ZUMBRO RIVER

ZUMBRO LAKE DAM
Wabasha County, Minnesota
INVENTORY NO 358

NATIONAL DAM SAFETY PROGRAM
INSPECTION REPORT

Prepared by

DEPARTMENT OF THE ARMY

ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

For

STATE of MINNESOTA

SEPTEMBER 1979

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GENERAL SUMMARY

The procedures and methodolgy used for the design of dams has undergone major evolution within the last half a century. Because the majority of dams within the State were constructed during or prior to this evolution, often there is little available design data which conforms to current practice. The emphasis of the National Dams Inspection Program is not to develop the data for a comprehensive analysis of a structure, but rather to identify conditions which constitute an existing or potential hazard. By necessity, the identification process presented in this report is generally limited to conditions which may be identified through the field inspection, approximate computations and other readily available sources of information. The contents of this report should not be treated as an in-depth engineering evaluation.

The Zumbro Lake Dam and powerhouse was constructed in 1919 for purposes of hydroelectric power generation. The dam was constructed for the City of Rochester, which still owns and maintains the dam. The dam currently generates electric power used by the City of Rochester and is operated by the City of Rochester Electric Department. The dam remains essentially unchanged from its original configuration, however, repair work has been accomplished on the existing structure since its construction. The dam consists mainly of a mass concrete gravity cross-section which serves as an uncontrolled overflow spillway. Other components are a powerhouse and non-overflow sections at the abutments. The maximum hydraulic height of the dam is approximately 80 feet and the total length of the dam is 900 feet.

The Zumbro Lake Dam is not located within an urban area, however, there are several residences downstream of the dam and the potential for additional development is high. There is also a campground immediately downstream of the dam which is used during the summer months. A sudden failure of the Zumbro Lake Dam would result in loss of life downstream and damage to downstream residences. Failure of the Zumbro Lake Dam due to either normal pool conditions or flood flow conditions would both result in loss of life downstream of the dam. Based on the potential for loss of life and damage to the areas downstream, the Zumbro Lake Dam is categorized as a "high hazard" dam.

CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the dam included an on-site inspection, a review of available data, and an evaluation of the hydraulic and hydrologic characteristics of the dam and reservoir. In addition, an evaluation of the operation and maintenance, geotechnical and structural aspects was conducted. The following are the major conclusions and recommendations resulting from the evaluation:

1. Discharge Capacity

   a. The Zumbro Lake Dam does not meet accepted dam safety criteria because it is not capable of passing the spillway design flood as recommended by the dam safety guidelines. The spillway design flood, as recommended by the dam safety guidelines, is the Probable Maximum Flood or 290,000 cfs. It is estimate that the overtopping discharge is approximately 50,000 cfs corresponding to the flood with 0.35 percent probability of annual occurrence. The 100-year flood or the flood with a 1 percent probability of annual occurrence has a discharge of 37,500 cfs which can be passed without overtopping the dam. Failure of the Zumbro Lake Dam resulting from overtopping would probably significantly increase the hazard to loss of life downstream from the dam from that which would exist just before overtopping failure because the tailwater elevations along the downstream dwellings would be at or near the foundations of the dwellings which would not cause them to be evacuated. Therefore, failure of the Zumbro Lake Dam due to overtopping would result in a high probability for loss of life downstream of the dam. Therefore:

      1. It is recommended that a spillway design flood be determined on a basis of more detailed evaluations of the hydrologic and hydraulic conditions and downstream damage potential and that the modifications required to allow safe passage of the spillway design flood be implemented.

2. It is recommended that a documented flood warning plan be developed for closing nearby bridges, evacuating nearby residences, and evacuating the downstream camping grounds during major floods.

3. It is recommended that a detailed floodplain analysis be made downstream of the dam to determine the hazards to the camping grounds and local residences.

4. It is recommended that a documented hydraulic operation plan be developed and implemented for the spillway especially as it relates to the flood warning plan.

2. Operation Plan

a. The Zumbro Lake Dam currently primarily functions as an uncontrolled spillway, although there is flow passed through the turbines which is controlled by the City of Rochester Electric Department. The only other operable outlets for the dam are a small ice chute gate adjacent to the powerhouse at the crest of the dam and a small diversion tunnel located at the center of the spillway near the base of the dam. The discharge capacities of these outlets are small. Operation of discharge facilities other than the turbines has been very infrequent.

3. Inspection and Maintenance Programs

a. No systematic program of periodic inspection has been developed for the Zumbro Lake Dam. A continuing program of inspection is a necessary part of an effective maintenance program. Therefore:

1. It is recommended that a documented program of inspection and maintenance be developed and implemented. This inspection program should be designed to detect deficiences related to the seepage, scour and structural distress.

4. Foundation Evaluation

a. The Zumbro Lake Dam is constructed upon a sandstone bedrock which is light brown in color and well cemented. The dam is keyed into the bedrock along the valley walls. The dam foundation would probably meet current recommended design criteria in regards to foundation stability.

5. Seepage and Scour

The dam has a past history of seepage through the spillway concrete construction joints. Repairs were conducted during 1935 and 1961 to repair this situation. Therefore:

1. It is recommended that, during periods of low flow when the spillway surface is dry, that an inspection be made to determine the extent of seepage through the spillway.

b. Both abutments have a considerable amount of tree growth. However, it is not recommended that these trees be removed upstream of the concrete core wall because the massive concrete core walls and mass concrete non-overflow sections of the dam would not be adversely affected by tree growth. There is also some severe erosion occurring on the upstream bank near the left abutment. Therefore:

1. It is recommended that the banks upstream of the left abutment be stabilized and the trees removed from the riprap on the banks upstream of the right abutment.

c. A scour hole in the downstream bedrock channel was detected. Therefore:

1. It is recommended that the scour holes should be periodically sounded to ensure that unchecked scour does not lead to possible stability problems.

6. Structural Evaluation

The Zumbro Lake Dam would probably meet current recommended design criteria in regards to overturning stability. However, the dam probably does not meet current recommended design criteria in regards to sliding stability, however, its stability in regards to sliding is probably satisfactory. The structural strength of the Zumbro Lake Dam structural components may meet current recommended design criteria. Temperature cracking was observed on the interior of the powerhouse. Severe deterioration of the right half of the spillway surface was observed. However, this does not present a hazard to the structural stability of the dam but may lead to accelerated concrete deterioration or hydraulic inefficiency. Therefore:

1. It is recommended that the severe spillway surface deterioration be repaired in the near future to reduce the amount of work and materials required and to improve the hydraulic operation of the spillway.

2. It is recommended that additional study be accomplished to conclusively evaluate the stability of the Zumbro Lake Dam.

3. It is recommended that the cracks in the powerhouse superstructure be repaired to prevent possible accelerated concrete deterioration.

7. Interim Measures

a. A high probability for loss of life downstream of the dam exists during large floods and is a result of sudden failure of the Zumbro Lake Dam during most flow conditions. Therefore:

   1. It is recommended that the residents downstream of the dam be informed of the hazard associated with the dam and that a flood warning and evacuation plan be developed and implemented during flood conditions.

8. Hazard Classification for Assessment

a. This report verifies that the dam is properly classified as a high hazard dam because of the proximity of the downstream residences and public use facilities. However, if the measures recommended in this report are implemented, there would be a "low threat" of failure of the Zumbro Lake Dam.

SIGNATURES OF INSPECTION TEAM

TEAM LEADER Daryl E. Zuelke

Charles C. Rehm

[illegible]

BARR ENGINEERING CO.
Minneapolis, Minnesota

INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
ZUMBRO LAKE DAM INVENTORY NO. 358
SOUTH FORK
ZUMBRO RIVER, MINNESOTA

SECTION 1
PROJECT INFORMATION

1.1 GENERAL

a. Authority

1) The F.Y. 1978 Public Works Appropriation Act, Public Law 95-96.

2) The National Dam Safety Act, Public Law 92-367, 8 August 1972.

b. Purpose of Inspection

The purpose of the inspection is to identify the existence of conditions which could threaten the integrity of the structure and thereby creating a downstream hazard.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances

The principal components of the Zumbro Lake Dam consists of a 243.5 foot long right non-overflow section, 440 foot long uncontrolled mass concrete spillway, a 100-foot long powerhouse, and a 117-foot long left non-overflow

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*Left and right are defined facing downstream.

Note: N/A means NOT APPLICABLE
N/O means NOT OBSERVED
Not Available means NOT AVAILABLE

section as shown on Plate 1-2. The spillway, powerhouse and non-overflow sections are presented in more detail in Plates 2-1 through 2-21. The spillway has an uncontrolled crest, a sloping downstream face, a small outlet structure in the center, and an ice chute on the left side of the spillway. The powerhouse is located to the left of the spillway and has two turbine intakes and provisions for a third. The turbine flow is currently remotely controlled from the City of Rochester steam electric generating plant. The right abutment of the non-overflow section is connected to a concrete core cutoff wall and keyed into bedrock.

b. Location

The Zumbro Lake Dam is located on the Zumbro River 13 miles north of Rochester, Minnesota and approximately 65 miles southeast of Minneapolis-St. Paul. The dam is located in Sec. 27, T109N, R14E.

c. Size Classification

The maximum storage capacity of the Zumbro Lake Dam is approximately 50,000 acre-feet. The hydraulic height of the dam, as measured from the natural streambed elevation to the top of the dam (in this report determined to be the top of the non-overflow section) is approximately 60 feet. This places the dam in the intermediate size category.

d. Hazard Classification

High (revised from inventory).

e. Ownership

The City of Rochester, Rochester Public Utilities, P.O. Box 6057, Rochester, Minnesota, 55901 is the owner of the Zumbro Lake Dam.

f. Purpose

The Zumbro Lake Dam is used for generation of hydro-electric power and the reservoir is used for recreational purposes.

g. Design and Construction History

The Zumbro Lake Dam was designed by Hugh L. Cooper & Co., Consulting Engineers, of New York. The dam was constructed in 1919 with resurfacing of parts of the spillway conducted in 1935. In 1961, repair work was accomplished on the spillway, which included the addition of a dewatering tunnel through the spillway. Section 2 of this report deals more completely with this subject.

h. Normal Operational Procedure

There is no formal documented procedure for operation or maintenance of the Zumbro Lake Dam. However, the City of Rochester Electric Department operates and checks the dam on a regular basis. Reservoir water is used for power generation. The powerhouse is unmanned as the turbines are remotely controlled from the City of Rochester's power plant.

1.3 PERTINENT DATA

Elevations presented are in reference to the datum used on the construction plans for the dam by Hugh L. Cooper Co. (probably 1912 Adj.). The elevations in parenthesis are approximate 1929 Adj. elevations. The 1929 Adj. elevations were derived by using the crest elevation of 915 as noted on the Zumbro Lake, Minnesota U.S.G.S. quadrangle dated 1972. In the following sections of the report, the estimated 1929 Adj. elevation will be used unless noted otherwise.

a. Drainage Area	811 square miles
b. Discharge at Dam Site (cfs)	
Maximum Known Flood at Dam	30,000 (estimated)
Diversion Tunnel at Low Pool Outlet at Pool Elevation 920.0 (915.0)	950
Diversion Tunnel Outlet at Pool Elevation 930.0 (925.0)	1060
Gated Spillway Capacity at Normal Pool Elevation	N/A

Gated Spillway Capacity at Maximum Pool Elevation	N/A
Ungated Spillway Capacity at Maximum Pool Elevation	50,000
Penstock Capacity at Normal Pool Elevation	610
Penstock Capacity at Maximum Pool Elevation	Not Available
Total Spillway Capacity at Maximum Pool Elevation	50,000

c. Elevation (feet above MSL) (1929 Datum)

Top of Dam	930.0± (925.0)
Maximum Pool Design Surcharge	930.0± (925.0)
Flood Control Pool	N/A
Normal Pool	920.0 (915.0)
Upstream Portal Invert Diversion Tunnel	978+ (973+)
Downstream Portal Invert Diversion Tunnel	978+ (973+)
Stream Bed at Centerline of Dam	
Maximum Known Tailwater	867 (862)(estimated)
Top Left Abutment	923.0 (918.0)
Top Right Abutment	925.0 (920.0)
Upstream Penstock Invert	898.0 (893.0)
Downstream Penstock Invert877.5 (872.75)	
Downstream Draft Tube Invert	855.5 (850.5)

d. Reservoir (miles)

Length of Maximum Pool	6.7
Length of Recreational Pool	5.7
Length of Flood Control Pool	N/A

e. Storage Design Values (acre-feet)

Normal Pool	12,300
Flood Control Pool	N/A

Top of Dam		21,000
Design Surcharge	(difference between top of dam and normal pool storage	8,700

f. Reservoir Surface (acres)

Top of Dam	1,020
Maximum Pool	1,020
Flood Control Pool	N/A
Normal Pool	710
Spillway Crest	710

g. Dam

Type	Concrete Gravity Dam
Length of Overflow Section	440 feet
Length of Left Non-Overflow Section	117 feet
Length of Right Non-Overflow Section	243.5 feet
Length of Powerhouse	99.5 feet
Total Length of Dam	900 feet
Maximum Hydraulic Height	80 feet
Side Slopes	1v to 2.0± h/upstream
Zoning	1v to 1.3± h/downstream
Zoning	Clay placed upstream of core wall.
Foundation	Bedrock
Impervious Core	Concrete
Slope Protection	Riprap

h. Spillway

Type	Uncontrolled overflow
Stilling Basin	30 feet concrete apron
Length of Overflow Section	440 feet
Crest Elevation	420.0 (915.0)
Gates	N/A
Upstream Channel	Lake with silt
Downstream Channel	Natural with some rubble

i. <u>Outlet Works</u>

Ice Chute	A 10-foot wide bay on spillway adjacent to powerhouse. Has a drop grade that adjusts from Elevation 920.0 (915.0) to Elevation 908.0 (903.0).
Diversion Tunnel	6'± high x 5'± wide tunnel through spillway. Invert elevation 878± (873±). Steel slide gate on upstream side. Gate has lifting chains extending up to steel bracket on crest of spillway. No hoist on site.
Powerhouse	2 turbines. 7'-11"± high x 9'-0" wide penstock intake. Headgate and stoplog control available at penstock intake. Wicket gate control at turbine. A third turbine pit is undeveloped.
Spillway	Reportedly, 4 foot high flashboards have been used to control discharge. However, these have not been used in recent years.

