University of Minnesota
St. Anthony Falls Hydraulic Laboratory

Project Report No. 210

HYDROPOWER FEASIBILITY AT THE FISH HOOK RIVER DAM MN 00234

by

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Prepared for

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I. INTRODUCTION

The Fish Hook River Dam MN 00234 is located on the Fish Hook River in Park Rapids, Minnesota. The earthen dam was originally built for logging in 1880 and rebuilt in 1928-1930. A hydropower facility was built in 1909 and taken out of operation in approximately 1943. The powerhouse and portions of the machinery are still in place. The dam is currently owned by the City of Park Rapids. The dam and reservoir are currently used solely for recreation.

A Dam Safety Inspection Report judged the safety of the dam to be inadaquate, and the City of Park Rapids has retained an engineering consulting firm to design a new spillway and specify other required work on the dam. The purpose of this study is to assess the feasibility of redeveloping hydroelectric power production at the dam site.

The Fish Hook River Dam was included in a grant agreement dated September 22, 1980, between the Minnesota Department of Natural Resources (DNR) and the St. Anthony Falls Hydraulic Laboratory for Hydroelectric Power Feasibility studies on seven municipally owned dam sites in the State of Minnesota. A cost-sharing agreement was subsequently made between the DNR and the City of Park Rapids.

This study begins with a hydraulic and hydrologic analysis of the site to determine the available power. The value of the power and marketing options is 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 Fish Hook River Dam is located in Park Rapids, Hubbard County, Minnesota. The dam is owned and operated by the City of Park Rapids. The existing Fish Hook Dam is approximately 620 ft. long, consisting mainly of a earth dam section. The top width of the earth berm is 20 ft. to 30 ft. with side slopes of approximately 2 to 1. The earth fill is composed primarily of sandy soils with traces of organics. Crest elevation is approximately 1429.5 ft. msl [1].[1] The dam is vegetated with trees and brush. Running along the full length of the dam is a municipal sanitary sewer line. A spillway and powerhouse are structurely integrated with the dam.

The structural elements of the powerhouse are a headrace, two turbine pits, a generator room, and a tailrace. Construction is primarily reinforced concrete with concrete masonry walls in the generator room. The headrace is supported on timber piles and the rest of the powerhouse structure is supported on spread footings. The two turbine units installed in 1909 and operated until 1943 are still in place but are in very poor condition. No generating equipment remains in the building.

The Fish Hook River Dam watershed is contained in the Crow Wing subwatershed of the Upper Mississippi River Basin. The drainage area of the dam is approximately 214 square miles.

There is a large amount of reservoir storage available for hydropower operation at the Fish Hook River Dam. The surface area of Fish Hook Lake is 80 million ft^2. In addition, two lakes immediately upstream, Potatoe Lake and Portage Lake, have surface areas of 92 million ft^2 and 18.4 million ft^2, respectively. Only the storage of the Fish Hook Lake was considered in assessing the power production of the Fish Hook Dam site. A drawdown of 1.0 foot, or only using the top 1.0 foot (80 million cubic feet) with a mean reservoir elevation of 1462.5, was assumed.

Under the PUC proposed rules, the energy produced by a hydropower facility with a generating capacity of 100 kW or less has a single value assessed to all energy production equal to that of "dependable" energy. Dependable energy would be worth the sum of the utility's avoided energy cost and the full avoided capacity cost per KWH. Adding the two components, the value of dependable energy sold to the Minnesota Power Co. would be 4.7¢/KWH (1982 base year). Hydropower facilities of greater than 100 kW will likely produce some energy which is not classified as

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[1]Numbers in brackets indicate reference on page 73.

dependable. In the proposed rules, this energy would be worth only the utility's avoided energy cost, i.e., 1.2¢/KWH for Minnesota Power. The development alternatives considered herein have been chosen so that all energy produced would be considered dependable, and worth approximately 4.7 ¢/KWH.

A managed store-release operational scheme will result in the greatest financial return from hydropower development. Such an operation is therefore assumed in this study. Reservoir storage management and minimum streamflow are the two basic components of this scheme and are described in the following:

(1) Reservoir Storage Management. The reservoir surface will be maintained between El. 1426 and 1427 ft above msl. Water surface fluctuations of only 1 ft are required, and they will not be rapid. Approximately 1 month will be required for a full 1 ft fluctuation. The installed turbines will be run at full power as long as the reservoir elevation is above El. 1426. If the reservoir surface elevation is equal to or below El. 1426, the turbines will not be run and a minimum streamflow release will be maintained. If the reservoir elevation is greater than or equal to 1427, the spillway gates will be opened to maintain reservoir elevation as close to 1427 as possible.

(2) Minimum Streamflow. In order to protect the fishery in the Fish Hook River downstream from the dam, a minimum streamflow release is recommended at all times. There is no well-established criteria for minimum streamflow, except that it should not be less than the seven-day, ten-year low flow (approximately 24 cfs at this site). Forty cfs at the 95 percent exceedance level on the flow duration curve was chosen as a representative minimum streamflow for this study.

Three development alternatives were considered in detail, each producing similar levels of annual energy with significant differences in initial cost. The alternative which gave the best economic return had a total initial project cost of $223,400 (1982 base year), an average annual energy production of 640,000 KWH, and an average annual income (1982) of $30,080. Based upon the economic assumptions herein, this alternative had a benefit-cost ratio of 1.90 for a 35 year project economic life and a payback period of seven years.

It was the assessment of a rehabilitation project team from the General Electric Company that rehabilitation of the existing unit(s) is probably not a viable development alternative. The determination was reached because of the age of the units, the condition of Unit #2 and the controls, the unknown condition of Unit #1, the lack of any electrical equipment including generators, the nebulous nature of determining reconditioning costs, and the probable low income that would be generated.

An economic sensitivity analysis indicated that even under adverse economic conditions the project would have positive feasibility. An economic analysis of a typical private development example indicated that private development would have an economic return which is similar to public development, e.g. the feasibility of private development is equally good.

The environmental impacts of the proposed development would not be extensive. Some of the impacts would be positive. The proposed operational scheme, for example, may have a positive impact upon the downstream fishery by imposing minimum streamflow criteria where none currently exists, and by providing a stable flow regime for large portions of the year.

III. RECOMMENDATIONS

1. Hydropower development at the Fish Hook River Dam will likely have a good economic return. It is recommended that the City of Park Rapids investigate the potential for hydropower development further and begin filing for the required permits and licenses. These include:

    - Application for local and state permits, as described in Section X.
    - Application for an Exemption from FERC Licensing, as described in Section X.
    - Negotiations with Minnesota Power based upon rate information received from the Minnesota Public Utilities Commission.
    - Design of the hydropower facility and negotiations with equipment manufacturers.
    - Discussion with potential private developers if private development is an option under consideration.

2. A managed store-release operational scheme, as outlined in Sections II and VII, is recommended.

3. It is recommended that control of the water surface elevation of Potato Lake and Portage Lake be incorporated into the operational management of a hydropower facility at Fish Hook River Dam if at all possible. This would significantly improve the reliability of hydropower production at the Fish Hook River Dam.

IV. SITE CHARACTERISTICS AND EXISTING FACILITIES

A. Site Description and Location

The Fish Hook River Dam is located in the City of Park Rapids (about 185 miles northwest of Minneapolis/St. Paul) in the NE1/4 of NW1/4 of section 25, T.140N, R.35W. The site location is given in Fig. 1. Park Rapids is the County Seat of Hubbard County with a 1980 population of 2976. The dam is owned and operated by the City of Park Rapids.

The existing Fish Hook Dam is approximately 620 ft. long, consisting mainly of a earth dam section. The top width of the earth berm is 20 ft to 30 ft with side slopes of approximately 2 to 1. The earth fill is composed primarily of sandy soils with traces of organics. Crest elevation is approximately 1429.5 ft msℓ [1]. The dam is vegetated with trees and brush. Running along the full length of the dam is a municipal sanitary sewer line. A spillway and powerhouse are structurely integrated with the dam. Figure 2 gives an overview of the site. Located just downstream of the dam is a Minnesota Department of Natural Resources Fish Hatchery. The fish hatchery consists of three buildings and their fishery rearing ponds.

The spillway consists of a reinforced concrete control structure and a timber flume. The concrete control structure is approximately 25 feet wide and 32 feet long. The timber flume is 4 feet deep and 10 feet wide, and extends 84 feet downstream from the end of the control structure [1]. As of this writing the City of Park Rapids has retained the engineering consulting firm of Mead and Hunt, Inc., to design a new spillway and specify other integrity improvements for the dam.

The structural elements of the powerhouse are a headrace, two turbine pits, a generator room and a tailrace. Construction is primarily reinforced concrete with concrete masonry walls in the generator room. The headrace is supported on timber piles, and the rest of the powerhouse structure is supported on spread footings. The powerhouse is shown in Photographs 1 and 2.

The headrace is approximately 65 ft long, 14 ft high and 16 ft wide. At it's entrance are angled wingwalls and a steel trashrack consisting of three vertical sides and a horizontal top section. Stoplog grooves exist at the entrance, although there are no stoplogs in place. The sanitary sewer line traverses the headrace as well as the spillway concrete control section. The sewer pipe is normally under the water surface in the powerhouse headrace. Situated in the east wall of the headrace is an intake for a 12 inch underground pipe that until recently was used by the fish hatchery. The line has been abandoned but the fishery ponds have continued

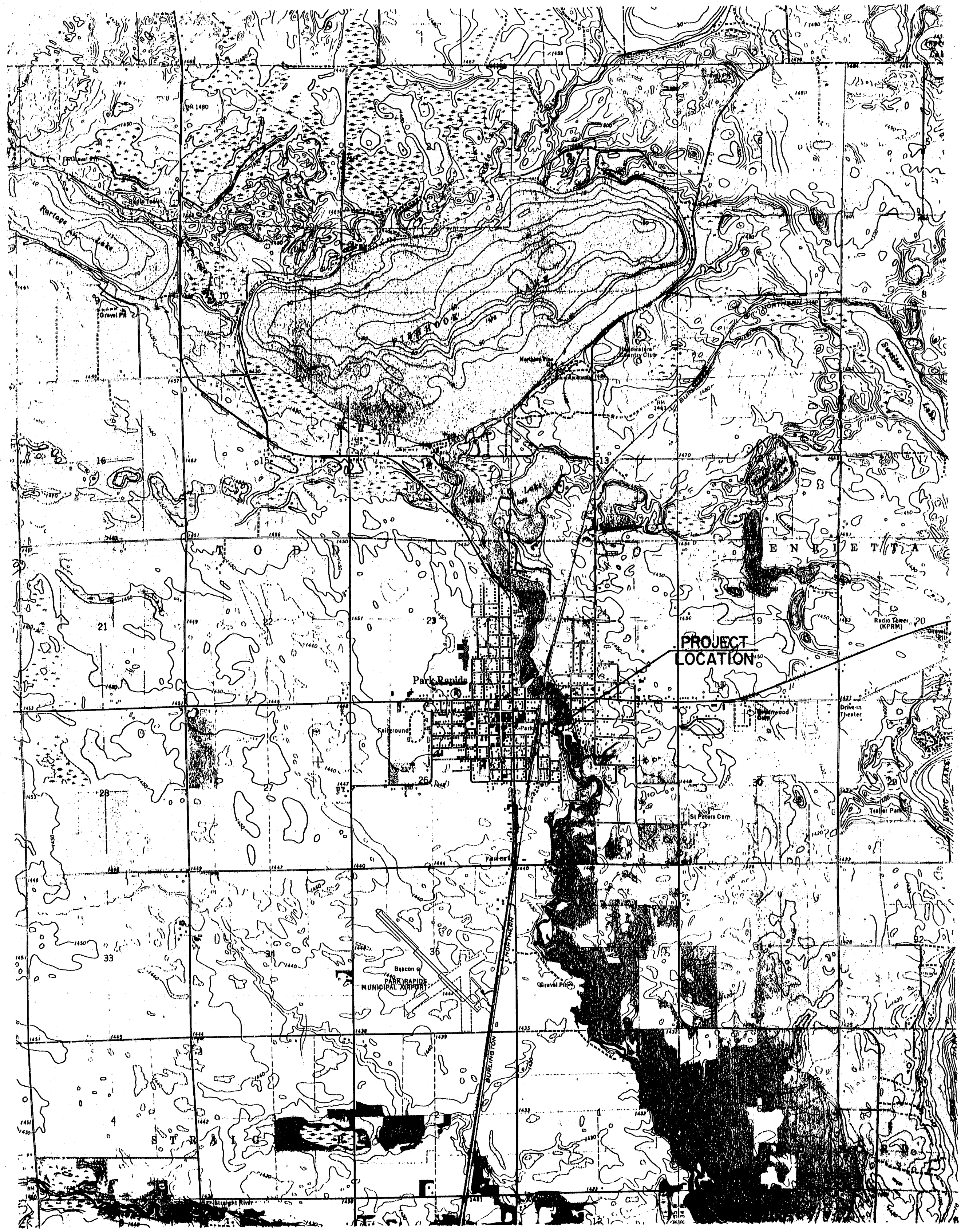

Fig. 1. Location of the Fish Hook River Dam in Park Rapids, Minnesota, on U.S.G.S. Quadrangle map.

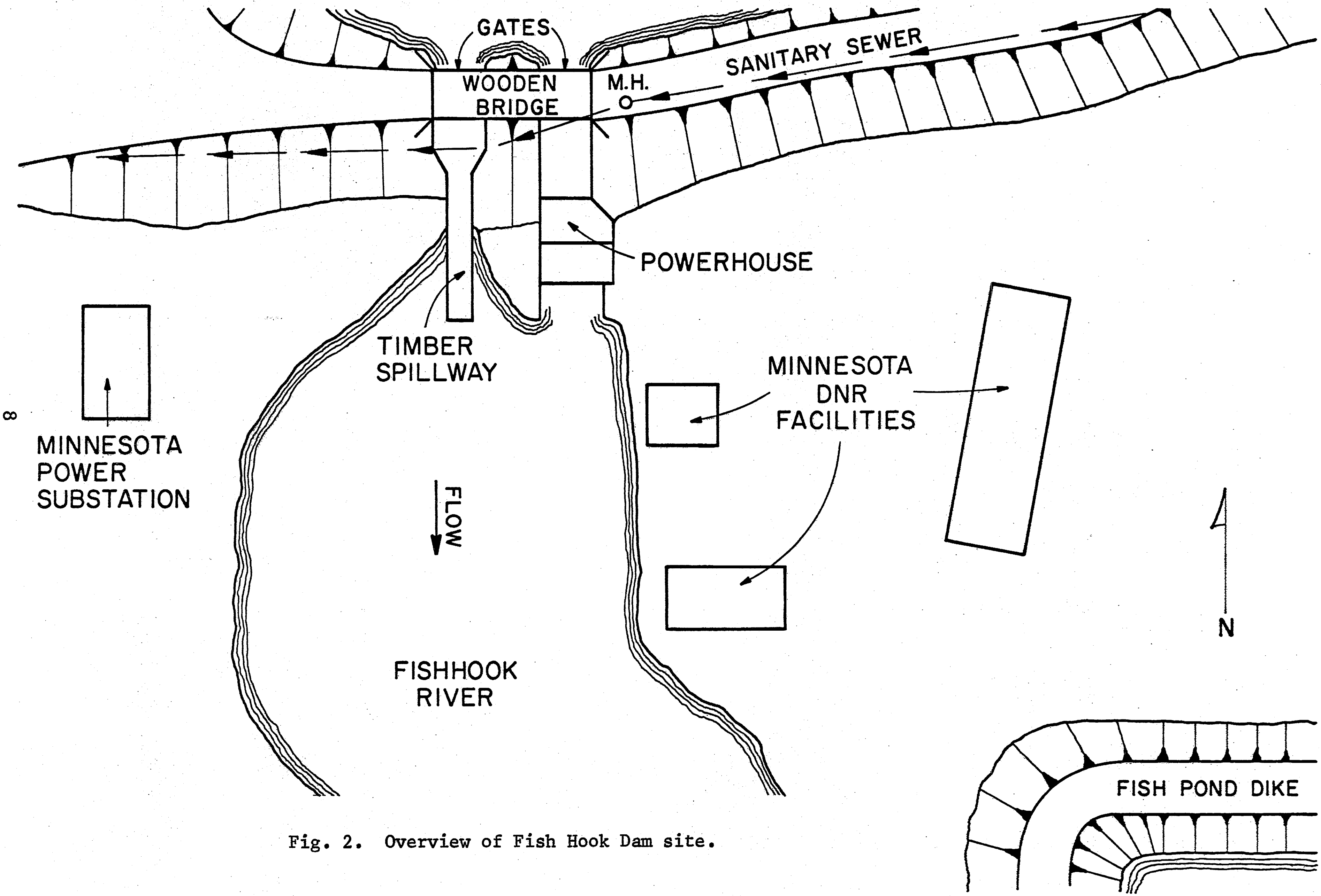

Fig. 2. Overview of Fish Hook Dam site.

Photo 1. View from the east of powerhouse; headrace and generator room with Minnesota Power Co. substation in the background.

