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MINNESOTA RIVER

MINNESOTA RIVER DAM, GRANITE FALLS
YELLOW MEDICINE COUNTY, MINNESOTA
INVENTORY NO. 510

NATIONAL DAM SAFETY PROGRAM

INSPECTION REPORT

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STATE OF MINNESOTA

PREPARED BY

ST. PAUL DISTRICT, CORPS OF ENGINEERS

ST. PAUL, MINNESOTA

FOR

STATE OF MINNESOTA

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OCTOBER 1978

NATIONAL DAM SAFETY PROGRAM REPORT

GRANITE FALLS DAM, MN 510

MINNESOTA RIVER

YELLOW MEDICINE COUNTY, MINNESOTA

OCTOBER 1978

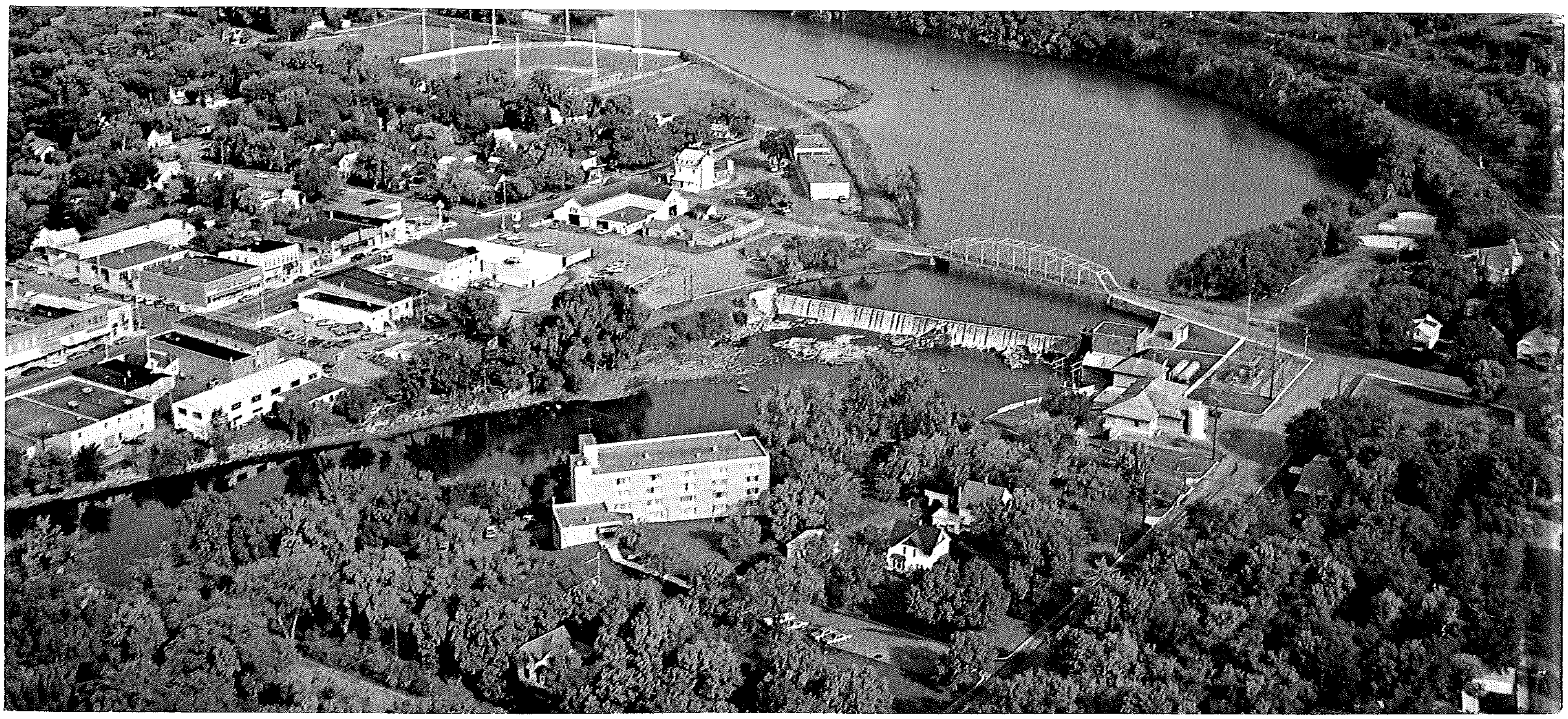
APPROVED: Forrest T. Gay III Date 30 Nov 78
DISTRICT ENGINEER

Roger G. Fast Date 15 Nov 78
CHIEF, ENGINEERING DIVISION

TECHNICAL REVIEW: Ralph B. Fletcher Date 11/6/78
CHIEF, DESIGN BRANCH

Peter A. Fricker Date 6 Nov 78
CHIEF, HYDRAULICS ENGINEERING
AND FOUNDATION MATERIALS BRANCH

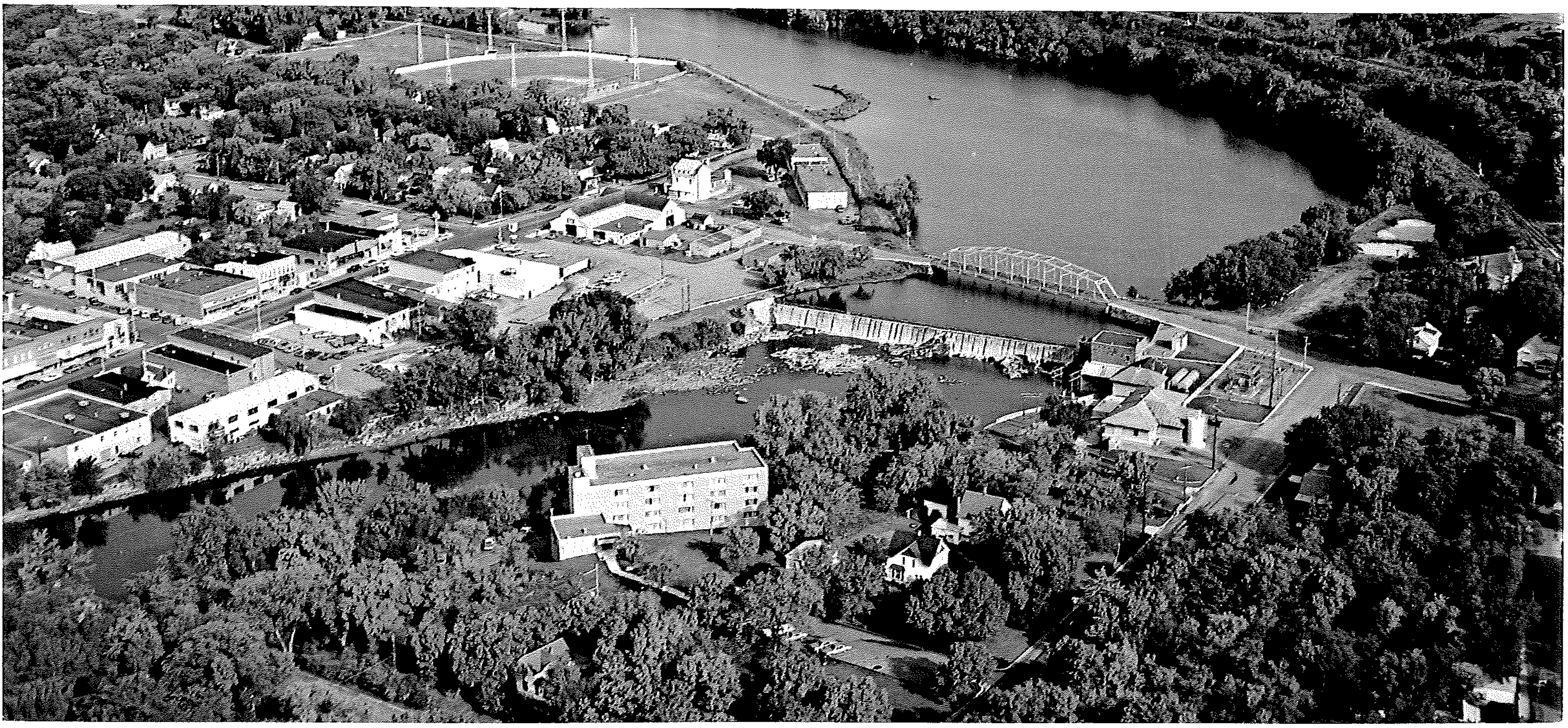
SUBMITTED BY: Roger E. Fleming Date 6 Nov 1978
PROJECT MANAGER, DAM SAFETY PROGRAM



OVERVIEW PHOTOGRAPH

GRANITE FALLS DAM

Aerial view looking northwest. Powerhouse and water supply intake are located at east end of dam. Commercial and residential areas of the city are located just downstream of the dam.



OVERVIEW PHOTOGRAPH

GRANITE FALLS DAM

Aerial view looking northwest. Powerhouse and water supply intake are located at east end of dam. Commercial and residential areas of the city are located just downstream of the dam.

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GENERAL SUMMARY

The procedures and methodology used for dam design have undergone major evolution within the last half century. Because the majority of dams within the State were constructed during or prior to this evolution, often there is little design information which conforms to current practice. The emphasis of the National Dams Inspection Program is not to develop the data and analyses necessary for 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 content of this report should, therefore, not be treated as an in-depth engineering evaluation.

The Granite Falls Dam was constructed by the City in 1911 for the purpose of producing water power at the site of a former dam built in 1871. The dam consists of a concrete gravity spillway section equipped with flashboards, supplemented by a short gated sluiceway and a powerhouse adjacent the east bank of the river.

The extent of flood prone areas downstream from the city dam is limited by the presence of the Northern States Power Company Dam located 3¼ miles downstream. Within the reach of river between the two dams there are 10 permanent dwellings, a county museum, and 11 commercial businesses within the flood plain. Sudden failure of the city dam would result in extensive property damage and could lead to loss of lives. The dam was classified as a high hazard dam. This report confirms that classification.

CONCLUSIONS AND RECOMMENDATIONS

The evaluation of the dam included an on-site inspection, a review of four general photos of the original construction, interviews with operating personnel, and a study of the geographical, geological and hydrologic characteristics of the river valley. The cooperation and assistance of Mr. John Knutson and Mr. Ed Steinbach in furnishing information and in the inspection is gratefully acknowledged. The following are the major conclusions of this evaluation.

Discharge Capacity

The dam is located in a portion of the river valley where substantial flood flows by-pass the main channel through an overflow channel west of the city. Prior to 1969 the total river flow that could be discharged without significant flood damage was approximately 13,000 cubic feet per second (cfs). This non-damaging flow capacity has been increased by construction of a levee along the right bank from the Oak Street bridge 200 feet upstream from the dam upstream 13,000 feet. The levee was constructed to a height to contain the record flood, thus the combined capacity of the dam and levee system has been increased to the record flow of 43,400 cfs. While the flood protection for the city is dependent on the integrity of the levee, the scope of this report is limited to an assessment of the dam per se. Hydrologic studies indicate that the record flood has about a 1 percent chance of recurring in any given year and that much larger floods are possible in the future. In the event of a flood substantially in excess of the capacity of the dam and by-pass channel, the city would probably attempt to raise the levee system to minimize flood damage. However, should the flood fight fail, it is believed that failure of the dam would also occur by overtopping and scouring of overburden material at the right abutment where a sandbag closure was utilized during the 1969 flood. The erosion of the right bank would allow water to by-pass around the west end of the dam. It is likely that this type of failure would occur over a period of a few hours rather than suddenly. Consequently, it would probably not result in loss of life and would not seriously aggravate the significant flood damage that would otherwise occur from failure of the levee system during a major flood. However, in view of the limited capacity of the dam and natural by-pass channel it is recommended that the feasibility of increasing the capacity of the system be investigated. The possibilities to be investigated would be increasing the capacity of the natural by-pass channel, increasing the height of the levee system, or increasing the capacity of the dam.

Operating Plan

The city has no documented plan for operation of the dam. However, the daily operation of the dam is dictated by the following physical requirements.

1. During low flows the pool is maintained at or near the top of the flashboards to maximize the head on the hydroelectric power units.

2. During high flows the gate section is opened to limit the overflow depth over the flashboards to less than 18", thus minimizing damage and loss of the boards.

3. During periods of flashboard replacement and repairs to the crest of the dam the gate section is opened as required to permit working on the dam. Care must be exercised to maintain the lowered pool at a minimum elevation of about a foot below the spillway crest to permit continued operation of a municipal water supply intake upstream.

The greatest present threat to the continued operation of the dam as outlined above is the poor structural condition of the gate section and the obsolesence and deterioration of mechanical gate hoisting equipment. It is recommended that the gate section be reconstructed and the mechanical gate hoisting equipment be replaced. It is also recommended that a documented operating plan be prepared and made available at the operating site.

Inspection and Maintenance Program

The dam is inspected and maintained periodically by employees of the Granite Falls Light Department. It is understood that a portion of the revenues from power production are allocated for the above purpose. While there is ample evidence that considerable effort has been spent on maintenance in the past, the deteriorated condition of portions of the structure indicates the need for additional resources for maintenance. It is recommended that a systematic program of inspection and maintenance be initiated.