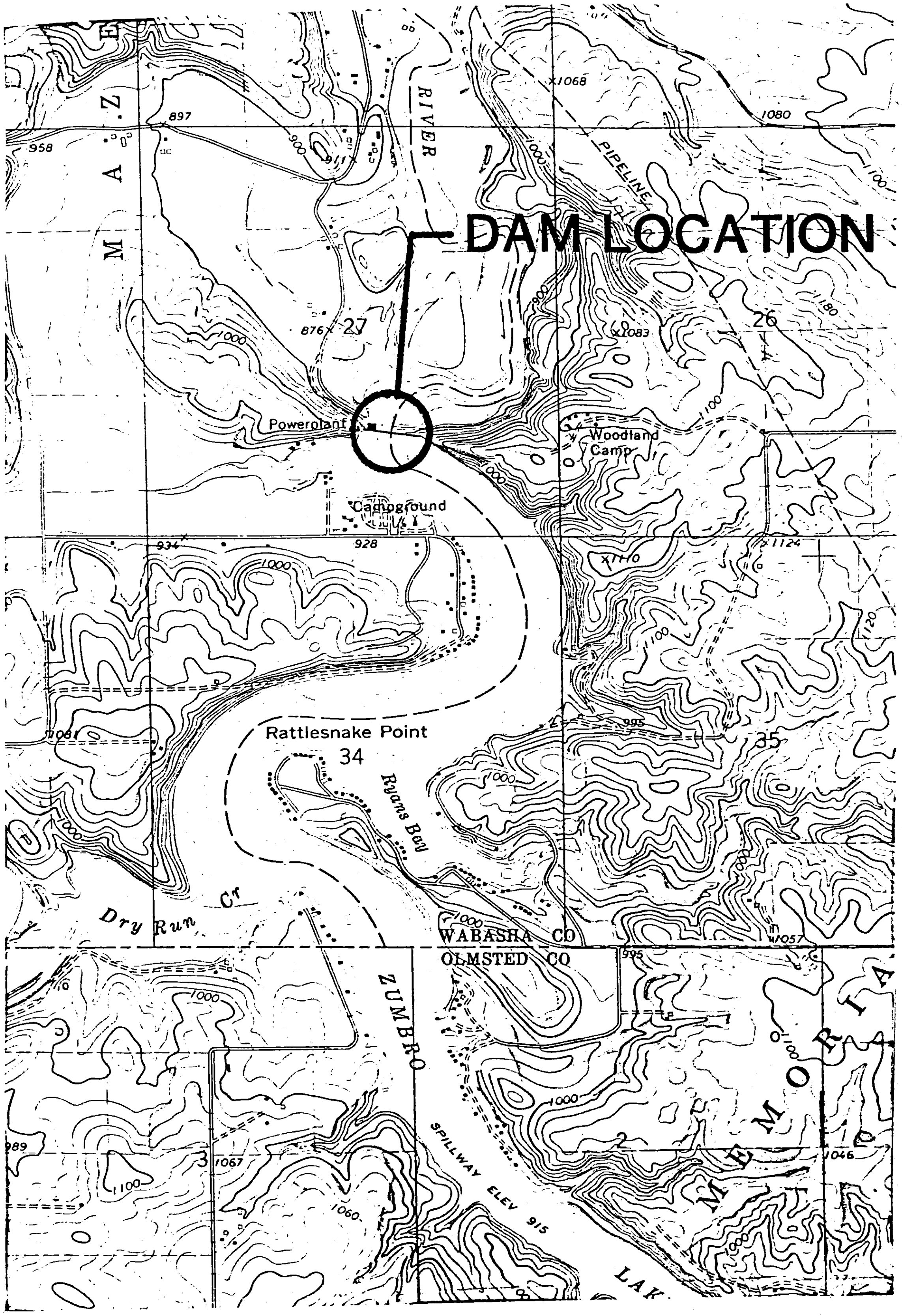
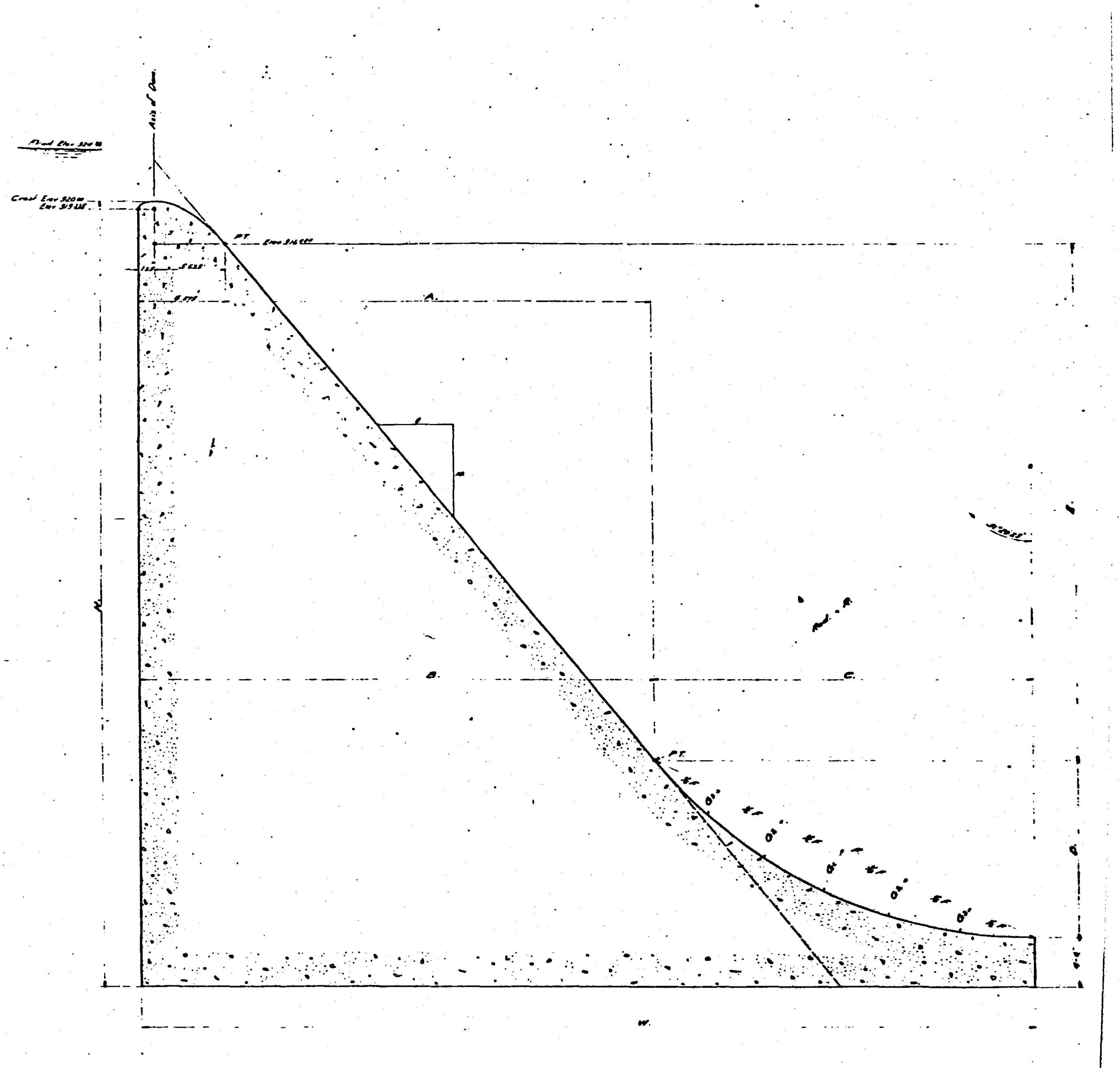

DAM LOCATION
RIVER
PIPELINE
Powerplant
Woodland Camp
Campground
Rattlesnake Point
34
27
26
35
Ryans Bay
Dry Run Cr
WABASHA CO
OLMSTED CO
ZUMBRO
SPILLWAY ELEV 915
LAK
MEMORIAL
MAZE

PLATE 1-1



TYPICAL CROSS SECTION OF DAM.

TYPICAL SECTION

SECTION 2

BACKGROUND ENGINEERING DATA

2.1 HISTORY

The Zumbro Lake Dam is owned by the City of Rochester Electric Department The dam is located approximately 18 miles north of Rochester in Wabasha County, Minnesota. The existing dam and powerhouse were constructed in 1919 for purposes of hydroelectric power generation. The dam remains essentially unchanged from its original configuration, however, repair work has been accomplished on the existing structure. The most significant modification to the structure has been the addition of a dewatering tunnel through the spillway section. This was accomplished during the 1961 repairs to enable the contractor to sufficiently lower the water level upstream of the dam to accomplish repairs to the upstream face. A gate was installed on the upstream side of this tunnel and a bracket which rests upon the crest is attached to the gate lift chains.

The following is an approximate chronology of major construction events associated with the dam:

1919 Construction of the existing Zumbro Lake Dam and powerhouse was completed.

1929 A gunite repair of the construction joints in the upper 14 feet of the upstream face of the spillway was accomplished.

1935 An overlay of the downstream face of the left half of the spillway was accomplished.

1961 A major renovation of the upstream face of the spillway. Much work was also done on the right half of the spillway crest. The dewatering tunnel was added during this renovation.

2.2 AVAILABLE DATA

The available data concerning the existing structure are as follows:

a. A complete set of construction plans for the dam is on file at the City of Rochester Electric Department at the steam electric generating plant in Rochester. These plans were prepared by Hugh L. Cooper and Company Consulting Engineers, New York, New York. The drawings are dated in the years 1917 through 1919. The number of drawings in this set of plans are far too numerous to include in this report, however, copies of selected plans showing critical components of the dam are presented as Plates 2-1 through 2-21. The set of plans on file at the Rochester Electric Department include a full set of the original plans from which prints may be obtained.

b. The operating records of the dam during its history are on file at the City Electric Plant in Rochester. These records contain water level readings, discharges and power produced at the hydro-electric plant.

c. A report prepared by Harza Engineering Company, Chicago, Illinois, entitled "Repairs to the Hydro Plant Dam". This report is dated January 10, 1952. This report outlines several repairs required at the dam. A drawing showing areas of spillway deterioration is presented as Plate 2-22. This report also refers to an earlier report which was prepared by Mr. J. S. Bohman in 1933. The 1935 repairs were accomplished as a result of the report filed in 1933.

d. A report filed with the City Electric Department by Mr. E. M. McGhie, P.E., who inspected the repairs to the dam in 1961. This report contains an abbrievated construction diary of events during repair of the dam and photographs of construction which are too numerous to include in this report. This report describes construction of the dewatering tunnel through the spillway.

e. A memorandum for the record filed by the St. Paul District Office of the U.S. Army Corps of Engineers dated July 28, 1978 describes a brief inspection made of the dam during an estimated high discharge of 18,000 cfs. This report was filed in response to the observation of a reported crack in the dam. It was determined in this memorandum that this crack presented no hazard to the safety of the dam.

f. Volume I - Technical Proposal, Research Proposal submitted to the Department of Energy, Idaho Operations Office, Program Research and Development Announcement ET-78-D-07-1706. Feasibility Determination of Low-Head Hydroelectric Power Development at Existing Sites has been submitted for the Zumbro Lake Dam by the City of Rochester. This proposal was prepared by R. W. Beck and Associates, Seattle, Washington.

SECTION 3

HYDRAULIC AND HYDROLOGIC EVLUATION

3.1 AVAILABLE DESIGN DATA AND RECORDS

a. A brief description of the Zumbro River watershed unit is presented in the Minnesota Department of Conservation, Hydrologic Atlas of Minnesota, Bulletin 10, April, 1959. This discussion includes such items as basin topography, climatology, stream flow characteristics, ground water and water supply.

b. The lake areas in the watershed were found in the Minnesota Department of Conservation, Inventory of Minnesota Lakes, Bulletin 25, 1968.

c. Although the U.S. Geological Survey did not maintain a stream gaging station at the Zumbro Lake Dam, the City of Rochester had maintained daily records at the dam from 1944 through 1969. The nearest continuous gaging station is located upstream on the South Fork Zumbro River near Rochester, and its years of record include 1953 to the present. The nearest downstream continuous gaging station on the Zumbro River is at Zumbro Falls with a period of record of June, 1909 to September, 1917, April to November, 1929 and March, 1930 to the present. The drainage area at the Zumbro Lake Dam is 810 square miles and the annual instantaneous peak discharges recorded at the dam are presented in Table 3-1.

d. U.S. Geological Survey topographic maps were used to determine the drainage area upstream of the Zumbro Lake Dam. These topographic maps were also used to determine the area-volume curve and stage volume curve.

3.2 RUNOFF CHARACTERISTICS OF MAJOR FLOODS

The South Fork Zumbro River generally reaches its highest annual instantaneous peak discharges in the spring due to runoff caused from snowmelt or a combination of snowmelt and rainfall. Of the 26 annual instantaneous peak discharges of record, it was determined that 14 annual instantaneous peak disharges occurred during the spring and 12 during the summer. Nine peak discharges were observed to occur in March, 5 in April, 2 in May, 4 in June, 2 in July, and 1 for each of the months of August, September, October and February.

The well-defined drainage pattern of the South Fork Zumbro River, which is developed on glacial drift, causes the runoff to be rapid. The average annual discharge on the South Fork Zumbro River at Rochester is 127 cfs or 5.67 inches of runoff over the watershed. The average annual discharge at the Zumbro Lake Dam is 390 cfs or 6.53 inches of runoff over the watershed. The average annual discharge of the Zumbro River at Zumbro Falls is 488 cfs or 5.86 inches of runoff over the watershed.

The highest flood on record at the Zumbro Lake Dam occurred as a result of intense rainfall in July, 1951. An instantaneous peak disharge of approximately 30,000 cfs occurred with a stage of 928.75 feet (dam datum). Another large flood occurred during July, 1978, when a peak discharge of approximately 18,000 cfs occurred with a stage of 2 to 3 feet above the crest. The 1951 flood corresponds to a probability of recurrence of 2% annually, or the flood that would occur on the average on once every 50 years. The 1978 flood corresponds to a probability of occurrence of 8% annually, or the flood that would occur on the average of once every 12 years.

3.3 HYDRAULIC ASPECTS OF OPERATION PROCEDURES

The dam is an uncontrolled overflow spillway and has no formal documented hydraulic operating plan. There are two turbines for generation of hydro-power which could be used to control the lake level down to elevation 889.0±. The turbines can be controlled remotely at the City electric generating plant in Rochester. There is an ice chute gate which may be used for discharge, however, its capacity is very small and it has not been operated in recent years. There is a dewatering gate which was installed at the center of the spillway during the 1961 renovation. This gate cannot be opened except by a crane or special hoisting equipment.

3.4 CONSEQUENCS OF SUDDEN BREACHING BY OVERTOPPING OR STRUCTURAL FAILURE

Consequences of a failure of the Zumbro Lake Dam were analyzed for various flow conditions. The downstream impact of a sudden failure of the dam is highly dependent upon the flow condition. Specific cases are described below.

Case 1 - Failure of the spillway under normal operating conditions with a pool elevation of approximately 915.0±.

Case 2 - Failure of the spillway under high flow conditions with a pool elevation of approximately 925.0±.

Case 3 - Failure due to floods above elevation 925.0 approaching the magnitude of the Spillway Design Flood.

a. Case 1 evaluates the effect of a structural failure of the spillway with a pool elevation of 915.0 and a tailwater elevation of aproximately 855.0. During this condition, it is possible to have little or no flow downstream of the dam. It is estimated that a maximum initial flood wave of approximately 26.7 feet would be propagated immediately downstream of the dam. It is also estimated that the maximum instantaneous discharge reached in the surge would be approximately 343,800 cfs. It is believed that the major energy of the surge would be dissipated in the channel and overbanks just downstream of the dam. The probability for loss of life and damage downstream of the dam as a result the failure is considered to be high.

b. Case 2 evaluates the effect of structural failure of the spillway at high pool elevation of approximately 925.0. During this condition, the tailwater elevation due to the flood would be approximately 865.0. It is estimated that a maximum initial flood wave of approximately 26.7 feet would be propagated immediately downstream of the dam. It is also estimated that the maximum instantaneous discharge reached in this surge would be approximately 343,800 cfs. It is believed that the major portion of the energy of the surge would be dissipated in the overbanks and channel beyond the spillway of the dam. The probability for loss of life and damage downstream damage as a result of failure of this type is considered to be high.

c. Case 3 evaluates the effect of a failure of the dam by overtopping the abutments under high flow conditions with a pool elevation of approximately 925.0 or higher. For a dam of large size and high hazard, the Spillway Design Flood, as recommended by the Dam Safety Guidelines, is the Probable Maximum Flood. The Probable Maximum Flood peak discharge at the Zumbro Lake Dam is approximately 290,000 cfs. This flood is approximately six times the discharge capacity of the Zumbro Lake Dam. For a flow of 290,000 cfs, it is estimated that the headwater above the Zumbro Lake Dam would be near elevation 935.2 and the tailwater is estimated to be near elevation 883.0. In this case, the initial maximum flood wave resulting from a failure of the dam is estimated to be approximately 23.2 feet high, immediately downstream of the dam. The probability for loss of life and downstream damage is considered to be high. At flood levels near Elevation 930.0, it appears possible that the reservoir could overflow the west side of the reservoir upstream of the dam. This would create an emergency type spillway but would also cause flooding of residences along the flow path.

Table 3-2 summarizes the above cases.

3.5 RELATIONSHIP BETWEEN STRUCTURE AND OTHER DAMS ON THE SAME WATER COURSE

The Oronoco Dam is located 11.9 river miles upstream from the Zumbro Lake Dam on the Middle Fork Zumbro River. It is believed that a failure of the Oronoco Dam would probably have little effect upon the Zumbro Lake Dam. The Mantorville Dam is located 23.1 river miles upstream from the Zumbro Lake Dam on the South Branch Middle Fork Zumbro River. It is believed that a failure of the Mantorville Dam would have little effect on the Oronoco Dam and, therefore, a failure of the Mantorville Dam would have no effect upon the Zumbro Lake Dam. There are dams on the South Fork Zumbro River, upstream of the Zumbro Lake Dam. One is near the City electric generating plant in Rochester, the other dam is the Mayowood Dam southwest of Rochester. The Silver Lake Dam on Silver Creek, which is tributary to the Zumbro River, is also located in Rochester. Failure of any of these dams would not affect the Zumbro Lake Dam. There are no dams downstream of the Zumbro Lake Dam.