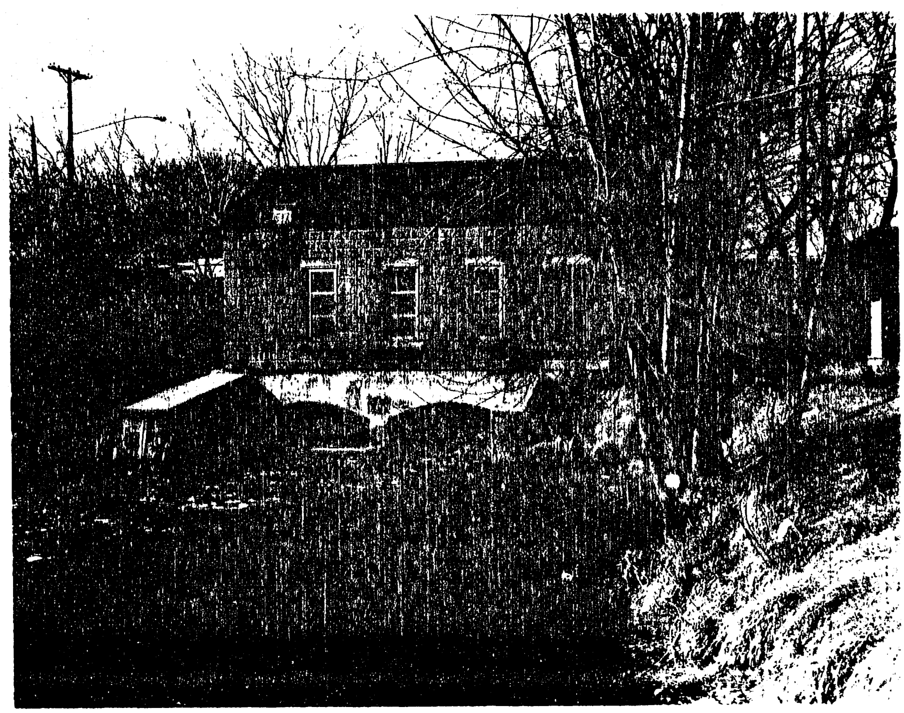

Photo 2. View from downstream of generator room and powerhouse outlet with wingwalls.

to be supplied by water drawn from the headrace through the use of a syphon.

At the downstream end of the headrace are two sets of timber head gates and two gates for each turbine pit. The head gates are manually operated vertical lift gates. The two right gates for wheel pit #1 are presently inoperable. The two left gates for wheel pit #2 are difficult to operate and will not completely shut off flow, as shown in Photo 3. A full length wood plank deck sits atop the headrace and turbine pits. The floor of the turbine pits has been reinforced with steel beams under the units [2].

The two turbine units installed in 1909 and operated until 1943 are still in place. They were manufactured by the S. Morgan Smith Company. Both units are of the same type: double hung open flume horizontal shaft with Francis runners and adjustable wicket gates. A description of the units follow.

UNIT # 1[2]

- 130 hp design output at 14 ft design head
- 250 rpm
- 24" runner diameter (twin runners)

UNIT #2[2]

- 200 hp design output at 14 ft design head
- 200 rpm
- 30" runner diameter (twin runners)

Adjacent to the downstream side of the turbine pits is a generator room. The generator room is constructed of 8 in. concrete blocks finished on the inside with metal lath and plaster. Inside dimensions are 29' x 18' x 12' minimum height [2]. The generator room has a peaked roof consisting of concrete slabs and metal roofing supported by steel trusses. No generating equipment remains in the generator building, as indicated in Photo 4. Presently the room contains minnow hatchery facilities, but it appears that the facilities are not being used. The tailrace passes underneath the generator room and opens with flared wingwalls at the base of the downstream side of the powerhouse structure. Plan and section views of the existing powerhouse are given in Figs. 3 and 4.

The powerhouse discharge mixes with spillway flow in a small pond adjacent to the Minnesota DNR fishery site. The river then flows past a fishery pond for a few hundred feet. There also exists an Artesian well

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[2]Personal communication, Allis Chalmers Co.

Photo 3. View inside wheel Pit #2 with S. Morgan Smith Co. turbine. Note holes in casing, severed wicket gate operating arms and leakage thru the timber gates at bottom of photo.

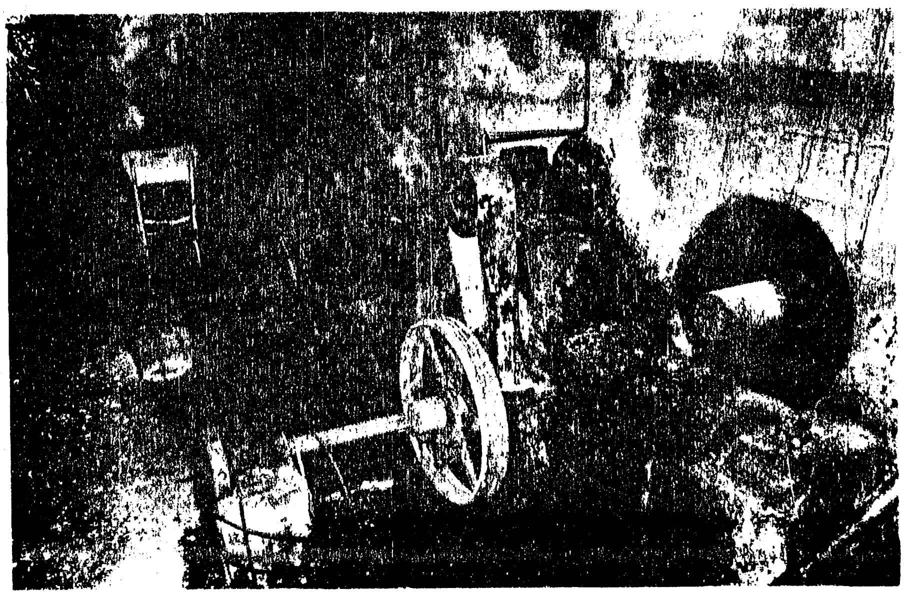

Photo 4. View inside generator room. Note that the turbine shaft has been cut off at the wall.

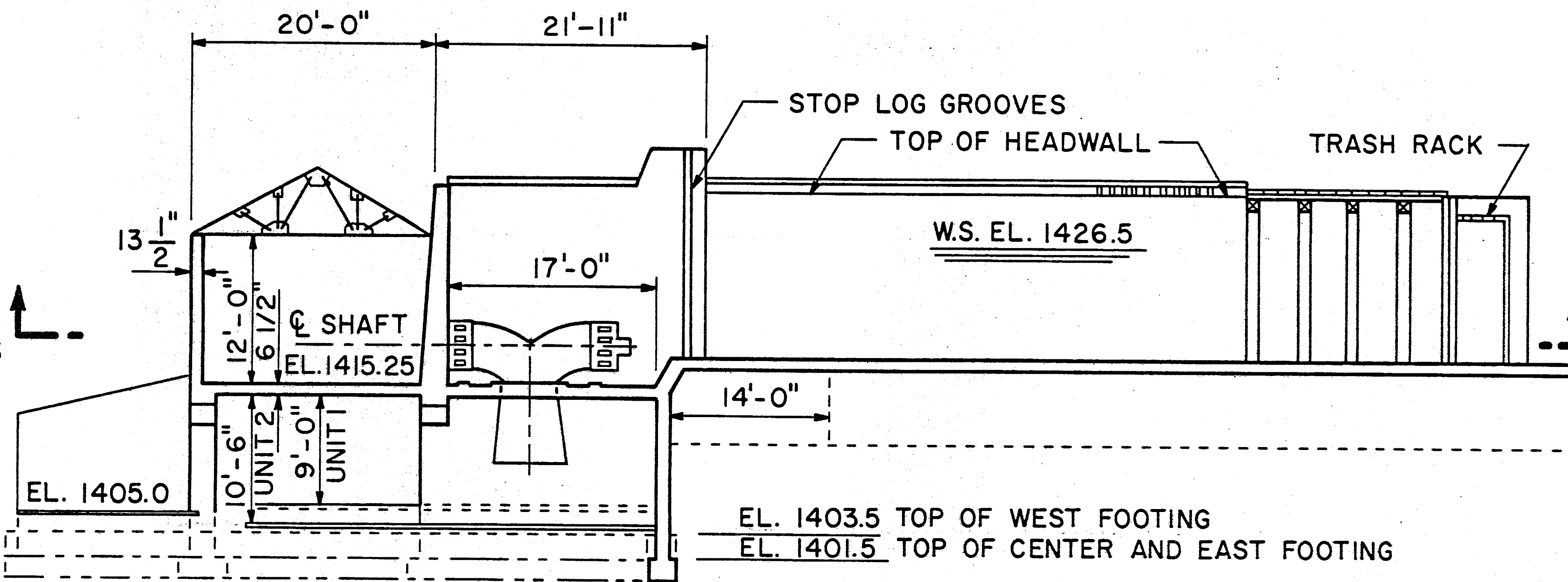

Fig. 3. Section view of existing powerhouse [3].

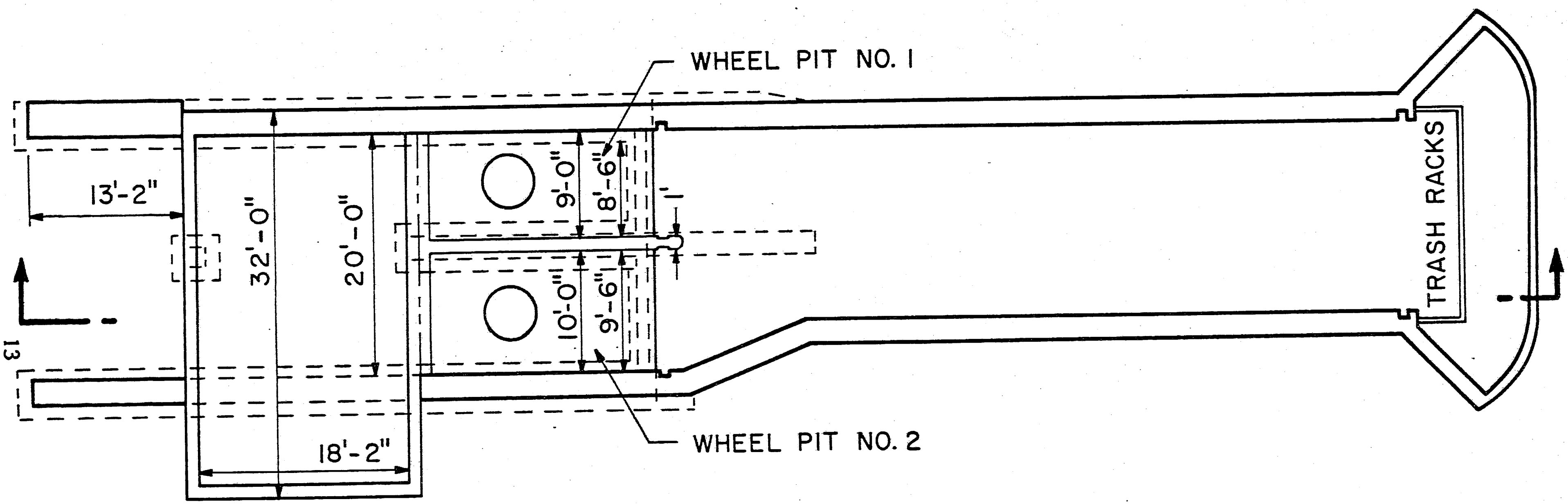

Fig. 4. Plan view of existing powerhouse [3].

approximately 300 feet downstream of the dam. The well supplies cool clear water to the DNR fishery [4].

B. Historical Background

Only scattered historical information could be obtained for the Fish Hook River Dam site. A dam was originally constructed at its present site in Park Rapids during the period of 1880-1881. The original purpose of the dam was probably for logging. In 1909-1910 the hydropower plant was built by L. H. Rice. The facility subsequently supplied power for a flour and feed mill and furnished Park Rapids with power and light.

The Minnesota Power and Light Co. (now Minnesota Power Co.) purchased the plant from L. H. Rice, under an optional agreement on August 1, 1924. By 1927 Minnesota Power and Light had purchased the electrical system of Park Rapids. During the period of 1928-1930 the dam was renovated.

The fish ponds at the DNR fishery were constructed in 1947.[3] As part of the construction, the river downstream of the dam was moved slightly to the west and straightened. The relocation affected a river reach of approximately one thousand feet. In 1945 the present concrete and timber spillway was constructed. Emergency repairs were done to the dam in 1972 with Minnesota DNR personnel inspecting the repair work.

On February 4, 1974, a preliminary engineering report was released by the U.S. Department of Agriculture Soil Conservation Service. This report included a study of the existing dam. The report recommended that the present "Mill Pond Dam should be reconstructed" due to the dam's "peat, wood zone, and seepage problems."

An additional study of the existing dam and pertinent structures was completed January, 1979. The reconnaissance study conducted by Barr Engineering Co. of Minneapolis, Minnesota, contained "the first detailed evaluation of the stability and strength of the existing structures." The study recommended in part that the existing dam be renovated and that the spillway be replaced [1].

The Minnesota State Legislature in 1979 appropriated $299,500 to be used to improve Fish Hook Dam. Because of excessive seepage the Minnesota DNR required the City of Park Rapids to lower the water level approximately one foot and to maintain reservoir water level no higher than elevation 1425.5.

C. Dam Integrity

The Fish Hook Dam is classified in the large size category as defined in the "Recommended Guidelines for Safety Inspection of Dams" published by

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[3]Communication, Minnesota Dept. of Natural Resources.

the U.S. Army Corps of Engineers. Size classification is based upon the dam's height and the storage capacity of its reservoir. The dam has also been given a high hazard classification. (Hazard classification refers to the potential of downstream economic damage or loss of life in case of misoperation or failure of the dam.) The Fish Hook River Dam reconnaissance study [1] made the following observations:

- Only 0.5 feet of freeboard would exist at the 100 year flood, a condition which violates freeboard requirements established by currently accepted dam safety criteria. In addition, the spillway and powerhouse are not capable of passing the spillway design flood without overtopping, as recommended by the currently accepted dam safety criteria.

- An overtopping failure of the earth embankment would probably occur at discharges exceeding the 100-year frequency flood event.

- The existing earth dam appears to be in fair condition, although it probably does not contain an effective seepage control system. In addition, the earth dam slopes are steep, its surface is heavily vegetated with many large trees, and a sanitary sewer line extends across its full length, causing conditions undesirable for earth dam stability and safety.

- The earth dam slopes are stable, but the existence of a high phreatic surface within the embankment and reports of seepage at the toe of the dam indicate that the dam does not have an effective seepage control system. No information is available regarding the original construction of and the subsequent modifications to the earth dam.

- The existing Fish Hook River Dam spillway is severely eroded or undermined beneath the apron and the left training wall. Foundation piles are exposed and the erosion or undermining is encroaching into the adjacent earth embankment. The probability of a surface failure is high. The concrete portion of the spillway is in good condition with no evidence of major spalling, cracking or deterioration. The timber flume portion of the spillway is seriously deteriorated, limiting its ability to convey large discharges. The present flume would probably fail if subjected to a large flow. The sewer line crossing the spillway may also restrict flow, and damage to the sewer pipe or even failure of the sewer could occur at large spillway flows.

- Overall, the powerhouse is in fair to good condition. The powerhouse concrete is in good condition with little cracking, spalling, or other deterioration. The headgates of the powerhouse are in fair condition, but two damaged gates are not functioning as intended. No seepage problems were observed at the powerhouse.

- The spillway and powerhouse are stable against overturning and sliding under normal hydrostatic conditions. The structures may be unstable or only marginally stable if subjected to severe ice forces, however.

- The spillway and powerhouse structures have sufficient internal strength to resist loads imposed by external forces under normal hydrostatic conditions; however, the reinforced concrete components do not satisfy the 1.7 load magnification factor used in design. Therefore, ice forces could overload structural elements in some cases. Structural continuity between the various reinforced concrete structural components in the dam is required to resist applied loads.

In addition the reconnaissance study [1] made the following recommendations.

- The discharge capacity of the Fish Hook River Dam should be increased to allow passage of the spillway design flood without overtopping, and the dam should be capable of passing the 100-year flood with at least 3 feet of freeboard.

- A documented hydraulic operating procedure outlining normal hydraulic operating procedures, flood operating procedures, and a flood warning system for downstream residents and users should be prepared for the Fish Hook River Dam.

- An operating and maintenance manual should be developed for the Fish Hook River Dam. The document should provide for routine and in-depth inspections of the dam and should present instructions for operating the equipment at the dam. Responsibility for the operation and maintenance of the dam should be delegated to a specific individual properly trained for these responsibilities.

- All undesirable conditions observed on the earth dam should be corrected. Corrective measures should include removal of existing trees, installation of an effective seepage control system, placement of upstream erosion protection, provision of milder slopes to increase surface erosion protection and stability, and abandonment of the sanitary sewer line in the dam.

- The erosion or undermining of the spillway should be repaired immediately, as the condition poses a direct hazard to the integrity of the spillway and the adjacent earth dam embankments. The deteriorated timber flume and timber apron of the earth dam should also be replaced. The sanitary sewer line spanning the area downstream of the spillway should also be removed as it could obstruct flow over the spillway.

- The powerhouse is structurally adequate, and it does not presently require major repairs. The headgates should be made operable, however, and some minor concrete spalling should be repaired.

- Effective scour protection should be provided downstream of the Fish Hook River Dam as there are currently no special provisions for energy dissipation or control of scour downstream.

