UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROBABLE MAXIMUM FLOOD AT LAKE CHIPPEWA NEAR WINTER, WISCONSIN

Open-File Report 76-800

Prepared in cooperation with the

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ABSTRACT

The probable maximum flood was computed for Lake Chippewa and routed through the lake to determine maximum lake stage. The peak discharge of the probable maximum flood at Lake Chippewa was computed to be about 75,000 cubic feet per second (2,100 cubic meters per second), primarily caused by rainfall on the lake. A secondary peak of about 41,000 cubic feet per second (1,200 cubic meters per second) was due to streamflow entering Lake Chippewa. The 14-day volume of this flood was 450,000 acre-feet (5.5×10^8 cubic meters). Using an assumed operating procedure for Winter Dam, the maximum lake stage for the probable maximum flood was computed to be about 1,318 feet (401.7 meters) above mean sea level--about 3 feet (0.9 meter) below the dam crest and 6 feet (1.8 meters) above the proposed normal summer operating level. The probability of this flood occurring in any year is less than 1 in 10,000.

INTRODUCTION

The Secretary of the Interior, on behalf of the Lac Courte Oreilles Band of Lake Superior Chippewa Indians, has recommended that the United States recapture the Chippewa Reservoir Project No. 108 (Lake Chippewa, commonly called Chippewa Flowage) and limit the fluctuation of water level on the Chippewa Flowage to a maximum of 2 ft (0.6 m). The United States Forest Service has prepared a comprehensive land-use plan for the Flowage and adjacent lands and has requested a determination of the probable maximum flood as it would affect the reservoir under the proposed operating plan. The Federal Power Commission requires a determination that the dam can safely pass the probable maximum flood.

The purpose of this report is to present the results of a hydrologic evaluation of the probable maximum inflow flood on Lake Chippewa, to determine the effect that flood would have on lake stage and discharge, and to estimate a frequency for that flood. The study was done in cooperation with the Bureau of Indian Affairs.

Lake Chippewa is in northwestern Wisconsin (fig. 1). The Flowage has a total basin area of 802 mi^2 (2,080 km^2) (drainage area revised on the basis of the latest topographic maps) and is drained mainly by the East Fork Chippewa River and the West Fork Chippewa River (fig. 2). The basin includes extensive marshlands and lakes, especially in the area drained by the West Fork Chippewa River.

This study includes three phases:

1. Determination of the probable maximum flood as inflow to the reservoir.

2. Routing of the inflow flood through the reservoir to determine maximum reservoir stage during the probable maximum flood.

3. Examination of the frequency of the probable maximum flood.

For use of readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	By	To obtain metric unit
inches (in)	2.540	centimeters (cm)
feet (ft)	.3048	meters (m)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	2.832×10^{-2}	cubic meters per second (m^3/s)
acre-feet (acre-ft)	1.233×10^3	cubic meters (m^3)

PROBABLE MAXIMUM FLOOD

The probable maximum flood is the flood resulting from the severest combination of meteorologic and watershed conditions that is reasonably possible in a region (Chow, 1964, p. 25-26). In the case of Lake Chippewa, the flood caused by the probable maximum precipitation, as determined by the U.S. Weather Bureau (1961) would produce a more severe condition than lesser rainfall on an extreme snowpack. From curves developed by the U.S. Weather Bureau (1961) it is apparent that heavy rainfall is much more probable during May to September than the rest of the year.

The probable maximum inflow flood into Lake Chippewa was computed as the sum of five components:

1. Precipitation on the surface of Lake Chippewa,
2. runoff from the local area surrounding the lake--including many small streams,
3. runoff from the North Fork Chief River basin,
4. runoff from the West Fork Chippewa River basin, and
5. runoff from the East Fork Chippewa River basin.