3.6 SUPPORTING DATA

a. A discharge-frequency curve for the Zumbro Lake Dam was developed using discharges obtained from the Log Pearson Type III analysis. This curve is presented as Plate 3-1.

b. A headwater rating curve was derived for various discharges using data obtained in the field. This curve is presented as Plate 3-2.

c. A tailwater rating curve was developed from the information obtained in the field and is presented at Plate 3-3.

d. A stage-volume curve and an area-volume curve were developed from the U.S. Geological Survey quadrangle maps. These curves are presented as Plates 3-4 and 3-5.

e. A synthetic Probable Maximum Flood hydrograph for the Zumbro Lake Dam was developed by combining the synthetic Probable Maximum Flood hydrographs from the Middle Fork Zumbro River and the South Fork Zumbro River. These two synthetic hydrographs were computed using Synder's Method, and the final Probable Maximum Flood hydrograph is presented as Plate 3-6.

3.7 SUMMARY AND RECOMMENDATIONS

a. The Zumbro Lake Dam does not meet accepted dam safety criteria because it is not capable of passing the Spillway Design Flood as recommended by the Dam Safety Guidelines. The Spillway Design Flood, as recommended by the Dam Safety Guidelines is the Probable Maximum Flood or 290,000 cfs. It is estimated that the overtopping discharge with turbines open is approximately 50,000 cfs corresponding to the flood with .035 percent probability of annual occurrence. The 100-year flood, or the flood with a 1 percent probability of annual occurrence has a discharge of 37,500 cfs, which can be passed without overtopping the dam. Therefore:

1. It is recommended that a spillway design flood be determined on the basis of more detailed evaluations of the hydrologic, hydraulic and

downstream damage potential and that the modifications required to allow safe passage of the spillway Design Flood be implemented.

b. The greatest hazard to the downstream area occurs during the failure of the spillway when the pool is at the normal elevation of 915.0.A failure under severe flood conditions would probably result in a high increase in the probability for the loss of life downstream of the dam. Overbank flooding from the high flow conditions would have already led to evacuation downstream of the dam, however, residences on the fringe of the flood area would be inundated by a sudden failure of the dam which would result in a high probability for loss of life. Therefore:

   1. It is recommended that a documented flood warning plan be developed for closing nearby bridges, evacuating nearby residences, and evacuating the downstream camping area during major floods.

   2. It is recommended that detailed floodplain analysis be made downstream of the dam to determine the hazards to the camping area and local residences.

c. No formal hydraulic operating plan was found to exist. Therefore:

   1. It is recommended that a documented hydraulic operating plan be developed and implemented for the spillway especially as it relates to the flood warning plan.

TABLE 3-1

ZUMBRO LAKE DAM
INSTANTANEOUS PEAK DISCHARGES

Year	Peak Discharge
1969	8,925
1968	3,194
1967	7,478
1966	7,699
1965	14,759
1964	530
1963	4,143
1962	16,136
1961	9,911
1960	9,912
1959	5,527
1958	6,874
1957	2,542
1956	6,909
1955	1,184
1954	4,266
1953	5,920
1952	11,691
1951	11,120
1950	2,586
1949	6,249
1948	10,726
1947	4,148
1946	3,953
1945	13,552
1944	4,039

TABLE 3-2

Case	Discharge Over Dam cfs	Frequency of Occurrence* (%)	Headwater Elevation (ft.)	Tailwater Elevation (ft.)	Flood Wave Height (ft.)	Frequency of Potential Hazard
1	0	--	915.0	855.0	26.7	High
2	50,000	0.35	925.0	865.0	26.7	High
3	290,000	0.01	935.2	883.0	23.2	High

*Note: The probability of occurrence of discharges with a probability of occurrence of less than 1 percent is estimated by interpolating between the Probable Maximum Flood (PMF) discharge frequency and the 1 percent frequency discharge. The PMF was estimated to have a probability of occurrence of .01 percent (i.e., the 10,000 year flood event).

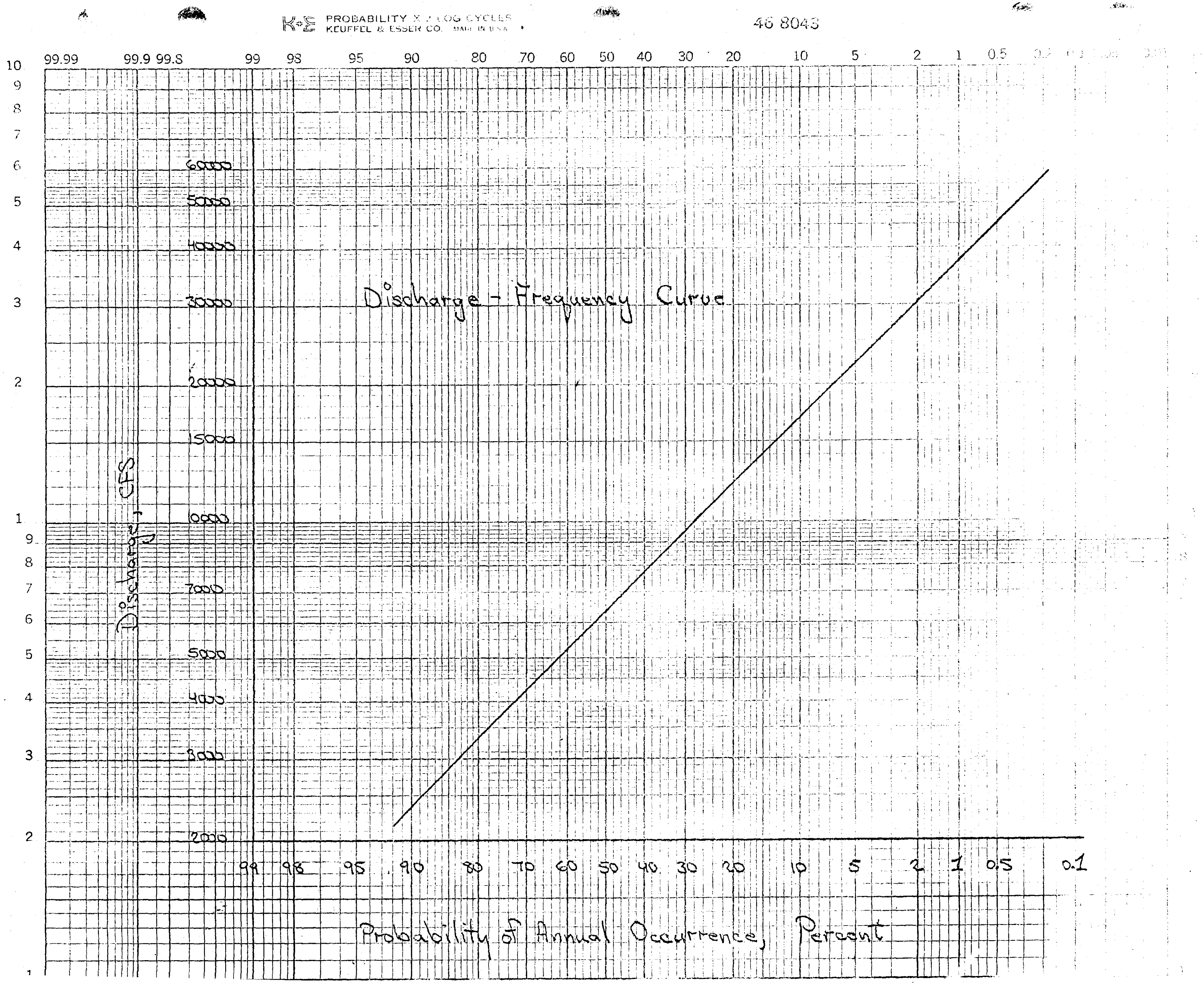

K+E PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8043
Discharge - Frequency Curve
Discharge, CFS
60000
50000
40000
30000
20000
15000
10000
7000
5000
4000
3000
2000
99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.1
Probability of Annual Occurrence, Percent

PLATE 3-1

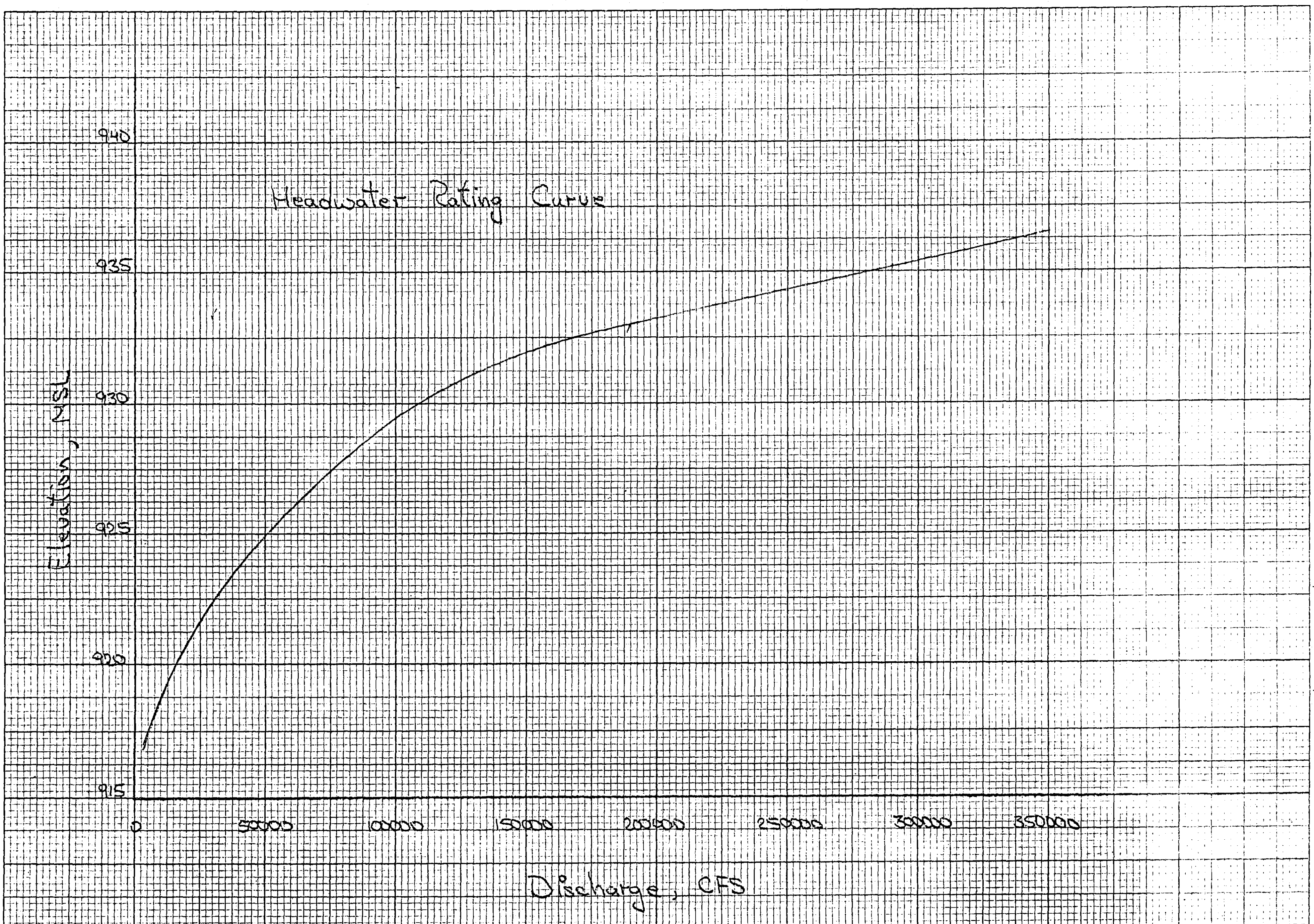

Headwater Rating Curve
Elevation, MSL
940
935
930
925
920
915
0
50000
100000
150000
200000
250000
300000
350000
Discharge, CFS

PLATE 3-2

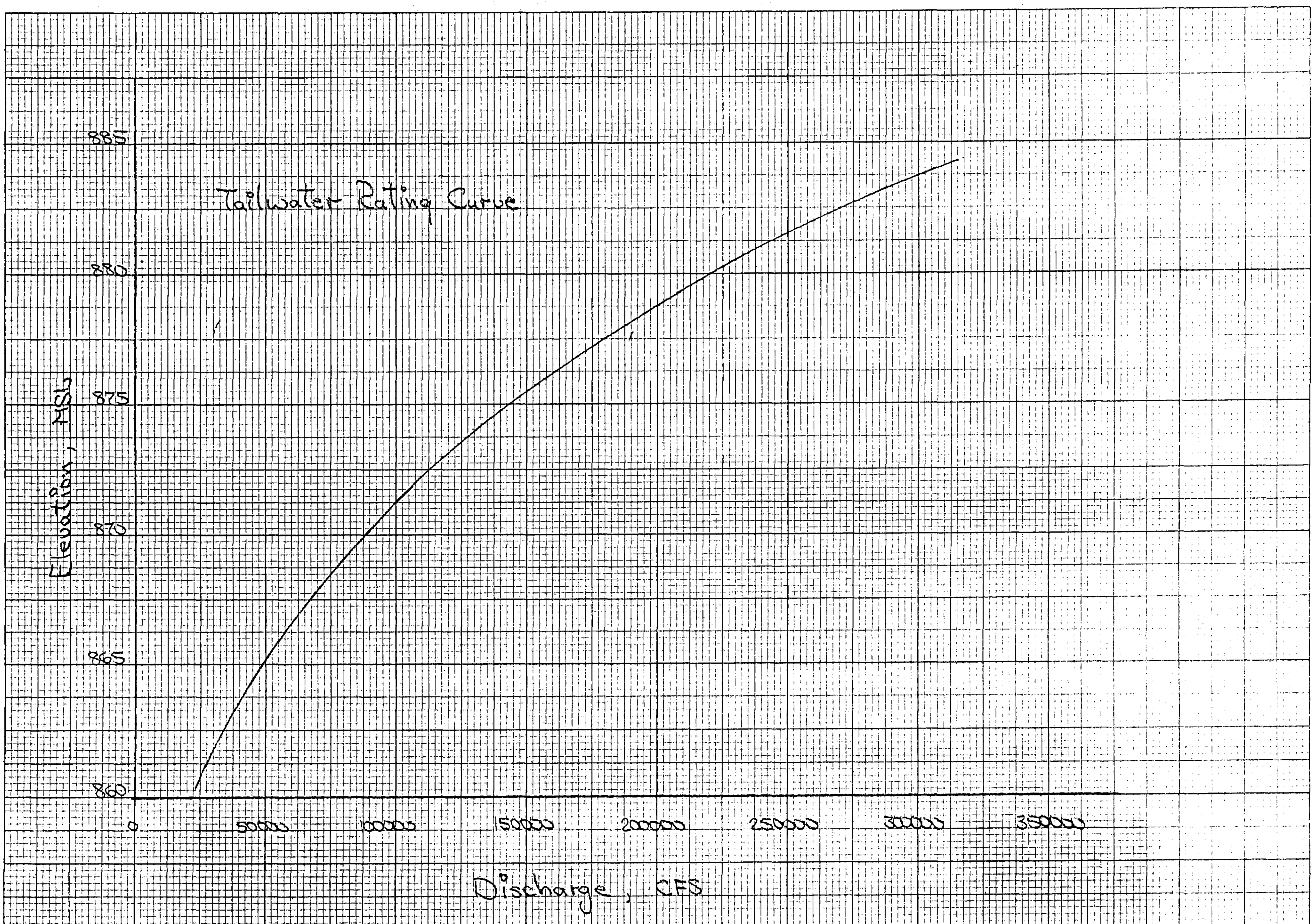

Tailwater Rating Curve
Elevation, MSL
885
880
875
870
865
860
0
50000
100000
150000
200000
250000
300000
350000
Discharge, CFS

