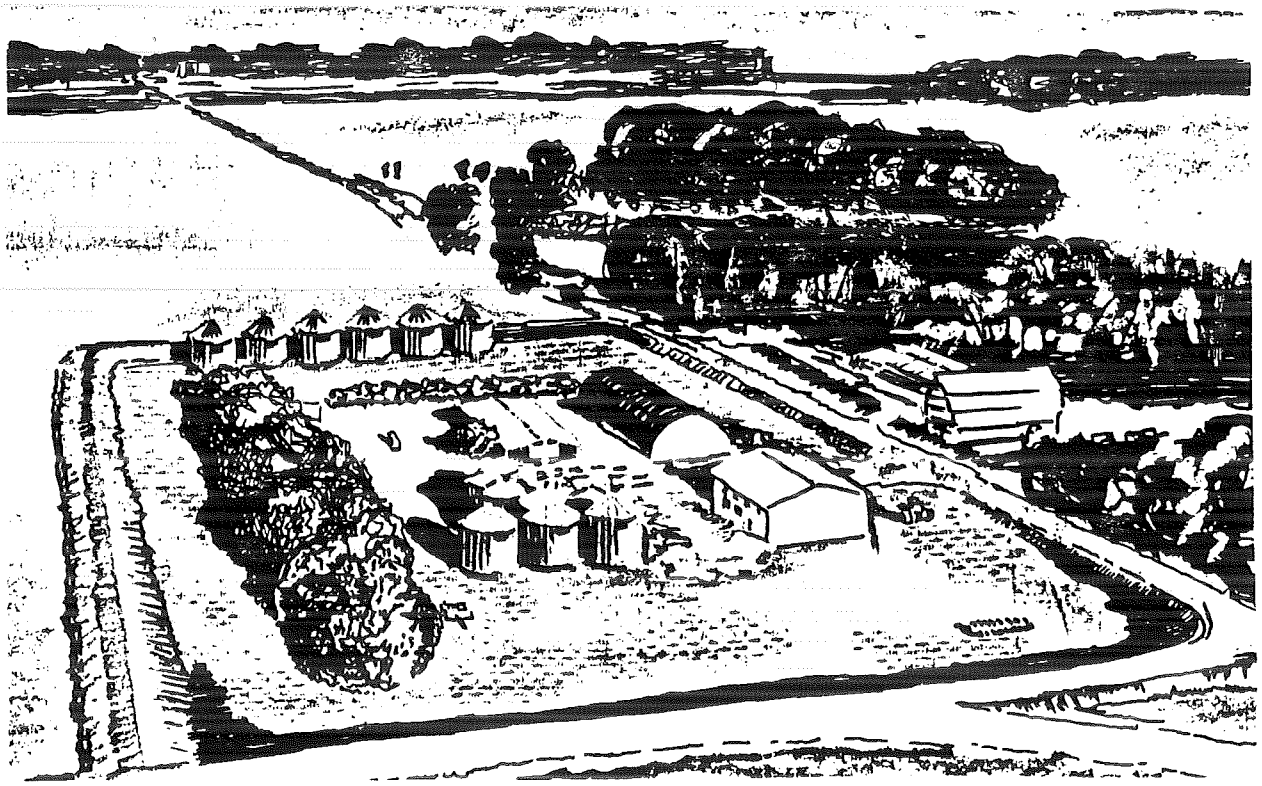
US Army Corps
of Engineers
St. Paul District

July 1985

Feasibility Report

Supporting Documentation



Red River of the North
Walsh and Pembina Counties, North Dakota
Farmstead Flood Protection

RED RIVER FARMSTEAD LEVEES

HYDROLOGY

HYDROLOGY

TABLE OF CONTENTS

ITEM	PAGE
CLIMATE	1
DRAINAGE AREA	1
RUNOFF AND STREAMFLOW DATA	2
HISTORICAL FLOODS AND RAINFALL EVENTS	4
FLOOD FREQUENCY	7
UNIT HYDROGRAPHS	16
PROBABLE MAXIMUM PRECIPITATION AND SNOWMELT	26
PROBABLE MAXIMUM RUNOFF	28
PROBABLE MAXIMUM FLOOD	29
STANDARD PROJECT FLOOD	35

TABLES

NUMBER		PAGE
1	MEAN ANNUAL AND EXTREME TEMPERATURES FOR RED RIVER OF THE NORTH BASIN	1
2	DRAINAGE AREAS ABOVE EMERSON RED RIVER OF THE NORTH	3
3	HISTORIC PEAK FLOOD ELEVATIONS AND DISCHARGES FOR THE REDRIVER MAIN STEM	6
4	STATIONS AND PERIODS OF RECORD USED IN THE RED RIVER MAIN STEM ANALYSIS	7
5	MEAN LOGS, STANDARD DEVIATIONS, AND EQUIVALIENT LENGTHS OF RECORD	8
6	FREQUENCY CURVE DATA RED RIVER OF THE NORTH USGS GAGING STATIONS	9
7	PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTANTANEOUS PEAK FLOWS AT WAHPETON, NORTH DAKOTA	10
8	PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTANTANEOUS PEAK FLOWS AT FARGO, NORTH DAKOTA	11
9	PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTANTANEOUS PEAK FLOWS AT HALSTAD, MINNESOTA	12
10	PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTANTANEOUS PEAK FLOWS AT GRAND FORKS, NORTH DAKOTA	13

11 PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTATNANEOUS PEAK FLOWS AT DRAYTON, NORTH DAKOTA 14

12 PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTANTANEOUS PEAK FLOWS AT EMERSON, MANITOBA 15

13 RED RIVER OF THE NORTH 12-HOUR UNIT HYDROGRAPHS FOR AREA AVOVE EMERSON - CFS 18

14 PMP AT FARGO, TOTAL RUNOFF AVAILABLE FOR UNIT HYDROGRAPHS 15 MARCH STORM CENTERED OVER LAKE TRAVERSE 30

15 PMP AT GRAND FORKS, TOTAL RUNOFF AVAILABLE FOR UNIT HYDROGRAPHS 15 MARCH STORM CENTERED OVER HALSTAD TO WAHPETON 31

16 PMP AT OSLO, TOTAL RUNOFF AVAILABLE FOR UNIT UNIT HYDROGRAPHS 15 MARCH STORM CENTERED OVER HALSTAD TO WAHPETON 32

17 PMP AT DRAYTON, TOTAL RUNOFF AVAILABLE FOR UNIT HYDROGRAPHS 15 MARCH STORM CENTERED OVER HALSTAD TO WAHPETON 33

18 PMP AT EMERSON, TOTAL RUNOFF AVAILABLE PER UNIT HYDROGRAPHS 15 MARCH STORM CENTERED OVER HALSTAD TO WAHPETON 34

19 RED RIVER OF THE NORTH PROBABLE MAXIMUM FLOOD PEAK DISCHARGES 35

20 ADOPTED PMF AT FARGO WITH SUBAREA FLOWS ROUTED TO FARGO 36

21 ADOPTED PMF GRAND FORKS WITH SUBAREA FLOWS ROUTED TO GRAND FORKS 38

22 ADOPTED PMF AT OSLO WITH SUBAREA FLOWS ROUTED TO OSLO 41

23 ADOPTED PMF AT DRAYTON WITH SUBAREA FLOWS ROUTED TO DRAYTON 43

24 ADOPTED PMF AT EMERSON WITH SUBAREA FLOWS ROUTED TO EMERSON 45

25 RED RIVER OF THE NORTH SPF PEAK DISCHARGES 47

PLATES

NUMBER

1 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH AT WAHPETON, NORTH DAKOTA

2 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH AT FARGO, NORTH DAKOTA

3 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH AT HALSTAD, MINNESOTA.

4 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH AT GRAND FORKS, NORTH DAKOTA

5 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH AT OSLO, NORTH DAKOTA

6 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH AT DRAYTON, NORTH DAKOTA

7 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH AT EMERSON, NORTH DAKOTA

8 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH AVOVE RED LAKE RIVER

9 DISCHARGE-FREQUENCY CURVE, RED RIVER OF THE NORTH BELOW SHEYENNE RIVER

10 STANDARD PROJECT FLOOD, RED RIVER OF THE NORTH AT FARGO, NORTH DAKOTA

11 STANDARD PROJECT FLOOD, RED RIVER OF THE NORTH AT OSLO, MINNESOTA

12 STANDARD PROJECT FLOOD, RED RIVER OF THE NORTH AT DRAYTON, NORTH DAKOTA

13 ADOPTED STANDARD PROJECT FLOOD, RED RIVER OF THE NORTH AT EAST GRAND FORKS, MINNESOTA

14 STANDARD PROJECT FLOOD, RED RIVER OF THE NORTH AT EMERSON, NORTH DAKOTA

HYDROLOGY

CLIMATE

The climate in the Red River basin is characterized by wide variations in temperature with moderate precipitation. The average annual temperatures for various locations within the basin are shown in table 1. The average length of the growing season is about 126 days.

Average annual precipitation in the Red River Valley varies from 19 inches in the northwest portion of the basin to 22 inches in the southeast. Most of this precipitation occurs during the frost-free part of the year, from May through August. Spring snowmelt, especially when accompanied by rainfall, causes serious flooding problems within the basin.

Table 1

MEAN ANNUAL AND EXTREME TEMPERATURES FOR
RED RIVER OF THE NORTH BASIN

Station	Years of Record(1)	Mean Annual	Temperature Maximum	(°F) Minimum
Pembina, N.D.	107	37.8	109	-44
Crookston, N.D.	98	40.7	114	-48
Ada, MN	88	39.7	111	-53
Hillsboro, N.D.	74	40.8	115	-40
Wahpeton, N.D.	87	42.8	111	-44

(1) Through 1980.

DRAINAGE AREA

The Red River of the North drains an area of 40,200 square miles above Emerson, at the US-Canada border. This drainage area was subdivided into two portions: contributing (effective) drainage area, and noncontributing (includes closed basins) drainage area. The effective

drainage area was also divided into two portions, primary and secondary drainage areas. These areas are defined as follows:

a. Primary contributing drainage area is that area with a direct watercourse to the main stem of the river.

b. Secondary contributing drainage area is that area which begins to contribute when a flood of about 50-year frequency occurs. For this area, some amount of initial loss should be applied in addition to a lag time which is dependent on the distance from the main stem. The 50-year frequency flood was chosen as a limit because most of the observed floods are below the 50-year level. The boundary between primary and secondary contributing areas was determined by assuming the secondary contributing area to be inclosed by a 5-foot contour line on 7.5-minute series topographic maps.

c. The noncontributing drainage area is that area which does not contribute to flow, and is similar to the term "closed area" as used by the USGS. The noncontributing area is assumed to be inclosed by a 10-foot or more contour line on the 7.5-minute topographic map.

The drainage areas as used in this study are listed on table 2. These drainage areas were obtained from other studies, and in some cases, are only approximate. Detailed studies have not been completed for all of the sub-basins at this time.

RUNOFF AND STREAMFLOW DATA

Streamflow data are currently being obtained by the USGS at several gaging stations for the drainage area above Emerson. In addition, the Corps maintains stations at Baldhill Dam, Lake Traverse, Orwell Dam and Red Lake Dam, while the National Weather Service maintains many staff gages throughout the basin for use during periods of flooding.

Streamflow is low during the winter season; some of the Red River tributary rivers and streams have no flow for long periods during the

Table 2

DRAINAGE AREAS ABOVE EMERSON
RED RIVER OF THE NORTH

Location	DRAINAGE AREA IN SQUARE MILES				
	Primary +	Secondary =	Effective	Non-Contributing	Total
Below Lake Traverse	1,160	-	1,160	-	1,160
Local at Wahpeton	1,020	-	1,020	-	1,020
Ottertail below Orwell	245	-	245	1,585	1,830
Wild Rice at Abercrombie, ND	1,370	120	1,490	590	2,080
Local at Fargo	710	-	710	-	710
Sheyenne River Basin					
Above Kindred	2,680	1,770	4,450	4,350(2)	8,800
Local at West Fargo	70	-	70	-	70
Maple at Mapleton	1,250	130	1,380	70	1,450
Rush at Amenia	116	-	116	-	116
Buffalo at Dilworth	840	200	1,040	-	1,040
Wild Rice at Hendrum	1,400	200	1,600	-	1,600
Local at Halstad(1)	1,924	-	1,924	-	1,924
Goose at Hillsboro	1,040	50	1,090	110	1,200
Red Lake River Basin					
Above High Landing	350	-	350	1,950	2,300
Thief at Thief River Falls	140	820	960	-	960
Clearwater @ Red Lake Falls	1,220	150	1,370	-	1,370
Local at Crookston	575	75	650	-	650
Local at East Grand Forks(3)	1,820	-	1,820	-	1,820
Local at Oslo	1,075	-	1,075	25	1,100
Local at Drayton	3,565	-	3,565	35	3,600
Pembina River at Walhalla	1,770	1,540	3,310	-	3,310
Local at Emerson(4)	2,050	-	2,050	40	2,090
TOTAL AT EMERSON	26,390	5,055	31,445	8,755	40,200

(1) The local drainage area at Halstad includes the Elm River.
(2) Includes the closed basin of Devils Lake.
(3) The local drainage area at East Grand Forks includes the Marsh and Sandhill Rivers.
(4) The local drainage area at Emerson includes the Two Rivers, Tongue River, and the Pembina River below Walhalla.

winter months. The streamflow rises in late March and April, usually reaching the highest flow of the year in April. The flow then recedes slowly throughout the summer until fall when the flow is again rather low. The average discharge of the Red River at East Grand Forks is 2,535 cfs. Extremes in recorded flow have varied from about 85,000 cfs in 1897 to 1.8 cfs in 1977. The low flow in 1977 was caused by unusual regulation during the repair of the dam at Grand Forks.

HISTORICAL FLOODS AND RAINFALL EVENTS

The topography of the Red River Valley is an important factor influencing flood occurrences. High flows are normally confined within the deeply entrenched tributary channels in the escarpment and beach ridge areas, but as the stream slopes become more mild and the tributary channels combine with the Red River main stem, the channel capacity decreases. This is particularly true in the flat valley area near the study area, where floodwaters escape the channel and move overland, inundating thousands of acres of farmland and even entire communities. Snow and ice accumulations in stream channels and ice jams, especially at river bridges and constricted reaches, often increase upstream river levels causing localized flooding. Standing and fallen trees and brush and sediment deposition within channel banks also tend to reduce the flow-carrying capacities of streams and ditches. Even wind-blown silt may accumulate in ditches and channels, further reducing the flow-carrying capacities.

Summer floods are characterized by high peak flows on the tributaries, but much less runoff volume than the spring snowmelt floods. The lesser runoff volumes are usually not sufficient to cause major flooding of the Red River. However, in 1975, a significant summer storm which was centered near Fargo, North Dakota - Moorhead, Minnesota, and near Crookston, Minnesota, caused a considerable amount of runoff, flooding farms on the Red River main stem.

The northward flow direction of the Red River is another unique and important element which often influences the magnitude of main stem

floods. Warming spring temperatures which produce snowmelt runoff normally progress slowly from the southern headwaters portion of the basin toward Canada. Hydrologic analysis of past tributary and main stem flood peaks indicates that local and tributary runoff, particularly in the southeastern quadrant of the basin (study area), often tends to synchronize with the Red River main stem flood peak stage and increases the volume. Also, spring floods from melting snow begin in the headwaters and flow into an area that may be blocked by the winter ice cover. The channel ice causes backwater and localized increases in flood stages.

River gaging data covering flood occurrences prior to 1873, when a river gage was established at Grand Forks, are not available in the United States. However, early records maintained near Winnipeg, Manitoba, indicate that several major floods occurred in the 1800's. The most notable of these were the 1826, 1852 and 1861 floods which exceeded by several feet the greatest floods of this century at Winnipeg. The flood of 1826 destroyed nearly all settlements in the valley and delayed further settlement for many years.

High-water marks, stage records and flow measurements recorded at Oslo, Drayton, and Emerson, Manitoba, since 1873 reveal that major flooding occurred generally in this reach of the river in 1882, 1883, 1893, 1897, 1916, 1943, 1947, 1948, 1950, 1952, 1965, 1966, 1969, 1970, 1972, 1974, 1975, 1978 and 1979. All of these floods, except those of 1965 and 1975, were caused by spring snowmelt. The 1965 flood was triggered principally by heavy widespread rainfall on deeply frozen soil. The greatest recorded floods in the United States portion of the basin were those of 1897, 1950 and 1979.

Historic peak flood elevations and discharges for the Red River of the North main stem within the study area are given in table 3.

Table 3

HISTORIC PEAK FLOOD ELEVATIONS AND DISCHARGES FOR THE RED RIVER MAIN STEM[1]

	Gage Location											
	Oslo (2)				Drayton (3)				Emerson (4)			
Year	Date	Gage Height (feet)	Elevation (cfs)	Peak Discharge (cfs)	Date	Gage Height (feet)	Elevation (cfs)	Peak Discharge (cfs)	Date	Gage Height (feet)	Elevation (cfs)	Peak Discharge (cfs)
1882		35.9	808.6							88.7	788.7	
1883												
1893												
1897		36.6	809.3		Apr	42.4	797.4			90.0	790.0	
1916		35.5	807.2						24 Apr	86.5	786.5	46,200
1943	13 Apr	29.16	806.81	27,300	17 Apr	33.6	790.1	28,700	20 Apr	77.54	776.97	29,500
1947	21 Apr	35.33	807.93	33,800	28 Apr	34.5	789.5	29,300	28 Apr	76.07	776.07	28,400
1948	17 Apr	36.17	808.82	41,400	21 Apr	41.5	796.5	57,000	27 Apr	87.62	787.62	51,800
1950	25 Apr			48,400	26 Apr			71,500	10 Apr			73,200
1950	10 May	31.83	809.48	63,000	12 May	41.85	798.0	86,500	11 May	90.89	790.89	95,500
1952	23 Apr	25.47	803.12	24,800	25 May	28.83	785.3	23,900	24 Apr		773.0	24,200
1965		36.10	808.84	50,600	22 Apr	40.43	795.43	47,200	26 Apr	85.19	785.19	46,200
1966	4 Apr	37.08	809.73	59,000	8 Apr	42.15	797.15	67,500	11 Apr	89.15	789.15	66,800
1967	4 Apr	34.55	807.2	32,000	8 Apr	36.70	791.9	32,200	9 Apr	80.79		33,600
1969	17 Apr	36.92	809.57	56,500	19 Apr	41.35	796.36	59,000	26 Apr	87.59	787.61	54,700
1970					29 Apr	38.20	793.2	31,700	29 Apr	84.72	784.72	39,600
1972					20 Apr	35.73	790.73	31,100	24 Apr	78.16		30,700
1974					25 Apr	39.85	794.85	43,900	28 Apr	86.51	786.51	43,500
1975	15 Jul		808.6	42,400	4 May	39.8	794.85	44,000	8 May	84.32	784.32	42,800
1978	12 Apr		810.56	56,200	16 Apr	41.19	796.19	56,200	18 Apr	86.89	786.89	50,600
1979	22-25 Apr	38.6	811.25	91,000	28 Apr	43.66	798.66	92,900	1 May	91.19	791.19	92,700

(1) Peak discharge often follows peak stage by one or two days.

(2) Drainage area - 31,200 square miles, period of record - 22 years, gage zero - 772.65 (1929 adj.), location - near center span downstream side of highway bridge in Oslo, river mile 271.2. This gaging station was discontinued after the 1969 flood.

(3) Drainage area - 34,800 square miles, period of record - 37 years, gage zero - 755.0 (1929 adj.), location - downstream end east pier on highway bridge 1 1/2 miles northeast of Drayton, river mile 207.0.

(4) Drainage area - 40,070 square miles, period of record - 66 years, gage zero - 700.0 (Geological Survey of Canada), datum 1928 (add 0.15 foot to get 1929 adj.), location - 3/4 mile downstream from international boundary, river mile

FLOOD FREQUENCY

Frequency curves used for this study were obtained from the Red River Main Stem Study, during which frequency curves for Red River Main Stem stations were developed using all available data, thereby producing frequency curves which are consistent along the main stem. A brief description of the analysis is presented below.

The methods used in computing the frequency curves followed those given in the Water Resources Council (WRC) Bulletin No. 17A, "Guidelines for Determining Flood Flow Frequency." This methodology included the use of expected probability, (Pn), and Weibull plotting points. Two computer programs from the Corps' Hydrologic Engineering Center, "Flood Flow Frequency Analysis" and "Regional Frequency Computation", were used in the calculations. The stations and period of record used in the analysis are shown in table 4.

Table 4

STATIONS AND PERIODS OF RECORD USED IN THE RED RIVER MAIN STEM ANALYSIS

Station Name	Station Number	Period of Record
Wahpeton, ND	515	1897, 1942-1979
Fargo, ND	540	1882, 1897, 1902-1979
Halstad, MN	645	1882, 1893, 1897, 1942-1979
Grand Forks, ND	825	1826, 1852, 1882-1979
Drayton, ND	920	1936, 1937, 1941-1979
Emerson, Manitoba	1025	1826, 1852, 1913-1979

The mean logs, standard deviations, equivalent lengths of record, and the computer program used in the final analysis for the six main stem stations used in the analysis are listed below. As noted in the table, the "Regional Frequency" program was used in three cases since this resulted in the longest equivalent length of record while maintaining an acceptable correlation coefficient.

Table 5

MEAN LOGS, STANDARD DEVIATIONS, AND EQUIVALENT LENGTHS OF RECORD

Station	Station Number	Mean Log	Standard Deviation	Equivalent Length of Record	Computer Program Regional Frequency	Computer Program Flood Flow Frequency
Wahpeton	515	3.252	0.374	88	X	
Fargo	540	3.4754	0.4383	98		X
Halstad	645	3.873	0.393	96	X	
Grand Forks	825	4.1558	0.3911	154		X
Drayton	920	4.220	0.360	96	X	
Emerson	1025	4.2973	0.3302	154		X

In addition to the six stations used in the analysis, a frequency curve was also computed for Oslo, Minnesota. This curve was developed from the other stations using general relations.

A tabulation of frequency data and discharges of selected frequencies for the seven stations is given in table 6. The frequency curves for these stations are presented in plates 1 - 7. Weibull plotting positions for the adopted frequency curves are presented in tables 7 - 12.

As stated above, these curves were computed using Pn and Weibull plotting points since they were developed for design purposes. They are <u>not</u> the administratively prescribed discharges currently being used for flood plain management purposes. The administrative discharges do <u>not</u> meet Corps criteria for project design.

Since these curves were computed, the methods for computing frequency curves have been updated by WRC Bulletin No. 17B, so the data presented in table 6 was compared to data computed using Bulletin 17B. This comparison showed that no change to the frequency curves is necessary because the difference between the two analyses was so small that it was considered to be insignificant. Therefore, the data presented above are the adopted values for the Red River main stem stations.

Table 6

FREQUENCY CURVE DATA
RED RIVER OF THE NORTH
USGS GAGING STATIONS

Station	Station Number	Mean Log	Standard Deviation	Adopted Skew	Equivalent Length of Record (yrs)	Discharge in cfs Exceedence Frequency in Percent (Return Period in Years) 10 (10)	2 (50)	1 (100)	0.2 (500)
Wahpeton, North Dakota	515	3.252	.374	-.19	88	5,350	9,800	12,000	18,600
Fargo, North Dakota	540	3.475	.438	0.0	98	11,100	24,900	33,300	60,800
Halstad, Minnesota	645	3.873	.393	-.19	96	23,600	45,000	56,000	87,000
Grand Forks, North Dakota	825	4.156	.391	-.2	154	45,000	84,900	106,000	161,000
Oslo, Minnesota	(1)	-	-	-	-	45,700	85,400	106,500	161,300
Drayton, North Dakota	920	4.220	.360	-.203	96	48,000	87,000	107,000	162,000
Emerson, Manitoba	1025	4.297	.330	0.0	154	53,800	99,000	122,000	193,000

(1) Discontinued, discharges from general relations.