Structural Stability

In the absence of design or "as built" information, it is not possible to evaluate the stability of the structure against sliding or overturning. There appears to be anchorage rods exposed at the downstream base of the dam but the details are unknown and, in fact, it is not known whether they extend into the foundation. A stability computation made as a part of this investigation assuming no anchorage and with no hydrostatic uplift pressure beneath the dam indicates that sliding is a more probable problem at the design flood than overturning. However, there is presently no visual evidence of structural or foundation inadequacy and the overall appearance of the structure is good. Therefore, no recommendation regarding additional investigations is made.

Concrete Condition

The quality of the concrete in the dam is quite variable. The right (west) half is very bad in surface appearance. The surface scaling has exposed much reinforcing steel, both at the crest and along the downstream face of the spillway. There are large voids and exposed coarse aggregate at the horizontal joints between lifts, however, this would appear to be largely a surface condition, since there is no indication of seepage through these joints. The concrete quality of greatest concern is in the relatively thin walls of the gate structure. In an attempt to improve appearance, the concrete has been covered with a layer of shotcrete. In some sections this layer has a hollow sound when tapped, indicating poor bond and possibly voids. There is also a question on the quality of the concrete beneath the shotcrete. Because of the vital role this structure plays in the operation of the dam, it is recommended that the structural integrity of the gate structure be checked in more detail, possibly by coring or drilling into the mass to evaluate the characteristics of the concrete. With regard to the safety hazard involved in the sudden failure of the 28 foot long gate section, a flood wave of perhaps 7 feet in height could be produced if failure occurred with the gates closed. Because of the limited width of the gate section the initial wave height would rapidly diminish as it proceeded downstream. Failure of the entire section with the gates open would produce a smaller wave.

Seepage

There does not appear to be any problem of uncontrolled seepage. The few indications of seepage are small in quantity and not at the abutments where piping or erosion could occur.

Erosion and Scour Protection

The entire structure is constructed of concrete founded on exposed bedrock, consequently concern for erosion and scour protection is limited to the abutments where the ends of the structure terminate in overburden material. The left abutment is protected by approach walls and downstream training walls of the powerhouse. The right abutment is protected by grouted riprap placed the full height of the earth slope. During major floods, such as that of the record flood in 1969, it is necessary to construct a sandbag closure between the right abutment and the approach fill of the Oak Street bridge approximately 200 feet upstream to prevent flanking of the dam by flood flows.

Preservation of the Natural By-Pass Channel

In view of the limited capacity of the dam to discharge the large flows of major floods, it is recommended that the flood carrying capacity of the natural by-pass channel west of town be maintained and increased, if possible.

Gates and Gate Hoists

The vertical lift gates at the gate section and powerhouse are operated manually through a gearing arrangement. The mechanical equipment is in very bad condition and operation of the gates requires a large expenditure of manpower and equipment. In view of the vital role played by the gate section in the overall operation of the dam and the deficiency in total discharge capacity of project it is recommended that the gates and gate mechanism be replaced.

Hazard Classification and Threat Assessment

This report verifies that the dam is properly classified as "high hazard" because of the presence of several permanent dwellings within the flood plain immediately downstream from the dam. Also the municipal water supply is dependent on maintenance of the impoundment above the dam. Implementation of the measures recommended in this report would significantly diminish the "threat" to life and property.

SIGNATURES OF INSPECTION TEAM

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SECTION 1

PROJECT INFORMATION

1.1 GENERAL

a. Authority.

(1) The FY 1978 Public Works Appropriation Act, Public Law 95-96.

(2) Purpose of Inspection. The purpose of the inspection is to identify the existence of conditions which could threaten the integrity of the structure or which differ from current design standards.

1.2 DESCRIPTION OF PROJECT

a. The dam consists of a concrete gravity section with flashboards extending from the right (west) bank across the river to a point near the left bank where a short gate section and a two unit hydroelectric power station is located. The concrete gravity section has a nominal height of 21 feet and a length of 300 feet. The gate section is 28 feet long and is equipped with four vertical lift gates 5'-4" wide. The powerhouse gate section is 30 feet long and is equipped with four vertical lift head gates each 6'-2" wide.

b. Location. The dam is located on the Minnesota River in the city of Granite Falls, Minnesota which is approximately 130 miles west of Minneapolis-St. Paul. The Dam is located in Section 34, T. 116 N., R. 39 W.

c. Size Classification. The dam is less than 25 feet high and has less than 1,000 acre feet of storage. Accordingly it is classified in the small category.

d. Hazard Classification. High.

e. Ownership. City of Granite Falls.

f. Purpose. Hydro-electric power and municipal water supply.

g. Design and Construction History. There is no design data or construction drawings for the project. Historical records indicate that it was constructed in 1911 by the city of Granite Falls.

h. Normal Operating Procedure. The dam is operated by city personnel to facilitate withdrawal of surface water for municipal supply and to maximize hydro-electric power production. These objectives are accomplished by manipulating four vertical lift gates in the gate section to minimize head on the flashboards during floods and to maintain a pool elevation of 904.1, the top of the flashboards.

1.3 PERTINENT DATA

a. Drainage Area. Total area - 6,370 square miles.

b. Discharge at Damsite

Maximum Known flood at damsite - 43,400 cubic feet per second (1969)

Warm water outlet at pool elevation - N/A (Not applicable)

Diversion tunnel low pool outlet at pool elevation - N/A

Diversion tunnel outlet at pool elevation - N/A

Capacity of power house at normal pool - 500 cfs

Gated spillway capacity at normal pool elevation - 5,000 cfs

Gated spillway capacity at maximum pool elevation - 5,000 cfs

Ungated spillway capacity (flashboard section) at maximum pool elevation - 31,800

Total spillway capacity at maximum pool - 36,800*

c. Elevations (feet above msl) Elevations are given in USGS sea level elevations.

Top of dam (crest of concrete overflow section)	901.3
Top of flashboards	904.1
Normal pool	904.1
Maximum pool at design discharge (SPF)	916.0
Flood Control Pool	N/A
Recreation Pool	N/A
Top of right bank levee (upstream)	912 (at Oak Street bridge)
Streambed at centerline of dam	880
Maximum tailwater (SPF)	906.8

* Additional flow by-passes the dam, total river flow was 43,400 during record flood.

d. Spillway

Type - Concrete crest with flashboards

Length of weir - 300 feet

Crest elevation without flashboards - 901.3 ft. above msl

Height of flashboards - 34"

e. Regulating outlets

Four vertical lift gates 5'-4" wide x 18'-0" high

Invert of outlets: Aprox. elevation 887

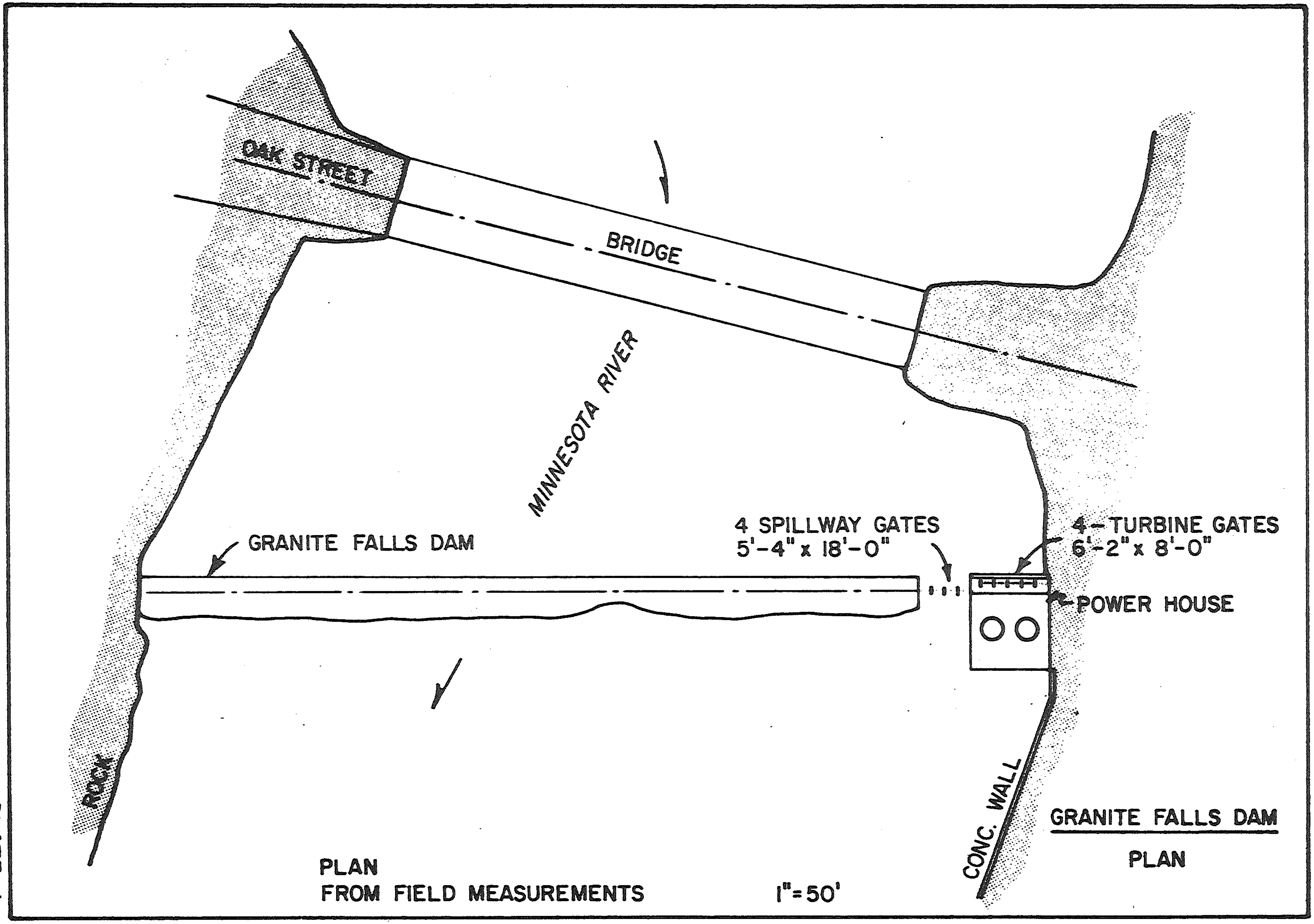
f. Powerhouse

Type of structure: Integral with dam

Headgates - Four vertical lift gates 6'-2" x 8'-0"

Number of turbines - Two

Discharge capacity - 500 cfs

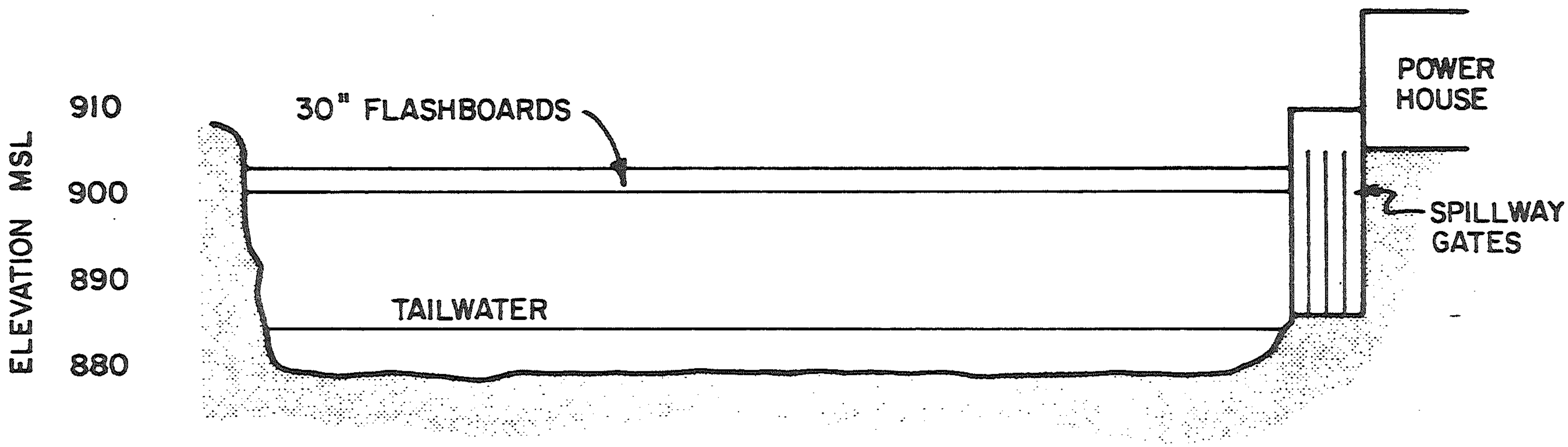


PLAN
FROM FIELD MEASUREMENTS 1"=50'