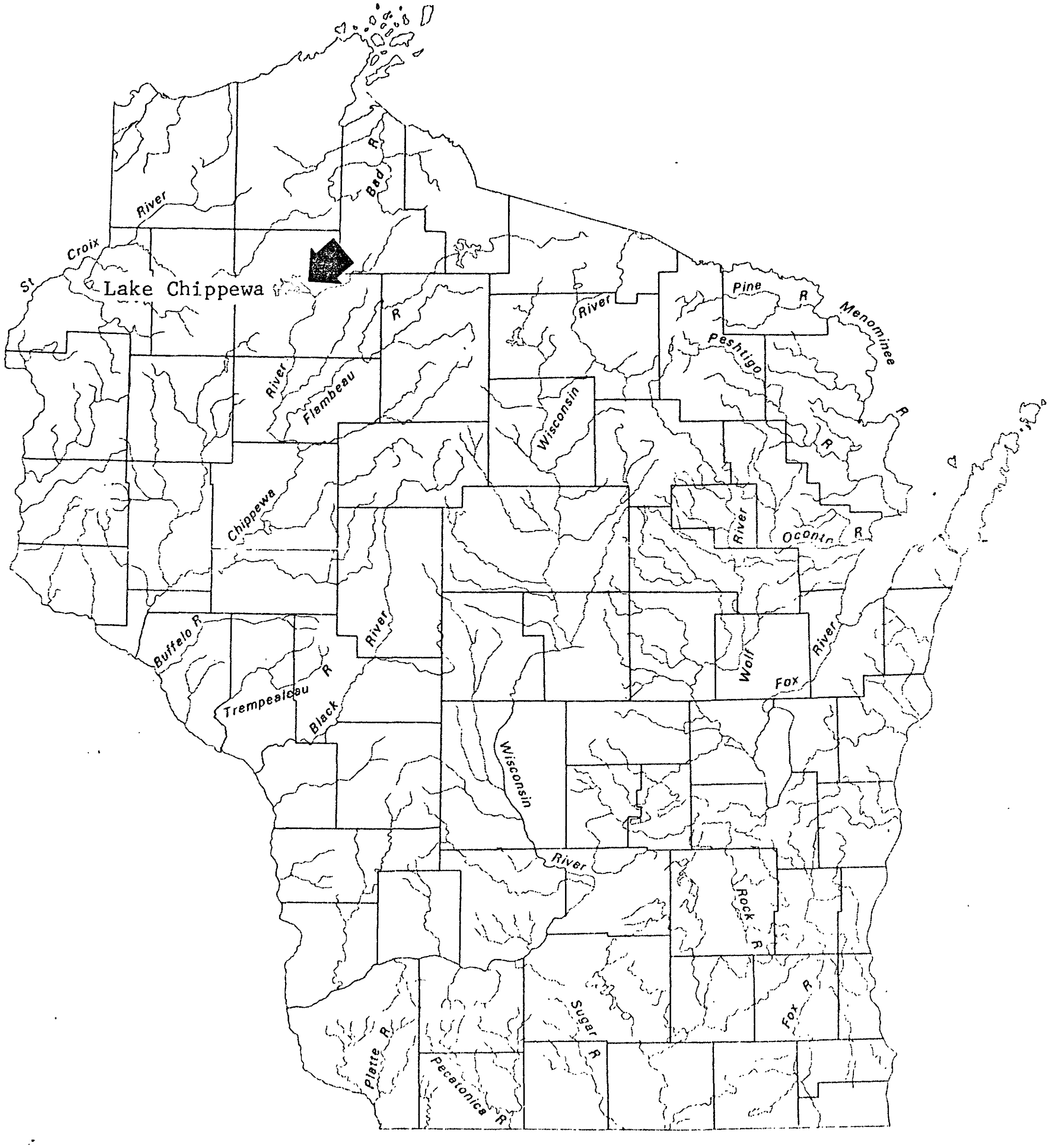
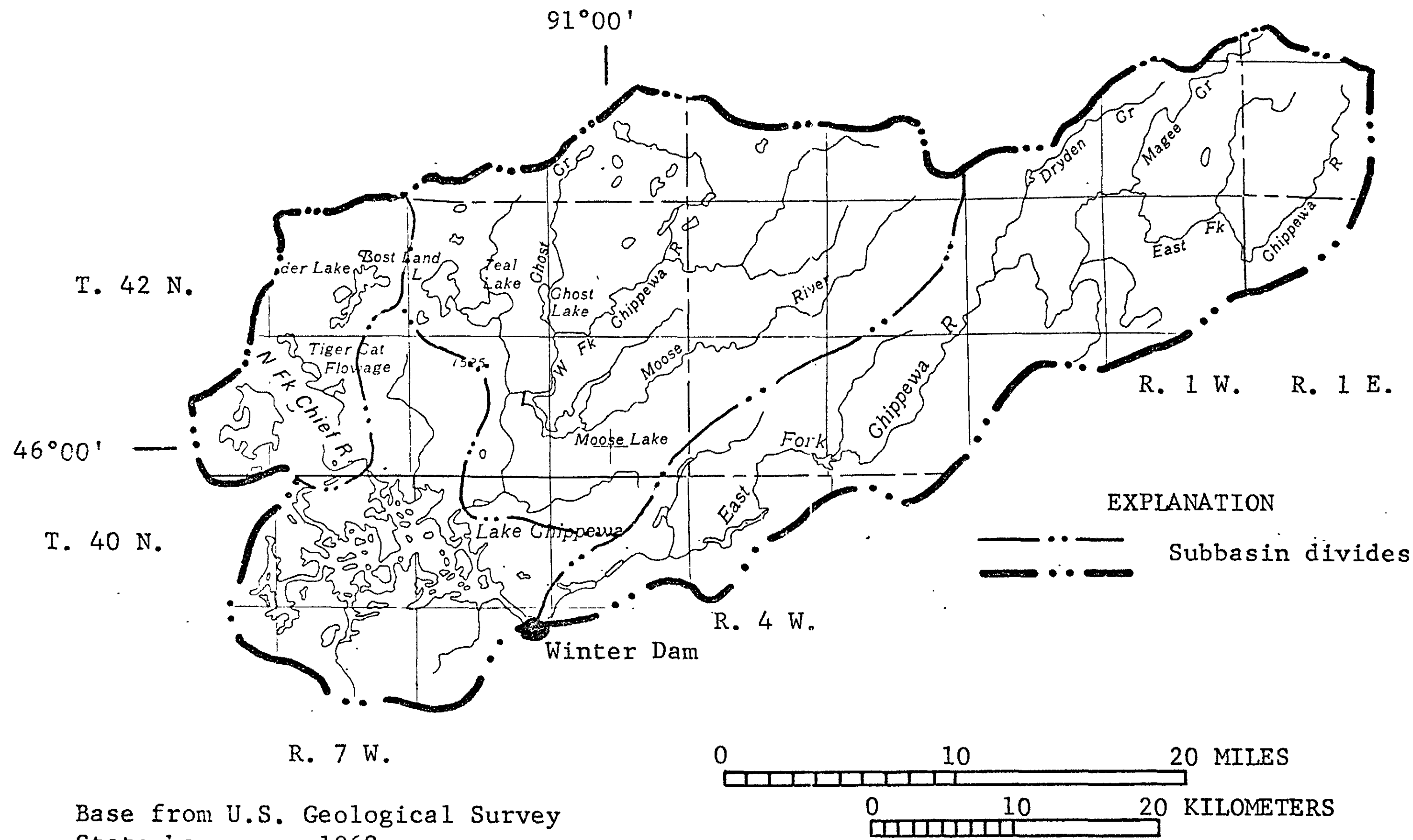