PLATE 3-3

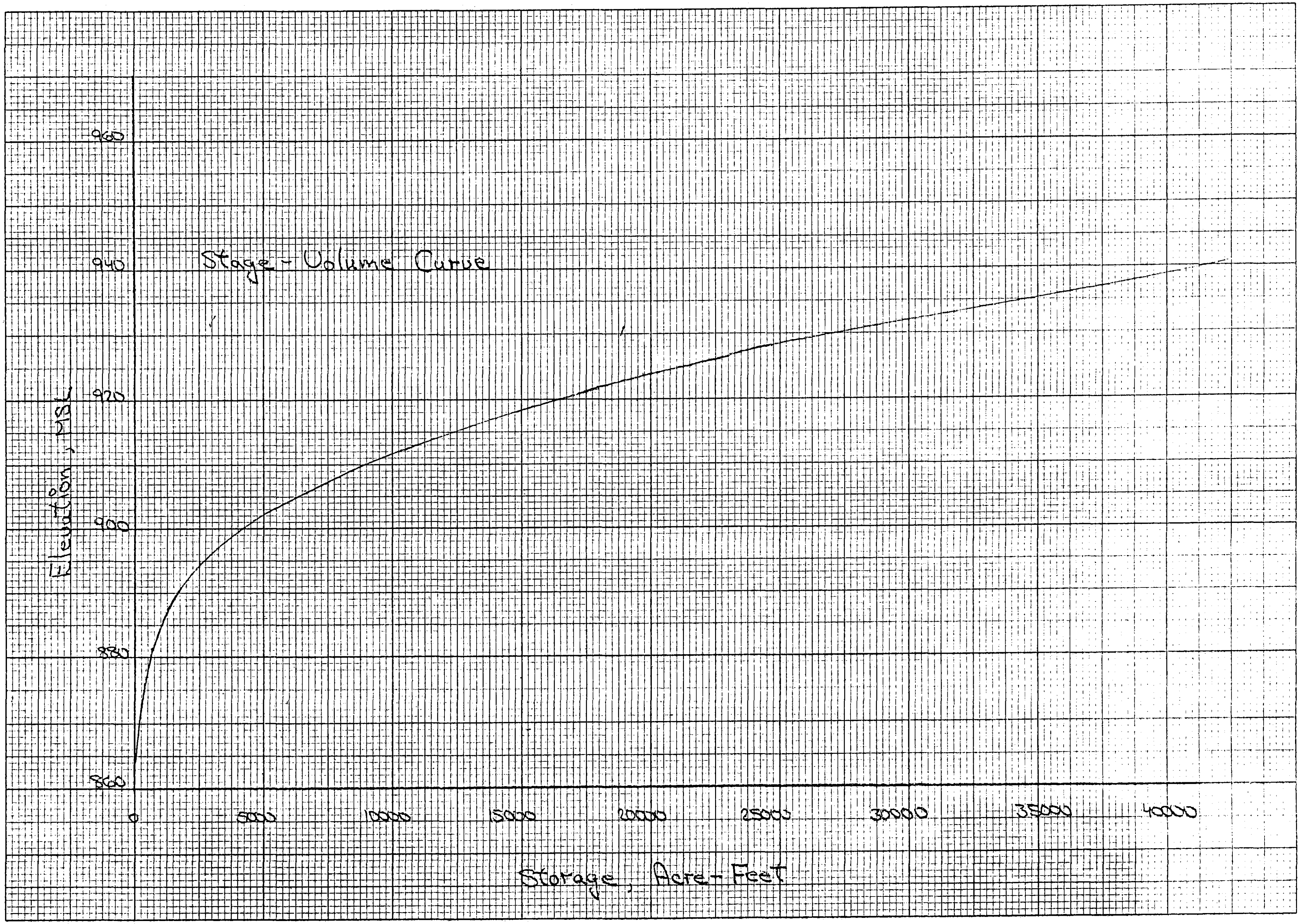

Stage - Volume Curve
Elevation, MSL
960
940
920
900
880
860
0
5000
10000
15000
20000
25000
30000
35000
40000
Storage, Acre-Feet

PLATE 3-4

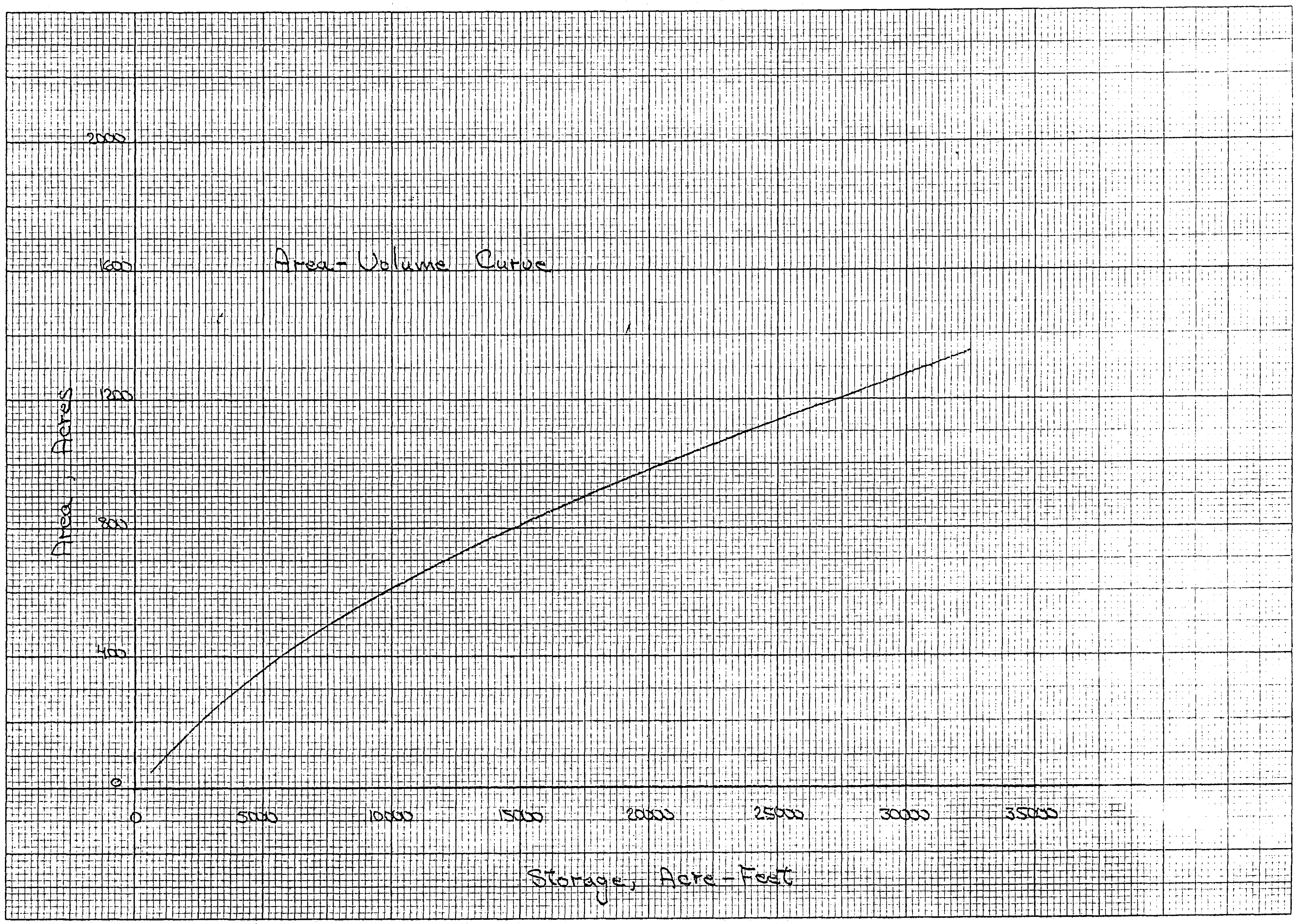
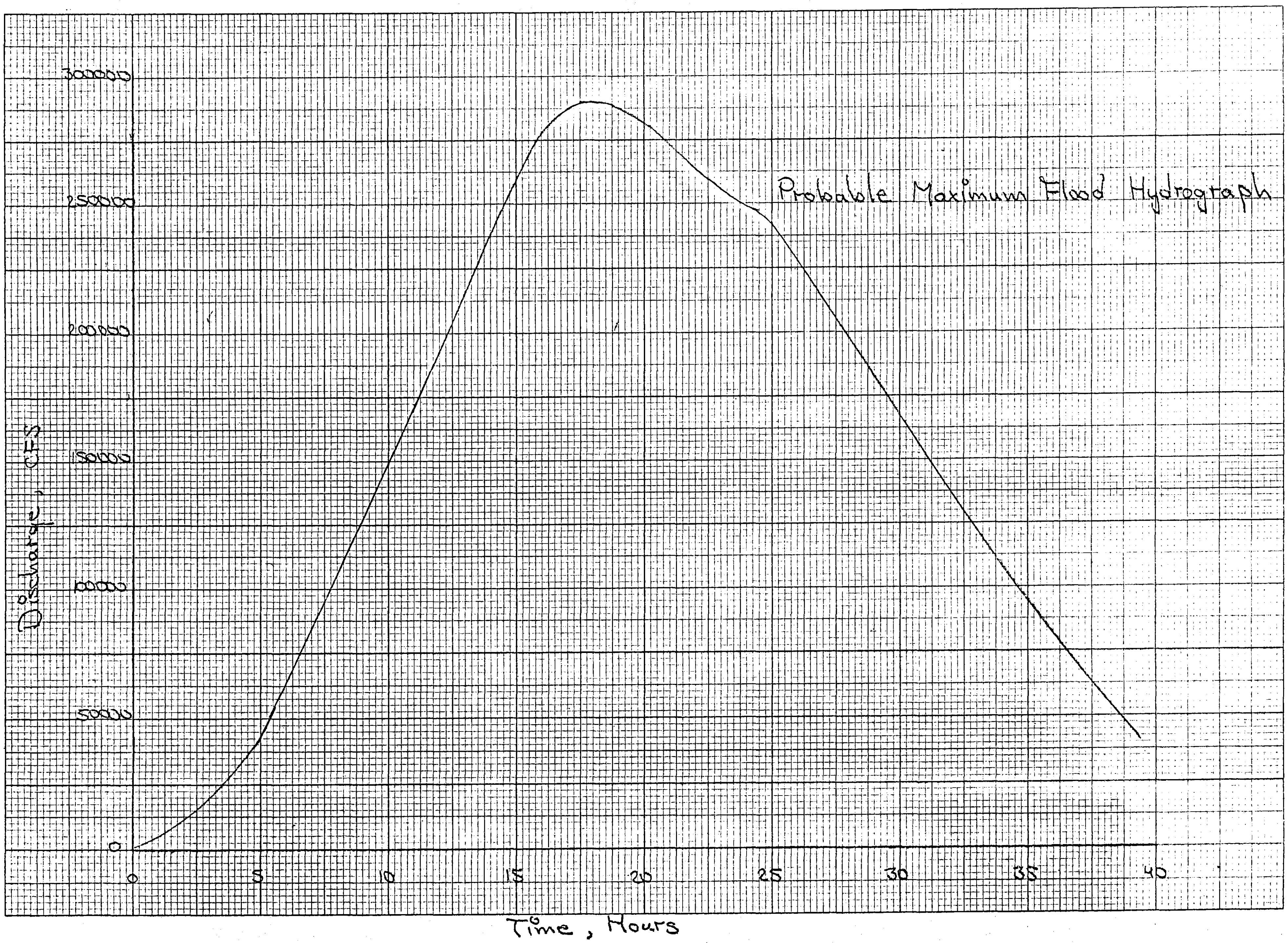

Area-Volume Curve
Area, Acres
2000
1600
1200
800
400
0
0
5000
10000
15000
20000
25000
30000
35000
Storage, Acre-Feet

PLATE 3-5


Probable Maximum Flood Hydrograph
Discharge, CFS
300000
250000
200000
150000
100000
50000
0
0
5
10
15
20
25
30
35
40
Time, Hours

SECTION 4
EVALUATION OF PHYSICAL ASPECTS
OPERATION AND MAINTENANCE

4.1 RESPONSIBILITY

The City of Rochester has responsibility for operation and maintenance of the Zumbro Lake Dam. The City Council has the authority to obtain maintenance and proper engineering when required. The City of Rochester Electrical Department is responsible for day to day operation of the dam and has personnel who are responsible for the dam.

4.2 OPERATION

This section deals with the ability of the structural and mechanical components of the dam to function as originally intended. The hydraulic implication of the operating procedures is discussed in Section 3. The existing operable facilities at the dam consists of two turbines in the powerhouse, an ice chute located at the right side of the powerhouse, and a gated dewatering tunnel located approximately in the middle of the spillway. The penstocks are controlled by headgates which are reportedly operational. These headgates are operated by hand, but a portable motorized drive unit was available to supply shaft power for gate hoists. There are also stoplog slots at the penstocks and stoplogs and equipment for their installation and removal are present at the site. The discharge through the turbines is controlled by the gates on the turbines. These gates are remotely controlled from the electric generating plant in Rochester, but with respect to flood flows, the discharge capacity of these turbines is small. At this time, it is doubtful as to whether the ice chute gate can be operated because it reportedly has not been operated in recent years.

4.3 MAINTENANCE

At this time, there is no formal documented maintenance program for the Zumbro Lake Dam. The City Electric Department of Rochester periodically visits the site to inspect and maintain the electrical generation equipment inside the powerhouse. The need for maintenance for the remainder of the dam is apparently based upon visual observations.

4.4 INSPECTION

An on-going maintenance program is essential to the integrity of a water retaining structure such as the Zumbro Lake Dam. The basis for such a maintenance program should consist of an informal and formal program of inspection. The informal program is often the most important and requires operating personnel who are conscious of the normal day to day condition of the structure and of specific features which have been identified as potential problems. This procedure wold allow any changes in site conditions to be noted and evaluated ina timely manner. The formal aspect of a continuing inspection program should consist of a regularly scheduled systematic inspection of the features of the structure. Such inspections usually involve formal documentation and, in some cases, photographs of the structure. Such an inspection provides a frame of reference for evaluating future changes in the condition of the structure. The recommended frequency for formal inspections is annually and during or after every instance of unusually high water or high wave conditions. A comprehensive inspection program currently does not exist for the Zumbro Lake Dam. However, the Rochester Electric Department does inspect the dam on an irregular basis.

4.5 SUMMARY AND RECOMMENDATIONS

The Zumbro Lake Dam currently functions primarily as an uncontrolled spillway although there is flow through the turbines which is controlled by the City of Rochester Electric Department. Operation of the other outlet strucutres has been very infrequent. Therefore:

1. It is recommended that a documented program of inspection and maintenance be developed and implemented. The inspection program should be designed to detect deficiencies related to seepage, scour and structural distress.

SECTION 5
GEOTECHNICAL EVALUATION

5.1 AVAILABLE SUBSURFACE DATA

The available subsurface data is listed in Section 2 of this report and consists of:

a. Soil borings performed in 1916 by Hugh L. Cooper & Co. along the proposed centerline for the Zumbro Lake Dam.

b. Shallow hand auger borings and visual observations by Barr Engineering Co. during the current dam safety inspection program together with published information.

5.2 GENERAL GEOLOGY

The Zumbro River drains the majority of Dodge, Olmsted, and Wabasha Counties and parts of Goodhue County. The land surface features of the area ranges from a fairly level till plain at the west end of the watershed to deeply incised river valleys at the eastern and northern parts of the basin. Elevations range from a high of more than 1,300 feet MSL in the western part of the watershed to elevations below 900 feet in the Zumbro River valley.

The western end of the watershed consists of glacial drift deposited from the Nebraskan, Kansan and Iowan glaciations, which is over 100 feet thick at places. The eastern and northern parts of the basin are predominantly loess ranging in thicknesses from 0 to 100 feet. Alluvial deposits, up to 75 feet in thickness, occur along the stream valleys, especially the Zumbro River valley.

The bedrock formations underlying the basin range in age from Pre-Cambrian to Upper Ordovician. The sedimentary rocks, including those of the Pre-Cambrian, have a total thickness of over 3,500 feet. Outcrops of the various rock formations can be seen quite easily along the Zumbro River Valley.

5.3 SITE GEOLOGY

Exposed rock outcrops are numerous at the site of the Zumbro Lake Dam. Sandstone seems to be the predominant type of rock found along the base of the dam and along the valley walls up to the crest of the dam. This sandstone is probably a member of the Prairie-du-Chien group. The sandstone found on the downstream apron has the characteristics of the Jordan sandstone. This sandstone is light brown in color and is fairly well cemented. Shallow hand auger borings and visual observations showed that bedrock was at or near the surface on the valley floor and on the sides of the abutments. The tops of the bluffs in the area above the dam seemed to be capped with a grayish dolomite and is probably a member of the Oneota-Shakopee formation. Alluvial deposits were quite noticeable downstream of the dam, with numerous sandbars and sand plains common in the area.

5.4 EXISTING STRUCTURE

The existing structure consists of a left non-overflow section, powerhouse, 440-foot long overflow spillway, and right non-overflow section. The entire structure was placed on grouted sandstone bedrock, as observed in the field and as noted on the construction plans and borings. The following paragraphs describe major components of the dam.

a. Spillway

The spillway, ranging in heights from 43 to 55 feet, is an uncontrolled overflow ogee spillway constructed of mass concrete. The spillway is abutted on the right by a concrete abutment wall and on the left by the powerhouse. An ice chute is located on the spillway adjacent to the powerhouse. The ice chute gate appears to be in fair condition; however, it has reportedly not been operated in recent years. A typical spillway section is presented as Plate 1-3.