GRANITE FALLS DAM

PLAN

PLATE I

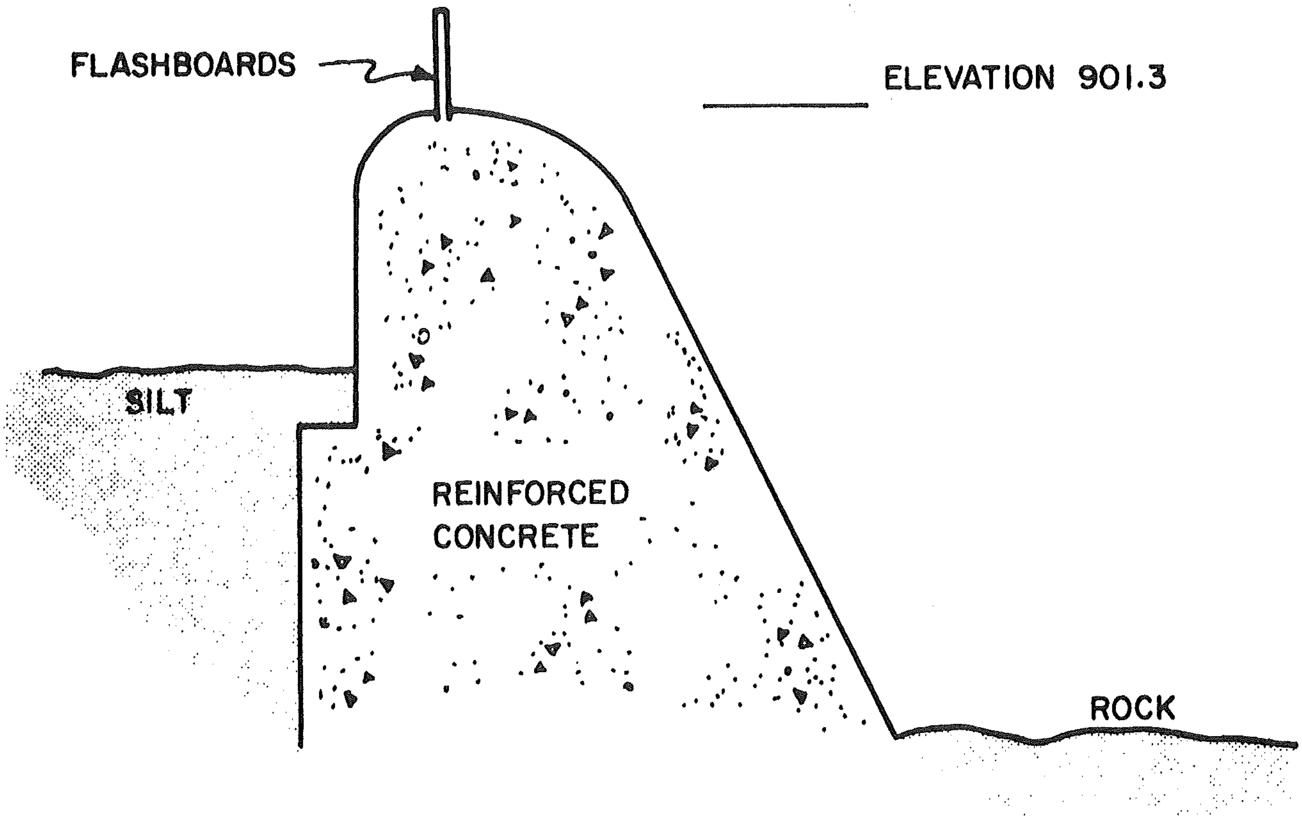


LOOKING UPSTREAM
HORIZONTAL SCALE 1" = 50'

ELEVATION
FROM FIELD MEASUREMENTS

GRANITE FALLS DAM

ELEVATION



SCALE 1"=5'

APPROXIMATE DAM SECTION
FROM FIELD MEASUREMENTS
JULY 25, 1978

GRANITE FALLS DAM
SECTION

SECTION 2

BACKGROUND ENGINEERING DATA

2.1 HISTORY

Historical data available at Granite Falls indicates that there have been two dams constructed at the present dam site. The original dam was built by Henry Hill in 1871 as a mill dam. This structure was apparently abandoned or destroyed around 1905. In 1911, the records indicate that the city of Granite Falls took over the power rights and facilities of the "Banner Mill" and constructed the present dam. There are no drawings available of the construction. However a series of four pictures of various stages of construction are on display in the powerhouse. A copy of one of these pictures is bound in Appendix C. While there is evidence that the structure has undergone minor repairs there is no indication of any significant failures during major flood events. The dam is presently used to generate hydro-electric power and to impound municipal water supply. The dates when these functions were initiated have not been researched as a part of this report.

2.2 AVAILABLE DATA

The following is a list of available data used in this evaluation:

a. Four historical photos of the original dam construction.

b. Photos of the present dam taken during the July 25, 1978 field inspection with the water drawn down below the crest of the dam.

c. Aerial photos of the dam obtained from the Minnesota Department of Transportation and the U.S. Department of Agriculture.

d. A USGS quadrangle sheet "Granite Falls" dated 1965 to a scale of 1:24,000 and a contour interval of 10 feet.

e. A floodplain information report for the city of Granite Falls dated June 1970 showing flood hazard areas in the city and containing river profiles of the 1969 flood of record and the profile of the standard project flood.

SECTION 3

HYDRAULIC AND HYDROLOGIC EVALUATION

3.1 AVAILABLE DESIGN DATA AND RECORDS

a. Design data and drawings for the existing dam could not be obtained. Extensive research including interviews with present city officials and former employees familiar with the operation of the structure revealed that original design data are not available. A few construction photographs and newspaper articles provided the only information relative to the original construction.

b. Headwater and tailwater discharge rating curves were developed using data from several sources. A Corps of Engineers rating curve is available for a location about 1/2 mile upstream from the dam. Water surface profiles for major floods above and below the dam are shown in a Flood Plain Information Report prepared by the Corps of Engineers in 1970. Data from these sources were combined to develop the rating curves shown on Figure 3-1.

c. The U.S. Geological Survey has maintained a stream gaging station since 1909 at Montevideo, Minnesota approximately 18 miles upstream from Granite Falls. By adjusting for the increased drainage area between Montevideo (6,180 sq.mi.) and Granite Falls (6,370 sq.mi.) these records were used to determine the flood discharges that have occurred at Granite Falls since 1909. A discharge frequency curve is shown on Figure 3-2. The highest 10 known floods are tabulated in the following table.

TABLE 3-1

HIGHEST 10 KNOWN FLOODS IN ORDER OF MAGNITUDE

MINNESOTA RIVER AT GRANITE FALLS, MINNESOTA

Order	Date of Crest Montevideo	Gage Height Stage feet	Gage Height Elevation feet	Peak Discharge Montevideo	Peak Discharge (1) Granite Falls
1	April 12, 1969	12.6	892.6	35,100	43,400 (2)
2	April 10, 1952	10.7	890.7	24,500	25,300
3	June 25, 1919	10.3	890.3	22,000	22,750
4	April 14, 1965	8.7	888.7	12,900	13,320
5	April 11, 1951	8.5	888.5	12,200	12,620
6	April 4, 1917	7.9	887.9	10,200	10,530
7	June 30, 1953	7.7	887.7	9,770	10,090
8	April 4-5, 1943	7.5	887.5	9,200	9,500
9	July 13, 1920	7.4	887.4	8,930	9,225
10	April 16-17, 1947	7.3	887.3	8,500	9,070

(1) Estimated from stage-discharge rating curve at Montevideo and computed stage-discharge relationships at Northern States Power Company plant, Granite Falls, Minnesota, unless otherwise noted.

(2) Measured by U. S. Geological Survey at Granite Falls, Minnesota, during 1969 flood.

3.2 RUNOFF CHARACTERISTICS AND MAJOR FLOODS

a. The drainage area of the Minnesota River at Granite Falls is 6,370 square miles. The major tributaries upstream from Granite Falls are the Whetstone, Yellow Bank, Pomme de Terre, Lac Qui Parle, and Chippewa Rivers. The headwaters of the Minnesota River are in the extreme northeast corner of South Dakota and the west-central portion of Minnesota. The river flows generally south-easterly from its source to Granite Falls. The watershed is somewhat horseshoe-shaped with one arm extending northerly containing the Pomme de Terre and Chippewa River Watershed and the other arm extending northwesterly containing the Little Minnesota and Whetstone River Watersheds. The terrain is generally flat to gently rolling farmland with many small lakes and ponds. Most of the area is devoted to agricultural or related uses.

   The watershed divide on the west is a steep bank rilled with gullies. This bank was formed in the glacial age and formed a portion of the shoreline of glacial Lake Agassiz. The north, east, and south boundaries of the watershed are not well defined, and the divides between adjacent watersheds are generally low and barely distinguishable. The highest elevation in the basin is about 2,050 and is located along the western watershed divide. The average elevation of the eastern boundary is approximately 1,200. The maximum fall from the headwaters to the lower limit of the city is approximately 1,160 feet. This is an average of 5.5 feet per mile for the watershed. The average drop within the basin is 5 feet per mile above the dam and 5 feet per mile below the dam.

   Except for the Lac Qui Parle Reservoir, the Minnesota River above Granite Falls flows through a winding channel in flood plains varying from about one-half mile up to two miles in width. The widest flood plains are at the upper end, north of Granite Falls, and are 1¼ mile wide. The flood flow splits into two or three channesl through town and narrows to about a 1,000-foot width near the lower end of the study reach at the southeast end of the city. The width of the flood plain does not substantially increase for the more severe floods such as the Standard Project Flood because of the steep banks on both sides of the flood plain. However, the more severe floods would cause considerably more damage due to the flow forced through the overflow channel near the center of the city.

b. The average discharge for the Minnesota River at Granite Falls is about 704 cfs based on the 68 years of record at the U.S.G.S gage at Montevideo, Minnesota.

c. Major floods of record which occurred in 1969 (43,400 cfs) and 1952 (25,300 cfs) were caused by rapid snow melt combined with rain. Other major floods occur in June and July following periods of heavy rain.

d. The maximum probable flood for the Minnesota River at Granite Falls, Minnesota was obtained by dividing the drainage basin into three sub-areas, then routing and combining the flows from the sub-areas. The sub-areas above Granite Falls, totaling 6,370 square are the area above Big Sone Dam and incremental areas to Lac qui Parle Dam and to Granite Falls. A unit hydrograph was derived for each area. Rainfall was obtained from the report "Probable Maximum Precipitation for the Minnesota River Basin", February 1966, Hydrometeorological Branch, Office of Hydrology, U.S. Weather Bureau. In the adopted computation, the probable maximum precipitation was centered on the intermediate sub-area between Big Stone Dam and Lac qui Parle Dam (2,890 square miles) with lesser amounts on the other sub-areas. A uniform loss rate of 0.10 inch per hour was used for these computations. The runoff hydrographs (including base flow) from each sub-area were routed, where necessary, through the reservoirs and downstream and combined for the total flow at Granite Falls. The maximum probable flood peak is then 235,700 cubic feet per second.

e. The standard project flood for Granite Falls was established as 120,000 cfs for the Flood Plain Information Report. The SPF hydrograph is approximately 0.509 times the maximum probable flood hydrograph. Since this flow is approximately one half of the PMF it has been adopted as the design flood flow. The flood hydrograph is shown on Figure 3-3.

3.3 HYDRAULIC ASPECTS OF OPERATION PROCEDURES

The hydraulic operation of the dam is dictated by the following physical requirements:

a. During normal and low flow periods it is necessary to maintain the pool at or near the top of the flashboards to maximize the head available for power production. This situation prevails during much of the year including the winter season. The wicket gates on the two turbines and the four vertical lift gates on the gated section of the dam are used to accomplish this purpose.

b. During spring runoff and at other times of high flow the gated section of the dam is opened as required to minimize damage and loss of flashboards.

c. During periods of extremely low flow or during repairs to the dam the pool must be maintained not lower than approximately 1 foot below the crest of the concrete spillway to permit continued pumping from the pool for municipal water supply.

The city maintains sporadic records of pool elevations and associated gate openings.

