processing plants constitute the primary source of employment in the subbasin. Continued expansion of agri-business type ventures is expected to place increasingly heavier demands upon the existing water supply.

The climate of North Dakota plays the major role in determining flows in the Park River.

North Dakota is typically plains country located near the center of the North American Continent. The State is situated in the middle of latitudes, 30^{o} to 49^{o} from the equator, in the interior of a large continent. The changes within this climatic region are almost all so gradual that comparative uniformity of conditions, rather than diversity, often prevails. The eastern part of the State is flat, with an elevation in the Red River Valley of 780 feet at Pembina in the north to 962 feet above sea level at Wahpeton in the south. To the west, there is a gradual rise of terrain until an elevation of 3,506 is reached at White Butte in the southwestern part of the State. The Turtle Mountains in the north central part of the State are only about 500 feet higher than the surrounding area, with the highest elevation about 2,300 feet above sea level.

The termperate climate of the State is exceptionally healthful, as revealed by the comparatively abundant energy of the people and recently published statistics showing North Dakotan's have the longest life expectancy in the Union. Summers are usually very pleasant, but hot winds and periods of prolonged high temperatures occur occasionally. However, minimum maximum night time temperatures seldom exceed 70° F. As a consequence, it is unusual to have uncomfortable nights. While open and mild winters are not unknown, North Dakota winters are considered cold, but the low humidity that prevails during the cold season is usually far less penetrating than many other areas having higher temperature readings.

The annual mean temperature for North Dakota ranges from about 36° F. in the northeast to 43° F. in the extreme south. Temperatures above 100° F. are occasionally recorded, and zero temperature readings are common in the winter. The average number of days a year when the temperature reaches 90°F. or higher is 14, and the average number with zero or lower is 53. The average growing season is about 121 days, ranging from 110 days in the northeast and north central to 135 in the extreme south. For the State, the average date of the last freeze in the spring is May 19, and the first in the fall is September 18. Freezing temperatures have occurred, however, as late as the first part of June and as early in the fall as the first few days of September.

Precipitation in the eastern third of the State averages about 19 inches, in the middle third about 16 inches, and in the western third about 15 inches. On the average, about 77 percent of the annual precipitation occurs during the

the crop-growing season, April to September, and almost 50 percent falls during May, June and July. The normal precipitation for the driest months, November to February, is about one-half an inch per month. The greatest amount of moisture falls between 5:00 PM and 8:00 PM and again about midnight. Most of the rain occurs in summer storms accompanied by thunder and lightning, often with great intensity for a short time. The average number of thunderstorm days is 30, mostly in June, July and August. In most years, at least some part of the State is visited by a storm that brings a rainfall of two or three inches in a 24-hour period, and occasionally five or six inches fall in one day. On an average, rain falls about one day in four during the summer months.

The annual number of days with measurable precipitation averages 66, ranging from about 50 in the west to 90 in the east. During the four years, 1933-1936, North Dakota's precipitation averaged slightly more than 12 inches per year. During the four years, 1941-1944, the State precipitation averaged slightly more than 20 inches. The first light snow in Autumn occasionally falls in late September, but usually measurable snowfall does not occur until after October. The average number of days with 0.1 inch or more of snow is 23. The average annual snowfall is 32 inches, with the greatest amount in the northeast and the least in the southwest. Occasionally, there is heavy snowfall in winter, and the snow on the ground accumulates to a considerable depth. The winter weather is often interspersed with Chinook winds which cause sufficient snow melt to bare the ground.

The prevailing direction of the wind in all months of the year is from the northwest, unless it is influenced by local conditions. More southerly winds are observed during the summer than during the winter. The average annual wind velocity is about 11 miles per hour. The highest velocities are in the spring and lowest in late summer. High winds frequently accompany severe thunderstorms.

The average relative humidity is about 68 percent slightly higher in the east than in the west. Humidity is frequently low during the afternoon in summer, sometimes below 20 percent. Dense fog conditions lasting for periods of two hours or more, are experienced, on an average, only eight days per year.

The average number of clear days is 160, partly cloudy 100, and cloudy 105. On a clear day, the sun shines for more than 15 hours from the middle of May to the end of July. These long hours of sunshine make it possible to grow many crops in what appears to be a comparatively short growing season. The yearly average amount of sunshine is 59 percent of the possible amount, with 74 percent occurring in July and 72 percent in August.

Tha above climate data is taken from a publication of the North Dakota State Water Commission. Figures 1 through 3 are taken from this same publication, entitled "North Dakota Interim State Water Resources Development Plan".

Figure 1 shows that most of the Forest River Basin may expect between 20 percent and 30 percent of years with less than 16 inches of moisture, whereas significant portions of the Red River Basin are below 20 percent. The figure also shows significantly higher average rainfall in the lower Red River Basin. Figures 2 and 3 show evaporation losses from open tanks. It is thus seen that even in wet years, evaporation exceeds precipitation. This makes large open reservoirs particularly susceptible to losses during drought years. Dissolved solids are bound to increase (see Table 3 and pages 4 and F-4 of Appendix B).