The spillway has a downstream apron extending approximately 30 feet beyond the end of the ogee. The apron elevation varies as it is stepped to match the downstream elevations of the ogee sections. At the right half of the spillway, the water flows past the end of the apron and onto a large sandstone outcrop, which extends approximately 50 feet beyond the toe of the apron. The top of this outcrop is approximately 15 feet above the downstream channel of the Zumbro River. The left half of the spillway has a concrete apron which was submerged under approximately 7 feet of water at the time of the inspection.

b. Powerhouse

The powerhouse substructure and superstructure are constructed of concrete. The powerhouse has three turbine pits, however, only two turbines were installed and are presently functioning. The powerhouse has a trashrack, penstock with a headgate, scroll case, draft tube and tailrace for each turbine installation. The penstock intake also has stoplog slots which may be used to block flow to the turbine. The turbines have wicket gates which are remotely controlled from the electric generating plant in Rochester. The powerhouse has a derrick and other appurtenances necessary to install and remove stoplogs. The hoisting mechanisms for the headgates are in place and appear to be functional. Downstream of the powerhouse, a concrete training wall extends outward between the powerhouse tailrace and the spillway, while nearly vertical exposed bedrock exists at the left of the tailrace. The powerhouse is presented in Plates 2-1 through 2-3 and Plates 2-9 through 2-11.

c. Non-Overflow Sections

The right non-overflow section starts at the right abutment as a 5-foot thick core wall keyed in the bedrock with adjacent earthfill for approximately 170 feet. The remaining 75 feet of non-overflow section is a mass concrete gravity dam. The right non-overflow sections are presented in Plates 2-14 through 2-17. The earthfill slopes in the core wall section are steep and have trees growing on them. The earthfill consisted of a thin cover of topsoil covering a rocky fill. There is no earth backfill at the gravity dam section until approximatley one-third of the way down its downstream side. Numerous bedrock outcrops were noticed near the toe of the downstream slope of the right non-overflow section.

The left non-overflow section starts at the powerhouse and ends at the left abutment. This section consists of a mass concrete gravity dam founded on and keyed into bedrock. The left non-overflow section is presented in Plates 2-7 through 2-8. Numerous bedrock outcrops are visible along the side of the hill into which this section terminates.

5.5 ASSESSMENT OF FOUNDATION AND SLOPE STABILITY

There is no record of formal stability analysis of the Zumbro Lake Dam. No signs of foundation instability such as cracking of the concrete or large displacements were observed on the dam. Since the dam abutments incorporate massive concrete core walls embedded in bedrock, the slope stability of the earth embankments placed against the core walls was not applicable. Failure of an earth slope would not create a hazard to the dam. Erosion did not seem to be a major problem due to the shallow bedrock depths on both abutments. The construction plans indicate that the dam is keyed quite deeply into bedrock. This probably also indicates that much bedrock was excavated to find competent rock for the dam foundation. The dam would probably meet current criteria with respect to foundation stability.

5.6 ASSESSMENT OF SAFETY OF STRUCTURE AGAINST UNCONTROLLED SEEPAGE

Only minor seepage was observed on both abutments. The spillway was damp from water which had been previously running over the crest and from rainfall that occurred the morning of the inspection, making it impossible to determine the extent of seepage through the spillway. In 1935 and 1961, repairs were made on the spillway to seal the seepage that had been flowing through the construction joints. Minor seepage was also observed to be exiting from the upstream wall on the interior of the powerhouse. Seepage observed at the dam was extremely small in quantity and did not indicate any major piping or erosion problem, which would be detrimental to the stability of the dam.

5.7 SLOPE PROTECTION

The right abutment was protected with riprap, however, heavy tree growth in this area could be detrimental to the riprap if the trees were uprooted in a storm causing a break in the riprap protection and leading to possible erosion. The left abutment banks have been heavily eroded resulting in near vertical slopes.

5.8 SCOUR PROTECTION

The existing energy dissipation works consists of a downstream apron. The material downstream of the apron is a sandstone which may be somewhat condusive to scour. There is no history of scour problems at the dam. The dam is set rather deeply into bedrock, however, unchecked scour chould eventually cause a hazard to the stability of the dam. During the field investigation, soundings indicated a 14 foot deep scour hole approximately 50 feet downstream of the highest spillway section.

5.9 CONCRETE AND MASONRY CONDITIONS

The concrete, in general, seems to be in good condition. Spalling and minor cracking were observed on the non-overflow sections, however, this deterioration does not pose a hazard to the safety of the dam. Repairs were made in 1935 and 1961 to replace and repair several sections on the upstream and downstream slope of the spillway. The right half of the spillway is severely eroded in areas, however, the spillway is constructed of mass concrete and the stability of the structure is not affected by this deterioration. The surface condition of the powerhouse concrete and the spillway overlay concrete appear to be in good condition with minor spalling noted. The upstream face of the spillway was submerged and the condition of the concrete could not be observed. Cracks were observed at the top of the archways within the powerhouse. This cracking is discussed in Section 6.

5.10 SUMMARY AND RECOMMENDATIONS

The following conclusions and recommendations are made regarding the foundation of the Zumbro Lake Dam and powerhouse:

a. This dam has a past history of seepage through the construction joints in the concrete spillway although construction repair took place in 1935 and 1961 to repair this situation. Therefore:

1. It is recommended that, during periods of low-flow when the spillway surface is dry, that an inspection be made to determine the extent of seepage through the spillway.

b. Both abutments have a considerable amount of tree growth. However, it is not recommended that these trees be removed upstream of the concrete core wall because the massive concrete core walls and mass concrete non-overflow sections of the dam would not be adversely affected by tree growth. There is some severe erosion occurring on the upstream banks near the left abutment. Therefore:

   1. It is recommended that the banks upstream of the left abutment be stabilized and the trees removed from the riprap on the banks upstream of the right abutment.

c. Based on soundings downstream of the apron:

   1. It is recommended that the scour holes should be periodically sounded to insure that unchecked scour does not lead to possible stability problems.

SECTION 6
STRUCTURAL EVALUATION

6.1 BACKGROUND DATA

The available data consist of the following information:

a. A complete set of construction plans for the dam is on file at the City of Rochester Electric Department, steam electric generating plant in Rochester. These plans were prepared by Hugh L. Cooper & Company, Consulting Engineers, New York, New York. The drawings are dated in the years 1917 through 1919. The number of drawings in this set of plans are far too numerous to include in this report, however, copies of selected plans showing critical components of the Dam are presented in Section 2.

b. A report prepared by Harza Engineering Company, Chicago, Illinois entitled "Repairs to the Hydro Plant Dam". This report is dated January 10, 1952. This report outlines several repairs required to the dam. This report also refers to and has excerpts from an earlier report which was prepared by Mr. J. S. Bowman in 1933.

c. A report filed with the Rochester Electric Department by Mr. E. M. McGhie, P.E., who inspected the repairs to the Dam in 1961. This report contains an abbreviated construction diary of events during construction of the Dam and photographs of construction which are too numerous to include in this report.

d. A memorandum for the record filed by the St. Paul District Office of the U. S. Army Corp of Engineers dated July 28, 1978, describes a brief inspection made of the dam made during an estimated high discharge of 18,000 cfs. This report was found to be in response to the observation of a reported crack in the Dam.

6.2 ASSESSMENT OF STRUCTURAL STABILITY

Examination of the Zumbro Lake Dam indicates that structural stability is acheived by use of mass concrete which resists sliding and overturning forces by gravity. The construction plans indicate that the mass concrete sections of the Dam are embedded in the bedrock, however, it appears that no intentional keyway into the bedrock was constructed. Most of the bedrock excavation was probably performed to remove fragmented or soft bedrock material. There is no anchorage to the bedrock other than the frictional resistance along the structure and bedrock interface. The construction plans for the spillway section of the Dam indicate that grout pipes were extended into the bedrock foundation below the mass concrete ogee section. Inspection of the upstream gallery at the base of the powerhouse substructure indicated that the ground pipes were installed and the grouting accomplished. No record of this grouting, however, has been located. The plans also indicate that the spillway apron contains drain holes and is anchored to the bedrock with reinforcing steel drilled 15 feet deep into the bedrock. The channel downstream of the structure is exposed bedrock and it appears that it is performing well with respect to scour and there appears to be no undercutting of the structure. The left non-overflow mass concrete section extends to the bedrock at the left abutment and the construction plans indicate that it is keyed deeply into the bedrock abutment. The right non-overflow mass concrete section extends approximtaely 75 feet beyond the end of the spillway section. From the end of the mass concrete section to the right abutment, the nonoverflow section has a rather massive core wall which is approximately 5 feet thick. This core wall is keyed deeply into bedrock with mass concrete completely filling the keyway below Elevation 902 (dam datum). Earth fill is placed upstream and downstream of this core wall which greatly adds to the overturning and sliding stability of this core wall. The slopes of this earth fill are rather steep, however, a failure of these slopes would not present a hazard to the dam. This core wall is also keyed into the bedrock at the right abutment of the dam.

No existing design calculations for stability were found to exist for the Zumbro Lake dam. The set of construction plans for the dam, however, do provide valuable information regarding the foundation of the dam and cross sections of its structural members. No design loadings or structural strengths were noted on the plan sheets.

Visual observations of the structural components of the Zumbro Lake dam indicate that there is no evidence of stability problems. The mass concrete sections of the Dam appear to be stable with no displacements or large cracks noted. There is severe detoriation of the concrete surface on the right half of the downstream face of the spillway, however, this detoriation probably does not affect the overall stability of the Dam. There has been a history of seepage problems along the construction joints of the mass concrete sections. Attempts to repair these leaks have been made and no displacement appears to have taken place along these joints. The left and right mass concrete non-overflow sections appear to be stable because no cracking or evidence of movement was observed. The thick concrete core wall at the right nonoverflow section appears to be stable with no movement or cracking observed along its exposed top surface.

Cracks were observed in the crowns of the second tier of arches on the upstream side of the powerhouse. The line of these cracks run parallel to the line of the dam. Cracks were also observed in the crowns of the arches above window sections near the corners of the powerhouse and at the center of the powerhouse. There is one expansion joint which runs near the center of the powerhouse which appears to be functioning properly. There appears to be no progressive detoriation occurring along these cracks as there is no additional cracking extending from them and little or no spalling around the cracks. The cracks appear to be primarily in the range of 1/8 inch to ¼ inch in width, their widest part at the crown of the arch. However, there are a few cracks which would probably range from 3/8 inch to ½ inch wide.

The cracks in the powerhouse are probably due to differential movement due to temperature expansion and contraction. The powerhouse structure is attached to a large mass concrete section of the dam which contains the turbine penstocks. This mass concrete section probably undergoes little expansion and contraction while the powerhouse section, with a large surface area exposed to varying temperatures, undergoes larger movements due to temperture variations. These movements have probably resulted in the cracking evident inside the powerhouse. A similar situation has probably caused a crack in the operating platform above the ice chute gate. It is reported that these cracks have existed for at least 20 years and probably longer.

The powerhouse structure below the turbine level appears to be very stable with no cracking or differential movement observed. Inspection of the gallery along the bottom of the mass concrete section in the powerhouse indicates that no cracking or differential movement deep within the section along the foundation has occurred.

The past peformance of the structure is good. There are no reports of stability problems occurring due to large loadings as the result of hydraulic or ice loadings. The Zumbro Lake dam maybe subjected to large ice loadings because of its vertical upstream face, long narrow reservoir and the fact that power production at the dam will probably keep the water level slightly below the level of the crest during low winter flow. On July 6, 1978 the Dam was subjected to high flows due to severe flooding on the south fork of the Zumbro River upstream of the Dam. At this time, the crack in the operator's platform of the ice chute gate was observed by visting personnel at the site and was thought to be a hazard to the safety of the Dam. However, subsequent inspection by Corps of Engineers personnel and others indicated that this crack existed prior to the flooding at the dam. A city employee with the Electric Department indicated that this crack has been present for many years and has shown no additional detoriation or movement. The cracking around the ice chute operator's platform does not present a hazard to the safety of the Dam.

Sliding and overturning stability calculations were performed on a critical section through the spillway. This critical section is the highest part of the spillway adjacent to the powerhouse. The stability of this section was examined when subjected to loadings due to hydrostatic pressure at a pool level at the crest (greatest differential head), ice, silt and uplift. The ice force was assumed to be 10,000 pounds per linear foot. The silt load is relatively low due to the fact that the soundings upstream indicated that no significant siltation has occurred at the dam. The relatively long narrow reservoir causes much sediment to settle before it is carried to the Dam, therefore, it is possible that the service life for the structure will be reached before significant siltation has occured along the upstream face of the dam. The uplift force along the base of the dam was assumed to have a triangluar distribution with a maximum pressure equal to the head on the dam at the upstream side to near zero at the downstream toe. The forces stablizing the section are the weight of the section and the frictional force developed along the concrete bedrock interface. A fiction factor of 0.5 was assumed for the interface. The contribution to stability by the tailwater or resistance from the downstream edge of the spillway keyed into bedrock was neglected for these stability computations.

The loading cases examined and the resulting sliding and overturning safety factors are presented as Table 6-1. This sliding and oveturning analysis is not to be considered as in-depth analysis and the purpose of this analysis is to indicate the relative stability of the dam. Examination of Table 6-1 indicates that several safety factors are below those required by recommended dam safety criteria. However, it is believed that the analysis conducted is conservative. Therefore, it is concluded that the safety factors with respect to overturning would probably satisfy the required dam safety criteria. It is also concluded that the dam would probably have an adequate factor of safety against sliding even though it may not satisfactorily meet design criteria.

6.3 ASSESSMENT OF STRUCTURAL STRENGTH

The majority of the Zumbro Lake Dam is a mass concrete structure with much of the spillway section being 60 feet high and approximately 70 feet wide at the base. The spillway apron is 3 feet thick and is anchored to the bedrock foundation. The retaining walls along the spillway and the concrete core wall at the right nonoverflow section are 5 feet thick which appears to be adequate for the loading conditions. The concrete components of the powerhouse superstructure appear to be relatively thick. The thinnest wall section appears to be in the range of 18 inches with column and arch sections being greater than 30 inches in thickness. The slabs supporting the first walkway tier and the main floor of the powerhouse appear to have a minimum thickness of 18 inches. This system appears to be more than adequate to support the applied loads. The roof of the powerhouse is a steel truss with a concrete roof slab. This roof structure appears to be adequate and in good condition. The upstream side of the powerhouse is a large mass concrete section which contains the turbine penstocks. These sections appear to be in good condition with no signs of detoriation due to inadequate structural strength. The cracks within the powerhouse appear to be due to temperature variations and not due to overloading of the powerhouse structural components.

The no existing structural strength calculations were found to exist for the Zumbro Lake dam. Also, no indications as to the required structural strength of the material components of the dam were found to exist on the construction plans.

Visual observations of the structural components indicate that there appears to be no severe cracking, deflections or material detoriation that would present a hazard to the safety of the Dam. No exposed reinforcing steel was noted in the structure. There is possibly a local failure in the area of the ice chute pier and operator's platform. Severe cracking has occurred through the operating platform's slab and through the pier so that it is possible that the pier and platform may become severed from the main Dam structure. This condition does not present a hazard to the safety of the Dam, however, it does present a safety hazard to operating personnel and the public using the downstream area.

There are no reported problems which would indicate failure of the dam structure materials to meet recommended design criteria. There is a history of structural repairs due to seepage through the construction joints in the main spillway, some of which were probably successful in sealing off some of the seepage or slowing down the deterioration of the concrete. Review of the structural features of the Zumbro Lake Dam indicate that is is probably stable and may meet current recommended design criteria for structural materials. This is based upon judgment as to the adequacy of the structural members based upon a review of the existing construction plans and visual observations made in the field. No calculations are available upon which to make conclusions regarding structural strength.

6.4 EVALUATION FOR THE NEED FOR ADDITIONAL STUDY

A phase II level stability analysis or structural strength evaluation is not currently available for the Zumbro Lake Dam. Section 3.6.1 Recommended Guidelines for Safety Inspection Dams" states that a Phase II level stability analysis should be on record for all dams in the high hazard category or large dams in the significant hazard category. Therefore, additional study would be required to place in the record a stability analysis which examines the Zumbro Lake Dam with respect to dam safety criteria. This recommendation does not indicate that there is a stability problem, rather that the results of this investigation, due to its limited scope, are inconclusive and that the structural stability of the Zumbro Lake Dam should be examined in more detail.