3.4 CONSEQUENCES OF SUDDEN BREACHING BY STRUCTURAL FAILURE

a. General considerations. Consideration of the consequences of a sudden structural failure of the dam at Granite Falls has been based on several factors peculiar to this particular site. These factors are discussed separately in the following paragraphs.

b. Failure possibilities. The structural characteristics of the dam are discussed in detail in sections 5 and 6 of this report. However, in considering the consequences of sudden breaching of the structure it should be noted that the dam is constructed entirely of concrete founded on rock outcrop and the possibility of sudden failure of a substantial portion of the dam is more remote than if it were an earth dam on an erodable foundation. Should a sudden failure occur it appears that it would happen at the gate section rather than within the concrete gravity section. There is also a distinct possibility that the dam could fail during an extreme flood by erosion of the overburden material at the right abutment. However, this failure would occur over some substantial period of time and would not result in a dam break flood wave.

c. Guidance on Wave Heights. The guidance used in this evaluation on wave heights is contained in Reseach Note No. 5, entitled, "Guidelines for Calculating and Routing a Dam Break Flood Wave" dated January 1977 published by the Hydrologic Engineering Center, Corps of Engineers, Davis, California. In summary this guidance indicates that the approximate height of a wave generated by a sudden dam failure is 4/9ths of the headwater depth. In this report the above quotient has been applied to either the headwater depth or the difference between headwater and tailwater, whichever is less. Applying the guidance to Granite Falls the following wave heights have been approximated:

DAM - BREAK WAVE HEIGHT APPROXIMATIONS

STREAMFLOW (cfs)	HEADWATER (Elev.)	TAILWATER (Elev.)	HW MINUS TW (Ft.)	UPSTREAM CHANNEL BOTTOM (Elev.)	HEADWATER DEPTH (Ft.)	APPROX. WAVE HEIGHT (Ft.)
200 (low flow)	904(1)	882	22	895(3)	9	4
5,000 (Bank-full)	905(1)	887	18	895	10	4½
120,000 (St.P.F.)	916(2)	907	9	895	21	4

Notes:

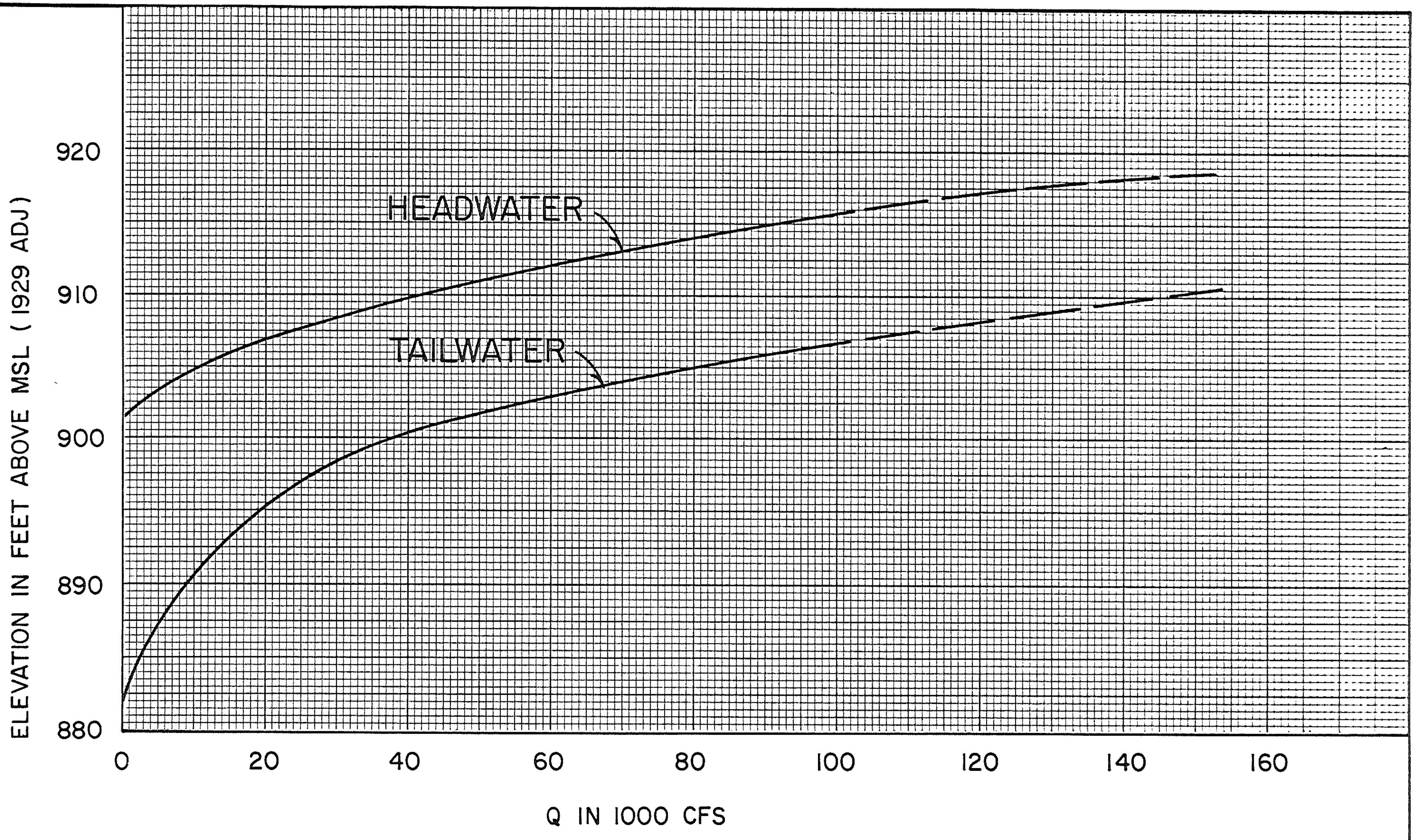
(1) These HW elevations assume flashboards are in place to Elev. 904.1

(2) This HW elevation is with no flashboards and concrete crest at 901.3

(3) The channel bottom is silted in to approximately 895 at the concrete gravity section and 889 at the gate section.

d. <u>Discussion of dam-break wave heights.</u> The above dam break wave height computations indicate that the magnitude of the wave resulting from a sudden failure of a substantial segment of the dam would be approximately the same (4 to 4½ feet) whether it occurred at low flow, bank-full flow, or at the design flood (SPF). This uniformity in values is due to the fact that the limited headwater depth governs during low and bank-full stages whereas the limited head differential between headwater and tailwater governs at the design flood condition. An exception to the above situation would prevail if either the gate section or powerhouse were to fail at low or bank-full stage because of the greater headwater depth immediately upstream from these sections. It is estimated that wave heights of perhaps 7 feet would be generated by failure of either of these sections. However, it should be noted that since these components of the dam have a width of only approximately one tenth of the width of the river, the height of the flood wave would rapidly diminish as it progressed downstream.

e. <u>Consequences of dam-break wave heights.</u> Occurrence of a dam break wave at low water would not result in property damage since the wave would be contained within the river channel below bank-full stage. Occurrence of a similar wave at bank-full stage would produce property damage since temporary flooding of the developments within the flood plain would occur. Loss of life could occur under either of the above situations due to the rapid rise in river stage and the possibility that someone might be swept downstream. A dam-break wave occurring coincident with the crest of the design flood would probably not be a serious aggrevation to the already catastrophic event. The flood plain information report prepared for the city of Granite Falls indicates that at the SPF all accesses to the city are inundated and that only small islands of high ground remain above the flood level. Presumably the town would have been evacuated except for patrol personnel who would be operating largely with floating equipment. It is speculated that the consequences of a dam-break wave occurrence would be the most damaging if it occurred at or near the record flood level of 1969 during the time when a flood fight was in progress. A flood wave in this event would probably result in the overtopping of local levees and could result in extensive added property damage and loss of life.



GRANITE FALLS DAM

RATING CURVES

FIGURE 3-1

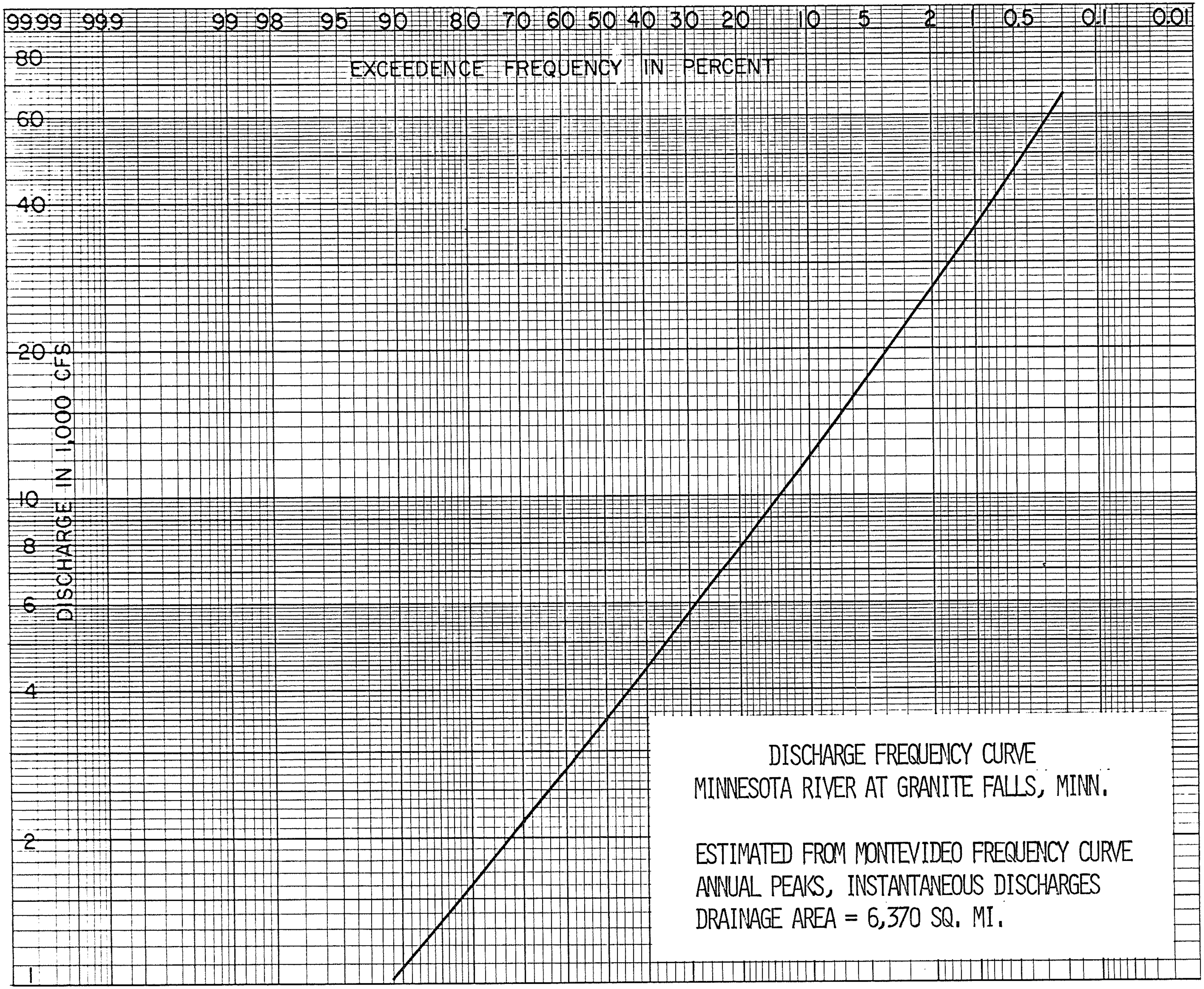

99.99 99.9 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.1 0.01
EXCEEDENCE FREQUENCY IN PERCENT
80
60
40
20
10
8
6
4
2
1
DISCHARGE IN 1,000 CFS
DISCHARGE FREQUENCY CURVE
MINNESOTA RIVER AT GRANITE FALLS, MINN.
ESTIMATED FROM MONTEVIDEO FREQUENCY CURVE
ANNUAL PEAKS, INSTANTANEOUS DISCHARGES
DRAINAGE AREA = 6,370 SQ. MI.

FIGURE 3-2

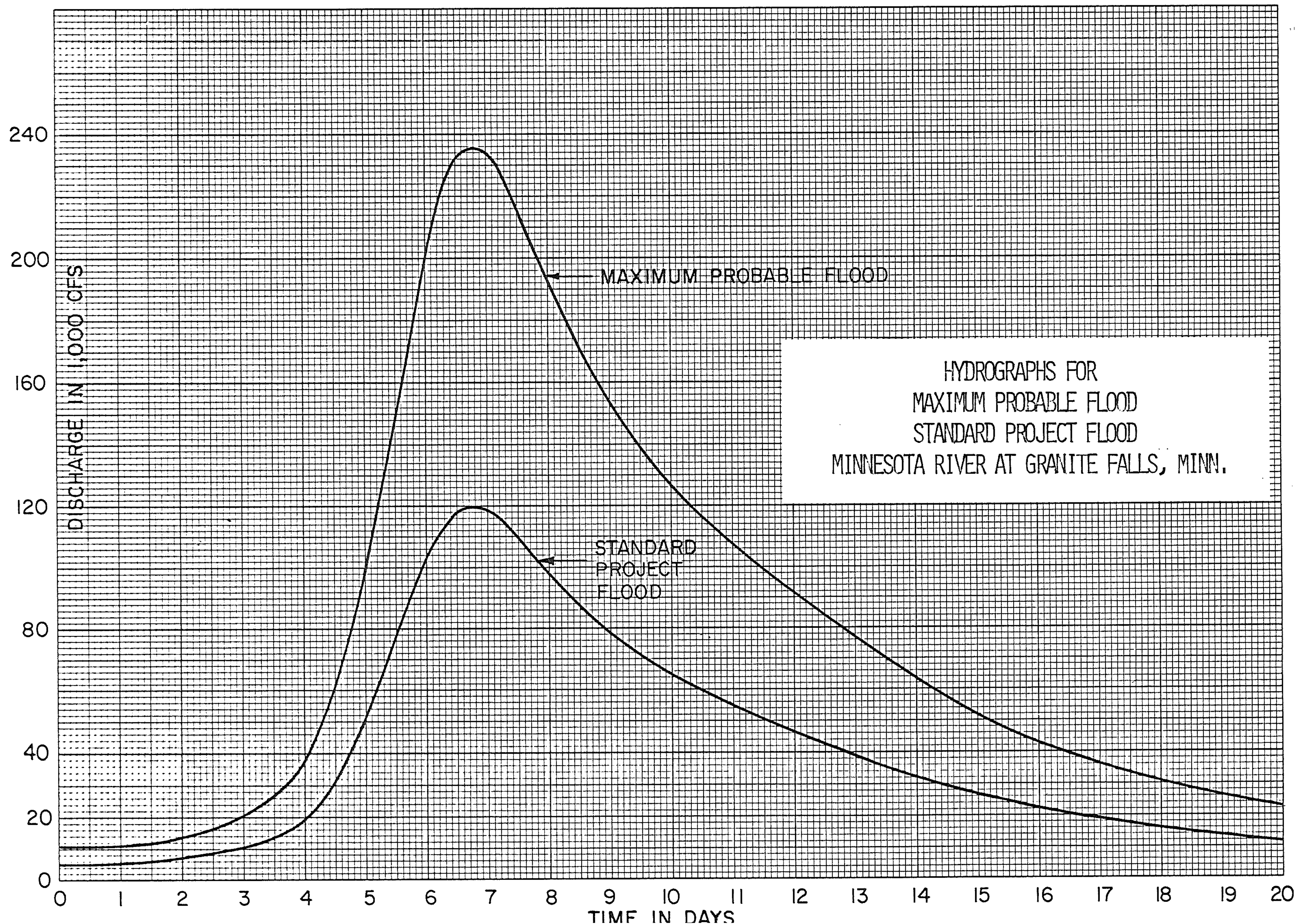

HYDROGRAPHS FOR
MAXIMUM PROBABLE FLOOD
STANDARD PROJECT FLOOD
MINNESOTA RIVER AT GRANITE FALLS, MINN.
MAXIMUM PROBABLE FLOOD
STANDARD PROJECT FLOOD
DISCHARGE IN 1,000 CFS
TIME IN DAYS
0
20
40
80
120
160
200
240
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

FIGURE 3-3

SECTION 4

PHYSICAL ASPECTS OF OPERATION AND MAINTENANCE

4.1 RESPONSIBILITY

The City of Granite Falls Light Department is responsible for operation of the dam.