Table 7

PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTANTANEOUS PEAK FLOWS AT WAHPETON, NORTH DAKOTA

Rank	Water Year	Flow in cfs	Weibull Plotting Position in Percent	Rank	Water Year	Flow in cfs	Weibull Plotting Position in Percent
1	1897	10,500	.0101	50	1954	1,860	.5051
2	1969	9,200	.0202	51		(1)	.5152
3		(1)	.0303	52		(1)	.5253
4	1952	7,130	.0404	53	1964	1,700	.5354
5	1979	7,050	.0505	54		(1)	.5455
6	1978	6,250	.0606	55		(1)	.5556
7	1951	6,090	.0707	56	1970	1,450	.5657
8		(1)	.0808	57		(1)	.5758
9		(1)	.0909	58		(1)	.5859
10	1965	5,690	.1010	59		(1)	.5960
11	1962	5,650	.1111	60	1974	1,250	.6061
12	1943	5,000	.1212	61		(1)	.6162
13	1966	4,760	.1313	62	1973	1,220	.6263
14		(1)	.1414	63		(1)	.6364
15	1947	4,610	.1515	64		(1)	.6465
16	1944	4,360	.1616	65	1955	1,150	.6566
17		(1)	.1717	66		(1)	.6667
18	1950	4,190	.1818	67		(1)	.6768
19		(1)	.1919	68		(1)	.6869
20		(1)	.2020	69	1959	1,050	.6970
21	1945	3,910	.2121	70		(1)	.7071
22		(1)	.2222	71		(1)	.7172
23	1975	3,850	.2323	72		(1)	.7273
24	1963	3,830	.2424	73		(1)	.7374
25	1972	3,380	.2525	74		(1)	.7475
26		(1)	.2626	75		(1)	.7576
27	1942	3,280	.2727	76		(1)	.7677
28		(1)	.2828	77	1971	927	.7778
29		(1)	.2929	78		(1)	.7879
30	1953	3,150	.3030	79		(1)	.7980
31	1946	3,110	.3131	80		(1)	.8081
32		(1)	.3232	81	1958	866	.8182
33		(1)	.3333	82		(1)	.8283
34		(1)	.3434	83		(1)	.8384
35		(1)	.3535	84		(1)	.8485
36	1976	2,700	.3636	85		(1)	.8586
37	1967	2,500	.3737	86	1968	708	.8687
38		(1)	.3838	87		(1)	.8788
39		(1)	.3939	88		(1)	.8889
40	1960	2,370	.4040	89	1961	548	.8990
41	1948	2,300	.4141	90	1977	526	.9091
42	1949	2,290	.4242	91		(1)	.9192
43	1957	2,290	.4343	92		(1)	.9293
44		(1)	.4444	93		(1)	.9394
45		(1)	.4545	94		(1)	.9495
46		(1)	.4646	95		(1)	.9596
47	1956	1,980	.4747	96		(1)	.9697
48		(1)	.4848	97		(1)	.9798
49		(1)	.4949	98		(1)	.9899

(1) Spacing of data based on Regional Frequency Program.

Table 8

PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE
OF ANNUAL INSTANTANEOUS PEAK FLOWS AT
FARGO, NORTH DAKOTA

Rank	Water Year	Flow in cfs	Weibull Plotting Positions in Percent	Water Rank	Water Year	Flow in cfs	Weibull Plotting Positions in Percent
1	1969	25,300	.0101	41	1906	3,050	.5088
2	1897	25,000	.0202	42	1955	2,760	.5215
3	1882	20,000	.0303	43	1949	2,660	.5341
4	1978	17,500	.0417	44	1927	2,650	.5467
5	1979	17,300	.0543	45	1908	2,600	.5593
6	1952	16,300	.0669	46	1957	2,540	.5720
7	1943	16,000	.0795	47	1970	2,480	.5846
8	1975	13,200	.0922	48	1903	2,450	.5972
9	1965	11,400	.1048	49	1964	2,400	.6098
10	1966	10,700	.1174	50	1958	2,280	.6225
11	1962	9,580	.1301	51	1921	1,970	.6351
12	1947	9,300	.1427	52	1973	1,950	.6477
13	1951	8,010	.1553	53	1954	1,920	.6604
14	1950	7,800	.1679	54	1971	1,910	.6730
15	1916	7,740	.1806	55	1909	1,780	.6856
16	1945	7,700	.1932	56	1926	1,600	.6982
17	1972	7,250	.2058	57	1913	1,560	.7109
18	1907	7,000	.2184	58	1941	1,390	.7235
19	1953	6,720	.2311	59	1937	1,390	.7361
20	1920	6,200	.2437	60	1938	1,350	.7487
21	1946	5,970	.2563	61	1930	1,340	.7614
22	1967	5,900	.2689	62	1959	1,250	.7740
23	1917	5,240	.2816	63	1902	1,180	.7866
24	1904	5,220	.2942	64	1912	1,100	.7992
25	1922	5,200	.3068	65	1936	1,050	.8119
26	1910	5,000	.3194	66	1940	1,030	.8245
27	1963	4,930	.3321	67	1961	1,020	.8371
28	1929	4,440	.3447	68	1935	942	.8497
29	1944	4,150	.3573	69	1925	940	.8624
30	1974	4,150	.3699	70	1977	878	.8750
31	1923	3,960	.3826	71	1932	875	.8876
32	1960	3,900	.3952	72	1918	874	.9003
33	1956	3,870	.4078	73	1968	788	.9129
34	1928	3,840	.4205	74	1919	680	.9255
35	1939	3,780	.4331	75	1911	608	.9381
36	1948	3,390	.4457	76	1933	605	.9508
37	1942	3,380	.4583	77	1924	530	.9634
38	1976	3,200	.4710	78	1931	365	.9760
39	1914	3,140	.4836	79	1934	323	.9886
40	1915	3,130	.4962				

NOTE: Plotting positions based on 98 years (H) and 3 high values (Z).
Weight (W) for systematic values = 1.2500.

Table 9

PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE
OF ANNUAL INSTANTANEOUS PEAK FLOWS AT
HALSTAD, MINNESOTA

Rank	Water Year	Flow in cfs	Weibull Plotting Positions	Rank	Water Year	Flow in cfs	Weibull Plotting Positions
1	1897	45,600	.0101	50	1949	7,710	.5051
2	1979	42,000	.0202	51	1944	7,200	.5152
3	1975	39,900	.0303	52	1955	7,200	.5253
4	1882	39,200	.0404	53		(1)	.5354
5	1969	35,700	.0505	54		(1)	.5455
6	1893	30,400	.0606	55		(1)	.5556
7	1978	28,800	.0707	56		(1)	.5657
8	1966	26,800	.0808	57		(1)	.5758
9		(1)	.0909	58	1973	6,200	.5859
10	1965	25,600	.1010	59		(1)	.5960
11	1947	24,500	.1111	60	1963	5,850	.6061
12	1943	21,800	.1212	61		(1)	.6162
13	1952	20,700	.1313	62		(1)	.6263
14		(1)	.1414	63		(1)	.6364
15	1950	18,700	.1515	64		(1)	.6465
16	1974	17,800	.1616	65	1971	5,480	.6566
17		(1)	.1717	66		(1)	.6667
18	1972	16,200	.1818	67		(1)	.6768
19	1948	16,000	.1919	68		(1)	.6869
20	1962	15,900	.2020	69	1942	5,060	.6970
21		(1)	.2121	70		(1)	.7071
22		(1)	.2222	71	1957	4,980	.7172
23		(1)	.2323	72		(1)	.7273
24		(1)	.2424	73	1954	4,660	.7374
25		(1)	.2525	74	1958	4,420	.7475
26	1967	13,800	.2626	75		(1)	.7576
27	1953	13,600	.2727	76		(1)	.7677
28	1945	13,300	.2828	77		(1)	.7778
29	1951	12,900	.2929	78	1959	3,780	.7879
30	1956	12,900	.3030	79		(1)	.7980
31		(1)	.3131	80		(1)	.8081
32		(1)	.3232	81		(1)	.8182
33	1970	11,600	.3333	82		(1)	.8283
34		(1)	.3434	83		(1)	.8384
35		(1)	.3535	84	1968	2,350	.8485
36		(1)	.3636	85		(1)	.8586
37		(1)	.3737	86		(1)	.8687
38		(1)	.3838	87	1977	2,050	.8788
39	1946	10,000	.3939	88		(1)	.8889
40	1976	9,950	.4040	89	1961	1,900	.8990
41		(1)	.4141	90		(1)	.9091
42		(1)	.4242	91		(1)	.9192
43		(1)	.4343	92		(1)	.9293
44		(1)	.4444	93		(1)	.9394
45	1960	8,600	.4545	94		(1)	.9495
46		(1)	.4646	95		(1)	.9596
47		(1)	.4747	96		(1)	.9697
48	1964	7,820	.4848	97		(1)	.9798
49		(1)	.4949	98		(1)	.9899

(1) Spacing of Data Based on Regional Frequency Program.

Table 10

PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE
OF ANNUAL INSTANTANEOUS PEAK FLOWS AT
GRAND FORKS, NORTH DAKOTA

Rank	Water Year	Flow in cfs	Weibull Plotting Position	Rank	Water Year	Flow in cfs	Weibull Plotting Position
1	1826	135,000	.0065	51	1949	15,200	.5014
2	1852	95,000	.0129	52	1902	15,000	.5115
3	1897	85,000	.0211	53	1957	14,700	.5215
4	1979	82,000	.0311	54	1953	14,600	.5315
5	1882	75,000	.0411	55	1936	14,500	.5415
6	1966	55,000	.0512	56	1901	14,000	.5515
7	1978	54,200	.0612	57	1919	13,600	.5615
8	1950	54,000	.0712	58	1941	13,400	.5715
9	1969	53,500	.0812	59	1964	13,200	.5815
10	1893	53,300	.0912	60	1885	13,040	.5915
11	1965	52,000	.1012	61	1928	12,200	.6015
12	1975	42,900	.1112	62	1921	11,500	.6115
13	1883	38,600	.1212	63	1973	11,200	.6215
14	1947	35,000	.1312	64	1942	11,000	.6315
15	1948	34,200	.1412	65	1963	10,800	.6415
16	1974	34,100	.1512	66	1886	10,800	.6515
17	1904	33,000	.1612	67	1927	10,600	.6616
18	1972	31,400	.1712	68	1944	10,400	.6716
19	1907	30,400	.1812	69	1932	10,400	.6816
20	1920	30,300	.1912	70	1940	10,000	.6916
21	1916	29,000	.2013	71	1925	9,690	.7016
22	1967	28,200	.2113	72	1954	9,620	.7116
23	1943	28,200	.2213	73	1930	9,610	.7216
24	1906	27,600	.2313	74	1968	9,420	.7316
25	1962	26,600	.2413	75	1909	9,260	.7416
26	1952	23,900	.2513	76	1899	9,000	.7516
27	1970	23,700	.2613	77	1914	8,240	.7616
28	1951	23,600	.2713	78	1926	7,720	.7716
29	1976	23,600	.2813	79	1958	7,500	.7816
30	1892	23,000	.2913	80	1887	7,300	.7916
31	1946	22,000	.3013	81	1939	6,720	.8016
32	1917	21,600	.3113	82	1938	6,660	.8117
33	1896	21,600	.3213	83	1959	6,300	.8217
34	1915	21,500	.3313	84	1891	6,000	.8317
35	1956	21,400	.3413	85	1912	4,730	.8417
36	1945	21,300	.3513	86	1898	4,500	.8517
37	1884	20,600	.3614	87	1918	4,480	.8617
38	1908	20,500	.3714	88	1933	4,380	.8717
39	1888	19,000	.3814	89	1937	4,180	.8817
40	1922	19,000	.3914	90	1900	4,000	.8917
41	1903	18,800	.4014	91	1911	3,520	.9017
42	1910	18,500	.4114	92	1890	3,470	.9117
43	1913	17,200	.4214	93	1961	3,400	.9217
44	1960	17,200	.4314	94	1934	3,210	.9317
45	1929	17,100	.4414	95	1889	3,000	.9417
46	1905	16,800	.4514	96	1935	2,920	.9517
47	1894	16,450	.4614	97	1924	2,530	.9618
48	1923	16,200	.4714	98	1977	2,190	.9718
49	1971	15,800	.4814	99	1895	2,000	.9818
50	1955	15,400	.4914	100	1931	1,630	.9918

NOTE - Plotting Positions based on 154 years (H) and 2 high values (Z).
Weight (W) for systematic values = 1.5510.

Table 11

PLOTTING POSITION FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTANTANEOUS PEAK FLOWS AT DRAYTON, NORTH DAKOTA

Rank	Water Year	Flow in cfs	Weibull Plotting Position in Percent	Rank	Water Year	Flow in cfs	Weibull Plotting Position in Percent
1			.0101	50	1955	18,000	.5051
2	1979	92,900	.0202	51		(1)	.5152
3	1950	86,500	.0303	52		(1)	.5253
4		(1)	.0404	53	1936	16,600	.5354
5	1966	67,500	.0505	54		(1)	.5455
6	1969	59,000	.0606	55		(1)	.5556
7	1948	57,000	.0707	56		(1)	.5657
8	1978	56,200	.0808	57		(1)	.5758
9		(1)	.0909	58	1964	15,600	.5859
10	1965	47,200	.1010	59		(1)	.5960
11	1975	44,000	.1111	60	1953	14,700	.6061
12	1974	43,900	.1212	61		(1)	.6162
13		(1)	.1313	62	1957	14,100	.6263
14	1967	32,300	.1414	63	1973	13,400	.6364
15	1962	32,200	.1515	64		(1)	.6465
16		(1)	.1616	65	1963	12,900	.6566
17	1970	31,700	.1717	66		(1)	.6667
18	1972	31,100	.1818	67	1968	12,500	.6768
19		(1)	.1919	68		(1)	.6869
20		(1)	.2020	69	1944	12,300	.6970
21		(1)	.2121	70		(1)	.7071
22	1947	29,300	.2222	71	1959	11,200	.7172
23		(1)	.2323	72	1954	11,100	.7273
24		(1)	.2424	73		(1)	.7374
25	1943	28,700	.2525	74		(1)	.7475
26	1956	28,000	.2626	75		(1)	.7576
27	1949	27,900	.2727	76		(1)	.7677
28	1976	27,600	.2828	77		(1)	.7778
29		(1)	.2929	78		(1)	.7879
30		(1)	.3030	79	1958	7,850	.7980
31		(1)	.3131	80		(1)	.8081
32		(1)	.3232	81		(1)	.8182
33	1960	24,700	.3333	82		(1)	.8283
34	1945	24,600	.3434	83		(1)	.8384
35	1951	24,600	.3535	84		(1)	.8485
36	1952	23,900	.3636	85		(1)	.8586
37	1971	23,300	.3737	86		(1)	.8687
38		(1)	.3838	87		(1)	.8788
39	1946	23,000	.3939	88		(1)	.8889
40	1941	22,800	.4040	89	1937	4,530	.8990
41		(1)	.4141	90		(1)	.9091
42	1942	21,900	.4242	91		(1)	.9192
43		(1)	.4343	92		(1)	.9293
44		(1)	.4444	93		(1)	.9394
45		(1)	.4545	94		(1)	.9495
46		(1)	.4646	95	1961	3,600	.9596
47		(1)	.4747	96		(1)	.9697
48		(1)	.4848	97	1977	3,400	.9798
49		(1)	.4949	98		(1)	.9899

(1) Spacing of data based on Regional Frequency Program.

Table 12

PLOTTING POSITIONS FOR ADOPTED FREQUENCY CURVE OF ANNUAL INSTANTANEOUS PEAK FLOWS AT EMERSON, MANITOBA

Rank	Water Year	Flow in cfs	Weibull Plotting Position in Percent	Rank	Water Year	Flow in cfs	Weibull Plotting Position in Percent
1	1826	167,000	.0065	36	1927	20,500	.5065
2	1852	120,000	.0129	37	1915	20,121	.5211
3	1950	95,500	.0234	38	1929	19,200	.5357
4	1979	92,700	.0381	39	1932	18,900	.5504
5	1966	66,800	.0527	40	1922	18,900	.5650
6	1969	54,700	.0674	41	1936	18,000	.5796
7	1948	51,800	.0820	42	1925	17,500	.5943
8	1978	50,600	.0966	43	1964	17,500	.6089
9	1965	46,200	.1113	44	1928	16,800	.6235
10	1916	46,200	.1259	45	1959	15,720	.6382
11	1974	43,500	.1405	46	1957	15,300	.6528
12	1975	42,800	.1552	47	1973	14,700	.6675
13	1970	39,600	.1698	48	1940	14,600	.6821
14	1956	33,800	.1844	49	1953	14,500	.6967
15	1967	33,600	.1991	50	1968	13,900	.7114
16	1962	33,400	.2137	51	1963	13,800	.7260
17	1976	32,900	.2284	52	1919	13,410	.7406
18	1972	30,700	.2430	53	1921	12,800	.7553
19	1960	30,500	.2576	54	1944	12,300	.7699
20	1943	29,500	.2723	55	1954	11,500	.7845
21	1945	29,400	.2869	56	1933	11,000	.7992
22	1949	29,200	.3015	57	1926	8,000	.8138
23	1947	28,400	.3162	58	1958	7,940	.8285
24	1942	27,900	.3308	59	1931	7,940	.8431
25	1941	27,800	.3455	60	1838	7,530	.8577
26	1920	26,700	.3601	61	1914	7,260	.8724
27	1951	26,600	.3747	62	1939	6,700	.8870
28	1971	26,600	.3894	63	1924	6,320	.9016
29	1923	26,000	.4040	64	1937	5,840	.9163
30	1917	25,900	.4186	65	1935	5,470	.9309
31	1913	25,600	.4333	66	1918	4,990	.9455
32	1952	24,200	.4479	67	1934	4,800	.9602
33	1946	24,100	.4625	68	1977	4,590	.9748
34	1955	24,000	.4772	69	1961	4,320	.9895
35	1930	20,800	.4918				

NOTE: Plotting positions based on 154 years (H) and 2 high values (Z). Weight (W) for systematic values = 2.2687.

A discharge-frequency curve was developed for the Red River just upstream of the mouth of the Red Lake River using Bulletin 17B and correlating to Grand Forks. The basic flow data were developed by routing the 77-year record (1903 to 1979) from Crookston downstream to the Grand Forks gage and subtracting it from the Grand Forks flows to determine peak flows upstream of the Red Lake River. Similar methods were used to develop a discharge frequency curve below the Sheyenne River. Plates 8-9 show the discharge-frequency curve for the Red River above the Red Lake River and below the Sheyenne River.

UNIT HYDROGRAPHS

Unit hydrographs used for this study were obtained from the East Grand Forks General Reevaluation Study (December 1983), the Phase 1 General Design Memorandum, Pembina River, North Dakota (September 1983), and the St. Paul District Water Control Center River Forecasting Model for the Red River of the North.

These unit hydrographs were developed for the effective drainage sub-areas within the Red River of the North basin in accordance with EM 1110-2-1405, "Flood Hydrograph Analysis and Computations." For some areas, this included developing two unit hydrographs per area; one for the primary drainage area and one for the secondary drainage area.

In general, the primary and secondary unit hydrographs were developed by the following methods. A single unit hydrograph was developed using established procedures. The most important part of this procedure was the selection of a historic flood in which the secondary drainage area contributed. Then, taking into consideration the basin characteristics and the relative volumes of the primary and secondary unit hydrographs, the single unit hydrograph was divided into primary and secondary unit hydrographs. For drainage areas for which no flood was found which could adequately show contribution from the secondary drainage area, a flood was selected to show the primary drainage area only. For these areas, a synthetic method was used to develop the secondary unit hydrographs from the primary unit hydrograph, taking into consideration the

basin characteristics. If these two methods could not be used, the unit hydrographs were developed by using synthetic methods to develop the total unit hydrograph. After this was done, the primary drainage area unit hydrograph was developed synthetically by removing the secondary areas from the area being considered. The difference between the total and primary unit hydrographs was considered to be the secondary unit hydrograph.

The physical characteristics of the secondary drainage area cause it to start contributing to the main stem later than the primary drainage area. This time lag is dependent on the location of the nearest main water course, the primary drainage area, and on storage losses such as potholes, marshes, ponds, etc. The first lag, the location lag, is shown in the hydrologic model by delaying the starting time of the secondary unit hydrograph. Not all of the unit hydrographs for secondary drainage areas have a location lag because some secondary areas are located relatively close to a main water course. The location lag will remain the same for all floods.

The second lag, the storage lag, is derived during the computation of runoff by adding the storage losses to the losses which were established for computation of runoff from the primary area. The time needed to fill the storage areas of the secondary drainage area can vary from flood to flood. Hence, the storage lag continuously changes according to the rate at which runoff occurs, which is itself dependent on such variables as temperature, soil moisture, etc.

The following table contains the unit hydrographs used in this study. Because the storage lag is specific for each flood, only the location lag is shown on the secondary unit hydrograph. The primary unit hydrographs are the 125 percent unit hydrographs or are unit hydrographs developed from synthetic methods and are being considered to be equivalent to 125 percent unit hydrographs. The secondary unit hydrographs have not been peaked since the nature of the secondary drainage area precludes this.