- The following steps should be taken to complete a detailed analysis of the Fish Hook River Dam:

  - Soundings should be performed upstream of the dam to determine an accurate streambed profile to the Fish Hook Lake outlet.

  - The powerhouse interior should be inspected after dewatering of the powerhouse headrace and turbine pits.

  - The foundation of the right training wall of the spillway should be inspected for erosion or undermining.

  - Additional soil borings should be made on the earth dam to determine the engineering properties of the embankment soils and foundation soils.

V. HYDRAULICS AND HYDROLOGY

A. Hydrologic Description

Fish Hook River Dam is located in the NW1/4 section 25, T140N, R35W. The drainage area of the dam is approximately 214 square miles.[4] The Fish Hook River Dam watershed is contained in the Crow Wing subwatershed of the Upper Mississippi River Basin.

The Fish Hook Dam watershed near its western edge includes Bass Lake. The watercourse flows to Kneebone Lake, then to Big Basswood Lake. Indian Creek forms at the outlet of Big Basswood Lake and flows southeasterly through Duck Lake to its confluence with Basswood Creek. Basswood Creek drains Boot Lake, then combines wth Labole Creek as it flows to its confluence with Indian Creek. The watercourse then proceeds to Two Inlets Lake.

Within the northern edge of the watershed located along the border of Hubbard and Becker Counties is Little Mantrap Lake. The watercourse travels from Little Mantrap Lake to Kane Lake through Little Dinner Lake (north) to Dinner Lake, then to Little Dinner Lake (south). Dinner Creek flows south from Little Dinner Lake (south) to Two Inlets Lake.

Hay Creek forms at the outlet of Two Inlets Lake and flows into Island Lake. The watercourse then extends through Eagle Lake into Potato Lake. Rice Lake and Blue Lake also drain into Potato Lake. Outletting Potato Lake is Potato River, which flows to Fish Hook Lake. The east edge of the watershed appeared to be defined by County Highway 4. The highway also appears to be the western border of a comparable watershed that is closed (no surface drainage from the watershed). At the outlet of Fish Hook Lake, the Fish Hook River flows south through Mud Lake into the Mill Pond which is being retained on its southern shore by the Fish Hook River.

Downstream of the Fish Hook Dam, the Fish Hook River flows past the Minnesota DNR fishery ponds shown in Photo 5. The downstream reach of the Fish Hook River is shown in Photo 6. Approximately four miles south of Park Rapids the Fish Hook unites with the Straight River. Long Lake drains into the Fish Hook River approximately 2.5 miles south of the Straight River and about at its confluence with the Shell River. The Shell River flows east to its junction with the Crow Wing River. Eventually the water source of the Crow Wing passes the U. S. Geological gaging station at Nimrod.

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[4]Communication, Minnesota Dept. of Natural Resources.

Photo 5. View from tailwater pool of powerhouse and the three Minnesota DNR fish hatchery buildings.

Photo 6. View of the Fish Hook River immediately downstream of tailwater pool. Fenced fishery pond is to the left.

B. Flow Duration

The U. S. Geological Survey stage-discharge gaging station 052440 is located approximately 45.7 river miles downstream of the Fish Hook River Dam on the Crow Wing River at Nimrod [5]. Flow data has been recorded at this site from 1940 to the present. These records were used to provide the data base for hydrologic computations.

The drainage area of the gaged watershed is 1010 mi^2 [5], compared with the 214 mi^2 drainage area of the Fish Hook Dam. The average annual runoff of the gaged watershed is 6.39 in./yr. To determine the flow rates required for the flow duration curve at the Fish Hook Dam, a simple straight ratio of areas was used. Large errors are possible when the disparity of the two areas is of the magnitude experienced here. For that reason the larger gaged watershed will be qualitatively compared with the smaller watershed herein.

If the smaller watershed is homogeneous with the larger watershed, the smaller watershed is more likely to experience greater extremes of rainfall occurrence. With the Fish Hook Dam watershed, there exists a number of hydrological factors to counteract the effect. One of the factors is the type of soil. The soils in the watershed are predominately hydrologic soil Series A [4]. The sandy soil along with the forest vegetation eventually combine such that most of the rainfall infiltrates into the soil. Water is then transported to the waterways by means of groundwater flow, interflow, and springs. Another factor is the percentage of the watershed covered by lakes and wetlands. The Fish Hook River Dam Watershed has 50 percent more area covered by lakes than the gaged watershed which it is within [4]. Thus, relative storage is larger for the Fish Hook Dam Watershed.

Relatively higher precentages of lakes and soils that contribute higher infiltrated sourced stream flows result in higher relative base flows and attenuated peak hydrograph flows. A possible additional factor is the eastern adjacent closed watershed. This watershed could contribute significantly to infiltration sourced flows. The net result of these factors is that the interpolated flow duration curve for the Fish Hook Dam Watershed is probably conservative. These factors would also have the effect on the Fish Hook Watershed of raising the relative low flows and decreasing the duration and the rate of occurrence of low flows when compared to the gaged watershed. A flow duration curve is given in Fig. 5.

C. Headwater and Tailwater Elevations

A single headwater elevation of 1426.5 was selected. This is the elevation that the reservoir has been historically maintained at with normal to low flows. The operating procedure used in the report has the headwater elevation fluctuating 1.0 foot with a mean operating elevation of 1426.5. The actual elevation would be determined by management of existing and future waterway flows. A surface wave will take approximately 10 minutes to transverse the reservoir. Therefore, the reservoir water surface may be

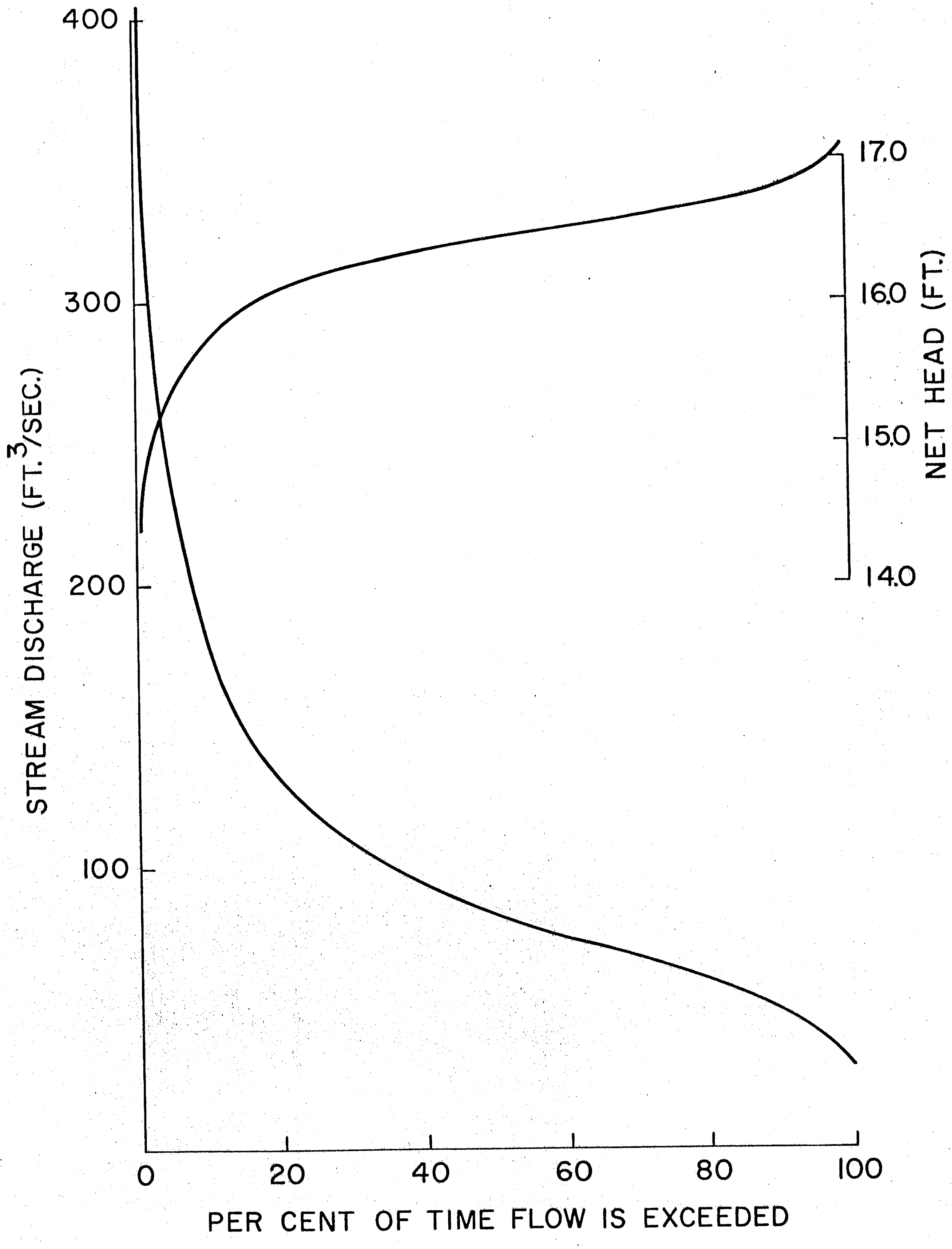

Fig. 5. Combined flow duration and available net head curves for the Fish Hook River Dam.

assumed level during drawdown since the time-of-travel for a disturbance is small compared to the time scale of interest for operation.

The tailwater elevations for corresponding tailwater flows were determined by computing normal flows using Manning's equation. The relatively straight and uniform channel running adjacent to the Fish Pond berms was used as a control section. Cross-sectional data was obtained in a field survey. Manning's roughness coefficient was established by engineering judgement from field observation and technical references [6]. A method developed by Engelund and Hanson was used to verify the selection of the coefficient [7]. The computed tailwater elevation curve is given in Fig. 6.

During the field survey, measurements were made to establish a stage-discharge data point, also shown in Fig. 6. The very good agreement between the tailwater curve and the data point is an indication that the computed curve is probably accurate at low to normal river flows. Since the headwater elevation can be assumed to remain at a constant elevation, the tailwater curve and headwater elevation may be transformed into a net head curve. For convenience, this curve has been combined with the flow duration curve in Fig. 5.

D. Low Flow Characteristics

Low flow data were used to establish the percentage of time design flows can be maintained or exceeded. Low flow characteristics for the Fish Hook Dam watershed were first extrapolated from the values for the gaged watershed [8]. A ratio of drainage areas was applied, and these values were adjusted to account for the reservoir storage available to the facility operation. The adjusted values were then transformed into a probability of occurrence for low flows of a given duration. This information was used to determined the percent of time various operation discharge would not be available.

There is a large amount of reservoir storage available for hydropower operation at the Fish Hook River Dam. The surface area of Fish Hook Lake is 80 million ft^2. In addition, two lakes immediately upstream, Potatoe Lake and Portage Lake, have surface areas of 92 million ft^2 and 18.4 million ft^2, respectively. Only the storage of the Fish Hook Lake was considered in assessing the power production potential of the Fish Hook River Dam site. A drawdown of 1.0 foot, or only using the top 1.0 foot (80 million cubic feet) with a mean reservoir elevation of 1426.5, was used.

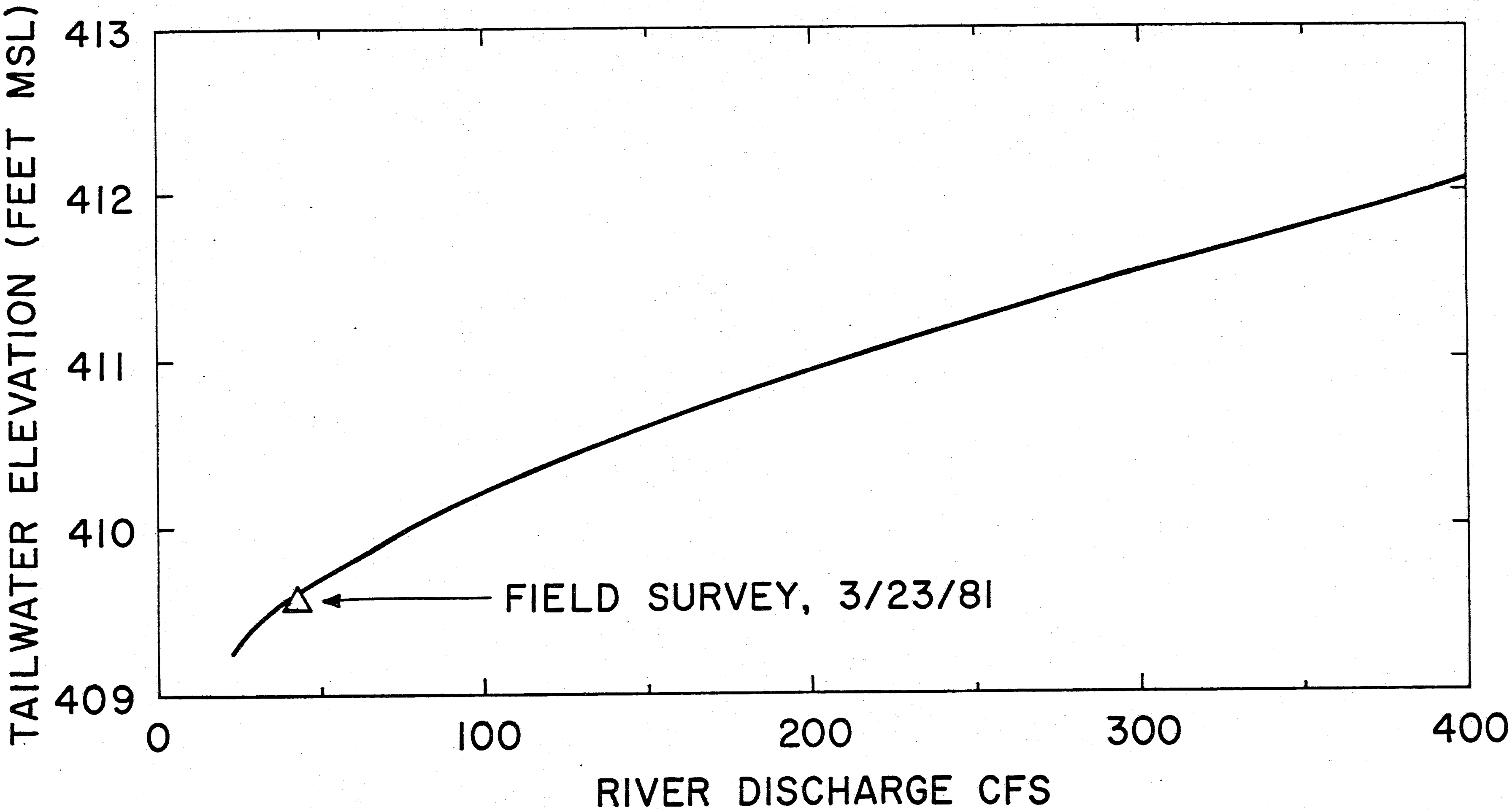

Fig. 6. Tailwater elevation curve for the Fish Hook River Dam.

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 Rules on Cogeneration and Small Power Production on February 19, 1981. The PUC subsequently issued proposed rules on March 15, 1982, which retain the provisions described herein with some revisions. The utility filings required to utilize the new proposed rules were not available at the time of this publication, however. 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 avoided cost as defined by the PUC consists of two components: avoided capacity cost and avoided energy cost. Avoided capacity cost would be the capital cost per KWH at the next power facility planned by the utility. The avoided energy cost is the cost per KWH of fuel operation and maintenance. In addition, the Draft Proposed Rules give guidelines for rates of purchase from a qualifying facility with capacity of 100 kW or less. Those guidelines are used herein to determine the value of hydroelectric power which would be produced at the Fish Hook Dam.

B. Marketing

The Fish Hook Dam is within a few hundred feet of a Minnesota Power Company transmission substation. Both 4 kV and 34.5 kV transmission line voltages are available. Because of the proximity of the substation, the viable arrangement would be to interconnect with Minnesota Power Co. A marketing agreement could be arranged with either Minnesota Power Co. or some other utility. If a marketing arrangement was made with a utility other than Minnesota Power Co., the energy could be wheeled through the transmission facilities of Minnesota Power Co.

One marketing alternative is to displace existing city government usage and sell the remaining energy produced to a utility. Park Rapids' current public demand is approximately 420,000 KWH annually, based on 1980 and 1981 billing information. The probable arrangement would be to wheel the hydroplant produced energy through Minnesota Power Co.'s transmission facilities. One shortcoming to this alternative might be in trying to coincide demand with production. Load management could minimize this problem and subsequently maximize the value of the energy produced. A program of increased demand, such as substituting critical resistive heating for nonelectric produced heat in public buildings, might be implemented to offset and balance power demand with power production.

A second marketing alternative would be to sell all energy produced to a utility. A third option would be for the City of Park Rapids to form a municipally owned utility; then the energy produced by the hydropower facility could offset energy purchased by the municipal utility. No wheeling changes could be incurred.

Finally, the City of Park Rapids also has the option of a contract for private development. The site would be developed in exchange for certain considerations. Various arrangements could be negotiated in reimbursement, the lease, and taxation. The developer could own and operate the equipment. A typical contract would give the city a portion of gross income with an option to purchase the powerhouse and equipment at a later date. This option would become more attractive if a proposal presently before the state legislature is realized. The bill, House File 1208, would eliminate the burden of property tax on hydropower equipment when a site is leased from a governmental body.