4.2 OPERATION

Operation of the dam is accomplished by the combined efforts of several city employees. One employee is on duty at the powerhouse and adjacent water treatment plant 24 hours each day and adjustments in the flow through the turbines can be made by the power plant operator. Any changes in the position of the vertical lift gates at the powerhouse and gate section requires a crew of several men because of the deteriorated condition of the hoists. In view of the long, fixed spillway crest, gate changes are infrequent. When they are required they are based on local rainfall information sometimes supplemented by sporadic information received from the operators of the Lac qui Parle dam upstream. This information is usually relayed to the city indirectly through Northern States Power Co. operators at the downstream steam plant. At times direct communication between Lac qui Parle dam and the city dam would be preferable, particularly since gate manipulation at the latter dam is not a push button type operation. Normally the travel time between the two dams is approximately 36 hours.

4.3 OPERATION OF FLASHBOARDS

The power pool at Granite Falls is maintained 2.8 feet above the crest of the overflow spillway by installation of flashboards across the 300 foot length of the crest. These boards consists of three 2" x 12" boards 16 feet long attached to double extra strength pipe placed at 5' - 4" centers in holes in the concrete crest. Because of the rather unusual height of these flashboards (two feet is more common) the flow over the boards must be limited to less than 18 inches or the pipe supports will fail by bending. Also ice must not be permitted to develop against the boards in the winter. Consequently considerable labor is expended in removing ice on a daily basis. As a matter of incidental interest it is understood that a bubbler system for ice removal has been tried unsuccessfully. While the use of flashboards can sometimes aggrevate flood heights if the boards remain totally or partially intact during flood flows, the experience at Granite Falls has been that the great pressure against the 32" height of boards invariably cause the pipes to bend down with surcharges at and above 18 inches.

4.4 MAINTENANCE AND INSPECTION

It is understood that a portion of the revenues from the production of hydroelectric power are allocated to a maintenance and operation fund. While there is ample evidence that considerable effort has been spent on maintenance in the past, the need for added maintenance is also obvious.

Similarly it is evident that the dam is under daily surveillance of the several city employees involved in operating the adjacent water supply plant, the hydro-electric plant, and by employees involved in the operation of the flashboards and gates. However, since a systematic, continuing program of inspection and maintenance is vital to the continued functioning of the project, it is recommended that such a program be developed further and implemented.

4.5 SUMMARY

The most urgent need with respect to the physical aspects of operating and maintenance at Granite Falls is to establish and implement a systematic program of inspection and maintenance with immediate emphasis on improvement of the gate structure and related mechanical equipment.

SECTION 5

GEOTECHNICAL EVALUATION

5.1 AVAILABLE SUBSURFACE DATA

No borings are available at this site, Bedrock is exposed in the valley at the damsite and can be examined directly. Profiles of the bedrock surface were not made during construction or at any subsequent date.

Information is available in the form of published maps and reports of various Geological Survey organizations. These have been referred to for background information in the preparation of this section.

5.2 GENERAL GEOLOGY

The bedrock in this area is a metamorphic granitic gneiss that is considered to be among the oldest rock formations in the world. Its surface is very irregular, with numerous outcrops in the valley floor, as well as some outcrops outside the valley.

The entire area has been glaciated with till being laid down by several advances of glaciation. The present surface material covering the region is the result of the Des Moines lobe of the Wisconsin Ice Age. The entire area is covered with ground moraine from this advance, and there are also a number of terminal moraines at positions where the glacier paused in its retreat.

A large valley was cut through the till surface by the Glacial River Warren draining Lake Agassiz, near the end of the last glaciation. This valley was cut to the bedrock surface and is one to two miles wide and 100' to 150' deep in the area. The Minnesota river now flows through this valley, but only occupies a very small part of the valley section.

The upland regions have typical ground moraine topography with elevations ranging between 1000' to 1060'. The drainage is imperfect with some small lakes and swampy areas. The valley is broad, with well defined sides, but with considerable relief on the valley floor where elevations range from 870' to 910' as river elevation, up to numerous hills of approximately 950' and at least one hill of 1000' elevation. There are a number of small lakes in abandoned river channels.

The soils on the upland would be the gray drift soils, a boulder clay soil containing a wide range of particle sizes. The soils in the valley would be alluvial silts and sands.

5.3 SITE GEOLOGY

The dam is situated on a rock outcrop near the northeast side of the valley. The impoundment is largely confined within the banks of the present Minnesota River and extends upstream for a relatively short distance. The reservoir shows evidence of a large amount of silting.

The valley floor immediately downstream of the dam is exposed bedrock that is extremely resistant to scour and erosion. The right abutment is placed directly on this bedrock surface, and the bedrock is also incorporated directly into the center portion of the dam.

5.4 EXISTING STRUCTURE (See Description in Section 1)

5.5 ASSESSMENT OF SAFETY OF STRUCTURE AGAINST UNCONTROLLED SEEPAGE

There does not appear to be any danger of uncontrolled seepage. The few indications of seepage are small in quantity and occur in areas that are not subject to piping or excessive erosion.

5.6 SLOPE PROTECTION AND SCOUR PROTECTION

Slope protection and scour protection are not subjects pertinent to the Granite Falls Dam since the entire dam is constructed of concrete and is founded on rock. A concrete retaining wall on the left bank and grouted riprap on the right bank protect against bank scour at the abutments.

5.7 CONCRETE CONDITION

The quality of the concrete in the dam is quite variable. The right half is very bad in surface appearance. The surface scaling has exposed much reinforcing steel both at the crest of the spillway and along the base of the downstream face. The construction joints of the lifts are also very poor, with large voids and exposed coarse aggregate. The deterioration would appear to be largely a surface condition, since there is no indication of seepage through these joints.

The left half of the dam is slightly better. The crest has been capped with a newer concrete surface. The downstream face has some of the same deteriorated appearance but does not look quite as severe as on the right half of the dam.

Possibly the most critical concrete is in the gate structure. In an attempt to improve the appearance, the concrete has been covered with a layer of shotcrete. In some sections this layer has a hollow sound when tapped, indicating poor bond and possible voids. There is also a question on the quality of the concrete mass. Coring or drilling into the mass to evaluate its resistance would be desirable but not essential with respect to dam safety.

5.8 SUMMARY

There does not appear to be a high risk of sudden, catastrophic failure of the dam. The foundation materials are excellent for a dam of this size. The stability against overturning or sliding has been satisfactory in times of high flood flows with high tailwater, and also in normal operating conditions with a probably greater head differential. Any possible scour problems appear to be nonexistant.

If there are major geotechnical concerns with this structure, it would probably be in the area of concrete deterioration and quality. The appearance is very bad in many sections with exposed steel and exposed aggregate. Many of these do not pose a severe safety problem, as the gravity dam is not in danger of falling apart. The exception to this may be in the gate structure where the stresses are greater and the deterioration may be more extensive. The entire gate structure is in need of repair and the quality of the concrete should be completely investigated.

The spillway section would be improved in general appearance and durability if the concrete surface were upgraded. The major question would probably be whether the improved appearance would be worth the cost of the resurfacing. However, because this is a mass concrete section, the upgrading would not materially improve the structural integrity of the structure.

SECTION 6

STRUCTURAL EVALUATION

6.1 BACKGROUND DATA

a. The following information was used in making this evaluation.

1. Four historical photos of the original construction in 1911.

2. Photos and measurements made during the inspection of the dam on July 25, 1978.

3. Discussions with Mr. John Knutson, Supt., Public Utilities and Mr. Ed Steinbach, employee of Public Utilities.

4. Sketches of the dam prepared from the above data.

b. The structure is constructed of concrete and from the inspection it was evident that the entire structure is founded on granite. Whether the structure is anchored into the rock is speculative.

6.2 ASSESSMENT OF STRUCTURAL STABILITY

a. Stability Analysis

In the absence of design or "as-built" information, it is not possible to completely analyze the dam to evaluate factors of safety with regard to overturning or sliding. The cross-section of the dam is not known, and the extent of anchors into the bedrock foundation is also not known. There appear to be anchorage rods exposed at the base of the dam, but the number, size, embedment, spacing, etc. are all unknown. The configuration of the contact surface is also an unknown quantity. Simple calculations assuming an approximate and regular cross-section, no support from anchorage bolts or from downstream rock buttresses, no uplift pressures under the dam, and hydrostatic pressures plus submerged soil pressures along the entire upstream face of the dam produce the following results: (1) The resultant vertical force acts at the third point of the base, which satisfies design criteria. (2) The friction factor required for no sliding to occur is .67, an unreasonably high value. This would not satisfy design criteria, but is also, obviously, not an accurate appraisal. It does not take into consideration the effect of the rock outcrop buttress at the center of the dam, which obviously provides a great deal of support, nor does it account for the surface roughness of the rock surface, nor support provided by foundation dowels or keys which are undoubtedly there (as partially visible in construction photographs) but are unknown quantity.

b. Loading Conditions. For the above mentioned stability analysis the following elevations affecting loading were used:

	Record Flood (1969)	Design Flood (SPF)
Headwater Elevation	909.2	916.1
Tailwater Elevation	900.0	906.8
Spillway Crest Elevation	901.3	901.3
Top of silt at upstream face of dam	895.0	895.0

Since the head differential on the dam remains essentially constant for flows in excess of the record flood, the summation of horizontal forces on the dam remains approximately constant for all flows with tailwater elevations at and above spillway crest (901.3).

c. Possible mode of failure. The Granite Falls Dam has proven to be stable for the above loading conditions imposed by the record flood. The approximate stability computations discussed in paragraph a. above indicate that the main spillway section has less of a factor of safety against sliding than against overturning for the record flood condition, assuming no uplift forces beneath the dam. In the event that significant uplift forces are present beneath the dam the factor of safety against sliding would be substantially less for the design flood than for the record flood. On this basis sliding is considered to be a possible mode of failure at the design flood. However, in actuality, this possible mode of failure would probably be preceded by flanking at the right abutment or failure of the gate section.

6.3 ASSESSMENT OF STRUCTURAL STRENGTH

a. Gate Section

City employees report encountering "soft concrete" when drilling holes in the gate section. From the appearance of the concrete in this section during the inspection this speculation appears possible. Thus, the gate section may be subject to stress problems.

b. Concrete Gravity Spillway Section

The concrete gravity dam sections, although subject to surface spalling did not appear to have stress problems.

6.4 Summary

Due in part to the complicated history of the site, the character and composition of the abutment and foundation areas is uncertain. Computations on the available data indicate that applicable structural and foundation criteria are satisfied. Since the quality of these computations is largely dependent upon knowledge of the components of the structure, there is a level of uncertainty about the results. Elimination of this uncertainty would require investigation and analysis beyond the scope of this program. There is presently no visual evidence of structural or foundation inadequacy and the overall appearance of the structure is good. Therefore, no recommendation regarding additional investigations is made.

APPENDIX A

REPORT OF FIELD INSPECTION

NATIONAL DAM SAFETY PROGRAM

CHECK LIST TO RECORD

FIELD OBSERVATIONS

ST PAUL DISTRICT
CORPS OF ENGINEERS

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 Granite Falls City

   b. I.D. Number 510

2. Date of Inspection July 25, 1978

3. Name or owner Granite Falls City

4. Location
   County Yellow Medicine and Chippewa Counties

   Township 116 N Range 39 W Section 34

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

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

6. Are items on inventory sheet correct?

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

7. Type of dam (check all appropriate)

   ( ) Earth and/or rockfill (use form a)
   (x) Concrete and /or masonry (gravity) (use form d)
   ( ) Other
   Explain This is an overflow structure

8. Year of construction 1911

9. Year(s) of major rehab U

10. Purpose of dam (check all appropriate)

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

11. Pool el. on day of inspection 901

12. Tailwater el. on day of inspection 885

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

Controlled	Uncontrolled	Type
( )	( )	Pipe or Conduit
(x)	( )	Chute or notch
( )	(x)	Overfall
( )	( )	Other
		Explain with flashboards

main spillway is overfall with flashboards

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

The dam is operated by the city on an "as needed" basis. There is evidently no formal plan of operation. The pool is regulated primarily for city water supply and power purposes.