TABLE 13

RED RIVER OF THE NORTH
12 HOUR UNIT HYDROGRAPHS FOR AREA ABOVE EMERSON - CFS

SHEYENNE RIVER AT COOPERSTOWN - PRIMARY DRAINAGE AREA

100	230	390	575	829	1085	1302	1647	1992	2346
2800	3204	3524	3411	3263	3105	2957	2790	2622	2425
2218	2031	1848	1667	1223	1184	1134	1016	917	829
740	681	592	543	484	435	395	366	336	306
207	267	237	216	197	176	164	149	134	119
104	80	65	50	45	35	27	18	9	0

SHEYENNE R. AT COOPERSTOWN - SECONDARY DRAINAGE AREA

0	0	50	130	210	310	420	550	620	840
1010	1210	1380	1520	1620	1710	1790	1860	1910	1950
1970	1990	2000	2005	2000	1995	1980	1970	1950	1920
1880	1830	1770	1700	1600	1480	1370	1250	1210	1140
1070	1010	960	900	850	810	770	730	690	650
630	600	570	540	510	490	465	440	415	395
375	355	335	310	290	270	250	235	215	200
150	160	145	130	115	100	85	70	55	40
20	0								

SHEYENNE R. AT DAZEY - PRIMARY DRAINAGE AREA

120	227	316	424	612	846	1322	2022	1716	1282
1056	836	710	602	513	444	385	320	266	247
217	197	178	160	153	135	125	115	100	95
89	79	69	59	54	49	44	39	35	30
25	20	15	10	5	3	2	0		

SHEYENNE R. AT DAZEY - SECONDARY DRAINAGE AREA

0	[illegible]	155	210	290	363	446	570	654	725
760	715	735	684	653	622	576	505	456	415
373	352	332	311	290	255	249	228	207	186
176	161	145	135	124	114	104	93	83	73
62	52	41	31	26	21	15	10	3	2
0									

SHEYENNE R. BALDHILL DAM - PRIMARY DRAINAGE

25	95	215	320	400	1560	1870	1550	1270	1[illegible]
770	610	500	420	350	290	240	150	150	120
80	50	30	[illegible]						

SHEYENNE R. BALDHILL DAM - SECONDARY DRAINAGE AREA

0	0	35	260	365	435	485	410	360	335
305	250	195	145	105	80	55	35	15	0

SHEYENNE R. VALLEY CITY - PRIMARY DRAINAGE AREA

560	1390	2420	1610	890	350	0

SHEYENNE R. VALLEY CITY - SECONDARY DRAINAGE AREA

461	986	1116	866	366	186	131	0

SHEYENNE R. LISBON - PRIMARY DRAINAGE AREA

110	390	550	880	1250	1660	2115	2370	2500	2560
2420	1600	1200	800	430	180	0			

SHEYENNE R. KINDRED - PRIMARY DRAINAGE AREA

60	180	320	490	700	980	1300	1650	1900	1960
1960	1940	1920	1640	1660	1440	1200	960	800	520
450	270	140	0						

SHEYENNE R. KINDRED - SECONDARY DRAINAGE AREA

30	50	60	70	80	90	100	110	110	110
105	105	105	105	100	100	90	80	50	40
30	0								

SHEYENNE R. WEST FARGO - PRIMARY DRAINAGE AREA

60	140	260	600	640	580	460	380	240	160
140	80	40	0						

MAPLE RIVER AT ENDERLIN N.D. - PRIMARY DRAINAGE AREA

157	585	1160	1670	2230	2780	3250	3440	3570	[illegible]
3250	2770	2140	1700	1320	1030	803	625	487	375
285	230	170	130	106	84	66	51	38	25
19	11	6	3	0					

MAPLE RIVER AT ENDERLIN N.D. = SECONDARY DRAINAGE AREA

0	0	16	59	113	183	246	309	360	394
419	421	400	369	296	245	202	161	129	104
83	67	54	43	35	26	23	18	14	12
10	8	6	4	2	0	0	0	0	0

MAPLE RIVER AT MAPLETON N.D. = PRIMARY DRAINAGE AREA

320	1130	2140	3140	3860	4100	3850	3080	2180	1540
1090	765	530	380	268	189	133	94	66	47
32	25	18	10	6	0				

MAPLE RIVER AT MAPLETON N.D. = SECONDARY DRAINAGE AREA

0	0	0	0	0	4	18	46	96	156
225	270	260	219	178	149	119	95	74	58
45	34	25	20	16	12	8	4	0	0

RUSH RIVER AT AMENIA N.D. = PRIMARY DRAINAGE AREA

235	503	1320	1400	1030	601	352	206	121	71
41	24	10	0						

LAKE TRAVERSE UNIT HYDROGRAPH

4735	9895	9315	7085	3335	7245	5760	3525	515	0

ORWELL DAM UNIT HYDROGRAPH

75	165	465	610	750	705	670	750	870	1095
1225	1275	1125	960	450	345	270	225	190	155
135	120	105	95	115	150	100	70	50	45
40	35	30	25	22	20	16	16	14	12
10	9	8	7	6	5	4	3	0	0

RED RIVER AT WAHPETON = PRIMARY DRAINAGE AREA = 1,000

100	400	1300	2920	3750	4050	4100	3900	3440	2[illegible]
2530	2250	2020	1810	1610	1450	1300	1180	1070	[illegible]
900	820	770	720	680	640	610	570	550	530
500	470	440	410	370	350	320	300	270	240
220	200	180	160	140	120	100	80	60	45
30	20	10	0						

WILD RICE R. N.D. - PRIMARY DRAINAGE AREA AT ABERCROMBIE

119	441	832	1380	1908	2449	2994	3531	4001	4350
4577	4690	4693	4584	4342	3911	3392	2933	2536	2192
1896	1639	1417	1225	1059	916	792	685	592	512
443	383	331	286	247	214	185	160	138	120
103	89	77	67	58	49	40	32	25	16
7	0								

WILD RICE R. N.D. - SECONDARY DRAINAGE AREA AT ABERCROMBIE

0	0	11	40	81	126	174	223	272	321
364	396	416	426	426	416	395	355	308	266
230	200	172	149	129	112	97	83	72	62
54	46	40	34	30	26	23	19	17	14
13	10	10	8	7	6	5	4	3	2
1	0								

RED RIVER AT FARGO - PRIMARY DRAINAGE AREA - LOCAL

535	1148	1946	2870	3629	3794	3522	3094	2578	2140
1761	1459	1205	1012	856	739	642	555	467	416
360	350	321	292	263	243	224	204	185	170
156	146	136	127	117	107	97	88	78	59
39	19	0							

BUFFALO RIVER AT HAWLEY MN. - PRIMARY DRAINAGE AREA

30	113	227	359	491	599	666	689	652	584
520	462	412	366	326	290	258	230	205	182
162	144	128	114	102	91	81	72	64	57
51	45	40	36	32	26	25	22	20	18
16	14	13	11	10	8	6	4	2	0

BUFFALO RIVER AT HAWLEY MN. - SECONDARY DRAINAGE AREA

0	0	17	64	130	207	295	381	454	501
548	535	470	427	366	350	317	287	260	235
213	193	175	158	143	130	117	105	95	86
78	71	63	56	52	47	42	39	35	32
28	25	23	21	18	17	15	12	9	7
5	3	0							

BUFFALO RIVER AT SABIN - PRIMARY DRAINAGE AREA

269	981	1920	2770	3230	3130	2650	2160	1760	1430
1170	951	775	632	515	420	342	279	227	185
151	123	100	81	66	54	44	36	29	15
5	0								

BUFFALO RIVER AT SABIN MN. - SECONDARY DRAINAGE AREA

0	0	0	0	2	12	30	60	100	140
150	130	110	100	80	70	60	50	40	35
30	25	20	16	13	11	9	8	7	6
5	5	3	0						

BUFFALO RIVER AT DILWORTH MN. - PRIMARY DRAINAGE AREA

145	490	860	1190	1420	1470	1350	1095	690	350
175	90	45	0						

BUFFALO RIVER AT DILWORTH MN. - SECONDARY DRAINAGE AREA

0	0	0	0	0	10	25	50	90	140
170	190	190	150	110	70	50	50	30	0

WILD RICE RIVER MN. AT TWIN VALLEY - PRIMARY DRAINAGE AREA

214	795	1599	2416	3009	3220	3027	2671	2357	2080
1835	1620	1429	1261	1113	982	867	765	675	595
525	464	409	361	319	281	248	219	193	170
150	133	117	103	91	80	71	63	55	49
43	38	34	30	26	23	20	17		

WILD RICE RIVER MN. AT TWIN VALLEY - SECONDARY DRAINAGE AREA

0	35	129	260	433	601	750	801	741	673
610	554	501	455	412	372	337	304	275	249
225	203	183	165	149	134	121	109	98	89
80	72	64	58	52	47	43	38	34	31
27	25	22	19	17	16	14	13	12	

WILD RICE RIVER AT HENDRUM - PRIMARY DRAINAGE AREA

745	1420	2125	2879	3594	3613	3624	3296	2820	2405
2055	1769	1509	1291	1062	874	725	586	477	377
298	220	169	109	60	6				

WILD RICE RIVER AT HALSTAD MN. - PRIMARY DRAINAGE AREA

1470	3050	7070	12800	15900	12700	10000	7930	6140	4770
3860	3170	2610	2220	1950	1680	1470	1280	1110	991
874	787	709	641	583	534	486	447	408	379
350	320	301	282	262	243	223	204	185	165
154	137	78	50	30	6				

GOOSE RIVER AT HILLSBORO - PRIMARY DRAINAGE AREA

332	1200	2350	3540	4720	5660	6160	6130	5440	4330
3430	2680	2120	1680	1350	1055	822	640	496	384
298	232	181	143	119	93	72	50	20	5

GOOSE RIVER AT HILLSBORO - SECONDARY D.A.

0	0	0	0	0	0	0	0	0	100
400	620	440	340	240	160	80	65	50	40
35	30	25	20	15	10				

RED LAKE DAM OUTFLOW AT HIGH LANDING

0	580	1600	3000	2760	2250	1850	1510	1240	1010
830	670	530	400	290	180	80	0		

THIEF RIVER AT THIEF RIVER FALLS - PRIMARY DRAINAGE

123	452	800	944	857	723	600	505	427	355
298	254	210	174	149	123	104	87	73	61
51	45	36	30	25	21	18	15	13	11
9	7	6	0						

THIEF RIVER AT THIEF RIVER FALLS - SECONDARY DRAINAGE

0	0	0	357	1320	2650	3870	4590	4110	3580
3110	2700	2350	2040	1770	1540	1340	1160	1010	870
760	660	573	497	431	374	325	282	244	212
184	159	138	120	104	90	83	72	62	54
47	40	35							

CLEARWATER RIVER AT RED LAKE FALLS - PRIMARY DRAINAGE

62	231	467	739	1030	1340	1660	1980	2310	2610
2270	3070	3210	3300	3350	3310	3250	3070	2820	2510
2270	2040	1840	1650	1480	1330	1200	1080	966	865
764	780	650	566	505	457	410	369	331	298
267	240	216	194	174	157	141	126	114	102
92	82	74	67	60	54	48	43	0	0

CLEARWATER RIVER AT RED LAKE FALLS - SECONDARY DRAINAGE

0	0	3	15	31	51	80	100	120	150
170	200	230	260	290	310	330	340	360	390
390	390	350	310	290	260	240	220	190	170
164	152	135	124	112	102	93	84	77	69
60	57	53	46	43	39	35	32	29	27
24	22	19	17	15	14	13	11	11	11

RED LAKE RIVER AT CROOKSTON, MN = PRIMARY DRAINAGE

640	2220	4140	5200	4310	3660	2690	1980	1460	1070
756	576	425	312	230	169	124	91	67	49
40	31	22	16	9	0				

RED LAKE RIVER AT CROOKSTON, MN = SECONDARY DRAINAGE

0	0	31	112	271	517	760	738	515	356
242	171	113	81	55	37	24	16	11	7
4	2	0							

RED RIVER AT GRAND FORKS- LOCAL PRIMARY D.A.

1314	2048	3263	4822	5553	5740	5513	5039	4634	4347
4100	3873	3646	3448	3261	3063	2885	2707	2519	2352
2174	1970	1778	1601	1423	1284	1146	1028	919	830
751	692	642	613	593	573	553	534	514	464
454	425	365	336	287	217	145	79	0	0

RED RIVER AT ASLO LOCAL PRIMARY DA

491	1433	3455	4519	4560	4138	3739	3378	3051	2757
2490	2250	2033	1836	1659	1499	1354	1223	1105	993
902	815	736	665	601	543	490	443	440	362
327	295	267	241	216	197	176	160	145	131
118	107	97	87	79	71	64	58	52	47
43									

RED RIVER AT DRAYTON

360	541	1342	1969	2709	4025	6550	8350	10450	12350
13900	14750	15600	16100	15075	14100	12550	10250	7900	5350
4050	3075	2340	1780	1350	1010	770	600	500	430
390	350	300	240	200	150	100	40		

PEMBINA RIVER AT MOUNT LAKE = PRIMARY DRAINAGE

187	575	798	1254	1725	2127	2392	2512	2435	2[illegible]
1900	1717	1516	1339	1181	1045	920	812	717	633
550	495	435	384	339	299	264	233	206	182
160	142	125	110	97	86	76	67	59	52
46	41	36	32	28	25	22	19		

PEMBINA RIVER AT ROCK LAKE - SECONDARY DRAINAGE

75	319	671	909	1276	1667	2042	2351	2578	2723
2786	2707	2496	2171	2126	1880	1711	1556	1416	1289
1172	1167	970	883	804	731	665	604	550	500
455	414	377	343	312	264	259	235	214	194
177	161	147	133	122	111	101	91	86	75
68	62	57	52	47	43	39	35	32	30
27									

PEMBINA RIVER AT SWAN LAKE - PRIMARY DRAINAGE

60	222	446	702	963	1182	1323	1351	1328	1191
1046	922	812	714	629	553	487	428	377	332
292	257	226	199	175	154	119	105	92	81
72	63	55	49	43	38	33	29	26	23
20	18	15	14	12	11				

PEMBINA RIVER AT SWAN LAKE - SECONDARY DRAINAGE

15	56	114	181	254	329	396	446	480	494
484	449	406	368	334	302	273	248	225	203
184	167	151	137	124	112	102	92	83	75
69	62	56	51	46	41	38	34	31	28
25	23	21	19	17	16	14	13	12	10
9	8	8	6	7	6	6	5	5	5

PEMBINA RIVER AT WINDY GATES - PRIMARY DRAINAGE

10	420	1100	2750	3675	3675	3720	3370	2950	2260
1620	1100	570	170						

PEMBINA RIVER AT WINDY GATES - SECONDARY DRAINAGE

									301
760	1220	1500	1940	2140	2240	2240	2140	1990	1780
1550	1430	1270	1120	970	820	610	460	310	100

DIVERSIONS AT CARALLA

450	1500	4000	3650	2000	1200	1500	1000	700	50
250	120								

PEMBINA AND RED RIVERS ABOVE EMERSON

400	1000	1600	2500	3800	5500	7000	6200	5800	4[illegible]
3000	7000	7000	6500	5500	4700	4000	3300	2800	2400
2000	1700	1400	1200	1000	1650	1700	1550	410	500
200	150	100	170	50	[illegible]				

PROBABLE MAXIMUM PRECIPITATION AND SNOWMELT

The probable maximum precipitation, PMP, for the Red River of the North was developed using the procedures and data presented and described in Hydrometeorological Report No. 48 (HMR No. 48), "Probable Maximum Precipitation and Snowmelt Criteria for Red River of the North above Pembina and Souris River above Minot, North Dakota," dated May 1973. The PMP was determined at the following locations along the Red River: Fargo, Oslo, Drayton and Emerson. The PMP at East Grand Forks was obtained from the 1983 East Grand Forks Study.

In order to find the most critical centering of the PMP at each location, a PMP was computed for several different centerings above each study location.

Snowmelt was computed according to the methods presented in EM 1110-2-1406, "Runoff from Snowmelt," 5 January 1960. It was assumed that the snowmelt will take place during a rain-free period and that the study area can be classified as an open, flat area, having less than 10 percent forest cover; so equation 25, paragraph 4-08, EM 1110-2-1406, was used for the snowmelt computations:

$$M = k' (0.00508Ii)(1-a) + (1-N)(0.0212T'a - 0.84) + N(0.029T'c) + k(0.0084v)(0.22T'a + 0.78T'd)$$

where:

- M is the snowmelt rate in inches per day.
- T'a is the difference between the air temperature measured at 10 feet and the snow surface temperature, in ^{o}F.
- T'd is the difference between the dewpoint temperature measured at 10 feet and the snow surface temperature, in ^{o}F.
- v is the wind speed at 50 feet above the snow, in miles per hour.
- Ii is the observed or estimated insolation (solar radiation on horizontal surface) in langleys.
- a is the observed or estimated average snow surface albedo.
- k' is the basin shortwave radiation melt factor.
- T'c is the difference between the cloud base temperature and snow surface temperature, in ^{o}F.

N is the estimated cloud cover.

k is the basin convection-condensation melt factor.

In some cases, not all, the snow cover would be melted before the PMP rainfall begins. For these cases, equation 20, paragraph 3-08 of EM 1110-2-1406, was used for snowmelt during the rain:

$$M = (0.029 + 0.0084kv + 0.007Pr)(Ta-32) + 0.09$$

where:

M is the total daily snowmelt in inches per day.

Ta is the mean temperature of saturated air at the 10-foot level, in ^{o}F.

v is the mean wind speed at the 50-foot level in miles per hour.

Pr is the rate of precipitation in inches per day.

k is the basin constant described in paragraph 3-05 of EM 1110-2-1406.

Air temperatures, dew point temperatures and wind speeds were obtained from HMR No. 48 for use in this equation.

Computations showed that the most critical probable maximum flood at Fargo occurred for a centering of the storm over the area above Lake Traverse. At Grand Forks, Oslo, Drayton, and Emerson, the critical event occurred for a storm centering over the area extending from Halstad to Wahpeton. This area did not include the drainage basins of the Sheyenne River above Kindred and the Wild Rice River in North Dakota. These centerings best reflect the relatively long times of concentration for the other tributaries above each location, such that a concentration of flows tends to occur, resulting in the most critical PMF peak.

PROBABLE MAXIMUM RUNOFF

Probable maximum runoff was computed by subtracting the uniform loss rate from the PMP values. The 6-hour depths were transformed to 12-hour depths by adding successive 6-hour depths.

For these computations, it was assumed that the antecedent conditions will be highly conservative. The initial losses for the basin were assumed to be zero for the primary areas and equal to 3 inches for the secondary areas during the 15 March and 31 March storms, 3.5 inches for the 15 April storm and 4.0 inches for the all-season storm. The uniform loss rates for rainfall were determined after careful analysis of available data to be equal to 0.02 inch per hour for the 15 March and 31 March storms. Loss rates used for the 15 April rainfall ranged from 0.02 - 0.05 inch per hour, and for the all-season rainfall from 0.02 - 0.10 inch per hour. The loss rate used for snowmelt was 0.02 inch per hour.

The snowmelt runoff was computed using the guidelines set forth in EM-1110-2-1406. Based on these guidelines, it was assumed that the snowpack was dry at 32°F at the start of the snowmelt, 10 days before the PMP storms. The first portion of the snowmelt is considered to be absorbed by the snowpack, with up to 10 percent of the water equivalent depth of the snow being absorbed. Any additional snowmelt, plus the melted water contained in the snow, becomes free water on the ground surface. It has been assumed in this study that the snowmelt computed for the total area above each study location would be representative of all subareas, above the respective study location and so was used for all centerings of the PMP's. The 24-hour snowmelt values were changed to 12-hour values by using the method given in EM 1110-2-1406.

The rainfall runoff depth is very dependent on drainage area size. It was, therefore, necessary to compute the rainfall excess caused by different centerings of the PMP storms over each area. The volume of the rainfall excess from the area over which the storm was centered was subtracted from the volume of the storm which was centered over the

total area. The difference or residual, was then applied uniformly to the remaining area. This method allowed the total volume of rainfall excess for the areas above each study location to be maintained.

The March 15 rainfall snowmelt event was found to be critical for the Red River of the North basin. This is consistent with the results of other studies performed in this area.

The following tables (14-18) display the total combined snowmelt and rainfall excess in 12 hour periods for the March 15 event, which is available for application to the unit hydrographs at each study location.

PROBABLE MAXIMUM FLOOD

Probable maximum flood (PMF) hydrographs were computed for primary and secondary drainage areas at each study location. The PMF for East Grand Forks was obtained from the 1983 East Grand Forks study. The PMF hydrographs were developed by applying the total runoff available to the computed unit hydrographs. Routing and combining of these developed flood hydrographs were accomplished by use of HEC-1, "Flood Hydrograph Package," dated 28 July 1982. Routing constants were developed from investigations of past events and data obtained from other studies. The PMF peak discharge for the most critical centering at each study location is listed in table 19. Tables 20 - 24 show the PMF hydrographs at each study location and at several points above each location.

The PMF flows computed at Oslo, Drayton and Emerson decreased slightly from those computed at East Grand Forks. Local inflows at these sites run off much faster than do the peaks from the upper Red River basin and thus do not contribute to the latter peaks. The peak discharges due to local flow are of a lesser magnitude than those contributed by the upper Red River. Hence, peak discharges at these three downstream locations would be equal to the peak discharges contributed by the upper Red River basin, reduced slightly by attenuation.

Table 14

PMP AT FARGO

TOTAL RUNOFF AVAILABLE FOR UNIT HYDROGRAPHS
15 MARCH STORM CENTERED OVER LAKE TRAVERSE

12 Hour period	Runoff in Inches: Area Above Lake Traverse Primary	Area Above Lake Traverse Secondary(1)	Remaining Area Above Fargo Primary	Remaining Area Above Fargo Secondary(2)
1	0.00		0.00	0.00
2	0.00		0.00	0.00
3	0.00		0.00	0.00
4	0.00		0.00	0.00
5	0.00		0.00	0.00
6	0.02		0.02	0.00
7	0.29		0.29	0.00
8	0.08		0.08	0.00
9	0.32		0.32	0.00
10	0.19		0.19	0.00
11	0.40		0.40	0.00
12	0.46		0.46	0.00
13	0.56		0.56	0.00
14	0.80		0.80	0.12
15	0.65		0.65	0.65
16	1.07		1.07	1.07
17	0.79		0.79	0.79
18	1.95		1.95	1.95
19	0.34		0.34	0.34
20	0.66		0.66	0.66
21	0.60		0.60	0.60
22	0.55		0.51	0.51
23	1.80		1.12	1.12
24	8.20		3.74	3.74
25	0.33		0.21	0.21
26	0.27		0.15	0.15
TOTAL RAINFALL:	11.75		6.33	6.33
TOTAL SNOWMELT:	8.58		8.58	5.58
TOTAL RUNOFF:	20.33		14.91	11.91

(1) Lake Traverse has no secondary area, therefore rainfall excess was not computed.

(2) Secondary drainage area storage losses of 3.0 inches have been subtracted.

Table 15

PMP AT GRAND FORKS

TOTAL RUNOFF AVAILABLE FOR UNIT HYDROGRAPHS
15 MARCH STORM CENTERED OVER HALSTAD TO WAHPETON

Runoff in Inches

12 Hour Period	Area above Halstad to Wahpeton		Remaining Area above East Grand Forks	
	Primary	Secondary(1)	Primary	Secondary(1)
0 to 8	0	0	0	0
9	.22	0	.22	0
10	.07	0	.07	0
11	.35	0	.35	0
12	.25	0	.25	0
13	.51	0	.51	0
14	.59	0	.59	0
15	.64	0	.64	0
16	.90	.53	.90	.53
17	.77	.77	.77	.77
18	1.72	1.72	1.72	1.72
19	.36	.36	.36	.36
20	.57	.57	.57	.57
21	.36	.36	.43	.43
22	.64	.64	.60	.60
23	1.29	1.29	.95	.95
24	4.34	4.34	1.38	1.38
25	.29	.29	.24	.24
26	.20	.20	.16	.16
Total	14.07	11.07	10.71	7.71

(1) Secondary drainage area storage losses of 3.0 inches have been subtracted.

Table 16

PMP AT OSLO

TOTAL RUNOFF AVAILABLE FOR UNIT HYDROGRAPHS
15 MARCH STORM CENTERED OVER HALSTAD TO WAHPETON

Runoff in Inches

12 Hour Period	Area above Halstad to Wahpeton		Remaining Area Above Oslo	
	Primary	Secondary(1)	Primary	Secondary(1)
0 to 8	0	0	0	0
9	.22	0	.22	0
10	.07	0	.07	0
11	.35	0	.35	0
12	.25	0	.25	0
13	.51	0	.51	0
14	.59	0	.59	0
15	.64	0	.64	0
16	.90	.53	.90	.53
17	.77	.77	.77	.77
18	1.72	1.72	1.72	1.72
19	.36	.36	.36	.36
20	.57	.57	.57	.57
21	.36	.36	.43	.43
22	.64	.64	.60	.60
23	1.29	1.29	.96	.96
24	4.34	4.34	1.42	1.42
25	.29	.29	.24	.24
26	.20	.20	.16	.16
Total	14.07	11.07	10.76	7.76

(1) Secondary drainage area storage losses of 3.0 inches have been subtracted.

Table 17

PMP AT DRAYTON

TOTAL RUNOFF AVAILABLE FOR UNIT HYDROGRAPHS
15 MARCH STORM CENTERED OVER HALSTAD TO WAHPETON

Runoff in Inches

12 Hour Period	Area above Halstad to Wahpeton		Remaining Area above Drayton	
	Primary	Secondary(1)	Primary	Secondary(1)
0 to 7	0	0	0	0
8	.01	0	.01	0
9	.13	0	.13	0
10	.07	0	.07	0
11	.23	0	.23	0
12	.24	0	.24	0
13	.41	0	.41	0
14	.54	0	.54	0
15	.52	0	.52	0
16	.80	0	.80	0
17	.66	.61	.66	.61
18	1.62	1.62	1.62	1.62
19	.50	.50	.50	.50
20	1.22	1.22	1.22	1.22
21	.36	.36	.53	.53
22	.64	.64	.47	.47
23	1.29	1.29	.96	.96
24	4.34	4.34	1.41	1.41
25	.29	.29	.19	.19
26	.20	.20	.21	.21
Total	14.07	11.18	10.72	7.82

(1) Secondary drainage area storage losses of 3.0 inches have been subtracted.

Table 18

PMP AT EMERSON

TOTAL RUNOFF AVAILABLE FOR UNIT HYDROGRAPHS
15 MARCH STORM CENTERED OVER HALSTAD TO WAHPETON

12 Hour Period	Runoff in Inches: Area From Wahpeton to Halstad, Primary	Area From Wahpeton to Halstad, Secondary (1)	Remaining Area Above Emerson, Primary	Remaining Area Above Emerson, Secondary (1)
1	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00
10	0.01	0.00	0.01	0.00
11	0.15	0.00	0.15	0.00
12	0.12	0.00	0.12	0.00
13	0.35	0.00	0.35	0.00
14	0.39	0.00	0.39	0.00
15	0.48	0.00	0.48	0.00
16	0.65	0.00	0.65	0.00
17	0.61	0.00	0.61	0.00
18	1.45	1.21	1.45	1.21
19	0.76	0.76	0.76	0.76
20	2.06	2.06	2.06	2.06
21	0.39	0.39	0.39	0.39
22	0.64	0.64	0.35	0.35
23	1.29	1.29	0.69	0.69
24	4.34	4.34	0.97	0.97
25	0.29	0.29	0.18	0.18
26	0.20	0.20	0.08	0.08
TOTAL RAINFALL:	7.15	7.15	2.66	2.66
TOTAL SNOWMELT:	7.03	4.03	7.03	4.03
TOTAL RUNOFF:	14.18	11.18	9.69	11.68

(1) Secondary drainage area storage losses of 3.0 inches have been subtracted.

