University of Minnesota
St. Anthony Falls Hydraulic Laboratory

Project Report No. 204

HYDROPOWER FEASIBILITY AT THE ST. CLOUD DAM MN 00506

by

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Prepared for

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I. INTRODUCTION

The Mississippi River Dam MN 00506 is located on the Mississippi River in St. Cloud, Minnesota. Power generation at the original dam was discontinued in 1967, at which time ownership was transferred from Northern States Power to the City of St. Cloud and plans were made to construct the present dam. The existing dam, completed in 1972, replaced the original dam which was constructed in 1887. The existing powerhouse and facilities were removed. The purpose of this study is to assess the feasibility of redeveloping hydropower production facilities at the St. Cloud Dam.

The St. Cloud Dam was included in a grant agreement dated September 22, 1980, between the Minnesota Department of Natural Resources and the St. Anthony Falls Hydraulic Laboratory for Hydroelectric Power Feasibility Studies on seven municipally owned dam sites in the State of Minnesota. The Minnesota Department of Natural Resources and the City of St. Cloud subsequently made a cost-sharing agreement for the feasibility study. Authorization to begin the St. Cloud Dam Hydropower Feasibility Study was given on November 20, 1980. A preliminary permit from the Federal Energy Regulatory Commission was awarded to the City of St. Cloud on May 22, 1981.

This study begins with a hydraulic and hydrologic analysis of the site to determine the available power. Marketing options and the value of the power are then determined. The core of the study is proposed development alternatives which include preliminary designs, project cost estimates, and the estimated power production of each alternative. Finally, the benefits and costs of each development alternative are compared and the environmental impact of the proposed development is evaluated.

II. SUMMARY AND CONCLUSIONS

The existing dam at St. Cloud was completed in 1972 for the purposes of recreation and water supply. The St. Cloud Dam consists primarily of an unregulated ogee spillway with provision for flashboard installation. There are presently no hydropower generating facilities. A Northern States Power transmission substation is located 700 ft downstream of the dam site.

The St. Cloud Dam is on the Mississippi River which is part of the Upper Mississippi River Basin. Two U.S.G.S. gages were used in the development of a flow duration curve. One gage is located near Royalton (U.S.G.S. Gage No. 05267000) with a drainage area of 11,600 sq. mi. and the other gage is located on the Sauk River near St. Cloud (U.S.G.S. Gage No. 05270500) with a drainage area of 925 sq. mi. The Sauk River discharges into the Mississippi River immediately upstream from the City of St. Cloud. The total drainage area of the St. Cloud Dam is 13,320 sq. mi. To obtain the flow duration curve for the St. Cloud Dam, the U.S.G.S. records for the two gages were combined and adjusted for the drainage area. Average annual flow at the St. Cloud Dam was similarly established to be 4970 cfs.

The Mississippi River at St. Cloud has a well established base flow throughout the year. In addition, the multiple turbine units proposed herein are sized so that they are not in operation approximately 5 per cent of the time (based upon the flow duration curve and minimum turbine discharge). This allows the site to be operated as a strict run-of-river facility with no peaking and/or drawdown required. During operation it is proposed that the headwater elevation will remain at or above the spillway crest. Each development alternative presented is a multiple combination of horizontal tubular units. Each tubular unit has a 3000 mm adjustable-blade propeller runner and fixed guide vanes. The design discharge for each unit is 1554 cfs at 16.5 ft head with a minimum discharge of 494 cfs and a rated output of 1840 kW. The alternatives considered are for 3, 4, and 5 tubular units. A plan of the four-unit option is given in Fig. 20. A section of the units is shown in Fig. 21. Performance curves for turbine and overall plant efficiencies are given in Fig. 22 for up to a four unit capacity.

Each of the development alternatives considered includes fully automatic control with headwater and tailwater elevation sensing and a microprocessor to determine the operating point of each turbine and the number of turbines on line. There will be automatic start and stop for the turbine units. This type of facility may be unmanned with weekly inspection for maintenance.

The St. Cloud Dam has provisions for the installment of temporary flashboards to aid in the inspection and repair of the spillway as described in Section VII. The opportunity to utilize permanent 2 ft flashboards during non-flood flows was investigated in addition to the non-flashboard option for each of the development alternatives. The only change required in the turbine/generator units considered is an increase in rated generator output to 2180 kW, corresponding to a rated head of 18.5 ft.

The St. Cloud Dam is located within 700 ft of a Northern States Power (NSP) transmission substation where both 34.5 kV and 115 kV transmission lines are available. An interconnection with NSP is therefore a logical market for the energy, although there is a possibility that the energy may be wheeled to another utility at current wheeling charges. A potential market also exists through a partial interconnection with St. Cloud State University. Based on data supplied by St. Cloud State University, the University had a demand for electricity during 1980 in the 3.5 to 4 MW range. The average payment for power (excluding demand payments) was $0.025/kWH. Currently all transmission lines and equipment are operated and maintained by NSP. Therefore, if this market is considered in the design phase, contractural arrangements using NSP's facilities would have to be pursued.

The Public Utility Regulatory Policy Act of 1978 (PURPA) and the subsequent Federal Energy Regulatory Commission (FERC) regulations were intended to encourage production of electric power by cogeneration and by small power producers of less than 80 MW who utilize renewable resources. These small power producers are termed Qualifying Facilities in the regulations. The regulations specify that a utility must purchase power from qualifying facilities at its avoided incremental cost, i.e., the costs the utility would otherwise incur to obtain an equivalent amount of electricity.

Northern States Power's estimated annual avoided energy cost was obtained from NSP [4] for the period 1980 to 1985 and is equal to 1.38 cents/kWH (1981 base year). The annual avoided capacity cost for NSP, calculated on the basis of the Proposed Rules of the Public Utilities Commission (PUC), is 2.1 cents/kWH (1981 base year).

The major differences between the development alternatives are 1) number of units installed (3, 4, or 5 units) and 2) plant operation with and without flashboards. The economic analysis in Section IX indicates that there is no significant economic feasibility difference between installations with three or four tubular units, as represented by net present value. Both types of installations indicate excellent feasibility. A proposed installation with five tubular units gave inferior economic indicators.

The economic analysis clearly demonstrates the economic superiority of a hydropower facility operated with two-foot flashboards installed on the spillway crest during non-flood flows. The cost of installing the flashboards is small, compared with the potential benefits.

An economic sensitivity analysis indicates that typical variations in project parameters and economic assumptions will not alter the positive feasibility of the proposed development. Variations in the value of energy, initial project cost, operation, maintenance and replacement costs, discount rate, and escalation rate were considered. In addition, the impact of a loss of dependable capacity credit and of a dry year upon cash flow were investigated.

The potential environmental impacts of the proposed development are minor, since no new impoundment will be developed and hydropower plant operation will be strict run-of-river. The greatest potential impacts would occur during construction, when dredging and other activities may impair water quality or interfere with fish spawning. Fish sampled in the Mississippi River near St. Cloud have higher than normal mercury concentrations. This is an indication that there may be a high concentration of mercury compounds in the river sediments.

III. RECOMMENDATIONS

1. The St. Cloud Dam is an economically feasible project for hydropower development.
2. If possible, two foot flashboards should be installed on the spillway crest during non-flood flows during hydropower facility operation.
3. This feasibility study concluded that a hydropower facility with three or four horizontal tubular units and a total capacity of 5.5 MW or 7.4 MW, respectively, will give the optimum economic return. Other combinations of turbine units should be considered in the design phase of the project development.
4. The facility should be operated on a strict run-of-river basis with no peaking and/or drawdown.
5. The energy and power from development may be sold to Northern States Power or through confractural arrangement with other municipal utilities or St. Cloud State University.
6. Analysis of the sediments behind the dam should be conducted prior to construction activity to determine whether or not contaminents are contained therein.
7. The effects of frazil ice formation upon hydropower production should be analyzed in greater depth. A more accurate tailwater curve is also required in the design phase of hydropower development at the St. Cloud Dam.
8. The Dam Safety Recommendations as outlined in Ref. [1] should be met.
9. Close coordination with applicable state and federal agencies in the final design phase is strongly recommended to insure that all potential environmental impacts are evaluated and mitigated.

IV. SITE CHARACTERISTICS AND EXISTING FACILITIES

A. Site Description and Location

The St. Cloud Dam MN 00506 is located on the Mississippi River within the City of St. Cloud approximately 500 feet below the 10th Street Bridge. St. Cloud, Minnesota, is located in Section 1 T.35N, R.31W, 75 miles northwest of St. Paul, Minnesota. The site location is shown in Fig. 1. The dam consists of a concrete, fixed crest spillway 19.5 ft high and 550 ft long centered on the river. It is flanked on the right bank by an earth embankment approximately 420 ft long with a top width of 28 ft and an elevation 12.5 feet higher than the spillway crest. On the left bank a concrete wall and earth embankment extends from the spillway a distance of 200 ft to high ground. The top of the wall is 16 ft above the spillway crest. Training walls extend from the spillway crest to a point approximately 180 ft downstream, thus confining the width of flow to 550 ft immediately below the dam [1].

A plan view and typical cross sections of the existing dam are given in Figs. 2 through 4. The reservoir lies in a deep, wooded valley that varies in width from 500 to 1000 feet, and extends from the dam to a point 2.6 miles upstream. A water treatment plant, the St. Cloud State University, city parks, and numerous residences are located in the area. Northern States Power (NSP) has a substation located 700 ft downstream of the dam on the right bank. Transmission line capacities are 34.5 kV and 115 kV. There are presently no existing hydropower facilities at the site. The old powerhouse and intake/outlet facilities have been removed. Only a portion of the foundation remains. The main component of the dam is the unregulated ogee spillway crest. Located approximately 1-1/2 miles upstream from the dam is the water supply intake for the City of St. Cloud. Water supply and recreation are two of the major purposes of the dam at the present time. This reach of the Mississippi River is included in the State Wild and Scenic River system. Photographs of the existing ogee spillway, earth embankment as well as photographs of the abandoned and proposed powerhouse locations are given in Figs. 5 through 12.

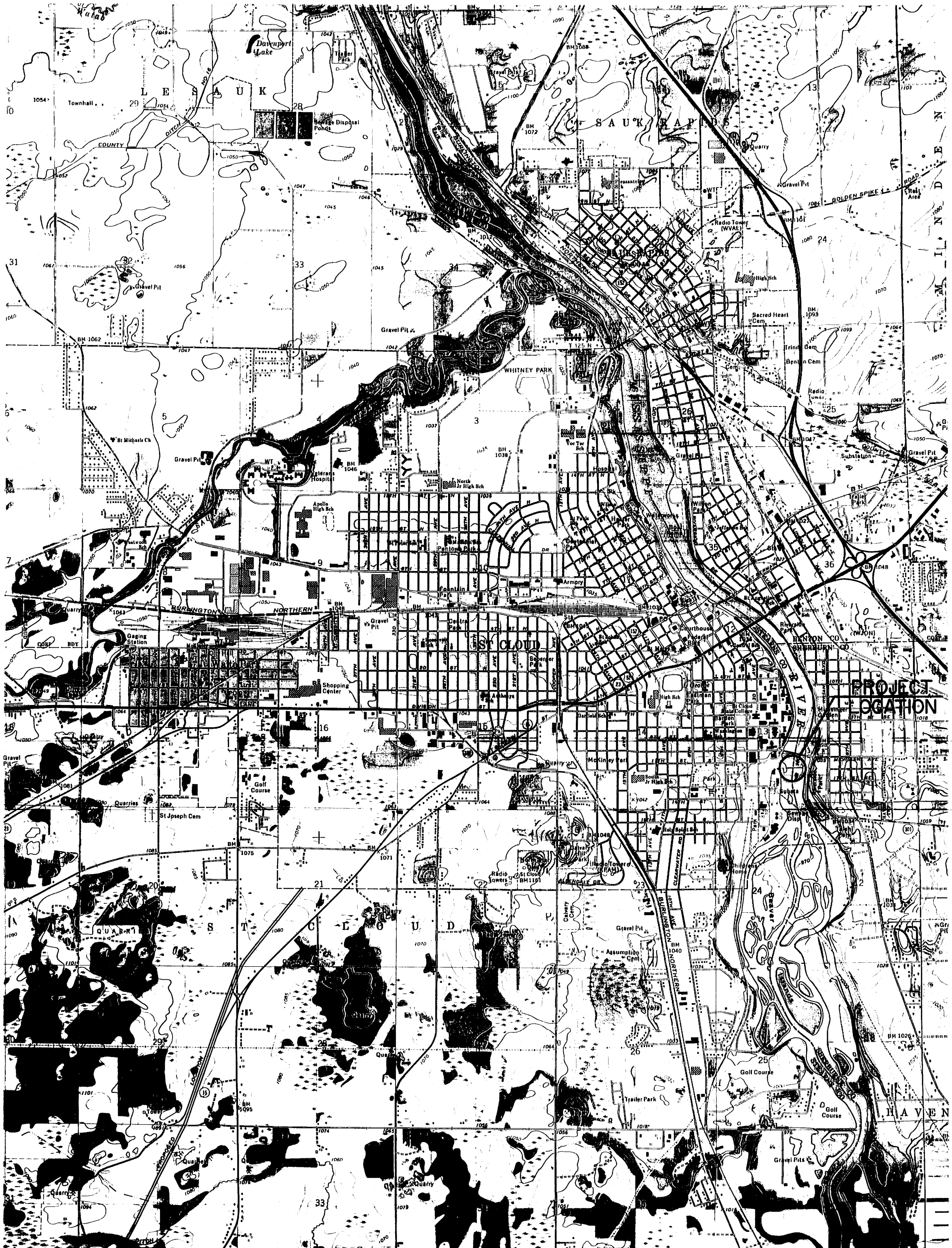

Fig. 1. Project Location.

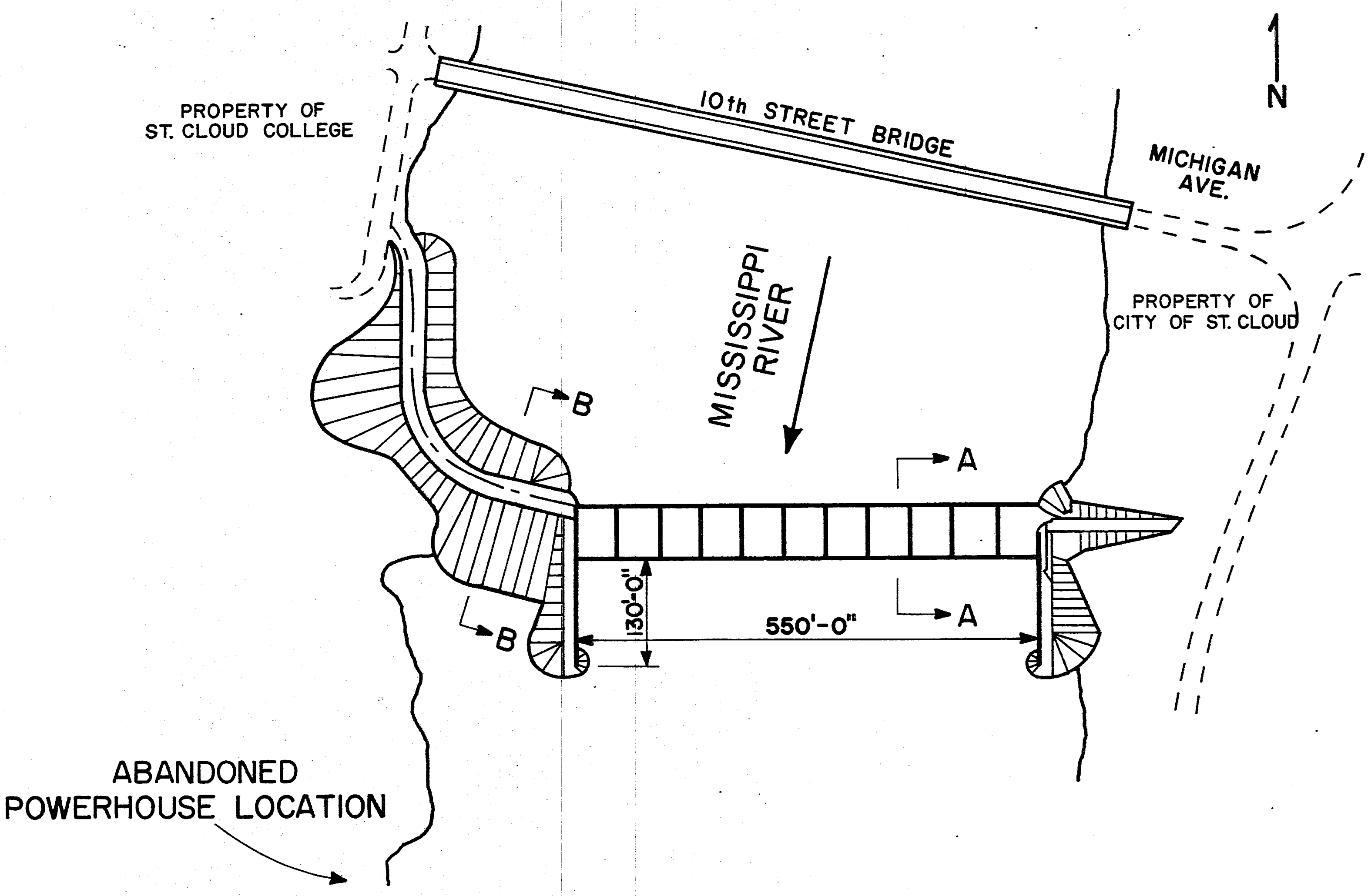

Fig. 2. Plan of Mississippi River at St. Cloud Dam [1].

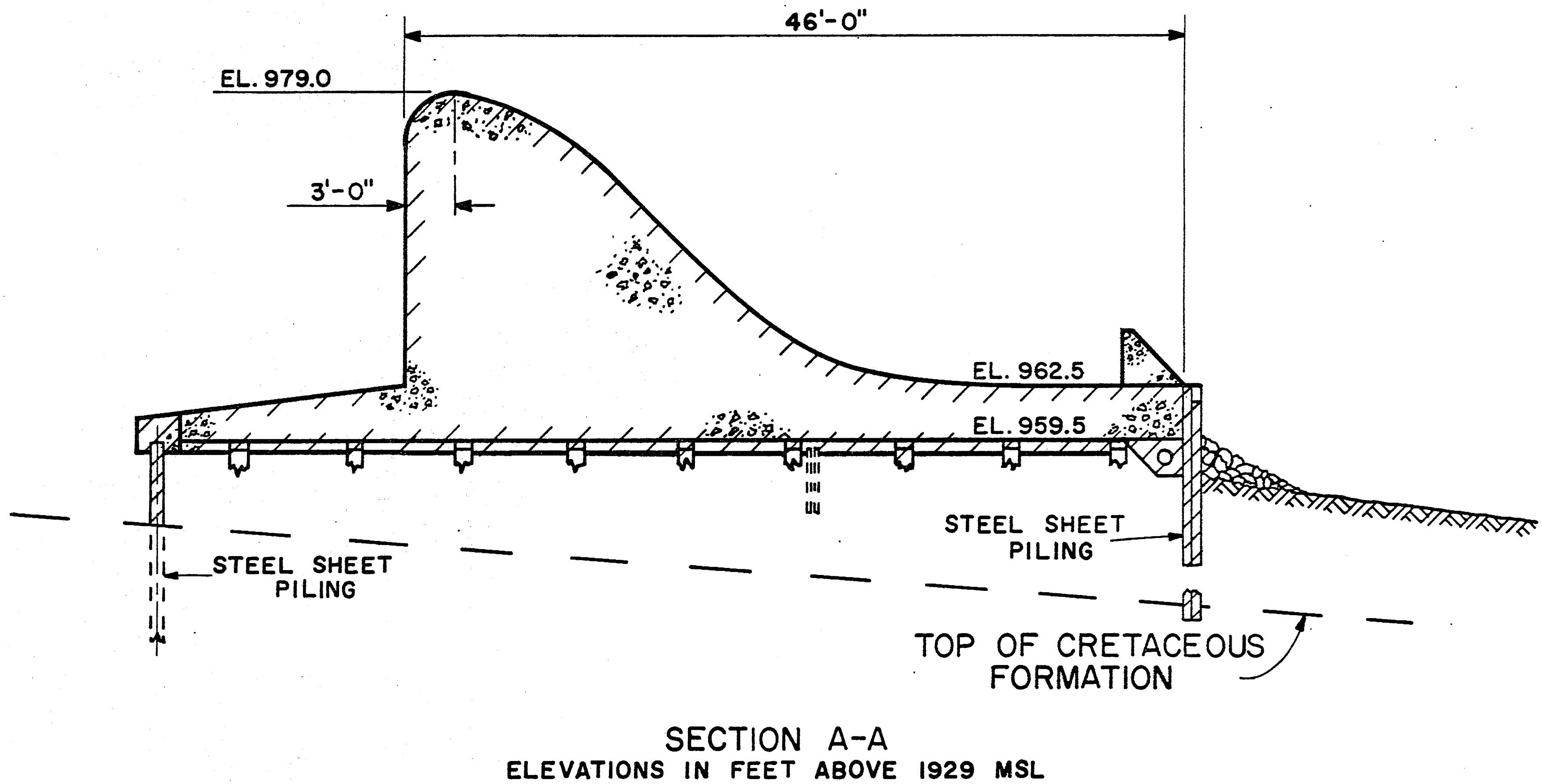

Fig. 3. Section A-A Through Ogee Spillway Crest [1].