Percent of Years With Less Than 16 Inches of Precipitation

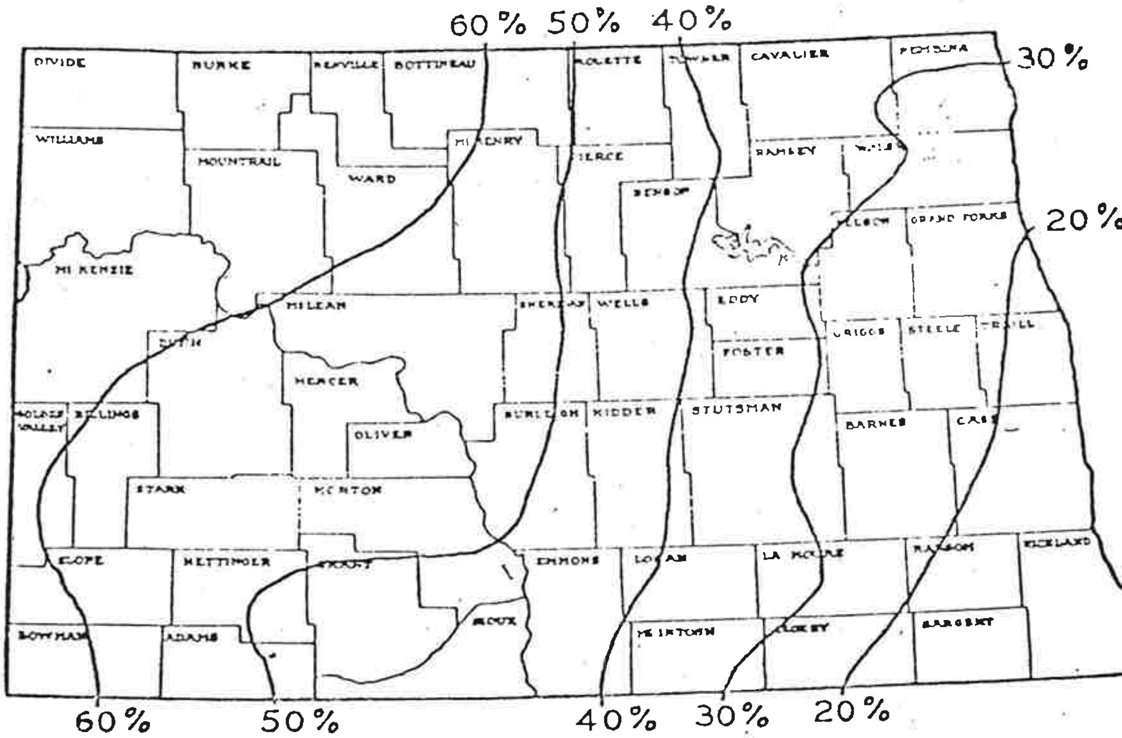


Figure 1

Average Summer Evaporation April - (Inches)
September from Evaporation Tanks

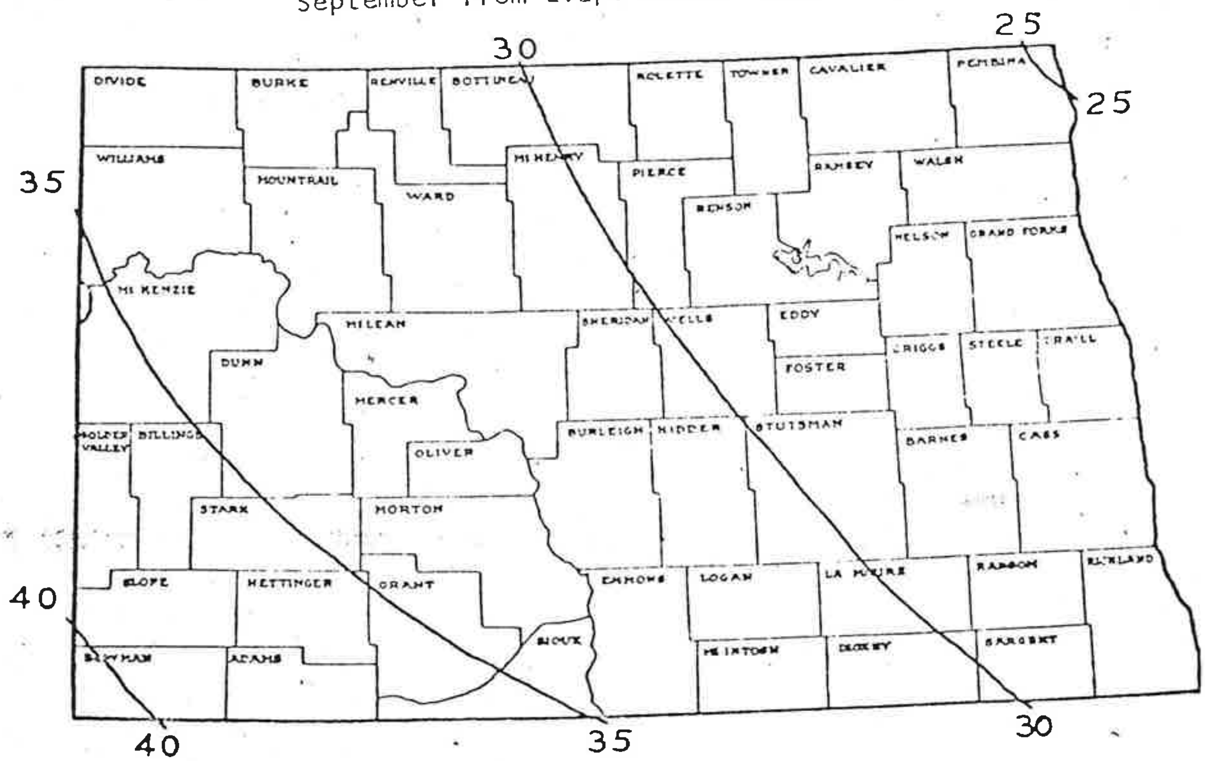


Figure 2

Average Annual Evaporation from Evaporation Tanks (Inches)

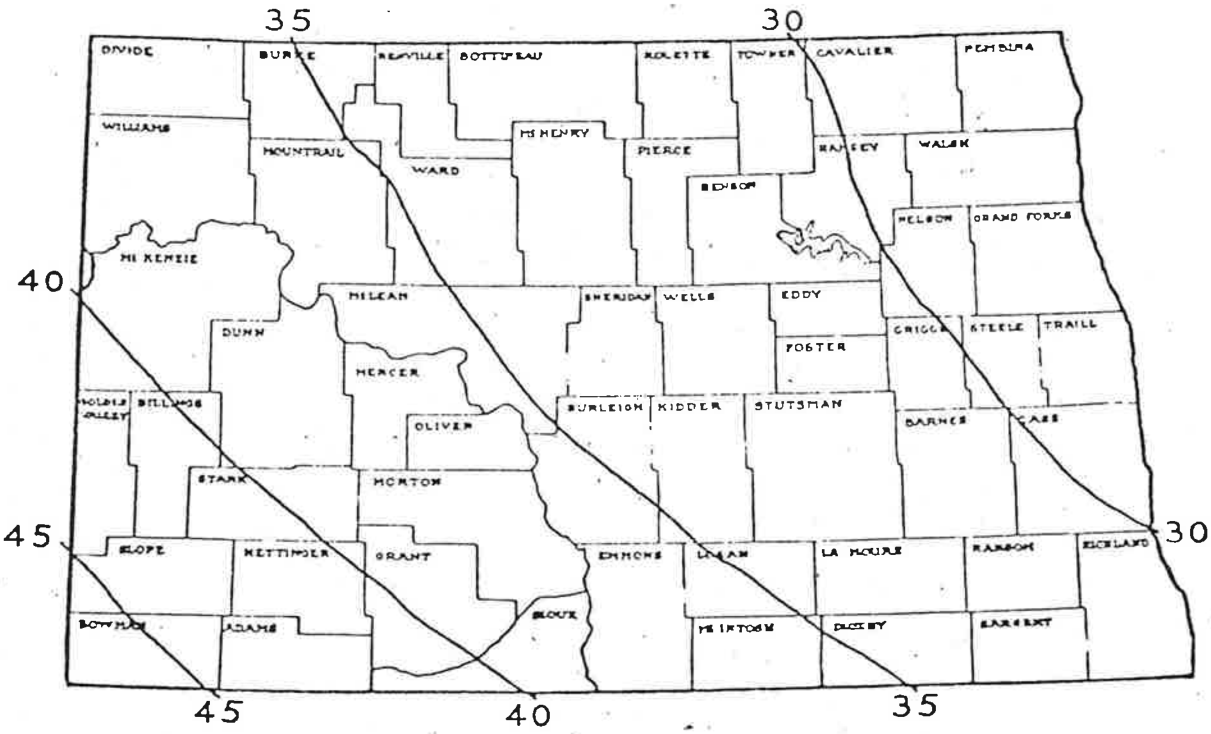


Figure 3

The City of Minto currently obtains its water supply from a small dam on the Forest River and a 2" feeder line from the Walsh County Water User's rural water system. Minto was not allocated water from the rural water system initially but they are currently obtaining approximately 15,000 GPD on off-peak periods. The dam was constructed on the Forest River as a WPA project in 1935. In February of 1973 the dam structure washed out. The State Water Commission put in a steel coffer dam with rock and concrete which is presently serving as a substitute for the original dam. The dam will provide Minto with an adequate water supply during periods of normal flows.

The past year, the City has had to lower their intake structure so they can be assured of having a water supply this winter.

This chapter has shown the problems that Minto has had with their water supply. It poses a definite threat to the health and welfare of the residents. The following chapter will show that the problem is directly related to drought conditions.

CHAPTER III

STATEMENT OF PROBLEM

On April 7, 1977 Governor Arthur Link declared all of North Dakota a drought disaster area by issuing Executive Directive 1977-2. At that time he set the State Drought Contingency Plan into operation. Rains since the date that the executive order was issued have not been sufficient to maintain the water level in the Forest River at a sufficient level to assure Minto of a reliable water supply.