The value of energy sold to a utility would be at a premium under two possible conditions: under the Minnesota Public Utilities Commission proposed rules on cogeneration and small power production. Full avoided capacity and energy cost would be given to facilities with installed generating capacities of 100 kW or less and to energy which is considered "dependable" for facilities of greater than 100 kW. Dependable energy can be defined as the energy produced at a dependable power level. As defined here, dependable power is the level of power demand that can be met at least 75 to 80 percent of the time, based on the typical operation of a coal-fired power plant.

C. Value of Energy and Power

1. Sale of all Energy and Power to Utility

The Public Utilities Commission has interpreted avoided energy cost to be the utility's avoided fuel cost. Estimates of avoided fuel costs for a small hydropower facility were obtained from Minnesota Power for the period from 1980 to 1985. Minnesota Power's avoided fuel cost for 1982 is estimated at 1.2 ¢/kWH.

With regard to avoided capacity cost, the proposed rules of the Public Utilities Commission state that

"Any Qualifying Facility 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."

Qualifying Facilities of equal to or less than 100 kW are entitled to full avoided capacity cost per KWH for all energy generated. For the Qualifying Facilities with greater than 100 kW capacity, this capacity payment is to be negotiated. The Proposed Rules provide a method of computing a utility's avoided capacity cost in ¢/KWH, which is a starting point for negotiations. 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 percent 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 percent scheduled and unscheduled outage rate, Minnesota Power's annual avoided capacity cost is 3.5 ¢/KWH (1982 base year).

All PUC rules on the value of energy apply equally to private or public development. If a private development option is chosen, the net value of energy to the City of Park Rapids would depend on the contract agreement between the parties involved.

The energy produced by a hydropower facility with a generating capacity of 100 kW or less has a single value assessed to all energy production, equal to that of "dependable" energy. Under the PUC proposed rules, dependable energy would be worth the sum of the utility's avoided energy cost and the full avoided capacity cost per KWH. Adding the two components, the value of dependable energy sold to the Minnesota Power Co. would be 4.7¢/KWH (1982 base year). Hydropower facilities of greater than 100 kW will likely produce some energy which is not classified as "not dependable." In the proposed rules, this energy would be worth only the utility's avoided energy cost, i.e., 1.2¢/KWH for Minnesota Power.

2. Offset of Municipal Demand and Sale of Remaining Energy to Utility

The present cost of Park Rapids municipally used energy basically consists of two components. One part of the cost is the energy charge which includes a fuel adjustment element. The energy charge is a cost per unit of energy or ¢/KWH. The other component is a demand charge, which is a cost per unit of power within a time interval, usually a month, expressed as $/kW/month. Demand charge reflects the cost to the utility for supplying and insuring the peak power demand within a time interval.

If the energy produced is directed to offset the municipal energy demand, the value of the energy would be the energy charge plus the reduction in the demand charge minus a transmission charge (wheeling). It should be noted that the demand charge depends on the consistency of demand. If the energy production/demand balance is not managed correctly, large demand charges could occur. The percent total charge for electricity purchased by the City of Park Rapids (energy charge plus demand charge) is 4.8¢/KWH, based on 1981 billing charges.

Energy produced in excess of what is demanded would have a negotiable value. The value of this energy would probably be the avoided energy cost plus some or none of the avoided capacity cost. If the City of Park Rapids was to form its own utility, the same energy value formula would apply, but the value of the avoided capacity cost would be appreciably greater.

As will be shown in Section VII, the optimum capacity of the proposed facility is approximately 100 kW, based upon flow duration and reservoir storage. For this capacity the facility will receive the most income by selling all energy and power produced to Minnesota Power Co. at the PURPA rates set by the Minnesota PUC. There are other marketing options which may be considered; however, the PURPA rates are a based rate schedule that a hydropower facility may rely on.

VII. FACILITY OPERATION

The City of Park Rapids currently owns and operates the Fish Hook River Dam and controls the surface level of Fish Hook Lake. Fish Hook Lake has a considerable amount of storage which, if utilized properly, will enhance the value of power and energy produced at a hydropower facility.

With the power and energy, values assumed in Section VI, a managed store-release operational scheme will result in the greatest financial return from a hydropower development. Such an operation is therefore assumed in this study. Reservoir storage management and minimum streamflow are the two basic components of this scheme and are described in the following:

(1) Reservoir Storage Management. The reservoir surface will be maintained between El. 1426 and 1427 ft above msl. Water surface fluctuations of only 1 ft are required, and they will not be rapid. Approximately 1 month will be required for a full 1 ft fluctuation. The installed turbines will be run at full power as long as the reservoir elevation is above El. 1426. If the reservoir surface elevation is equal to or below El. 1426, the turbines will not be run and a minimum streamflow release will be maintained. If the reservoir elevation is greater than or equal to 1427, the spillway gates will be opened to maintain reservoir elevation as close to 1427 as possible.

(2) Minimum Streamflow. In order to protect the fishery in the Fish Hook River downstream from the dam, a minimum streamflow release is recommended at all times. There is no well-established criteria for minimum streamflow, except that it should not be less than the seven-day, ten-year low flow (approximately 24 cfs at this site). Forty cfs at the 95 percent exceedance level on the flow duration curve given in Fig. 5 was chosen as a representative minimum streamflow for this study.

The power generated by a managed stored-release operational scheme as described above is considered "dependable" if it can be sustained over a large enough percentage of time. A minimum of 75 percent was selected, based on the typical operation of a coal fired power plant. The dependable energy is calculated by applying the dependable level of power to the percent of time it is sustained. This scheme would maximize the value of the energy. Provisions to assist in accurate management of the hydropower plant and reservoir level have been incorporated into each development considered herein. These provisions include surface level sensors and a control computer capable of efficiently coordinating plant operations.

Utilization of the storage in Fish Hook Lake will give a considerable amount of dependable energy production from any installed hydropower facility. The reliability of this power may be improved by including other reservoirs in the management operation. It is therefore recommended that control of the water surface elevation of Potato Lake and Portage Lake be incorporated into the operational management of any hydropower facility at the Fish Hook River Dam, if at all possible.

VIII. PROJECT DEVELOPMENT ALTERNATIVES

In this section the costs and expected annual energy production of three development alternatives for the Fish Hook River Dam hydropower facility are considered. Other alternatives, which include the rehabilitation of the existing turbines, were initially considered and were ruled out of a more detailed analysis. A description of some of these alternatives has been included. 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. The unit's cost included, along with the cost of the turbine and generator, the cost of a speed increaser, hydraulic operated gates and a control panel.

- All the turbines selected for this study are fixed flow units. Therefore, expected annual energy production was computed by applying the percentage of time the specific design flows would be sustained. The percentage of time down due to unscheduled maintenance or breakdown was assumed to be 2 percent. Headwater and tailwater elevations and turbine, generator, and speed increaser efficiency data were also used in computing annual energy production.

- 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 percent contingency allowance was added to cover smaller items and possible omissions. A 10 percent profit factor was also included in the total civil works cost.

- Electrical equipment costs were estimated based upon information obtained from a well-known generator/switchgear/controls manufacturer or was included in the turbine manufacturer's package price. Electrical equipment costs include switchgear, transformer, power factor correction, lighting accessories, circuit breakers, wire and cable system, conduit, grounding, and lighting.

- It is anticipated that the site will be automated. A control computer with pond level sensors will automatically control start-up and shutdown, and insure optimum reservoir levels. Also to be controlled when applicable are a dump valve for minimum stream flow, turbine alternation, and turbine hierarchy. This type of automatic control has the capability of remote start-up. The automatic control equipment was estimated based on costs supplied by a manufacturer/distributor.[5]

- Miscellaneous power plant equipment costs were estimated according to guidelines in Ref. [9]. Equipment for ventilation, fire protection, communication, and turbine/generator bearing cooling water are included in this category. The cost estimates include 15 percent for freight and installation. The 1978 cost base was escalated to a 1982 cost base according to the Consumer Price Index.

- A multiplier of 20 percent was applied to the total cost of the above items for engineering, construction management, and other costs [9]. These costs include expenditures for license and permit application, preliminary and final design, construction management, and administration.

- Annual operation, maintenance and replacement costs (O.M.&R.) were estimated based on the plant generating capacity [9]. Since all the development alternatives have approximately equal generating capabilities, the same O.M.&R. cost was assumed for each.

A. Alternative A: One 1000 mm Vertical Bulb Type Unit[5]

Alternative A is to remove the existing turbine machinery and replace it with a vertical bulb type unit and a dump valve. The turbine/generator unit is a self contained cylinder containing an axial flow turbine runner which turns a speed increaser and powers an induction generator placed inside a water tight cylindrical section.

The new unit has a 1000 mm diameter fixed blade reaction runner with fixed guide vanes. Design discharge is 85 cfs at 16.4 feet net head with a rate generating output of 93 kW. The capacity of the generator is 100 kW. With the operational plan given in Section VII, Alternative A is estimated to run at full capacity 83 percent of the time. The minimum base flow will be passed through a dump valve for the remainder of time.

The new turbine/generator unit would probably be installed in wheel pit #2 of the existing powerhouse. This unit would include a draft tube, a bell mouth and a hydraulic plug valve. To maintain minimum stream flows a hydraulic dump valve would be installed in wheel pit #1. Automatic controls and electrical switch gear could be installed in the existing generator room or in some other nearby housing. Plan and section views of a preliminary layout are given in Figs. 7 and 8. A breakdown of the cost estimate for development Alternative A is as follows:

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[5]Essex Turbine Co., Inc., Magnolia, Massachusetts.

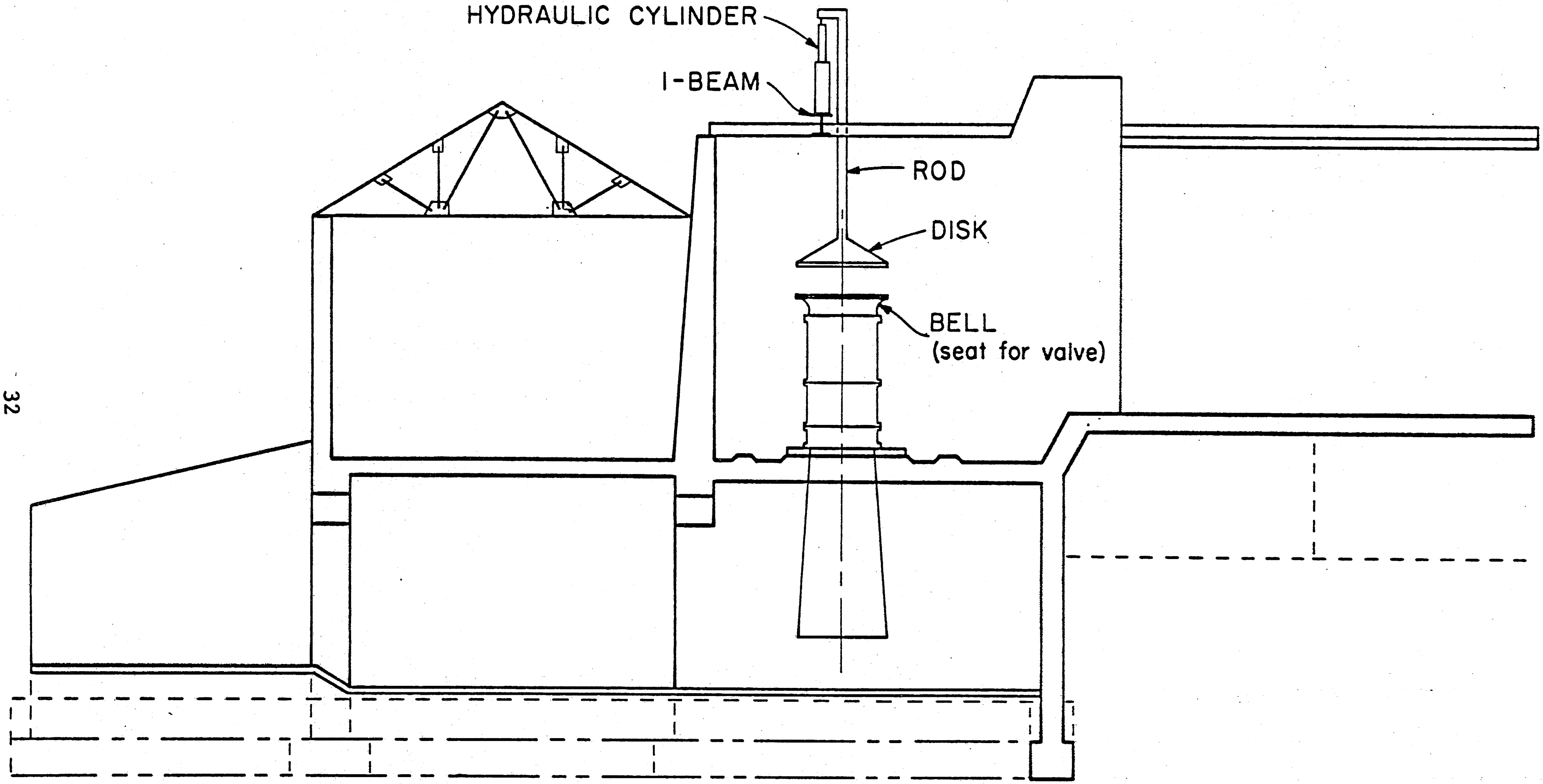

Fig. 7. Section view of Alternative A: one vertical bulb type unit with 1000 mm diameter runner.

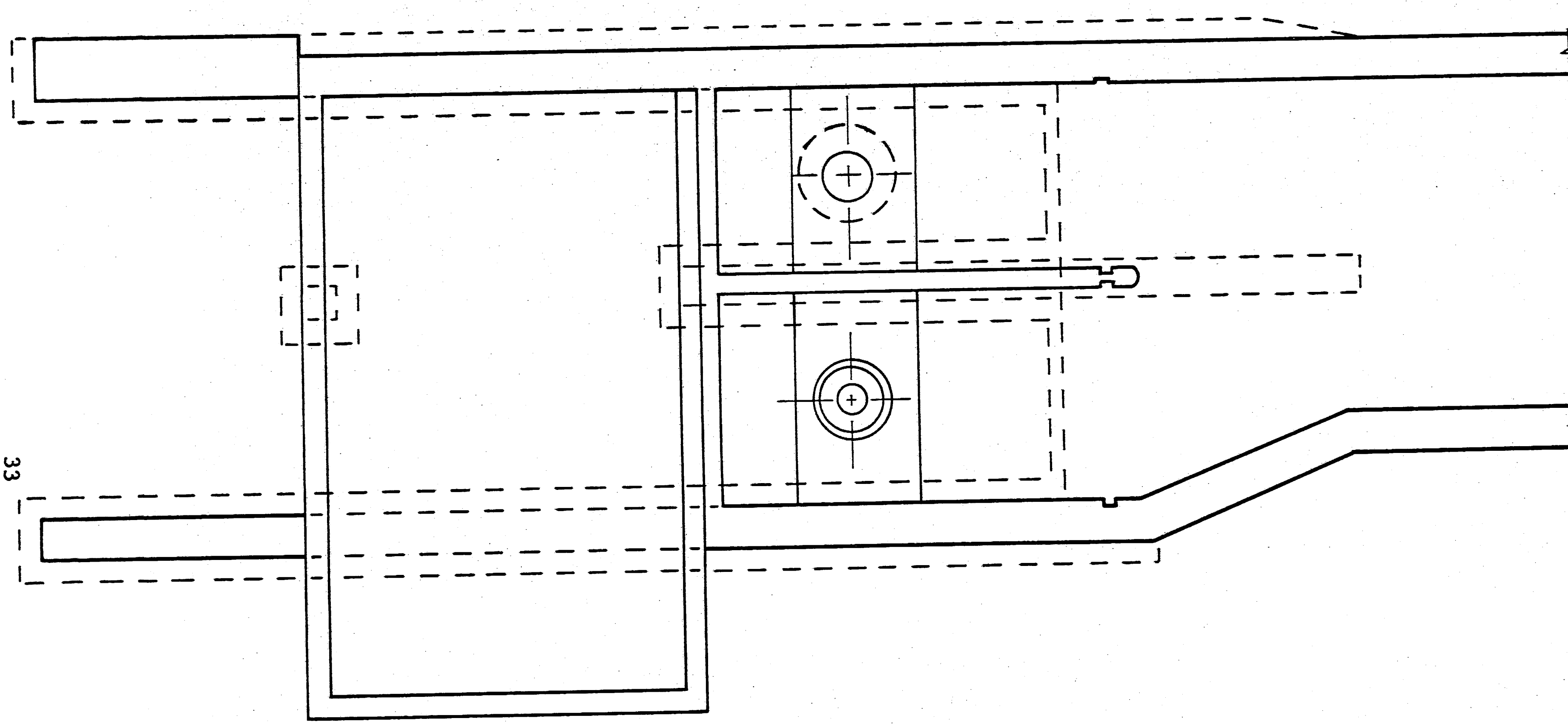

Fig. 8. Plan view of Alternative A: one vertical bulb type unit with 1000 mm diameter runner and one dump valve.