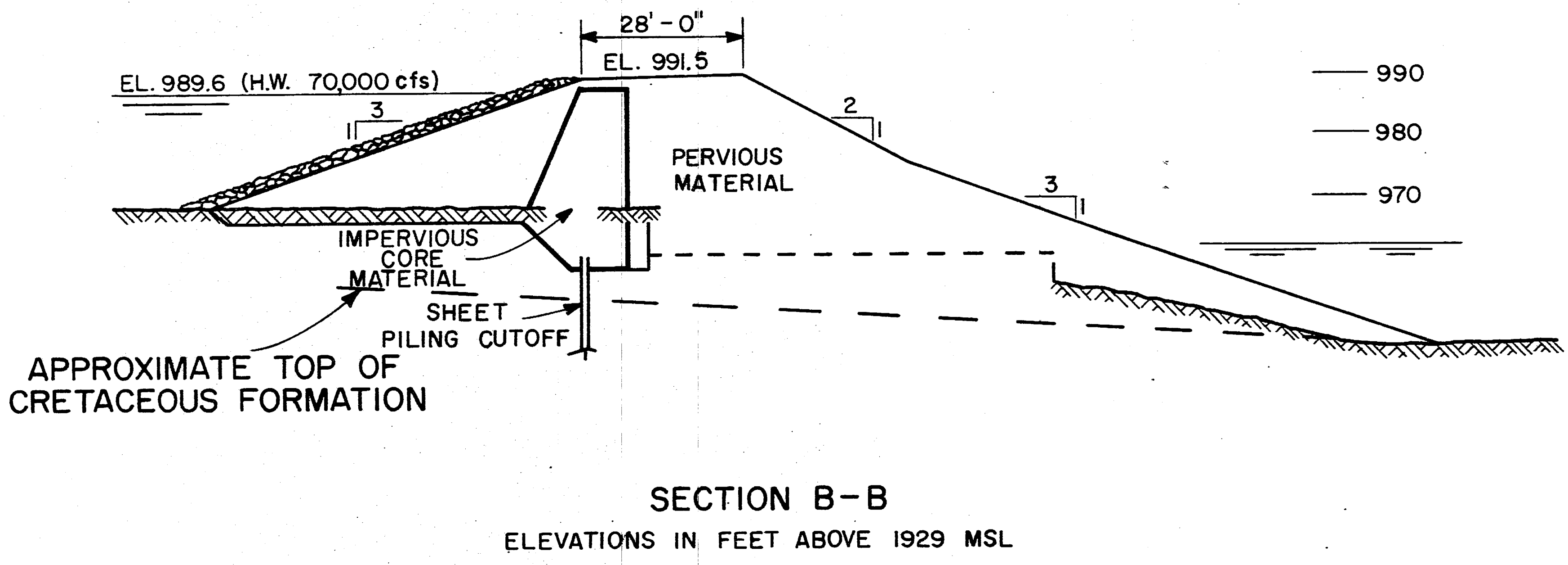

Fig. 4. Section B-B Through Earth Embankment [1].

Fig. 5. View from Right Bank Showing Unregulated Ogee Spillway and 10th Street Bridge in Background.

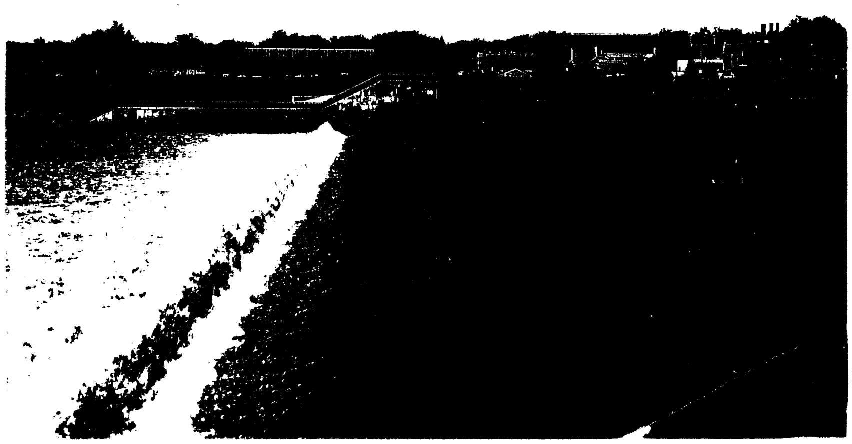

Fig. 6. View from Left Bank Showing Ogee Spillway with Stilling Blocks.

Fig. 7. View of Right Bank Showing Spillway and Proposed Site Location at Right-Center. Abandoned Powerhouse is Located on Left.

Fig. 8. Location of Abandoned Powerhouse Foundation and Outlet Works on Right Bank. Note St. Cloud State University in Background.

Fig. 9. View of Right Bank Headwater from 10th Street Bridge (proposed location of powerhouse).

Fig. 10. Right Bank Looking Upstream. Abandoned Powerhouse and Existing Substation are Located Near Rip-Rap in Left of Photo. Proposed Powerhouse to be Located in Earth Embankment (center of photo).

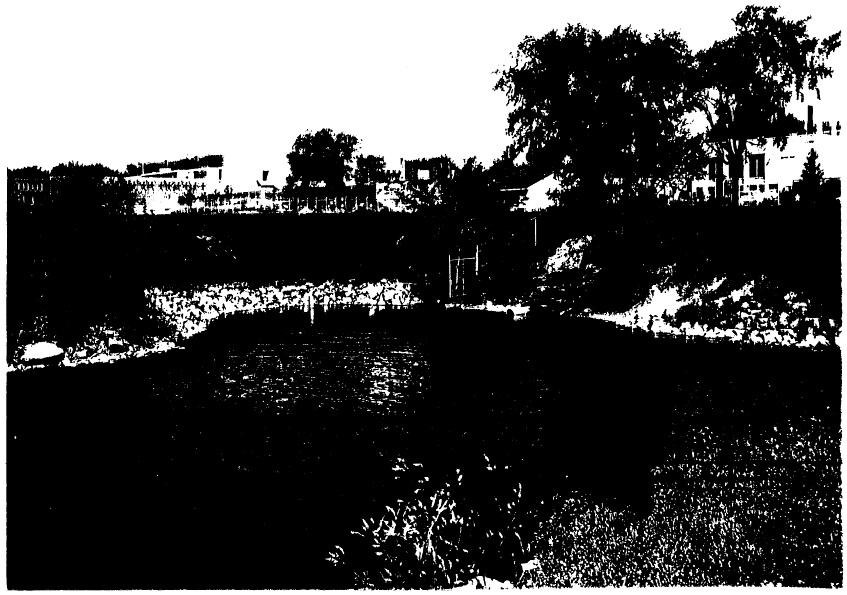

Fig. 11. View of Earth Dam and Lagoon Area. Proposed Location of Powerhouse and Tailrace.

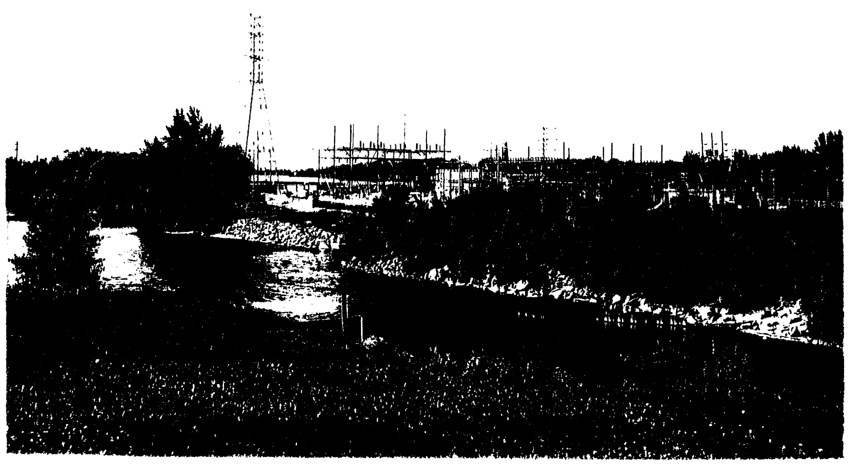

Fig. 12. View from Earth Embankment Showing Proposed Tailrace Area. Note NSP Substation, Riprap, Sheet Piles and Tailwater Gage.

B. Historical Background

A chronology of developments at the Mississippi River Dam since 1887 is presented below. Data were gathered from several sources, including "Mississippi River Dam Inventory #506" of the National Dam Safety Inspection Report [1], "Operation Manual for St. Cloud Dam, St. Cloud, Minn." [2], and "Engineering Report on Effects of Lower Mississippi Water Levels on Existing Water Supply Facilities" [3].

1887	A rock-filled timber crib dam was built at the site by the St. Cloud Water Power and Mill Company by Act of Congress. The purpose of the dam was to supply water power for flour milling purposes.
1924	Northern States Power (NSP) assumed ownership and operation of the dam.
1931-35	Major repairs were made to the original structure. The dam was removed to the tailwater elevation and a similar dam was reconstructed to maintain a headwater elevation of 981.0.
1961	NSP had problems with seepage and downstream erosion. A report stated that power generation was no longer economically feasible.
1967	NSP discontinued power generation and the pool was lowered approximately 6 feet. Ownership was transferred to the City of St. Cloud. It was apparent that major repairs were necessary to preserve the dam.
1969-72	The present dam was constructed to replace the old dam. The new dam was designed by Barr Engineering Company, Minneapolis, Minnesota.
1976	The St. Cloud Dam was included in a State Wild and Scenic River designation for the Mississippi River.

C. Dam Integrity

The St. Cloud Dam was inspected in 1978. The National Dam Safety Inspection Report [1] concluded that the overall condition of the dam was good. In addition, the Dam Safety Report [1] recommended that modifications be made to the earth embankments to increase the safe discharge capacity. This constituted the only major recommendation regarding the safety of the dam.

In order to fully comply with current dam safety criteria, the dam should be evaluated for a discharge of 100,000 cfs. This capacity can be accommodated by raising the west earth embankment by 3.5 ft. It was recommended that this modification be made as soon as practicable [1]. A vertical crack approximately 1/4 inch wide has developed at the construction joint between the east retaining wall of the spillway monolith. Similarly, there has been a lateral movement of 1 inch between the east retaining wall and the spillway monolith wall. Neither of these openings presents a safety hazard. It was recommended that the movements of these three independent structures be accurately monitored at periodic intervals. Furthermore, it was recommended that brass plugs be installed in several locations on both sides of the crack and precise measurements be taken at periodic intervals to determine direction and magnitude of movements involved. This data should then be analyzed in an attempt to determine the cause of the cracks and the need for remedial treatment.

There does not appear to be a high risk of sudden catastrophic failure of this dam. The design has provided for control of seepage, reduction of hydraulic gradients, protection of slopes and provision for scour protections. There are also provisions in the operation of the dam to monitor the pressures in piezometers and to check for changes in the scour patterns. The Dam Safety Report also recommended that the design manual be modified to define the elevation of scour below which remedial action is necessary. Finally, it was recommended that the scour monitoring program prescribed in the operating manual be continued and the elevation of critical scour be more specifically defined [1].

The Dam Safety Report verifies that the dam is properly classified as "high hazard" because of the presence of residences and industrial development on the fringe of the flood plain downstream.

V. HYDRAULICS AND HYDROLOGY

A. Flow Duration and Reservoir Storage

The St. Cloud Dam MN 00506 is on the Mississippi River which is part of the Upper Mississippi River Basin. Two U.S.G.S. gages were used in the development of a flow duration curve. One gage is located near Royalton (U.S.G.S. Gage No. 05267000) with a drainage area of 11,600 sq. mi. and the other gage is located on the Sauk River near St. Cloud (U.S.G.S. Gage No. 05270500) with a drainage area of 925 sq.mi. The Sauk River discharges into the Mississippi River immediately upstream from the City of St. Cloud. The total drainage area of the St. Cloud Dam is 13,320 sq. mi. To obtain the flow duration curve for the St. Cloud Dam, the U.S.G.S. records for the two gages were combined and adjusted for the drainage area. The resulting curve is shown in Fig. 13. Average annual flow at the St. Cloud Dam was similarly established to be 4970 cfs.

Flow duration curves were also computed for each month over the period of record and are shown in Fig. 14. The driest and wettest years of record are water years (October through September) 1977 and 1966, respectively. The flow duration curves for these years are shown in Fig. 15.

The St. Cloud Dam has little or no capacity for seasonal or daily peaking. If two foot flashboards are added (see Sections VII and VIII) the potential for additional power will be significantly increased. The river provides sufficient base flow such that a strict run-of-river operation is best suited as a mode of operation for the St. Cloud Dam.

B. Headwater and Tailwater Elevations

A headwater curve was developed using the equation

$$Q = CLH_c^{3/2}$$

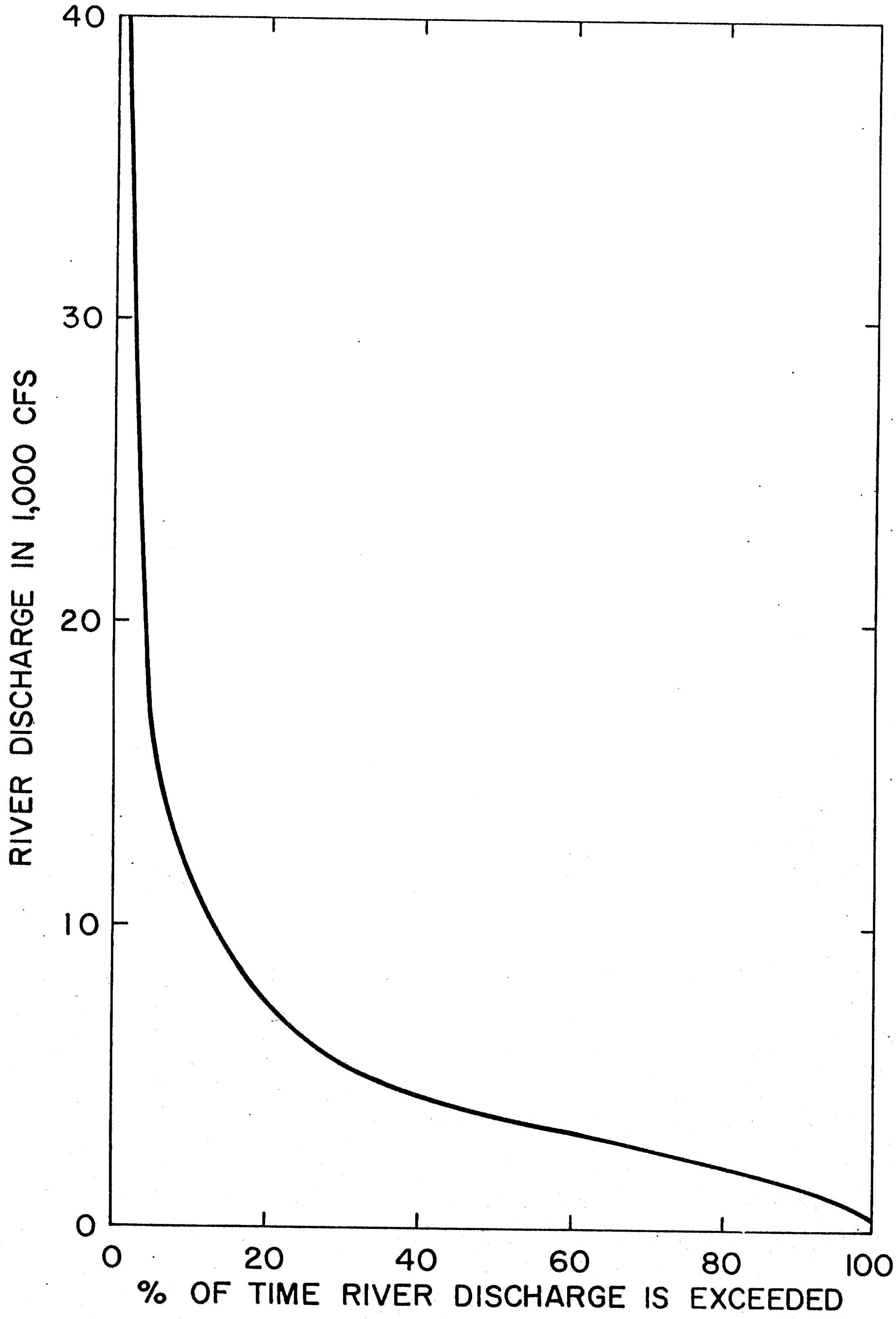

Fig. 13. Flow Duration Curve at St. Cloud Dam.

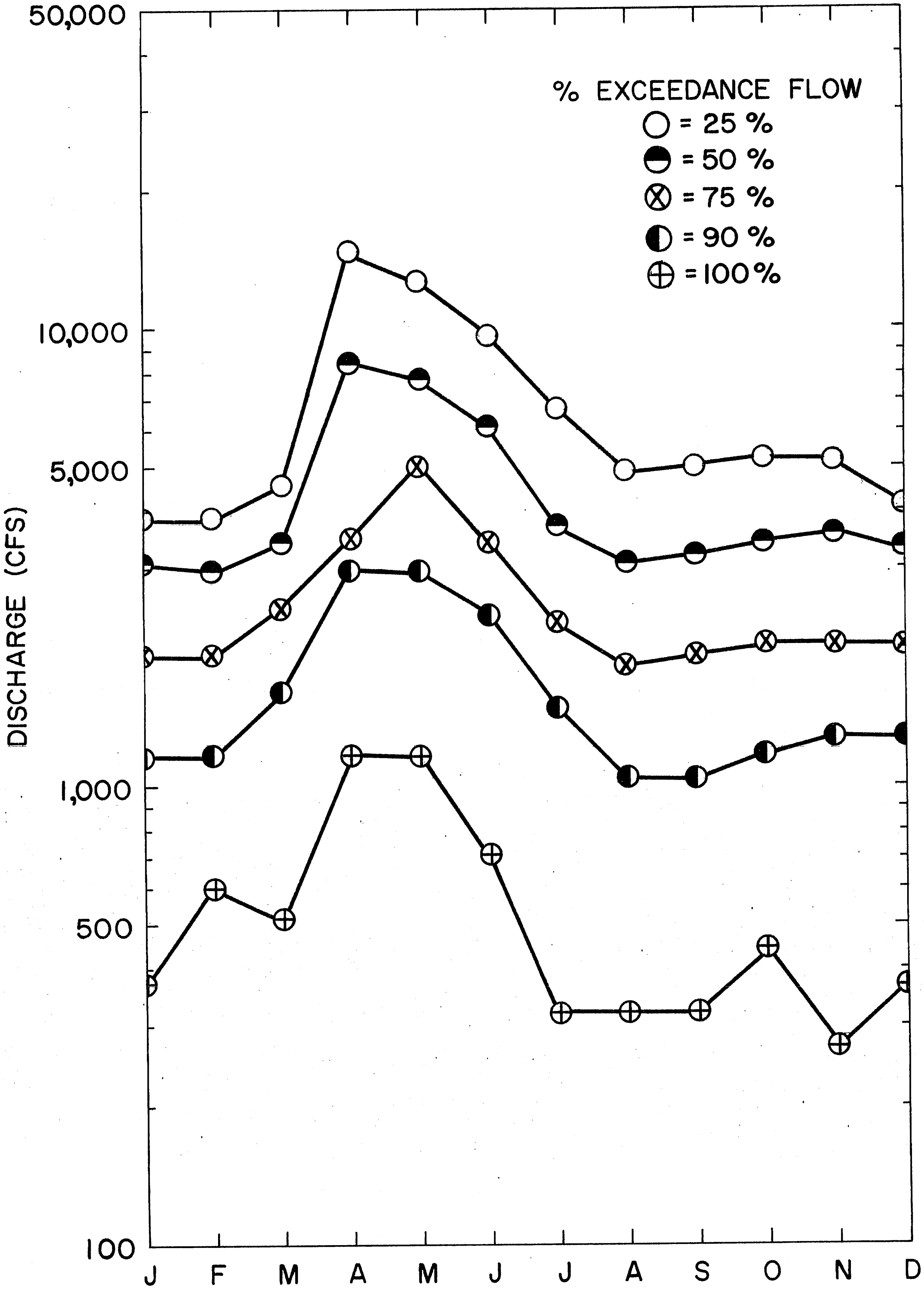

Fig. 14. Summary of Monthly Flow Duration Curves at St. Cloud Dam.