Table 19

RED RIVER OF THE NORTH
PROBABLE MAXIMUM FLOOD PEAK DISCHARGES

Study Location	PMF Peak Discharge (cfs)
Fargo	205,000
Grand Forks	350,000
Oslo	348,000
Drayton	345,000
Emerson	346,000

STANDARD PROJECT FLOOD

The standard project flood (SPF) for each study location was developed using the guidelines presented in paragraph 2-04 of EM 1110-2-1411, which state that the SPF usually equals 40 to 60 percent of the PMF with 50 percent considered to be representative of average conditions. Accordingly, 50 percent of the PMF flow was computed at each study location. The SPF peak at East Grand Forks was obtained from the 1983 East Grand Forks Study. The resulting SPF peak values at each study location are shown in table 25. The SPF hydrographs for each location are shown in plates 10-14.

TABLE 20
ADOPTED PMF AT FARGO, WITH SUBAREA FLOWS ROUTED TO
FARGO - FLOWS IN CFS

12 HOUR PERIOD	LAKE TRAVERSE INFLOW	LAKE TRAVERSE OUTFLOW	ORWELL DAM INFLOW	ORWELL DAM OUTFLOW	WAHPETON TOTAL	WILD RICE AT ABERCROMBIE	TOTAL AT FARGO
1	0.00	0.00	2000.00	2000.00	2020.00	40.00	2080.00
2	0.00	0.00	2000.00	2000.00	2020.00	40.00	2080.00
3	0.00	0.00	2000.00	2000.00	2020.00	40.00	2080.00
4	0.00	0.00	2000.00	2000.00	2020.00	40.00	2080.00
5	0.00	0.00	2000.00	2000.00	2020.00	40.00	2080.00
6	0.00	0.00	2000.00	2000.00	2020.00	40.00	2080.00
7	194.70	27.10	2001.50	2001.10	2023.20	42.38	2080.00
8	3021.05	467.16	2025.05	2018.88	2075.60	83.35	2080.30
9	3834.65	1291.35	2063.15	2055.71	2220.40	195.05	2085.71
10	6765.85	2407.35	2184.25	2154.99	3029.43	396.74	2105.09
11	8214.60	3822.31	2296.15	2279.41	4570.66	712.65	2149.69
12	11947.70	5564.64	2490.55	2445.78	6554.73	1166.33	2234.17
13	15612.20	7516.23	2661.90	2636.25	9116.02	1803.05	2321.91
14	20217.15	7649.88	2925.50	2866.15	12200.42	2669.86	2627.44
15	26192.50	7855.64	3266.90	3202.06	15659.38	3829.61	3145.5
16	30080.35	8146.85	3704.30	3616.07	18031.13	5315.23	4360.00
17	37743.50	8464.73	4307.05	4184.95	20757.50	7162.86	6047.49
18	41798.90	12695.20	4927.60	4816.28	24040.32	9408.09	10113.66
19	56815.25	33621.43	5779.60	5600.85	27825.48	12168.46	15585.69
20	54713.80	49870.32	6526.50	6408.61	35939.28	15452.74	22250.89
21	54685.40	53609.76	7480.35	7278.59	61117.18	19069.56	29771.45
22	52183.75	53459.60	8157.20	8061.90	81695.13	22881.74	37595.61
23	51028.30	51925.38	8824.50	8637.64	88534.65	26736.93	45207.18
24	59483.90	54725.72	9355.10	9244.54	90419.80	30597.51	52497.18
25	130103.45	89120.12	10106.85	9897.44	90771.42	34799.36	61785.59
26	124672.00	125104.66	11087.30	10836.50	95573.06	39429.79	73986.35
27	111439.40	116476.25	12472.70	12102.86	133785.77	44015.12	85857.92
28	95413.95	104324.54	13198.65	13086.58	175501.76	48103.85	104267.18
29	92188.00	94428.82	13460.20	13412.66	171746.03	51734.44	118486.19
30	76959.25	85461.38	12774.80	13016.49	157827.03	54535.77	129873.68
31	58681.55	70340.54	11963.65	12147.72	146219.88	56560.14	139644.09
32	34506.95	50312.96	11242.50	11416.69	133750.07	57749.76	152969.42
33	6974.45	28613.19	11134.00	11110.07	113839.36	57916.62	170082.72
34	1148.70	15228.81	11320.70	11267.48	69138.67	56943.32	165017.97
35	139.05	8735.25	11123.15	11206.33	64152.37	55062.36	152596.95
36	0.00	8628.48	10547.45	10708.33	48474.59	52531.62	144007.74
37	0.00	8522.18	9114.95	9531.03	39790.78	49439.24	203166.41
38	0.00	8417.16	6854.30	7407.57	37311.41	45868.34	204579.08
39	0.00	8313.48	5649.45	5720.06	34373.61	41789.14	201570.62
40	0.00	8211.05	4922.05	5085.89	30712.45	37142.39	189935.7
41	0.00	8103.25	4415.59	4476.90	27676.66	32413.89	170736.04
42	0.00	7986.90	4090.63	4150.13	25864.24	28125.21	150400.68
43	0.00	7872.22	3836.87	3877.99	24197.06	24356.65	131143.00
44	0.00	7763.46	3621.38	3660.63	22097.73	21047.85	112912.89
45	0.00	7663.68	3373.69	3422.63	21812.60	18207.35	95755.03
46	0.00	7565.18	3206.74	3229.43	20785.89	15749.09	80789.28

12 HOUR PERIOD	LAKE TRAVERSE INFLOW	LAKE TRAVERSE OUTFLOW	ORWELL DAM INFLOW	ORWELL DAM OUTFLOW	WAHPETON TOTAL	WILD RICE AT ABERCROMBIE	TOTAL AT FARGO
47	0.00	6805.83	3070.56	3096.88	19902.82	13619.50	68844.42
48	0.00	4911.23	2963.83	2980.53	19081.31	11780.74	60077.42
49	0.00	3544.05	2989.25	2974.70	17695.81	10192.34	53476.52
50	0.00	2557.46	3007.10	3008.97	15215.76	8819.24	48264.05
51	0.00	1845.51	2754.01	2821.46	13402.15	7631.30	43606.76
52	0.00	1331.76	2588.81	2602.36	12003.73	6600.61	39536.90
53	0.00	961.03	2494.45	2513.68	10715.98	5712.40	36114.18
54	0.00	693.50	2402.88	2418.75	9623.82	4943.96	33159.56
55	0.00	500.44	2352.84	2359.05	8756.61	4280.69	30335.21
56	0.00	361.13	2306.29	2316.00	8006.24	3701.03	27682.52
57	0.00	260.60	2264.22	2271.11	7360.44	3201.79	25167.45
58	0.00	188.05	2225.57	2232.83	6789.63	2765.73	22749.90
59	0.00	135.70	2196.89	2201.29	6257.61	2391.53	20446.88
60	0.00	97.93	2174.09	2178.22	5825.54	2065.50	18264.32
61	0.00	70.67	2152.42	2156.37	5402.19	1783.97	16188.48
62	0.00	50.99	2131.82	2135.56	5041.15	1531.54	14315.79
63	0.00	36.80	2111.90	2115.55	4665.73	1314.34	12736.55
64	0.00	26.55	2093.59	2096.85	4319.06	1121.25	11353.56
65	0.00	19.16	2076.21	2079.40	4022.50	950.65	10149.96
	0.00	13.83	2064.20	2065.97	3746.66	797.79	9101.27
67	0.00	9.98	2050.87	2053.65	3486.21	673.04	8204.34
68	0.00	7.20	2042.86	2043.74	3256.55	556.17	7471.18
69	0.00	5.20	2034.55	2036.39	3041.13	458.25	6816.76
70	0.00	3.75	2027.02	2028.21	2848.74	370.76	6235.80
71	0.00	2.71	2020.27	2021.55	2675.08	300.28	5710.33
72	0.00	1.95	2012.81	2014.24	2514.91	237.68	5237.40
73	0.00	1.41	2001.23	2003.70	2384.75	183.27	4805.83
74	0.00	1.02	2000.45	1999.52	2278.89	127.56	4414.78
75	0.00	0.73	2000.00	2000.55	2183.26	77.90	4056.95
76	0.00	0.53	2000.00	1999.75	2119.59	44.38	3735.73
77	0.00	0.38	2000.00	2000.12	2067.38	41.29	3444.23
78	0.00	0.28	2000.00	1999.95	2025.38	40.00	3187.38
79	0.00	0.20	2000.00	2000.02	2022.00	40.00	2962.57
80	0.00	0.14	2000.00	1999.99	2020.22	40.00	2766.91
81	0.00	0.10	2000.00	2000.01	2020.22	40.00	2600.08
82	0.00	0.07	2000.00	2000.00	2020.13	40.00	2460.46
83	0.00	0.05	2000.00	2000.00	2020.11	40.00	2346.59
84	0.00	0.04	2000.00	2000.00	2020.07	40.00	2260.22
85	0.00	0.03	2000.00	2000.00	2020.06	40.00	2197.63
86	0.00	0.02	2000.00	2000.00	2020.04	40.00	2152.12
87	0.00	0.01	2000.00	2000.00	2020.03	40.00	2119.77
88	0.00	0.01	2000.00	2000.00	2020.02	40.00	2099.38
89	0.00	0.01	2000.00	2000.00	2020.01	40.00	2085.95
90	0.00	0.01	2000.00	2000.00	2020.01	40.00	2081.04
MAX	130103.45	125104.66	13460.20	13412.66	175501.76	57916.62	204379.08
MIN	0.00	0.00	2000.00	1999.52	2020.00	40.00	2080.00
AVE	14075.14	14075.14	4212.31	4212.31	27416.63	13136.80	45024.72

TABLE 21
ADOPTED PMF AT GRAND FORKS, WITH SUBAREA FLOWS ROUTED TO
GRAND FORKS - FLOWS IN CFS

12 HOUR PERIOD	AREA ABOVE HALSTAD	GOOSE RIVER BASIN	RED LAKE RIVER	LOCAL AT G.F.	TOTAL AT G.F.
1	2500.00	40.00	1120.00	20.00	3680.00
2	2500.00	40.00	1120.00	309.08	3969.08
3	2500.00	40.00	1120.00	694.54	4354.54
4	2548.73	47.30	1143.47	1515.12	5254.62
5	2676.36	76.03	1235.19	2606.55	6594.13
6	2994.63	147.31	1454.24	4263.39	8859.57
7	3645.75	291.80	1862.68	6450.70	12250.93
8	4723.09	546.90	2513.15	9157.12	16942.26
9	6419.14	969.40	3460.53	12527.45	23396.52
10	8827.17	1609.12	4819.92	16301.07	31557.27
11	12106.04	2527.89	6568.07	21508.11	42790.11
12	16605.96	3779.84	8732.74	26202.00	55320.54
13	22367.16	5434.63	11366.92	30392.43	69561.15
14	29503.73	7543.29	14511.41	33680.36	85238.79
15	37894.62	10083.66	18004.46	36387.65	102370.59
16	47437.14	12987.71	21561.36	38743.34	120729.56
17	57315.28	16142.51	24906.46	41701.52	140065.77
18	67374.46	19421.60	28026.53	43965.47	158788.05
19	78199.19	22707.49	31109.77	45614.65	177631.31
20	90306.16	25891.15	34275.52	46325.15	196797.98
21	104195.63	28842.19	37574.01	45963.29	216575.13
22	120375.27	31457.13	40959.06	44391.06	237183.12
23	136457.99	33639.21	44324.38	42005.83	256427.41
24	151169.01	35218.07	47528.94	39513.84	273250.45
25	163899.65	36059.13	50333.05	36774.82	287066.68
26	174935.47	36110.29	52571.04	34439.28	298056.08
27	185265.56	35575.64	54314.45	32270.09	307224.05
28	195444.71	33946.57	55852.35	30160.25	315403.90
29	205076.73	31973.52	57391.37	28147.28	322588.90
30	213868.33	29554.79	59001.91	26201.39	328626.42
31	221231.54	26790.97	60490.10	24291.75	332804.35
32	226618.24	23792.42	61690.51	22416.05	334517.21
33	232009.84	20630.43	62458.35	20622.00	335720.63
34	236419.69	17454.40	62660.34	18917.32	337471.76
35	240249.36	14443.21	62296.15	17286.02	340275.35

12 HOUR PERIOD	AREA ABOVE HALSTAD	GOOSE RIVER BASIN	RED LAKE RIVER	LOCAL AT G.F.	TOTAL AT G.F.
36	254793.06	11725.04	61288.99	15791.77	343598.86
37	263398.23	9400.33	59681.16	14353.03	346832.75
38	271248.04	7473.77	57526.40	13012.69	349260.90
39	277691.32	5879.25	54904.92	11780.65	350256.33
40	282147.50	4579.70	51910.10	10695.00	349332.30
41	284249.14	3551.44	48648.47	9728.92	346177.98
42	283749.21	2741.16	45230.87	8916.79	340638.03
43	280611.06	2109.55	41765.60	8197.87	332684.09
44	274946.49	1621.18	38343.51	7590.80	322501.99
45	267015.56	1243.53	35026.07	7055.43	310340.60
46	257185.50	947.69	31850.04	6583.73	296566.96
47	245850.88	715.35	28837.62	6154.09	281557.95
48	233409.77	534.76	26008.11	5766.10	265716.74
49	220226.93	396.38	23370.27	5395.50	249389.06
50	206675.05	291.36	20939.21	5032.25	232937.87
51	193065.81	213.63	18713.41	4675.49	216688.34
52	179748.58	155.57	16688.46	4294.02	200886.62
53	166904.90	112.29	14856.73	3896.85	185770.77
54	154746.03	81.27	13209.75	3471.63	171508.68
55	143376.57	60.55	11737.30	3045.81	158220.24
56	132855.72	48.08	10427.95	2601.71	145933.46
57	123187.30	42.49	9259.82	2181.25	134660.86
58	114324.29	40.52	8251.82	1796.51	124413.14
59	106195.57	40.08	7362.66	1423.45	115021.76
60	98714.97	40.00	6589.89	1155.60	106500.46
61	91791.46	40.00	5919.93	887.22	98638.61
62	85343.86	40.00	5338.36	630.10	91352.32
63	79304.11	40.00	4832.57	397.29	84573.98
64	73619.19	40.00	4391.65	199.26	78250.10
65	68276.04	40.00	4005.98	62.64	72304.66
66	63258.84	40.00	3667.42	32.64	66998.90
67	58562.50	40.00	3369.17	20.00	61991.96
68	54192.99	40.00	3105.48	20.00	57358.47
69	50152.72	40.00	2872.25	20.00	53084.97
70	46444.30	40.00	2664.61	20.00	49168.91

12 HOUR PERIOD	AREA ABOVE HALSTAD	GOOSE RIVER BASIN	RED LAKE RIVER	LOCAL AT G.F.	TOTAL AT G.F.
71	43063.45	40.00	2478.98	20.00	45602.43
72	39995.36	40.00	2311.34	20.00	42366.70
73	37221.06	40.00	2159.67	20.00	39440.73
74	34718.40	40.00	2021.99	20.00	36800.40
75	32441.71	40.00	1897.02	20.00	34396.73
76	30359.95	40.00	1783.99	20.00	32203.93
77	28444.36	40.00	1681.55	20.00	30185.90
78	26670.85	40.00	1589.31	20.00	28320.16
79	25020.01	40.00	1506.34	20.00	26586.34
80	23476.12	40.00	1432.90	20.00	24969.02
81	22028.15	40.00	1367.80	20.00	23455.95
82	20669.00	40.00	1310.99	20.00	22040.00
83	19394.69	40.00	1262.32	20.00	20717.01
84	18204.09	40.00	1222.02	20.00	19486.11
85	17096.21	40.00	1189.80	20.00	18346.01
86	16068.81	40.00	1165.01	20.00	17293.82
87	15101.64	40.00	1146.91	20.00	16368.55
88	14426.95	40.00	1134.44	20.00	15621.38
89	13796.52	40.00	1126.69	20.00	14983.21
90	13261.56	40.00	1122.60	20.00	14464.16
MAX	284249.14	36110.29	52680.34	46325.15	350258.33
MIN	2500.00	40.00	1120.00	20.00	3680.00
AVE	108806.94	6098.46	20465.50	11654.15	147025.05

TABLE 22
ADOPTED PMF AT OSLO, WITH SUBAREA FLOWS ROUTED TO OSLO - FLOWS IN CFS

12 HOUR PERIOD	AREA ABOVE FARGO	AREA ABOVE HALSTAD	ABOVE GRAND FORKS	LOCAL AT OSLO	TOTAL AT OSLO
1	2020.00	2500.00	3680.00	20.00	3700.00
2	2020.00	2500.00	3969.08	128.02	3808.02
3	2020.00	2500.00	4354.54	457.63	4137.63
4	2020.00	2548.73	5254.62	1080.26	4789.17
5	2020.00	2676.36	6594.13	2020.33	5796.69
6	2020.00	2994.63	8859.57	3261.84	7195.66
7	2024.40	3645.75	12250.93	4920.88	9146.12
8	2038.45	4723.09	16942.26	7022.75	11765.94
9	2124.69	6419.14	23396.52	9576.35	15176.64
10	2361.18	8827.17	31557.27	12511.81	19438.32
11	2826.50	12186.04	42790.11	16027.33	24925.49
12	3633.93	16605.96	55320.54	20009.62	31695.51
13	4897.10	22387.16	69581.15	23478.09	39074.99
14	6692.07	29503.73	85238.79	25650.72	46382.77
15	8826.91	37894.62	102370.59	26452.25	53706.96
16	11376.77	47437.14	120742.70	26954.75	62207.88
17	14341.35	57315.28	140144.81	28349.23	73180.00
18	17710.07	67374.46	158934.00	30484.12	86503.21
19	23874.01	78199.19	177846.07	32148.15	100956.62
20	31895.44	90306.16	197087.95	32162.80	115170.45
21	40082.00	104195.63	216946.65	30387.77	128840.37
22	47900.39	120375.27	237624.73	27799.58	142805.25
23	55620.38	136457.99	256924.68	25197.11	157618.43
24	63478.75	151189.01	273793.18	22764.74	173416.48
25	71159.75	163899.68	287652.00	20567.90	189954.00
26	77734.33	174935.49	298673.30	18583.73	206825.27
27	80387.55	185266.01	307856.25	16790.11	223559.79
28	79909.88	195445.12	316040.37	15170.75	239733.49
29	77794.88	205077.78	323228.98	13707.76	255041.64
30	74517.16	213870.64	329272.02	12393.77	269438.29
31	69982.65	221236.18	333452.94	11194.66	282777.47
32	63877.72	226627.33	335166.22	10126.83	294928.05
33	56902.34	232027.21	336369.88	9147.55	305599.39
34	50242.79	238451.09	338121.66	8277.41	314483.40
35	44233.22	246302.54	340929.04	7485.19	321635.70
36	38892.78	254877.67	344263.78	6768.79	327352.15
37	34294.38	263525.54	347518.06	6129.83	332040.89
38	30477.95	271429.85	349975.92	5538.92	336009.03
39	27509.06	277939.01	351008.99	5046.50	339482.79
40	25411.00	282470.86	350129.86	4514.54	342344.39
41	23762.02	284655.04	347025.81	4090.36	344698.21
42	22255.57	284240.64	341539.19	3693.46	346387.09
43	20910.44	281186.35	333636.53	3347.42	347398.34
44	19747.72	275599.32	323500.70	3042.85	347731.07

12 HOUR PERIOD	AREA ABOVE FARGO	AREA ABOVE HALSTAD	ABOVE GRAND FORKS	LOCAL AT OSLO	TOTAL AT OSLO
45	18626.99	267735.06	311376.26	2773.53	347188.41
46	17453.77	257957.30	297627.08	2466.44	345419.23
47	16237.81	246658.43	282627.55	2227.57	342225.08
48	15002.78	234235.71	266780.47	2007.65	337341.49
49	13755.31	221054.57	250432.10	1816.58	330661.37
50	12492.50	207489.50	233947.65	1642.75	322168.00
51	11226.26	193875.30	217654.86	1486.08	311953.64
52	9964.50	180504.56	201802.67	1344.57	300193.91
53	8871.59	167622.50	186632.69	1207.80	287120.04
54	7992.00	155423.67	172316.11	1088.76	273027.35
55	7268.49	144015.59	158975.55	972.63	258210.83
56	6656.01	133459.39	146640.72	870.18	242989.92
57	6128.77	123759.77	135345.41	768.11	227647.78
58	5673.81	114870.06	125040.53	673.64	212454.68
59	5274.66	106718.71	115616.59	585.44	197638.26
60	4917.82	99218.86	107066.79	495.63	183374.46
61	4594.22	92278.46	99179.52	420.60	169817.88
62	4299.48	85815.47	91869.28	314.57	157023.76
63	4029.44	79760.76	85068.14	272.16	145133.82
64	3780.42	74060.32	78721.39	225.69	134094.01
65	3549.61	68700.50	72832.82	188.92	123900.78
66	3336.29	63665.04	67425.93	149.78	114502.17
67	3139.98	58948.97	62396.49	100.66	105838.78
68	2961.97	54557.43	57739.09	37.84	97854.48
69	2801.35	50494.13	53440.67	26.88	90548.63
70	2658.37	46761.92	49499.17	20.00	83811.60
71	2532.59	43357.25	45907.42	20.00	77594.01
72	2423.73	40266.02	42647.27	20.00	71837.25
73	2330.97	37469.90	39698.32	20.00	66510.04
74	2253.85	34947.13	37036.86	20.00	61587.84
75	2190.99	32652.39	34616.26	20.00	57050.86
76	2142.30	30554.72	32404.78	20.00	52882.40
77	2106.35	28625.16	30372.10	20.00	49060.75
78	2080.20	26839.30	28493.38	20.00	45558.63
79	2062.17	25177.39	26747.90	20.00	42356.19
80	2050.76	23623.36	25119.88	20.00	39431.62
81	2044.09	22165.88	23596.74	20.00	36762.35
82	2041.04	20797.63	22171.13	20.00	34324.42
83	2040.31	19514.52	20838.83	20.00	32093.35
84	2040.07	18315.45	19598.97	20.00	30045.73
85	2040.05	17199.47	18450.33	20.00	28159.79
86	2040.04	16164.42	17390.14	20.00	26416.00
87	2040.03	15270.51	16477.85	20.00	24914.27
88	2040.02	14510.00	15704.66	20.00	23633.69
89	2040.02	13874.68	15061.47	20.00	22556.37
90	2040.01	13355.76	14538.39	20.00	21666.93
MAX	80387.55	284655.04	351008.99	32162.80	347731.07
MIN	2020.00	2500.00	3680.00	20.00	3700.00
AVE	17656.68	109046.10	148249.94	6878.54	154171.58