Tables 2 through 7 show daily mean river flows at eight gaging stations within the Red River Basin. Two of these stations are on the Park River (one near Union and one at Grafton). Two are on the Red River (one at Grand Forks and one at Drayton). One of the stations is on the Forest River at Minto. The remainder of the stations monitor rivers within the general area. The size of the drainage area of the Red River makes it meaningless to directly compare flow on the Red River to precipitation in the immediate area of Grand Forks. The precipitation within the area does give a good indication of the runoff and surface water supply of the surrounding area. The following tables of data give a representative picture of the correlation between precipitation and flow. There are many instances where next to no rainfall shows next to no flow. Therefore the lack of surface water within the area can be attributed to the lack of precipitation.

It is obvious that a water supply taken from these surface waters will definitely be drought affected. The only river in the area that would have sufficient flow in periods of severe drought would be the Red River.

The minimum flow for the drought year 1977 is 127 cfs, which is plenty for a small municipal water supply. All flow data contained in this report was obtained from official records published by the U. S. Geological Survey.

TABLE 2

1951 WATER YEAR

ation	Drainage Area Sq. mi.	Daily Mean Flow (cfs except as noted) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Yr. Max.	Yr. Min.
d River, and Forks	30,100	2,720	1,990	2,040	1,930	1,820	2,270	14,400	8,190	4,090	2,250	1,110	1,430	23,600	950
Forest River @ Minto	740	8.41	9.24	4.6	3.6	4.5	31.2	199	27.4	15.5	6.48	9.32	8.42	900	3
uth Branch ver below mme Dam	226	1.37	2.86	1.86	1.6	1.6	8.13	93.7	9.76	3.42	0.96	1.0	36.2	900	0.4
ddle Branch rk Riv. Union	15.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
rt Creek, untain	16.9	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ark River, rafton	695	2.18	1.61	2.11	1.1	0.57	12.1	331	33.8	6.43	0.71	2.98	41.3	1,640	0
d River, rayton	34,800	2,950	1,990	2,010	1,970	1,830	2,280	17,200	9,020	4,470	2,440	1,250	1,710	24,600	1,010
mbina iver, Neche	3,410	152	87.8	37.4	31.5	25.0	38.4	845	513	266	120	67.3	48.6	2,000	23
ngue ver, Akra	162	3.54	2.81	2.07	1.25	1.0	4.57	46.8	5.9	1.91	1.24	0.54	0.58	260	0.4

tation		Precipitation (Inches) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Yearly Total
and Forks		0.47	0.48	0.48	0.59	0.58	0.70	0.68	0.25	2.25	1.28	7.9	1.12	16.78
rafton		0.62	1.06	0.31	0.63	0.80	0.69	0.41	0.68	1.98	1.34	6.32	1.32	16.16
ark River		0.38	0.43	0.27	0.32	0.31	0.20	0.52	0.12	2.12	1.62	5.32	1.2	12.81
mbina		0.42	0.48	0.23	0.13	0.86	0.29	1.01	0.64	1.45	1.22	5.93	1.67	14.33

TABLE 3

1955 WATER YEAR

Station	Drainage Area Sq. mi.	Daily Mean Flow (cfs except as noted) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Yr. Max.	Yr. Min.
Red River, Grand Forks	30,100	640	700	680	720	670	680	5,600	1,710	2,240	2,150	1,580	780	15,400	3
Forest River @ Minto	740	7.01	6.57	4.00	1.31	0.51	0.03	291	22.1	92.4	11.2	2.85	1.69	4,200	0
South Branch River below Homme Dam	226	5.9	3.46	2.0	2.04	2.45	8.58	159	19.6	18.6	6.01	2.31	16.5	1,600	0.
Middle Branch Park Riv.,Union	15.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cart Creek, Mountain	16.9	0.45	0.4	0.14	0	0	5.89	21.3	1.86	1.52	0.28	0	0	392	0
Park River, Grafton	695	4.87	3.92	1.17	0.2	0.2	0.8	445	46.4	76.8	10.5	1.3	11.8	2,100	0
Red River, Drayton	34,800	660	730	680	720	650	660	7,270	2,080	3,020	2,270	1,680	860	18,000	49
Pembina River, Neche	3,410	144	76.5	28.0	10.5	16.1	13.6	1,511	854	579	304	109	57.0	2,700	8
Tongue River, Akra	162	5.54	4.68	1.92	1.23	1.60	1.61	168	18.1	22.5	34.9	2.01	1.95	700	0.7

Station		Precipitation (Inches) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Yearly Total
Grand Forks FAA		0.71	0.69	0.36	0.40	1.55	1.45	0.75	2.86	3.84	4.30	1.89	0.99	19.79
Grafton		0.27	1.02	0.13	0.81	1.45	0.90	1.49	2.79	6.18	2.40	1.37	2.72	21.53
Park River		0.26	0.42	0.05	0.40	0.29	0.77	2.01	3.17	4.74	2.58	1.59	3.24	19.52
Pembina		0.41	0.79	0.06	0.69	1.02	0.85	1.53	2.25	1.34	6.72	1.45	5.26	21.87

TABLE 4

1963 WATER YEAR

Station	Drainage Area Sq. mi.	Daily Mean Flow (cfs except as noted)												Yr. Max.	Y M
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept		
Red River, Grand Forks	30,100	2,334	2,113	1,583	1,305	1,104	1,962	5,767	3,343	6,245	2,459	1,114	1,195	10,700	967
Forest River @ Minto	740	13.2	15.8	4.87	0.95	0.0	42.2	34.5	18.9	22.7	26.5	3.73	0.80	220	0
South Branch River below Homme Dam	226	3.14	1.68	0.99	8.93	9.85	6.37	5.48	2.93	47.1	6 .97	5.55	1.83	209	0.
Middle Branch Park Riv. Union	15.3	--	--	--	--	--	--	--	--	--	--	--	--	--	-
Cart Creek, Mountain	16.9	0.60	0.61	0.14	0	0	2.57	1.74	1.75	8.64	1.98	0.04	0	77	
Park River, Grafton	695	0.25	0.48	0.08	0	0.24	30.3	25.7	8.74	105	17.2	8.83	0	292	
Red River, Drayton	34,800	2,379	2,114	1,602	1,343	1,120	1,743	6,430	3,511	6,511	2,850	1,172	1,197	12,800	9
Pembina River, Neche	3,410	62.2	31.5	22.1	18.4	1.67	91.1	197	192	268	172	127	743	864	0.
Tongue River, Akra	162	9.45	12.8	1.51	4.86	5.22	5.16	11.4	9.5	67.4	17.0	8.44	7.34	200	0.