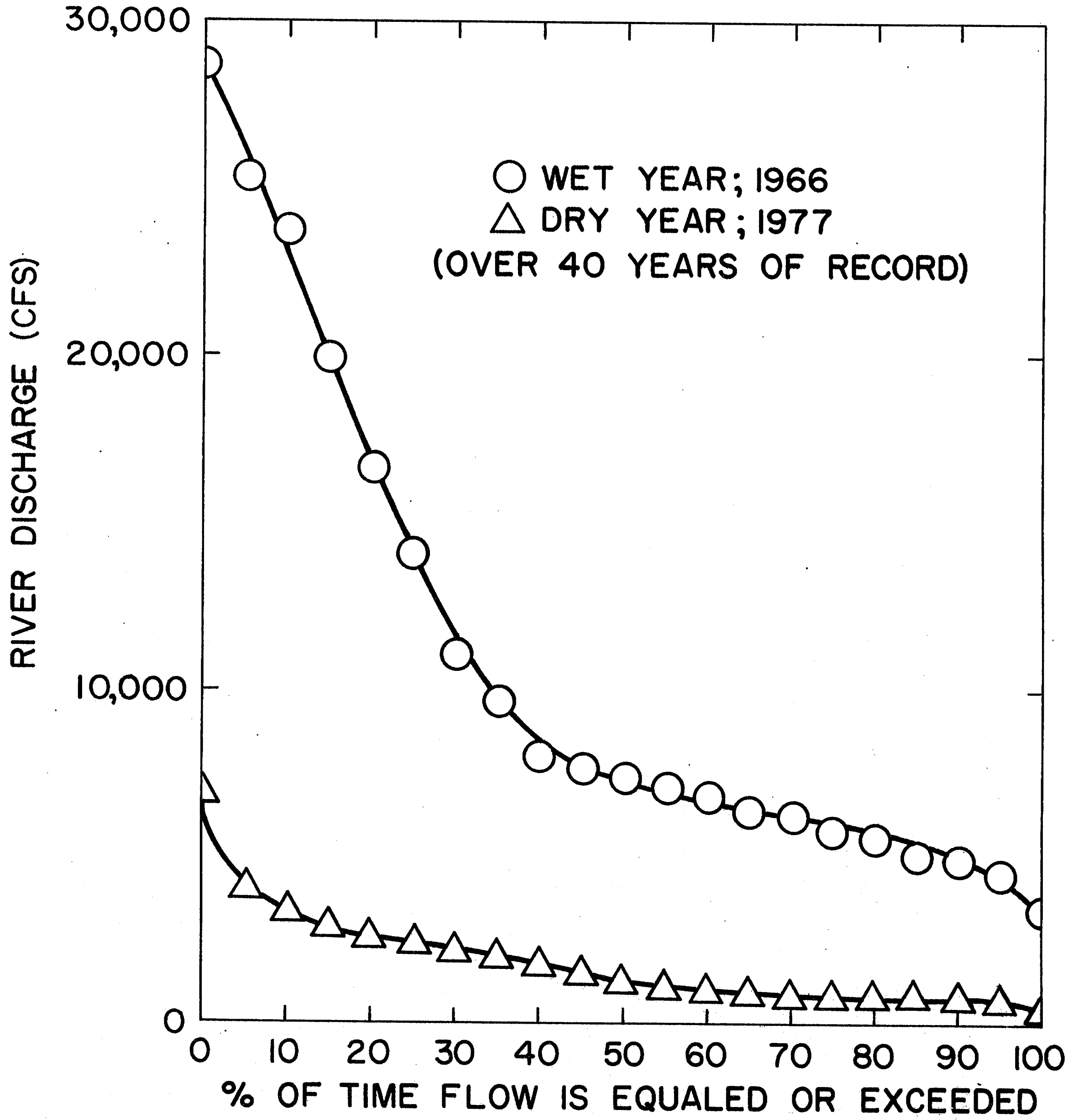

Fig. 15. Flow Duration Curves for Wet and Dry Years at St. Cloud Dam.

where: Q = discharge (cfs)

C = variable coefficient of discharge

L = effective length of spillway crest

H_c = total head on crest (including approach velocity head)

According to Barr Engineering Co. design data, the design flood is 70,000 cfs, the length of the spillway crest is 550 ft, and the corresponding theoretical value of C is 3.88. The actual C value varies between 3.7 and 3.9 (due to inherent construction imperfections). A value of 3.7 was used for the design flood and appropriate adjustments in the coefficients were made for lower flows and velocity head in the preparation of the stage discharge curve.

The headwater curve is shown in Fig. 16. A curve developed independently using design criteria developed by the U.S. Army Corps of Engineers, Waterways Experiment Station, compared well with this headwater rating curve. The headwater curve used in this feasibility study assumes the reservoir is held at the spillway crest until the river discharge equals the design discharge of the turbines (note title on abcissa). Upon reaching flows greater than the turbine design discharge, headwater elevation is determined from the curve given in Fig. 16.

The tailwater elevation curve given in Fig. 17 was determined from Ref.[2] and is originally based upon NSP records. During periods of ice cover on the Mississippi River, the tailwater curve will be approximately 1 ft higher for any particular discharge than shown on this curve. The Dam Safety Inspection Report [1] states that at the present time, the tailwater rating curve is poorly defined and a more accurate definition would be valuable in a review of scour patterns below the dam.

Headwater and tailwater elevation measurements were made during a field inspection of the Dam on July 9, 1981. In addition, Ref. [1] gives one set of measured headwater and tailwater elevations on July 7, 1978. These measured elevations are:

	7/9/81	9/7/78
Headwater Elevation	981.2 (MSL)	981.5 (MSL)
Tailwater Elevation	963.5 (MSL)	963.6 (MSL)

These elevations correspond reasonably well with the curves given in Figs. 16 and 17.

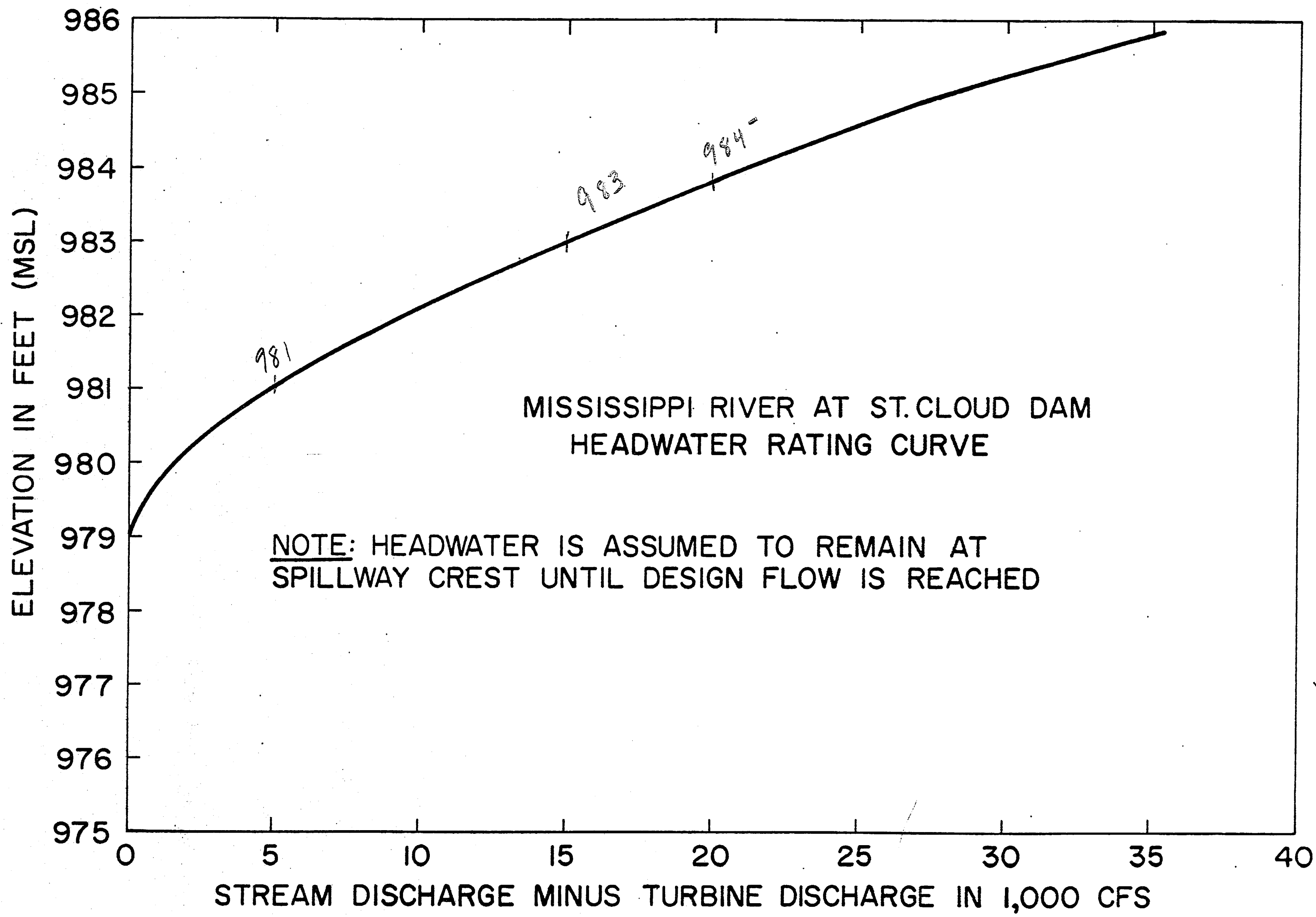

Fig. 16. Headwater Elevation Curve for the St. Cloud Dam.

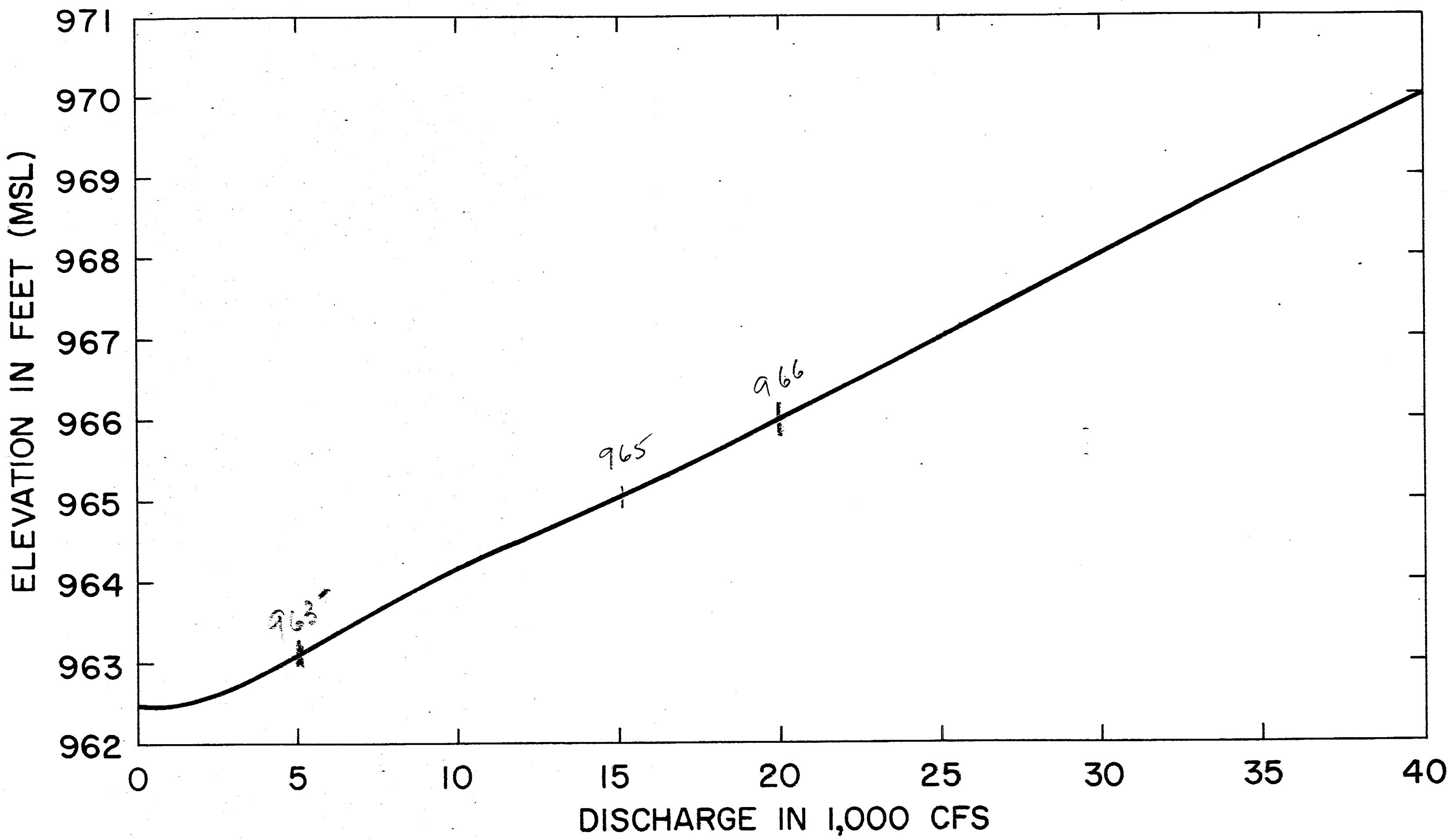

Fig. 17. Tailwater Elevation Curve for the St. Cloud Dam.

C. Spillway Design Flood

The design flood (standard project flood) for the St. Cloud Dam was computed based upon a compromise between a minor classification (100 yr recurrence interval; 62,000 cfs) and an intermediate classification (200 yr - 125,000 cfs) [2]. Classifications are danger potentials determined by the Corps of Engineers as determined by the peak discharge of a flood wave immediately downstream of the dam by a sudden dam failure. The compromise consisted of designing the structure for 70,000 cfs (200-year recurrence interval) with consideration given to the effects of a flood wave of 125,000 cfs. The physical dimensions and ultimate strength of the new concrete structure allows flows and headwaters which accompany a flood of 125,000 cfs. The spillway is structurally designed to accept loads imposed on it by a flow of 70,000 cfs utilizing accepted factors of safety [2]. The earth dam on the west side of the installation is designed with a 1.5 ft free board over the 70,000 cfs design flood. In cases of flows higher than 70,000 cfs, it will be necessary to sandbag or build up the top elevation of the earth dam to accommodate the increase in stage.

The maximum known flood to occur was in 1965 with an estimated peak flow of 52,800 cfs. The next major flood occurred in 1969 with an estimated peak flow of 45,400 cfs. The headwater level corresponding to the 100 year flood is approximately 988.6 ft above MSL, which is important in locating the switchyard and in the final design of the powerhouse.

VI. POWER VALUE AND MARKETING

A. Background

The Public Utility Regulatory Policy Act of 1978 (PURPA) and the subsequent Federal Energy Regulatory Commission (FERC) regulations were intended to encourage production of electric power by cogeneration and by small power producers of less than 80 MW who utilize renewable resources. These small power producers are termed Qualifying Facilities in the regulations. The regulations specify that a utility must purchase power from qualifying facilities at its avoided incremental cost, i.e., the costs the utility would otherwise incur to obtain an equivalent amount of electricity.

The FERC delegated the responsibility of determining avoided incremental costs and overseeing PURPA implementation to the public utility regulatory commission from each state. The Minnesota Public Utilities Commission (PUC) approved a draft proposed rule on Cogeneration and Small Power Production on February 19, 1981. In addition, the 72nd session of the State of Minnesota Legislature passed House File No. 473 which essentially extended the proposed PUC rules to all Minnesota electric utilities, including cooperative electric associations and municipal electric utilities. The proposed rules state that "for qualifying facilities with capacity greater than 100 kW (now changed to 40 kW), the customer shall negotiate a contract with the utility which shall set the applicable rates for payments to the customer of avoided capacity and energy costs." The proposed rule does offer guidelines, however, to use in the determination of avoided incremental costs. Those guidelines are used herein to determine the value of hydroelectric power which would be produced at the St. Cloud Dam.

B. Marketing

The St. Cloud Dam is located within 700 ft of a Northern States Power (NSP) transmission substation where both 34.5 kV and 115 kV transmission lines are available. An interconnection with NSP is therefore a logical market, although there is a possibility that the energy may be wheeled to another utility at current wheeling charges. A potential market also exists through a partial interconnection with St. Cloud State University. Based on data supplied by St. Cloud State University during 1980, the University had a demand for electricity in the 3.5 to 4 MW range. The average payment for power (excluding demand payments) was $0.025/kWH. Currently all transmission lines and equipment are operated and maintained by NSP. Therefore, if this market is considered in the design phase, contractural arrangements using NSP's facilities would have to be pursued. The economic return of the project with an energy value of $0.025/kWH is given in Section IX.C.

C. Value of Energy and Power

Northern States Power's estimated annual avoided energy cost was obtained from NSP [4] for the period 1980 to 1985 and is equal to 1.38 cents/kWH (1981 base year). The annual avoided capacity cost for NSP was calculated on the basis of the Proposed Rules of the Public Utilities Commission (PUC). The proposed rules of the Public Utilities Commission state that

> "Any Qualifying Facilty Offering electricity to a utility which has capacity additions planned for the ensuing ten years shall be entitled to payment for the present value of such future capacity including if the Qualifying Facility contributes to an aggregate capacity value to the utility."

For the Qualifying Facilities with greater than 40 kW capacity, this capacity payment is to be negotiated. The Proposed Rules do provide a method of computing a utility's avoided capacity cost in cents/kWH, which is a starting point for negotiations and will be used herein. This method is as follows:

1. "The completed cost per kilowatt of the utility's next major generating facility addition shall be multiplied by the utility's Marginal Capital Carrying Charge. The Marginal

Capital Carrying Charge used shall be the utility's actual calculated rate, but in no event shall the rate used be less than 20% unless the Commission shall find, after notice and hearing, that a lesser rate is appropriate."

2. "The dollar amount resulting from the calculation set forth in the preceding paragraph shall then be discounted to present value from the in-service date of the generating unit. The discount rate used shall be the utility's last authorized overall rate of return."

3. "The dollar per kilowatt figure as discounted to present value shall then be divided by the projected average number of kilowatt-hours per kilowatt per year the plant will generate during its useful life. The resulting figure is the utility's Annual Avoided Capacity Cost in dollars per kilowatt hour."

Using the above method and assuming a 20 per cent scheduled and unscheduled outage rate, NSP's annual avoided capacity cost is 2.1 cents/kWH (1981 base year), based upon addition of a third unit at the NSP Sherburne Plant.

A portion of the energy generated by a hydropower facility will qualify for capacity payment. There is currently no method to determine capacity payments for small hydropower facilities which is accepted throughout the industry.* Coal fired power plants have a 10 to 15 per cent unscheduled outage rate. This would correspond to capacity credit for hydropower available 90 per cent to 85 per cent of the time (exceeding 90% to 85% on the flow duration curve). The Bureau of Reclamation (Bu Rec) recognizes that a hydropower facility should also receive additional credit for intermittent capacity, e.g. capacity that is available most, but not all of the time. The Bu Rec formula for capacity credit is as follows [5].

$$CC = C_c * [E_{90} + \frac{1}{2} (E_{75} - E_{90}) + \frac{1}{4} (E_{50} - E_{75})] \quad (1)$$

*Pacific Gas and Electric Company and Southern California Edison Company have developed standard criteria for capacity payments to hydropower facilities.

where CC = capacity credit ($),

C_c = value of capacity (annual avoided capacity cost, $/kWH),

E_{90} = energy which is available 90 per cent of the time (annual kWH).

The terms used in Eq. 1 are given for a typical power duration curve in Fig. 18. The energy terms in Eq. 1 are equal to the corresponding area under the power duration curve.

The average annual income generated by a hydropower facility is therefore

$$AI = C_E * AAE + CC \tag{2}$$

where AAE = average annual energy production (kWH),

AI = annual income for sale of power to a utility ($),

CC = capacity credit ($),

C_E = value of energy (utility's avoided energy cost)($/kWH).

The two values, C_E = 1.38 cents/kWH) and C_c = 2.1 cents/kWH (for NSP) were used in the above equations to determine capacity credit and annual income for each proposed hydropower development at the St. Cloud Dam.

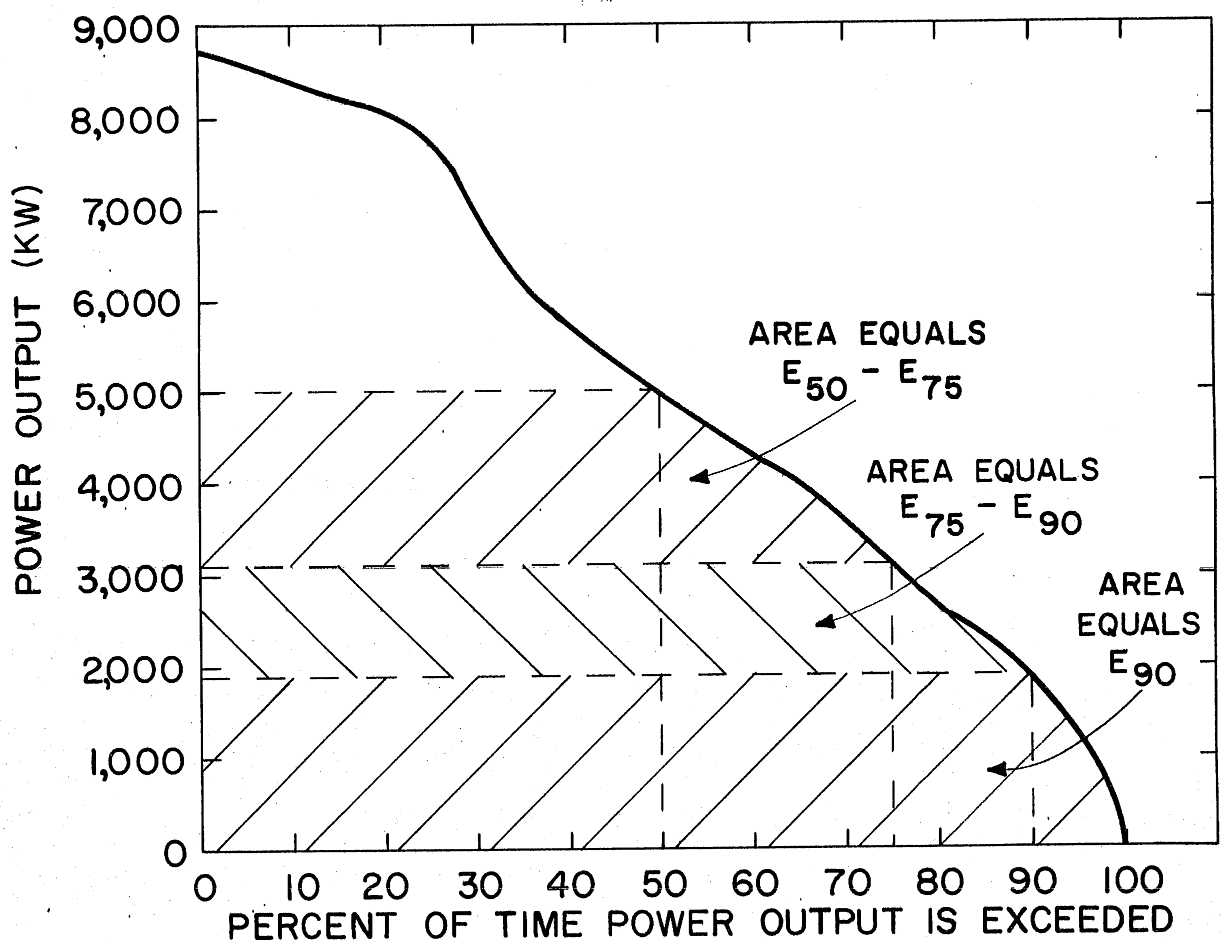

Fig. 18. Typical Power Duration Curve for the Computation of Capacity Credit in Equation 1.