TABLE 23
ADOPTED PMF AT DRAYTON, WITH SUBAREA FLOWS ROUTED TO DRAYTON - FLOWS IN CFS

12 HOUR PERIOD	AREA ABOVE HALSTAD	ABOVE GRAND FORKS	AREA ABOVE OSLO	LOCAL AT DRAYTON	TOTAL AT DRAYTON
1	2500.00	3680.00	3700.00	20.00	3720.00
2	2500.00	3693.14	3704.91	23.53	3723.53
3	2500.00	3877.30	3782.16	74.11	3774.11
4	2502.21	4158.46	4008.52	165.48	3865.97
5	2536.11	4778.71	4456.62	355.47	4064.18
6	2627.19	5793.55	5183.44	667.71	4407.27
7	2850.99	7521.50	6267.75	1209.36	5024.58
8	3312.81	10216.72	7871.29	2162.75	6126.32
9	4105.47	13956.67	10083.43	3528.50	7748.84
10	5395.59	19244.34	12974.71	5567.43	10204.90
11	7301.99	26016.98	16574.48	8369.40	13645.21
12	10033.88	35657.13	21272.08	12423.18	18626.46
13	13709.58	46713.27	27256.95	17583.02	25073.75
14	18592.11	60293.31	34310.58	24014.14	33261.59
15	24735.97	75445.27	41997.54	31716.67	43311.60
16	32262.32	92156.29	49905.11	40600.21	55225.34
17	41202.78	110593.31	58409.74	51233.39	69612.61
18	50964.96	130747.86	68532.60	62862.50	85713.89
19	61512.23	150746.76	80663.48	75057.07	103122.66
20	73106.67	171032.62	94142.50	87210.30	121342.02
21	86007.61	191595.67	107713.56	98106.74	139296.47
22	100613.18	212729.51	121055.84	108230.73	157537.24
23	117446.97	234526.68	135000.39	117386.95	175807.37
24	134176.92	254731.15	150061.94	123863.82	192262.61
25	149540.46	272353.51	166347.42	127677.95	206851.09
26	162739.55	286860.18	183537.08	127996.50	218744.77
27	174048.93	298399.44	201191.34	125822.57	229005.83
28	184251.18	307692.87	218821.24	119792.01	236338.47
29	193785.62	315432.07	235940.39	111464.14	242288.76
30	202611.99	321974.87	252133.60	101187.29	247040.77
31	210674.56	327402.33	267249.41	89718.00	251099.17
32	217523.99	331157.65	281116.79	77056.11	254236.39
33	222594.12	332676.54	293596.50	65273.10	258406.97
34	227889.60	333910.70	304439.10	53666.54	262806.50
35	234407.19	335874.87	313357.40	42234.03	267233.60
36	242551.54	339041.47	320464.08	31874.19	272311.47
37	251597.65	342856.95	326078.16	23988.49	279126.78
38	260891.15	346715.95	330641.37	18207.61	287038.60
39	269591.61	349903.71	334480.22	13932.52	295252.19
40	277013.10	351752.38	337876.38	10797.64	303299.32
41	282537.01	351760.50	340788.67	8429.77	310785.44
42	285728.01	349560.00	343351.48	6646.20	317576.14
43	286284.41	344942.14	345358.46	5263.95	323547.82
44	284103.99	337810.01	346834.20	4217.19	328724.53

12 HOUR PERIOD	AREA ABOVE HALSTAD	ABOVE GRAND FORKS	AREA ABOVE OSLO	LOCAL AT DRAYTON	TOTAL AT DRAYTON
45	279252.73	328313.60	347752.74	3400.53	333084.06
46	271935.74	316646.95	347865.68	2789.93	336712.98
47	262493.18	303159.77	346794.02	2278.26	339640.84
48	251325.59	288230.40	344313.71	1868.16	341970.90
49	238855.59	272276.47	340116.60	1482.50	343656.82
50	225481.02	255678.45	334071.81	1137.30	344678.86
51	211610.24	238838.04	326130.18	853.20	344958.40
52	197639.19	222134.56	316362.32	622.80	344347.54
53	183908.87	205870.29	304924.51	434.70	342693.59
54	170688.09	190308.97	292045.19	269.90	339829.87
55	158181.53	175641.11	278015.96	126.90	335643.48
56	146500.99	161977.14	263151.62	48.60	330086.28
57	135707.65	149353.52	247778.69	28.40	323092.40
58	125803.49	137798.29	232210.76	20.00	314612.59
59	116739.29	127249.49	216734.44	20.00	304711.06
60	108438.48	117602.01	201604.58	20.00	293500.77
61	100809.63	108847.30	187012.97	20.00	281162.55
62	93759.73	100782.32	173131.21	20.00	267915.83
63	87202.97	93363.08	160026.76	20.00	254004.10
64	81064.92	86476.17	147840.85	20.00	239680.99
65	75287.10	80040.47	136515.97	20.00	225191.22
66	69852.57	74067.93	126092.15	20.00	210770.78
67	64742.87	68579.02	116498.59	20.00	196620.79
68	59952.38	63464.08	107658.54	20.00	182914.84
69	55486.20	58725.80	99518.65	20.00	169786.83
70	51349.78	54348.78	92076.22	20.00	157331.61
71	47548.24	50333.19	85214.82	20.00	145610.03
72	44077.32	46671.29	78889.50	20.00	134657.19
73	40924.80	43346.93	73038.08	20.00	124477.38
74	38073.72	40340.88	67626.98	20.00	115053.20
75	35502.87	37629.42	62625.37	20.00	106354.34
76	33166.92	35165.59	58011.84	20.00	98332.95
77	31034.08	32916.63	53770.73	20.00	90943.89
78	29074.00	30850.43	49880.50	20.00	84135.86
79	27260.65	28940.37	46314.26	20.00	77863.07
80	25572.90	27164.66	43052.89	20.00	72085.27
81	23993.77	25506.92	40074.35	20.00	66764.83
82	22511.27	23954.24	37355.94	20.00	61862.50
83	21117.69	22499.40	34873.31	20.00	57348.45
84	19808.96	21138.34	32601.61	20.00	53195.09
85	18584.40	19870.64	30516.85	20.00	49378.62
86	17443.69	18695.66	28596.60	20.00	45876.08
87	16454.54	17680.60	26947.49	20.00	42873.70
88	15609.26	16816.79	25544.77	20.00	40332.68
89	14900.31	16095.24	24366.94	20.00	38215.77
90	14319.60	15506.75	23395.73	20.00	36487.88
MAX	286284.41	351760.50	347865.68	127996.50	344958.40
MIN	2500.00	3680.00	3700.00	20.00	3720.00
AVE	108710.13	147765.36	153571.96	22818.66	174651.80

TABLE 24
ADOPTED PMF AT EMERSON, WITH SUBAREA FLOWS ROUTED TO EMERSON - FLOWS IN CFS

12 HOUR PERIOD	HALSTAD	GRAND FORKS	OSLO	DRAYTON	EMERSON
1	2500.00	3680.00	3700.00	3720.00	4103.33
2	2500.00	3680.00	3700.00	3720.00	4103.33
3	2500.00	3680.00	3700.00	3720.00	4103.33
4	2500.00	3680.00	3700.00	3720.00	4103.33
5	2500.00	3680.00	3700.00	3720.00	4103.33
6	2500.00	3680.00	3700.00	3720.00	4103.33
7	2500.00	3680.00	3700.00	3720.00	4103.33
8	2500.00	3680.00	3700.00	3720.00	4103.33
9	2500.00	3680.00	3700.00	3720.00	4103.33
10	2500.00	3680.00	3700.00	3720.00	4103.33
11	2522.15	3693.14	3704.91	3723.53	4107.25
12	2883.22	3903.58	3791.98	3781.16	4171.95
13	3623.52	4277.12	4069.73	3900.10	4313.70
14	5445.07	5153.28	4678.92	4175.99	4628.73
15	8848.33	6643.55	5754.67	4673.00	5238.76
16	13627.88	9003.33	7361.17	5516.69	6281.59
17	20578.12	12600.42	9562.85	6971.74	7978.29
18	28733.37	17534.20	12365.36	9132.52	10493.71
19	39714.16	25060.16	16116.78	12602.51	14311.97
20	52023.68	34351.84	21124.22	17419.60	19399.58
21	68277.92	47297.43	27754.08	24185.77	26261.38
22	86522.08	61774.82	35778.21	32732.93	34657.88
23	102559.20	78060.74	44069.39	43151.04	44508.73
24	120242.91	96407.61	51988.45	56216.86	56086.22
25	137753.63	116836.85	60143.55	71528.88	69327.40
26	155768.53	137676.28	69697.19	89293.38	83302.85
27	178216.86	158710.01	80915.02	107891.47	96815.60
28	207374.98	179875.53	92922.95	126194.72	110139.77
29	216217.14	201505.78	105499.45	144854.61	122535.31
30	214032.36	223664.39	119222.18	162878.74	134565.03
31	206033.72	243973.35	134434.17	178895.38	145167.73
32	202516.41	261662.57	151128.38	192765.36	155585.56
33	202269.96	276201.21	168775.02	203976.24	165241.06
34	206964.09	287796.25	186937.10	213055.16	174612.83
35	215528.33	296801.55	205101.60	218369.49	183520.11
36	227305.30	303704.54	222750.73	222727.10	192594.68
37	240605.56	309241.03	239400.51	225735.86	201966.09
38	254461.99	313767.45	254786.12	227979.94	211507.08
39	267584.24	316960.57	268741.67	229906.60	221220.87
40	279042.65	318276.66	281143.49	234144.17	230947.29
41	288042.54	319639.45	291791.23	239901.08	240333.21
42	293663.81	321961.01	300451.48	246237.49	249385.96
43	295451.83	325584.23	307287.45	253350.41	257968.01
44	293457.45	329869.02	312659.99	261748.63	267097.43
45	288190.72	334162.23	317007.93	270860.07	274854.61
46	279819.44	337723.37	320674.36	279920.23	283588.96
47	268662.83	339850.21	323955.39	288542.41	289459.05
48	255086.00	340048.97	326890.56	296421.23	295723.60
49	240050.82	337951.14	329605.54	303466.59	300707.10
50	224253.11	333334.81	331807.95	309592.41	307386.53

12 HOUR PERIOD	HALSTAD	GRAND FORKS	OSLO	DRAYTON	EMERSON
51	208445.19	326126.07	333580.49	314856.47	312933.36
52	192917.94	316483.71	334805.80	319255.47	317757.20
53	177999.02	304640.16	335201.66	322898.04	321620.69
54	163968.15	290975.75	334382.79	325859.69	326078.54
55	150949.44	275901.65	332068.09	328269.20	330059.13
56	139006.41	259865.59	327979.23	330067.15	333811.96
57	128202.39	243281.34	321976.80	331232.96	337181.55
58	118492.49	226560.85	314030.15	331674.45	340078.32
59	109744.45	210073.68	304229.75	331265.19	342389.63
60	101820.64	194140.48	292750.74	329847.55	344236.79
61	94565.56	179010.24	279844.69	327193.87	345548.47
62	87863.32	164824.35	265818.11	323189.35	346281.26
63	81564.29	151645.37	251005.59	317762.17	346407.68
64	75547.26	139478.31	235747.37	310851.40	345909.00
65	69783.42	128333.85	220357.29	302428.59	344750.35
66	64268.08	118118.97	205123.80	292565.05	342887.56
67	59114.43	108761.28	190287.51	281393.97	340269.60
68	54329.76	100243.20	176034.85	269108.43	336830.14
69	49916.06	92407.15	162513.99	255939.50	332501.13
70	45864.99	85282.53	149787.26	242139.97	327239.35
71	42386.32	78684.78	137962.63	227968.39	321006.07
72	39314.90	72552.46	126973.09	213672.05	313776.37
73	36593.32	66893.44	116911.46	199483.84	305549.72
74	34163.91	61715.40	107660.05	185599.34	296356.94
75	31974.99	56944.77	99149.93	172189.92	286257.95
76	29986.83	52569.95	91330.81	159381.19	275339.94
77	28159.09	48579.40	84183.84	147260.46	263716.94
78	26461.51	44964.40	77625.50	135881.16	251519.77
79	24867.15	41702.11	71607.31	125270.79	238891.38
80	23347.28	38765.16	66079.43	115429.85	225982.95
81	21898.82	36124.61	61008.92	106339.19	212950.83
82	20529.26	33748.82	56357.19	97968.40	199949.89
83	19239.22	31586.40	52101.17	90273.03	187125.47
84	18026.92	29603.33	48220.81	83211.44	174606.63
85	16895.87	27770.97	44690.10	76730.41	163063.97
86	15850.77	26067.81	41478.89	70786.49	152540.49
87	14891.43	24590.85	38744.75	65693.58	143060.71
88	14012.82	23321.61	36448.09	61382.58	134631.19
89	13315.85	22250.51	34550.48	57786.27	127241.11
90	12785.79	21363.29	33014.38	54845.80	120865.53
MAX	295451.83	340048.97	335201.66	331674.45	346407.68
MIN	2500.00	3680.00	3700.00	3720.00	4103.33
AVE	104200.24	138503.27	143138.63	161117.49	185091.47

Table 25

RED RIVER OF THE NORTH
SPF PEAK DISCHARGES

Study Location	SPF Peak Discharge (cfs)
Fargo	103000
Grand Forks	169000
Oslo	174000
Drayton	173000
Emerson	173000

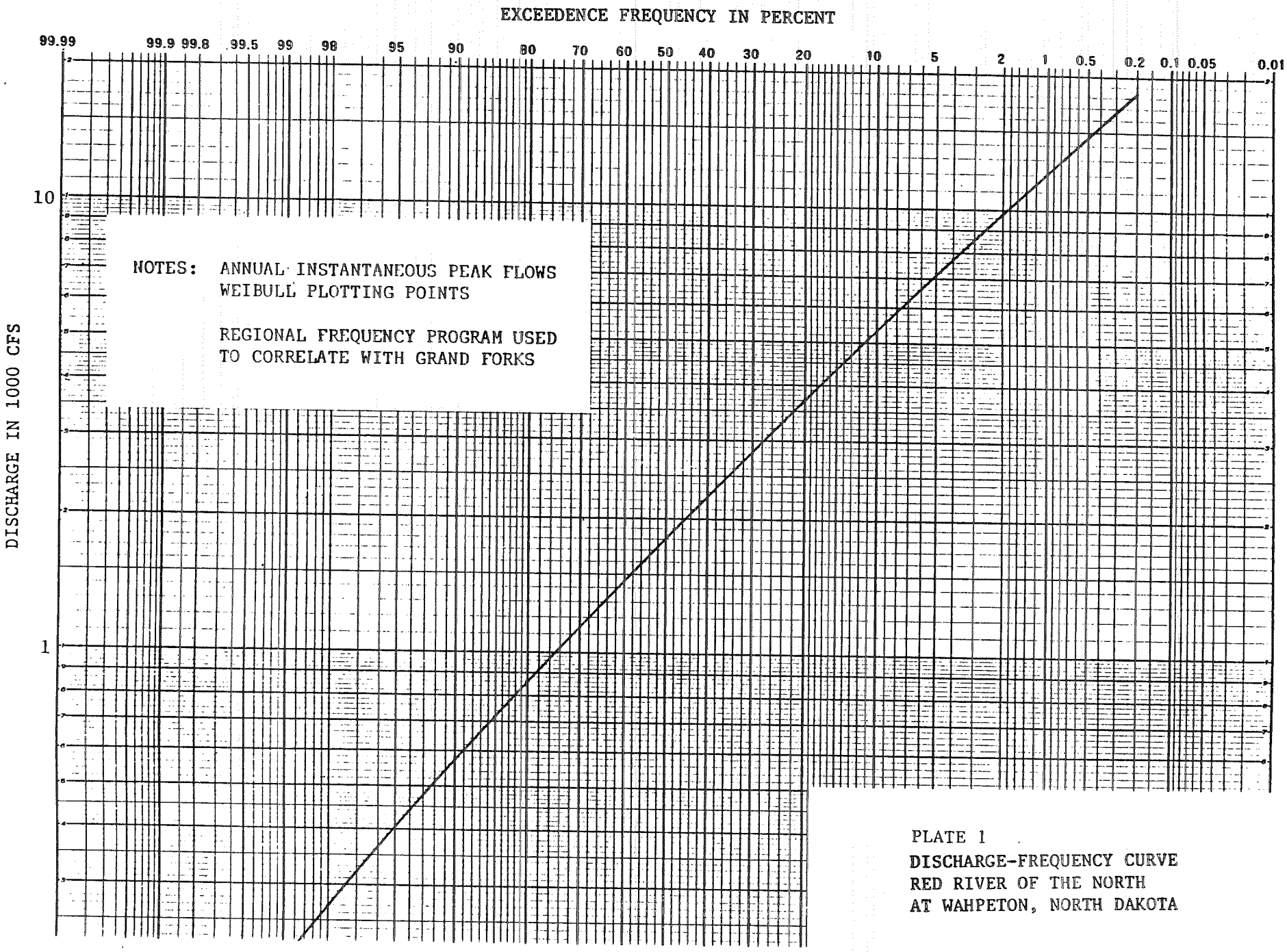


PLATE 1
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
AT WAHPETON, NORTH DAKOTA

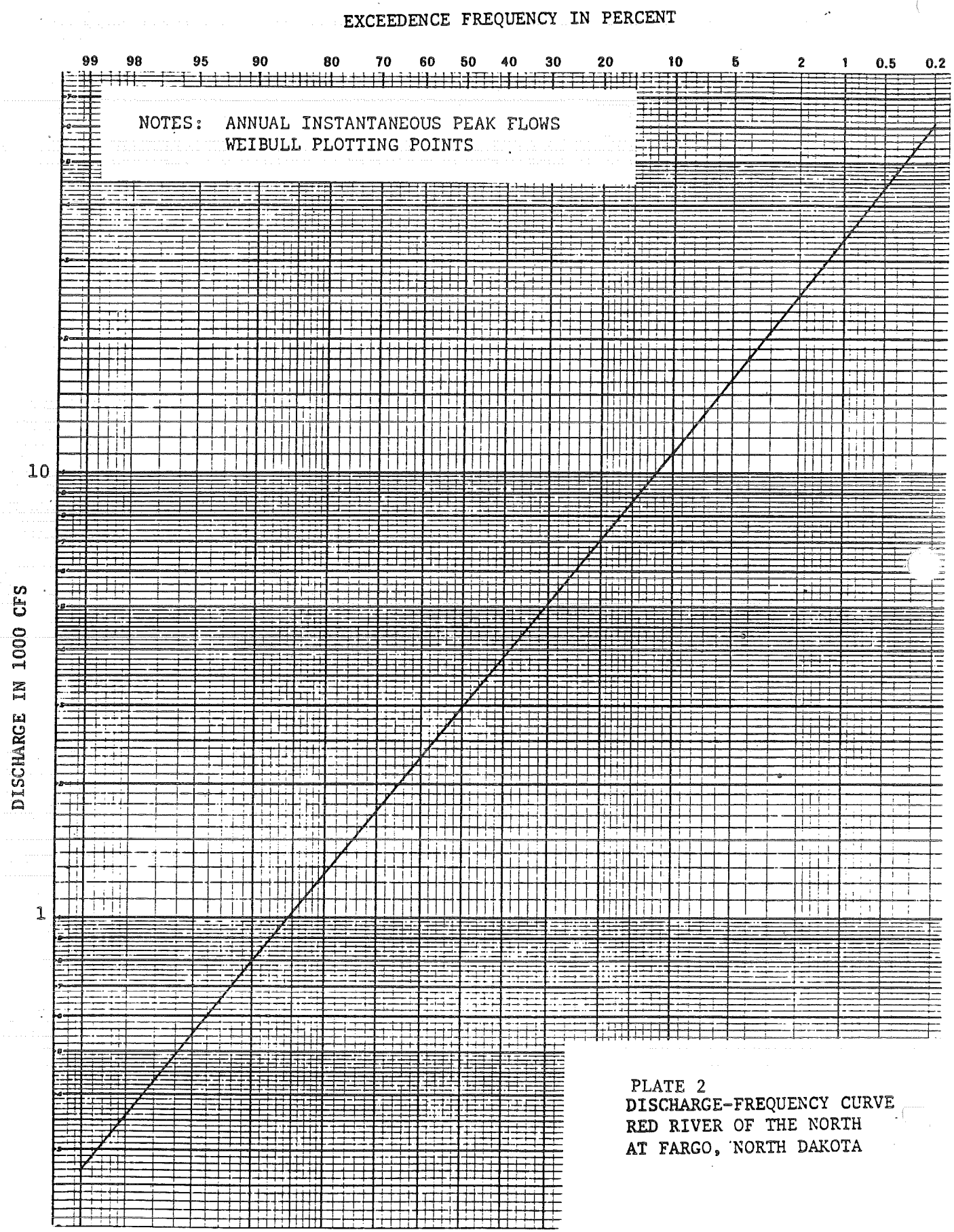


PLATE 2
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
AT FARGO, NORTH DAKOTA

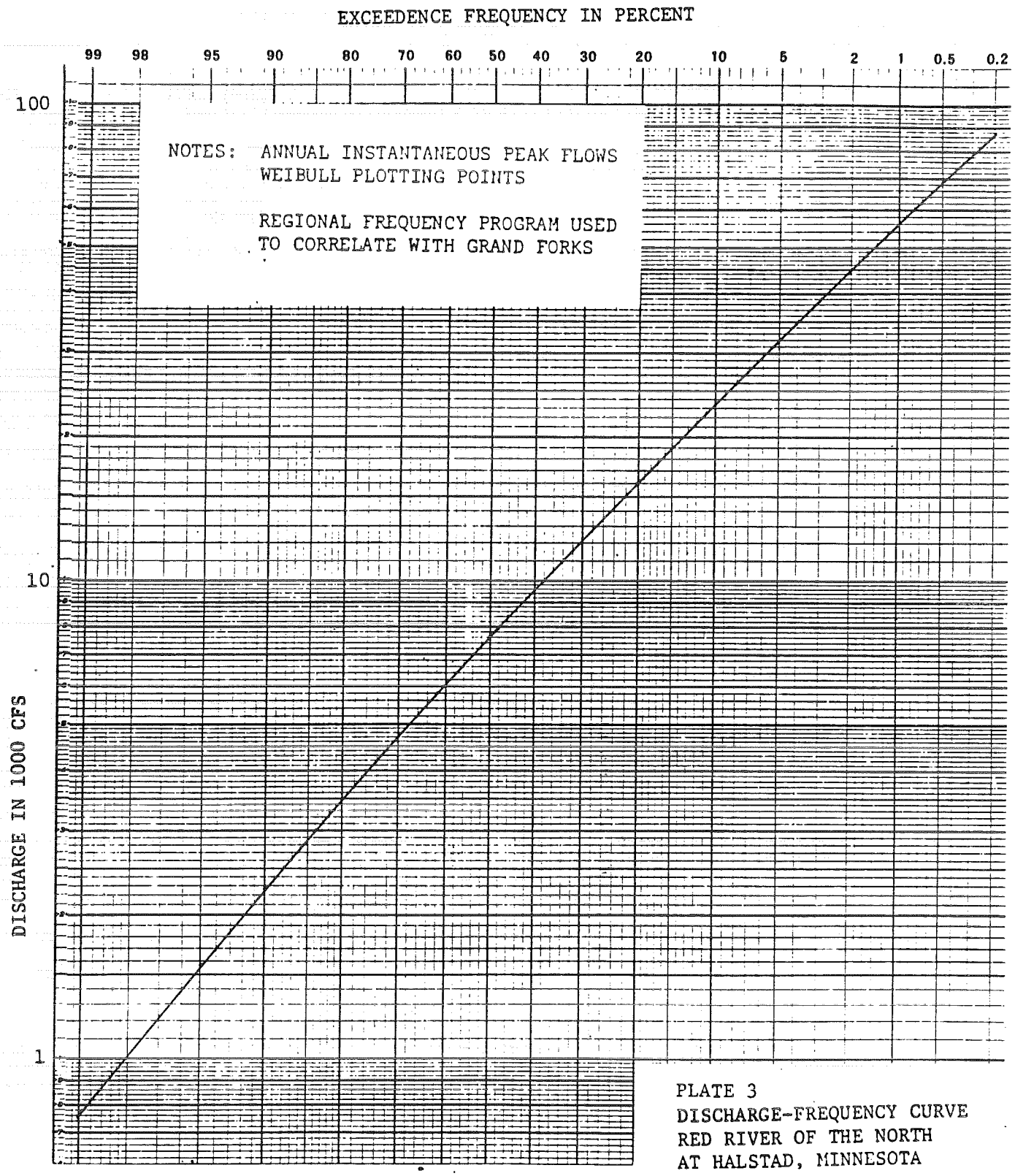


PLATE 3
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
AT HALSTAD, MINNESOTA