Station		Precipitation (Inches)												Yearly Total
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	
Grand Forks FAA		0.32	0.37	0.56	0.14	0.22	0.33	1.79	0.94	1.88	3.42	0.69	0.53	11.10
Grafton		0.61	0.74	0.48	0.04	0.31	0.29	1.48	2.02	5.06	4.99	0.75	0.42	17.19
Park River		0.47	0.78	0.45	T	0.51	0.33	1.27	1.91	4.52	2.66	0.74	0.41	14.05
Pembina		0.36	0.76	0.36	0.10	0.44	0.09	0.95	2.62	3.99	4.79	0.59	0.57	15.62

TABLE 5

1969 WATER YEAR

Station	Drainage Area Sq. mi.	Daily Mean Flow (cfs except as noted)												Yr. Max.	Y M
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept		
Red River, Grand Forks	30,100	1,465	1,657	1,608	1,495	1,513	2,111	28,690	12,070	4,518	3,246	1,503	1,432	53,400	1.
Forest River @ Minto	740	8.91	10.9	5.61	0.82	0.41	0.46	522	53.3	20.2	12.3	4.70	5.14	3,330	0.
South Branch River below Homme Dam	226	3.23	2.26	4.95	11.5	13.1	13.0	355	16.4	11.9	3.31	4.25	3.43	2,410	[illegible]
Middle Branch Park Riv.,Union	15.3	0.06	0.04	0	0	0	0	23.1	0.14	0.16	0.05	0	0.01	170	[illegible]
Cart Creek, Mountain	16.9	0.50	0.47	0.04	0	0	0	36.6	1.90	1.00	0.41	0.03	0	300	[illegible]
Park River, Grafton	695	0.16	0.08	0.12	0.08	2.28	8.02	859	30.6	14.5	7.12	0.42	2.25	4,890	
Red River, Drayton	34,800	1,600	1,865	1,660	1,525	1,576	2,153	27,480	18,430	5,060	3,548	1,666	1,471	56,600	1,
Pembina River, Neche	3,410	378	191	56.4	23.3	17.0	23.5	3,146	1,805	622	364	183	121	6,940	12
Tongue River, Akra	162	7.19	9.02	9.03	2.34	3.25	6.34	256	37.3	[illegible]	7.64	1.17	0.56	603	0.

Station	Precipitation (Inches)												Yearly Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	
Grand Forks FAA	0.46	0.18	0.66	1.58	0.54	0.15	0.96	2.09	4.69	1.42	1.97	3.61	18.31
Grafton	0.29	0.19	0.13	0.77	0.51	0.04	0.62	0.80	1.65	1.69	0.57	1.93	9.19
Park River	0.24	0.53	0.94	1.16	1.20	0.02	0.42	1.33	3.34	1.79	0.32	1.88	13.17
Pembina	0.52	T	1.03	1.13	0.62	0.11	1.10	1.91	3.07	1.48	1.81	2.66	14.31

TABLE 6

1976 WATER YEAR

Station	Drainage Area Sq. mi.	Daily Mean Flow (cfs except as noted)												Yr. Max.	Y M
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept		
Red River, Grand Forks	30,100	2,345	2,315	1,772	1,705	1,699	3,704	9,237	2,515	1,556	1,106	976	700	22,900	5
Forest River @ Minto	740	11.1	9.54	3.75	3.60	4.14	108	388	34.6	17.5	8.50	2.90	1.53	1450	0.
South Branch River below Homme Dam	226	2.05	7.76	4.84	6.98	7.73	32.7	188	5.81	46.3	4.78	3.42	2.39	826	0
Middle Branch Park Riv.Union	15.3	0.05	0.05	0.03	0.01	0	0.36	13.3	0.11	4.33	0.02	0	0.01	90	
Cart Creek, Mountain	16.9	0.10	0.12	0	0	0.12	0.52	14.0	0.77	3.35	0.07	0	0	58	
Park River, Grafton	695	0.08	7.36	6.97	5.17	4.55	33.8	542	26.7	81.7	3.69	0.40	0.38	1,700	C
Red River, Drayton	34,800	2,364	2,573	1,724	1,630	1,729	3,298	13,300	3,016	1,914	1,359	1,163	713	44,000	1
Pembina River, Neche	3,410	44.0	28.2	12.0	13.2	15.0	30.7	2,776	1,450	502	252	85.2	41.2	4,370	
Tongue River, Akra	162	1.46	0.56	0.70	3.99	4.56	4.73	142	5.45	30.8	1.79	2.00	1.62	312	0.

Station		Precipitation (Inches)												Yearly Total
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	
Grand Forks FAA		1.88	0.91	0.21	1.48	0.54	1.36	1.10	0.47	3.08	1.87	2.54	0.58	16.02
Grafton		1.04	1.02	0.24	1.08	0.64	0.93	1.12	0.27	1.94	0.13	2.97	0.57	11.95
Park River		1.01	0.40	0.42	0.83	0.45	1.38	2.41	0.53	2.16	0.30	2.64	0.82	13.35
Pembina		0.88	0.21	0.55	0.80	0.48	0.86	1.21	0.56	5.89	1.58	3.18	0.91	17.11

TABLE 7

1977 WATER YEAR

Station	Drainage Area Sq. mi.	Daily Mean Flow (cfs except as noted)												Yr. Max.	Y M
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept		
Red River, Crand Forks	30,100	407	303	213	215	215	494	1,305	791	514	561	240	N/A	2,110	1
Forest River @ Minto	740	1.39	2.19	0.49	0	0	11.0	32.9	18.1	11.0	8.27	4.60	N/A	77.0	0
South Branch River below Homme Dam	226	5.18	6.30	5.70	5.20	5.51	5.64	0.64	0.73	1.65	1.54	1.62	N/A	10	0
Middle Branch Park Riv. Union	15.3	0.07	0.02	0	0	0	0.98	1.24	1.59	0.07	0.18	N/A	N/A	3.6	0
Cart Creek, Mountain	16.9	0	0	0	0	0	0.87	2.50	1.84	0.31	0.83	0	N/A	8.2	0
Park River, Grafton	695	0.23	1.70	2.12	2.13	2.32	6.54	6.73	4.81	1.60	0.13	0.15	N/A	13	
Red River, Drayton	34,800	376	260	140	195	199	424	1,902	929	696	624	245	N/A	3,250	110
Pembina River, Neche	3,410	28.0	14.7	2.53	2.19	2.22	15.3	69.3	80.1	48.9	20.8	5.67	N/A	234	2.
Tongue River, Akra	162	1.22	2.23	1.95	1.72	1.60	7.09	4.02	4.25	3.70	7.84	1.8	N/A	35	1

Station		Precipitation (Inches)												Yearly Total
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	
Grand Forks FAA		0.32	0.03	0.35	0.50	1.41	0.77	0.16	3.55	1.57	3.01		N/A	8.63
Grafton		0.39	T	0.52	0.50	0.58	1.18	0.41	6.00	1.71			N/A	11.29
Park River		0.05	T	0.66	0.43	0.60	1.30	0.28	4.07	3.08			N/A	10.47
Pembina		0.31	T	0.62	0.33	0.43	1.36	0.11	5.71	2.99			N/A	11.86

TABLE 8

MEAN MAXIMUM/MINIMUM FLOW COMPARISONS (CFS)

Station	1951		1955		1963		1969		1976		1977	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
Red River, Grand Forks	23,600	950	15,400	362	10,700	967	53,400	1,060	22,900	513	2,110	127
Forest River @ Minto	900	3.0	4,200	0.0	220	0.0	3330	0.25	1450	0.20	77	0
Middle Branch Park River, Union	--	--	--	--	--	--	170	0	90	0	3.6	0
Cart Creek, Mountain	--	--	392	0	77	0	300	0	58	0	8.2	0
Park River, Grafton	1,640	0	2,100	0	292	0	4,890	0	1,700	0.2	13	0
Red River, Drayton	24,600	1,010	18,000	490	12,800	990	56,600	1,070	44,000	1,010	3,250	110
Pembina River, Neche	2,000	2.3	2,700	8	864	0.1	6,940	12	4,370	11	234	2.0
Tongue River, Akra	260	0.4	700	0.7	200	0.1	603	0.25	312	0.02	35	1

WATER YEAR PRECIPITATION (INCHES)

Station	1951	1955	1963	1969	1976	* 1977
Grand Forks	16.78	19.79	11.10	18.31	16.02	8.63
Grafton	16.16	21.53	17.19	9.19	11.95	11.29
Park River	12.81	19.52	14.05	13.17	13.35	10.47
Pembina	14.33	21.87	15.62	14.31	17.11	11.86