VII. FACILITY OPERATION

The Mississippi River at St. Cloud has a well established base flow throughout the year. In addition, the multiple turbine units proposed herein are sized so that they are inoperable for approximately 5 per cent of the time (based upon the flow duration curve and minimum turbine discharge). This allows the site to be operated as a strict run-of-river facility with no peaking and/or drawdown required. The number of turbine units for each alternative development are summarized in Section VIII.

The operation of the powerhouse facility should be consistent with the operational scheme for the dam as outlined in Refs. [1] and [2].

Each of the development alternatives considered herein (Section VIII) includes fully automatic control with headwater and tailwater elevation sensing and a microprocessor to determine the operating point of each turbine and the number of turbines on line. There will be automatic start and stop for the turbine units. This type of facility may be unmanned with weekly inspection for maintenance.

According to the Dam Safety Report, at times it will be necessary to install temporary flashboards on portions of the crest of the dam for diversion and to facilitate inspection and repair of the apron and baffles. Four inch steel pipe sleeves have been embedded at 8 ft, 1 inch, intervals along the crest to facilitate this operation. Therefore, the possibility of utilizing flashboards during non-flood flows will be considered. The dam was designed for a 70,000 cfs design flood which corresponds to a headwater elevation equal to 989.6 ft above MSL. The placement of 2 ft flashboards would raise the crest elevation from 979.0 ft MSL and 981.0 ft MSL, well below the design headwater elevation. NSP records indicate that the old timber crib dam had a crest elevation 2 ft higher than the current spillway crest. The cost of building the present spillway to the height of the old timber crib dam was considered by the City of St. Cloud to be prohibitive and therefore was not undertaken. Also, the flood hazard was reduced by using a lower spillway crest without interfering with the City water supply intake.

Since the site historically had a dam with a higher crest elevation, it is possible that two foot flashboards may be installed. However, backwater and environmental considerations should be analyzed in more depth if the option is considered in the design phase. Operation of the dam with 2 ft flashboards would increase the capacity of the site, and therefore increase annual energy and income (see Sections VIII and IX).

An operational plan for the St. Cloud Dam should also incorporate the potential problems associated with frazil ice. Frazil ice formation in a river can jam up under surface ice, backing up the water, completely obliviating the river stage-discharge relationship [6]. The net effect is a reduction in the effective cross-sectional flow area of the river and an increase in river stage. Frazil ice buildup is accentuated at lower water surface elevations. Furthermore, frazil ice formed from super-cooled water often attaches itself to metallic rocks, screens, conduits, and pumps. This ice has formed on impellers of pumps threatening complete shut-down of the pumping facilities. Frazil ice has been known to completely choke off power plant intakes [6].

Studies by the City of St. Cloud indicate significant build-up of frazil ice or slush-ice,and resultant raising of the surface elevation will occur during a cold spell of about four days of temperatures below zero degrees F. The rapids located immediately upstream of the existing reservoir are the apparent major cause of this frazil ice condition in the reservoir.

The influence of the frazil ice problem upon hydropower production should be addressed in the final design phase. The possibility that frazil ice will block the intake entrance and interrupt production should also be considered.

VIII. PROJECT DEVELOPMENT ALTERNATIVES

In this section, the costs and expected annual energy production of four development alternatives for the St. Cloud Dam hydropower facility are considered. Other alternatives considered in the initial phase but which have subsequently been ruled out are also described. Project development alternatives were formulated in the following manner:

- Once the hydraulic and hydrologic analysis was performed, the first step in choosing development alternatives was to determine which types of hydroturbines are most applicable to the site. Turbine and generator manufacturers were then contacted to obtain cost estimates of specific turbine/generator units, since they are the major equipment item in a hydropower facility. Turbine performance curves were also obtained.

- The expected annual energy production was computed for a strict run-of-river operation using flow duration, headwater and tailwater information, and turbine, generator, and speed increaser performance curves.

- Construction costs were estimated on the basis of unit costs applied to preliminary layout drawings. Construction cost estimates included facility structural costs as well as diversion, removal, and excavation costs. A 25 per cent contingency allowance was added to cover smaller items and possible omissions. A 10 per cent profit factor was also included in the total civil works cost.

- Freight and installation estimates for turbines and generators were based upon manufacturer's recommendations.

- Electrical equipment costs were estimated based upon information obtained from a well-known generator/switchgear/controls manufacturer. Electrical equipment costs include switchgear, transformer, control switchboard, circuit breakers, wire and cable system, conduit, grounding, and lighting.

- It is anticipated that the site will be completely automated with water level sensors, automatic start and stop, and a digital controller. With this type of automatic control, the only remote communication required is an operating status indication through telephone lines. The control equipment costs were estimated from guidelines in Ref [7]. The 1978 cost base was escalated to 1981 according to the Consumer Price Index.
- Miscellaneous power plant equipment costs were estimated according to guidelines in Ref. [5]. Equipment for ventilation, fire protection, communication, and turbine/generator bearing cooling water are included in this category. The cost estimates include 15 per cent for freight and installation. The July 1978 cost base was escalated to July 1981 according to the Consumer Price Index.
- A multiplier of 20 per cent was applied to the total cost of the above items for engineering, construction management, and other costs [5]. These costs include expenditures for license and permit application, preliminary and final design, construction management, and administration.

Three locations for the powerhouse were considered. The first option, which best suits the site conditions, incorporates the powerhouse as an integral part of the earth embankment on the right bank as shown in Fig. 19. This option minimizes earthwork and maximizes use of existing facilities, i.e. minimal construction is required for the tailrace area. A second option utilized penstocks through the right embankment. The third option incorporated the powerhouse as an integral part of the concrete spillway. Each of the development alternatives described herein incorporates the first option for powerhouse location.

Each development alternative presented is a multiple combination of horizontal tubular units.* Each tubular unit has a 3000 mm adjustable-blade, propeller runner and fixed guide vanes. Also included in each unit is a hydraulic cylinder operated intake gate, synchronous generator,

*Based on cost estimates and other information obtained from Allis-Chalmers.

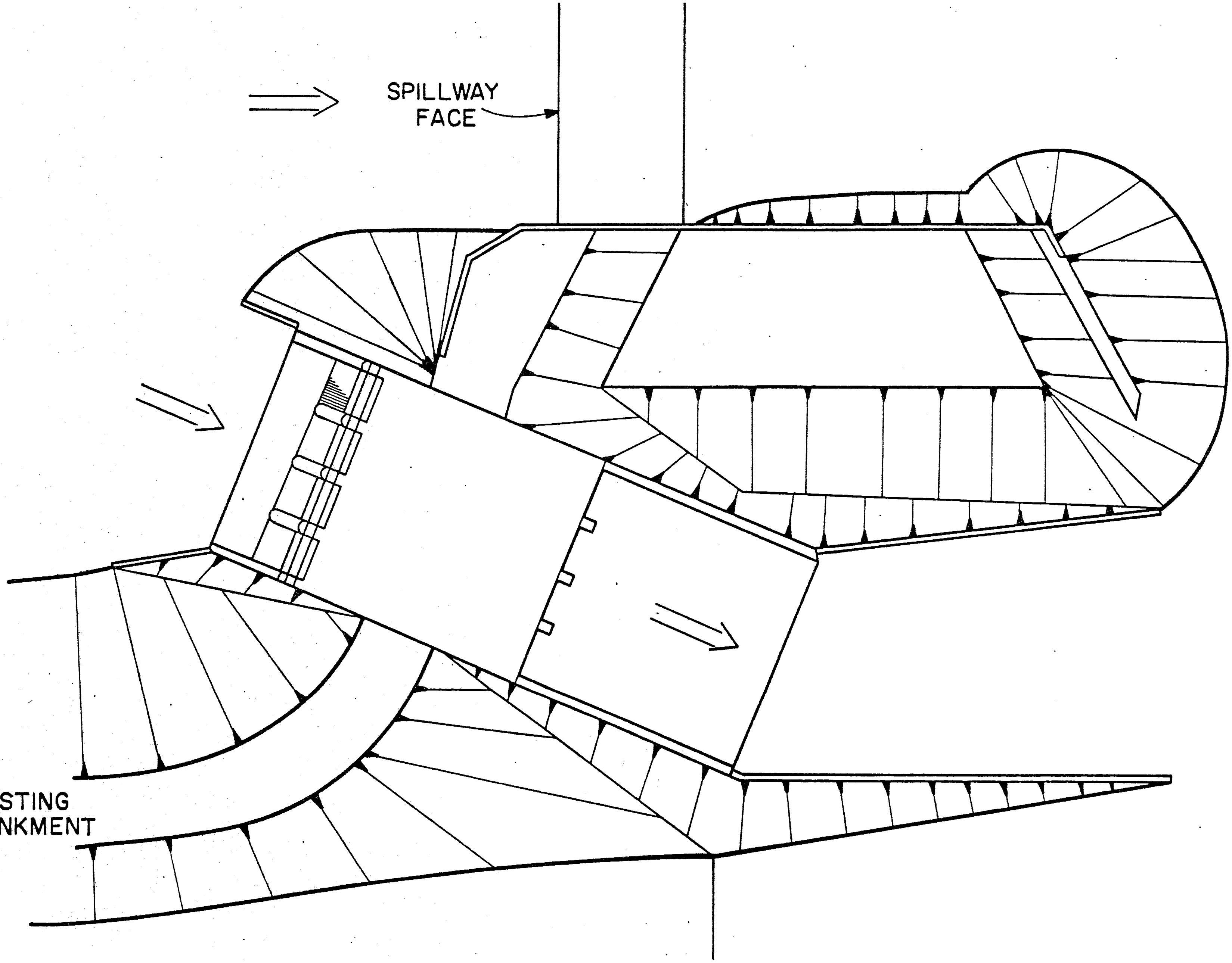

Fig. 19. Plan View Showing Powerhouse with Four Horizontal Units in Right Earth Embankment.

electrical control cubicle, speed increaser, and hydraulic pressure unit. The design discharge for each unit is 1554 cfs at 16.5 ft head with a minimum discharge of 494 cfs and a rated output of 1840 kW. The alternatives considered are for 3, 4, and 5 tubular units. These alternatives are summarized in the following sections. A plan of the four-unit option is given in Fig. 20. A section of the units is shown in Fig. 21. Performance curves for turbine and overall plant efficiencies are given in Fig. 22 for up to a four unit capacity.

The St. Cloud Dam has provisions for the installment of temporary flashboards to aid in the inspection and repair of the spillway as described in Section VII. The opportunity to utilize permanent 2 ft flashboards during non-flood flows was investigated in addition to the non-flashboard option for each of the alternatives outlined below. The only change required in the turbine/generator units considered is an increase in rated generator output to 2180 kW, corresponding to a rated head of 18.5 ft. This would not significantly increase the cost of the turbine/generator units.*

A. Alternative A: Four Horizontal Tubular Units

Alternative A utilizes four horizontal tubular units (as described above) for two options, with and without flashboards. Plan and section views of a preliminary layout are given in Figures 20 and 21.

The cost estimates for Alternative A are as follows (1981 base year):

1.	Turbine/Generator package**	$4,000,000
2.	Construction costs	2,530,000
3.	Electrical equipment†	213,000
4.	Miscellaneous plant equipment	135,000
5.	Installation and freight	680,000
6.	Automatic controls	91,000
7.	Engineering, construction management, etc.	1,530,000
	Total Initial Cost	$9,179,000

*Based upon personal communication with Allis-Chalmers, Inc.
**Allis-Chalmers, Inc. cost estimate.
†Brown-Boveri, Inc. cost estimate.

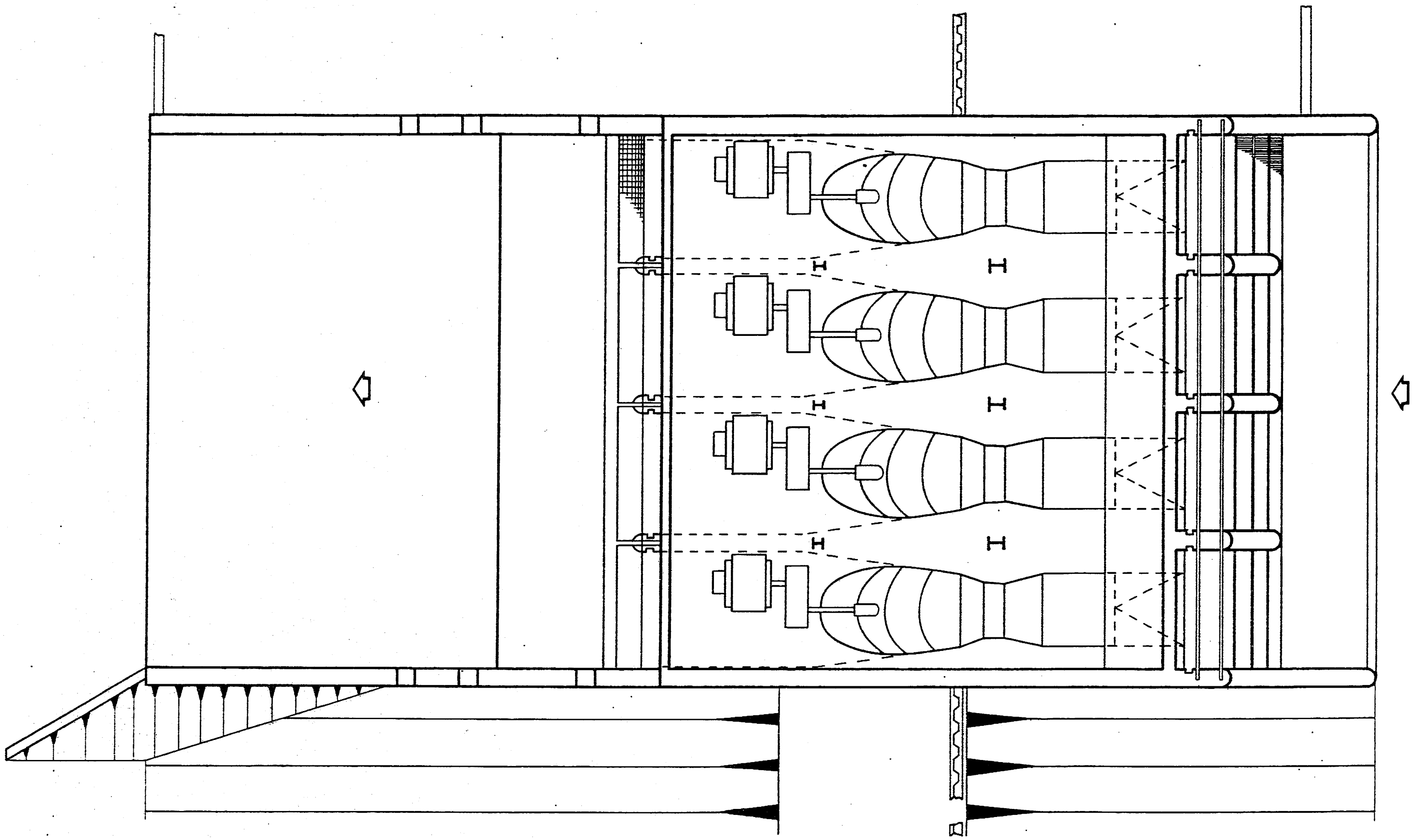

Fig. 20. Plan Layout of Four Horizontal Tubular Units in Powerhouse.

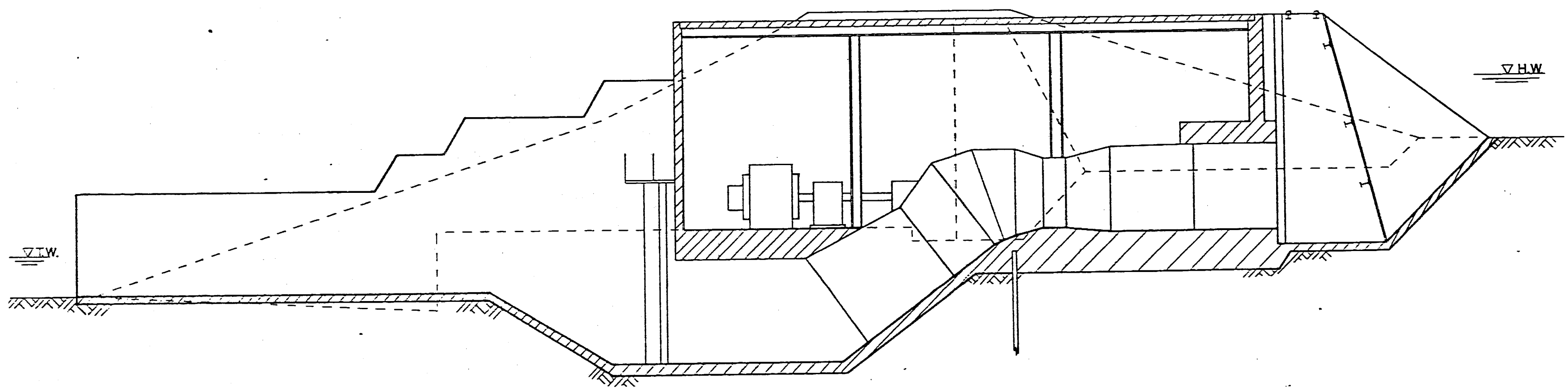

Fig. 21. Cross Section Through Powerhouse Showing Typical Arrangement of a Horizontal Tubular Unit Set in the Earth Embankment. Dashed Lines Indicate Existing Embankment.

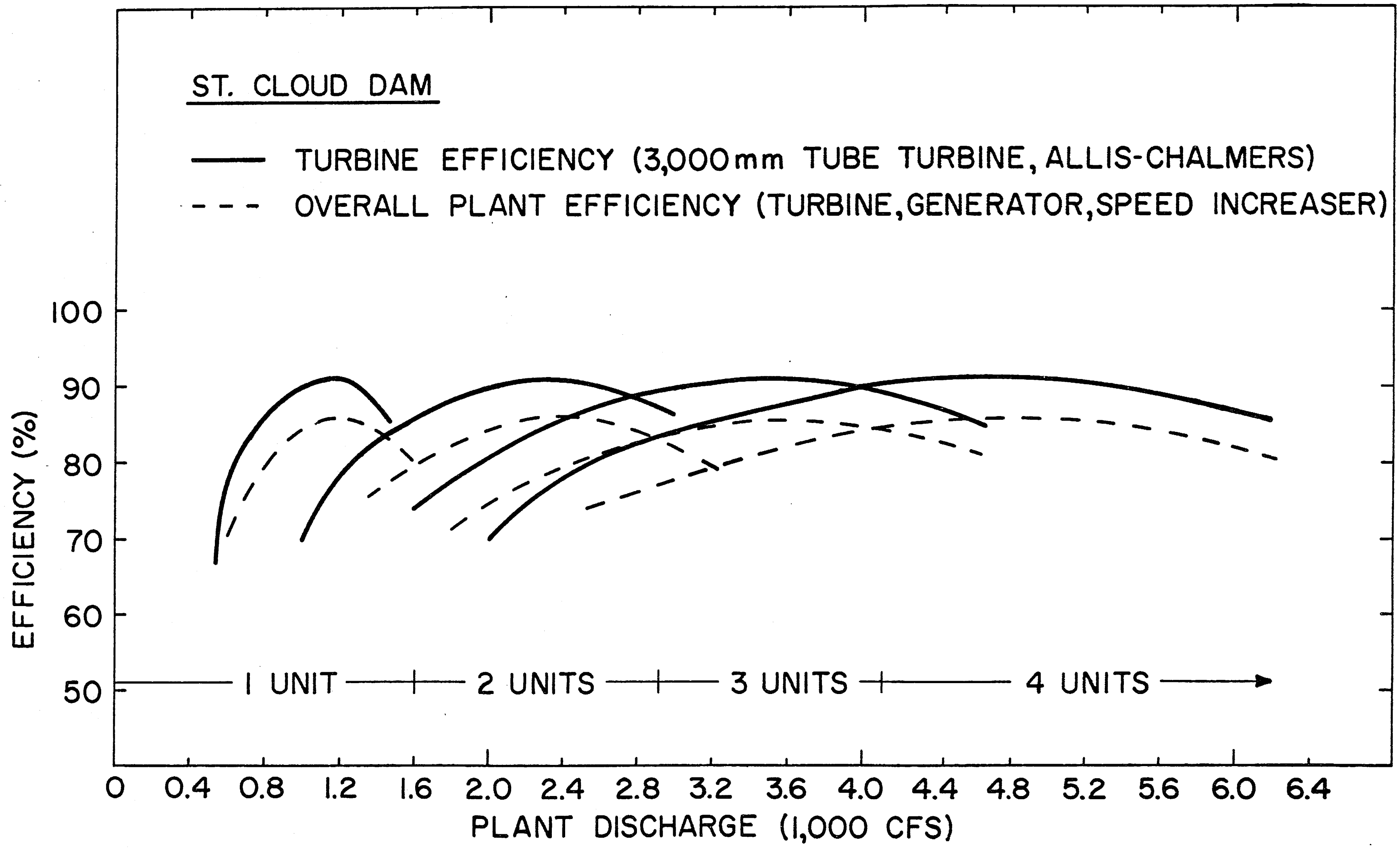

Fig. 22. Turbine and Overall Plant Efficiencies for Four Units. Operating Ranges Denoted at Bottom of Figure Indicate Optimum Overall Efficiencies for a Four Unit Installation.