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

There is inspection and maintenance but perhaps not on a regular systematic basis. It is to an extent to permit operation of the dam. During winter months the maintenance foreman said the ice was cut along flashboards daily if needed to reduce pressure and damage to the boards and so prevent loss of pool for water safety.

16. Do the following exist?

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

Remarks Owner has no drawings or other design data

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

( ) Yes, (×) No, Remarks WEATHER BUREAU WARNINGS

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

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

Explain Structure is an overflow dam. The flood of 1969 had 8.1' of water over the crest. There is no evidence of overtopping of Pwhse area.

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 The east abutment of the new bridge just upstream of the spillway - Pwhse area now serves as a barrier in protecting the area from ice flows and build up of ice. There is extensive visual evidence of silt in the pool above the dam.

LIST OF POTENTIAL DOWNSTREAM HAZARD

Remarks N.S.P. Dam - I.D. 152

Expect little effect on the N.S.P. dam considering the distance and volume of water.

		Type of Improvement (indicate number)										Loss Of Life Potential			Economic Loss Potential			
Approx. Ht. Above Stream (ft.)	Valley Distance (miles)	Occupied dwelling	Unoccupied dwelling	Agricultural Building	Industrial Building	Other Building	Road	Railroad	Urban Area	Dam (give ID number)	Other	Likely more than 4	Likely 4 or less	Possible, but not likely	Less than $____	$____ to $____	More than $____	Remarks
	3									x								
	0-.25					11												PUBLIC BUILDINGS AND COMMERCIAL BUILDINGS
	.50	5																MUSEUM AND CITY PARK
	1.0						X				X							BRIDGE - U.S. HWY 212, MN. 23
	2.0	5			X													NSP - POWER PLANT

21. The above list was ended because:

- (x) 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
- (x) Other
  Explain Effect on N.S.P. Dam, 3 miles D.S.

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

Team member	1. High	2. Significant	3. Low	Can't Decide
R.W. LEONARD	(X)	( )	( )	( )
LYLE [illegible]SON	( )	( )	( )	( )
[illegible]	( )	( )	( )	( )
HAR[illegible] [illegible]Y	(X)			

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

FLOOD PLAIN REGULATIONS HAVE BEEN ADOPTED BY THE CITY.

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

(X) 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.
(X) 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?

(X) No
( ) Monumentation
( ) Relief wells
( ) Piezometers
( ) Weirs, etc.
( ) Other
Explain ______________________________

____

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. City should take steps to repair the spillway gate operating mechanism..
2. and check quality of concrete in spillway gate control structure,
3. however, failure of gate operation or gate super structure should not
4. effect the safety of the dam.
5.
6.
7.
8.
9.
10.
11.
12.

Participants in the dam inspection:

Name	Title	Agency
Olaf Lein	P.E. Civil	Wehrman- Chapman Assoc.
Richard Leonard	"	" "
Lyle Pederson	"	" "
Harold W. Toy	"	" "
Memos Katsoulis		Minn. DNR
Douglas Spaulding		Corps of Engrs.

List of attached forms

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

FORM B - SPILLWAY

1. Give name of feature inspected (as shown on drawings, common usage, etc.)

( ) Emergency spillway
(x) Primary spillway
( ) Other
Name ____________________

2. If plans are available the following item need not be completed. On a separate sheet, draw a plan of the spillway and one or more cross-sections of the spillway which show dimensions, location of concrete sills, etc. Show the elevation of the top of the dam in relation to the spillway crest. If possible show maximum, minimum and normal pool and tailwater elevations. Describe features not adequately shown on the sketch.

SEE SKETCH OF DAM SECTION -
PRIMARY SPILLWAY IS 300 FT OF
OVERFALL SPILLWAY WITH FLASHBOARDS.

3. Check all the applicable items which describe the spillway.

(x) Gated spillway - Type, Tainter ____ Roller ____ Stop log ____
( ) Lined with concrete or slope protection
( ) Concrete control sill
( ) Unlined in soil
( ) Unlined in rock

Remarks: The SECONDARY spill way is a chute section controlled by 4 5'4" x 18'0" slide gates.

4. Is there any evidence of erosion of the spillway itself?

Yes	No	N/A	Can't Tell	
( )	( )	(x)	( )	Spillway floor
( )	( )	(x)	( )	Spillway side slopes
( )	( )	( )	(x)	Around control sill
(x)	( )	( )	( )	Around spillway gates or control structure

5. Give your opinion of the seriousness of the erosion of the spillway proper.

( ) Unlikely that it will become a problem in the foreseeable future
( ) May or may not become a problem
(x) 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.
( ) Not Applicable

6. 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 ________________________________

No [illegible]

7. What is the condition of riprap?

(x) No riprap

( ) Badly displaced

( ) Occasional holes and pockets

( ) Rock deteriorated

( ) Rock sound and in good condition

( ) Other

8. Give your opinion of the seriousness of the upstream and downstream erosion.

(×) 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.

9. Describe the material in which the spillway is constructed. Estimate the uniform soil classification if in soil or type of rock and formation if in rock.

Granite Foundation

10. 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: One gate operable with some effort, two gates with much effort, one gate operable without extensive repair - raising mechanism cannibalized

11. Are spillway gate normally

( ) N/A, no gates.
( ) open
( ) closed
( ) other
Explain Operated; Based on inflow

12. 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.
(x) Gate have some problems not likely to impair operation
( ) Gate have some problems which could lead to failure during and emergency
( ) Gates are in such poor condition that failure could occur at anytime

Remarks: Two lifting bases cracked, additional deterioration of gate ~~astessories~~ accessories could make them ~~operable~~ inoperable which would lessen pool control.

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

( ) N/A. No gates
( ) Little or none
(x) 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 ______

14. 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
(x) Would drain lake, but no safety problems
( ) May cause serious erosion of dam
( ) Could release enough water to be a flood hazard
( ) Other ______

15. Wall drains and floor weepholes

(x) None
( ) Generally appear open and functioning
( ) Generally appear non functioning
( ) Amount of flow observed

None ( )
Trickle ( )
Moderate ( )
Heavy ( )

16. Give your opinion of the general condition of the spillway.

SPILLWAY GATES AND GATE STRUCTURE ARE IN RELATIVELY POOR CONDITION

17. Are there any obstruction to flow through the spillway?
( ) Yes (X) No

Describe flow pattern: ______

18. In your opinion would an abnormally large spillway discharge have a tendency to erode the embankment?
(X) No
( ) Yes
Describe ______

19. Summary

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

(1) NO EMBANKMENT

(2) ______

(3) ______

(4) ______

(5) ______

(6) ______

Signature(s) of Person(s) responsible for this section

Aloz Leon

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.

SEE SKETCH OF DAM IN
SECTION 1

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

Granite - sound but jointed with varying joint patterns

Fractured granite

3. Basis for foundation description

( ) Borings

( ) Construction records

( ) Verbal testimony

(x) Visual observation

( ) Waterwell records

( ) Other - Explain

3. (Cont'd)

____

____

____

____

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

(x) 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.

(x) 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 No records of design available.

____

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
(x) 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.

(x) 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 Overturning and sliding criteria should be checked

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: Basin heavily silted

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

(x) 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	
( )	(x)	( )	( )	Downstream of dam
( )	(x)	( )	( )	Left abutment (looking downstream)
( )	(x)	( )	( )	Right abutment (looking downstream)
( )	(x)	( )	( )	Through structure
( )	(x)	( )	( )	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.

____

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

(x) 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
(x) Fixed crest with flash boards
( ) Tainter gate
( ) Stoplog
(x) Roller gate
( ) Other

Describe Flash boards of 2" wood plank. 2'10" high are seated on a concrete sill. Flashboards are held in place by extra heavy upright 2" pipe every 5'-4" feet.

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
(x) 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: Four spillway slide gates 5'4" x 18'0" in spillway - Four turbine gates 6'2" x 8' 0"

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

( ) N/A. No stop logs or flash boards
(x) 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 Flashboards are left in place often damaged by ice, etc. which requires repair and replacement.

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

(x) 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
(x) No, but owner indicates that they are operable (See Note)

1 flood gate operated with difficulty, 2 flood gates required much effort to operate, 1 flood gate virtually inoperable, cannabilized in parts.

Remarks: The turbine gates appear operable but required up to five men to operate them. The frames of two flood gate lifting gear are cracked.

18. Are spillway gates normally

( ) N/A. No gates
( ) Open
(x) Closed
(x) Other
Explain Gate operation depends on inflow

____

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

( ) N/A. No gates
( ) Little or none
(x) 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
(x) 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	
( )	(x)	( )	( )	Spillway floor
( )	(x)	( )	( )	Spillway side slopes
( )	(x)	( )	( )	Around control sill or overflow ogee
( )	(x)	( )	( )	Around spillway gates or control structure

Right abutment against granite, left abutment against powerhouse wall

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
(x) 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?

N/A structure in granite channel

( ) 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?

(x) 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?

a. Is it visible? U.S. _____ D.S. _____ No , located in a granite channel

b. What is its condition?

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

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

(x) 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) Gate structure
(2) Gates
(3) The structure appears to be in good condition, however there is evidence of
(4) deterioration of the spillway gate structure concrete which should not present a safety problem.

27. (Cont'd)

(5) ______________________________

(6) ______________________________

(7) ______________________________

(8) ______________________________

(9) ______________________________

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

Lyle Pederson

Aloy Leim

____

FORM E - POWERHOUSE

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

(x) Yes ( ) No. Separate Powerhouse

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

( ) Not in place ( ) In place, not functioning
(x) In place and functioning (1 of 2 Units)

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

(x) 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: ______________________________

____

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

(x) 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 ______________________________

____

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?

- (x) 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?

- (x) 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.

- (x) 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?

- (x) 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	
( )	(x)	( )	( )	Downstream of powerhouse
( )	(x)	( )	( )	Left side (looking downstream)
( )	(x)	( )	( )	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.

____

____

____

____

____

____

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

- (x) No seepage noted.
- ( ) Unlikely that it will become a problem in the forseeable 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: 1 POWERHOUSE GATE CLOSED FOR TURBINE REPAIR

13. Are spillway gates normally

( ) N/A. No gates
( ) open
( ) closed
( ) other
Explain See SEC D

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: See SEC D

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

(1) ______________________________

(2) ______________________________

(3) ______________________________

(4) ______________________________

(5) ______________________________

(6) ______________________________

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

Aloy Lein

____

____

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

1. Identify the feature for which this section applies.

1) Concrete Dam

2) Overflow and spillage sections

2. General condition of concrete

( ) Good
2) (x) Satisfactory
1) (x) Poor

Remarks: ~~2) The overflow section is eroded and weathered~~ - ½ of the crest has been recapped. (left side). The spillway ~~super~~ gate structure has been coated with shot- crete which sounded drummy when tapped. A check of the quality of concrete in spillway structure is recommended

3. Cracks (x) Yes ( ) No

Describe 1) Cracks and seams along pour lines with deterioration of concrete indicating poor distribution of mortar.

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
( ) Leaching
( ) Stalactites
( ) Stalagmites

4. Scaling ( ) Yes (x) 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 (x) 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 General weathering

____

____

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
- (x) Exposed steel
- (x) Previous patching or other repair
- ( ) Chemical attach

7. (Cont'd)

Describe Some exposed steel in the DS face at the right abutment. Left ½ of crest has been recapped. The DS face of right ½ of overflow section somewhat eroded.

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 The overflow section has some erosion but appears in generally good condition. Some question is made of the spillway structure concrete. The city has ~~and~~ had troubles with eroding concrete in the gate slots and surfaces which were repaired with shot-crete.

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

Lyle Pederson

Oloy Leim

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 (x)
   Non-glacial ( )

2. Glacial
   ( ) Till plain
   ( ) End moraine
   ( ) Outwash plain
   (x) Combination - Explain Minnesota River Valley

   Non-Glacial
   ( ) Deeply disected
   ( ) Rather level

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

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

5. Empoundment
   ( ) Lake
   (x) River
   ( ) Combination - Explain

6. Soils

Origin

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

Explain ____________________

Types

( ) Sand-gravels
( ) Clays
(x) 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 Pre-cambrian Gneiss

Rock Type Gneiss

General Depth to Rock Surface

Outcrops in Valley Walls Yes

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

11. <u>General Water Table</u>

Source of water to stream flow
(x) 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. <u>Geologic Setting</u>

( ) <u>Glacial</u>
- ( ) Outwash plain
- ( ) Till plain
- ( ) End moraine

( ) <u>Non-glacial</u>
- ( ) Deeply disected plain
- ( ) Alluvial plain

( ) <u>Terraces</u>
- ( ) Soil
- ( ) Rock

16. <u>Bedrock</u>

Formation Names: ______________________

(x) Exposed
( ) Deeply buried
( ) Sandstone
( ) Limestone
( ) Shale
( ) Igneous
- ( ) Bolsalt
- ( ) Granite
- (x) Other - Explain ______________

Assorted Gneiss

17. Abutments and Foundation

( ) Soil
Types ______

(x) Rock
Types Granite Gneiss

18. Seepage
( ) 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
(x) Close spaced
( ) Widely spaced
(x) Direction and inclination to structure

Center of dam - slopes toward dam right abutment. Dip away from dam.