Alternative A Cost Estimate (1982 Base Year)

1.	Construction costs	$ 11,600
2.	Turbine/generator/dump valve	85,000
3.	Electrical equipment	27,500
4.	Freight	3,500
5.	Installation	28,700
6.	Miscellaneous plant equipment	29,900
7.	Engineering, construction management, etc.	37,200
	Total Initial Cost	$223,400

The average annual operation, maintenance and replacement costs for this alternative are estimated to be $7,000/yr (1982).

The average annual energy production and average annual income for Alternative A are (1982 Base Year)

Average Annual Energy Production	640,000 KWH
Average Annual Gross Income	$30,080

B. Alternative B: One 30-Inch Inclined Unit[6]

As with Alternative A, Alternative B is to replace the existing turbines with a new turbine and a dump valve. The new turbine is of a inclined axial flow tubular case design. It has a fixed blade propeller with fixed guide vanes. The design discharge is 84 cfs at 16.2 feet net head with a rated generating output of 91 kW. This specific turbine has been developed by altering standardized pumps to operate as turbines.

The unit would have an induction generator with a production capacity of 100 kW. The generator would be attached to the outside of the tubular casing. Power would be transmitted from the turbine shaft to the generator by a belt drive which would incorporate a speed increaser. A hydraulic roller intake gate would control the flow into the unit. As with Alternative A, Alterative B is estimated to run at full capacity 83 percent of the time. The dump valve will pass the minimum flow during the remaining 17 percent of the time.

Comparatively extensive construction work would be required to install this unit. Removal of the floor in wheel pit #2 would be required and extensive concrete base for the unit would need to be formed and poured. Masonry work would be required around the draft tube and at the intake to produce a dry operating room. To insure dry conditions, a roof over wheel pit #2 has been included. The electrical equipment that needs to be housed could be placed along side the unit, installed in the existing generator

[6]Allis-Chalmers, Inc.

room or some other structure such as a housing over the unit. Plan and section views of the preliminary layout are given in Figs. 9 and 10. A breakdown of the cost estimate for development Alternative B is as follows:

Alternative B Cost Estimate (1982 Base Year)

1.	Construction costs	$ 31,100
2-3.	Turbine/generator/dump valve/electrical equipment package	191,500
4.	Freight	3,500
5.	Installation	34,500
6.	Miscellaneous plant equipment	29,800
7.	Engineering, construction management, etc.	58,100
	Total Initial Cost	$348,500

The average annual operations, maintenance, and replacement costs for Alternative B are estimated to be $7,000/hr.

The average annual energy production and average annual income for Alternative B are (1982 base year):

Average Annual Energy Production	610,000 KWH
Average Annual Gross Income	$28,670

C. Alternative C: Two 36-Inch Diameter Pump/Turbines[7]

Alternative C is to replace the existing turbines with the vertical axial flow pumps to be used as turbines. The two units are identical, each with a fixed blade propeller and fixed guide vanes, with inside intake pipe diameter of 36 inches. This unit would have a hydraulic operated intake butterfly valve and a draft tube. Design discharge on each unit is 44 cfs at 16.5 feet net head with a rated generating output of 49 kW. The generator would be an induction type with a production capacity of 50 kW. The generators are housed on top of the pump/turbines.

A dump valve would probably not be required. The design flow of one turbine would likely serve the need for minimum discharge. If a lower flow is desired, the butterfly valve could be used to throttle discharge or the flow could be regulated at the spillway. Alternative C is estimated to run at full capacity 80 percent of the time and at half capacity 17 percent of the time. The larger base flow of 44 cfs would be available 97 percent of the time because it is associated with the operating discharge of one of the turbines.

[7]Worthington Pump, Inc.

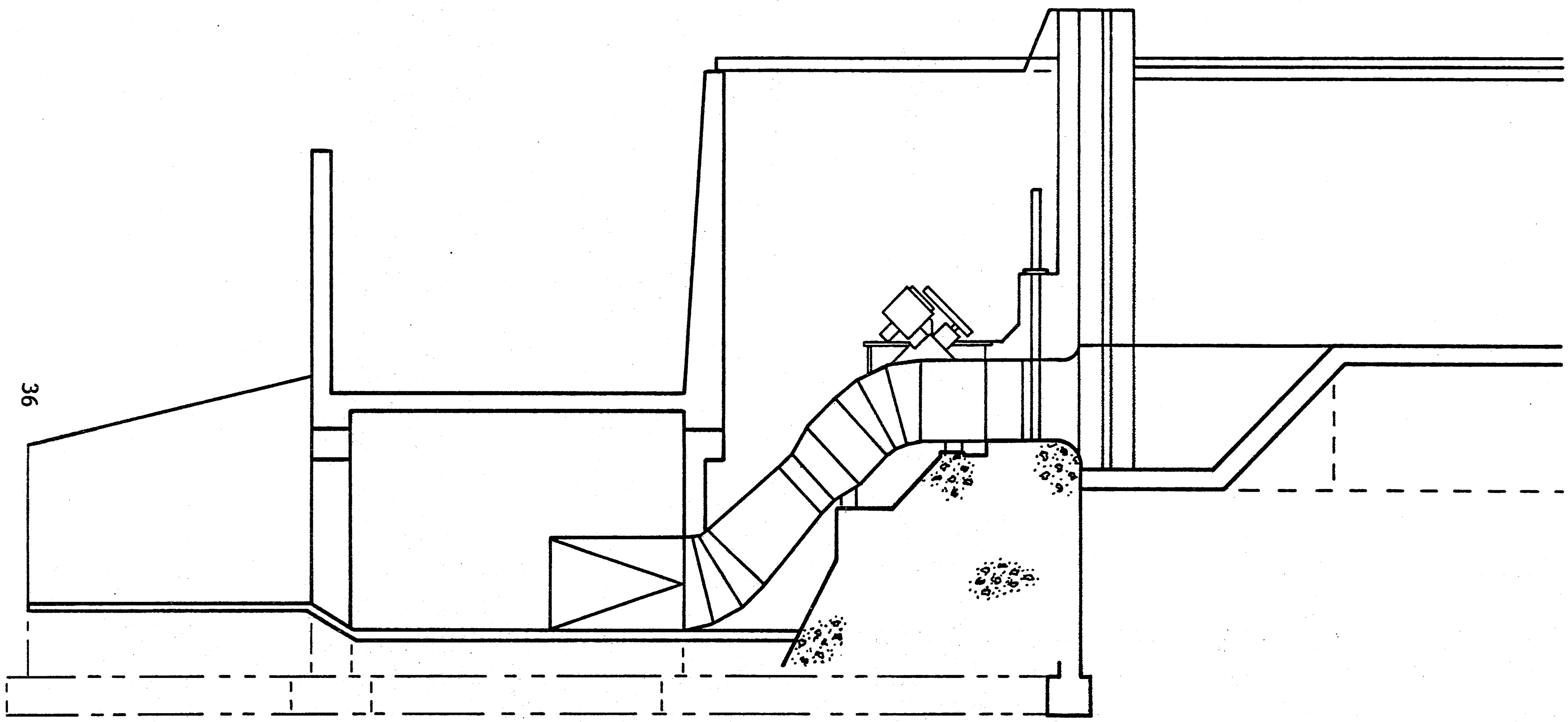

Fig. 9. Section view of Alternative B: one inclined tubular unit with 30-inch diameter axial runner.

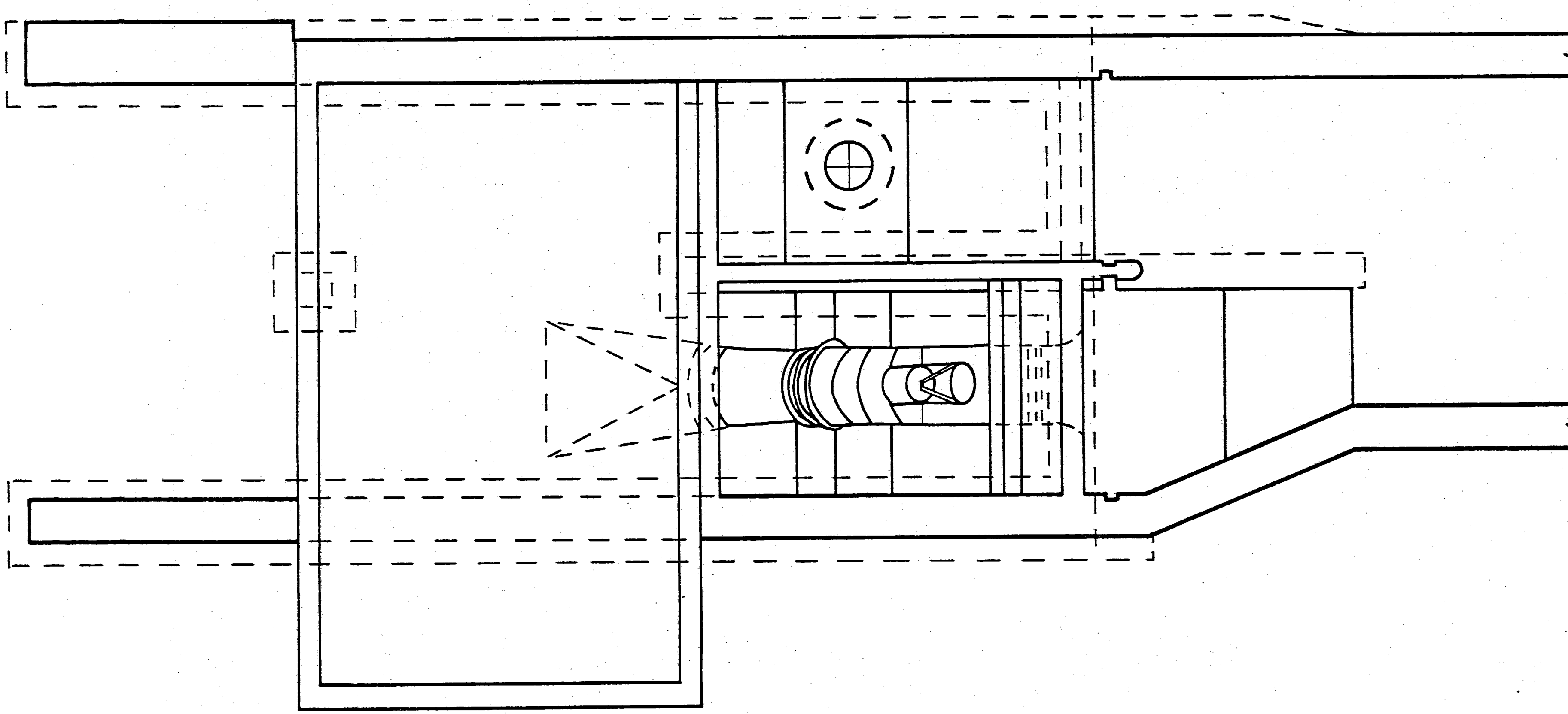

Fig. 10. Plan view of Alternative B: one inclined tubular unit with 30-inch diameter axial runner and one dump valve.

To provide dry operating conditions, walls would be required at the intakes to the turbines. As with Alternative B, electrical equipment could be installed alongside the unit, in the generator room, or in some other structure. A roof over the existing structure has been included in the construction costs. Figures 11 and 12 present plan and section views of a preliminary layout of Alternative C. A breakdown of the cost estimate for development Alternative C is as follows:

Alternative C Cost Estimate (1982 Base Year)

1.	Construction Costs	$ 20,300
2.	Turbine/Generator	85,000
3.	Electrical equipment	35,700
4.	Freight	5,800
5.	Installation	48,300
6.	Miscellaneous plant equipment	29,900
7.	Engineering, construction management, etc.	45,000
	Total Initial Cost	$270,000

The average annual operations, maintenance and replacement costs for Alternative C are estimated to be $7,000/yr.

The average annual energy production and average annual income for Alternative B are (1982 base year):

Average Annual Energy Production	720,000 KWH
Average Annual Gross Income	$33,840

D. <u>Rehabilitation of Existing Turbine(s)</u>

The possibility of reconditioning one or both of the existing turbines was considered. Two site visits were conducted, and on each occasion only wheel pit #2 was dewatered sufficiently enough to view the turbine unit.

During the first site visits it was found that both generators and all electrical equipment have been removed from the powerhouse. The condition of the larger unit, within wheel pit #2 is in very poor condition. This unit has several holes in one casing. The wicket gates were inoperable. The wicket gate operating arms have been severed, and the gate rings have been damaged. It also appears that pieces of one of the turbine's runners have broken off. The condition of the smaller unit in wheel pit #1 is unknown. This unit has not operated for at least 25 years and is suspected of being in poor condition. Reconditioning the smaller unit is still a possibility, although remote, which should be considered in later stages of project development.

Another detriment to using the existing turbines is that the units have been sized for relatively large design flows. The use of both of

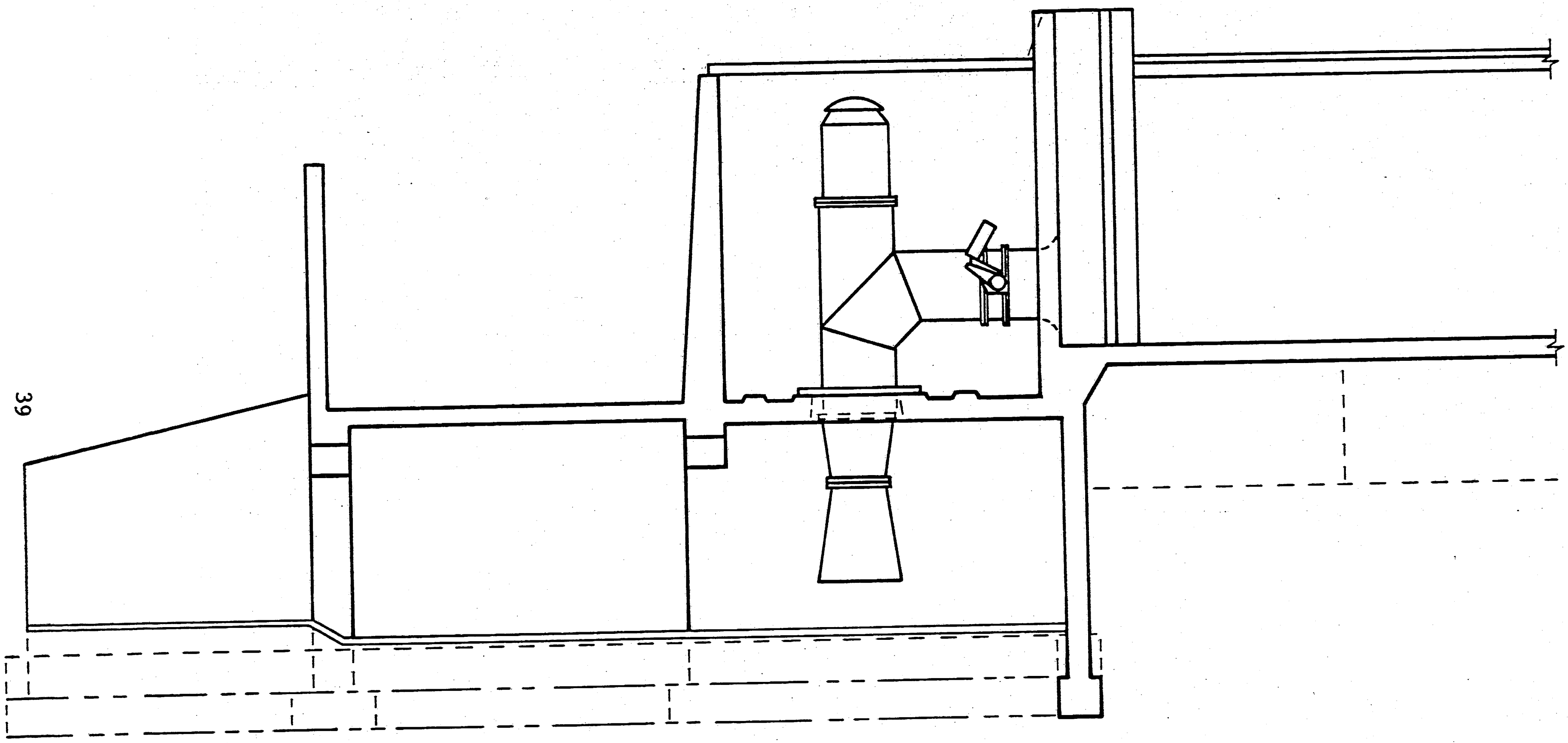

Fig. 11. Section view of Alternative C: two 36-inch intake diameter axial flow pump/turbine units.