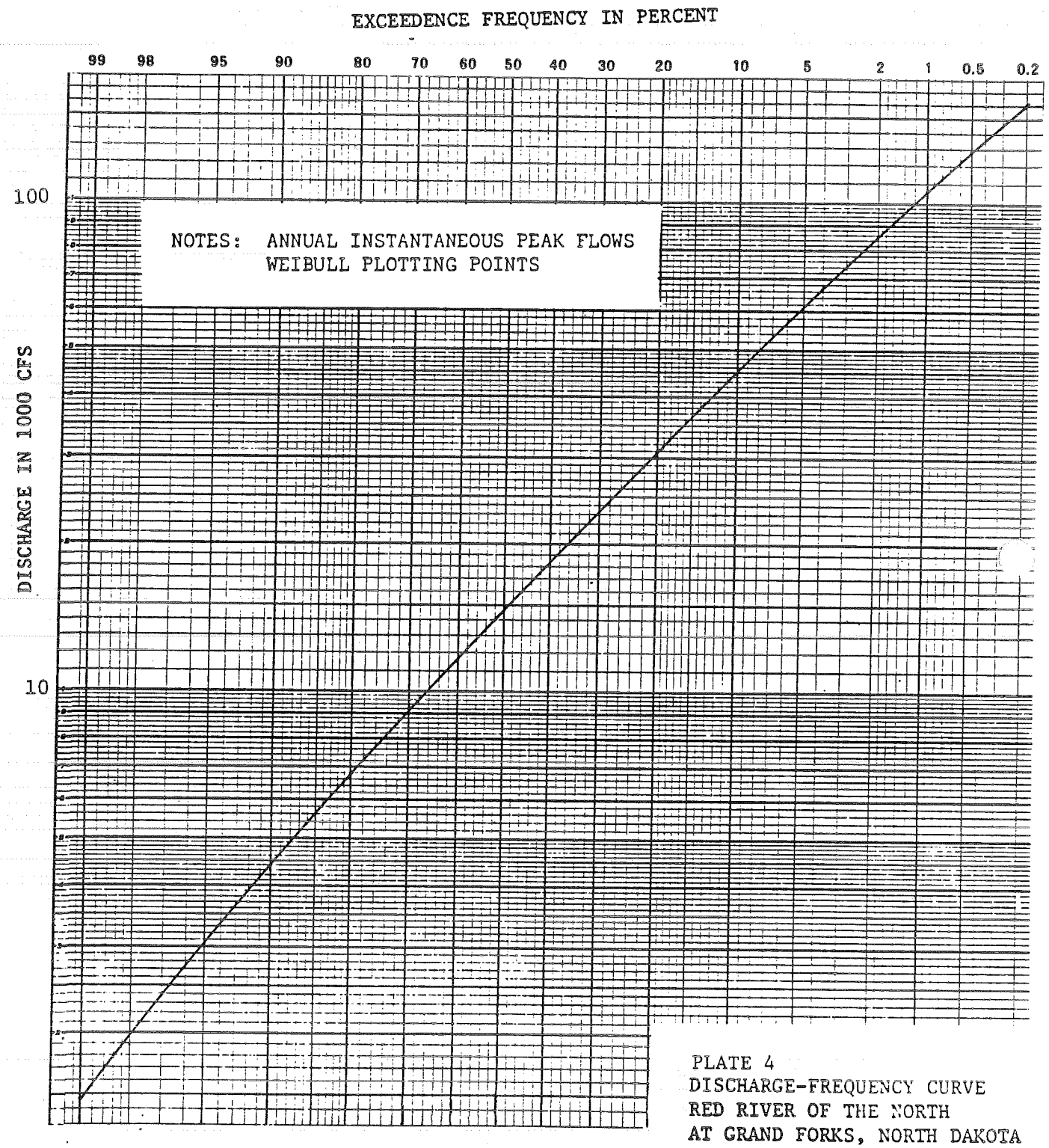


PLATE 4
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
AT GRAND FORKS, NORTH DAKOTA

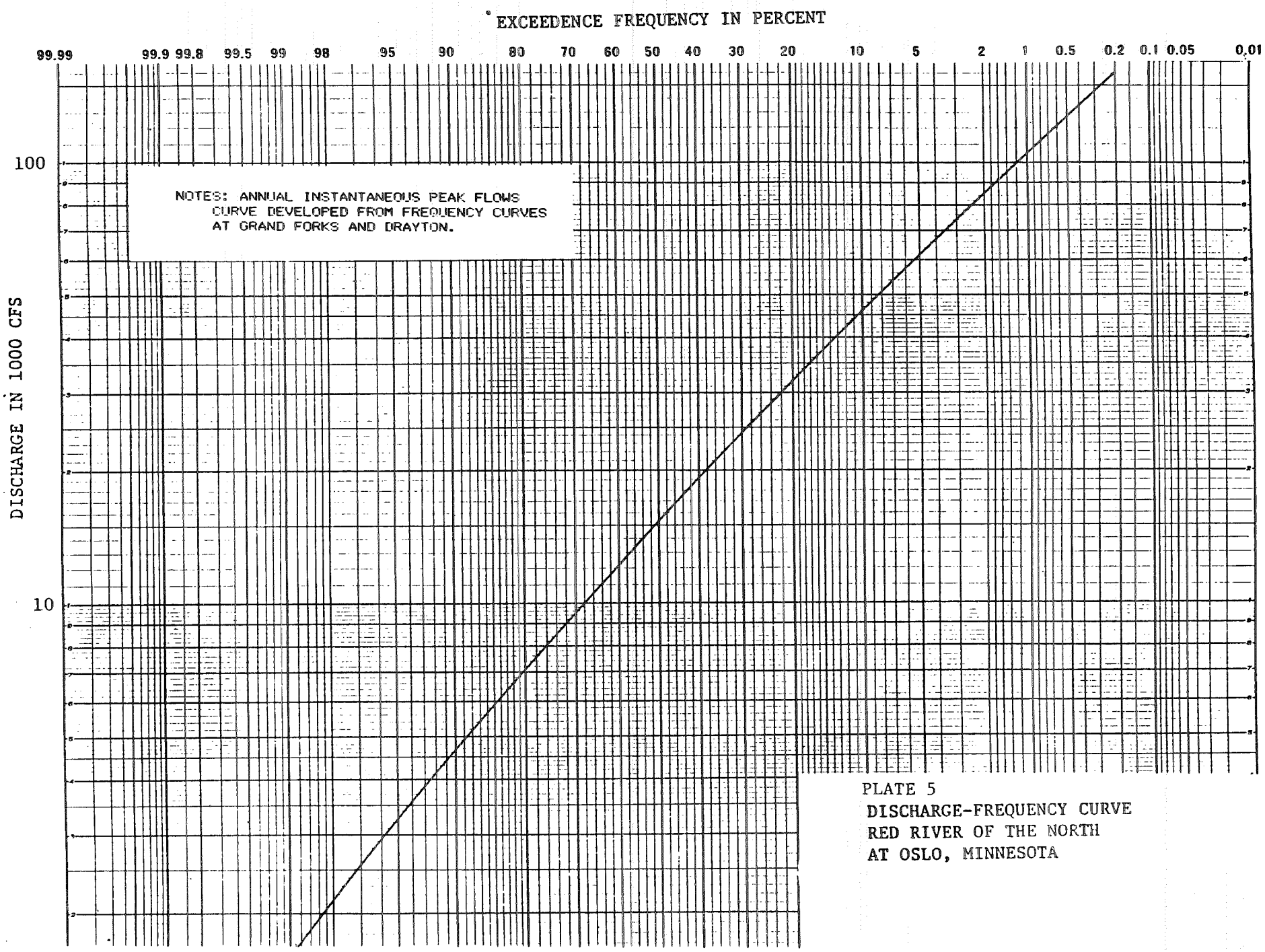


PLATE 5
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
AT OSLO, MINNESOTA

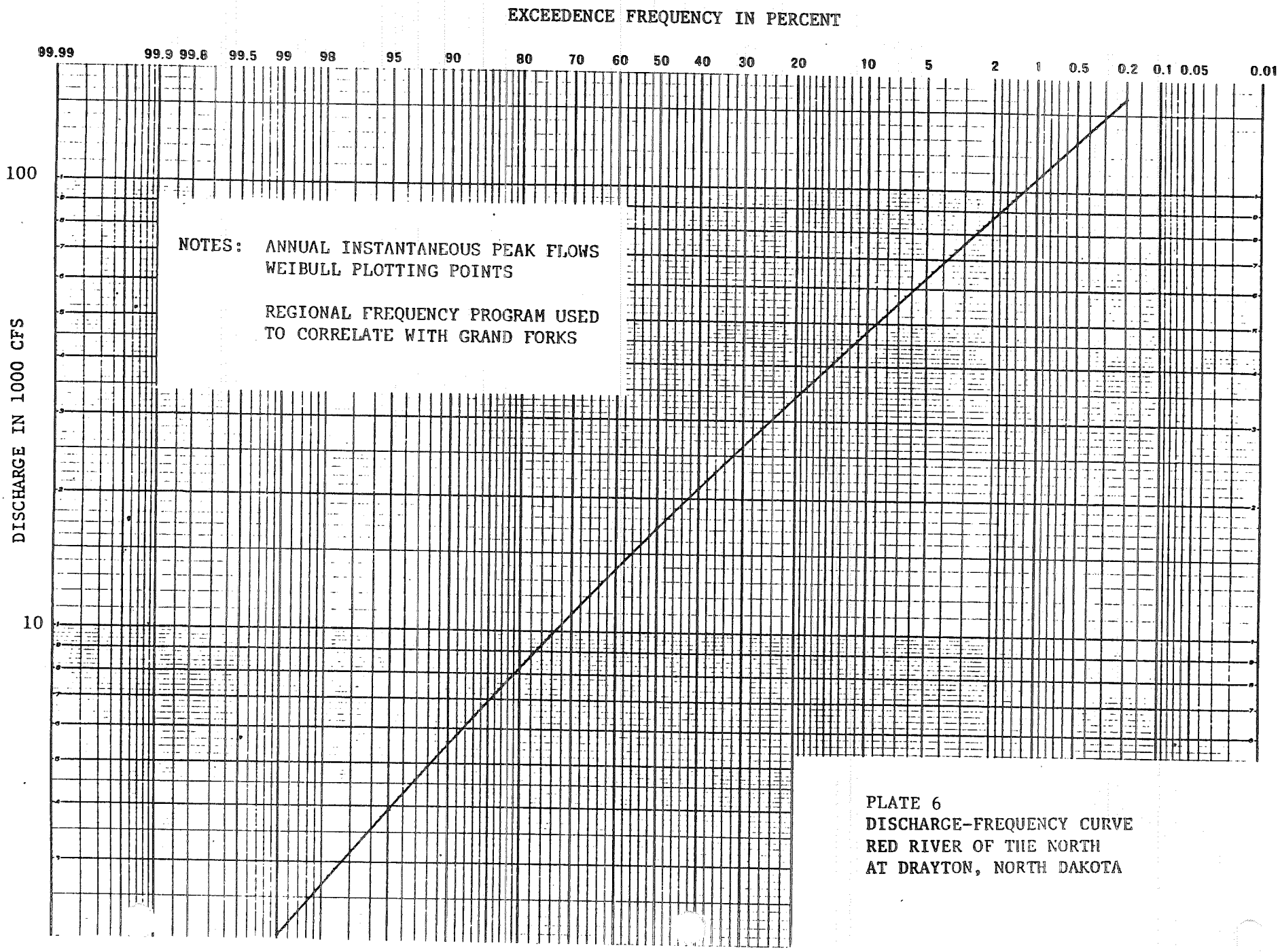


PLATE 6
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
AT DRAYTON, NORTH DAKOTA

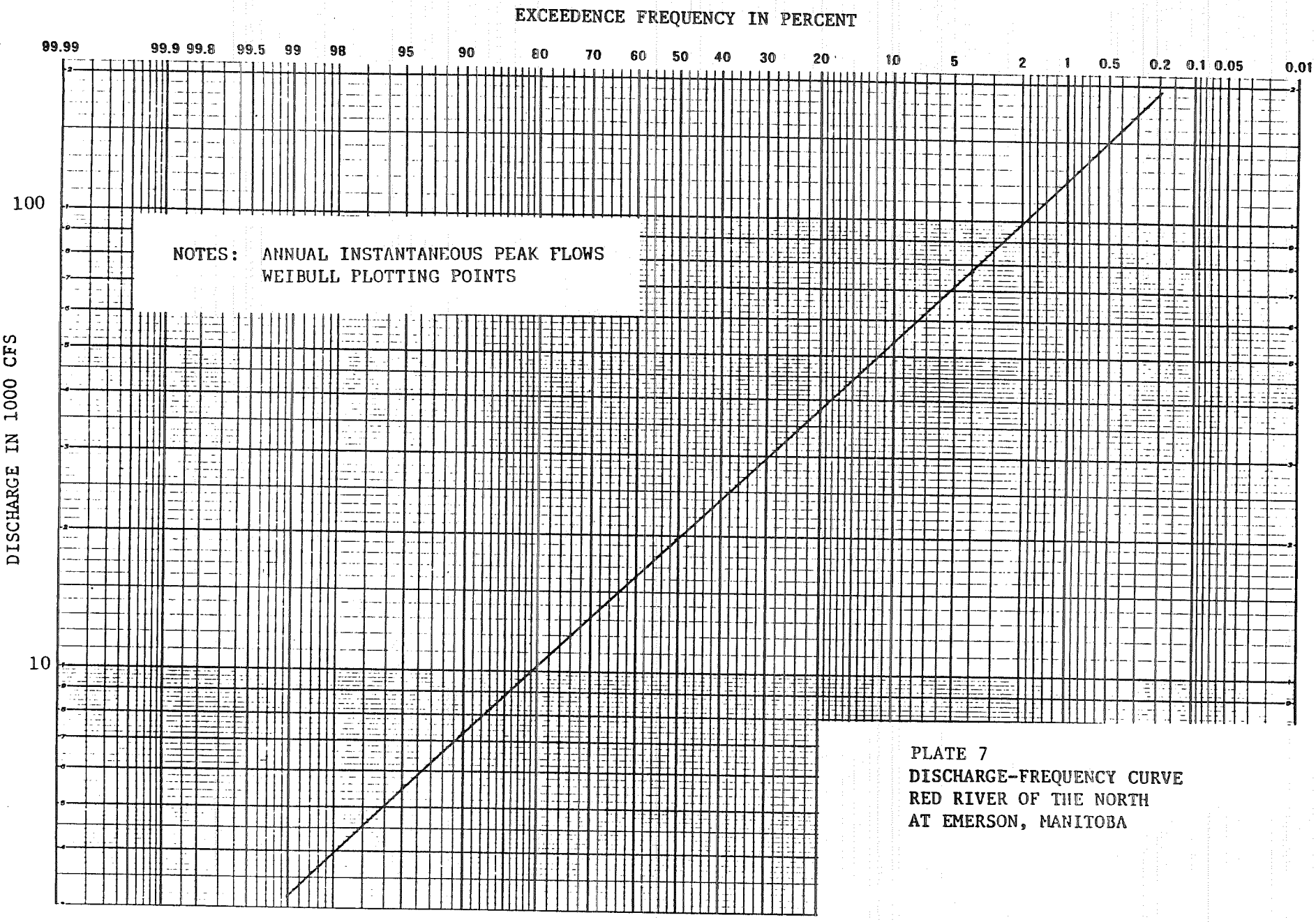


PLATE 7
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
AT EMERSON, MANITOBA

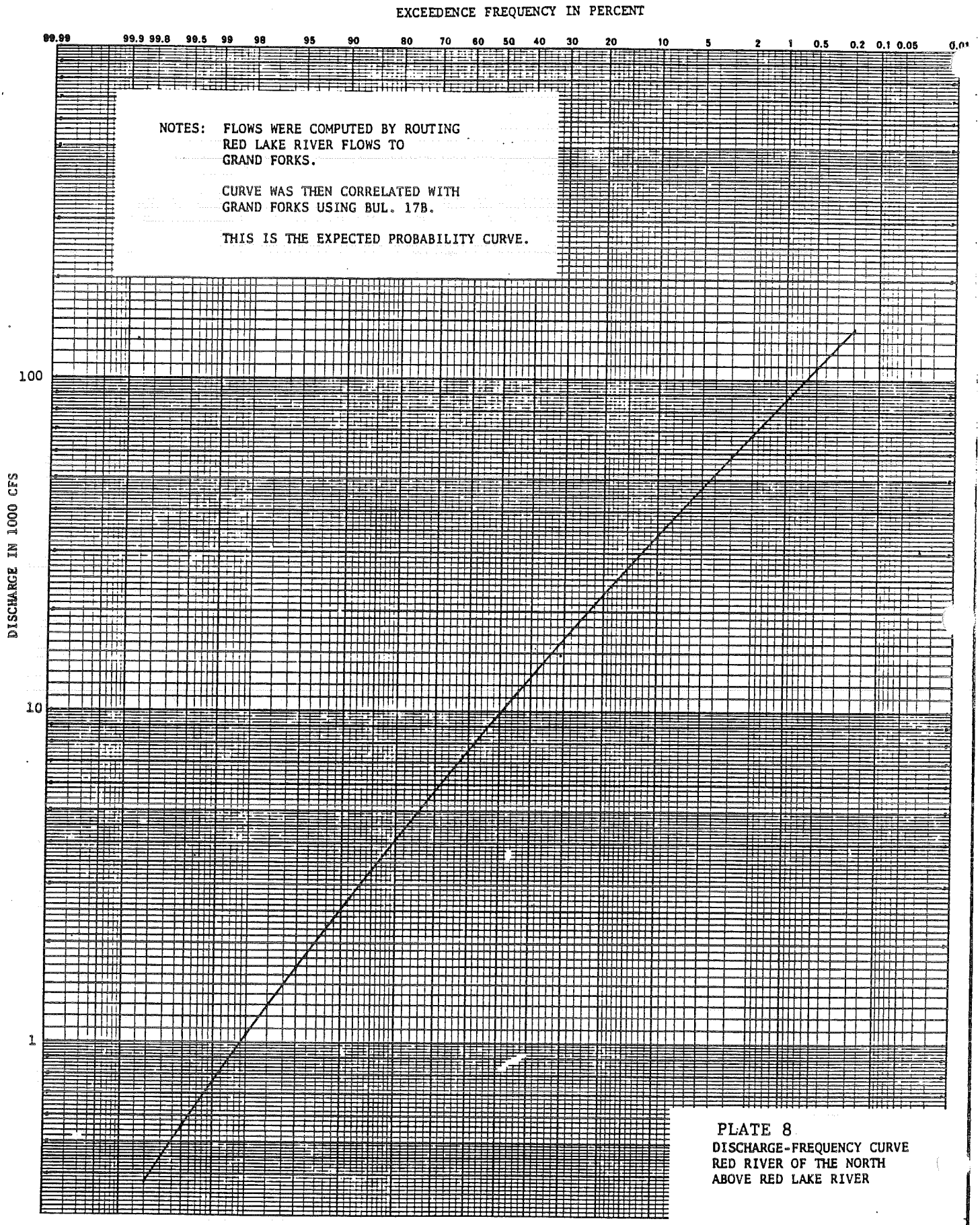


PLATE 8
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
ABOVE RED LAKE RIVER