6.5 SUMMARY AND RECOMMENDATIONS

The Zumbro Lake Dam would probably meet current recommended design criteria with respect to overturning stability. The dam probably does not meet current recommended design criteria with respect to sliding stability, however, its stability with respect to sliding is probably satisfactory. The structural strength of the Zumbro Lake Dam structural components may meet current recommended design criteria. Severe deterioration of the right half of the spillway surface was observed, however, this does not present a hazard to the structural stability of the dam but may lead to accelerated concrete deterioration or hydraulic inefficiency. Therefore:

1. It is recommended that the severe spillway surface deterioration be repaired in the near future.

2. It is recommended that additional study be performed to conclusively evaluate the stability of the Zumbro Lake Dam.

3. It is recommended that the cracks in the powerhouse superstructure be repaired to prevent possible accelerated deterioration.

TABLE 6-1

STABILITY OF ZUMBRO LAKE SPILLWAY*

Loading Case	Sliding Safety Factor	Overturning Safety Factor
a. Normal Pool, No Ice, Silt, or Uplift Pressure	1.48	5.21
b. Normal Pool with Silt. No Ice, or Uplift Pressure.	1.10	4.02
c. Normal Pool With Silt or Ice Pressure. No Uplift Pressure.	1.38	4.34
d. Normal Pool With Silt and Ice Pressure. No Uplift Pressure.	1.04	3.44
e. Normal Pool With Silt, Ice and Triangular Uplift Pressure.	0.60	1.37
f. Normal Pool with Triangular Uplift Pressure.	0.83	1.59
g. Non-overflow Section With Ice Load and Normal Pool	1.37	3.12
h. Spillway Section With Normal Pool and Ice Load With 17' Deep Scour Hole.	1.15	—

*Effect of Bedrock Key Neglected.

APPENDIX A

REPORT OF FIELD INSPECTION

CHECKLIST

This checklist contains information obtained from visual observations on the day of the inspection. It is not intended that specific information in the checklist coincide exactly with the main report. Further study during preparation of the report may significantly alter previous judgements and conclusions as noted in the checklist.

NATIONAL DAM SAFETY
PROGRAM

GENERAL CHECKLIST

This form should be filled out by the team leader but should represent a consensus of the opinions and input of all team members.

1. a. Name of Dam Zumbro Lake Dam

   b. I.D. Number 358

2. Date of Inspection May 22, 1979

3. Name or owner City of Rochester

4. Location
   County Wabasha

   Township 109 N Range 14 E Section 27

5. Is location shown on county map; or U.S.G.S. Quadsheet?

   (✓) Yes (correctly)
   ( ) Yes (incorrectly)
   ( ) No - show correct location

6. Are items on inventory sheet correct?

   ( ) Yes (information is all correct)
   (✓) Yes (corrections attached)
   ( ) No (completed form attached)

7. Type of dam (check all appropriate)

   ( ) Earth and/or rockfill (use form a)
   (✓) Concrete and /or masonry (gravity) (use form d)
   ( ) Other
   Explain

8. Year of construction 1917-1919

9. Year(s) of major rehab 1933-35, 1951-52, 1961

10. Purpose of dam (check all appropriate)

   ( ) Flood Control
   ( ) Water Supply
   (✓) Hydro Power
   (✓) Recreation
   ( ) Navigation
   ( ) Other
   Explain

11. Pool el. on day of inspection 914.75

12. Tailwater el. on day of inspection 865.7

13. Type of spillway and/or outlet (check all appropriate)

Controlled	Uncontrolled	Type
( )	( )	Pipe or Conduit
( )	( )	Chute or notch
( )	(✓)	Overfall
( )	( )	Other
		Explain ______

14. General description of operating procedures. (Is there any formal documented hydraulic operating plan? If so, who operates?)

No formal documented operating procedure. Dam is controlled automatically from city electric plant. Dam operator from city of Rochester visits the plant about once a week.

15. Is there any program of regular systematic inspection and maintainance? If so describe.

No formal systematic inspection or maintanance. Informal and regular inspection performed by city personnel.

16. Do the following exist?

	Yes Inclosed	Yes, Not Inclosed	No	Don't Know	Where
Design data	( )	( )	(✓)	( )	
Plans and specs	(✓)	( )	( )	( )	
Shop drawings	( )	(✓)	( )	( )	
As builts	(✓)	( )	( )	( )	
O & M Manuals	( )	( )	(✓)	( )	
History of const photos	( )	( )	(✓)	( )	

Remarks Complete set of plans on file at City of Rochester electric plant.

Is there any formal flood warning system at the dam other than notification by local authorities?

( ) Yes, (✓) No, Remarks

18. Is there any evidence that the dam has ever been overtopped?

(✓) No
( ) High water marks
( ) Erosion
( ) Evidence of repair
( ) Verbal reports
( ) Other
Explain

19. Estimate the degree of lake siltation.

( ) No noticeable siltation in lake
(✓) Some minor amount of siltation
( ) Lake has major amounts of siltation
( ) Lake is completely silted in

Remarks

LIST OF POTENTIAL DOWNSTREAM HAZARD

20.

Approx. Ht. Above Stream (ft.)	Valley Distance (miles)	Type of Improvement (indicate number): Occupied dwelling	Unoccupied dwelling	Agricultural Building	Industrial Building	Other Building	Road	Railroad	Urban Area	Dam (give ID number)	Other	Loss Of Life Potential: Likely more than 4	Likely 4 or less	Possible, but not likely	Economic Loss Potential: Less than $	$ to $	More than $	Remarks
4'	0.1					1							✓					Campground, 1/8 mi. downstream
4'	0.2	[illegible]																
20'	[illegible]	[illegible]											✓	/				
	0.7-1.0	7											✓					
	1.5																	C.S.A.H 7 Bridge
	[illegible]																	Confluence with N.F. Zumbro R.
	[illegible]																	Confluence with Mississippi R.

21. The above list was ended because:

- ( ) We do not feel that points further downstream are seriously threatened by the dam
- (✓) We have already established a very high downstream hazard, but further downstream hazard exists
- (✓) We cannot tell, further study is needed
- ( ) Other
  Explain ______________________________

22. Give your overall opinion of the downstream hazard potential.

Team member	1. High	2. Significant	3. Low	Can't Decide
D. Zuelke	(✓)	( )	( )	( )
[illegible] Rahn	(✓)	( )	( )	( )
[illegible] Zeag	(✓)	( )	( )	( )

Category	Loss of Life (Extent of Development)	Economic Loss (Extent of Development)
Low	None expected (No permanent structures for human habitation)	Minimal (Undeveloped to occasional structures or agriculture)
Significant	Few (No urban developments and no more than a small number of inhabitable structures)	Appreciable (Notable agriculture, industry or structures)
High	More than few	Excessive (Extensive community, industry or agriculture)

23. Are there any floodplain regulations or other constraints in force which would limit future development or future hazard downstream?

No ✓ Yes ____ Describe ______________________________

24. Is there any development in the emergency spillway area which may suffer damage due to flow through the spillway?

(✓) N/A No emergency spillway
( ) No
( ) Yes, Describe ______________________________

25. Check which item best describes the condition of the channel upstream of the lake.

(✓) Clear of debris, trees, etc.
( ) Some minor debris in channel and a few trees periodically in channel
( ) Much debris in channel and many trees in channel
( ) Channel completely blocked by debris and trees

Remarks ______________________________

26. Are there any type of instruments on the dam?

( ) No
( ) Monumentation
( ) Relief wells
(✓) Piezometers
( ) Weirs, etc.
( ) Other
Explain Water level manometer inside the dam.

27. If planviews are not available at the time of the inspection, sketches and typical cross sections should be made on the back of these sheets to name and locate principal components of the dam.

28. Based on the visual inspection of the dam, are there any areas which deserve special consideration in regard to safety of the structure? (summarize from input on forms a thru g)

1. Investigate [illegible] ... of [illegible] ... powerhouse.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.

Participants in the dam inspection:

Name	Title	Agency
Daryl Zuelke [illegible]	Team leader/Structural	Barr Engineering Co.
Charles Rohn [illegible]	Geotechnical	Barr Engineering Co.
[illegible] Zeng	Hydrology/Hydraulics	Barr Engineering Co.

List of attached forms

( ) Inventory Form
( ) U.S.G.S or County Map
(✓) Form A Embankment Dam
( ) Form B Spillway
( ) Form C Conduit
( ) Form D Concrete Masonry or Timber Gravity Dam
( ) Form E Powerhouse
( ) Form F Concrete Condition
(✓) Form G Site Geology
( ) Other
List:

FORM A - EMBANKMENT DAM

(If plans are available item no. 1 need not be completed.)

1. On a separate sheet, draw one or more sections through the dam. Show crest, width, height, slopes, major type(s) of materials, foundation treatment, provisions for internal drainage (if any), location of outlets, slope protection, upstream and downstream water surface, high water marks, eroded or damaged areas, seepage, etc. Describe features not adequately shown on sketch.

Deleted

This section only pertains to the embankment at the right abutment of the dam. It does not include the mass concrete gravity dam non-overflow section and is backfilled with soil at the right side of the spillway.

2. Based on the exposed material in the downstream channel and any other physical evidence. Describe the foundation and embankment material.

Bedrock foundation, Rock [illegible] fill. Riprap on upstream side

3. Basis for foundation and embankment description.

- (✓) Borings
- (✓) Construction records
- ( ) Verbal testimony
- (✓) Visual observation
- ( ) Waterwell records
- ( ) Other explain

4. Are there any signs of instability?

( ) Cracks
( ) Sloughing
( ) Irregularities in crest or waterline
( ) Excessively steep slopes
( ) History of sliding
(✓) Other

Remarks The embankments have steep side slopes, but the thick core wall does not make these [illegible] a hazard to the safety of the dam. Also no cracks or sloughs noted

5. Give your opinion of the stability of the dam.

( ) Embankment has no visible stability problems and may meet criteria set forth in the guidelines
(✓) Embankment has no visible stability problems but probably does not meet the criteria set forth in the guidelines
( ) Embankment has minor stability problems but unlikely to lead to failure
( ) Embankment has stability problems which if not corrected could lead to failure
( ) Embankment has serious stability problems which could lead to failure at any time
( ) Other
Explain

6. Is there any evidence of seepage?

Yes	No	N/A	Can't Tell	
( )	(✓)	( )	( )	Downstream slope
( )	(✓)	( )	( )	Downstream of dam
( )	(✓)	( )	( )	Left abutment (looking downstream)
( )	(✓)	( )	( )	Right abutment (looking downstream)
( )	(✓)	( )	( )	Around structure
( )	( )	( )	( )	Other

Explain fully (quantity, turbidity, location, point source or general area, etc.) __________

7. Give your opinion of seriousness of seepage based on visual observations.

- (X) Unlikely that it will become a problem in the foreseeable future
- ( ) May or may not become a problem
- ( ) Is a problem but not likely to lead to failure
- ( ) Is presently a problem which if not corrected could lead to failure
- ( ) Serious problem which could lead to failure at any time

Remarks __________

8. Are there any toe drains or relief wells? No

Are they functioning? __________

Quantity of observed flow? Slight ( ) Moderate ( ) Heavy ( )

Not observalbe ( )

9. Is there any slope protection on the embankment? Yes (✓) No ( )
(describe) Rip rap on upstream slope

10. Is there any evidence of erosion of embankment material?

Yes	No	N/A	Can't Tell	
(✓)	( )	( )	( )	Upstream slope
(X)	( )	( )	( )	Downstream slope
( )	(✓)	( )	( )	Crest
( )	(✓)	( )	( )	Around structures

10. (Cont'd)

Yes	No	N/A	Can't Tell	
( )	(✓)	( )	( )	Right abutment (looking downstream)
( )	(✓)	( )	( )	Left abutment (looking downstream)
( )	(✓)	( )	( )	Others

Remarks ______________________________

11. Describe material being eroded - estimate uniform soil classification.

SM - SP

12. Give your opinion of the seriousness of the erosion based on visual observations.

(✓) Unlikely that it will become a problem in the foreseeable future
( ) May or may not become a problem
( ) Is a problem but not likely to lead to failure
( ) Is a problem which if not corrected could lead to failure
( ) Is a problem which could lead to failure at any time

13. Is there any evidence to indicate that the embankment has ever been overtopped? Yes ( ) No (✓)
(Explain) ______________________________

14. General condition of dam - maintenance, mowing, trees in embankment, animal burrows, etc.

Many trees are on the embankment, no mowing, no animal burrows noted, good grass cover on crest and downstream slope. Riprap on upstream slope is heavily grown over with trees.

15. Summary

Based on your field observations list the items which you feel may represent a potential hazard to the embankment.

(1) [illegible]

(2) ______

(3) ______

(4) ______

(5) ______

(6) ______

Signature(s) of Person(s) completing this report

[illegible]

______

______

FORM D - CONCRETE, MASONRY, OR TIMBER GRAVITY DAM

1. (If plans are available the following need not be completed.) On a separate sheet, draw one or more sections through the dam. Show crest width, height, major types of foundation, water surface upstream and downstream and any pertinent features. On a plan or elevation, show location by dimension of outlets and other features. Describe features not adequately shown on sketch. Identify foundation treatment measures taken.

____

2. Based on the exposed material in the downstream channel and any other physical evidence, describe the foundation material.

Foundation material is sandstone bedrock

3. Basis for foundation description

(✓) Borings

( ) Construction records

( ) Verbal testimony

(✓) Visual observation

( ) Waterwell records

( ) Other - Explain

3. (Cont'd)

4. Are there any signs of instability (i.e. sliding, overturning, bearing)?

- (✓) No signs of instability observed
- ( ) Cracks in the concrete, other than temperature or deterioration cracks
- ( ) Displacement at joints
- ( ) Evidence of movement
- ( ) History of sliding or tipping
- ( ) Other

Remarks: ______________________________

5. Give your opinion of the stability of the dam based on the observations from question 4.

- (✓) Structure has no visible stability problems and may meet criteria set forth in the guidelines
- ( ) Structure has no visible stability problems but probably does not meet the criteria set forth in the guidelines
- ( ) Structure has minor stability problems but unlikely to lead to failure
- ( ) Structure has stability problems which if not corrected could lead to failure
- ( ) Structure has serious stability problems which could lead to failure at anytime
- ( ) Other
  Explain ______________________________

6. For concrete structures Form F (Surface Condition of Concrete) should be completed. Are there any items listed on Form F which may be caused by overstress of structural members rather than concrete deterioration?

6. (Cont'd)

- ( ) No N/A
- (✓) No
- ( ) Cracks due to overstress in bending on tension
- ( ) Cracks due to shear or bearing
- ( ) Spalls or other deterioration due to overstress
- ( ) Large deflections

General Locations ______________________________

____

____

7. Give your opinion of the ability of the structural components to carry the applied loads using modern design criteria.

- (✓) Structure has no visible structural strength problems and may meet criteria set forth in the guidelines
- ( ) Structure has no visible structural strength problems but probably does not meet the criteria set forth in the guidelines
- ( ) Structure has minor structural strength problems but unlikely to lead to failure
- ( ) Structure has structural strength problems which if not corrected could lead to failure
- ( ) Structure has serious structural strength problems which could lead to failure at anytime
- ( ) Other
  Explain ______________________________

____

8. Are there any loads on the structure which may not have been included in the original design but could be causing overstress in some structural components?

- (✓) None observed
- ( ) Large silt deposits on upstream face
- ( ) Increased load due to heavier traffic
- ( ) Additional or larger equipment loads (cranes, generators, dead load)

Remarks: ______________________________

____

____

9. Are there any drains or weepholes which appear to be functioning improperly?

- (✓) No drains or weepholes noted
- ( ) Generally yes
- ( ) Generally no
- ( ) Can't tell

10. Is there evidence of seepage? (Seepage at embankment tie-ins should be covered in section on embankment dams.)

Yes	No	N/A	Can't Tell	
(✓)	( )	( )	( )	Downstream of dam
(✓)	( )	( )	( )	Left abutment (looking downstream)
(✓)	( )	( )	( )	Right abutment (looking downstream)
( )	( )	( )	(✓)	Through structure
( )	( )	(✓)	( )	Other (relief drains)

Explain fully (quality, turbidity, location, point source of general area, etc.) and/or locate evidence of seepage on a profile and plan sketch.

Water is clear and quantity to small to be measured.