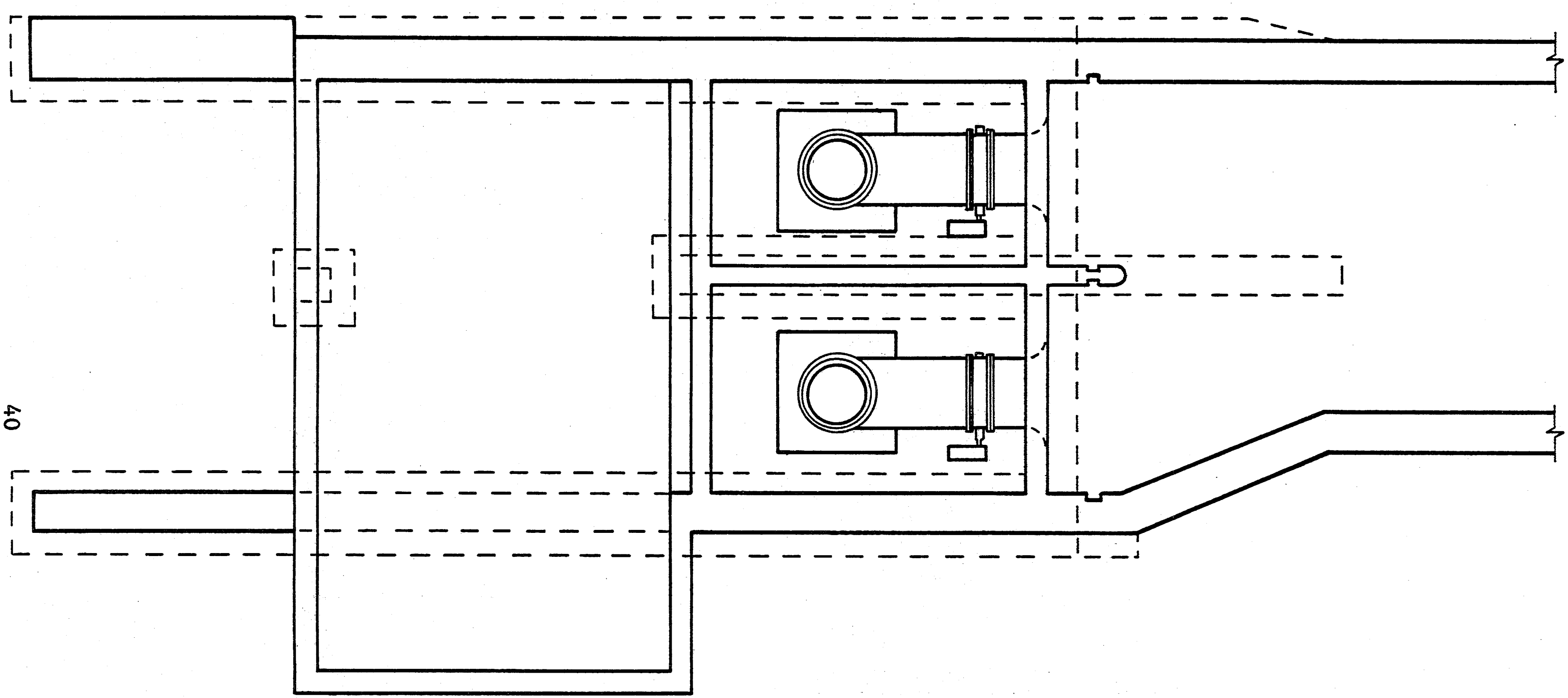

Fig. 12. Plan view of Alternative C: two 36-inch intake diameter axial flow pump/turbine units.

these hydromachines could only be justified by a very short duration peaking operation.

To aid in determining the feasibility of rehabilitating the existing equipment, a second site visit was conducted with two representatives of the General Electric Company. L. Dale Larson, Manager of Hydro Projects, Central Service Dept., was assisted by Paul M. Soderholm of the Electric Utility Section of the Sales Division.

It is Mr. Larson's opinion that reconditioning the existing turbine units is possible but probably not worthwhile. The reliability of reconditioning 70 year old hydromachines would be questionable. Also Mr. Larson was unable to supply probable costs in rehabilitating the existing equipment. The cost and scope of this type of work is highly speculative and possibly excessive. Mr. Larson's letter is given in Appendix A.

E. Other Development Alternatives Considered

Project development alternatives were considered which included other type of turbines. Turbines which allow for variable operating flows are unnecesssary. This type of turbine changes operating discharge by varying the pitch of the axial runner blades. The expense for this type of feature is appreciable, in addition to requiring greater installation, construction, and operational costs. If the management of the reservoir is involved in the plant's operational scheme, consistent flows can be attained, thereby rendering the application of a variable pitch blade unit unwarranted.

Larger versions of the types of turbines selected for the development alternatives were also considered. Total energy production might be increased, depending on reservoir management, but at the expense of dependable energy production. With large units the amount of time a power level could be sustained would fall below the percentage required to be considered dependable; therefore, the value of energy would significantly decrease. Even if the annual total energy increases with an installation of a larger unit than those considered herein, actual income would decrease.

There are other manufacturers of equipment similar to the units selected in this report. Two of those are Cornell Pump Co. and the Rand Corporation. They should be contacted in later stages of project development.

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 conjunction with one of the turbine manufacturers mentioned herein. Three generator manufacturers who have made bids for low-head hydroelectric developments are General Electric, Brown-Boveri, and Westinghouse.

F. Summary of Project Development Alternatives

The three different development alternatives produce similar levels of annual energy with significant differences in total initial costs. Variation in the initial costs might be viewed as correlating to the risks involved with the various alternatives. Each alternative's unit(s) has a different performance history. Actually all the alternatives incorporate turbine units which have been developed relatively recently. In addition, each of the three units considered represent one model in a line of standardized hydromachinery.

Alternative A has a turbine unit that was developed as a hydroturbine by a recently founded, and relative small, company. The unit has been independently tested and has displayed favorable results. There is no performance record associated with this unit, however. As of this writing, this units has only been installed at one operating site, Goffstown, New Hampshire. The City of Goffstown is the owner and operator of the site.

The turbine/generator unit used in Alternative A does have a relatively low initial cost. The manufacturer also offers most of the equipment required to develop the site in a package arrangement. Including most of the equipment in a package should insure compatibility of components. This should be reflected in shorter construction time with fewer delays and lower installation costs.

The hydromachine used in Alternative B was developed from a pump design which was altered and revised to be used specifically as a hydroturbine. The manufacturer of this unit is a large and well established manufacturer with a long history of marketing pumps and turbines. This type of turbine unit has been installed at various sites in the past few years. The turbine/generator unit used in Alternative B does have a relatively high initial cost. For this particular installation, it would also require greater civil work construction. As Alternative A, this turbine/generator unit is offered in a package. It therefore would realize the advantages associated with that arrangement.

Alternative C has a turbine unit which uses an unaltered pump runner with redesigned guide vanes, which is connected to an induction generator. This turbine/generator unit is marketed by a large and established manufacturer of pumps. These pumps have only just recently been marketed as turbines. Because these units are standardized pumps, they have a relatively low cost. These pump-turbine/generator units are not presently marketed within a package and therefore do not possess the corresponding advantages. Lack of inclusion in a package also makes it more difficult to estimate equipment costs.

The difference in the operational schemes of the development alternatives is in how the minimum flow is managed. In Alternative C the energy of the required low flow is recovered by running the flow through a pump/turbine. The minimum flows in development of Alternatives A and B are passed through a dump valve with no recovery of the energy in that flow.

There are only slight differences in the average annual incomes of the three development alternatives. The total initial cost of Alternative B is significantly greater than Alternatives A and C. These differences and similarities are illustrated in Table 1. Also presented in Table 1 is the ratio of annual benefit to total initial cost (not to be confused with the "benefit-cost ratio"). The ratio is computed by dividing average annual income by total initial cost. This ratio gives a parameter that can be used in a quick comparison of alternatives.

TABLE 1. Comparison of Energy Production Benefits and of Total Initial Project Costs for Development Alternatives A, B, and C (1982 Base Year)

Development Alternative	A	B	C
Average Annual Energy Production, KWH	640,000	610,000	720,000
Total Average Annual Income ($)	30,080	28,670	33,840
Total Initial Project Cost ($)	223,400	348,500	270,000
Annual Benefits/Total Initial Cost	0.135	0.082	0.125

IX. ECONOMIC ANALYSIS

A. Background and Assumptions

This section of the report will compare the benefits and costs of hydropower development at the Fish Hook River 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.D. Public development and financing is assumed, although one private financing example as been included.

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.

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

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 initial project costs will be amortized over the typical period used in public works, 20 years.

- 11 percent interest and discount rate. The discount rate is used in computing present worth. Economic analysis typically equate interest rate and discount rate. Interest rates on tax-exempt bonds have been climbing since the beginning of 1980.

  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 non-tax-exempt financing rates will decrease by approximately 1.5 percent[8]. For this reason, a two percent spread between interest rate and escalation rate will be used. An economic analysis is primarily sensitive to the difference between interest rate and discount rate rather than the actual values of the rates.

- Nine percent 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

[8]Donald Porter. First Boston Corporation, New York, N. Y.

inflation over the next 20 years[9]. The annual increase in the consumer price index between 1977 and 1981 has averaged 9.9 percent. The CPI is currently moderating; however, most economic forecasters are still predicting inflation rates near 9 percent over the next 5 to 10 years[10].

- Annual operation, maintenance and replacement costs in 1982 dollars were determined from Ref. [5].

- Nine percent annual escalation in operation, maintenance and replacement costs. This rate was chosen to coincide with the predicted inflation rate.

- A one year construction period.

- 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. Cost and Benefit Streams

Cost and benefit streams (or cash flow) for Alternatives A, B, and C are given in Tables 2, 3, and 4. The assumption used in the analysis are those presented in Section IX-A. Alternatives A and C produce similar and very favorable cost and benefit streams. The cash flow of Alternative B does not compare as well. The results of Alternative A are slightly better than those of Alternative C; Alternative A produces the earliest positive case flow, becoming positive after the second year. Also the net present value is positive after seven years (payback period) with Alternative A, the earliest of the three alternatives.

C. Comparison of Project Development Alternatives

The first year cost of energy, present new value, benefit-cost ratio and the internal rate of return for each of the development alternatives are compared in Table 5. A 35-year and 50-year project life was used. The 35-year project economic life is commonly used for hydropower facilities. Experience has indicated, however, that the project economic life of a typical hydropower facility has been significantly greater (50 years or more). A 50-year project economic life analysis has therefore also been included.

As in the cost and benefit stream analysis, the economic indicators of Alternative B, although good, are consistently less beneficial than the

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[9] Minnesota Energy Agency.

[10] Data Resources, Inc.

TABLE 2. Benefit and Cost Streams for Alternative A Beginning with First Year of Construction. All figures in $. Present worth Base Year = 1982

Year	Debt Service	OM & R Costs	Gross Income	Present Worth Benefits	Present Worth Costs	Present Worth Cash Flow	Net Present Value
1	28054	0	0	0	-25274	25274	-25274
2	28054	8317	35738	29006	29519	-513	-25787
3	28054	9065	38954	28483	27141	1342	-24444
4	28054	9881	42460	27970	24989	2981	-21463
5	28054	10770	46282	27466	23040	4426	-17037
6	28054	11740	50447	26971	21275	5696	-11341
7	28054	12796	54987	26485	19676	6809	-4532
8	28054	13948	59936	26008	18226	7782	3250
9	28054	15203	65331	25539	16910	8629	11880
10	28054	16572	71210	25079	15716	9363	21243
11	28054	18063	77619	24627	14632	9995	31238
12	28054	19689	84605	24184	13647	10537	41775
13	28054	21461	92219	23748	12751	10997	52772
14	28054	23392	100519	23320	11935	11385	64157
15	28054	25497	109566	22900	11192	11707	75864
16	28054	27792	119427	22487	10515	11972	87836
17	28054	30293	130175	22082	9898	12184	100020
18	28054	33020	141891	21684	9333	12351	112371
19	28054	35999	154661	21293	8818	12476	124847
20	28054	39231	168581	20910	8346	12564	137411
21	0	42762	183753	20533	4778	15755	153166
22	0	46610	200291	20163	4692	15471	168636
23	0	50805	218317	19800	4608	15192	183828
24	0	55378	237965	19443	4525	14918	198747
25	0	60362	259382	19093	4443	14650	213396
26	0	65794	282727	18749	4363	14386	227782
27	0	71716	308172	18411	4284	14126	241908
28	0	78170	335908	18079	4207	13872	255780
29	0	85205	366139	17753	4131	13622	269402
30	0	92874	399092	17433	4057	13376	282778
31	0	101232	435010	17119	3984	13135	295914
32	0	110343	474161	16811	3912	12899	308813
33	0	120274	516835	16508	3842	12666	321479
34	0	131099	563351	16211	3772	12438	333917
35	0	142898	614052	15918	3704	12214	346131
36	0	155759	669317	15632	3638	11994	358125
37	0	169777	729555	15350	3572	11778	369903
38	0	185057	795215	15073	3508	11566	381469
39	0	201712	866785	14802	3445	11357	392826
40	0	219866	944795	14535	3383	11153	403979
41	0	239654	1029827	14273	3322	10952	414930
42	0	261223	1122511	14016	3262	10754	425685
43	0	284733	1223537	13764	3203	10561	436245
44	0	310359	1333656	13516	3145	10370	446615
45	0	338291	1453685	13272	3089	10183	456799
46	0	368737	1584516	13033	3033	10000	466799
47	0	401924	1727123	12798	2978	9820	476619
48	0	438097	1882564	12567	2925	9643	486261
49	0	477525	2051995	12341	2872	9469	495730
50	0	520503	2236674	12119	2820	9298	505029
51	0	567340	2437975	11900	2769	9131	514160

Payback period = 7 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $358,125
Benefit Cost RAtio = 1.90
Internal Rate of Return = 22.7 percent

Economic Analysis for a Project Life of 50 Years
Present Net Value = $514,160
Benefit Cost Ratio = 2.15
Internal Rate of Return = 22.9 percent

TABLE 3. Benefit and Cost Streams for Alternative B Beginning with First Year of Construction. All figures in $. Present worth Base Year = 1982

Year	Debt Service	OM & R Costs	Gross Income	Present Worth Benefits	Present Worth Costs	Present Worth Cash Flow	Net Present Value
1	43763	0	0	0	39426	-39426	-39426
2	43763	8317	34063	27646	42269	-14623	-54049
3	43763	9065	37128	27148	38628	-11480	-65529
4	43763	9881	40470	26659	35337	-8678	-74207
5	43763	10770	44112	26179	32363	-6184	-80391
6	43763	11740	48082	25707	29674	-3967	-84359
7	43763	12796	52410	25244	27242	-1999	-86357
8	43763	13948	57127	24789	25042	-254	-86611
9	43763	15203	62268	24342	23051	1291	-85320
10	43763	16572	67872	23904	21249	2655	-82665
11	43763	18063	73981	23473	19616	3856	-78809
12	43763	19689	80639	23050	18137	4913	-73896
13	43763	21461	87897	22635	16796	5839	-68058
14	43763	23392	95807	22227	15580	6647	-61410
15	43763	25497	104430	21826	14476	7351	-54060
16	43763	27792	113829	21433	13373	7960	-46100
17	43763	30293	124073	21047	12562	8484	-37616
18	43763	33020	135240	20668	11734	8934	-28682
19	43763	35992	147411	20295	10980	9315	-19367
20	43763	39231	160678	19930	10294	9636	-9732
21	0	42762	175140	19570	4778	14792	5060
22	0	46610	190902	19218	4692	14526	19586
23	0	50805	208083	18872	4608	14264	33850
24	0	55378	226811	18532	4525	14007	47856
25	0	60362	247224	18198	4443	13755	61612
26	0	65794	269474	17870	4363	13507	75118
27	0	71716	293727	17548	4284	13263	88382
28	0	78170	320162	17232	4207	13024	101406
29	0	85205	348976	16921	4131	12790	114196
30	0	92874	380384	16616	4057	12559	126755
31	0	101232	414619	16317	3984	12333	139088
32	0	110343	451935	16023	3912	12111	151199
33	0	120274	492609	15734	3842	11893	163091
34	0	131099	536944	15451	3772	11678	174770
35	0	142898	585268	15172	3704	11468	186238
36	0	155759	637943	14899	3638	11261	197499
37	0	169777	695357	14630	3572	11058	208557
38	0	185057	757940	14367	3508	10859	219416
39	0	201712	826154	14108	3445	10663	230080
40	0	219866	900508	13854	3383	10571	240551
41	0	239654	981554	13604	3322	10283	250833
42	0	261223	1069894	13359	3262	10097	260931
43	0	284733	1166184	13118	3203	9915	270846
44	0	310359	1271141	12882	3145	9737	280583
45	0	338291	1355543	12650	3089	9561	290144
46	0	368737	1510242	12422	3033	9389	299533
47	0	401924	1646164	12198	2978	9220	308753
48	0	438097	1794319	11978	2925	9054	317807
49	0	477525	1955807	11763	2872	8891	326697
50	0	520503	2131830	11551	2820	8730	335428
51	0	567340	2323695	11342	2769	8573	344001

Payback period = 20 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $197,499
Benefit Cost RAtio = 1.38
Internal Rate of Return = 16.1 percent

Economic Analysis for a Project Life of 50 Years
Present Net Value = $344,001
Benefit Cost Ratio = 1.60
Internal Rate of Return = 16.7 percent

TABLE 4. Benefit and Cost Streams for Alternative C
Beginning with First Year of Construction.
All figures in $. Present worth Base Year = 1982