* 9 Months

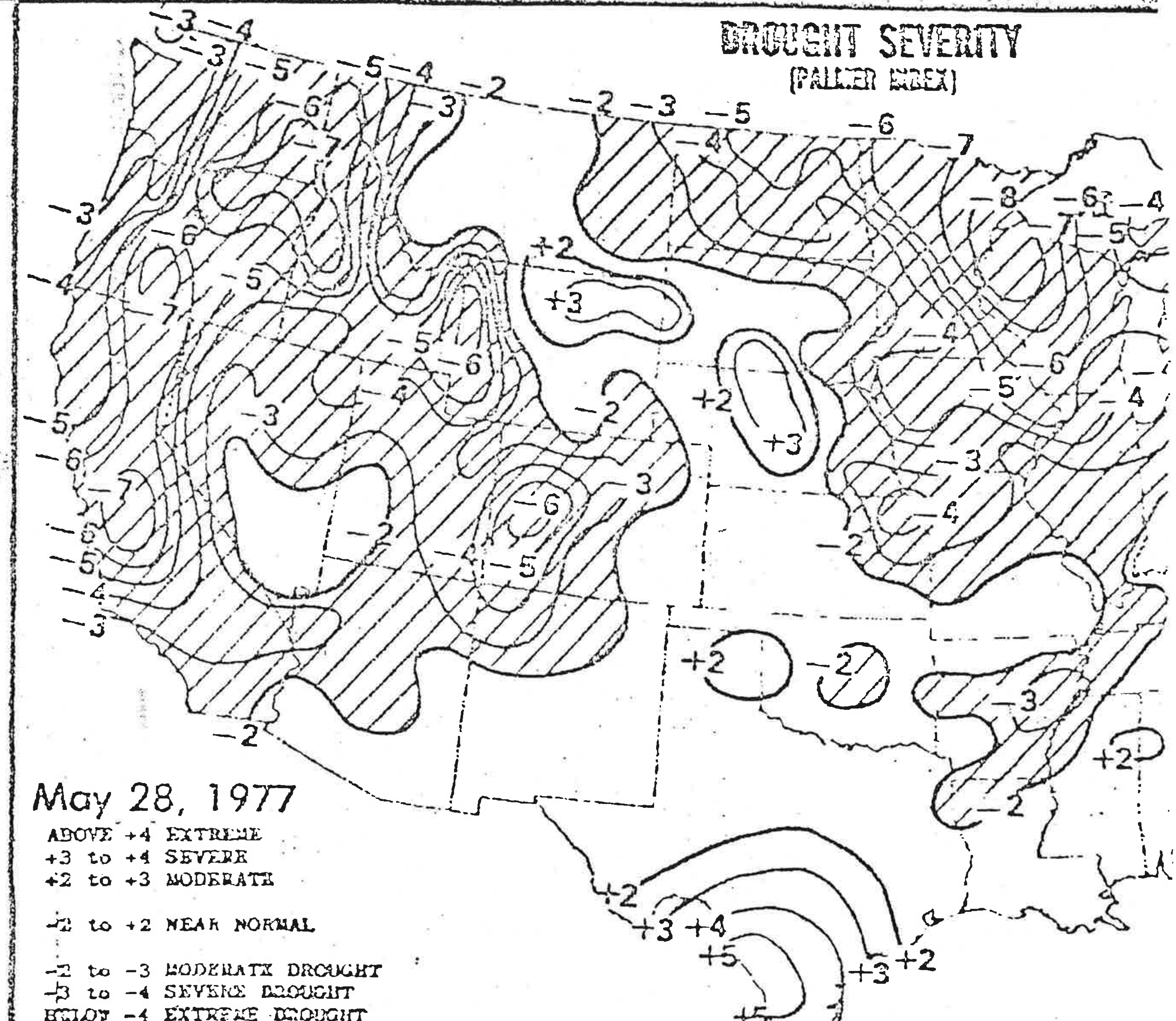
Earlier, it was stated that Governor Link had declared North Dakota a drought disaster area. Further evidence of this is shown by the Palmer Index as published by the U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service. Figure 1 shows the entire State of North Dakota to be in a drought condition, with the Forest River Basin to be in a condition of extreme drought. Appendix A contains a description of the Palmer Index and how it is determined and interpreted. In any case, it certainly substantiates Minto's assertations that their water supply problem is drought related.

Raising the level of the dam would result in the impoundment of more water but it would not insure an adequate water supply during periods of severe drought. There are two sources that could provide sufficient water for the City of Minto during periods of drought. One source is the Fordville Aquifer. The other source is the Red River. These two alternatives will be addressed in the following chapter.

This chapter has clearly pointed out that Minto's water supply is highly drought affected. It has also established the fact that the area is undergoing a severe drought. It has been shown that Minto could possibly be without a raw water supply next summer. This would pose major threats to the health and safety of the citizens of the City. Based on this data, it is imperative that the City immediately seek solutions to the water supply problem.

JUN 7 1977

DROUGHT SEVERITY (PALMER INDEX)