( ) N/A - Explain ______

d. Bedding Planes
( ) Open
( ) Closed

e. Hardness of Rock
( ) Soft
( ) Medium
(x) 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) EXTENT OF KEYS TO ROCK ARE UNKNOWN

(2) __________

(3) __________

(4) __________

(5) __________

(6) __________

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

Lyle Pedersen

APPENDIX B

HYDROLOGY AND HYDRAULICS STUDY CHECK LIST

Sheet 1 of ____
Date ________
ID ________

NATIONAL DAM SAFETY PROGRAM

HYDROLOGY AND HYDRAULICS STUDY CHECK LIST

Name of Dam Granite Falls Dam State Minn County YELLOW MEDICINE

River Minnesota Nearest Downstream Town GRANITE FALLS

1. General Data

Drainage area 6,370 sq. mi.

Total length of longest watercourse (L) u miles*

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

Average slope of the basin u feet/feet*

Time of concentration (t_c) u hours*

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

Urban		%
Forest	5	%
Grassland	15	%
Crop	80	%
Lake and swamps		%
Other		%
Explain		
Total	100	%

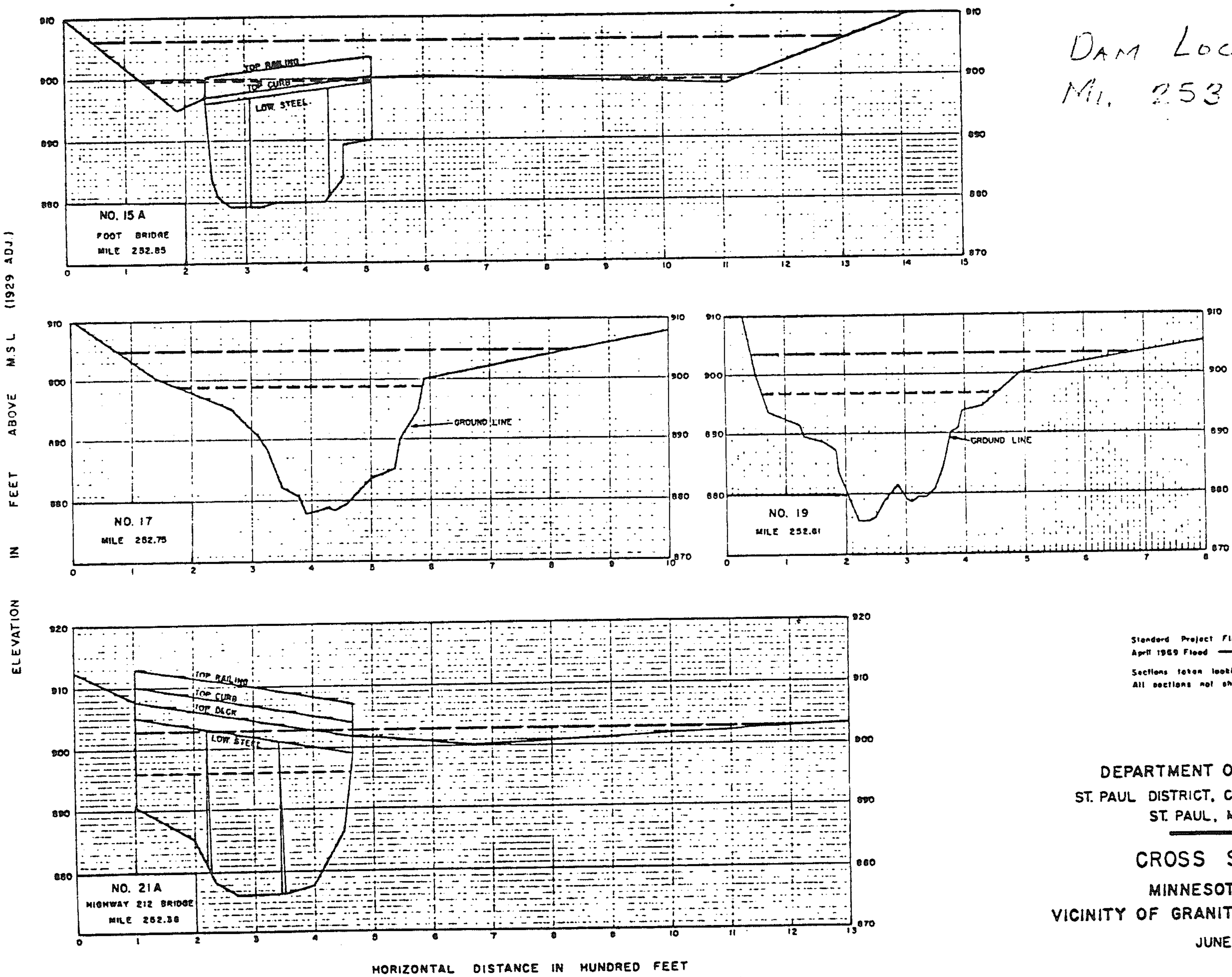
Frequency curve: Yes ✓ No ____ Incl # 1

Maximum probable index rainfall 21.4 inches in 24 hours

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

NCS Form 150 Issued 30 January 1978

Dam Location Mi. 253



Standard Project Flood
April 1969 Flood
Sections taken looking downstream
All sections not shown

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

CROSS SECTIONS

MINNESOTA RIVER
VICINITY OF GRANITE FALLS, MINNESOTA
JUNE 1970

Current spillway design flood: Yes ✓ No___ Peak Q 120,000 cfs

Current spillway design flood hydrograph: Yes ✓ No___ Incl# Fig 3-3

Other pertinent data:

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.

(See Following Sheet)

2. Channel capacity in critical downstream reach 5,000 cfs.

3. Flood Plain Development

First 1000 feet downstream — 11 COMMERCIAL BLDGS

Between 1000 feet and 1 mile — 10 RESIDENCES, 1 MUSEUM

Between 1 mile and 5 miles — NSP POWER PLANT (Steam)

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 X Incl# ____

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

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 X Incl# ____

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

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 X Incl# ____

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

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

Elevation	Area (acres)	Capacity (ac - ft)

8. As built design flood:

Outlet works N/A cfs. Service spillway ______ cfs.

Emergency spillway " cfs. Project ______ cfs.

Design freeboard " feet. Expected wave ______ feet.

9. Headwater rating curve: Yes X No ____ Incl# FIG 3-1

10. Tailwater rating curve: Yes X No ____ Incl # FIG 3-1

11. Downstream channel material GRANITE ; erodible: Yes ____ No X

12. Erosion Protection:

Upstream embankment face – N/A

Downstream embankment face – N/A

At stilling basin – N/A

Downstream – N/A

13. Critical depths at stilling basin:

Normal discharge:

Q = 704 cfs, d_1 = .5, d_2 = 0.7 ft 882.6 elev., tailwater elev. 883.5

As built project design spillway capacity:

Q = " cfs, d_1 = ____, d_2 = ____ ft ____ elev., tailwater elev. ____.

Other critical condition: (MAXIMUM OF RECORD - 1969)

Q = 36,800* cfs, d_1 = 2.8, d_2 = 13.5 ft 890.9 elev., tailwater elev. 900.0

Current spillway design flood: (STANDARD PROJECT FLOOD)

Q = 102,000* cfs, d_1 = 7.5, d_2 = 24 ft 905.9 elev., tailwater elev. 906.8

14. Critical heads across structure: Top of dam elev. 901.3

Elev. bottom channel downstream 881.9

At normal operating pool: (WITH FLASHBOARDS) Elev. 904.1

	Q	Tailwater Elev.	Head
No flow			
Normal =	904	883.5	20.6
Design =			
Spillway =			
Other Critical =			

At ~~full pool~~ record flood. Elev. 909.2

	Q	Tailwater Elev.	Head
No flow			
Normal =			
Design =			
Spillway =			
~~Other Critical~~ 1969 RECORD FLOOD =	909.2	900.0	9.2

* TOTAL RIVER FLOWS FOR THESE FLOODS ARE 43,000 and 120,000 CFS, RESPECTIVELY

At as built spillway capacity pool:
Elev. N/A

	Q	Tailwater Elev.	Head
No flow			
Normal =			
Design =			
Spillway =			
Other Critical =			

At current spillway design flood: (SPF)
Elev. 916.0

	Q	Tailwater Elev.	Head
No flow			
Normal =			
~~Design~~ =			
Spillway =	162,000	906.8	9.2
Other Critical =			

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

120% SDF Pool Elev. N/A Tailwater Elev. ____ H ____

80% SDF Pool Elev. N/A Tailwater Elev. ____ H ____

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

a. Results of routing spillway design flood through pool.

(1) Performed ____ See Incl# ____

(2) Not performed X Reason: FLOW IS CONTAINED IN RIVER CHANNEL

b. Dam overtopping and/or breeching analysis.

(1) Yes X 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? Natural rock channel dissipates energy

18. At existing spillway capacity is erosion downstream expected?
No

19. Will erosion jeopardize safety of structure?
No

20. Does stilling basin adequately dissipate energy for spillway design flood?
No stilling basin.

21. For spillway design flood is erosion downstream expected?
No

22. Will erosion jeopardize safety of structure?
—

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 -
Spillway is adequate

b. Consequences of overtopping by current spillway design flood related to breeching dam, downstream flood wave and hazard -
Commercial buildings in community would be subjected to additional 4-5 foot flood depths

c. Adequacy of outlet works and control gates -
Vertical lift gates are in poor condition

d. Adequacy of stilling basins -
There is no stilling basin. The natural rock channel provides adequate depth

e. Adequacy of downstream erosion protection -
For normal flows - rock bank protection is provided on both banks.

f. Adequacy of erosion protection at dikes, embankment, or dam -
Upstream emergency closures required to prevent flanking of the right dam abutment

g. Upstream urbanization potential and consequences -
Upstream levees have protected the community from bypass flows.

h. Downstream urbanization potential and consequences -
Flood plain regulations control use of downstream areas.

i. Consequences of dam failure at full pool and zero discharge related to downstream floodwave and hazard -
Minor stage increases downstream would not cause significant damages.

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

APPENDIX C

PHOTOGRAPHS TAKEN 25 JULY 1978

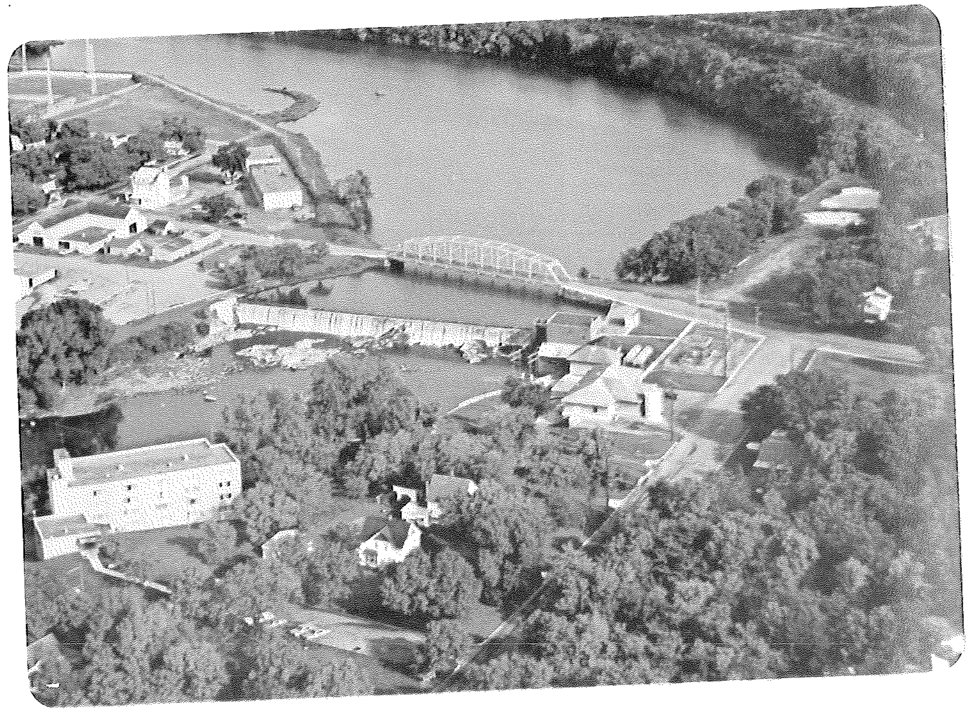
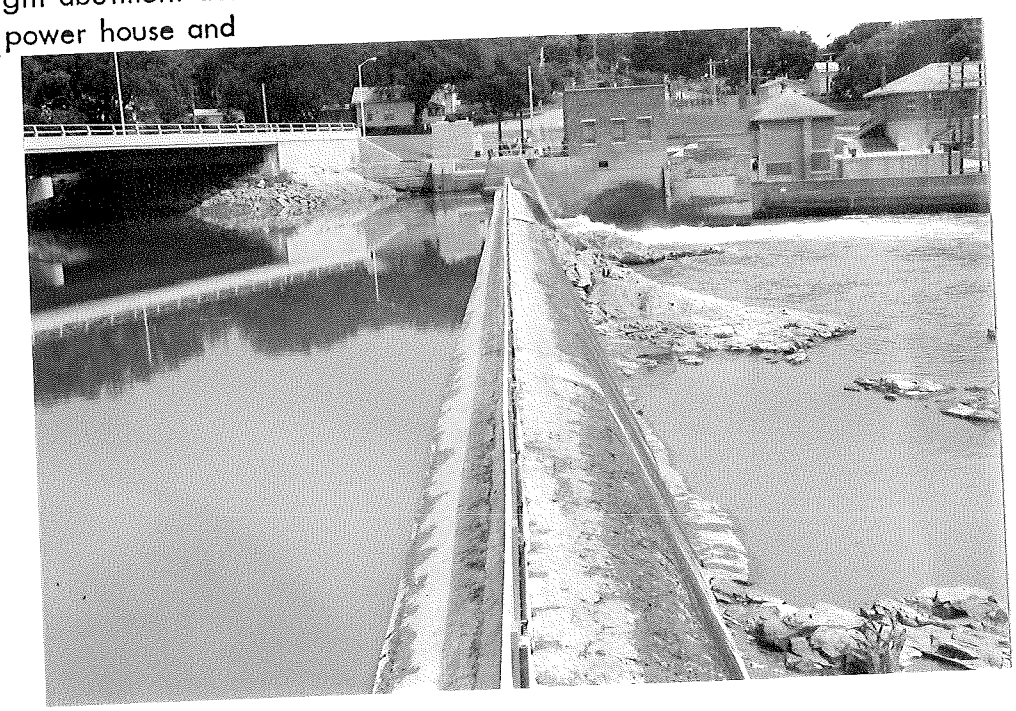


Photo 1. An aerial view of the Granite Falls Dam showing the business district below the dam.