11. Give your opinion of the seriousness of the seepage based on field observations.

- ( ) No seepage noted
- ( ) Unlikely that it will become a problem in the foreseeable future
- (✓) May or may not become a problem
- ( ) Is a problem but not likely to lead to failure
- ( ) Is presently a problem which if not corrected could lead to failure
- ( ) Serious problem which could lead to failure at anytime
- ( ) Other

Remarks:

12. If gravity dam is not designed as an overflow structure do not complete items 12 through 24.

Check the type of spillway section(s) included in the gravity section

(✓) Ungated fixed crest
( ) Fixed crest with flash boards
( ) Tainter gate
( ) Stoplog
( ) Roller gate
( ) Other
Describe ______________________________

____

____

13. Give your opinion of condition of gates

(✓) N/A. No gates
( ) Gates appear to be in good condition and unlikely to cause problems in the foreseeable future
( ) Gates have some problems not likely to impair operation
( ) Gates have some problems which could lead to failure during an emergency
( ) Gates are in such poor condition that failure could occur at anytime

Remarks: ______________________________

____

14. Give your opinion of condition of stop logs or flash boards

(✓) N/A. No stop logs or flash boards
( ) Stop logs/flash boards appear to be in good condition
( ) Stop logs/flash boards have some problem areas but are not likely to impair operation
( ) Stop logs/flash boards have serious problems which could cause operation problems

15. Describe how flash boards are controlled and what head controls them

(✓) N/A. No flash board
( ) Description ______________________________

____

16. Where are stop logs kept when not in use?

(✓) N/A. No stop logs
(   ) Location ______________________________

____

17. Did you attempt to operate the gates?

(✓) N/A. No gates
(   ) Yes, successfully
(   ) Yes, unsuccessfully
(   ) Yes, partial success
(   ) No, couldn't get permission
(   ) No, necessary equipment not available
(   ) No, obviously inoperable
(   ) No, but owner indicates that they are operable

Remarks: ______________________________________

____

18. Are spillway gates normally

(✓) N/A. No gates
(   ) Open
(   ) Closed
(   ) Other
Explain ______________________________________

____

19. In your opinion, what problems would failure of the gates to open cause?

(✓) N/A. No gates
(   ) Little or none
(   ) Would make drawing down the lake difficult
(   ) Would partially reduce the ability to safely pass a flood
(   ) Would drastically reduce the ability to safely pass a flood
(   ) Other ______________________________________

____

20. In your opinion, what problems would a failure of the gates that permitted uncontrolled release of water cause?

- (✓) N/A. No gates
- ( ) Little or none
- ( ) Would drain lake, but no safety problem
- ( ) May cause serious erosion of dam
- ( ) Could release enough water to be a flood hazard
- ( ) Other ______________________________

---

21. Is there any evidence of erosion or deterioration of the spillway portion of the dam?

Yes	No	N/A	Can't Tell	
(✓)	( )	( )	( )	Spillway floor
( )	( )	(✓)	( )	Spillway side slopes
(✓)	( )	( )	( )	Around control sill or over-flow ogee
( )	( )	(✓)	( )	Around spillway gates or control structure

22. Give your opinion of the seriousness of the erosion of the spillway portion of the dam.

- ( ) Unlikely that it will become a problem in the foreseeable future
- ( ) May or may not become a problem
- (✓) Is a problem but not likely to lead to failure
- ( ) Is a problem which if not corrected could lead to failure
- ( ) Is a serious problem which could lead to failure at anytime
- ( ) N/A

23. Is there any evidence of erosion upstream or downstream of the spillway?

- ( ) Visual evidence ____ U.S. ____ D.S.
- (✓) Sounding data ____ U.S. __✓__ D.S.
- ( ) Flow pattern ____ U.S. ____ D.S.
- ( ) Operators observation ____ U.S. ____ D.S.
- ( ) Other evidence ______________________________

---

24. Is there any evidence of undermining of the structure due to erosion?

- (✓) No
- ( ) Yes, see attached sketch or map
- ( ) Yes, describe location(s) and amount(s) of erosion ________

____

____

25. Is there an upstream or downstream riprap apron? No.

   a. Is it visible? U.S. _____ D.S. _____

   b. What is its condition?

   - ( ) Intact
   - ( ) Ends undermined or eroded
   - ( ) Rock displaced or missing

26. Give your opinion of the seriousness of the erosion.

- ( ) No erosion noted
- ( ) Unlikely that it will become a problem in the foreseeable future
- (✓) May or may not become a problem
- ( ) Is a problem but not likely to lead to failure
- ( ) Is a problem which if not corrected could lead to failure
- ( ) Is a serious problem which could lead to failure at anytime
- ( ) Other

Remarks: ________________________________

____

____

27. Based on field observations list items believed to represent significant potential hazards to the integrity of the dam.

(1) None noted

(2) ________________________________

(3) ________________________________

(4) ________________________________

27. (Cont'd)

(5) ____________________

(6) ____________________

(7) ____________________

(8) ____________________

(9) ____________________

Signature(s) of Person(s) completing this section

____

____

____

FORM E - POWERHOUSE

1. Does the Powerhouse function as part of the dam and retain water?

(✓) Yes ( ) No. Separate Powerhouse

2. Is the power generation equipment still in place and functioning?

( ) Not in place ( ) In place, not functioning
(✓) In place and functioning

3. Are there any signs of instability (i.e. sliding, overturning, bearing)?

( ) No signs of instability observed
( ) Cracks in the concrete, other than temperature or deterioration cracks
( ) Displacement at joints
( ) Evidence of movement
( ) History of sliding or tipping
(✓) Other

Remarks: Cracks in the arches of the powerhouse. Nature of cracks is unknown. Cracks have been noted for over 40 years with no additional observed movement.

4. Give your opinion of the stability of the powerhouse based on the observations from question 3.

( ) Structure has no visible stability problems and may meet criteria set forth in the guidelines
( ) Structure has no visible stability problems but probably does not meet the criteria set forth in the guidelines
( ) Structure has minor stability problems but unlikely to lead to failure
( ) Structure has serious stability problems which could lead to failure at any time
(✓) Other
Explain See question 3.

5. For concrete structures form F (surface condition of concrete) should be completed. Are there any items listed on form F which maybe caused by overstress of structural members rather than concrete deterioration?

(✓) No signs of overstress noted
( ) Cracks due to overstress in bending or tension
( ) Cracks due to shear or bearing
( ) Spalls or other deterioration due to overstress
( ) Large deflections

General Location: ____________________

____

____

6. Are there any loads on the structure which may not have been included in the original design but could be causing overstress in some structural components?

(✓) None observed
( ) Large silt deposits on upstream face
( ) Increased load due to heavier traffic
( ) Additional or larger equipment loads (cranes, generators, dead load)

Remarks: ____________________

____

7. Give your opinion of the ability of the structural components to carry the applied loads using modern design criteria.

( ) Structure has no visible structural strength problems and may meet criteria set forth in the guidelines
(✓) Structure has no visible structural strength problems but probably does not meet the criteria set forth in the guidelines
( ) Structure has minor structural strength problems but unlikely to lead to failure
( ) Structure has structural strength problems which if not corrected could lead to failure
( ) Structure has serious structural strength problems which could lead to failure at any time
( ) Other
Explain ____________________

____

8. Are there any drains or weepholes which appear to be functioning improperly?

- (✓) No drains or weepholes noted
- ( ) Generally yes
- ( ) Generally no
- ( ) Can't tell

9. Is there evidence of seepage?
(Seepage at embankment tie-ins should be covered in section on embankment dams)

Yes	No	N/A	Can't Tell	
( )	( )	( )	(✓)	Downstream of powerhouse
(✓)	( )	( )	( )	Left side (looking downstream)
( )	( )	( )	(✓)	Right side (looking downstream)
(✓)	( )	( )	( )	Through structure
( )	( )	( )	( )	Other (relief drains)

Explain fully (quality, turbidity, location, point source of general area etc.) and/or locate evidence of seepage on a profile and plan sketch.

Clear water exiting at joint with bedrock outcropping on left side at about 10-20 gpm.
Seepage noted at construction joints.

10. Give your opinion of the seriousness of the seepage based on field observations.

- ( ) No seepage noted.
- ( ) Unlikely that it will become a problem in the foreseeable future
- (✓) May or may not become a problem
- ( ) Is a problem but not likely to lead to failure
- ( ) Is presently a problem which if not corrected could lead to failure
- ( ) Serious problem which could lead to failure at any time
- ( ) Other

Remarks:

11. Type of powerhouse gates

- ( ) N/A gates removed openings permanently sealed.
- (✓) Slide gates
- ( ) Stop logs
- ( ) Tainter gate
- ( ) Other ______________________________

12. Did you attempt to operate the gates?

- ( ) N/A. No gates
- ( ) Yes, successfully
- ( ) Yes, unsuccessfully
- ( ) Yes, partial success
- ( ) No, couldn't get permission
- ( ) No necessary equipment not available
- ( ) No, ovbiously inoperable
- (✓) No, but owner indicates that they are operable.

Remarks: ______________________________

13. Are spillway gates normally

- (✓) N/A. No gates
- ( ) open
- ( ) closed
- ( ) other

  Explain ______________________________

14. Give your opinion of condition of gates.

- ( ) N/A. No gates
- (✓) Gates appear to be in good condition and unlikely to cause problems in the forseeable future
- ( ) Gates have some problems not likely to impair operation
- ( ) Gates have some problems which could lead to failure during an emergency
- ( ) Gates are in such poor condition that failure could occure at any time

Remarks: ______________________________

14. Give your opinion of condition of gates.

( ) N/A. No gates
( ) Gates appear to be in good condition and unlikely to cause problems in the forseeable future
( ) Gates have some problems not likely to impair operation
( ) Gates have some problems which could lead to failure during an emergency
( ) Gates are in such poor condition that failure could occur at any time

Remarks: ____

____

15. In your opinion, what problems would failure of the gates to open cause?

( ) N/A. No gates
(✓) Little or none
( ) Would make drawing down the lake difficult
( ) Would partially reduce the ability to safely pass a flood
( ) Would drastically reduce the ability to safely pass a flood
( ) Other ____

____

16. In your opinion, what problems would a failure of the gates that permitted uncontrolled release of water cause?

( ) N/A. No gates
(✓) Little or none
( ) Would drain lake, but no safety problems
( ) May cause serious erosion of dam
( ) Could release enough water to be a flood hazard
( ) Other ____

____

17. Is there any evidence of erosion upstream or downstream of the powerhouse?

( ) Visual evidence ___U.S. ___D.S.
(✓) Sounding data ___U.S. _✓_D.S.
( ) Flow Pattern ___U.S. ___D.S
( ) Operators Observation ___U.S. ___D.S.
( ) Other evidence ______________________________

____

18. What is the condition of riprap

(✓) No riprap
( ) Badly displaced
( ) Occasional holes and pockets
( ) Rock deteriorated

19. Are there any obstruction to flow through the powerhouse?

( ) Yes (✓) No

Describe flow pattern: ______________________________

____

____

20. In your opinion would an abnormally large powerhouse discharge have a tendency to erode the embankment?

( ) No
(✓) Yes
Describe Evidence of repair work to rock outcropping downstream of powerhouse

____

21. Based on your visual observations list any conditions which you believe may have a potential affect on the integrity of the dam.

(1) Cracking of the arches in the powerhouse

(2)

(3)

(4)

(5)

(6)

Signature(s) of person(s) completing this section

[illegible signature]

[illegible signature]

Charles Rehm

FORM F - SURFACE CONDITION OF CONCRETE
(From ACI Report 65-67)

1. Identify the feature for which this section applies. ______

Spillway and powerhouse

2. General condition of concrete

( ) Good
(✓) Satisfactory
( ) Poor

Remarks: Right half of spillway, looking downstream, is severely eroded. Spalling on left abutment of retaining dam.

3. Cracks (✓) Yes ( ) No

Describe Cracks in the arches of the powerhouse.

Direction
( ) Longitudinal
( ) Transfers
(✓) Vertical
( ) Diagonal
( ) Random

Maximum Width
( ) fine (less than 1 mm or 3/64")
( ) medium (1 mm to 2 mm or 3/64" to 5/64")
(✓) wide (more than 2 mm or more than 5/64")

Type
( ) Pattern cracking
( ) Checking
( ) Hariline cracking
(✓) D-cracking

Mineralization None
( ) Leaching
( ) Stalactites
( ) Stalagmites

4. Scaling ( ) Yes (✓) No
Describe ______

4. (Cont'd)

Severity
- ( ) Light (C.A. not exposed)
- ( ) Medium (1/2 to 1 cm or 13/64" to 25/64", C.A. exposed)
- ( ) Severe (C.A. clearly exposed and stands out)
- ( ) Very severe (loss of C.A.)

5. Popouts ( ) Yes (✓) No

Describe ______________________________

Size
- ( ) Small (less than 1 cm diameter or 25/64" diameter)
- ( ) Medium (1 to 5 cm diameter or 25/64" to 2" diameter)
- ( ) Large (more than 5 cm diameter or 2" diameter)

6. Spalls (✓) Yes ( ) No

Describe Spalling of left abuttment on downstream face of retaining dam. Minor spalling on right abuttment of spillway.

Size
- ( ) Small (less than 2 cm deep and 15 cm long or 3/4" deep and 6" long)
- (✓) Large

7. Is(are) there any?

- ( ) None
- ( ) Pitting
- ( ) Dusting
- ( ) Honeycomb
- (✓) Stains
- (✓) Exposed steel
- (✓) Previous patching or other repair
- ( ) Chemical attach

7. (Cont'd)

Describe All [illegible] [illegible] left spillway.

8. In your opinion, what is the effect of the condition of the concrete on the safety of the dam?

( ) Little or none
(✓) Aesthetic problems but nothing that would effect the integrity of the structure.
( ) May create operational problems, but no safety problem
( ) If uncorrected, could eventually become a safety problem
( ) It is a safety problem that could result in a large uncontrolled release of water
( ) Other
Explain

Signature(s) of person(s) completing this section

[illegible signature]

[illegible signature]

[illegible signature]

FORM G - GEOLOGY

The items in this report are divided into two general categories:

a. Description of the General Geology of the basin (items 1 through 14)

b. Description of site geology (items 15 through 21)

GENERAL GEOLOGY OF THE BASIN

1. Glacial (✓)
   Non-glacial ( )

2. Glacial
   (✓) Till plain
   ( ) End moraine
   ( ) Outwash plain
   ( ) Combination - Explain ____________________

   Non-Glacial
   ( ) Deeply disected
   ( ) Rather level

3. River Valley
   ( ) Deeply incised
   ( ) Shallow
   ( ) Broad
   (✓) Steep sided
   ( ) Terraced
   ( ) Meandering
   ( ) Other - Explain ____________

4. Topography
   ( ) Level or even
   ( ) Rolling
   (✓) Hilly
   ( ) Knob & kettle
   ( ) Other - Explain ____________________

5. Empoundment
   ( ) Lake
   ( ) River
   (✓) Combination - Explain ____________________

6. Soils

Origin

( ) Outwash
(✓) Loess
(✓) Boulder Clay
(✓) Alluvial
( ) Marsh
( ) Glaciofluvial

Explain ____________________

Types

(✓) Sand-gravels
(✓) Clays
(✓) Silts
(✓) Organic
( ) Other
Explain ____________________

7. Effect of Topography on Drainage
(✓) Rapid
( ) Even
( ) Slow

8. Effect of Soil Type on Drainage
(✓) Rapid
( ) Even
( ) Slow

9. Bedrock Geology of Basin

Formation Name Prairie Du Chien Group

Rock Type Sandstone / Dolomite

General Depth to Rock 0-2'

Outcrops in Valley Walls Yes

10. Source of Bedrock Information
(✓) Visual
( ) Well records
(✓) Borings
(✓) Published data

11. General Water Table

Source of water to stream flow
(✓) Surface runoff
(   ) Lakes, marshes
(   ) Springs
(✓) Ground water

12. (   ) Slumping or slides in reservoir
(   ) Slumping or slides in downstream channel

13. (   ) Sink holes or surface depression

14. (✓) Groundwater discharge area
(   ) Groundwater recharge area

SITE GEOLOGY

15. Geologic Setting

(   ) Glacial
- (   ) Outwash plain
- (   ) Till plain
- (   ) End moraine

(✓) Non-glacial
- (✓) Deeply disected plain
- (   ) Alluvial plain

(   ) Terraces
- (   ) Soil
- (   ) Rock

16. Bedrock

Formation Names: Prarie Du Chien Group

(✓) Exposed
(   ) Deeply buried
(✓) Sandstone
(✓) ~~Limestone~~ Dolomite
(   ) Shale
(   ) Igneous
- (   ) Balsalt
- (   ) Granite
- (   ) Other - Explain ______

17. Abutments and Foundation

( ) Soil
Types ________________

(✓) Rock
Types [illegible]

18. Seepage [illegible]

( ) Pervious soils
( ) Bedding planes or joints in rock
( ) Fracture zones in rock

19. Rock Structure

a. Bedding
(✓) Horizontal
( ) Dipping
( ) Massive bedded
( ) Medium bedded
( ) Thin bedded

b. Bedding Planes
(✓) Open
( ) Closed

c. Joints
( ) Close spaced
(✓) Widely spaced
( ) Direction and inclination to structure

____

( ) N/A – Explain ________________

____

~~d. Bedding Planes~~
~~( ) Open~~
~~( ) Closed~~

e. Hardness of Rock
(✓) Soft
(✓) Medium
( ) Hard

f. Cementation
(✓) Well cemented
( ) Poorly cemented
( ) Non-cemented

20. On a separate sheet of paper draw an approximate geologic profile along the centerline of structure showing assumed or known soil and rock profile in the abutment and foundation areas. Identify major soil types or rock formations.