Figure 1. Location of Lake Chippewa in Wisconsin.



Base from U.S. Geological Survey
State base map, 1968

Figure 2. Drainage basin of Lake Chippewa.

Probable maximum precipitation for 6 hours on 10 mi^2 (26 km^2) in the Lake Chippewa basin was determined to be 23.2 in (58.9 cm) (U.S. Weather Bureau, 1961). Probable maximum precipitation for durations up to 48 hours and for the drainage area of the basin were computed using appropriate adjustment factors (Bureau of Reclamation, 1960, p. 30). The probable maximum precipitation amounts for the entire drainage basin were distributed among the subbasins so as to cause the severest inflow flood. The distribution causing the highest peak discharge consisted of the most intense rain on the lake itself, the second greatest intensity on the local drainage that responds quickest to rainfall, and decreasing intensity on the other basins, which respond more slowly. The rainfall distribution used is summarized in table 1.

Direct precipitation on the lake surface was converted to discharge by multiplying precipitation intensity by the area of the lake. Runoff from each of the other basins was computed by reducing the probable maximum precipitation to account for water infiltrating the ground and otherwise prevented from running off and routing the remaining excess precipitation to the lake using the unit hydrograph derived for each basin.

Table 1.--Probable maximum precipitation on subbasins and the entire Lake Chippewa drainage basin

Subbasin	Drainage area (mi^2)	Probable maximum precipitation, in inches			
		6 hours	12 hours	24 hours	48 hours
Lake Chippewa	25	21.0	23.1	25.5	27.5
Local drainage	101	15.8	18.1	20.0	22.0
North Fork Chief River	81	14.0	16.1	17.6	19.3
West Fork Chippewa River	294	12.3	14.3	15.8	17.7
East Fork Chippewa River	301	10.8	12.9	14.7	15.8
Weighted average for entire basin	802	12.6	14.7	16.4	18.0

A unit hydrograph was derived by analyzing several storms, as recorded at the U.S. Geological Survey gaging station on the South Fork Flambeau River near Phillips, Wis. (Not shown on map.) Rainfall was recorded at hourly intervals at three sites near the basin. Unit hydrographs for the four subbasins of the Lake Chippewa basin (fig. 3) were computed from the unit hydrograph for the South Fork Flambeau River using a dimensionless unit hydrograph computed by procedures described in "Design of Small Dams" (Bureau of Reclamation, 1960). This dimensionless graph was compared to others derived in previous studies at small basins in northern Wisconsin (W. A. Gebert, written commun., 1976). Differences in the dimensionless unit hydrographs were small.

A constant base flow of 1,100 ft^3/s (31 m^3/s) was assumed, based on analysis of many recorded floods. This is an upper limit for base flow because flows preceding most significant floods have been much lower.

The combination of five runoff components and base flow produces a hydrograph for the probable maximum flood shown in figure 4. The hydrograph has an abrupt peak of 75,000 ft^3/s (2,100 m^3/s) caused by the direct precipitation (21.0 in or 53.3 cm in 6 hours) on a lake of nearly 25 mi^2 (65 km^2). A secondary but broader peak of 41,000 ft^3/s (1,200 m^3/s) was the result of runoff from upstream areas. The total volume of the flood is 450,000 acre-ft (5.5×10^8 m^3).

LAKE ROUTING

To determine the effects of the probable maximum flood on lake stage, it was necessary to route this flood hydrograph through the lake to account for storage in the lake. A 6-hour interval was used to compute inflow, outflow, and storage. It was assumed that discharge from the lake would be changed every 6 hours in response to the lake level and the rate of rise in the level over the past 6 hours and that lake level was at 1,312 ft (399.9 m) above mean sea level, the proposed normal summer operating level.