Year	Debt Service	OM & R Costs	Gross Income	Present Worth Benefits	Present Worth Costs	Present Worth Cash Flow	Net Present Value
1	33905	0	0	0	30545	-30545	-30545
2	33905	8317	40205	32632	34268	-1637	-32182
3	33905	9065	43824	32044	31420	624	-31558
4	33905	9881	47768	31466	28844	2623	-28936
5	33905	10770	52067	30899	26513	4386	-24549
6	33905	11740	56753	30343	24404	5939	-18611
7	33905	12796	61861	29796	22494	7302	-11309
8	33905	13948	67428	29259	20765	8494	-2815
9	33905	15203	73497	28732	19198	9534	6719
10	33905	16572	80112	28214	17777	10437	17156
11	33905	18063	87322	27706	16489	11217	28373
12	33905	19689	95181	27206	15319	11887	40260
13	33905	21461	103747	26716	14258	12459	52719
14	33905	23392	113084	26235	13293	12942	65661
15	33905	25492	123262	25762	12415	13347	79008
16	33905	27792	134355	25298	11617	13681	92688
17	33905	30293	146447	24842	10890	13952	106640
18	33905	33020	159627	24395	10228	14167	120807
19	33905	35992	173994	23955	9623	14332	135139
20	33905	39231	189653	23523	9071	14452	149591
21	0	42762	206722	23100	4778	18321	167912
22	0	46610	225327	22683	4692	17991	185904
23	0	50805	245606	22275	4608	17667	203571
24	0	55378	267711	21873	4525	17349	220919
25	0	60362	291805	21479	4443	17036	237955
26	0	65794	318068	21093	4363	16729	254685
27	0	71716	346694	20712	4284	16428	271112
28	0	78170	377896	20339	4207	16132	287244
29	0	85205	411907	19972	4131	15841	303085
30	0	92874	448978	19613	4057	15556	318641
31	0	101232	489386	19259	3984	15275	333916
32	0	110343	533431	18912	3912	15000	348916
33	0	120274	581440	18571	3842	14730	363646
34	0	131099	633769	18232	3772	14464	378111
35	0	142898	690809	17908	3704	14204	392314
36	0	155759	752981	17586	3638	13948	406262
37	0	169777	820750	17269	3572	13697	419959
38	0	185057	894617	16958	3508	13450	433409
39	0	201712	975133	16652	3445	13207	446616
40	0	219866	1062895	16352	3383	12970	459586
41	0	239654	1158555	16057	3322	12736	472322
42	0	261223	1262825	15768	3262	12506	484828
43	0	284733	1376480	15484	3203	12281	497109
44	0	310359	1500363	15205	3145	12060	509169
45	0	338291	1635395	14931	3089	11842	521011
46	0	368737	1782581	14662	3033	11629	532640
47	0	401924	1943013	14398	2978	11420	544060
48	0	438097	2117884	14138	2925	11214	555273
49	0	477525	2308494	13884	2872	11012	566285
50	0	520503	2526258	13633	2820	10813	577098
51	0	567340	2742722	13388	2769	10618	587717

Payback period = 8 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $406,262
Benefit Cost RAtio = 1.91
Internal Rate of Return = 22.1 percent

Economic Analysis for a Project Life of 50 Years
Present Net Value = $587,717
Benefit Cost Ratio = 2.19
Internal Rate of Return = 22.3 percent

TABLE 5. First Year Cost of Energy, Present Net Value, Benefit-Cost Ratio and Internal Rate of Return for Fish Hook Dam Development Alternatives A, B, and C

	Development Alternatives		
	A	B	C
First Year Cost of Energy ($/KWH)	.055	.083	.057
Payback Period (yrs)	7	20	8
35-Year Project Economic Life			
Present Net Value (Thousand $, 1982 Base Yr)	358	197	406
Benefit Cost Ratio	1.90	1.38	1.91
Internal Rate of Return (Annual %)	22.7	16.1	22.1
50 Year Project Economic Life			
Present Net Value (Thousand $, 1982 Base Yr)	514	344	588
Benefit Cost Ratio	2.15	1.60	2.19
Internal Rate of Return (Annual %)	22.9	16.7	22.3

economic indicators of Alternatives A and C. The economic indicators of Alternatives A and C are similar, with both displaying very good economic return.

D. Sensitivity Analysis

Sensitivity analysis investigates the impact of variations in project parameters and economic assumptions on the economic feasibility indicators. Development Alternative A was selected for the sensitivity analysis. Although the economic feasibility indicators of Alternatives A and C are similar, Alternative A was chosen because the estimated project cost included more actual manufacturer's quotations than the project cost of development Alternative C. Thus, the estimated costs for Alternative A are more firm. In the sensitivity analysis the original development Alternative A will be represented as A1 for comparison with the sensitivity calculations A2 through A20.

1. Value of Energy

Hydropower feasibility is naturally dependent upon the price at which the generated electricity is sold. The net value of the energy is determined by legislation, negotiation, or a combination of both. At the Fish Hook Dam the value of energy produced depends on the type (dependable or non-dependable) of energy produced and the power production capacity of the site. In Section VI this value was estimated to be 4.70 ¢/KWH (1982 base year). Table 6 presents the economic feasibility indicators over a range of energy values for Alternative A. As would be expected, project feasibility increases consistently with increases in energy value. Figure 13 illustrates the increase in the benefit-cost ratio, with project lives of 35 and 50 years, as the value of energy increases.

2. Variation of 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 10, 20 and 30 percent greater and less than the estimate given in Section VIII for Alternative A. The effects of the variation on the economic feasibility indicators is given in Table 7. Although an increase in initial project cost reduces overall economic return, economic feasibility is good with a project cost overrun of up to 30 percent. The variation is presented graphically in Figure 14.

3. Variations in Operation, Maintenance and Replacement Costs

Probably the most difficult cost to accurately predict is the annual operation, maintenance, and replacement (O.M.&R.) cost. It is the only cost in the economic analysis which is not set at the beginning of the

TABLE 6. Benefit-Cost Ratio, Percent Net Value, Internal Rate of Return and Payback Period at Various Values of Energy for Development Alternative A, Fish Hook River Dam

	Development Alternatives					
	A1	A2	A3	A4	A5	A6
Value of Energy ($/KWH)	.047	.02	.03	.04	.05	.06
---------- 35-Year Project Life ----------						
Benefit-Cost Ratio	1.90	0.81	1.21	1.61	2.02	2.42
Present Net Value (Thousand $, 1982)	358	-77	84	245	407	568
Internal Rate of Return (%)	22.7	9.2	14.9	19.5	24.0	28.7
---------- 50-Year Project Life ----------						
Benefit-Cost Ratio	2.15	0.91	1.37	1.83	2.29	2.74
Present Net Value (Thousand $, 1982)	514	-38	166	371	576	780
Internal Rate of Return (%)	22.9	10.8	15.6	19.8	24.2	28.8
Payback Period (yrs)	7	(over 50)	24	12	6	3

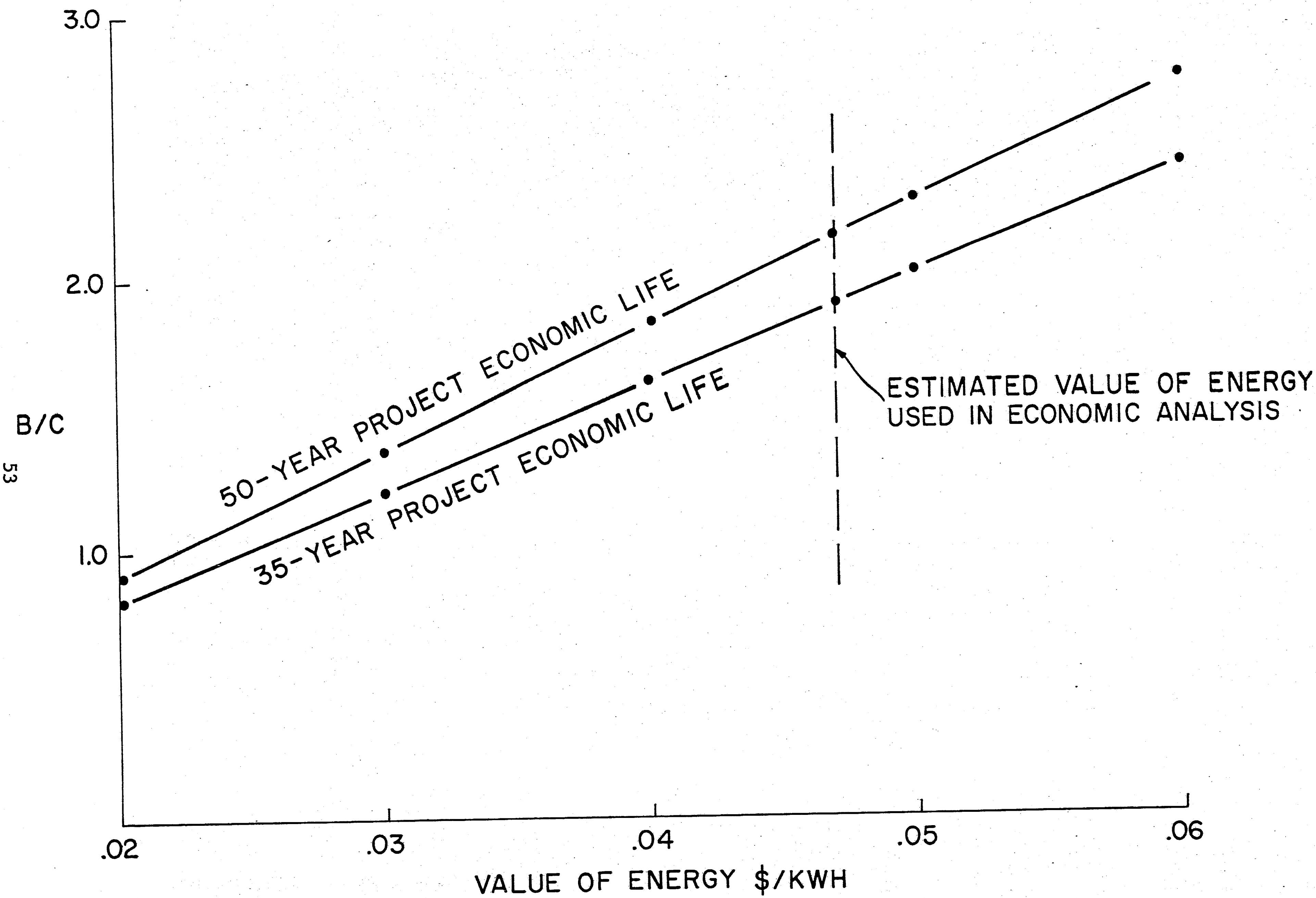

Fig. 13. Benefit-cost ratio for 35- and 50-year project economic life versus value of energy.

TABLE 7. Benefit-Cost Ratio, Percent Net Value, Internal Rate of Return and Payback Period at Different Initial Project Costs for Development Alternative A, Fish Hook Dam

	Development Alternatives						
	A1	A7	A8	A9	A10	A11	A12
Internal Project Costs (Thousand $, 1982)	233 (±0%)	156 (-30%)	179 (-20%)	201 (-10%)	246 (+10%)	268 (+20%)	290 (+30%)
35-Year Project Life							
Benefit-Cost Ratio	1.90	2.28	2.13	2.01	1.80	1.71	1.62
Present Net Value (Thousand $, 1982)	358	425	403	380	336	313	291
Internal Rate of of Return (%)	22.7	29.9	26.8	24.5	21.2	20.0	28.9
50-Year Project Life							
Benefit-Cost Ratio	2.15	2.53	2.39	2.26	2.05	1.95	1.87
Present Net Value (Thousand $, 1982)	514	581	559	536	492	469	447
Internal Rate of Return (%)	22.9	29.9	26.9	24.6	21.4	20.3	19.3
Payback Period	7	3	4	5	9	11	13

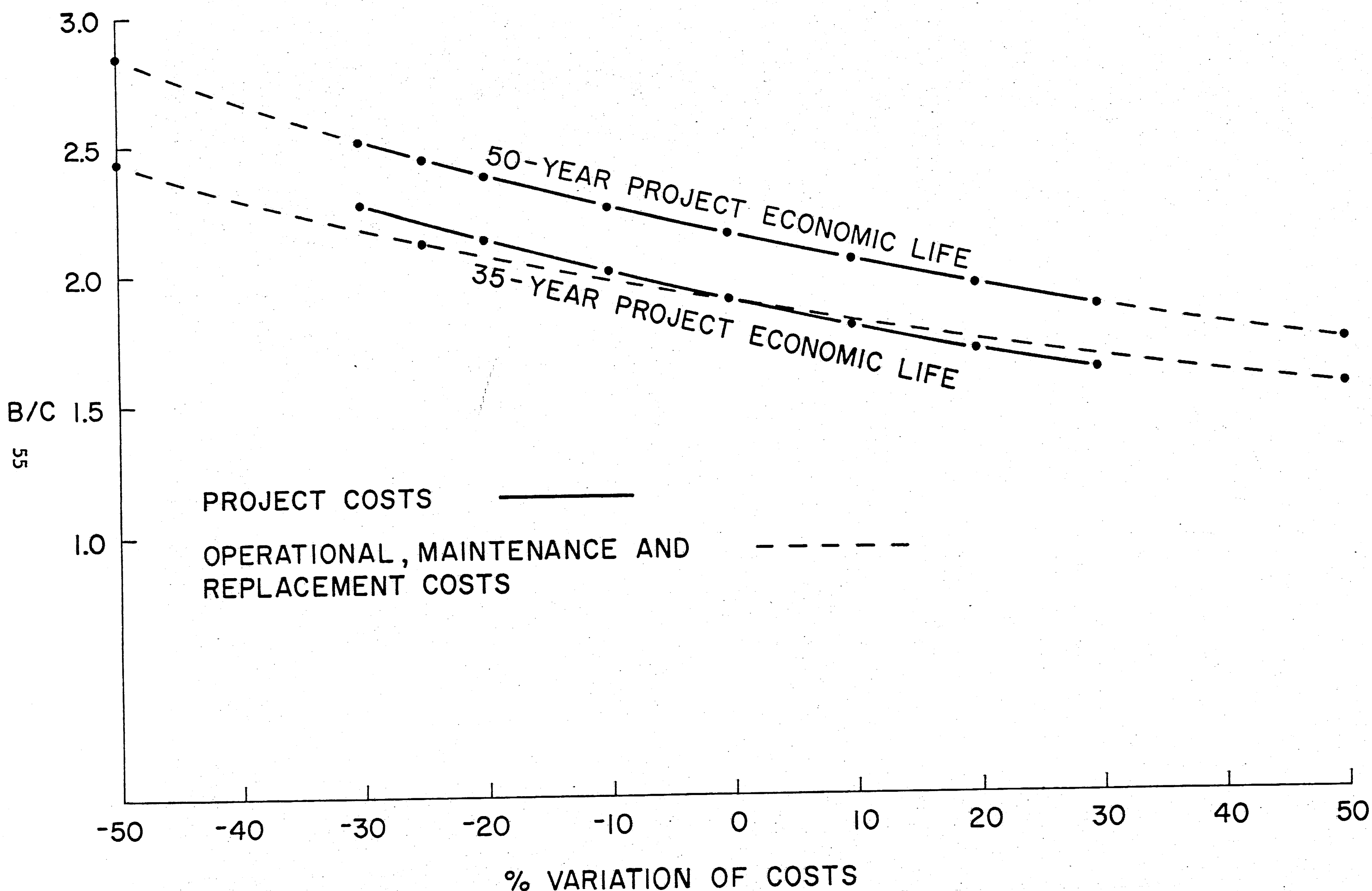

Fig. 14. Benefit-cost ratio versus 2 percent variation in initial project cost and in operation, maintenance, and replacement costs.

project. The O.M.&R. costs are incurred throughout the life of the facility. Consequently, any prediction of these costs will be more speculative when compared to the other costs.

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 both 25 and 50 percent in the original estimate of O.M.&R. costs were used in the sensitivity analysis. The response of the various economic indicators is given in Table 8, which indicates that an increase of up to 50 percent in O.M.&R cost does not undermine the economic feasibility of the development of the site. The results of this sensitivity analysis are also presented in Figure 14.

4. Variations in Interest Rate

Economic feasibility is extremely sensitive to the difference between interest and escalation rates. In all cases the energy value escalation rate and the escalation rate for operation, maintenance and replacement costs are fixed and assumed to be equal. The interest rate has been varied, producing economic feasibility indicators for four other interest rates. Table 9 lists the results and compares them to the indicators using the original values of Alternative A. Even with the interest rate six percentage points greater than the escalation rate, a favorable economic return is indicated.

5. Dry Year Analysis

Very often a report of this type will include a study of the impact of a dry year on the economics of development. Flow data has not been gathered at the Fish Hook River Dam site. Therefore, an accurate and detailed dry year analysis is not possible. Data on the low flow characteristics of the watershed which contains the Fish Hook Dam does exist, however. It appears from the data that a catastrophic dry year is improbable, although an event of this type is possible because we are dealing with natural occurrences. An extended low flow period could cause significant negative cash flows. The early years of development are more susceptible to large negative cash flows because of the greater debt service. Prior to development the City of Park Rapids should be aware of the impact of an extended low flow episode.

E. Private Development Example

The City of Park Rapids may wish to consider leasing the Fish Hook River Dam to a private concern for hydropower development. For this reason a typical example of the return which may be expected by a private developer is included. Recent state legislation enables the City of Park Rapids to waive property taxes for the development in lieu of the lease arrangement.