CHAPTER IV

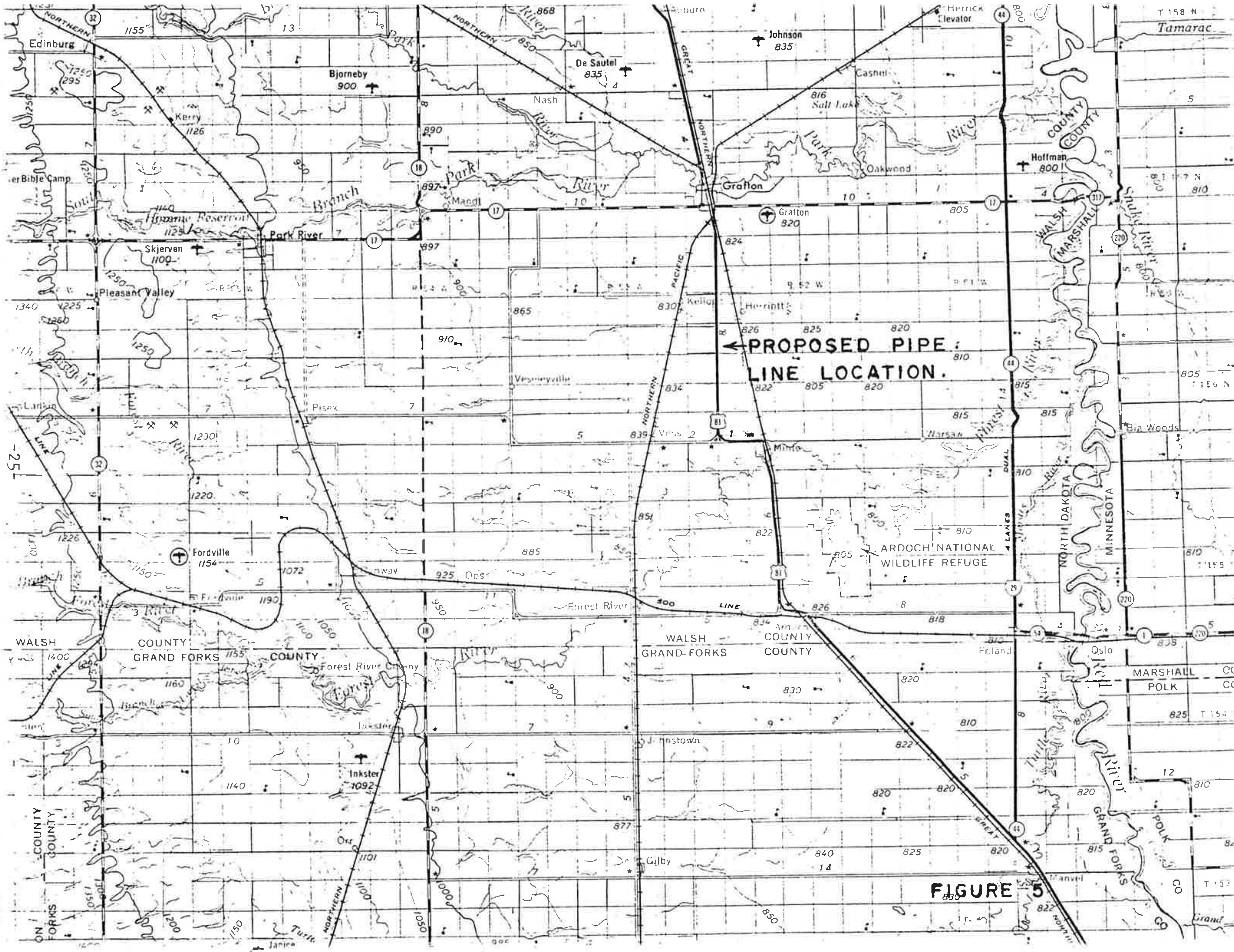
SOLUTION TO PROBLEM

In the past a number of solutions to Minto's water supply problems have been proposed. The most comprehensive study of the problem was conducted by the North Dakota State Water Commission in June of 1975. The study is a feasibility report for flood control and related purposes for the Forest River Basin. Appendix B contains excerpts from that report which pertain to the Minto water supply project. The three most economical alternatives include annexation with the city of Grafton, wells in the Fordville aquifer and the building of a new dam on the Forest River. It has been shown that the building of a new dam would not be a viable alternative because it would not be a reliable supply during periods of drought. The alternative that would obtain water from the Fordville aquifer would involve approximately 21 miles of pipeline in addition to treatment and pumping costs. It would be more economical to purchase water from Grafton because it would involve only nine miles of pipe, they would not have to build a treatment facility, and there would be much less operation and maintenance expense to the city of Minto. Therefore, the most viable alternative is to purchase water from Grafton.

The city of Grafton has been awarded a grant and a loan under the drought emergency fund to build a water supply line to the Red River and expand their treatment facility. For details of the project, refer to the Engineering Report for Drought-Related Problems, Grafton, North Dakota, 1977, as prepared by Richmond Engineering, Inc. of Grand Forks, North Dakota. In this report, there is detailed information showing that the Red River will be a reliable source for a municipal water supply even during periods of low flow.

The city of Minto would be buying treated water from Grafton at a rate established by negotiation between the two entities. Grafton has indicated that they will be willing to supply Minto with whatever water they may need. The city of Grafton has an elevated storage tank 160 feet above ground. With an estimated positive static head of 10 feet for a total head of 170 feet and assuming an estimated head loss of 130 feet the elevated tower could supply Minto with no additional pumping required. The city of Minto currently has a 20,000 gallon on-ground storage reservoir and a 50,000 gallon elevated storage tank. In order to ensure that the city will have sufficient storage to serve the city for one day, an additional storage tank with a capacity of 50,000 gallons will be included in the project. This additional storage would allow Grafton to supply Minto with water during Grafton low-peak periods.

The proposed pipeline will be a 6 inch PVC pipe with a length of approximately nine miles. See Figure 5 for the location of the proposed alignment of the pipeline. This report is only intended as a preliminary guideline to the design of the proposed system. The following Chapter contains an itemization of the estimated project cost.



PROPOSED PIPE LINE LOCATION.
ARDOCH NATIONAL WILDLIFE REFUGE
Edinburg
Bjorneby
De Sautel
Johnson
Herrick Elevator
Auburn
Kerry
Nash
Cashel
Salt Lake
Hoffman
Oakwood
Grafton
Mandt
Park River
Skjerven
Pleasant Valley
Kellogg
Herriott
Vesleyville
Pisek
Veso
Minto
Warsaw
Big Woods
Fordville
Conway
Ops
Forest River
Ardoch
Poland
Oslo
Forest River Colony
Inkster
Johnstown
Gilby
Orr
Manvel
Janice
Tamarac
WALSH COUNTY
GRAND FORKS COUNTY
MARSHALL COUNTY
POLK COUNTY
NORTH DAKOTA
MINNESOTA
NORTHERN PACIFIC
GREAT NORTHERN
SOO LINE
DUAL 4 LANES

FIGURE 5

CHAPTER V

ESTIMATED PROJECT COST

A list of the project components and their respective costs are contained in the following page. This is a preliminary cost estimate. A more refined estimate will be obtained as the project progresses.

PRELIMINARY

COST ESTIMATE

WATER SUPPLY SYSTEM

MINTO, NORTH DAKOTA

Item	Estimated Quantity	Unit	Unit Price	Amount
Metering and Controls @ Grafton Storage Tank	1	L.S.		$ 6,000.00
Pipeline	50,000	L.F.	$3.50	175,000.00
Storage Tank and Appurtenances	1	L.S.		45,000.00
System Controls	1	L.S.		5,000.00
	Estimated Construction Cost			$231,000.00
	Legal and Administrative			5,800.00
	Engineering			18,500.00
	Construction Inspection			16,200.00
	Contingencies			20,800.00
	Interest During Construction			2,900.00
	Estimated Total Project Cost			$295,200.00

APPENDIXES

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
Silver Spring, Md 20910

Date : June 28, 1974

Reply to Attn. of: W111x1

To : Recipients of Technical Procedures Bulletin Series

for A. Sadowski
Duane S. Cooley

From : Chief, Technical Procedures Branch
Weather Analysis and Prediction Division, NWS

Subject: Technical Procedures Bulletin No. 117: REVISED DROUGHT/WETNESS CHART (PALMER INDEX)

This bulletin was prepared by Mr. Alexander Sadowski from information provided by Mr. Lyle M. Denny, Agricultural Weather Support Service Program of the National Weather Service. It revises slightly the previous bulletin.

This bulletin supersedes bulletins Nos. 74 and 87 which should be destroyed.

REVISED DROUGHT/WETNESS CHART (PALMER INDEX)

1. INTRODUCTION

A general drought/wetness index, properly interpreted, can be very useful for agricultural purposes. One such index which measures the degree to which the weather has been abnormally dry or wet is the procedure developed by Palmer (1). The Palmer Index is universal in that persistently normal temperature and precipitation produce an index near zero in all seasons in all climates. The extended period of greatest abnormal dryness of long record produces an index around -6, regardless of the degree of aridity or wetness of the climatic averages of the region being studied; similarly, extreme wet periods produced an index of +4 to +6.

2. DERIVATION OF THE PALMER INDEX

The method requires a climatological analysis of a long record in order to derive five constants which define certain moisture characteristics of the climate of the area of interest. Therefore, the first thing required is a month by month water balance accounting for a long record, such as 30 years or more. Palmer used a 2-layer soil model and the Thornthwaite method of computing potential evapotranspiration; however, other methods could be substituted. Potential values are also derived for runoff, moisture recharge and moisture loss.

Next, the results of the water balance accounting must be summarized so as to produce the five constants for each of the 12 calendar months. One constant, alpha, is the coefficient of evapotranspiration, the ratio of the computed mean monthly evapotranspiration (ET) to the mean monthly potential evapotranspiration (PE). This ratio is near 1.0 in humid climates, but approaches zero in very arid regions. Another constant, beta, the coefficient of recharge, is the ratio of the mean monthly moisture gain (R) to the mean maximum possible gain (PR). The coefficient of loss, delta, is the ratio of mean moisture loss (L) to mean potential loss (PL), where potential loss is the amount of evapotranspiration that would have occurred if no precipitation had fallen during the month. The coefficient of runoff, gamma, is the ratio of computed mean runoff (RO) to mean potential runoff (PRO).* An additional constant, K, is an empirically derived weighting factor which depends on a number of measures of the moisture supply-and-demand characteristics of the climate in question.