Operating rules were assumed as follows: Increase discharge to hold the lake level at 1,312 ft (399.9 m) above mean sea level within the limits in table 2. These rules are modified from those proposed by the U.S. Forest Service and the Lac Courte Oreilles (1976, Appendix Y). The proposed rules were suggested as an illustration of the type rules that could be used to operate the reservoir. They were found to be inadequate for very large floods. A maximum discharge of 24,000 ft^3/s (680 m^3/s) was used because the Federal Power Commission (1973) considers this to be the maximum safe discharge.

Based on these operating rules, the lake level would rise to almost 1,318 ft (401.7 m) above mean sea level. This is 6 ft (1.8 m) above the proposed normal summer operating level and 3 ft (0.9 m) above the current

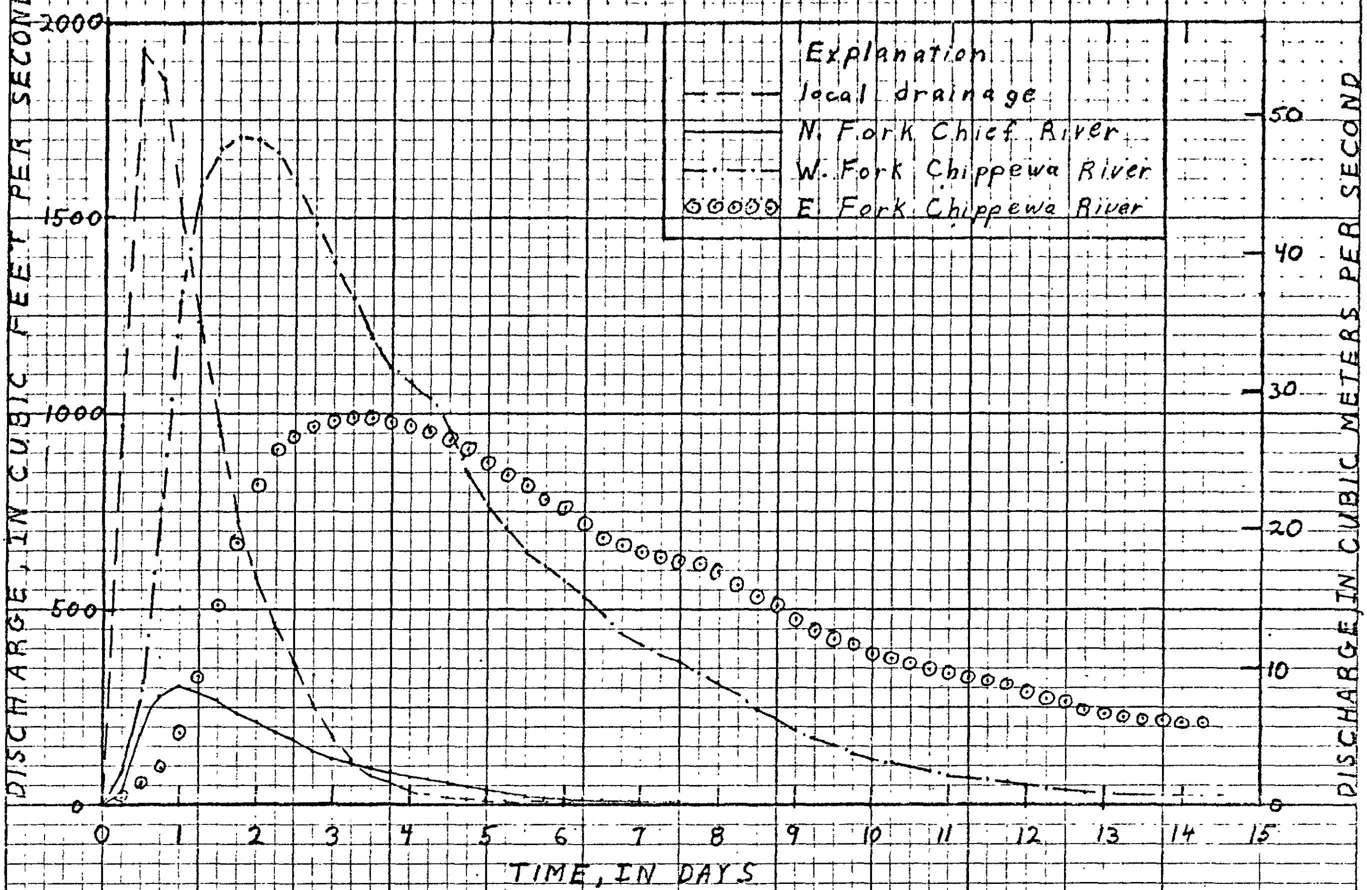


Figure 3 — Six-hour unit hydrographs of the four sub basins draining into Lake Chippewa