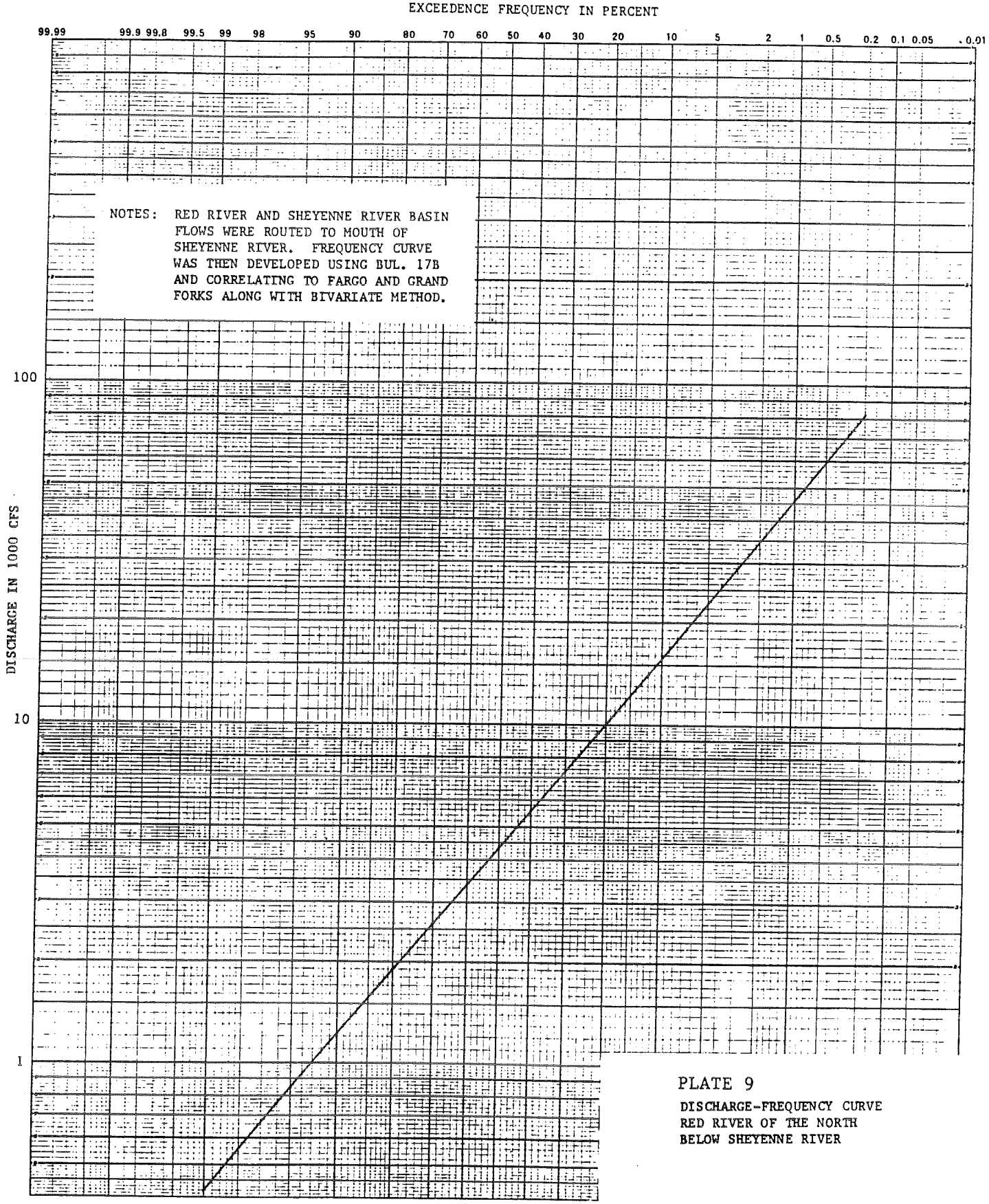
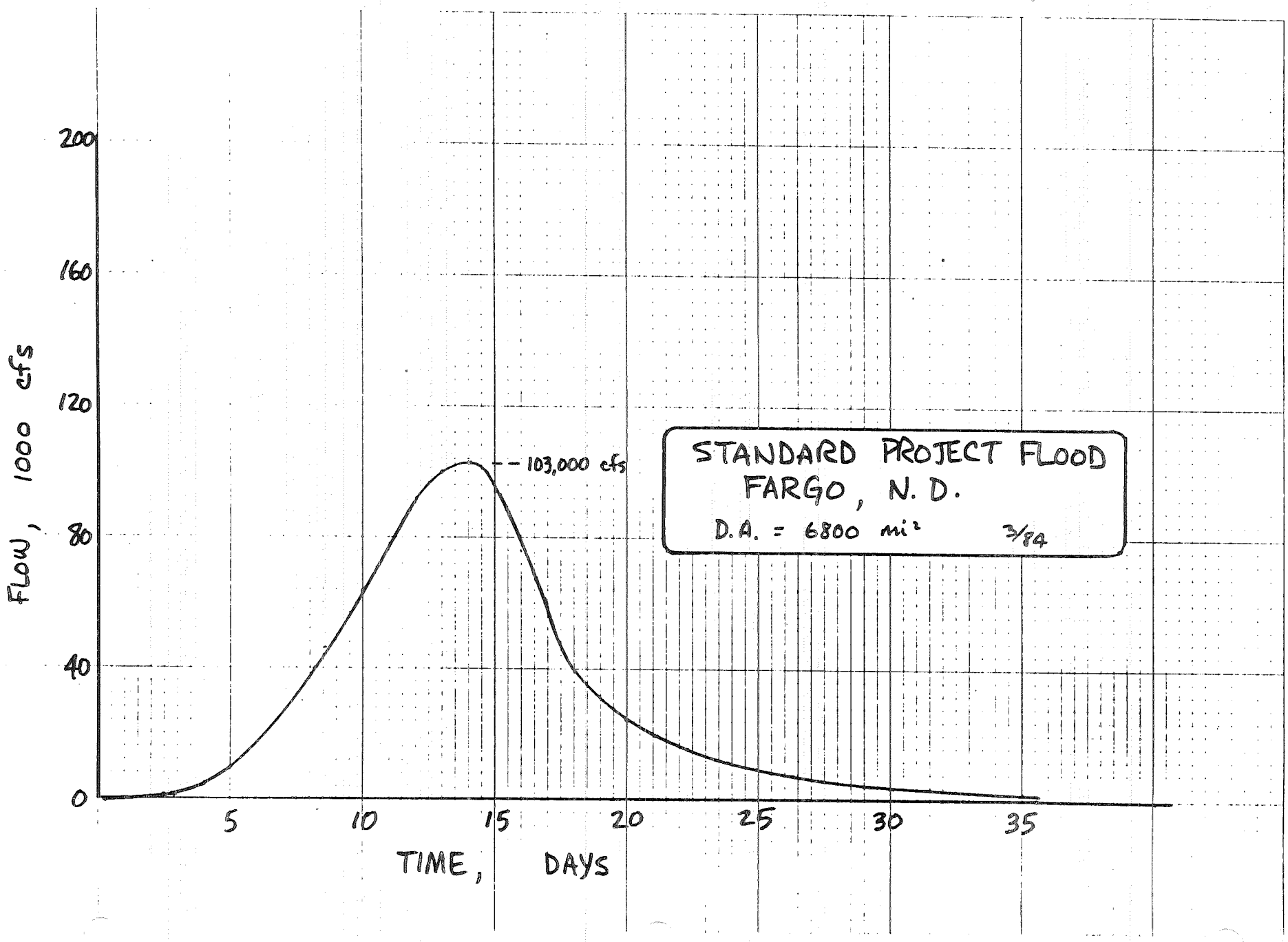
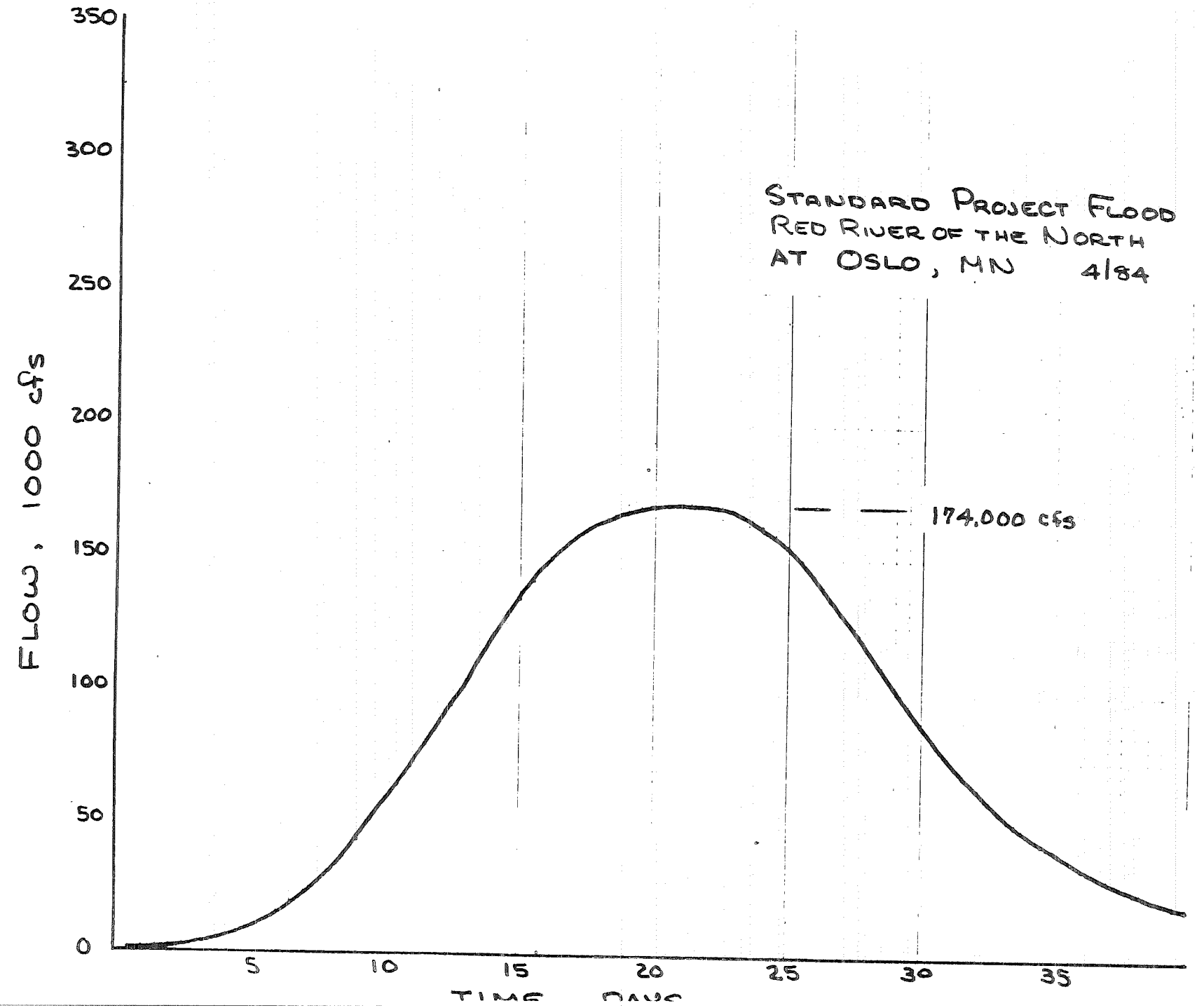


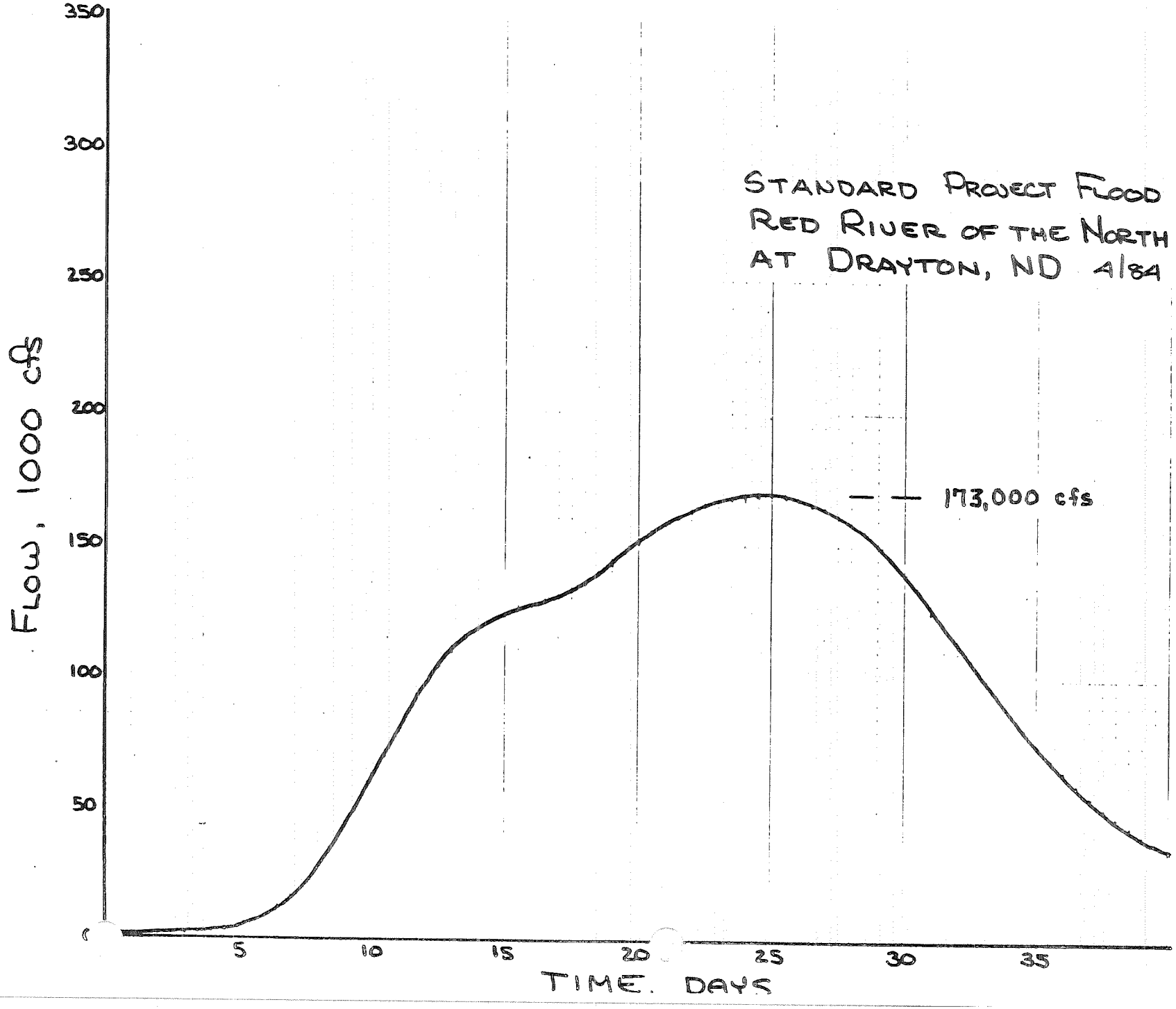
PLATE 9

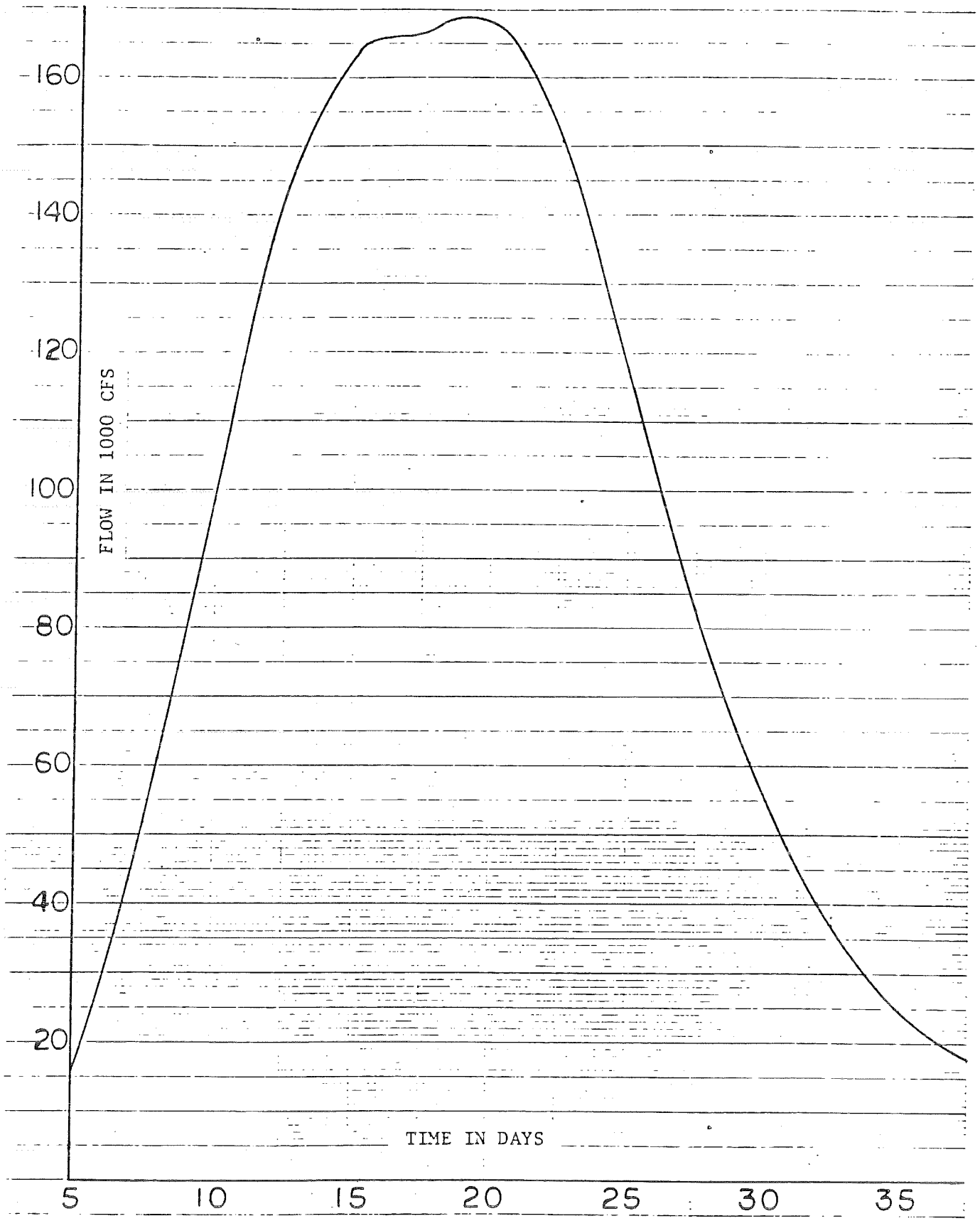
DISCHARGE-FREQUENCY CURVE
RED RIVER OF THE NORTH
BELOW SHEYENNE RIVER

10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.




STANDARD PROJECT FLOOD
RED RIVER OF THE NORTH
AT OSLO, MN 4/84
174,000 cfs
FLOW, 1000 cfs
350
300
250
200
150
100
50
0
5
10
15
20
25
30
35

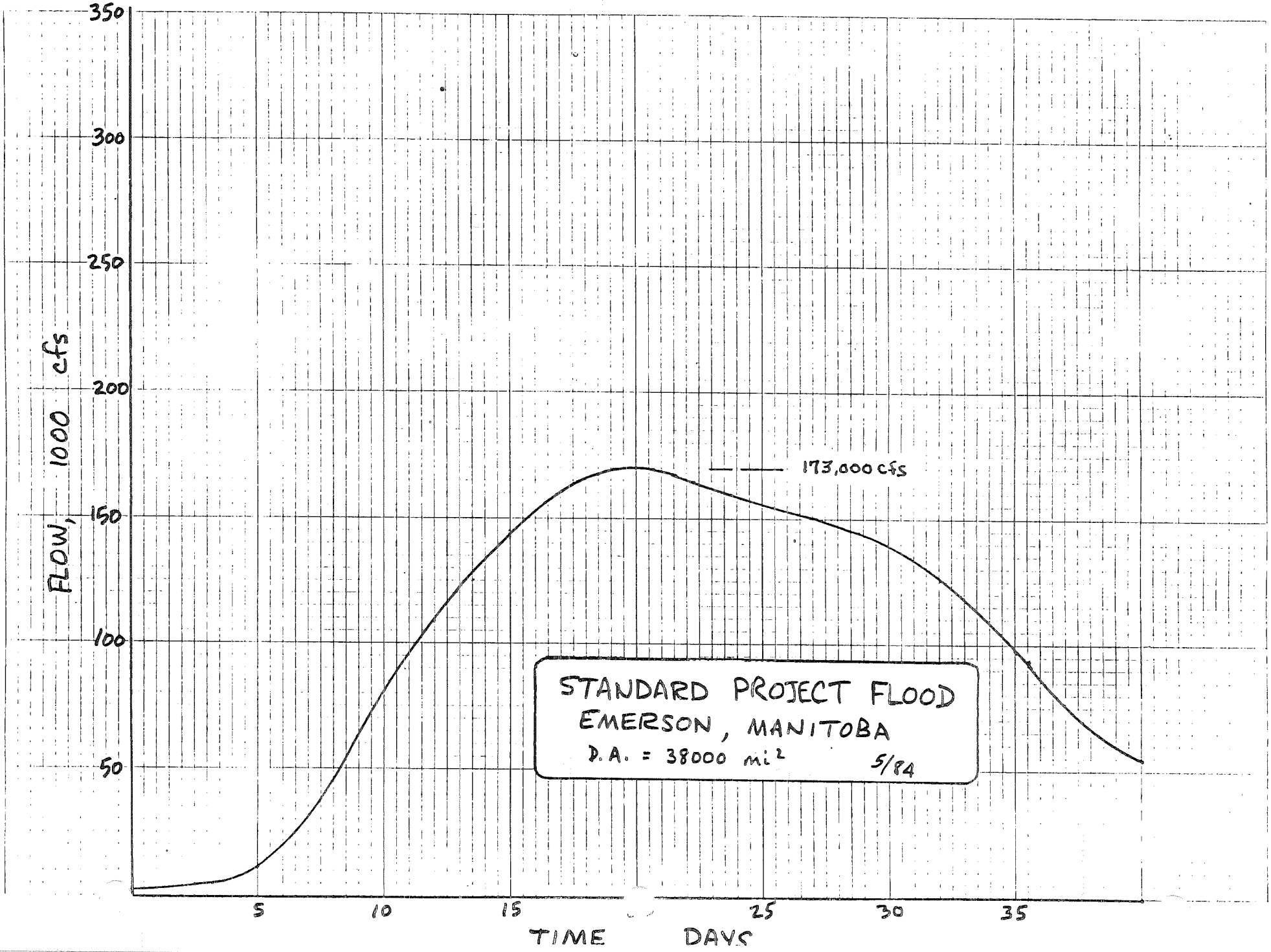

STANDARD PROJECT FLOOD
RED RIVER OF THE NORTH
AT DRAYTON, ND 4/84
173,000 cfs
FLOW, 1000 cfs
350
300
250
200
150
100
50
0
5
10
15
20
25
30
35
TIME, DAYS



ADOPTED STANDARD PROJECT FLOOD
RED RIVER OF THE NORTH AT
EAST GRAND FORKS, MINNESOTA
PLATE 13

K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0700



SECTION 2

HYDRAULICS

TABLE OF CONTENTS

Item	Page
INTRODUCTION	C-2-1
HEC-2 MODEL DATA	C-2-1
HEC-2 MODEL ASSUMPTIONS AND LIMITATIONS	C-2-7
HEC-2 MODEL CALIBRATION	C-2-8
WATER SURFACE PROFILES	C-2-9
REFERENCES	C-2-9

TABLES

Number		Page
1	WATER SURFACE ELEVATIONS	C-2-11

FIGURES

RATING CURVE - RED RIVER OF THE NORTH AT EMERSON, MANITOBA

RATING CURVE - RED RIVER OF THE NORTH AT DRAYTON, NORTH DAKOTA

RATING CURVE - RED RIVER OF THE NORTH AT OSLO, MINNESOTA

RATING CURVE - RED RIVER OF THE NORTH AT GRAND FORKS, NORTH DAKOTA

HYDRAULICS

INTRODUCTION

The hydraulic computations were made using computer program 723-X6-L202A, HEC-2, Water Surface Profiles, developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California (reference A). HEC-2 uses a standard step method to compute water surface profiles. The HEC-2 computer model of the Red River is maintained by the St. Paul District, Corps of Engineers, St. Paul, Minnesota.

HEC-2 MODEL DATA

Cross section data were obtained from various sources. Three cross sections in the Canadian reach were obtained from topographic maps and two bridge drawings, on file in the District office. Ten cross sections at Pembina-St. Vincent surveyed in 1967 and three cross sections surveyed in 1967 at Oslo were available. Topographic maps developed for flood control projects at those locations were also used. The remainder of the cross sections were surveyed in November 1977 for the study (reference B). Cross sections were extended as needed with data from USGS 7 1/2-minute quadrangle maps. Bridge sketches were obtained during the November 1977 survey and supplemented with approach profile data provided by the States of Minnesota and North Dakota. A total of eight bridges exist in this reach. Elevations used refer to the National Geodetic Vertical Datum of 1929. A total of 130 cross sections, including bridges and dams, were used in the analysis. (A typical width for the survey cross sections is 2 to 3 miles. With extension, the cross sections typically are 6 to 8 miles wide.) Cross section data, alignment sheets, bridge sketches and other data used in the HEC-2 model are available in the Hydraulics Section, St. Paul District office.

Historic flood data for the Red River of the North are available for various floods of record. Highwater mark data for the floods of 1950,

1965, 1969, 1975, 1978, and 1979 are available. Some highwater mark data was provided by watershed districts in the Red River Valley (reference H). The largest quantities of data available are for the 1969, 1978, and 1979 flood events.

Elevation-discharge rating curves for various locations between Emerson and Grand Forks are shown on Figures 1 through 4. The locations and pertinent data are listed as follows:

Location	Period of Record	Remarks
Emerson, Manitoba Gage 05102500	1902 (gage heights only) 1912-1929 (monthly discharges only) 1929 - Present	Records good. See Figure 1.
Drayton, ND Gage 05092000	1936-1937 1941 - Present	Fragmentary records. Prior to April 1941. Records good. See Figure 2.
Oslo, Minnesota	1936-1937 April 1941-43 1945-1960 Discontinued	Stage readings only taken during floods by locals. Partial discharge measurements by USGS. Data prior to 1945 should not be used. See Figure 3.
Grand Forks, ND Gage 05082000	April 1882 - Present (Monthly discharges only prior to May 1901)	Records good. Gage location changed several times from 1882 - present. See Figure 4.

In developing the HEC-2 model, calibration of the Oslo to Grand Forks reach used the 1969 and 1978 historical flood profiles. The 1979 profile was not used due to uncertainties regarding the levee overtopping conditions observed in 1979.