21. Based on visual observations made at the site list the geologic conditions which are believed to represent major potential threats to the safety of the dam.

(1) None Noted

(2) ______

(3) ______

(4) ______

(5) ______

(6) ______

Signature(s) of Person(s) completing this section

[signature]

[signature]

[signature]

STATE SEQ RIV PRIMARY SECONDARY
ID. NO. DIV ST CO CO ST CO CO --------------NAME OF DAM-------------- LAT LONG REPORT DATE

MN 00438 NCO MN 157 01 J. SIBLEY 4413.5 9231.5 01JUN73

------------POPULAR NAME-------------- ----------NAME OF IMPOUNDMENT--------

REG BA --------RIVER OR STREAM-------- -------NEAREST DS CITY-------- DIST POPULATION

07 05 TR-ZUMBRO ZUMBRO FALLS 7 164

TYPE OF DAM YR-COM -PURPOSES- S-HGT H-HGT MAX-STR NOR-STR

RE 1958 C 29 27 20 3

---------REMARKS----------REMARKS----------REMARKS----------REMARKS--------

STR-20 109 14 FS-S.C.S.

H CREST T WDTH DISCH VOLUME --POWER I/P-- --------NAVIGATION LOCKS----------

2 260 N 18 90 5850

-----------OWNER---------- ------ENGINEERING BY------ ------CONSTRUCTION BY----

RICHARD SIBLEY USDA SCS USDA SCS

-------DESIGN------- ----CONSTRUCTION---- ------OPERATION----- ----MAINTENANCE-----

USDA SCS USDA SCS DNR-DIV OF WATERS DNR-DIV OF WATERS

-----------INSPECTION BY----------- INSP DATE -----AUTHORITY FOR INSPECTION-----

NONE

---------REMARKS----------REMARKS----------REMARKS----------REMARKS--------

STATE SEQ RIV PRIMARY SECONDARY
ID. NO. DIV ST CO CO ST CO CO --------------NAME OF DAM-------------- LAT LONG REPORT DATE

MN 00358 NCO MN 157 01 ZUMBRO LAKE 4412.8 9228.7 16JAN74

------------POPULAR NAME-------------- ----------NAME OF IMPOUNDMENT--------

ZUMBRO LAKE

REG BA --------RIVER OR STREAM-------- -------NEAREST DS CITY-------- DIST POPULATION

07 05 ZUMBRO RIVER ZUMBRO FALLS 10 198

TYPE OF DAM YR-COM -PURPOSES- S-HGT H-HGT MAX-STR NOR-STR

PG 1919 H ~~45~~ ~~55~~ ~~35000~~ ~~20000~~ QUAD IU-20
78 80 21000 12300

---------REMARKS----------REMARKS----------REMARKS----------REMARKS--------

26-27-ESTIMATED FS-BULLETIN 20,MARZA STR-27 109 14

H CREST T WDTH DISCH VOLUME --POWER I/P-- --------NAVIGATION LOCKS----------

~~2~~ 440 ~~N~~ ~~440~~ ~~30000~~ 35000 ~~[illegible]~~ ~~[illegible]~~
1 U 440 50000 2.3 2.3

-----------OWNER---------- ------ENGINEERING BY------ ------CONSTRUCTION BY----

CITY OF ROCHESTER HUGH L. COOPER AND CO. CITY OF ROCHESTER

-------DESIGN------- ----CONSTRUCTION---- ------OPERATION----- ----MAINTENANCE-----

NONE NONE DNR-DIV OF WATERS DNR-DIV OF WATERS

-----------INSPECTION BY----------- INSP DATE -----AUTHORITY FOR INSPECTION-----

DNR-DIV OF WATERS 6AUG74 MN STATUTES CHAP. 105
Barr Engr. Co. 22 May 79 PL92-367

---------REMARKS----------REMARKS----------REMARKS----------REMARKS--------

32, 33, 34 ESTIMATED

APPENDIX B

HYDRAULIC AND HYDROLOGIC CHECKLIST

Sheet 1 of ______
Date ______
ID ______

NATIONAL DAM SAFETY PROGRAM

HYDROLOGY AND HYDRAULICS STUDY CHECK LIST

Name of Dam Zumbro Lake State Mn. County Wabasha

River Zumbro River Nearest Downstream Town Zumbro Falls

1. General Data

Drainage area 661 sq. mi.

Total length of longest watercourse (L) [illegible] miles*

Fall of basin from the farthest point to the dam 455 feet*

Average slope of the basin 0.00177 feet/feet*

Time of concentration (t_c) 21.9 hours*

Type of cover (develop by approximate estimate, not precise computation).

Urban	5	%
Forest	3	%
Grassland	20	%
Crop	72	%
Lake and swamps	0	%
Other	0	%
Explain		
Total	100	%

Frequency curve: Yes ✓ No ______ Incl. # ______

Maximum probable index rainfall 17.3 inches in 6 hours

* See page 14-7 of Chows, "Handbook of Hydrology" for definition.

NCS Form 150 Issued 30 January 1978

Current spillway design flood: Yes ✓ No ___ Peak Q 241,000 cfs

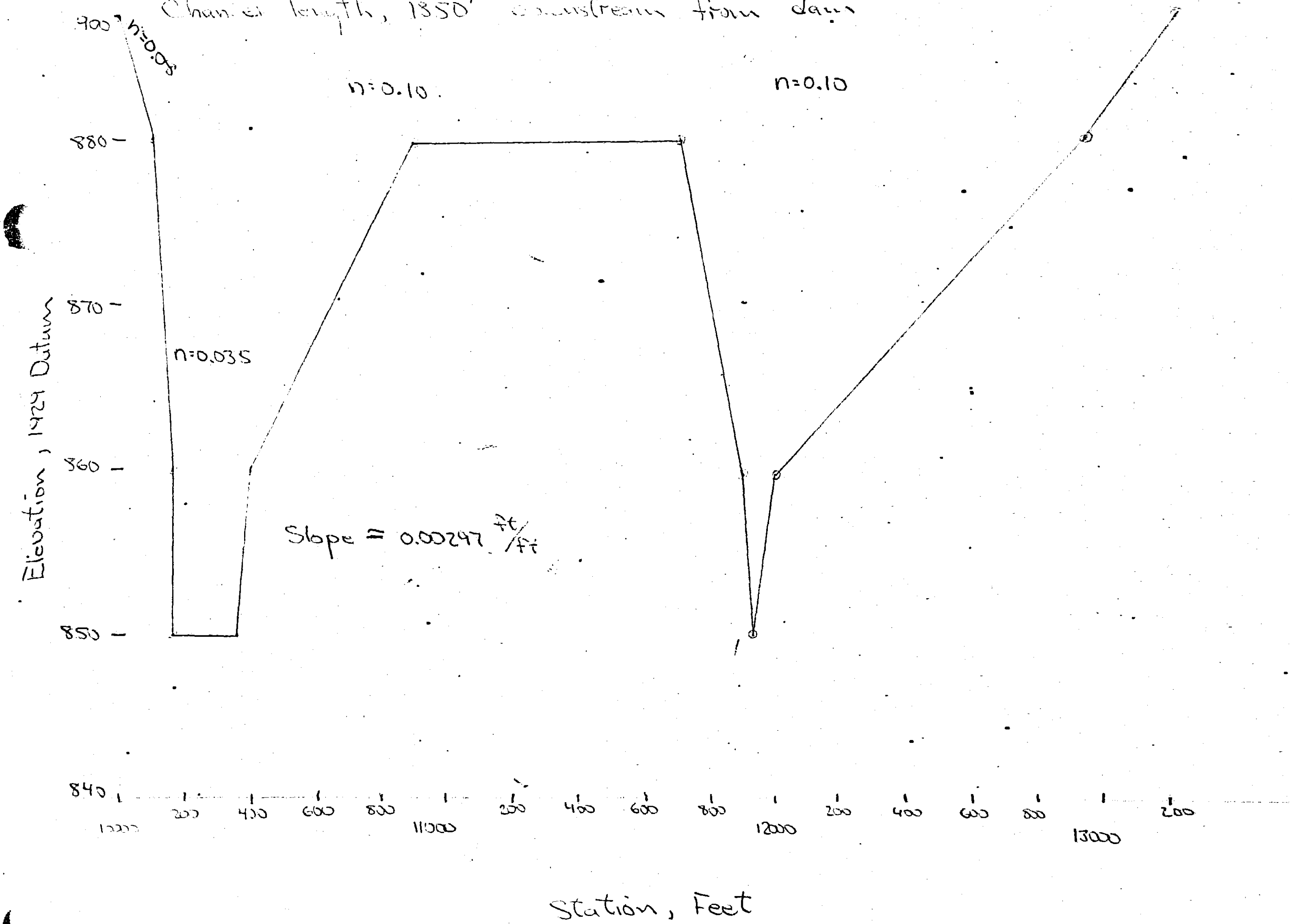
Current spillway design flood hydrograph: Yes ✓ No ___ Incl# ___

Other pertinent data:
Maximum Probable Flood generated and routed

Downstream Channel X - Sections: Yes ✓ No ___ Incl# ___

Rough sketches of cross-section downstream of dam showing distance below the dam, channel and overbank dimensions, n values, and slope.

Left is Right looking upstream.
Channel length, 1850' downstream from dam



2. Channel capacity in critical downstream reach [illegible] cfs.

3. Flood Plain Development:

First 1000 feet downstream Privately owned campgrounds

Between 1000 feet and 1 mile Agriculture and light residential development

Between 1 mile and 5 miles Agriculture and light residential development

Other critical reach

4. Description of outlet works, including stilling basin. Give plan, profile, cross-section sketches with important elevations, dimensions, and water surfaces. Plans available: Yes ✓ No ____ Incl# ____

	cfs	% frequency
Capacity: with [illegible] ft. of freeboard	—	—
without freeboard	—	—
normal operating capacity at 925 elevation	600	99

5. Description of service spillway, including stilling basin. Give plan, profile, cross-section sketches with important elevations, dimensions, and water surfaces. Plans available: Yes ✓ No ____ Incl# ____

	cfs	% frequency
Capacity: with ____ ft. of freeboard	—	—
without freeboard	—	—
normal operating capacity at 925 elevation	50000	0.3

6. Description of emergency spillway, including stilling basin. Give plan, profile, cross-section sketches with important elevations, dimensions, and water surfaces. Plans available: Yes ____ No ____ Incl# ____

	cfs	% frequency
Capacity: with ____ ft. of freeboard		
without freeboard	N/A	
normal operating capacity at ____ elevation		

Sheet 4 of ______
Date ______
ID ______

7. Storage capacity curves of reservoir: Yes ✓ No ______ Incl# ______

Elevation	Area (acres)	Capacity (ac - ft)
860	0	0
880	65	550
900	330	4300
915	696	[illegible]
930	1145	27000
940	1610	41560

1929 Datum

8. As built design flood:

Outlet works ~ 600 cfs. Service spillway 50000 cfs.

Emergency spillway — cfs. Project — cfs.

Design freeboard — feet. Expected wave — feet.

9. Headwater rating curve: Yes ✓ No ______ Incl# ______

10. Tailwater rating curve: Yes ✓ No ______ Incl # ______

11. Downstream channel material Rubble; erodible: Yes ✓ No ______

12. Erosion Protection:

Upstream embankment face - Natural Vegetation

Downstream embankment face - Natural Vegetation

At stilling basin - Bedrock and Rubble

Downstream - Rubble in channel, and natural vegetation on overbanks

Sheet 5 of ______
Date ______
ID ______

13. Critical depths at stilling basin:

Normal discharge:

Q = ______ cfs, d_1 = ______, d_2 = ______ ft ______ elev., tailwater elev.______.

As built project design spillway capacity:

Q = 50000 cfs, d_1 = ______, d_2 = ______ ft ______ elev., tailwater elev.______.

Other critical condition:

Q = ______ cfs, d_1 = ______, d_2 = ______ ft ______ elev., tailwater elev.______.

Current spillway design flood:

Q = ______ cfs, d_1 = ______, d_2 = ______ ft ______ elev., tailwater elev.______.

14. Critical heads across structure: Top of dam elev. ______

Elev. bottom channel downstream 860.0

At normal operating pool: Elev. 915	Q	Tailwater Elev.	Head
No flow	0	800	55'
Normal =	600	860	55'
Design =			
Spillway =			
Other Critical =			

At full pool: Elev. 925	Q	Tailwater Elev.	Head
No flow			
Normal =			
Design =			
Spillway =	50000	865	60'
Other Critical =			

At as built spillway capacity pool:
Elev. [illegible]

	Q	Tailwater Elev.	Head
No flow			
Normal =			
Design =			
Spillway =	50000	[illegible]	60
Other Critical =			

At current spillway design flood:
Elev. 935.5

	Q	Tailwater Elev.	Head
No flow			
Normal =			
Design =			
Spillway =	241,000	883.5	52
Other Critical =			

15. Sensitivity analysis of estimated spillway design flood (SDF):

120% SDF Pool Elev. 936.4 Tailwater Elev. 885.1 H 51.3

80% SDF Pool Elev. 934.0 Tailwater Elev. 880.5 H 53.5

16. Will routing the current spillway design flood through the pool significantly (by more than 10%) attenuate the peak? Yes ____ No ✓

a. Results of routing spillway design flood through pool.

(1) Performed ✓ See Incl# ____

(2) Not performed ____ Reason: ____

b. Dam overtopping and/or breeching analysis.

(1) Yes ✓ See Incl# ______

(2) No ______ Reason: ______

______

c. Summary of impacts of spillway design flood evaluation.

See Incl# ______.

17. Does stilling basin adequately dissipate energy over expected range of discharge? The apron below the dam is short and may not be effective at lower discharges. The tailwater at the dam may submerge any hydraulic jump at the larger discharges

18. At existing spillway capacity is erosion downstream expected?

Possible, downstream of apron

19. Will erosion jeopardize safety of structure?

Possibly if large discharge occurs over long period of time.

20. Does stilling basin adequately dissipate energy for spillway design flood? The apron below the dam may be to short to induce a hydraulic jump above the apron. A hydraulic jump will probably occur downstream of the apron in the channel.

21. For spillway design flood is erosion downstream expected?

Probable, In the channel and overbanks of the channel

22. Will erosion jeopardize safety of structure?

Probably not.

23. Has downstream development constrained use of any outlet works or spillway?

No

24. Has downstream development constrained design operating plan?

No

25. Summary of Findings:

a. Adequacy of spillway and top of dam -
Dam will be overtopped by the [illegible] year Flood, [illegible] cfs.

b. Consequences of overtopping by current spillway design flood related to breeching dam, downstream flood wave and hazard -
See section 3.4

c. Adequacy of outlet works and control gates -
Outlet works includes only hydro-power gates

d. Adequacy of stilling basins -
Adequate for only small discharges

e. Adequacy of downstream erosion protection -
Natural rubble and bedrock are adequate for smaller discharges

f. Adequacy of erosion protection at dikes, embankment, or dam -
Erosion protection is inadequate

g. Upstream urbanization potential and consequences -
Zumbro Lake shore line is highly developed for recreational purposes and increased pressure is likely.

h. Downstream urbanization potential and consequences -
Potetential for development is high and overbank flooding will occur at large discharges

i. Consequences of dam failure at full pool and zero discharge related to downstream floodwave and hazard -
See Section 3.4

NOTE: Mark U for unknown N/A for not applicable