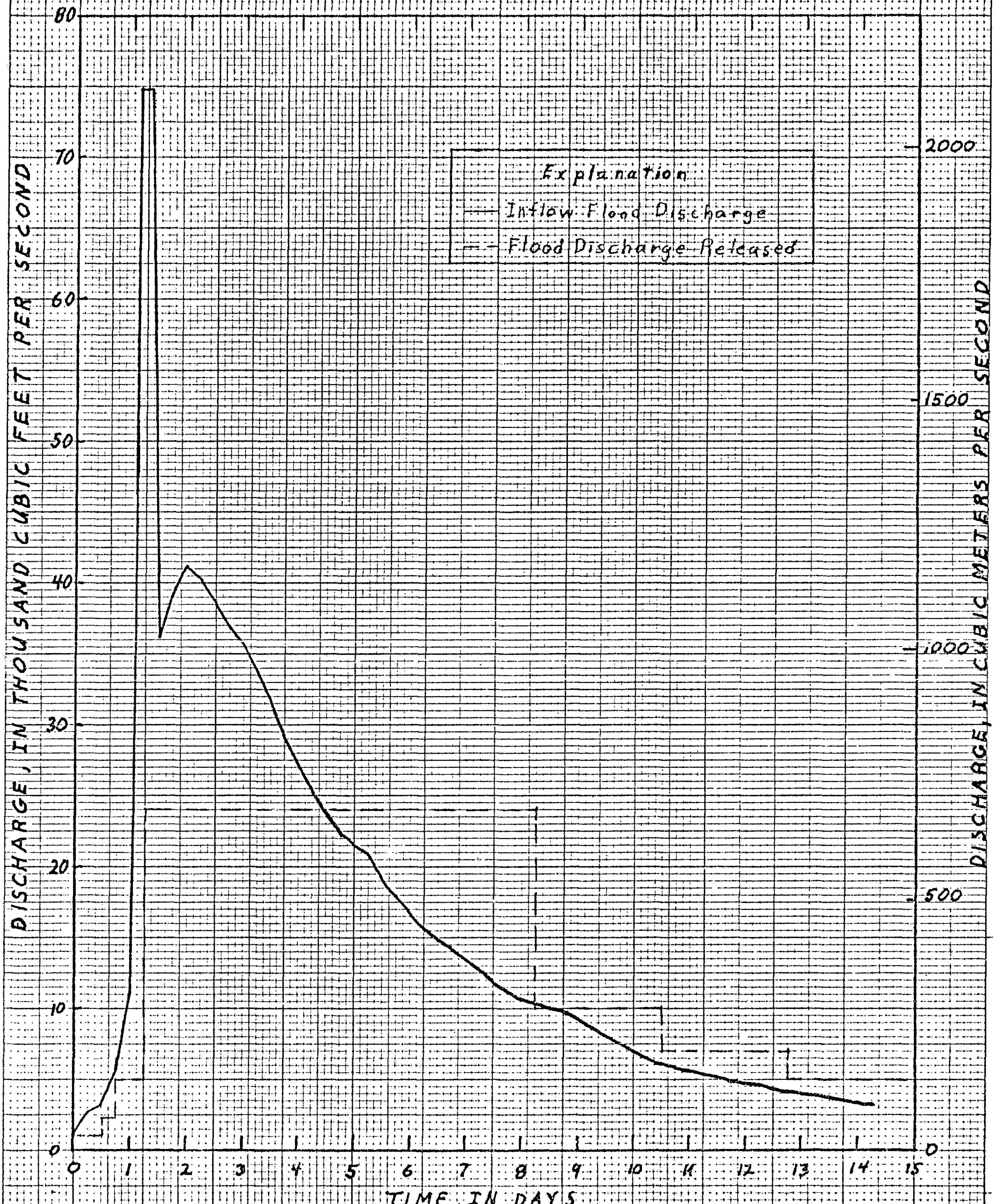


Figure 4.—Hydrographs of probable maximum flood entering Lake Chippewa, and discharge released from lake.

Table 2.--Maximum allowable discharge, in cubic feet per second, based on stage and rate of rise

Lake stage, in feet above mean sea level	Rise, in feet, of lake stage in preceding 6 hours				
	Less than 0.25	0.25 to 0.50	0.50 to 0.75	0.75 to 1.00	Greater than 1.00
1,312 to 1,313	5,000	5,000	7,000	10,000	24,000
1,313 to 1,314	5,000	7,000	10,000	24,000	24,000
1,314 to 1,314.5	7,000	10,000	24,000	24,000	24,000
1,314.5 to 1,315	10,000	24,000	24,000	24,000	24,000
Over 1,315	24,000	24,000	24,000	24,000	24,000

emergency pool elevation of 1,315 ft (400.8 m), but nearly 3 ft (0.9 m) below the crest of the dam. A graph of the lake stage versus time is shown in figure 5.

The set of operating procedures used in this study are only one possible set that, if followed, would prevent the dam from being overtopped. Actual operating rules would consider other factors beyond the scope of this report, such as discharges at various points both upstream and downstream. Some revision of these rules may be necessary to insure acceptable operation for smaller floods.