Having developed these coefficients, it is possible to compute the amount of precipitation (P) that should have occurred during a particular month to sustain the evapotranspiration, runoff and moisture storage that could be considered as "normal" and appropriate for the climate, having taken account of antecedent moisture conditions. The equation is

$$P = \alpha\, PE + \beta\, PR + \gamma\, PRO - \delta\, PL \qquad (1)$$

where the potential values are those that apply to the particular time in question.

This computed precipitation is, in fact, an adjusted normal precipitation, the adjustment being dependent on the antecedent weather as reflected by the computed moisture storage, and on the anomaly of the potential evapotranspiration during the month in question. Over the long term the mean of the computed precipitation is equal to the mean of the actual precipitation. But, for a particular month the actual precipitation minus the computed precipitation provides a measure (d) of the degree to which the month was abnormally wet or abnormally dry. When multiplied by the weighting factor K, the moisture anomaly index.

$$Z = Kd \qquad (2)$$

provides a measure which is comparable in space and time.

Inasmuch as a succession of months, most of which were abnormally dry, produces a drought of gradually increasing severity, the final drought index (X) depends on the sequence of Z values. These were combined by the empirical equation

$$X_c = .897\, X_p + Z_c/3.0 \qquad (3)$$

where the subscript c refers to the current month in question and p refers to the previous month.

---

* Palmer used PRO = Avail. Water Capacity − PR, but indicated PRO could be defined as $3\bar{P}$ − PR, where $\bar{P}$ = normal monthly precipitation.

Results from the analysis of a long record provide a series of monthly index values which, in general, range from around + 6 to - 6. The positive values provide realistic measures of the degree of unusualness of extended periods of abnormally wet weather. The completed analysis breaks the meteorological record into separate periods of either abnormal drought, near normal, or abnormal wetness. The following table lists the descriptive terms which have been assigned to describe the character of the weather represented by various intervals of the index. The descriptive terms refer to departures from the normal moisture climate of the area for an extended period of past weather.

INDEX	CHARACTER OF RECENT WEATHER
4.00 or more	Extremely wet
3.00 to 3.99	Severely wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	
.50 to .99	
.49 to -.49	Near normal
-.50 to -.99	
-1.00 to-1.99	
-2.00 to-2.99	Moderate drought
-3.00 to-3.99	Severe drought
-4.00 or less	Extreme drought

3. OPERATIONAL PROCEDURE

This procedure has been widely used in the United States and in some other areas of the world. Results are reported as being realistic in all areas. The procedure is mathematically simple, but it is involved and tedious. When done by hand, it is slow and time consuming, but where computers are available, results can be attained quickly and rather inexpensively. The method is better suited for climatological analysis than for operational use. However, during periods when a major moisture anomaly is developing and spreading, it affords a useful means for routinely assessing the areal distribution of the various degrees of drought or moisture. In the United States this is done on a weekly basis during critical situations. Of course, some of the original constants and equations are modified in order to treat weekly rather than monthly data.

These weekly computations are made by electronic computer at the National Climatic Center (NCC) at Asheville. The computations are based on weekly temperature and rainfall observations over all 344 climatological divisions in the conterminous United States. Most states have 7 to 10

ı divisions. The temperature observations are used to estimate the
e at which moisture was evaporated, and the rainfall measurements
icate the replenishment of the moisture supply. This "water balance
ounting," done weekly, provides estimates of the amount of water
ored" in each climatological division.

the basis of these moisture supply-and-demand figures, we compute the
rameters, PE, PR, PRO, and PL, which when introduced in equation (1)
eld the amount of rainfall (P) that should have occurred over each divi-
on each week to sustain the evaporation, runoff, and moisture storage
ich could be considered as "normal" and appropriate for the climate and
ather of each area. Solutions of eqs. (2) and (3) then give the drought
ıdex (X).

DEPICTION

ıe Palmer Index Chart will be transmitted generally late Tuesday at 2355Z
ı NAMFAX in slot A201N and early Wednesday at 0115Z on NAFAX in slot N6
uring critically dry or wet situations. The chart is transmitted during
pril through September. The conditions depicted on the chart are repre-
entative of the week ending the previous Saturday.

Areas will be depicted on the chart according to the descriptive terms in
the table on page 3. These descriptive terms will also be included in a
legend on the chart. Mild drought (-1.00 to -1.99) and mild wetness
(+1.00 to +1.99) will be optionally depicted. Different stippling of dry
and wet areas will be optional as preparation time permits. A narrative
will be on the chart giving the relevant highlights of the week. An example
of a chart is shown on page 5.

5. INTERPRETATION

When abnormally dry weather continues in a given area week after week with
only minor interruptions, the Palmer Index (X) becomes negative, indicating
drought conditions. If the abnormally dry weather continues more or less
uninterrupted for a long time, the drought becomes progressively worse, and
severity goes from "mild" to "moderate," through "severe" and finally to
"extreme."

From time to time one finds drought or wetness of similar severity occurring
in two regions which have very dissimilar climates - New Jersey as opposed
to eastern Oregon, for instance. In effect, the climates n both areas will
have been temporarily more arid or moist than usual. Each area, in its own
way, becomes disrupted by the unusual dryness or wetness. For example,
extreme drought in New Jersey might well lead to reports of low water tables,
deficient streamflow, depleted reservoirs and, now and then, serious short-
ages of soil moisture. On the other hand, one could expect extreme drought
in eastern Oregon to produce complaints of dry ranges, critical fire danger,
and a shortage of water for irrigation and livestock. The opposite of these
conditions would be evident in the case of extreme wetness. Thus, the many
and varied effects of a prolonged period of abnormally dry or wet weather
depend on the climatic averages and the established activities in the affected
areas.

ore recently, the wet anomaly of the Palmer Index is being used to haracterize areas of excessive rainfall. It should be noted that inasmuch s the index values indicate departures from the normal moisture climate, a igh positive value does not necessarily indicate muddy surface soils. The esulting maps are, of necessity, generalized. Local differences caused by he occurrence or absence of heavy showers cannot be determined or shown on uch maps. Similarly, within a general drought area, those localities which ave received a few showers have a slightly less serious drought situation han shown on the map. At the same time, the driest localities in the area ave a somewhat greater drought severity than the maps indicate. The important nformation, both meteorologically and economically, is the overall picture f extensive areas subjected to unusually dry or wet weather.

. HISTORICAL DROUGHT/WETNESS SEVERITY DATA

ıe Palmer Index has been computed for each month from January 1931 (January 929 in the northeastern U.S.) to date for each of the 344 climatological ivisions of the U.S. and 6 divisions in Puerto Rico. The final index values ɔr each month for each division are on magnetic tape at NCC in Asheville. ıta for about 12 states have been published and are being prepared for ıblication in a number of others.

ı addition, the monthly records from some 50 individual stations have been ıalyzed. Many of these start around 1900 or earlier, but few are more ırrent than about 1967. In response to special requests NCC has also carried ıt many years of weekly analyses for the March-October period at a number stations, as well as the preliminary weekly analysis by climatological visions which has been done since 1966.

. REFERENCE

Palmer, W.C., "Meteorological Drought, "U.S. Weather Bureau Research search Paper No. 45, 1965, 58 pp. (Limited supply is available at the ;ricultural Weather Support Service Program, W115x3.)