The average annual energy production and annual income for Alternative A with and without flashboards are given in Table 1.

TABLE 1. Average Annual Energy Production and Annual Income for Alternative A, St. Cloud Dam (1981 base year)

	No Flashboards	Flashboards
Average Annual Energy Production (GWH)	38.79	44.28
Annual Capacity Credit ($)	145,000	160,000
Annual Energy Income (C_E = 1.38 ¢/kWH)	535,000	611,000
Annual Gross Income ($)	680,000	771,000

B. Alternative B: Three Horizontal Tubular Units

Alternative B uses the same configuration as Figs. 20 and 21. except with the installation of 3 units. Therefore, the required powerhouse size is reduced as well as the civil works, equipment costs, and average annual power production.

The cost estimates for Alternative B are as follows (1981 base year):

1.	Turbine/Generator package*	$3,000,000
2.	Construction costs	1,627,000
3.	Electrical equipment**	194,000
4.	Miscellaneous plant equipment	120,000
5.	Installation and freight	510,000
6.	Automatic controls	91,000
7.	Engineering, construction management, etc.	1,108,000
	Total Initial Cost	$6,649,000

The average annual energy production and annual income for Alternative B with and without flashboards are shown in Table 2.

*Allis-Chalmers Cost estimate.
**Brown-Boveri cost estimate.

TABLE 2. Average Annual Energy Production and Annual Income for Alternative B, St. Cloud Dam (1981 base year)

	No Flashboards	Flashboards
Average Annual Energy Production (GWH)	32.78	37.44
Annual Capacity Credit ($)	145,000	160,000
Annual Energy Income (C_E = 1.38 ¢/kWH)	452,000	517,000
Annual Gross Income ($)	597,000	677,000

C. Alternative C: Five Horizontal Tubular Units

Alternative C utilizes five of the units described earlier. It uses a greater percentage of the flow duration curve than Alternatives A or B. In plan view, the powerhouse is similar to Figs. 19 and 21, except with the addition of one more turbine bay. A section view is given in Fig. 20. Alternative C has a higher initial cost and generates more average annual energy than Alternatives A or B.

The cost estimates for Alternatives C are as follows (1981 base year):

1.	Turbine/Generator package*	$5,000,000
2.	Construction costs	3,115,000
3.	Electrical equipment**	247,000
4.	Miscellaneous plant equipment	144,000
5.	Installation and freight	850,000
6.	Automatic controls	91,000
7.	Engineering, construction management, etc.	1,889,000
	Total Initial Cost	$11,336,000

The average annual energy production and annual income for Alternative C with and without flashboards are shown in Table 3.

*Allis-Chalmers cost estimate.
**Brown-Boveri cost estimate.

TABLE 3. Average Annual Energy Production and Annual Income for Alternative C, St. Cloud Dam (1981 base year)

	No Flashboards	Flashboards
Average Annual Energy Production (GWH)	42.12	47.87
Annual Capacity Credit ($)	145,000	160,000
Annual Energy Income (C_E = 1.38 ¢/kWH)	581,000	661,000
Annual Gross Income ($)	726,000	821,000

D. Alternative D: Three Standardized Tubular Units with Four Unit Powerhouse

Alternative D consists of three turbines set in a powerhouse constructed to accommodate a total capacity of four tubular units. In effect, Alternative D allows for the possibility of expansion to a larger capacity at some point in the future. The turbine and generator costs make up a significant portion of the overall costs. Therefore, if present economic conditions prohibit the purchase of four units, an option will be to first purchase three units. If energy costs escalate to a point where the purchase of a fourth unit is justified, all the civil works necessary to accommodate a fourth unit will be in place. The costs for Alternative D are as follows (1981 base year):

1.	Turbine/Generator package*	$3,000,000
2.	Construction costs	2,530,000
3.	Switching gear package**	194,000
4.	Miscellaneous plant equipment	120,000
5.	Installation and freight	510,000
6.	Automatic controls	91,000
7.	Engineering, construction management, etc.	1,289,000
	Total Initial Cost	$7,734,000

*Allis-Chalmers cost estimate.
**Brown Boveri cost estimate.

The average annual energy production and annual income for Alternative D with and without flashboards are shown in Table 4.

TABLE 4. Average Annual Energy Production and Annual Income for Alternative D, St. Cloud Dam (1981 base year)

	No Flashboards	Flashboards
Average Annual Energy Production (GWH)	32.78	37.44
Annual Capacity Credit ($)	145,000	160,000
Annual Energy Income ($) ($C_E$ = 1.38 ¢/kWH)	452,000	517,000
Annual Gross Income ($)	597,000	677,000

E. Other Alternatives Considered

Information received from turbine manufacturers included two other options in addition to horizontal tubular turbines. These options were for bulb and for rim generating (Straflo) units. Bulb units inherently have higher initial cost and more complex civil works construction is required to accommodate these units in a powerhouse. In addition, these units have a larger runner diameter and more excavation is required to install each unit at the required centerline setting (to avoid cavitation damage to the runner). Similar problems are encountered with the rim generating units. Bulb and rim generating units, therefore, were eliminated from serious consideration as a development alternative in this feasibility study.

A number of generator manufacturers also respond to requests for bids on hydroelectric projects. In this case, the generator manufacturer would submit a bid in conjuction with one of the turbine manufacturers. The generator manufacturers who have made bids for low head hydroelectric developments are General Electric, Brown Boveri, and Westinghouse. The turbine manufacturers who responded to our requests for information include Allis-Chalmers, Axel Johnson (KMW), Hydro Energy Systems (Neypric), and Sulzer Brothers.

F. Summary of Alternatives

The major differences between the development alternatives are (1) number of units installed (e.g., 3, 4, or 5) and (2) operation with and without flashboards. The option which generates more energy and income utilizes two foot flashboards. However, in the event that flashboards cannot be used, the following summary table includes the alternatives without flashboards. The major decision between alternatives is a choice between the number of units selected. The basis for this decision can only be determined with a thorough economic analysis, which will be presented in Section IX. The results of the various alternatives are summarized in Table 5 below.

TABLE 5. Summary of Project Development Alternatives (1981 base year)

	No Flashboards				Flashboards			
Alternative: Description	A	B	C	D	A	B	C	D
Total Initial Cost ($)	9,179,000	6,649,000	11,336,000	7,752,000	9,179,000	6,649,000	11,336,000	7,752,000
Average Annual Energy (GWH)	38.79	32.78	42.12	32.78	44.28	37.44	47.87	37.44
Annual Energy Income ($)	535,000	452,000	581,000	452,000	611,000	517,000	661,000	517,000
Capacity Credit ($)	145,000	145,000	145,000	145,000	160,000	160,000	160,000	160,000
Average Annual Income ($:0.0138/kWH)	680,000	597,000	726,000	597,000	771,000	677,000	821,000	677,000
Annual Benefits/Total Initial Cost	C.074	0.089	0.064	0.077	0.084	0.102	0.072	0.087

IX. ECONOMIC ANALYSIS

A. Background and Assumptions

This section of the report will compare the benefits and costs of hydropower development at the St. Cloud Dam. Certain basic assumptions, which are required in benefit/cost analysis, will be outlined before describing the results of the economic analysis. The sensitivity of the benefit/cost comparisons to these basic assumptions is investigated in Section IX.C.

1. Economic Feasibility Indicators.

A number of economic feasibility indicators will be given herein to provide interested parties with a choice of decision rules and to outline the economic advantages and disadvantages of each option. These indicators are:

- The first year cost of power is the cost of debt service, operation and maintenance, and other costs divided by the average annual energy production.
- The benefit-cost ratio is the present worth of project benefits divided by the present worth of initial project costs and annual costs.

$$B/C = \frac{\sum_{i=0}^{n} B_i (1 + d)^i}{C_i + \sum_{i=0}^{n} OMi (1 + d)^i} \tag{3}$$

where B/C = benefit-cost ratio for a project economic life of n years,

B_i = benefits in year i,

C_i = initial project cost,

OM_i = operation, maintenance, and replacement costs in year i,

d = discount rate, and

n = project economic life.

- The net present value is the present worth of project benefits minus the present worth of project costs:

$$NPV = \sum_{i=0}^{n} NB_i/(1 + d)^i \qquad (4)$$

where NPV = net present value for a project economic life of n years, and

NB_i = net project benefits in year i (benefits minus costs).

- The internal rate of return is the discount rate which would give zero net present value at the end of the project economic life.

- Payback period is the number of years generating power required to reach a zero net present value.

2. Assumptions

The following assumptions are incorporated into the economic analysis:

- The economic life of the project is assumed to be 50 years. For this reason the initial project cost will be amortized over a 50-year period.

- 11 per cent interest and discount rate. Interest rates on tax-exempt bonds have been climbing since the beginning of 1980. As of July 1981, Moody's A-rated municipal bond index had stabilized at approximately 11 per cent.

  Historically, A-rated tax-exempt bonds have been near the rate of inflation. The recent tax cuts, however, have reduced the attractiveness of tax-exempt bonds. Many economic analysts believe the difference between long-term rates for tax-exempt bonds and nontax-exempt financing rates will decrease by approximately 1.5 per cent*.

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*Donald Porter. First Boston Corporation, New York, N. Y.

For this reason, a two per cent spread between interest rate and escalation rate will be used.

- Nine per cent annual escalation in the value of energy and power. Power producing utilities in the State of Minnesota have projected that the value of electricity will increase at or near the rate of inflation over the next 20 years*. The annual increase in the consumer price index between 1977 and 1981 has averaged 9.9 per cent. The CPI is currently moderating; however, most economic forecasters are still predicting inflation rates near 9 per cent over the next 5 to 10 years**.
- Annual operation, maintenance and replacement costs in 1981 dollars were determined from Ref. [5].
- Nine per cent annual escalation in operation, maintenance and replacement costs. This rate was chosen to coincide with the predicted inflation rate.
- A two year construction period [5].
- A linear expenditure of capital during project construction.

The sensitivity of the benefit/cost analysis to discount rate and escalation rates will be described in Section IX.C.

B. Comparison of Project Development Alternatives

The first year cost of power, benefit-cost ratio, net present value, and internal rate of return of each of the development alternatives are compared for facility operation with and without flashboards in Tables 6 through 9. A 35-year and 50-year project economic life were used. The 35-year project economic life is commonly used for hydropower facilities. The useful life of a hydropower facility, however, is anywhere from 50 to 100 years. The 50 year project life is also used herein because it corresponds more closely to the useful life of any proposed facility.

Examination of Tables 6 through 9 indicate the overall economic superiority of operation with flashboards. It is the authors' recommendation

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*Minnesota Energy Agency.
**Data Resources, Inc.

TABLE 6. First Year Cost of Power for the St. Cloud Dam ($/kWH, 1981 base year)

Flashboard Option	Development Alternative			
	A	B	C	D
Without	.028	.024	.032	.028
With	.024	.021	.028	.024

TABLE 7. Benefit-Cost Ratio for a 35-Year and 50-Year Economic Project Life, St. Cloud Dam

Flashboard Option	Development Alternative			
	A	B	C	D
35-Year Project Economic Life				
Without	1.64	1.92	1.43	1.70
With	1.85	2.18	1.62	1.93
50-Year Project Economic Life				
Without	1.96	2.29	1.72	2.04
With	2.22	2.60	1.95	2.31

TABLE 8. Net Present Value for a 35-Year and 50-Year Economic Project Life, St. Cloud Dam (million $, 1981 base year)

Flashboard Option	Development Alternative			
	A	B	C	D
35-Year Project Economic Life				
Without	6.54	7.10	5.44	6.09
With	8.79	9.06	7.78	8.05
50-Year Project Economic Life				
Without	10.45	10.56	9.56	9.54
With	13.30	13.06	12.53	12.03

TABLE 9. Internal Rate of Return for a 35-Year and 50-Year Economic Project Life, St. Cloud Dam (annual per cent)

	Development Alternative			
	A	B	C	D
35-Year Project Economic Life				
Without	19.3	22.5	17.3	19.9
With	21.4	25.3	19.0	22.2
50-Year Project Economic Life				
Without	19.6	22.7	17.8	20.2
With	21.7	25.5	19.4	22.2

that any hydropower development at the St. Cloud site should operate with flashboards installed, if possible. Section VII indicates that installation of flashboards would not interfere with the existing dam stability and/or integrity.

Net present value is an estimate of the expected net income or profit over an assumed project life, in present dollars. Of the indicators given herein net present value is generally considered as the most appropriate means of comparing development alternatives. Use of the other economic indicators will result in a conservative choice of development alternative.

Each of the development alternatives indicate an excellent economic return. The difference in net present value between Alternatives A (4 units) and B (3 units) is generally small. The one exception is the 35-year project life without flashboards, which indicates a 9 per cent greater net present value for Alternative B. The economic indicators for Alternative C (5 units) are consistently less favorable than for the other alternatives. Alternative D, three turbine units with a four unit powerhouse, is essentially a compromise between Alternatives A and B. The economic analysis summarized in Tables 6 through 9, however, indicates that either Alternative A or B should be chosen over Alternative D.

With the capacity and energy values used in this economic analysis, there is no significant difference between Development Alternatives A and B. The impact of energy value on the choice between Alternatives A and B is presented in Section IX. The addition of flashboards gives a significantly greater economic return for all development alternatives.

C. Cost and Benefit Streams

Cost and benefit streams for Alternatives A and B (with and without flashboards) are given in Tables 10, 11, 12 and 13. The assumptions used in the analysis are as indicated in Section IX. The tables clearly indicate that the flashboard option is more favorable than operation without flashboards. Moreover, the analysis indicates that there is not a significant difference between Alternatives A and B.

TABLE 10. Cost and Benefit Streams for Development Alternative A Without Flashboards at St. Cloud Dam. Base year for present worths is 1981. Two-year construction period. 11 per cent discount rate and 9 per cent escalation rate. All figures in dollars.

Year	Debt Service	O & M Costs	Gross Income	------- Present Worths -------- Benefits	Costs	Cash Flow	Present Value
1	507651	0	0	0	457343	-457343	-457343
2	1015301	0	0	0	824041	-824041	-1281384
3	1015301	89616	881011	644188	807906	-163718	-1445102
4	1015301	97681	960302	632581	733156	-100576	-1545678
5	1015301	106473	1046729	621183	665718	-44535	-1590213
6	1015301	116055	1140935	609990	604869	5121	-1585092
7	1015301	126500	1243619	598999	549958	49041	-1536051
8	1015301	137885	1355544	588207	500398	87808	-1448243
9	1015301	150295	1477543	577608	455660	121948	-1326295
10	1015301	163822	1610522	567201	415269	151932	-1174363
11	1015301	178566	1755469	556981	378974	178187	-996175
12	1015301	194636	1913461	546945	345850	201096	-795079
13	1015301	212154	2085673	537091	316088	221003	-574076
14	1015301	231248	2273384	527413	289193	238220	-335856
15	1015301	252060	2477988	517910	264884	253026	-82829
16	1015301	274745	2701007	508579	242906	265673	182844
17	1015301	299472	2944098	499415	223028	276387	459230
18	1015301	326425	3209066	490417	205045	285371	744601
19	1015301	355803	3497882	481580	188870	292810	1037411
20	1015301	387825	3812692	472903	174035	298868	1336279
21	1015301	422729	4155834	464382	160689	303694	1639972
22	1015301	460775	4529859	456015	148595	307420	1947393
23	1015301	502245	4937547	447799	137630	310168	2257561
24	1015301	547447	5381926	439730	127684	312046	2569607
25	1015301	596717	5866299	431807	118658	313149	2882757
26	1015301	650422	6394266	424027	110460	313567	3196323
27	1015301	708960	6969750	416387	103011	313376	3509699
28	1015301	772766	7597027	408884	96237	312648	3822347
29	1015301	842315	8280760	401517	90072	311445	4133792
30	1015301	918123	9026028	394282	84457	309825	4443616
31	1015301	1000754	9838371	387178	79340	307839	4751455
32	1015301	1090822	10723824	380202	74670	305532	5056987
33	1015301	1188996	11688968	373351	70406	302945	5359932
34	1015301	1296006	12740975	366624	66508	300116	5660048
35	1015301	1412647	13887663	360019	62941	297077	5957125
36	1015301	1539785	15137553	353532	59673	293859	6250984
37	1015301	1678365	16499933	347162	56675	290487	6541470
38	1015301	1829418	17984927	340907	53922	286985	6828455
39	1015301	1994066	19603570	334764	51390	283374	7111829
40	1015301	2173532	21367891	328732	49058	279674	7391503
41	1015301	2369150	23291001	322809	46908	275901	7667405
42	1015301	2582373	25387192	316993	44922	272071	7939476
43	1015301	2814787	27672039	311281	43084	268197	8207673
44	1015301	3068118	30162522	305673	41382	264291	8741963
45	1015301	3344248	32877149	300165	39802	260363	8732326
46	1015301	3645231	35836093	294757	38333	256423	8988749
47	1015301	3973301	39061341	289446	36966	252480	9241229
48	1015301	4330898	42576862	284230	35690	248541	9489770
49	1015301	4720679	46408779	279109	34497	244612	9734382
50	1015301	5145540	50585570	274080	33380	240700	9975082
51	507651	5608639	55138271	269142	29855	239287	10214369
52	0	6113417	60100715	264292	26884	237409	10451778

Payback period = 14 years

Economic Analysis for a Project Life of 35 years
Present Net Value = $ 6,541,470
Benefit Cost Ratio = 1.64

Economic Analysis for a Project Life of 50 Years
Present Net Value = $10,451,778
Benefit Cost Ratio = 1.96

TABLE 11. Cost and Benefit Streams for Development Alternative B Without Flashboards at St. Cloud Dam. Base year for present worths is 1981. Two-year construction period. 11 per cent discount rate and 9 per cent escalation rate. All figures in dollars.

				------- Present Worths --------			
Year	Debt Service	O & M Costs	Gross Income	Benefits	Costs	Cash Flow	Net Present Value
1	367742	0	0	0	331300	-331300	-331300
2	735485	0	0	0	596936	-596936	-928236
3	735485	76666	773604	565652	593838	-28185	-956421
4	735485	83566	843228	555460	539534	15926	-940494
5	735485	91087	919119	545452	490530	54922	-885572
6	735485	99284	1001839	535624	446302	89322	-796250
7	735485	108220	1092005	525973	406378	119596	-676654
8	735485	117960	1190285	516496	370332	146164	-530490
9	735485	128576	1297411	507190	337783	169407	-361083
10	735485	140148	1414178	498051	308384	189667	-171416
11	735485	152761	1541454	489078	281826	207252	35836
12	735485	166510	1680185	480265	257827	222438	258275
13	735485	181496	1831401	471612	236136	235476	493751
14	735485	197830	1996227	463114	216524	246590	740341
15	735485	215635	2175888	454770	198788	255982	996323
16	735485	235042	2371718	446576	182743	263833	1260156
17	735485	256196	2585172	438530	168221	270308	1530464
18	735485	279254	2817838	430628	155075	275554	1806018
19	735485	304386	3071443	422869	143167	279702	2085720
20	735485	331781	3347873	415250	132377	282873	2368593
21	735485	361641	3649182	407768	122595	285172	2653765
22	735485	394189	3977608	400421	113723	286698	2940463
23	735485	429666	4335593	393206	105670	287535	3227998
24	735485	468336	4725796	386121	98358	287763	3515761
25	735485	510486	5151118	379164	91714	287450	3803211
26	735485	556430	5614719	372332	85672	286661	4089872
27	735485	606509	6120043	365623	80173	285450	4375322
28	735485	661095	6670847	359036	75166	283870	4659192
29	735485	720593	7271223	352567	70602	281964	4941156
30	735485	785447	7925633	346214	66439	279775	5220931
31	735485	856137	8638940	339976	62637	277339	5498271
32	735485	933189	9416445	333850	59161	274689	5772960
33	735485	1017176	10263925	327835	55981	271854	6044814
34	735485	1108722	11187678	321928	53067	268860	6313675
35	735485	1208507	12194570	316127	50395	265732	6579407
36	735485	1317273	13292081	310431	47941	262490	6841897
37	735485	1435827	14488368	304838	45685	259153	7101050
38	735485	1565051	15792321	299346	43607	255739	7356789
39	735485	1705906	17213630	293952	41691	252261	7609050
40	735485	1859438	18762857	288655	39921	248734	7857784
41	735485	2026787	20451514	283454	38285	245170	8102954
42	735485	2209198	22292150	278347	36768	241579	8344533
43	735485	2408026	24298444	273332	35361	237971	8582503
44	735485	2624748	26485304	268407	34053	234354	8816857
45	735485	2860975	28868981	263571	32835	230736	9047593
46	735485	3118463	31467189	258822	31699	227123	9274715
47	735485	3399125	34299236	254158	30638	223521	9498236
48	735485	3705046	37386168	249579	29644	219935	9718171
49	735485	4038500	40750923	245082	28711	216371	9934542
50	735485	4401965	44418506	240666	27835	212831	10147373
51	367742	4798142	48416171	236330	25216	211114	10358487
52	0	5229975	52773627	232072	22999	209073	10567559

Payback period = 9 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $7,101,050
Benefit Cost Ratio = 1.92

Economic Analysis for a Project Life of 50 Years
Present Net Value = $10,567,559
Benefit Cost Ratio = 2.29

TABLE 12. Cost and Benefit Streams for Development Alternative A With Flashboards at St. Cloud Dam. Base year for present worths is 1981. Two-year construction period. 11 per cent discount rate and 9 per cent escalation rate. All figures in dollars.