ESTIMATED FREQUENCY OF PROBABLE MAXIMUM FLOOD

By its definition, the probable maximum flood discharge far exceeds any flood that can be assigned a frequency by statistical analysis of historic data. Two approaches were tried to estimate the frequency of the probable maximum flood.

The probable maximum flood was computed for the South Fork Flambeau River near Phillips, using the unit hydrograph derived from records at that site. The peak discharge of 23,000 ft^3/s (650 m^3/s) for the probable maximum flood was compared with the frequency curve computed from 46 years of record by the log-Pearson type III method (Water Resources Council, 1976) (fig. 6). This frequency curve gives a 100-year discharge of 9,820 ft^3/s (278 m^3/s). Extrapolating this curve, far beyond the range of its applicability, yields a 10,000-year discharge of 14,900 ft^3/s (420 m^3/s). A more

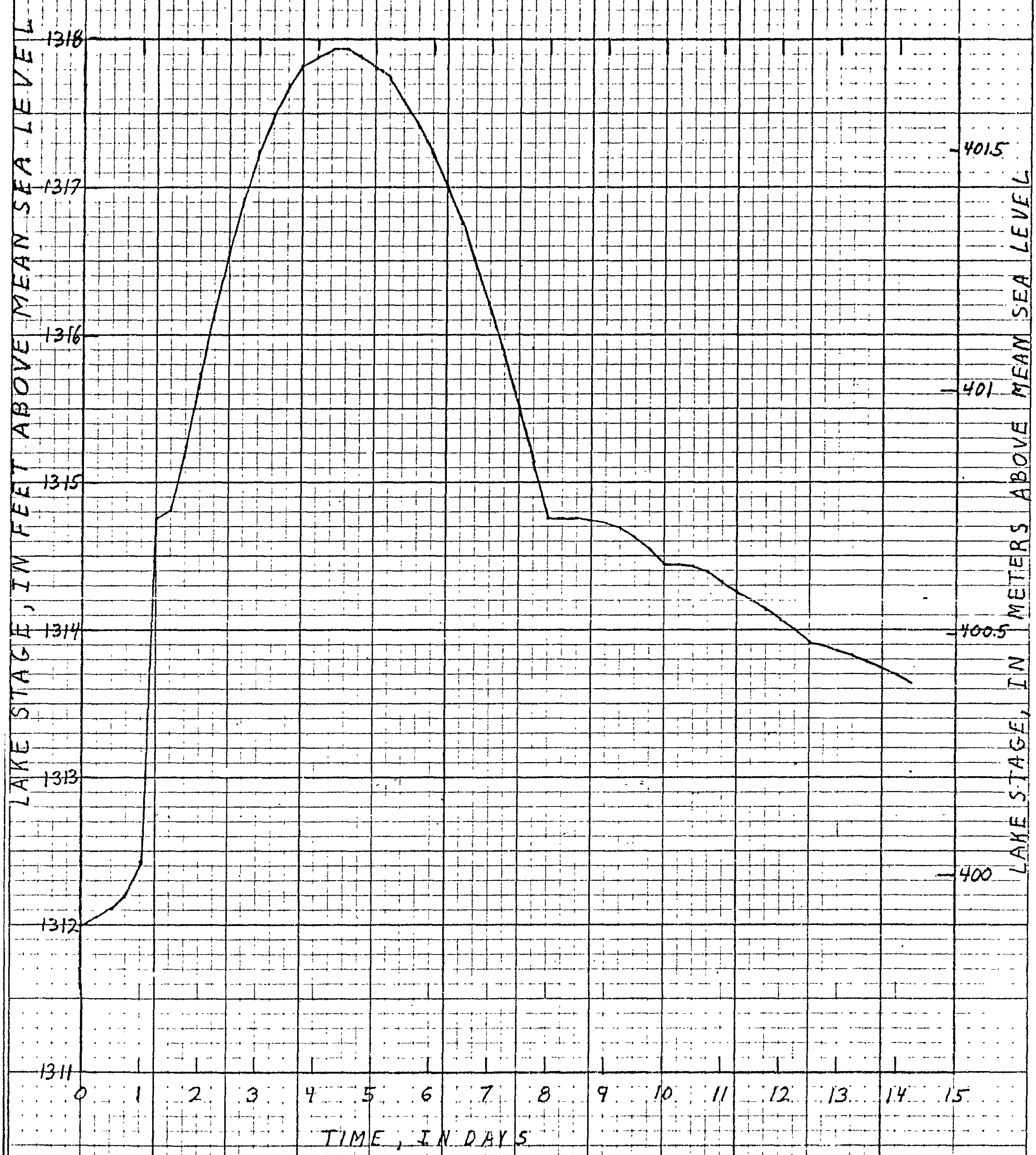


Figure 5: Predicted stage variation of Lake Chippewa during probable maximum flood