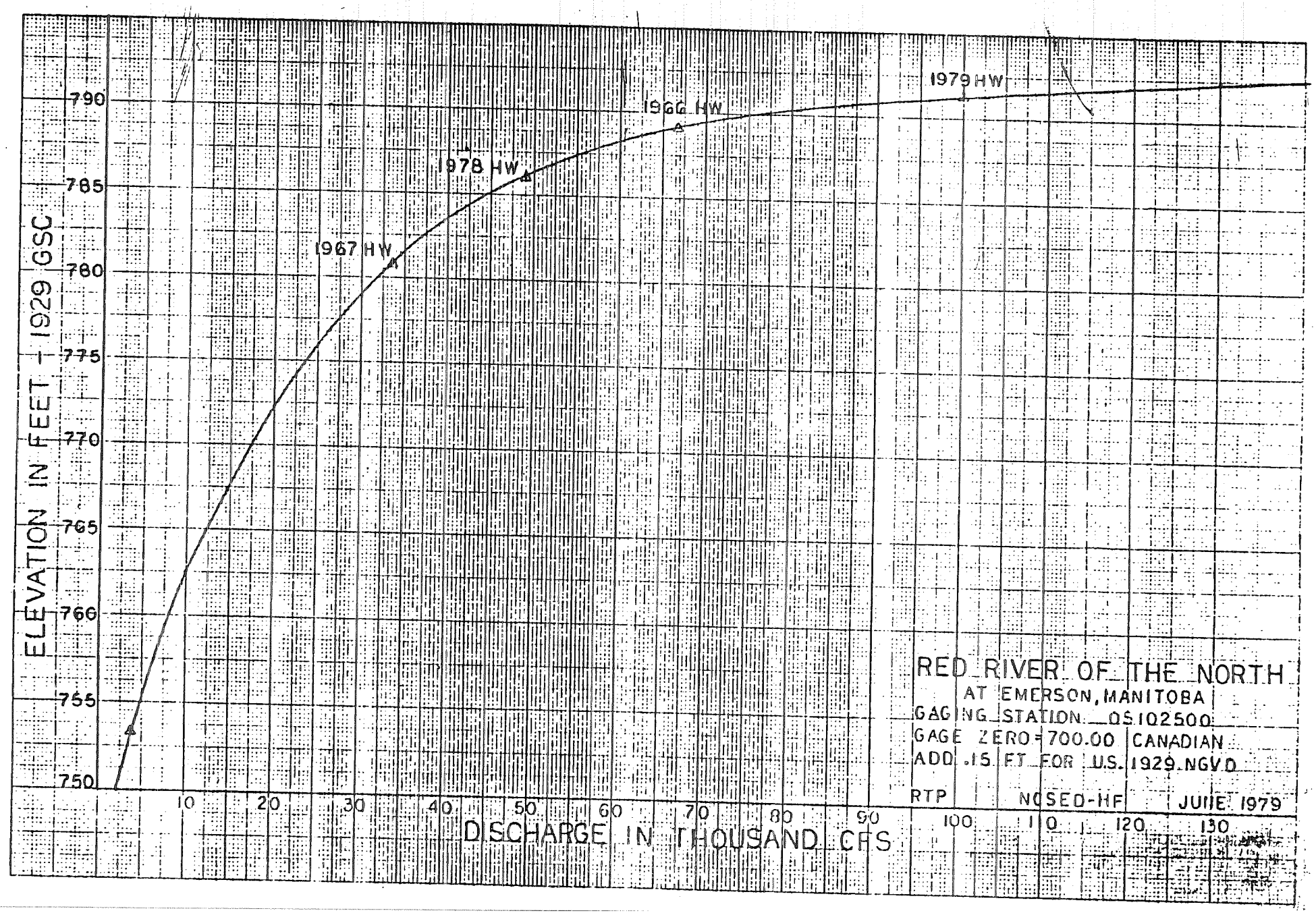

ELEVATION IN FEET - 1929 GSC
790
785
780
775
770
765
760
755
750
1979 HW
1966 HW
1978 HW
1967 HW
10
20
30
40
50
60
70
80
90
100
110
120
130
DISCHARGE IN THOUSAND CFS
RED RIVER OF THE NORTH
AT EMERSON, MANITOBA
GAGING STATION 05102500
GAGE ZERO = 700.00 CANADIAN
ADD .15 FT FOR U.S. 1929 NGVD
RTP
NOSED-HF
JUNE 1979

Figure 1

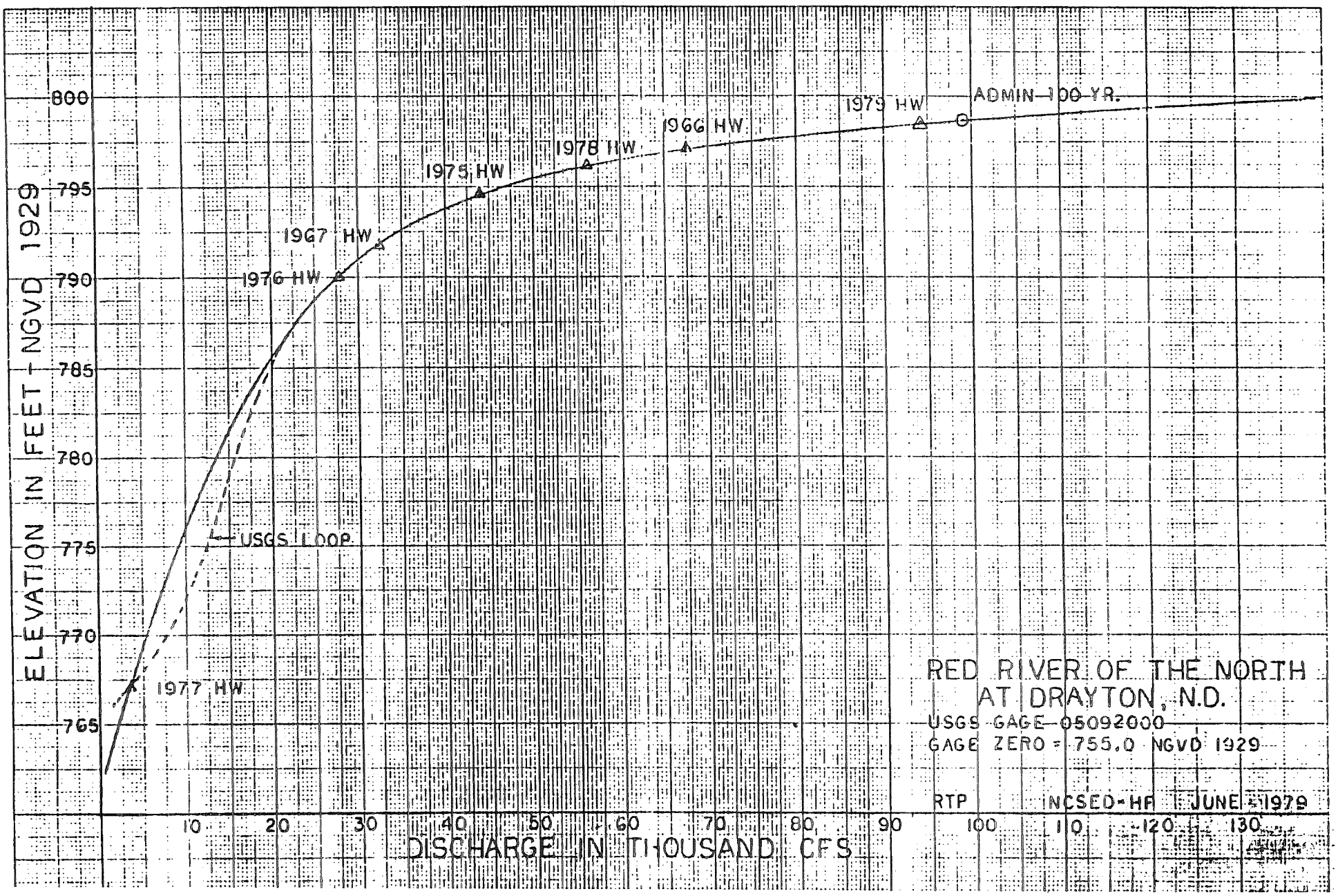

ELEVATION IN FEET - NGVD 1929
800
795
790
785
780
775
770
765
1979 HW
ADMIN-100 YR.
1966 HW
1978 HW
1975 HW
1967 HW
1976 HW
USGS LOOP
1977 HW
RED RIVER OF THE NORTH
AT DRAYTON, N.D.
USGS GAGE 05092000
GAGE ZERO = 755.0 NGVD 1929
RTP
INCSED-HF
JUNE 1979
10
20
30
40
50
60
70
80
90
100
110
120
130
DISCHARGE IN THOUSAND CFS

Figure 2

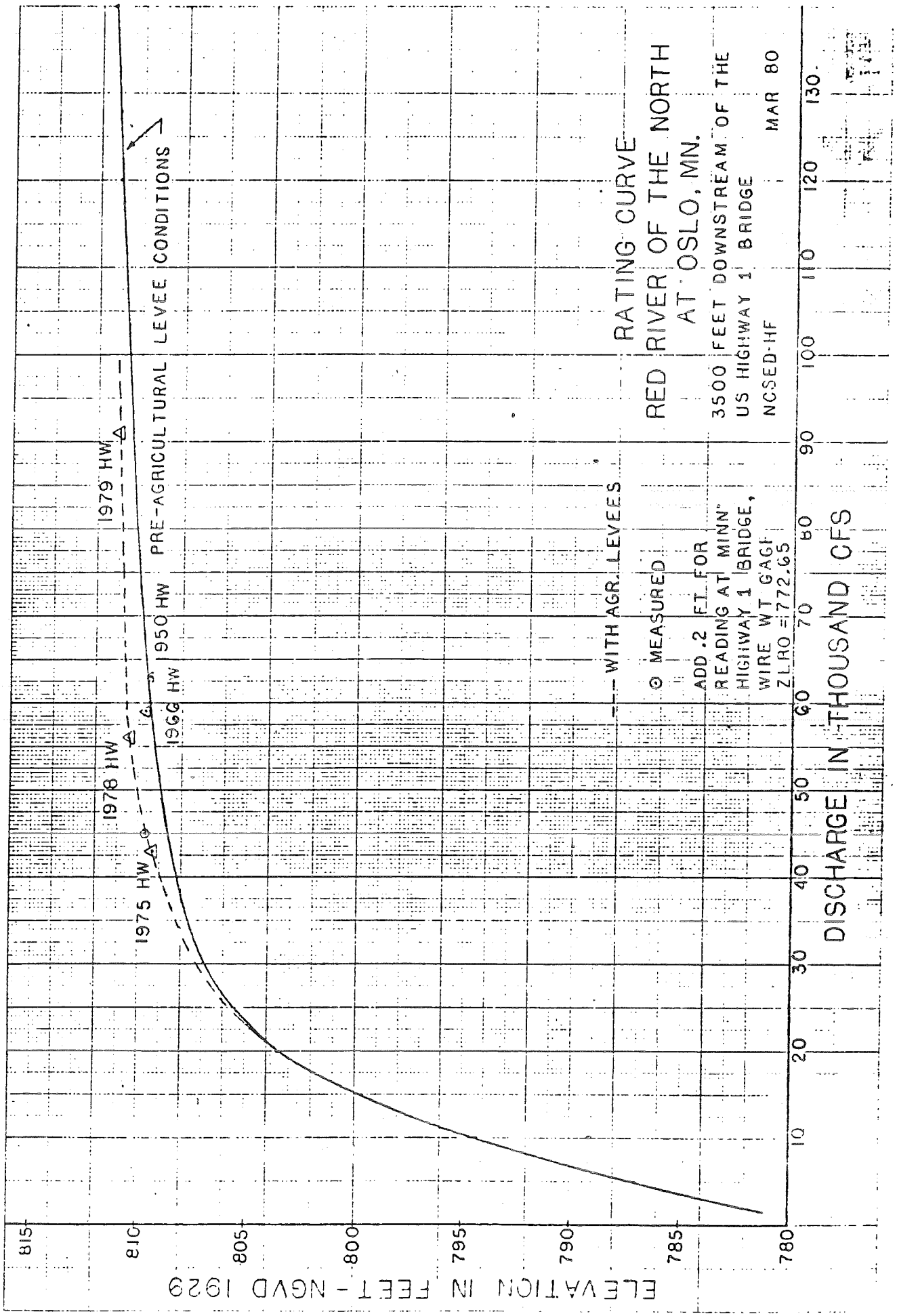

RATING CURVE
RED RIVER OF THE NORTH
AT OSLO, MN.
3500 FEET DOWNSTREAM OF THE
US HIGHWAY 1 BRIDGE
NCSED-HF
MAR 80
PRE-AGRICULTURAL LEVEE CONDITIONS
1979 HW
1978 HW
1975 HW
1966 HW
1950 HW
WITH AGR. LEVEES
MEASURED
ADD .2 FT. FOR
READING AT MINN
HIGHWAY 1 BRIDGE,
WIRE WT GAGE
ZERO = 772.65
DISCHARGE IN THOUSAND CFS
ELEVATION IN FEET - NGVD 1929
10
20
30
40
50
60
70
80
90
100
110
120
130
780
785
790
795
800
805
810
815

Figure 3

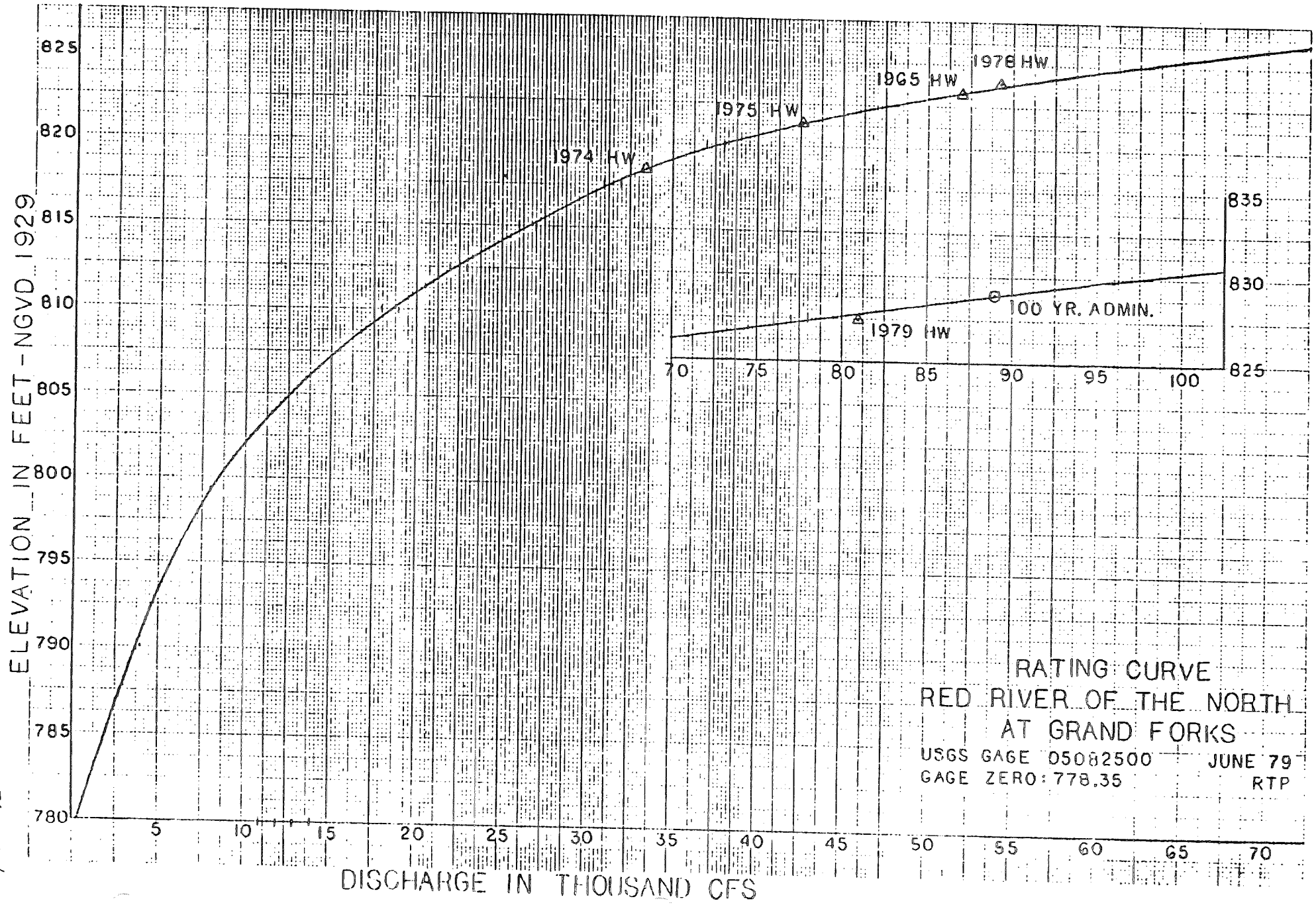

ELEVATION IN FEET-NGVD 1929
825
820
815
810
805
800
795
790
785
780
DISCHARGE IN THOUSAND CFS
5
10
15
20
25
30
35
40
45
50
55
60
65
70
1974 HW
1975 HW
1965 HW
1978 HW
1979 HW
100 YR. ADMIN.
70
75
80
85
90
95
100
835
830
825
RATING CURVE
RED RIVER OF THE NORTH
AT GRAND FORKS
USGS GAGE 05082500
GAGE ZERO: 778.35
JUNE 79
RTP

Figure 4

HEC-2 MODEL ASSUMPTIONS AND LIMITATIONS

Numerical modeling of the Red River of the North with HEC-2 requires that certain assumptions regarding the floodplain be made. These assumptions are as follows:

a. Cross sections: The field surveyed cross sections were extended in the overbank areas as needed by the use of USGS 7 1/2-minute topographic maps. The limit of extension was determined by engineering judgment based on inspections of aerial flood photos (references C, D, E) and topographic maps. On the North Dakota side of the river, the effective flow limit was set at Interstate Highway I-29. On the Minnesota side of the river, Highways 220, 22 and 7 were used where appropriate; in other areas the limit of the 1-percent chance floodplain was used.

b. The flood control projects at Emerson, Pembina-St. Vincent, and Oslo were modeled by assuming the cross sectional area between the ring levees was ineffective. This was accomplished by removing the cross section area between and below the top of levees and then assigning a Manning's "n" value of 0.20 to the area between and above the levees.

c. There are numerous township, county, and State roads in the floodplain. Only those roads which were part of the bridge approach systems at the eight bridges mentioned were included in the model (reference I). All other roadways were not included in the HEC-2 model.

d. Bridges were assumed to retain the geometry surveyed in the field. No consideration was given to debris plugging, ice jams, scour or other considerations which could change the cross section data at the bridges during a flood.

e. Ten tributaries join the Red River between Emerson and Grand Forks. Where the tributaries join the Red River, a change in discharge value was entered by the "QT" card in the HEC-2 model. Inflows from judicial ditches

were not included as such, but were assumed to be contributing to tributary inflows. This was necessary since no gaging data was available for the ditches.

f. The spoil banks for judicial ditches 75 and 1 between Oslo and Grand Forks were coded into the model. Judicial ditch 75 at river mile 282.2 acts like a levee, completely blocking overbank flows on the Minnesota side of the river. A discharge greater than the 0.2-percent chance flood would be necessary to overtop judicial ditch 75.

g. The agricultural levee system from mile 236 to 285 was coded into the model. On the cross section data, the area removed from the floodplain is minimal. This levee data which identifies the riverward toe, the landward toe, and the top of levee are coded into the ground elevation-station data (references B, F, G).

HEC-2 MODEL CALIBRATION

The HEC-2 model consists of three major reaches between Emerson and Grand Forks. Reach 1 begins at Emerson and terminates at Drayton. Reach 2 begins at Drayton and ends at Oslo. Reach 3 begins at Oslo and terminates at Grand Forks. These reaches were chosen because discharge records are available at the four above cities and rating curves developed from the discharge measurements provide good starting and ending water surface elevations. The model could then be calibrated from rating curve site to rating curve site. The HEC-2 model was calibrated to the historic floods of 1969, 1978, and 1979 as a base condition. The model was then calibrated to match the rating curves at Drayton, Oslo, and Grand Forks for a range of flows from 500 cfs to 180,000 cfs.

Calibration to the floods of 1969, 1978, and 1979 involved matching the computed water surface profile to the recorded high water profile. A

difference of no more than ± 0.3 foot was set as a limit for calibration purposes. In most cases a difference of 0.2 foot or less was achieved between the recorded and computed profiles.

WATER SURFACE PROFILES

Water surface profiles for the 10, 2, 1, and 0.2-percent chance floods were computed. Water surface elevations for the 1-percent chance flood are shown on table 1. Also shown for comparison are the water surface elevations for the standard project flood. Channel velocities for the 1-percent chance flood averaged about 2 to 4 feet per second, except at bridges where averages of 4 to 7 feet per second were computed. Overbank velocities were less than 1 foot per second, averaging between 0.3 and 0.7 foot per second.

REFERENCES

A list of references used in this study is as follows:

A. Computer Program 723-X6-L202A, HEC-2, Water Surface Profiles, HEC-2 release dated November 1976 updated April 1980, error corrections 01, 02, 03, 04 and modifications 50, 51, 52, 53 and 54, U.S. Army Hydrologic Engineering Center, Davis, California.

B. Valley Cross Sections and Dike Profiles - Contract No. DACW37-78-C-0037
Drawing Numbers R-S-10/72 through R-S-10/85 inclusive.
Drawing Numbers R-S-15/9 through R-S-15/12 inclusive. By Widseth, Smith, Nolting and Associates, Crookston, Minnesota, November 1977, dated July 1978.

C. Aerial Photos - 1979 flood - Contract No. DACW37-79-M-1854
Scale: 1:24000
KBM, Inc., Grand Forks, North Dakota

D. Red River Agricultural Levee Profiles. Barr Engineering Company. Under contract to Minnesota Department of Natural Resources, July 1979.

E. Water Surface Profiles for the 1975 and 1979 floods. Middle River-Snake River Watershed District. Warren, Minnesota.

F. Road profile and bridge approach data provided by the States of North Dakota and Minnesota.

G. NCSED-HF DF, 30 July 1980, Red River of the North Main Stem Agricultural Levee Overtopping Analysis to Limit Stage Increases to One-Half Foot for the 1-Percent Chance Flood.

H. NCSED-GH DF, 7 November 1980, Red River of the North Main Stem Hydraulic Analysis 43,000 cfs Discharge for Modified Agricultural Levee Alignment Plans.

The remainder of the hydraulic information such as discharge data, highwater marks and other data not referenced in items listed above was available in the St. Paul District Office, U.S. Army Corps of Engineers, St. Paul, Minnesota.

Table 1

[illegible]
SPF and 1%-Chance Flood For River Mile 157 to 171

X-SEC NO.	RIVER MILE	THALWEG ELEV.	SPF W.S. ELEV.	1% W.S. ELEV.
6	157.97	740.10	795.57	793.86
5.1	158.03	740.10	795.64	793.98
5	158.03	740.10	795.64	793.93
4.1	158.11	736.00	795.72	793.98
4.2	158.11	736.00	795.73	793.99
4	158.13	739.12	795.82	794.11
3	158.16	738.00	795.92	794.13
2	158.60	737.20	796.06	794.21
1	159.17	737.92	796.13	794.39
200	159.46	739.89	796.28	794.41
300	160.46	739.96	796.51	794.63
400	161.69	734.20	796.73	794.89
500	162.87	735.60	796.92	795.10
600	163.71	743.06	797.08	795.29
700	165.99	742.63	797.41	795.66
800	167.73	741.00	797.69	795.95
900	169.49	741.30	797.87	796.16
1000	171.05	741.70	798.06	796.36
1100	172.34	739.70	798.16	796.48
1200	175.46	746.10	798.29	796.63
1300	179.44	742.29	798.37	796.71
1310	179.54	741.30	798.38	796.71
1320	179.55	741.30	798.38	796.71
1400	179.63	739.74	798.37	796.71
1500	181.63	738.35	798.43	796.78
1600	183.22	748.00	798.54	796.89
1700	184.48	745.99	798.59	796.95
1800	186.08	739.84	798.73	797.10
1900	187.61	747.20	798.87	797.25
2000	189.52	747.66	799.04	797.42
2100	190.04	743.34	799.11	797.49
2200	192.27	750.60	799.28	797.66
2300	194.04	748.80	799.46	797.82
2400	195.92	749.00	799.63	797.98
2500	197.52	748.50	799.75	798.08
2600	200.20	751.60	799.88	798.21
2700	202.71	752.90	800.15	798.45
2710	203.50	753.50	800.24	798.55
2720	203.51	763.00	800.24	798.54
2730	203.51	763.00	800.24	798.54
2740	203.51	753.90	800.25	798.55
2800	204.64	755.10	800.41	798.68
2900	206.56	752.95	800.77	798.97
2905	206.70	752.95	800.80	798.99
2910	206.71	754.73	800.85	798.95
2920	206.71	754.73	800.88	798.95
2930	206.71	756.28	800.88	798.94

Table 1 (cont.)

3000	206.77	756.33	800.94	793.33
3100	208.21	745.93	801.15	795.37
3200	210.13	755.40	801.28	799.40
3300	212.12	756.39	801.37	799.50
3400	214.37	757.21	801.69	799.82
3500	216.76	755.33	801.98	800.12
3600	218.53	754.40	802.13	800.29
3700	220.72	757.56	802.24	800.41
3800	221.91	755.56	802.24	800.41
3900	225.01	755.30	802.41	800.58
4000	226.72	757.80	802.46	800.64
4100	229.86	756.40	802.58	800.78
4200	231.76	757.34	802.65	800.87
4300	235.96	758.80	802.76	801.21
4310	236.07	759.20	802.73	801.33
4320	236.08	759.20	802.89	801.35
4400	236.16	759.10	802.96	801.15
4500	237.18	759.10	803.02	801.21
4600	239.44	762.07	803.13	801.35
4700	242.46	757.83	803.38	801.72
4800	243.88	762.40	803.64	802.03
4900	245.46	765.20	803.92	802.38
4922	247.17	762.80	804.05	802.56
5000	248.94	764.49	804.34	802.88
5100	252.76	762.40	805.45	803.97
5200	254.91	765.50	806.00	804.50
5300	258.22	768.20	806.70	805.24
5400	259.81	760.92	807.27	805.88
5500	262.06	768.00	808.22	806.96
5600	266.19	767.40	809.98	808.80
5650	269.69	770.30	811.32	810.24
5670	270.20	770.30	811.62	810.54
5700	270.74	768.80	812.01	810.90
5800	271.18	759.70	812.15	810.90
5805	271.20	759.90	812.16	810.76