Year	Debt Service	O & M Costs	Gross Income	------- Present Worths -------- Benefits	Costs	Cash Flow	Net Present Value
1	507651	0	0	0	457343	-457343	-457343
2	1015301	0	0	0	824041	-824041	-1281384
3	1015301	89616	998550	730131	807906	-77775	-1359158
4	1015301	97681	1088420	716976	733156	-16180	-1375339
5	1015301	106473	1186378	704057	665718	38339	-1337000
6	1015301	116055	1293152	691372	604869	86502	-1250497
7	1015301	126500	1409535	678914	549958	128956	-1121541
8	1015301	137885	1536393	666682	500398	166284	-955257
9	1015301	150295	1674669	654669	455660	199009	-756248
10	1015301	163822	1825389	642874	415269	227605	-528643
11	1015301	178566	1989674	631290	378794	252496	-276147
12	1015301	194636	2168745	619916	345850	274066	-2081
13	1015301	212154	2363932	608746	316087	292659	290578
14	1015301	231248	2576685	597778	289193	308585	599163
15	1015301	252060	2808587	587007	264884	322123	921286
16	1015301	274745	3061360	576430	242906	333525	1254811
17	1015301	299472	3336882	566044	223028	343016	1597826
18	1015301	326425	3637202	555845	205045	350800	1948626
19	1015301	355803	3964550	545830	188770	357060	2305686
20	1015301	387825	4321359	535995	174035	361960	2667645
21	1015301	422729	4710282	526338	160689	365649	3033294
22	1015301	460775	5134207	516854	148595	368259	3401553
23	1015301	502245	5596286	507541	137630	369911	3771465
24	1015301	547447	6099951	498396	127684	370712	4142177
25	1015301	596717	6648947	489416	118658	370759	4512935
26	1015301	650422	7247352	480598	110460	370138	4883073
27	1015301	708960	7899614	471939	103011	368928	5252001
28	1015301	772766	8610579	463435	96237	367199	5619200
29	1015301	842315	9385531	455085	90072	365013	5984213
30	1015301	918123	10230229	446885	84457	362428	6346640
31	1015301	1000754	11150950	438833	79340	359494	6706134
32	1015301	1090822	12154535	430926	74670	356256	7062390
33	1015301	1188996	13248444	423162	70406	352756	7415145
34	1015301	1296006	14440803	415537	66508	349029	7764174
35	1015301	1412647	15740476	408050	62941	345109	8109283
36	1015301	1539785	17157119	400698	59673	341025	8450308
37	1015301	1678365	18701259	393478	56675	336803	8787111
38	1015301	1829418	20384373	386388	53922	332466	9119578
39	1015301	1994066	22218966	379427	51390	328036	9447614
40	1015301	2173532	24218673	372590	49058	323532	9771146
41	1015301	2369150	26398354	365877	46908	318969	10090115
42	1015301	2582373	28774205	359284	44922	314363	10404477
43	1015301	2814787	31363884	352811	43084	309726	10714203
44	1015301	3068118	34186634	346454	41382	305072	11019275
45	1015301	3344248	37263431	340211	39802	300409	11319684
46	1015301	3645231	40617139	334081	38333	295748	11615432
47	1015301	3973301	44272682	328062	36966	291096	11906528
48	1015301	4330898	48257223	322151	35690	286461	12192990
49	1015301	4720679	52600373	316346	34497	281849	12474839
50	1015301	5145540	57334407	310646	33380	277266	12752105
51	507651	5608639	62494503	305049	29855	275194	13027299
52	0	6113417	68119009	299553	26884	272669	13299968

Payback period = 11 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $8,787,111
Benefit Cost Ratio = 1.85

Economic Analysis for a Project Life of 50 Years
Present Net Value = $13,299,968
Benefit Cost Ratio = 2.22

TABLE 13. Cost and Benefit Streams for Development Alternative B With Flashboards at St. Cloud Dam. Base year for present worths is 1981. Two-year construction period. 11 per cent discount rate and 9 per cent escalation rate. All figures in dollars.

Year	Debt Service	O & M Costs	Gross Income	------- Present Worths ------- Benefits	Costs	Cash Flow	Net Present Value
1	367742	0	0	0	331300	-331300	-331300
2	735485	0	0	0	596936	-596936	-928236
3	735485	76666	876310	640750	593838	46913	-881323
4	735485	83566	955178	629205	539534	89671	-791652
5	735485	91087	1041144	617868	490530	127338	-664314
6	735485	99284	1134847	606735	446302	160434	-503880
7	735485	108220	1236983	595803	406378	189426	-314454
8	735485	117960	1348311	585068	370332	214736	-99719
9	735485	128576	1469659	574526	337783	236743	137025
10	735485	140148	1601929	564174	308384	255790	392815
11	735485	152761	1746102	554009	281826	272183	664998
12	735485	166510	1903252	544027	257827	286200	951198
13	735485	181496	2074544	534225	236136	298089	1249287
14	735485	197830	2261253	524599	216524	308075	1557362
15	735485	215635	2464766	515147	198788	316359	1873721
16	735485	235042	2686595	505865	182743	323122	2196843
17	735485	256196	2928388	496750	168221	328529	2525372
18	735485	279254	3191943	487800	155075	332725	2858097
19	735485	304386	3479218	479011	143167	335844	3193940
20	735485	331781	3792348	470380	132377	338003	3531943
21	735485	361641	4133659	461904	122595	339309	3871252
22	735485	394189	4505688	453582	113723	339859	4211111
23	735485	429666	4911200	445409	105670	339739	4550850
24	735485	468336	5353208	437384	98358	339026	4889875
25	735485	510486	5834997	429503	91714	337789	5227665
26	735485	556430	6360147	421764	85672	336093	5563757
27	735485	606509	6932560	414165	80173	333991	5897749
28	735485	661095	7556491	406702	75166	331536	6229285
29	735485	720593	8236575	399374	70602	328772	6558057
30	735485	785447	8977867	392178	66439	325740	6883797
31	735485	856137	9785875	385112	62637	322476	7206273
32	735485	933189	10666603	378173	59161	319012	7525285
33	735485	1017176	11626598	371359	55981	315378	7840664
34	735485	1108722	12672991	364668	53067	311601	8152264
35	735485	1208507	13813560	358098	50395	307702	8459967
36	735485	1317273	15056781	351645	47941	303704	8763671
37	735485	1435827	16411891	345309	45685	299625	9063295
38	735485	1565051	17888961	339088	43607	295481	9358776
39	735485	1705906	19498968	332978	41691	291287	9650063
40	735485	1859438	21253875	326978	39921	287057	9937120
41	735485	2026787	23166724	321087	38285	282802	10219922
42	735485	2209198	25251729	315301	36768	278533	10498455
43	735485	2408026	27524385	309620	35361	274259	10772714
44	735485	2624748	30001579	304042	34053	269988	11042703
45	735485	2860975	32701721	298563	32835	265728	11308431
46	735485	3118463	35644876	293184	31699	261485	11569915
47	735485	3399125	38852915	287901	30638	257264	11827179
48	735485	3705046	42349677	282714	29644	253070	12080249
49	735485	4038500	46161148	277620	28711	248908	12329158
50	735485	4401965	50315652	272618	27835	244782	12573940
51	367742	4798142	54844060	267706	25216	242490	12816430
52	0	5229975	59780026	262882	22999	239883	13056314

Payback period = 7 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $9,063,295
Benefit Cost Ratio = 2.18

Economic Analysis for a Project Life of 50 Years
Present Net Value = $13,056,314
Benefit Cost Ratio = 2.60

D. Sensitivity Analysis

Sensitivity analysis investigates the impact of variations in project parameters and economic assumptions on the feasibility indicators. Because of the similar economic return of Development Alternatives A and B, both alternatives will be included in the sensitivity analysis. The sensitivity analysis will also assume that flashboards are in place on the spillway crest.

1. Loss of Dependable Capacity Credit

Certain utilities in the State of Minnesota have stated on record that qualifying facilities (such as small scale hydroelectric facilities) from which they purchase energy should receive no dependable capacity credit because they currently have excess capacity. The final decision on rates for the purchase of power by either utility from a qualifying facility is made by the Minnesota Public Utility Commission (PUC). It is possible that the PUC will rule in favor of these utility's viewpoints. In that case, a hydroelectric facility at the St. Cloud Dam may receive no dependable capacity credit.

The impact of a loss of capacity credit on the various feasibility indicators is given in Table 14 for development Alternatives A and B. For a 50-year project life, the net present value of Alternatives A and B is reduced from 13.30 and 13.06 million dollars to 8.23 and 8.03 million dollars, respectively. Although this is a significant reduction, both development alternatives would still have excellent economic feasibility.

2. Value of Energy

Hydropower feasibility is naturally dependent upon the price at which the generated electricity is sold. In Section VI, this value was estimated to be 1.38 cents/kWH for the St. Cloud Dam (1981 base year). Tables 15 and 16 present the economic indicators over a range of energy values for Alternatives A and B. Project feasibility increases consistently with an increase in energy value, as would be expected. Figure 23 illustrates the increase in net present value for Alternatives A and B with project lives of 35 and 50 years, as the value of energy increases. Assuming a project life of 35 years, the net present value of Alternatives A and B are equal when the value of energy is 1.69 cents/kWH. This indicates the

TABLE 14. Benefit-Cost Ratio, Net Present Value, Payback Period, and Internal Rate of Return without Capacity Payments for Development Alternatives A and B with Flashboards, St. Cloud Dam (1981 base year)

	Development Alternative	
	A	B
35-Year Project Economic Life:		
Benefit-Cost Ratio	1.47	1.66
Net Present Value (Million $)	4.83	5.10
Internal Rate of Return (%)	17.6	19.7
50-Year Project Economic Life:		
Benefit-Cost Ratio	1.76	1.98
Net Present Value (Million $)	8.23	8.03
Internal Rate of Return (%)	18.1	20.1
Payback Period (years)	17	13

TABLE 15. Benefit-Cost Ratio, Net Present Value, and Internal Rate of Return, and Payback Period at Various Values of Energy for Alternatives A and B with a Project Life of 35 Years, with Flashboards, St. Cloud Dam

	Value of Energy ($/kWH)				
	.0138	.0150	.0175	.0200	.0225
Alternative A					
Benefit Cost Ratio	1.85	1.98	2.25	2.51	2.78
Net Present Value (million $)	8.79	10.10	12.84	15.58	18.32
Internal Rate of Return (%)	21.4	22.8	25.7	29.0	32.9
Payback Period (years)	11	9	7	5	4
Alternative B					
Benefit Cost Ratio	2.18	2.33	2.63	2.93	3.23
Net Present Value (million $)	9.06	10.18	12.49	14.81	17.12
Internal Rate of Return (%)	25.3	27.1	31.3	36.7	46.2
Payback Period (years)	7	6	4	4	3

TABLE 16. Benefit-Cost Ratio, Net Present Value, and Internal Rate of Return and Payback Period at Various Values of Energy for Alternatives A and B with a Project Life of 50 Years, with Flashboards, St. Cloud Dam

	Value of Energy ($/kWH)				
	.0138	.0150	.0175	.0200	.0225
Alternative A					
Benefit-Cost Ratio	2.22	2.37	2.69	3.01	3.33
Net Present Value (million $)	13.30	14.97	18.44	21.92	25.39
Internal Rate of Return (%)	21.7	23.0	25.8	29.1	33.0
Alternative B					
Benefit-Cost Ratio	2.60	2.77	3.13	3.49	3.85
Net Present Value (million $)	13.06	14.47	17.40	20.34	23.28
Internal Rate of Return (%)	25.5	27.2	31.3	36.7	46.2

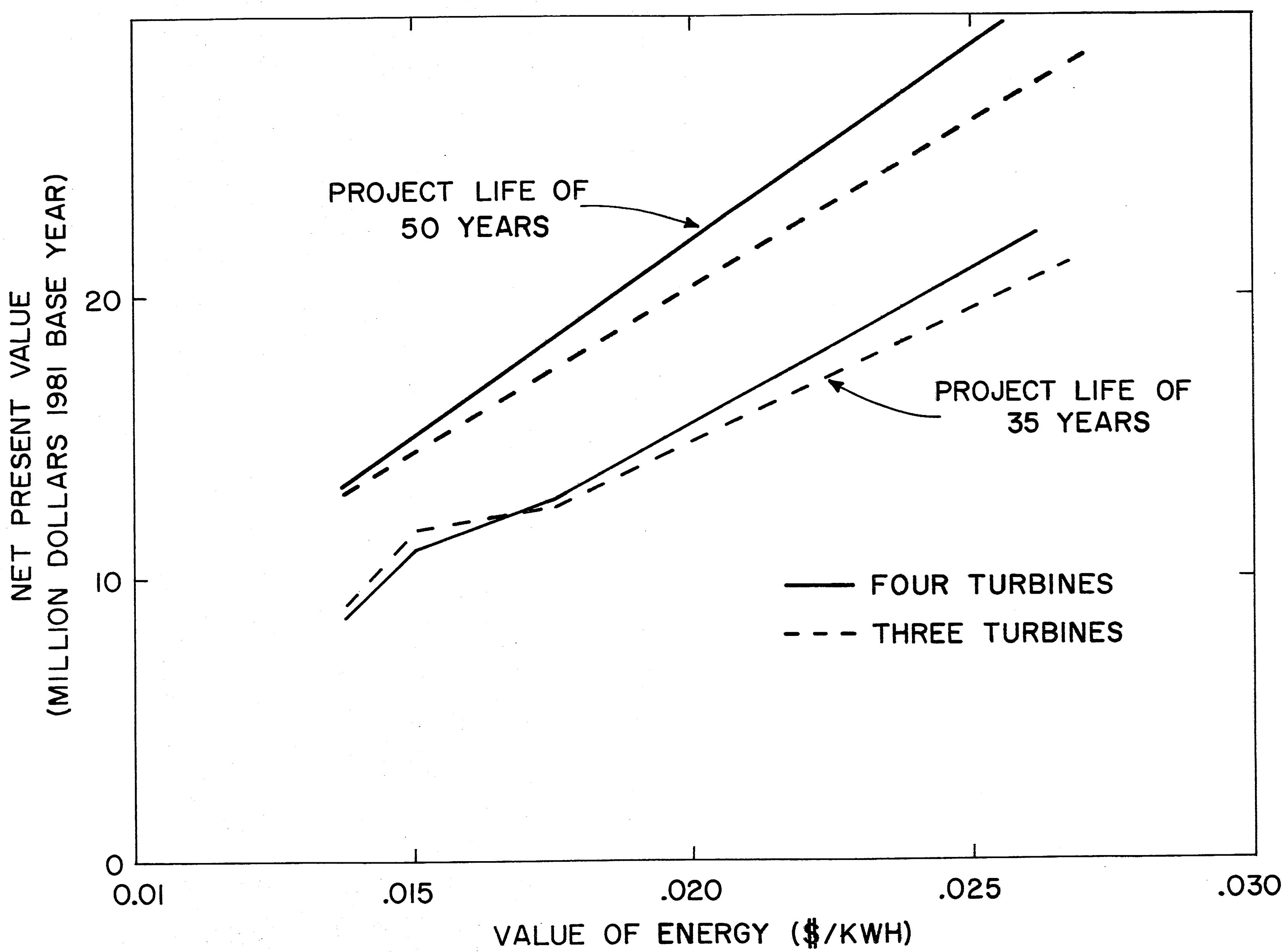

Fig. 23. Net Present Value vs. Value of Energy (1981 Base Year).

trade-off point between Alternatives A and B, based upon value of energy. For the 50-year project life, Alternative A has a net present value which is consistently greater than Alternative B. Note that in Fig. 23 the gap between these alternatives for the 50-year project life widens significantly with increasing value of energy. All energy values in Fig. 23 are in 1981 $'s.

3. Variation in Project Cost

Cost estimates in a feasibility study are not as detailed as in the final design stage of the project. Feasibility cost estimates, therefore, have a limited degree of accuracy. In addition, unforeseen future events can alter project development costs. Cost overruns should be considered in the sensitivity analysis. In this section, economic feasibility indicators will be computed for initial project costs 20 per cent greater and 20 per cent less than the estimates given in Section VIII for Alternatives A and B with flashboards assumed to be in place on the spillway crest. The effects of these variations on the economic feasibility indicators are given in Table 17. Although an increase in initial project cost reduces overall economic return, Alternatives A and B still have good economic feasibility with a project cost overrun of 20 per cent.

4. Variations in Operation, Maintenance, and Replacement Costs

Operation and maintenance costs cannot be precisely determined until the facility is in operation. A sensitivity analysis has been developed to test the response of the economic indicators at various annual operation, maintenance, and replacement costs. An addition and reduction of 20 per cent in the original estimate of operation, maintenance, and replacement (O, M, & R) costs were used in the economic analysis of Alternatives A and B. The response of the various economic indicators are given in Table 18. An increase in operation and maintenance costs by 20 per cent does not significantly affect the economic feasibility of the St. Cloud Dam.

5. Discount and Escalation Rate

Economic feasibility is extremely sensitive to discount and escalation rates. The economic feasibility indicators for Alternatives A and B are given in Table 19 for five combinations of discount and escalation rates. In all but one case the energy escalation rate and the escalation rate

TABLE 17. Benefit-Cost Ratio, Net Present Value, Internal Rate of Return and Payback Period at Different Initial Project Costs for Development Alternatives A and B, with Flashboards, St. Cloud Dam. The initial project costs, from left to right, correspond to 1) Section VIII estimate, 2) 20% increase, and 3) 20% decrease.

35 Year Project Economic Life			
Alternative A:	Initial Project Cost (million $, 1981 base yr)		
	9.18	11.02	7.34
Benefit-Cost Ratio	1.85	1.59	2.22
Net Present Value (million $, 1981 base yr)	8.79	7.07	10.50
Internal Rate of Return (%)	21.4	18.6	26.0
Alternative B:	Initial Project Cost (million $, 1981 base yr)		
	6.65	7.98	5.32
Benefit-Cost Ratio	2.18	1.88	2.60
Net Present Value (million $, 1981 base yr)	9.06	7.82	10.31
Internal Rate of Return (%)	25.3	21.6	32.1
50 Year Project Economic Life			
Alternative A:	Initial Project Cost (million $, 1981 base yr)		
	9.18	11.01	7.34
Benefit-Cost Ratio	2.22	1.91	2.64
Net Present Value (million $, 1981 base yr)	13.30	11.55	15.04
Internal Rate of Return (%)	21.7	19.1	26.1
Payback Period (yrs)	11	15	7
Alternative B:	Initial Project Cost (million $, 1981 base yr)		
	6.65	7.98	5.32
Benefit-Cost Ratio	2.60	2.25	3.07
Net Present Value (million $, 1981 base yr)	13.06	11.79	14.32
Internal Rate of Return (%)	25.5	21.9	32.1
Payback Period (yrs)	7	10	4

TABLE 18. Benefit-Cost Ratio, Net Present Value and Internal Rate of Return and Payback Period at Different Annual Operation, Maintenance, and Replacement Costs for Development Alternatives A and B, with Flashboards, St. Cloud Dam. O, M, & R costs from left to right correspond to 1) estimate in Section VIII, 2) 20% increase, and 3) 20% decrease.