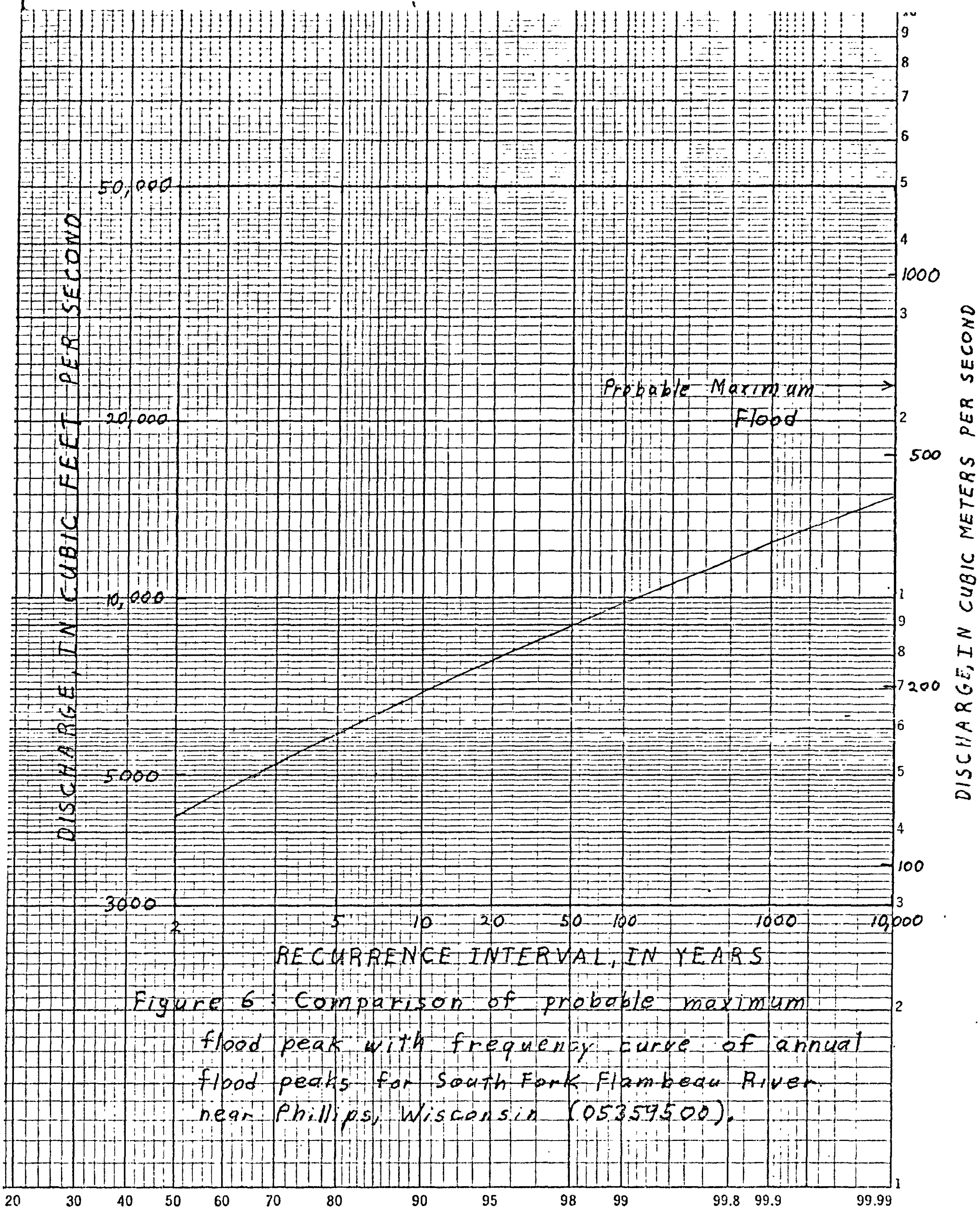


Figure 6: Comparison of probable maximum flood peak with frequency curve of annual flood peaks for South Fork Flambeau River near Phillips, Wisconsin (05359500).

reasonable guide was to express the probable maximum flood as a ratio to the 100-year flood. For the South Fork Flambeau River near Phillips this resulted in the probable maximum flood peak discharge, being about 2.3 times larger than the 100-year flood-peak discharge.

As a second approach, the maximum 1-day, 3-day, and 7-day mean discharges of the probable maximum flood were compared with frequency curves of the same values computed from inflow to the reservoir (fig. 7). Inflow data were obtained from the Inland Lakes Demonstration Project (Dave Daniel, written commun., 1975). These values are summarized in table 3.

From these analyses it can be concluded that the probability of the probable maximum flood in any year is less than 1 in 10,000.