Photo 2. View from the right abutment across the dam crest showing the power house and water intake structures.



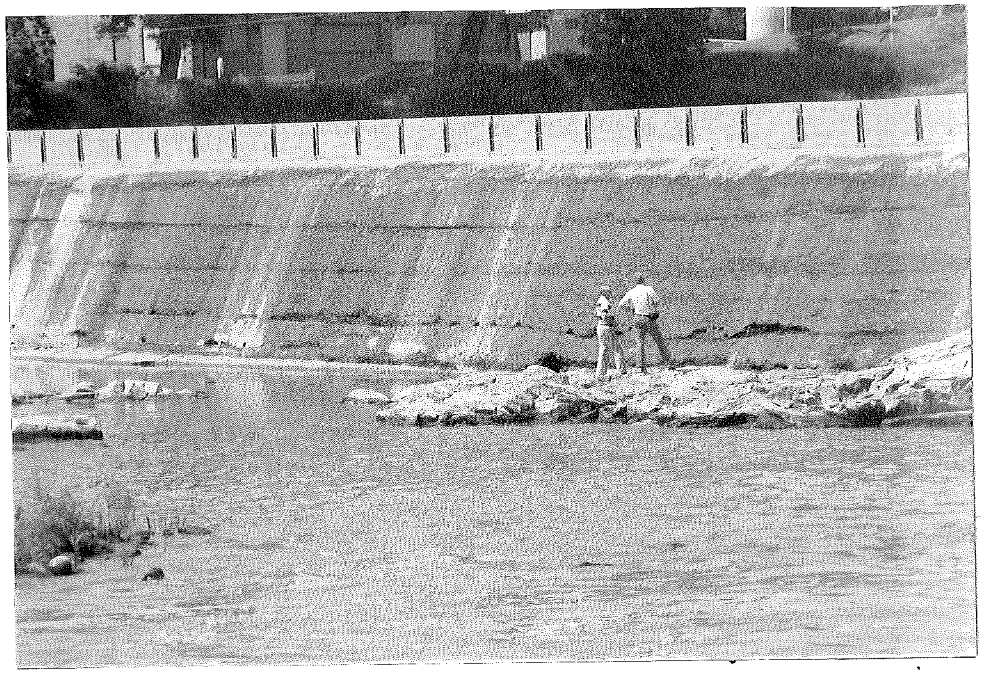


Photo 3. Right downstream face of dam showing cold joints and wood flash boards in place on dam crest.

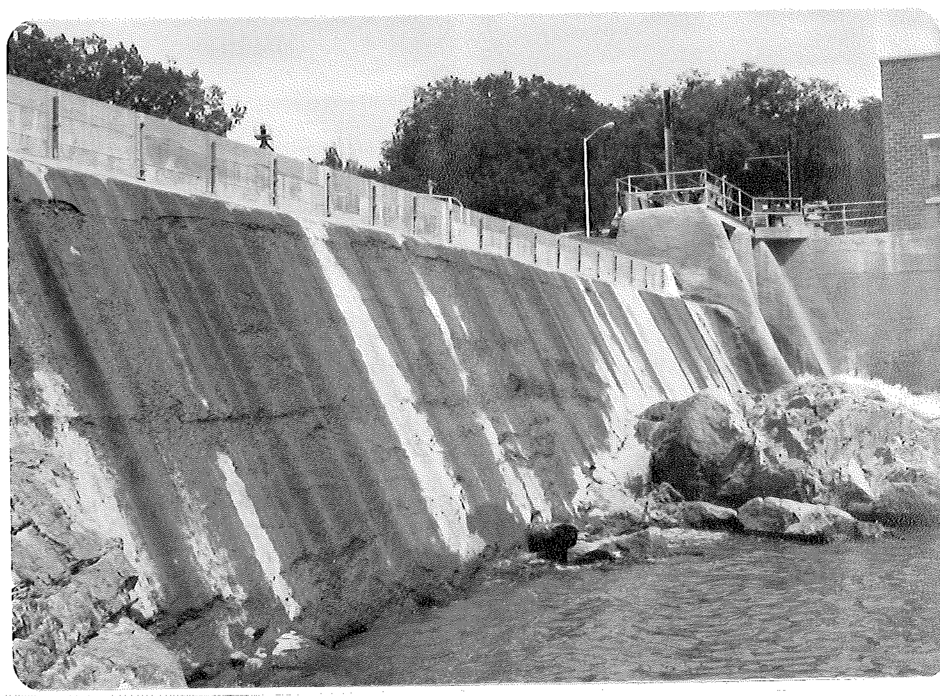


Photo 4. Left section of dam showing downstream face with gate section and powerhouse in background.

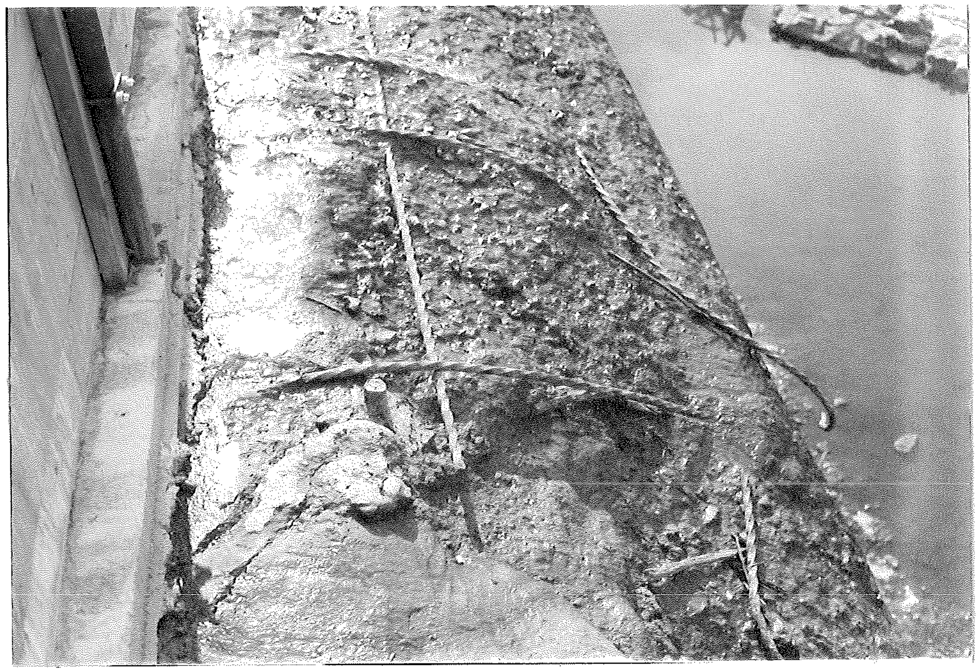


Photo 5. View of right spillway crest showing exposed aggregate and reinforcing bars.

Photo 6. Power house and gate structure at left abutment of dam.

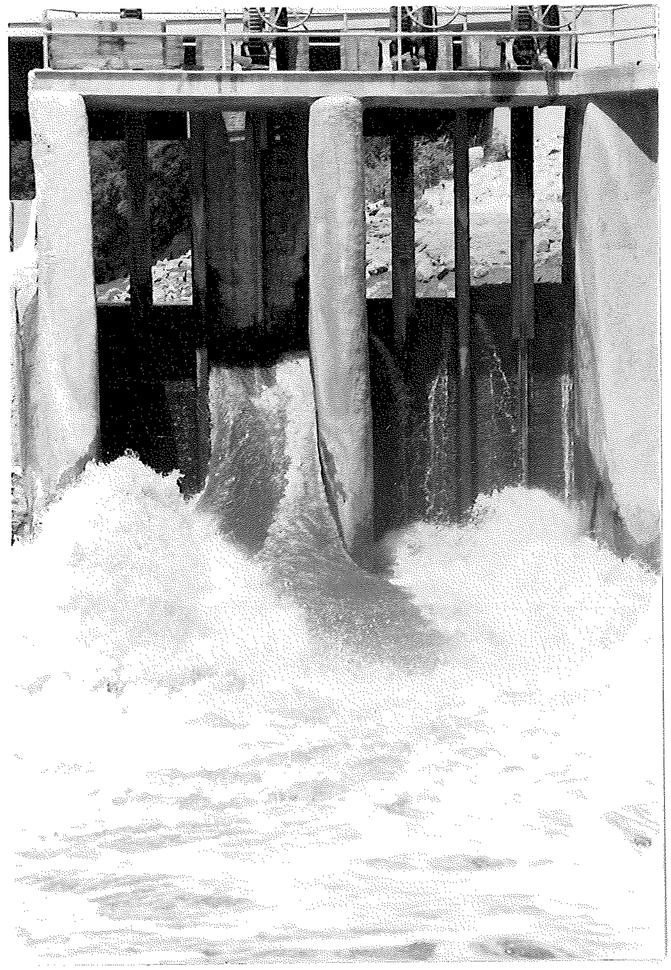


Photo 7. Discharge through the one sluice gate which is operational.

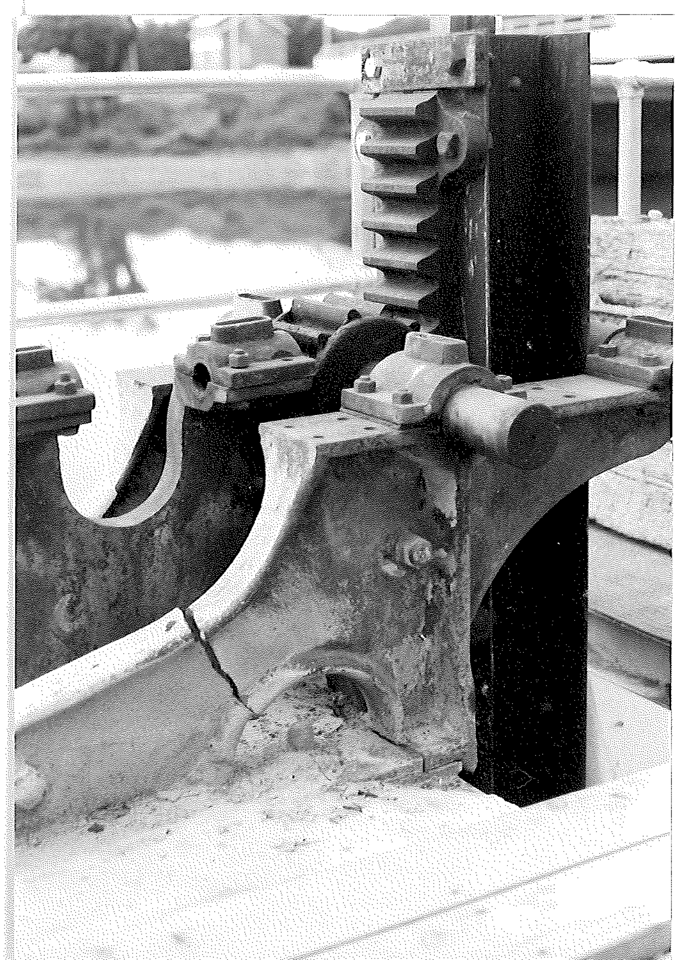


Photo 8. Broken sluice gate machinery which prevents operation of gates.

Photo 9. Headwater and tailwater at dam during the 1969 flood period.

Photo 10. Construction photograph showing the upstream face of the gravity section and the gate structures at the left abutment.