Alternative A			
	Annual O, M & R Costs ($)*		
	69,200	83,000	55,400
35 Year Project Economic Life:			
Benefit-Cost Ratio	1.85	1.79	1.92
Net Present Value (million $, 1981 base yr)	8.79	8.45	9.13
Internal Rate of Return(%)	21.4	21.1	21.8
50 Year Project Economic Life:			
Benefit-Cost Ratio	2.22	2.14	2.31
Net Present Value (million $, 1981 base yr)	13.30	12.87	13.73
Internal Rate of Return (%)	21.7	21.4	22.0
Payback Period (yrs)	11	11	10
Alternative B			
	Annual O, M & R Costs ($)*		
	59,200	71,000	47,400
35 Year Project Economic Life:			
Benefit-Cost Ratio	2.18	2.10	2.27
Net Present Value (million $, 1981 base yr)	9.06	8.77	9.36
Internal Rate of Return (%)	25.3	24.9	25.8
50 Year Project Economic Life:			
Benefit-Cost Ratio	2.60	2.48	2.72
Net Present Value (million $, 1981 base yr)	13.06	12.69	13.43
Internal Rate of Return (%)	25.5	25.0	25.9
Payback Period (yrs)	7	7	7

*Annual Operation, Maintenance and Replacement Costs ($, 1981 Base Yr).

TABLE 19. Benefit-Cost Ratio, Net Present Value and Internal Rate of Return, at the Original Plus Four Other Combinations of Discount and Escalation Rates for Development Alternatives A and B, with Flashboards, St. Cloud Dam

	Variations in Discount and Escalation Rates				
35 Year Project Economic Life					
Discount Rate (%)	11	9	9	9	9
Escalation Rate for Energy Value (%)	9	9	11	7	11
Escalation Rate for O&M (%)	9	9	11	7	9
Alternative A:					
Benefit Cost Ratio	1.85	2.46	3.27	1.85	3.60
Net Present Value (million $, 1981 base yr)	8.79	16.03	27.40	8.72	28.52
Internal Rate of Return (%)	21.4	21.4	24.7	18.3	25.0
Alternative B:					
Benefit Cost Ratio	2.18	2.87	3.76	2.18	4.20
Net Present Value (million $, 1981 base yr)	9.06	15.43	25.43	9.00	26.39
Internal Rate of Return (%)	25.3	25.3	29.1	21.8	29.5
50 Year Project Economic Life					
Alternative A:					
Benefit-Cost Ratio	2.22	3.14	4.47	2.19	5.36
Net Present Value (million $, 1981 base yr)	13.30	26.29	51.07	13.05	53.51
Internal Rate of Return (%)	21.7	21.7	24.9	18.6	25.2
Payback Period (yrs)	11	7	5	9	5
Alternative B:					
Benefit Cost Ratio	2.60	3.62	5.05	2.56	6.18
Net Present Value (million $, 1981 base yr)	13.06	24.50	46.30	12.85	48.39
Internal Rate of Return (%)	25.5	25.5	29.2	21.9	29.5
Payback Period (yrs)	7	4	4	5	4

for operation maintenance and replacement were assumed to be equal. Alternatives A and B still have good indicators for the worst case, e.g. where the energy escalation rate is less than the discount rate.

6. Dry Year Analysis

In the event that flows reach exceedingly low values during the first year of operation, the income due to energy sales would be significantly reduced. The City of St. Cloud should be prepared for the negative cash flow which would result if the first year of operation is a dry year. Figure 15 shows the flow duration curve for low flow year based upon 44 years of U.S.G.S. flow data. The annual energy generated in this dry year with Development Alternative A (4 units) and B (3 units) without flashboards is estimated to be 18.0 GWH and 17.6 GWH, respectively. If this dry year occurred during the first year of operation, the negative cash flow would be $436,000 and $227,000 in 1981 dollars for Alternatives A and B, respectively.

X. ENVIRONMENTAL IMPACT OF PROPOSED DEVELOPMENT

A. Background

Because small-scale hydropower facilities are generally developed at existing dam sites, the environmental impact is usually limited; there is no land inundated due to new dam construction and the character of the stream is not greatly altered. The environmental impact of small-scale hydropower facilities should not be entirely discounted, however. There are likely to be a few cases where a fishery may be harmed, public health may be threatened due to dredge spoils, or a historic structure may be destroyed. The scope of this Section is to identify the potential environmental impacts of hydropower development at the St. Cloud Dam. The goal of Section X is to determine the potential impacts in accordance with the Federal Energy Regulatory Commission's (FERC) requirements for the filing of a Major License for hydroelectric power development.

In order to evaluate the environmental impacts of a hydropower facility, the mode of operation must be specified. Operational modes may be divided into two general categories:

1. Run-of-River. Hydropower plants which do not have sufficient reservoir storage for seasonal peaking are classified as run-of-river. This category includes facilities which have enough reservoir storage for peaking on a daily basis. The authors prefer to differentiate between these two sub-categories with the terms "strict run-of-river" and "daily storage."

2. Seasonal Peaking. If the facility will be used for store-release peaking on a seasonal basis, the river or stream will be subject to larger and more intermittent water level fluctuations. A seasonal peaking operation may therefore have a more detrimental effect on the environment.

The following effects are considered important in the operation of a small-scale hydropower facility:

1. Minimum flow
2. Water level fluctuation
3. Fish passage through hydraulic turbines
4. Dredging and disposal of dredged material
5. Water quality impacts
6. Threatened or endangered species

There will also be additional temporary impacts during construction. Timing of construction activities may be such that they minimize impact upon the spawning activities of fish and other facets of aquatic life.

Other construction activities which could have an adverse effect upon the environment include dredging and dust control. This is most easily controlled by installing a cofferdam to reduce excessively turbid releases to the stream. Land use impacts that should be addressed concern the fact that powerhouses and dams alter the general scenery along a river, displace streamside vegetation, and present obstacles to terrestrial wildlife species [8]. Indirect impacts of small-scale hydropower may lead to new opportunities and responsibilities for supporting recreational, commercial, agricultural, or residential activity [8].

There are also several other considerations for which the degree of severity or applicability must be determined on a site-specific basis. These considerations include powerline construction, noise reduction, earthwork, historical and archaeological significance, endangered species (plants and animals), recreation (parks, canoe routes, etc.), and aesthetic quality. Also of prime importance in determining impacts would be the designation of a river or stream as a Wild and Scenic River on either a state or federal basis. There are usually no impacts incurred by the dam itself because if these impoundments have been in place a long time, it is likely that environmental modifications have already taken place. Fish and wildlife have probably been modified by the existing dam [8].

An effective means of screening the site-specific environmental impacts is by utilizing an environmental impact matrix as shown in Fig. 24 [9] for the St. Cloud Dam. The facility will be operated as a strict run-of-river facility since the Mississippi River at St. Cloud has a well established base flow and there is no need for drawdown. In the authors' opinion there is a significant positive impact upon the utility

● SIGNIFICANT IMPACT

◉ LIMITED IMPACT

☐ INSIGNIFICANT OR NO IMPACT

PROPOSED ACTIVITIES		NATURAL FACTORS: TERRESTRIAL		NATURAL FACTORS: HYDROLOGICAL				NATURAL FACTORS: BIOLOGICAL				NATURAL FACTORS: ATMOSPHERIC		CULTURAL FACTORS: SOCIAL							CULTURAL FACTORS						CULTURAL FACTORS: LAND USE - LAND VALUE					CULTURAL FACTORS: INFRASTRUCTURE				CULTURAL FACTORS: RECREATION					
		SOILS	LAND FORM	SURFACE WATER LEVELS	SURFACE WATER QUALITY	UNDERGROUND WATER QUALITY	WELL WATER SUPPLY	VEGETATION	FISH AND AQUATIC WILDLIFE	BIRDS	TERRESTRIAL WILDLIFE	AIR QUALITY		SCENIC VIEWS & VISTAS	OPEN SPACE QUALITIES	HISTORICAL ARCHEOLOGICAL SITES	RARE AND UNIQUE SPECIES	HEALTH AND SAFETY	AMBIENT NOISE LEVEL	RESIDENTIAL ACTIVITY	EMPLOYMENT (SHORT TERM)	EMPLOYMENT (LONG TERM)	HOUSING (SHORT TERM)	HOUSING (LONG TERM)	LOCAL GOVERNMENT FISCAL EFFECTS	BUSINESS ACTIVITY	AGRICULTURAL	RESIDENTIAL	COMMERCIAL	INDUSTRIAL	OPEN SPACE	TRANSPORTATION	UTILITIES	WASTE DISPOSAL	GOVERNMENT SERVICES	HUNTING	FISHING	BOATING	SWIMMING	PICNICKING	HIKING-BIKING
CONSTRUCTION	EARTHWORK CLEARING/GRADING/EXCAV.			◉	◉									◉					◉															◉			◉				
CONSTRUCTION	DEMOLITION/DISPOSAL				◉																													◉							
CONSTRUCTION	INTERIM FLOOD CONTROL				◉																																				
CONSTRUCTION	COFFER DAM/DEWATERING				◉																																				
CONSTRUCTION	HEAVY EQUIPMENT USE		◉											◉				◉	◉																						
CONSTRUCTION	MATERIAL TRANSP./STORAGE																																								
CONSTRUCTION	TEMPORARY STRUCTURES AND FACILITIES													◉																											
CONSTRUCTION	WORKER AND EQUIP. ACCESS		◉											◉																											
CONSTRUCTION	WORKER INFLUX																				◉					◉															
PHYSICAL PLANT & OPERATION	PERMANENT STRUCTURES & FACILITIES		◉											◉																											
PHYSICAL PLANT & OPERATION	ELECTRIC DISTRIB. CIRCUITS		◉											◉																											
PHYSICAL PLANT & OPERATION	ELECTRIC GENERATION																																●								
PHYSICAL PLANT & OPERATION	FLOW CONTROL																																								
PHYSICAL PLANT & OPERATION	IMPOUND, MANAGEMENT																																								
PHYSICAL PLANT & OPERATION	WORKER & EQUIP. ACCESS																																								
PHYSICAL PLANT & OPERATION	SECURITY & SAFETY																																								

Fig. 24. Potential Impacts for St. Cloud Dam Shown in an Environmental Matrix.

infrastructure since the development will supply 5 to 8 MW of capacity to the power grid.

B. FERC Requirements

The Federal Energy Regulatory Commission (FERC) in its application procedure for a hydropower license requires an environmental report to be filed. The environmental report should be consistent with the scope of the project and environmental impacts of the proposed action [10].

The report must be prepared in consultation with local, state, and federal agencies with expertise in environmental matters. The names and addresses of these agencies may be obtained from the Director, Division of Licensed Projects. All contact with the local, state, and federal agencies should be made well in advance of the final design phase of the project. The application for licensing should be filed during the final design phase.

The environmental report should include the following sections [10]:

1. General description of the project locale.
2. A report on the current consumptive water use and the impact of the project on water quality.
3. A report on fish, wildlife, and botanical resources in the vicinity of the project and the impact of the project on those resources. Special attention should be given to endangered plant and animal species, critical habitats, and sites on Wild and Scenic Rivers.
4. A report on historical and archeological resources, with emphasis on sites eligible for or included on the National Register of Historic Places.
5. A report on recreational resources which considers the existing and proposed recreational facilities and recreational opportunities of the project.
6. A report on land management and aesthetics which includes the management of wetlands, flood plains and other lands within the project boundary and the protection of the recreational and scenic values of the project.

C. Water Level Fluctuations and Instream Flows

The significance of water level fluctuations depends upon the mode of operation of the small-scale hydroelectric facility, the magnitude and timing of fluctuations, and the site-specific environmental setting [11]. Water fluctuation due to peaking operations may be of differing amplitude or frequency than normal seasonal fluctuations, adversely affecting fauna and flora adapted to seasonal cycles [12]. In addition to the obvious aesthetic effects of fluctuating water levels, biological production can potentially be restricted. Water level fluctuations can also erode shorelines and transport nutrients from shallow zones to deepen regions of a reservoir [12]. These effects upon the reservoir apply mainly to hydropower installations which operate on a "peaking" basis, and are not of concern to strict run-of-river installations.

In conjuction with maintaining acceptable water levels is the requirement for sustaining minimum flows within a river. Minimum flows should be maintained in order to accommodate downstream recreational activities and fishery habitat [9]. A strict run-of-river hydroelectric plant would operate according to the natural stream flows, and the operation of the plant would not alter the normal downstream flows. Since the proposed hydropower facility operation for the St. Cloud Dam is strict run-of-river, there will be no unnatural fluctuations of water level and instream flows due to the hydropower facility, e.g., there is no impact upon water levels and instream flows.

One option for each development alternative, however, is to increase headwater elevation by installing two foot flashboards on a permanent basis during non-flood flows, thus raising the present spillway crest by two feet. If this alternative is considered viable, the final design should consider the potential impacts to the environment due to the backwater effect of increased reservoir elevation. However, the two foot flashboards will actually raise the spillway crest of the present dam to 981.0 ft above MSL. The environment has experienced this inundation previously because according to NSP records the original timber crib dam crest was at this elevation. Also, the seasonal changes in flow have caused the environment to adjust to a natural frequency of inundation. Careful analysis should be performed to determine the actual impact upon the littoral zone habitat upstream of the St. Cloud Dam.

D. Water Quality

"Developing new sites or retrofitting existing sites for hydroelectric generation can alter water quality in both the impoundment and the tailwaters. The significance of this issue is primarily dependent upon operation of the facility, thermal stratification of the impoundment, and the location (depth) of the outlet. Most projects operated in a run-of-river mode will have only limited pondage, thus strong stratification will be unlikely due to short water detention time. Projects with existing dams that are operated in this manner would not be expected to significantly alter the water quality of the river over that which existed prior to retrofitting the dam for power production" [13].

Potential water quality consideration in tailwaters below dams include:

1. Alteration of temperature regimes,
2. Reduced turbidity,
3. Changes in dissolved oxygen,
4. Increases in the dissolved form of some metals, and
5. Altered nutrient and organic matter regimes [12].

Important aspects to consider are thermal and chemical stratification in the reservoir and depth of water withdrawal. If water is discharged from the hypolimnion, colder tailwaters may occur in the summer and warmer tailwaters in the winter. Possible adverse results from such discharge patterns include reductions in aquatic life, benthic invertebrate diversity and modifications in the spawning activity of fish. This is true of very deep reservoirs. Shallow reservoirs, however, are often insufficiently deep to allow significant thermal stratification to take place. Therefore, in run-of-river projects without significant storage capacity or depth, these types of problems will not be encountered. Most low-head turbine installations intake a column of water and do not draw water off at a certain level. With this mixing of the water column, the problems associated with low dissolved oxygen will not be encountered. A stratified reservoir would require a much more detailed investigation of its possible impacts.

Water Quality - St. Cloud

The St. Cloud Dam reservoir has a low storage capacity and a corresponding small hydraulic residence time. At the normal storage capacity of 3000 acre-ft, and the average annual discharge (4760 cfs), the hydraulic residence time of the reservoir is only 7.6 hours. At 1000 cfs, the river discharge which is exceeded 95 per cent of the time, the reservoir hydraulic residence time is still only 36 hours. In addition, reservoir depth at the spillway was measured to be only 10 ft. The addition of 2 ft flashboards at the spillway crest will increase the reservoir hydraulic residence time by 9 per cent. Thus, with the addition of flashboards the reservoir will still have a relatively short hydraulic residence time. With the short hydraulic residence time and shallow reservoir depth at the St. Cloud Dam, a strong thermal stratification is unlikely during operating periods. It is therefore unlikely that the dissolved oxygen concentrations of the reservoir will be depleted during facility operation. The water quality problems associated with dissolved oxygen depletion, such as high nutrient levels, heavy metal and toxics released from reservoir sediments, and high biochemical oxygen demand, will not occur. In addition, the facility intakes will take water from the complete water column. This will eliminate the possibility of selective withdrawal of cold hypolimnetic water. The facility will not significantly alter the natural downstream temperature regime. The potential for high mercury levels in the reservoir sediments is considered in Section X.F.

E. Fish Passage Through Hydraulic Turbines

An impoundment acts as a barrier to the migration of fish. Since the scope of this report emphasizes the rehabilitation of existing dam sites, it is evident that the environmental impact due to the impoundment has already taken place. At sites where turbines are presently operating, fish pass either over the spillway or through the hydraulic turbines, depending upon the natural river flows. At sites where power generation has been stopped, fish pass only over the spillway. Existing impoundments usually create two separate environments, namely, the two reaches upstream and downstream. The habitats and populations of fish in each reach can vary greatly.

For instance, in general, fish populations (as determined through electrofishing) show that more fish exist downstream of the impoundment. This is primarily due to the fact that fish prefer the fast, rushing water to the slow moving water behind the impoundment. Therefore, fish in the downstream reach may be primarily affected by the fluctuating water levels, but also by passage through the turbines.

The mortality of fish passing through hydraulic turbines has been shown to correspond to various turbine characteristics [14]. For example, the survival of fish was found to be at a maximum when the turbine was operated at maximum efficiency. Furthermore, fish survival is greater when cavitation is eliminated in turbine operation.

Most of the new turbine designs have not been tested for fish mortality. However, many of the newer designs are of the propeller type. Studies have been conducted on similar turbines in the past. The results indicated that of the many factors affecting fish passage through turbines "... cavitation is believed to be the most serious. Decapitation and the production of 'pulpy' tissues and internal hemorrhages are examples of severe injuries attributable to cavitation. Pressure changes of a magnitude less than those producing cavitation can also be harmful to fish. In addition, shear forces produced by rapid changes in the direction of water flowing through the unit and contact between fish and the turbine's mechanical features (runner hub, runner blades, wicket gates, etc.) may cause mortality" [14]. In general, total mortality increases as the tailwater level is dropped, even though the point of cavitation is not reached. The above factors become less important at lower head sites, such as the St. Cloud Dam, because the pressure changes are not as severe. Recent tests have indicated fingerling survival rates as high as 97 per cent for low-head hydropower facilities*.

It must be emphasized that turbine mortality is just one means by which a fish could die in its travel downstream. For example, at existing dams, fish have historically been passed directly over spillways as well as through turbines. Trash racks located at the intake to turbines have metal bars which are spaced so that only the smallest fingerlings may pass

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* NEYPRIC, Inc. (1981). Personal communication on the Rock Island Hydropower Facility, Ohio River.

into the turbines. This partially eliminates possible fish mortality at the source.

Fish Passage Through Hydraulic Turbines - St. Cloud

"It is important to put turbine related fish mortality at conventional hydroelectric facilities into prospective. Turbine related mortality is only one of many causes of fish mortality to downstream migrating juveniles as a result of hydropower development; other factors affecting survival are spillway downstream passage facilities, predation,and delay in migration" [15]. With the trash racks in place, only the smallest juveniles are capable of being passed through the turbines. All downstream migrants who are too large to pass through the trash racks will be passed over the spillway (as has been done historically).

Most fish in this reach of the Mississippi River are sedentary. However, fish which do enter the turbine may be subject to mechanical injury with the turbine runner or internal injury due to pressure changes. However, it is known that the highest fish survival rates occur when the turbine is operated at maximum efficiency. This condition is a goal which will be strived for in the operation of the plant since it will produce the most efficient power production from a given stream flow. Problems encountered by fish due to cavitation will also be minimized when the turbine is operated at maximum efficiency.

The above results were obtained from tests of older model turbines. "The relationship of studies conducted to date to the newer turbine design, which is currently being installed in small-scale hydropower operation, is unclear; more data need to be obtained on more modern small-scale prototypes" [15]. The turbines which are being considered for installation at the St. Cloud site should not pose any significant fish mortality problems.

Impingement against the trash racks is another potential source of fish mortality at the St. Cloud Dam. At design discharge, the average velocity through the trash racks is 2.3 ft/sec. This trash rack velocity will not cause severe fish impingement problems, but some limited fish impingement may occur.

F. Construction Impacts

In some circumstances, it is possible that the impacts due to construction activities may be greater than impacts associated with normal plant operation [16]. The primary construction impacts are related to dredging and disposal of dredged material. An analysis of the accumulated sediments should be taken to determine whether or not the sediments contain large amounts of nutrients or significant levels of toxic substances.

Dredging is required at most existing dam sites to clear intake/outlet structures and to repair powerhouses. Accumulation of material may occur at a dam site over a number of years, and it may be necessary to reclaim partial reservoir storage capacity. Dredging may also be needed during the operation of the plants if a significant amount of deposition occurs in the inlet/outlet works. The significance of impacts associated with dredging and dredged material disposal will be primarily influenced by the physical and chemical characteristics of the sediments and the amount of dredging required [13].

The physical effects due to dredging operations include resuspension of sediments, changes in water circulation patterns, changes in particle size and porosity of sediment, mobilization into the water column of nutrients and contaminants present in resuspended sediments [12]. Potential adverse impacts to biological systems as a result of dredging operations include loss of primary production and stress to fish due to increased turbidity, destruction of benthic habitat, and secondary effects on aquatic biota from resuspension of nutrients, heavy metals or toxic contaminants and disposal of dredged material [12].

Dumping the spoil on the river's bank might result in sediment runoff and possibly toxic pollution where chemicals are found in the dredged spoil. On the other hand, dredged spoil might well be used in nearby landfill projects which pose no threat to either the terrestrial or aquatic environments [8]. If the sediments at the site are highly contaminated, it may be necessary to use specialized dredging equipment and upland disposal which may result in high transportation costs [9].

"Disturbance of bottom sediments may result in changes in the species composition, distribution, and abundance of benthic invertebrates. Resuspension of sediments during reservoir dredging operations or runoff from the disposal site, if located adjacent to the reservoir, can increase silt deposition below the dam. Biological consequences could include (1) destruction of fish spawning areas, (2) alteration of benthic invertebrate habitats, and (3) smothering of mussels, submerged macrophytes, benthic algae, and invertebrates" [13].