ALTERNATIVE WATER SUPPLY FOR THE CITY OF MINTO

Municipal Water Supply

Six alternatives were investigated for supplying water to the city of Minto; two using water directly from the Forest River, two using ground-water supply and two using water from the Red River. All water system alternatives were based on population estimated at 750 by 2020, and an average daily consumption of 100,000 gal/day. The present average daily consumption is 55,000 gal/day and a peak demand of 80,000 gal/day. The present water plant and distribution system has a rated capacity of 150 gpm (216,000 gpd) with a storage capacity of 70,000 gallons. The treatment plant is in good condition and is presently treating for hardness and biological agent.

Presently the city of Minto has a two inch feeder line to the existing Walsh County Rural Water District line, one mile north of the city. The pipeline north of Minto is a four inch line and does not have the capacity to meet existing or projected needs of Minto.

Alternative 1: Main Stream Forest River at Minto

The city of Minto currently receives its municipal water supply from the main stream of the Forest River. The water is stored within the channel of the Forest River by a lowhead channel dam. The existing dam is in a state of temporary repair and construction of a new dam has been proposed.

A new dam could be constructed at one of three sites: (1) the existing dam site; (2) 100 feet upstream from the existing site, and (3) 2,200 feet downstream from the existing site, Figure C-5. The capacity of these impoundments at control elevation 808.0 are:

The existing site	48 acre-feet
The upstream site	47 acre-feet
The downstream site	68 acre-feet

The dam would be a low-head reinforced concrete channel dam designed with a capacity sufficient to handle the bank full flood stage without creating any backwater effect.

Upgrading of a dam on the Forest River would require construction of new intake facilities for municipal water supply. Estimated costs for a dam and related facilities are $406,000 with annual operation and maintenance costs totaling $1200.

Alternative 2: Fordville Aquifer

As previously mentioned, the Fordville aquifer is 21 miles west of Minto and is the largest and most productive glacial-drift aquifer in Walsh County, Figure C-6. Ground-water withdrawals from the Fordville aquifer are by wells. A well field consisting of 10 wells, each capable of producing 144,000 gpd, has been installed in the northern part of the aquifer by the U. S. Army for the purpose of supplying water to military installations. The city of Fordville, near the south end of the aquifer, pumps about 30,000 gpd. The total well pumpage for all purposes including farm use probably is small compared to the quantities that are being discharged naturally.

The aquifer-test data and test drilling indicate that yields of more than 500 gpm are obtainable from the northeastern part of the Fordville aquifer. Based on an areal extent of 33 square miles, an average saturated thickness of 20 feet and a storage coefficient of 0.15, about 63,000 acre-feet of water is in storage.

Water from the Fordville aquifer is a calcium sodium bicarbonate type of relatively good quality. Dissolved solids range from 315 mg/l to 595 mg/l.

Based on studies by the North Dakota State Water Commission additional development of the Fordville aquifer for the Minto city water supply is feasible. The system serving Minto would have two production wells located in the north-eastern portion of the aquifer with a rated capacity of 75 gpm for each well. Pumping and control facilities would be constructed at the Fordville site. Twenty one miles of four inch plastic pipe would be required to connect the well field to the city of Minto. Roadway right-of-way would undoubtedly have to be purchased for pipeline construction. The estimated cost for this plan is $211,000 with operating and maintenance averaging $2,700 per year. Project location is shown on Figure C-6.

Alternative 3: Red River Direct to Minto

This alternative involves the diversion of water from the Red River of the North twelve miles east to Minto. A lowhead dam would be constructed on the Red River to provide a pumping pool. A pumping station with a rated capacity of 150 gpm (two 75 gpm pumps) would be constructed adjacent to the river and within the pumping pool. In addition, two pumps would be installed to increase the reliability of the system and a telemetering system installed to provide for constant monitoring at the city water works. A four inch plastic line running east from the pumping station, parallel to existing roadways, would connect the pump site to Minto's existing treatment plant, Figure C-7. The water quality in the Red and Forest Rivers is basically the same; therefore, the present treatment system should be adequate to treat water from the Red River. The estimated costs for this alternative are $566,000 with annual operating and maintenance costs averaging $3700.

Alternative 4: City of Grafton

At the present time the city of Grafton is considering installing a water supply system from the Red River. The proposed plan would involve construction of a check dam on the Red River to serve as a pumping forebay, pumping facilities and a 20-inch, 14 mile pipeline to deliver water to the water treatment plant at Grafton. The system would provide Grafton with an assured supply of 1.6 million gallons per day. The estimated cost of this system is $3,100,000 plus an additional $500,000 to upgrade the water treatment plant.

Construction of this diversion system may allow the city of Minto to purchase treated water from Grafton. Minto would have to construct a pipeline from Grafton to the existing distribution system. A four inch line could parallel existing roadways between Grafton and Minto, as shown in Figure C-8 The estimated costs for the pipeline are $73,000 with average annual operation and maintenenace costs of $500. The estimated average monthly cost for treated water delivered to the city of Minto is $1200 at a rate of 100,000 gpd. This does not include any charges for the water which Grafton may choose to apply.

Alternative 5: Desalination of Ground Water

The Dakota Formation which underlies the Minto area is a possible water supply source; however, the water from this aquifer is highly saline, a T.D.S. of 4,000 mg/l, and would require desalination. The reverse osmosis process was used to estimate the cost of this alternative.

The salt brine from the desalting process could be disposed of by expanding the current sewage lagoon system. The estimated costs for this project are $550,000 with annual operating and maintenance costs averaging $46,000.

Alternative 6: Upstream Reservoir

The Soil Conservation Service has constructed six reservoirs and plans to construct one additional reservoir in the upper reaches of the Forest River. Of these seven reservoirs, only three have sufficient storage to meet Minto's requirements of 111 acre-feet per year. Whitman Dam, 41 miles southwest and Matejcek Dam, 31 miles southwest of Minto, have sufficient storage to meet Minto's present and future needs.

Dam No. 4 located on the Middle-South Branch of the Forest River in the SE¼ Section 6 and the NE¼ Section 7, Township 154 North, Range 55 West, in Grand Forks County, is scheduled for construction in 1976. The structure is primarily flood control and recreation. However, the dam could provide municipal water supply to the city of Minto. A pumping station would be located along the reservoir above the maximum pool elevation. A plastic pipeline would connect the pumping plant at the dam site to Minto's existing treatment plant. The line would make use of existing road rights-of-way wherever possible. The estimated cost for this alternative is $320,000 with average annual operation and maintenance costs of $5000.

Summary of Water Supply Alternatives for the City of Minto

As previously stated, the city of Minto receives its municipal water supply from the impoundment of water by a lowhead channel dam on the Forest River. This dam is in poor condition and in danger of failing. Also, groundwater sources at Minto are not considered adequate for domestic use. Therefore, based on the existing water supply problems at Minto and the projected water supply demands, development of a new source for water supply is needed. Of the water supply alternatives identified and evaluated the Fordville Aquifer, and the city of Grafton are the most economical sources and both have very little effect on the natural environment. However, the costs and charges identified for the city of Grafton alternative do not include any charges for the water which Grafton may choose to apply.

Considering all water resource planning objectives, either the pipeline from Grafton or a pipeline from the Fordville Aquifer would provide the best single-purpose water supply alternatives.

COORDINATION

The study findings and the conclusions that further investigation by the Corps of Engineers was not warranted at this time were presented and discussed at a public meeting in Minto, North Dakota, on 7 May 1975. The general conclusions reached at this public meeting were that (a) action should be taken to adopt and enforce a sound floodplain regulation and flood insurance program, (b) local interests should continue to work through the North Dakota State Water Commission to obtain an assured water supply.