Table 3.--Comparison of highest mean discharge for 1, 3, and 7 consecutive days for probable maximum flood, 100-year flood, and estimated 10,000-year flood for Chippewa River at Lake Chippewa, Wisconsin

Period	Mean discharge, in ft^3/s			
	Probable maximum flood	100-year flood	10,000-year flood	Ratio of probable maximum flood to 100-year flood
1 day	48,000	13,100	25,200	3.7
3 days	38,700	11,000	21,800	3.5
7 days	26,300	9,370	19,300	2.8

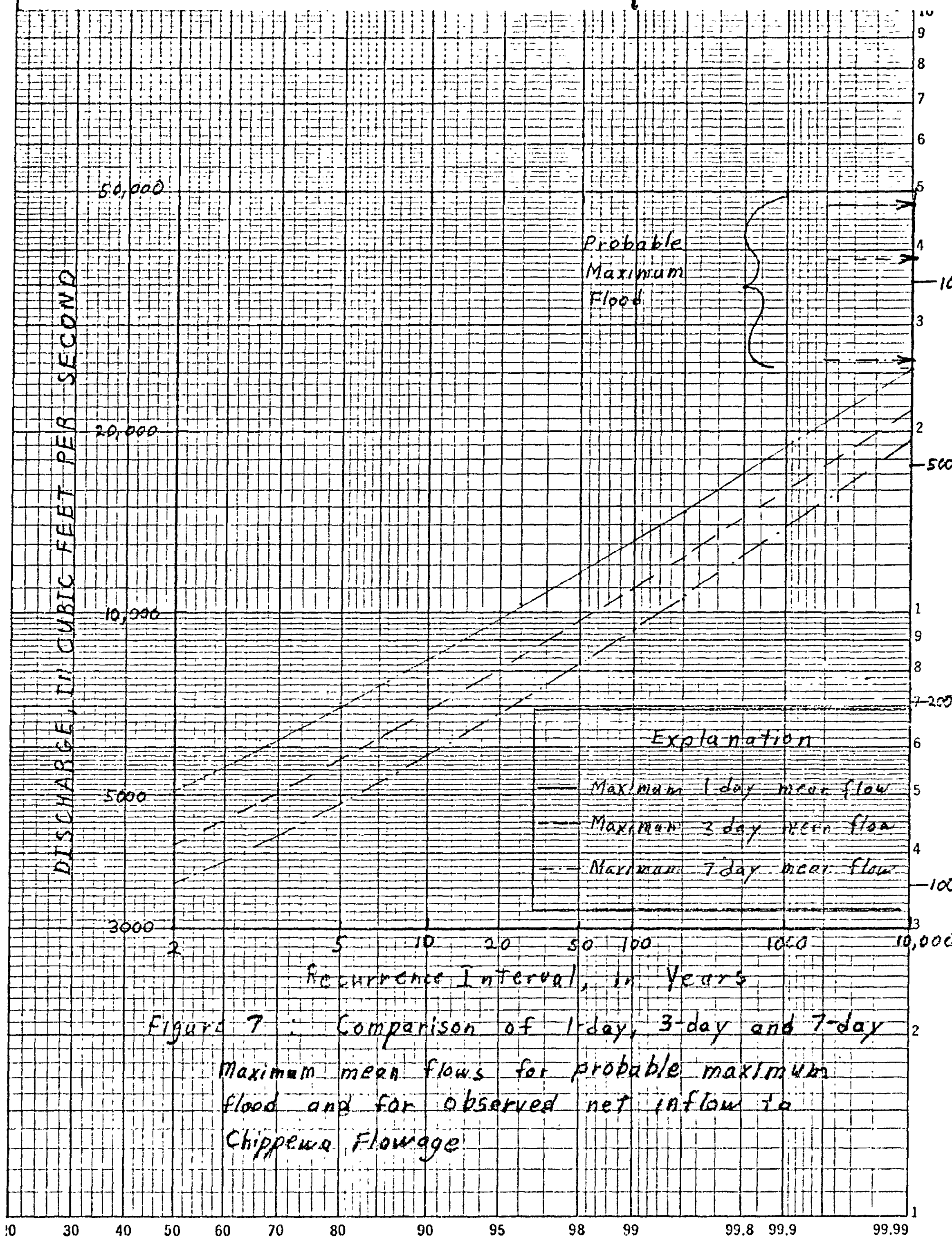


Figure 7 : Comparison of 1-day, 3-day and 7-day Maximum mean flows for probable maximum flood and for observed net inflow to Chippewa Flowage

CONCLUSIONS

The probable maximum flood would produce an instantaneous peak discharge into the reservoir of about 75,000 ft^3/s (2,100 m^3/s) caused primarily by very intense precipitation on the lake surface. Peak discharge from streams entering the lake would be about 41,000 ft^3/s (1,200 m^3/s). Winter Dam controlling Lake Chippewa could be operated so that the probable maximum flood would not overtop the dam, with a maximum discharge from the reservoir during the flood of 24,000 ft^3/s (680 m^3/s) for about 7 days.

The probable maximum flood is beyond the magnitude for which frequency can be determined by statistical analysis. It is larger both in peak discharge and in volume than the values determined for a 10,000-year flood by extrapolating the frequency curves determined by statistical analysis. The probable maximum flood appears to be 2 to 4 times the 100-year peak discharge.

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