Bank erosion due to hydropower operation may be significant depending upon the particular mode of operation. "Peaking plants have more potential for causing bank erosion than run-of-river plants because reservoir levels may fluctuate causing shoreline slides. Downstream, power plant discharges can cause scouring, even though power generation drastically reduces the energy left in the water compared to what would have existed without the dam and powerhouse. Nonetheless, hydroplant impoundments reduce stream velocities and therefore reduce stream bed erosion. Since erosion varies exponentially with water velocity, the erosion limiting benefits of hydroplants can be significant, particularly under flood conditions" [16].

Removal of the sediments is not only expensive, but it is potentially dangerous to aquatic organisms. Therefore, careful operations and timing of dredging is essential in eliminating contamination of downstream communities if toxic pollutants are present in the sediments, and to avert burial of eggs and subsequent reproductive failure of fish spawning in the area. Seasonal timing of dredging operations is important because, depending upon the fish species of major concern, eggs could be present during almost any month of the year [16].

Other impacts may result from excavation and clearing activities. For example, removal of vegetation and disposal of spoil changes of land form may collectively or individually lead to erosion if not adequately protected. An interruption in releases during construction could possibly affect aquatic wildlife and downstream users. This may be considered necessary in circumstances where building in the stream bed may result in temporary increase in stream turbidity. Related impacts involving noise and dust control must also be mitigated.

Mitigation of several of the above impacts may be achieved by damping for dust control, reseeding of vegetation and spacing of blasting to avoid disturbance (e.g. if recreation users are nearby). "Depending on the design and existing outlet works, cost increases (in the mitigation effort) might also result where the releases from the reservoir must be maintained during the construction period" [17].

<u>Construction Impacts - St. Cloud</u>

The temporary impacts due to construction activities at the St. Cloud Dam could potentially have adverse impacts on the environment. The biggest problem which may occur during construction concerns dredging and other activities which could affect water quality. All necessary precautions should be taken so that no excessively turbid water is released to the stream. All necessary state and federal permits should be obtained. A consultation with these agencies well in advance of scheduled construction is advised to insure that all regulations will be followed.

Care should be taken so that construction activities will not interfere with the natural spawning activities of fish. Species and diversity taken above and below the St. Cloud Dam are shown in Tables 20 and 21. The dates for the spawning season of each species are also shown. Activities such as dredging usually involve clearing intake structures, repairs to the powerhouse, and clearing of sediment in the tailrace. Turbid water must not be released during the spawning season of the fish. Timing of dredging activities should be such that no communities will be contaminated.

During 1970 and 1971, 587 fish were collected from 28 Minnesota waters and analyzed for mercury levels in the flesh. Sampling was widely distributed and represented many lakes and the more important watersheds. Results of the sampling program indicated that fish in the Mississippi River from Grand Rapids to Monticello (including St. Cloud) had levels considerably higher than anywhere else in the state. The source of the high mercury concentrations is believed to be the wood pulp and paper industries discharge of mercury compounds used as slimicides. This is currently prohibited but some residues may remain in the bottom sediments. The Minnesota Department of Natural Resources recommended in 1970 that consumption of fish taken from this reach of the Mississippi River be limited to one meal a week. This was based on the FDA action level of 0.5 ppm.

Testing and/or sampling of the sediments should be taken to determine its physical, chemical, and biological characteristics to make a

TABLE 20. Species and Diversity of Fishery Taken Downstream of St. Cloud Dam, October 8, 1974*.

Species	Number	Per Cent of Catch	Spawning** Season
Carp	110	21.1	Mid-May
Smallmouth Bass	159	30.5	May - July
Northern Redhorse	140	26.9	Late May - Early June
Black Bullhead	22	4.2	Jay - June
Black Crappie	1	0.2	May - June
Silver Redhorse	12	2.3	Late May - Early June
Walleye	15	2.9	Spring shortly after spring thaw
White Sucker	10	1.9	Mid-May
Rock Bass	1	0.2	May - Early June
Burbot	6	1.1	January - February before thaw
Bluegill	1	0.2	Late May - Early June
Northern Pike	1	0.2	April - Early May
Yellow Perch	1	0.2	May
Largemouth Bass	6	1.9	May - July
Yellow Bullhead	1	0.2	May - June
Hornyhead Chub	2	0.4	--
Lorgenose Dace	4	0.8	May - June
Common Shiner	1	0.2	Late May
Spotfin Shiner	3	0.6	Summer
Spottail Shiner	2	0.4	Late June - Early July
Bluntnose Minnow	1	0.2	May - June
Logperch	16	3.1	May - June
Johnny Darter	5	1.0	May - June
Troutperch	1	0.2	Late May - Mid June

*Source: Minnesota Department of Natural Resources, Division of Fish and Wildlife, Ecological Service. Principal Investigator: John W. Enblom, Aquatic Biologist. Method: Electrofished.

**Eddy, S. and J. C. Underhill, Northern Fishes, University of Minnesota Press, 1974.

TABLE 21. Species and Diversity of Fishery Taken Upstream of St. Cloud Dam, September, 1966*.

Species	Number	Per Cent of Catch	Spawning** Season
Walleye	20	10.5	Spring shortly after spring thaw
Northern Pike	20	10.5	April - Early May
Smallmouth Bass	40	21.0	May - July
Northern Redhorse	41	21.5	Late May - Early June
White Sucker	50	26.5	Mid-May
Carp	20	10.5	Mid-May

*Source: Minnesota Department of Natural Resources, Division of Game and Fish. Principle Investigator: James A. Schneider, Aquatic Biologist. Method: Electro-shocking.

**Eddy, S. and J. C. Underhill, Northern Fishes, University of Minnesota Press, 1974.

proper determination of adverse effects caused by sediment resuspension. Particular care in the analysis of sediment at the St. Cloud Dam site is needed due to the potentially high mercury concentation. A suitable disposal site for the dredged material should also be chosen. Close coordination with state agencies is a necessity to insure that all regulations and restrictions are met, especially those regulations implemented through the State Wild and Scenic River Act.

G. Historic Preservation

In the course of FERC's licensing procedure, the Advisory Council on Historic Preservation and the State Historic Preservation Officer must be consulted to assure that no historic or cultural sites will be adversely affected. "Many older hydropower sites, while not of national significance, have played an important role in the local history of an area and thus important enough to stimulate local concerns. Additions and other needed alterations of the exterior of a structure should be designed in keeping with the historic and aesthetic value of an area, especially if other historic structures are in the close proximity" [18]. Sites on the National Register of Historic Places are given special protection by federal law. Therefore, it is important to review each site for potential archeological, cultural, and historic significance.

The proposed implementation of hydropower at the St. Cloud Dam will not alter any historical sites or facilities. The abandoned powerhouse foundation and outlet structures shown in Fig. 8 are the only remains of the existing generating facilities and will not be altered in the proposed development.

H. Endangered Species

"The development of sites with existing dams could be expected to have less of an impact on populations of threatened or endangered species because the degree of habitat alteration would, in most cases, be less than usually associated with the construction of new dam/impoundment systems. Retrofitting existing dams, however, could significantly affect the mussel fauna of a river or stream where the existence of small undeveloped dams has actually enhanced these populations. These dams function as silt traps and thus have reduced downstream siltation in rivers and streams that had previously been degraded by heavy sediment loads from erosion and runoff in the watershed. As a result, remnant mussel populations often exist in the spillways below such dams. These populations are frequently the only remaining mussels in these rivers or streams and often consist of threatened or endangered species. When the dams are retrofitted for hydroelectric power production, dredging and water level fluctuations could adversely affect these species" [11].

The most difficult environmental issue to mitigate is the presence of a threatened or endangered species or its critical habitat in the vicinity of a proposed hydroelectric site. Mitigative measures will vary depending upon the distribution and abundance of the species at the site and the proposed design and operation of the project. At sites where the occurrence of an endangered species or its critical habitat is suspected, personnel in the appropriate state and federal agencies should be consulted. Such consultation should take place during the initial stages of project development.

Endangered Species - St. Cloud

The operation of the St. Cloud plant will not interfere with any endangered plant or animal species. The Minnesota Natural Heritage Program (Minnesota Department of Natural Resources) performed an information search for the St. Cloud site. The Natural Heritage Program has located two priority plant communities in the project area. The first is an Oak savanna, located in Talahi Park (Sec. 12 T35N, R31W), and managed by prescribed burning. Savanna acreage in Minnesota has been severely reduced by agriculture and urbanization. Oak savannas with high quality prairie understories are considered high priority for protection. The second is a Floodplain Forest located on the Beaver Islands (Sec. 12, T35N, R31W; Sec 24 T12N, R28W), approximately one-third mile downstream from the dam. Their noteworthy features include a relatively undisturbed floodplain forest and the northernmost documented station for Bladdernut (Staphylea trifolia).

The Minnesota Natural Heritage Program performed a survey of the site area and found no recorded occurrence of rare or endangered species or priority animals near the project site.

I. Recreation - St. Cloud

Wilson Park, Riverside Park, Talahi Park, St. Cloud Wildlife Refuge, and Beaver Island all border the Mississippi River in the vicinity of the St. Cloud Dam. The Mississippi River between St. Cloud and Anoka is a uniquely scenic area of Minnesota. The Mississippi is by far the largest river in the central portion of the state. Between St. Cloud and Anoka, it flows through a broad valley averaging 100 ft or more from the waters edge.

Outstanding recreational opportunities are available along the Mississippi River from St. Cloud to Anoka. The river is excellent for fishing, canoeing, and boating. Small boats can be operated along the entire 55 miles between St. Cloud and Anoka. Because of the recreation value, this section has been included in the Minnesota Wild and Scenic River System.

All of the project development alternatives proposed herein will have a minor (if any) impact upon recreational resources near the St. Cloud Dam.

J. Agency Contacts/Correspondence

Close coordination with public agencies is essential early in the developmental phases of the project to assure that regulatory requirements and acceptable policies become known. "Both beneficial and adverse effects of small hydropower development will be a function of project design and operation as well as the nature of the existing environment that will be altered. Successful mitigation of adverse effects associated with such development will depend upon (1) accurate prediction of the magnitude of adverse impacts and (2) early awareness of potentially significant environment issues. Ecologists and environmental scientists must be consulted during the preliminary design phase of project development. By defining the relevant environmental issues at this stage, meaningful discussions can be held with all responsible and interested agencies and groups"[11].

It should be noted that mitigation of impacts at existing dam sites should be viewed in the context of an already perturbed environment [19]. Feasibility studies completed to date have validated this assumption: "The experience of our firm in conducting feasibility studies at three hydroelectric sites indicates that identifiable adverse environmental impacts associated with restoration of the three facilities are relatively minor" [9].

The various stage contact agencies are included on the following pages [20]:

STATE AGENCIES TO BE CONTACTED FOR SMALL HYDROPOWER DEVELOPMENT

1. MINNESOTA DEPARTMENT OF NATURAL RESOURCES - Division of Waters
   a. Inquiries to the Director, Attn: Development Section
   b. EAW (Environmental Assessment Worksheet). Even if not mandatory, we strongly suggest that one be prepared by mutual cooperation within DNR. Purposes:
      - to give early and preliminary thought to any and all problems and benefits which may occur, and
      - to bring the project before the public early in development and avoid delays later in project.
   c. One permit may be issued to cover the concerns of:
      - work in public waters,
      - water appropriation,
      - dam safety - modification of dam,
      - water regulation & usage,
      - fish and wildlife habitat (including rare species),
      - recreation, and
      - water quality.

      The decision to issue single permit is made on a site specific basis.
   d. Generally DNR requires permits for raising or lowering of spillway level, fluctuating water level, and discharge which are different than historical records, dam modification, dredging and disposal

of dredged material (spoil), shore protection, riprap, shoreline excavation, partial or complete drainage, water level control structure, stream or channel enlargement , or relocation.

2. MINNESOTA POLLUTION CONTROL AGENCY

a. Inquiries to the Director, Attn: Permit Section - Water Quality

b. The 1977 Clean Water Act gives authority to the MPCA to certify hydropower projects. This MPCA Certification is a prerequisite for permitting by FERC, COE, Coast Guard or any other Federal Agency issuing permits of this type.

c. The MPCA has authority to become the primary agency issuing NPDES (National Pollutant Discharge Elimination Systems) permits, replacing FERC, Corps, etc., but has not exercised this authority. They may possibly do so in the future.

d. Primarily concerned with water quality during construction and operation. These concerns include but are not limited to: maintaining minimum and constant flows, reaeration, thermal stratification dredging and downstream water-supply.

e. The MPCA must also review all secondary considerations, such as downstream flooding, effects of fish and wildlife, etc., before issuing certification according to Minnesota Statutes, Part 116B.09, Subd. 2.

3. STATE PLANNING AGENCY (including Environmental Quality Board-EQB)

a. Power Plant Siting

- Certificate of site compatibility N/A to sites less than 50 MW
- Construction permit for transmission lines if:
  - greater than 200 kV
  - greater than 50 miles

b. Environmental Planning

Current Rules

<u>Actions Requiring Environmental Assessment Worksheet with Local Government as Responsible Agency</u>:

- An action that will eliminate or significantly alter a wetland of Type 3, 4 or 5 (as defined in U.S. Department of Interior, Fish and Wildlife Service, Circular 39, "Wetlands of the U.S., 1956) of five or more acres in the seven-county metropolitan area, or of 50 or more acres outside the seven-county metropolitan area, either singly or in a complex of two or more wetlands.

Actions Requiring Environmental Assessment Worksheet with State Agency as Responsible Agency:

- Any new or additional impoundment of water creating a water surface in excess of 200 acres. (DNR)
- Construction of electric generating plants at a single site designed for, or capable of, operation at a capacity of 200 or more megawatts (electrical). (PCA)
- Construction of electric transmission lines and associated facilities designed for, or capable of, operation at a nominal voltage of 200 kilovolts AC or more, or operation at a nominal voltage of ± 200 kilovolts DC or more and of 50 miles or more in length. (EQB)

Proposed Rules - (possibly effective in Oct. - not yet approved)

- Impoundment of 160 acres or more
- Generating capacity 10-200 megawatts - require an EAW
- Generating capacity 200 or more megawatts - required an EIS.

c. EQB could also serve as staff agency and oversee the analysis of EAW and EIS if required.

4. WATERSHED DISTRICTS
   a. Each concerned district should be contacted.
   b. Permit may be required.

5. COUNTY

   Individual county may have zoning or shoreline management requirements.

6. MINNESOTA ENERGY AGENCY

   Certificate of Need - for sites greater than 50 MW.

7. MINNESOTA HERITAGE PROGRAM
   a) Concerned with rare species.
   b) Part of DNR Environmental Review Process.

XI. PROJECT FINANCING AND IMPLEMENTATION

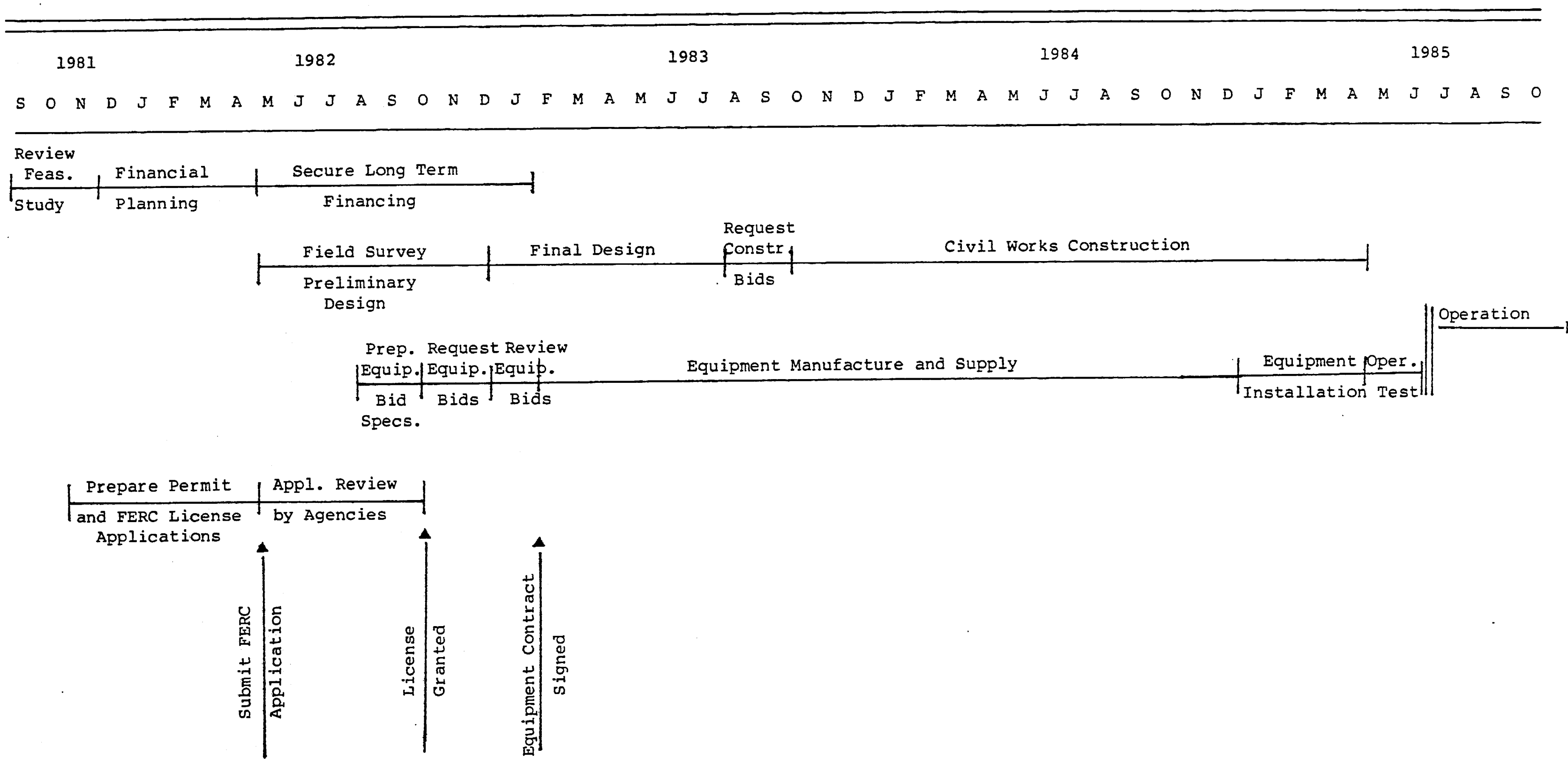
The most likely source of financing for the development of a hydropower facility at the St. Cloud Dam is to issue Municipal tax-exempt bonds. The City of St. Cloud has an A-1 bond rating. As of July 24, 1981, Moody's Tax-Exempt Market Index was 11.20 per cent for A-rated bonds.

Another option is to obtain assistance from the Department of Housing and Urban Development (HUD). The specifications and limitations of HUD financing require that private funding be at least 2.5 times the HUD grant. In addition, awards are made quarterly to the grant applicant who must be a municipality or urban county and pass grant funds to the developer. The availability of this funding, however, is currently in doubt.

A third option is for the City of St. Cloud to enter into a lease-develop agreement with a private developer. One possible agreement, for example, would be for the developer to lease the property, finance and construct the hydropower facility, and sell the electricity during the lease period. The City of St. Cloud would be given a certain portion of the gross income and take over ownership of the facility at the end of the lease. There are many other lease-develop agreements which are possible for the proposed development.

Table 22 gives a suggested project implementation schedule for the timely development of the site. This schedule is likely to be revised at later stages of project development. The project implementation schedule assumes tax-exempt bonds will be issued by the City of St. Cloud for project development.

TABLE 22. Suggested Project Implementation Schedule for Development of Hydropower at the St. Cloud Dam.



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MINNESOTA HISTORICAL SOCIETY

FOUNDED IN 1849

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9 September 1981

Robert J. Knowlton
St. Anthony Falls Hydraulic Laboratory
Mississippi River at 3rd Avenue S.E.
Minneapolis, MN 55414

Dear Mr. Knowlton:

RE: Historical Significance of the ST. CLOUD DAM, Stearns and Sherburne COUNTIES, and the MINNESOTA FALLS DAM, Yellow Medicine and Chippewa COUNTIES.

MHS Referral File Number: N 436

Thank you for the opportunity to review and comment on the above project. It has been reviewed pursuant to responsibilities given the State Historic Preservation Officer by the National Historic Preservation Act of 1966 and the Procedures of the National Advisory Council on Historic Preservation (36CFR800).

It is our opinion that neither the St. Cloud Dam nor the Minnesota Falls Dam is eligible for inclusion on the National Register of Historic Places. Consequently, there are no sites of historic, architectural, cultural, or archaeological significance listed on the National Register of Historic Places, or eligible for inclusion on the area of the above-referenced dams. I hope that this information will be of assistance to you in your feasibility studies.

If you have further questions or comments, please do not hesitate to contact Ms. Susan Hedin, Environmental Assessment Officer, State Historic Preservation Office, 240 Summit Avenue, St. Paul, MN 55102, (612) 296-0103.

Again, thank you for your attention to cultural resources in your planning process.

Sincerely,

Dennis A. Gimmestad
for Russell W. Fridley
State Historic Preservation Officer

RWF/sl