There are many additional tax considerations to be incorporated into an economic analysis of private development. The tax bracket is individual

TABLE 8. Benefit-Cost Ratio, Present Net Value, Internal Rate of Return and Payback Period at Different Annual Operation, Maintenance and Replacement Costs for Development Alternative A

	Development Alternatives				
	A1	A13	A14	A15	A16
Operation, Maintenance and Replacement Cost ($, 1981 Base Year)	7,000 (±0%)	3,500 (-50%)	5,250 (-25%)	8,750 (+25%)	10,500 (+50%)
35-Year Project Life					
Benefit-Cost Ratio	1.90	2.43	2.13	1.71	1.55
Present Net Value (Thousand $, 1982)	358	446	402	314	270
INternal Rate of Return (%)	22.7	25.2	23.9	21.4	20.2
50-Year Project Life					
Benefit-Cost Ratio	2.15	2.87	2.46	1.91	1.72
Present Net Value (Thousand $, 1982)	514	626	570	458	402
Internal Rate of Return (%)	22.9	25.3	24.1	21.7	20.5
Payback Period (Year)	7	5	6	9	10

TABLE 9. Benefit-Cost Ratio, Present Net Value, Internal Rate of Return and Payback Period at Different Discount Rates for Development Alternative A, Fish Hook Dam

	Development Alternatives				
	A1	A17	A18	A19	A20
Interest and discount Rate (%)	11.0	7.0	9.0	13.0	15.0
Escalation Rate (%)	9.0	9.0	9.0	9.0	9.0
---------- 35-Year Project Life ----------					
Benefit-Cost Ratio	1.90	2.64	2.25	1.60	1.35
Present Net Value (Thousand $, 1982)	358	945	584	211	113
Internal Rate of Return (%)	22.7	22.7	22.7	22.7	22.7
---------- 50-Year Project Life ----------					
Benefit-Cost Ratio	2.15	3.12	2.62	1.75	1.44
Present Net Value (Thousand $, 1982)	514	1,730	931	283	147
Internal Rate of Return (%)	22.9	22.9	22.9	22.9	22.9
Payback Period (Years)	7	3	5	20	14

to each developer, so a 50 percent tax bracket is chosen herein as "typical," although the incremental tax bracket may be significantly higher. In addition, the following assumptions were made:

- 25 percent equity in year 1,
- 21 percent investment and renewable energy tax credit in the first year of operation,
- 15 year ownership after construction,
- 15 year depreciation period, straight-line, and
- present worth salvage value of facility after 15 years of operation is 70 percent of initial project cost. (This corresponds to a linear decrease in present worth salvage value over 50 years).

The analysis does not include lease provisions to the City of Park Rapids, which would reduce economic return.

The economic analysis was performed for 15 and 13 percent discount rates, corresponding to a difference of 6 and 4 percent between discount and escalation rates, respectively. The resulting benefit and cost streams and economic indicators are given in Tables 10 and 11. These results indicate that the excellent economic return of public development applies to private development as well. The cash flow of both Tables 10 and 11 is positive after only one year of operation. Under adverse economic conditions, e.g. a 6 percent difference between discount and escalation rates as given in Table 11, the payback period is still only 7 years, with an internal rate of return of 23 percent.

TABLE 10. Benefit and Cost Streams for a Private Development Example, Beginning with First-Year of Construction. Discount Rate: 13 Percent. All Figures are in Dollars. Base Year for Costs and Present Worths = 1982.

				------ Present Worths-----			
Year	Equity and Debt Service	O.M.&R Costs	Gross Income	Income and Net Tax Benefits	Costs	Cash Flow	Net Present Value
1	81777	0	10891	9638	72369	-62731	-62731
2	25927	8317	87279	68352	26818	41534	-21197
3	25927	9065	42078	29162	24251	4911	-16286
4	25927	9881	43934	26946	21962	4984	-11302
5	25927	10770	45945	24937	19918	5020	-6283
6	25927	11740	48124	23115	18092	5023	-1260
7	25927	12796	50483	21458	16460	4999	3739
8	25927	13948	53037	19950	14999	4951	8690
9	25927	15203	55801	18575	13692	4884	13573
10	25927	16572	58791	17319	12520	4800	18373
11	25927	18063	62025	16170	11468	4702	23074
12	25927	19689	65521	15116	10524	4592	27667
13	25927	21461	69299	14148	9675	4474	32140
14	25927	23392	73381	13258	8911	4348	36488
15	25927	25497	77789	12438	8222	4216	40703
16	0	22792	579249	81962	3932	78029	118732

Payback Period = 6 Years

Economic Analysis for a Project Life of 15 Years
Present Net Value = $118,732
Benefit cost Ratio = 1.40
Internal Rate of Return = 23.0 percent

TABLE 11. Benefit and Cost Streams for a Private Development Example, Beginning with First-Year of Construction. Discount Rate: 15 Percent. All Figures are in Dollars. Base Year for Costs and Present Worths = 1982.

				------ Present Worths-----			
Year	Equity and Debt Service	O.M.&R Costs	Gross Income	Income and Net Tax Benefits	Costs	Cash Flow	Net Present Value
1	84504	0	12366	10927	73482	-62554	-62554
2	28654	8317	88954	67262	27955	39307	-23247
3	28654	9065	43759	28772	24801	3971	-19276
4	28654	9881	45616	26081	22032	4048	-15228
5	28654	10770	47622	23676	19601	4076	-11152
6	28654	11740	49788	21525	17463	4061	-7091
7	28654	12796	52124	19595	15583	4013	-3078
8	28654	13948	54643	17863	13927	3936	858
9	28654	15203	57357	16304	12467	3838	4696
10	28654	16572	60279	14900	11179	3721	8417
11	28654	18063	63421	13632	10041	3590	12007
12	28654	19689	66797	12485	9036	3449	15456
13	28654	21461	70422	11446	8145	3301	18757
14	28654	23392	74309	10502	7356	3146	21903
15	28654	25497	78472	9644	6655	2989	24892
16	0	27792	579626	61942	2970	58972	83864

Payback Period = 7 Years

Economic Analysis for a Project Life of 15 Years
Present Net Value = $ 83,864
Benefit cost Ratio = 1.30
Internal Rate of Return = 23.0 percent

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 Fish Hook River 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 Minor License for hydroelectric power development, or an exemption from hydroelectric licensing requirements.

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 powerhouse and dams alter the general scenery along a river, displace streamside vegetation, and present obstacles to terrestrial wildlife species. Indirect impacts of small-scale hydropower may lead to new opportunities and responsibilities for supporting recreational, commercial, agricultural, or residential activity. [10]

There are also several other considerations for which the degree of severity or applicability must be determined on a site-specific basis. These consideration 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. An effective means of screening the site-specific environmental impacts is by utilizing an environmental impact matrix as shown in Fig. 15 [11] for the Fish Hook River Dam. The facility will be operated using one foot depth of reservoir storage to smooth out seasonal variations in streamflow. This operation will have a limited impact on fishing which may, in fact, be positive.

B. FERC Requirements

The Federal Energy Regulatory Commission (FERC), in its application procedure, 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; e.g., authorization to operate and maintain a project...using an existing dam or other facility would require less detailed information than authorization to construct a new project" [11].

The City of Park Rapids has two options in complying with FERC requirements. The first is to file a "short-form (minor) license" for hydroelectric power development. The second option is to file for an exemption from licensing. Both options will specifically require an envionmental report; however, annual license fees and periodic review and renewal are not required with an exemption. In addition, the processing period for an exemption from licensing is significantly shorter. The disadvantage to an exemption is that it provides no legal protection from downstream or upstream developments which may harm power production. Some State of Minnesota permits also will require an environmental analysis.

It is recommended that the City of Park Rapids file for an exemption from licensing rather than a short form license. The contents of an environmental report in the exemption should include [12]:

(1) Brief description of project and mode of operation (run-of-river or peaking).

(2) Description of environmental setting in or near project area. (Special attention should be given to endangered plant and animal species, critical habitats, sites on Wild and Scenic Rivers, sites eligible for or included on National Register of Historic Places.)

(3) Impact of continued operation of project or from construction of an existing dam or facility.

(4) Description of equivalent alternative power means if application is not authorized.

⊗ POSITIVE IMPACT

● SIGNIFICANT IMPACT

⊙ LIMITED IMPACT

□ INSIGNIFICANT OR NO IMPACT

PROPOSED ACTIVITIES	NATURAL FACTORS											
	TERRESTRIAL		HYDROLOGICAL				BIOLOGICAL				ATMOSPHERIC	
	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	
CONSTRUCTION												
EARTHWORK CLEARING/GRADING/EXCAV.												
DEMOLITION/DISPOSAL												
INTERIM FLOOD CONTROL												
COFFER DAM/DEWATERING												
HEAVY EQUIPMENT USE		⊙										
MATERIAL TRANSP./STORAGE												
TEMPORARY STRUCTURES AND FACILITIES												
WORKER AND EQUIP. ACCESS		⊙										
WORKER INFLUX												
PHYSICAL PLANT & OPERATION												
PERMANENT STRUCTURES & FACILITIES												
ELECTRIC DISTRIB. CIRCUITS												
ELECTRIC GENERATION												
FLOW CONTROL												
IMPOUND, MANAGEMENT												
WORKER & EQUIP. ACCESS												
SECURITY & SAFETY												

PROPOSED ACTIVITIES	CULTURAL FACTORS																											
	SOCIAL													LAND USE - LAND VALUE					INFRASTRUCTURE				RECREATION					
	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.																												
DEMOLITION/DISPOSAL								⊗																				
INTERIM FLOOD CONTROL																												
COFFER DAM/DEWATERING								⊗																				
HEAVY EQUIPMENT USE	⊙				⊙	⊙		⊗																				
MATERIAL TRANSP./STORAGE																												
TEMPORARY STRUCTURES AND FACILITIES																												
WORKER AND EQUIP. ACCESS	⊙																											
WORKER INFLUX													⊗															
PHYSICAL PLANT & OPERATION																												
PERMANENT STRUCTURES & FACILITIES	⊙								⊗																			
ELECTRIC DISTRIB. CIRCUITS	⊙																											
ELECTRIC GENERATION									⊗											⊗				?				
FLOW CONTROL																												
IMPOUND, MANAGEMENT																												
WORKER & EQUIP. ACCESS																												
SECURITY & SAFETY																												

Fig. 15. Potential Impacts of Fish Hook River Dam Hydropower Development Shown in an Environmental Matrix.

(5) Description of steps taken by the applicant in consulting with federal, state and local agencies during preparation of the environmental report. Indicate which agencies received the final report and provide copies of letters containing the comments of the agencies.

C. Water Level Fluctuations and In-stream Flows

The significance of water level fluctuations is a function of the mode of operation of the small-scale hydroelectric facility, the magnitude and timing of fluctuations, and the site-specific environmental setting [12]. Water fluctuation due to operations that incorporate management of reservoir storage may be of differing amplitude or frequency than normal seasonal fluctuations, thereby adversely affecting fauna and flora adapted to seasonal cycles [13]. 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 deeper regions of a reservoir [13]. These effects upon the reservoir apply mainly to hydropower installations which operate on a "seasonal peaking" basis, where relatively large fluctuations can result.

The unnatural cycles caused by water level fluctuation can also significantly modify the aquatic habitat below a hydropower facility. Streambeds and banks that were stable (neither aggrading or degrading when streamflow was unregulated may become highly unstable and erode under a regimen of fluctuating flow. Areas formerly with minimal or no sedimentation farther downstream may begin to fill with sediment [14].

The maximum water level fluctuation of the reservoir impounded by the Fish Hook River Dam due to the mode or operation proposed by this report is limited to one foot. Lowering of the surface level would be gradual. The greatest possible rate of drawdown due to the proposed hydropower operation would be 1.2 inches per day. Hydropower development would have a slight affect on the rate at which the reservoir rises but only within the one foot zone that is managed by the operation of the proposed plant. Because the proposed hydropower development would induce only gradual drawdown within a limited zone of operation the impact on the reservoir would not be significant.

In conjunction 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.

There are criteria established (such as the Montana Method) for determining an acceptable minimum flow in a stream or river. The criteria basically established seasonal flows based upon a percentage of the average annual flow. Tennant [15] indicates that the absolute minimum acceptable streamflow is 10 percent of the average annual flow. This will sustain short-term survival habitat for most aquatic life forms. At this percentage "...riparian vegetation may suffer due to lack of water, much of the litterol zone will be exposed, fish may be vulnerable to over harvest and natural beauty and stream esthetics are badly degraded" [15].

With higher percentages of average annual flow (i.e. 30%), the base flow will sustain good survival habitat for most aquatic life forms [15]. However, since flows nasturally drop to low levels, a regulated stream with a minimum flow at 10 percent of the average annual flow will occasionally provide some enhancement over a natural flow regimen [15].

Downstream flows would be modified by the operation of the proposed hydropower development. Because a consistent turbine operating flow is required, a consistent downstream flow would be produced much of the time. The streamflow would be less susceptible to fluctuations which would have a beneficial impact on aquatic habitat, sedimentation, and stream bank and bed stability. Also enhancement of downstream recreation would result.

The proposed minimum flow, which is in excess of 30 percent of the average annual flow, is sufficient to maintain survival of downstream aquatic life forms. Regulating the minimum flow such that a constant minimum flow is produced, when conditions allow, can lessen the occurrence of sharp reductions in flow and the duration of inadequate stream flows. The impact of the proposed hydropower development, due to stabilitization flow on the downstream reach, is beneficial.

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 hydropower intake.

The potential water quality impacts of hydropower development 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 [14].

None of these potential impacts are likely to be of importance at the Fish Hook River Dam. Neither temperature regime nor any of the other parameters listed above will be significantly altered because the design flow is small compared to reservoir storage volume, and the inlet to the hydropower plant, as proposed herein, is approximately 10 ft deep, which is at or above the normal depth of temperature stratification.

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 an existing dam site, 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 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 [16]. 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 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" [16]. 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 Fish Hook River Dam because the pressure changes are not as severe. Recent tests have indicated fingerling survival rates as high as 97 percent for low-head hydropower facilities.[11]

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

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[11]NEYPRIC, Inc. (1981). Personal Communication on the Rock Island Hydropower Facility, Ohio River.

through turbines. Trash racks located at the intake to turbines have metal bars which are spaced so that only the smallest fingerlings may pass into the turbines. This partially eliminates possible fish mortality at the source.

Impingement against the trash racks is another potential source of fish mortality at the Fish Hook River Dam. At design discharge, the average velocity through the trash racks is only 0.75 ft/sec. This trash rack velocity will not cause even minor fish impingement problems.

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 [17].

The hydropower facility considered herein has virtually none of these construction impacts because there is little or no dredging and little or no excavation required. The existing powerhouse is utilized with only minor alteration; both the substructure and superstructure of the powerhouse will remain entact.

If construction activities which will result in highly turbid water downstream are to be undertaken, these activities should be timed so as not to interfere with natural fish spawning activities. The Fish Hook River below the dam is a Northern Pike and Walleye fishery. Walleye spawn shortly after spring thaw. The northern spawning season is from April to early May [18]. A summary of the water chemistry and fishes of the Fish Hook River watershed is given in Appendix B.

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 close proximity" [19]. Sites on the National Register of Historic Places are given special protection by federal law. Therefore, it is imporant to review each site for potential archeological, cultural, and historic significance.

The proposed implementation of hydropower at the Fish Hook River Dam will not alter any historical sites or facilities. The exterior of the existing powerhouse will not be altered in any significant manner. Correspondence with the Minnesota Historical Society is given in Appendix A.

H. Endangered Species

Hydropower operation at the Fish Hook River Dam 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 site and has no recorded occurrences of rare or endangered plant or animal species at the site. Correspondence with the Natural Heritage Program and the U. S. Fish and Wildlife Service is given in Appendix B.

I. 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 environmental 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" [13].

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" [11].

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 a 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 discharges 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, DOE, 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 consideration, 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.

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

- 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.

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APPENDIX A

CORRESPONDENCE

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, 2621 VICTORY PARKWAY, CINCINNATI, OHIO 45206

INSTALLATION AND SERVICE ENGINEERING DIVISION

January 11, 1982

St. Anthony Falls Hydraulic Laboratory
University of Minnesota
Mississippi River & 3rd Avenue S.E.
Minneapolis, Minnesota 55414

Attention: Mr. Loyal Gake

Reference: Fishook River Dam
Park Rapids, Minnesota

On November 11, 1981 we visited the Fishook River Dam at Park Rapids, Minnesota in order to evaluate the potential for rehabilitating the facility for hydro-generation. Unit #2 had been dewatered for the purpose of inspection. The following paragraphs are intended to provide you with our assessment and evaluation of the facility and equipment and to make recommendations and suggestions for returning the facility to active power generation.

The existing turbines are identified as double camelback horizontal francis turbines. The #2 turbine pit could not be completely dewatered but I was able to examine the top half of the unit. Several holes about 2 inches in diameter had been burned in the top halves of the turbine casings in order to place a rod through the unit to effectively brake and prevent the unit from rotating. It appeared tnat the wicket gate operating arms had been used for this purpose. There was evidence that part of the gate ring connecting to the gate operating arms had been broken off one or two gates or cracked or broken. It was difficult to see all of the turbine runners but there was a significant piece broken out of the blade on one of the runners. The turbine shaft on both units (#1 & #2) had been cut off where the shaft penetrated the powerhouse wall. Presumably Unit #1 with respect to casing holes, gates and turbine runners would be in about the same condition. I saw nothing in the inspection of Unit #2 that would preclude being able to patch up and repair the unit for future service.

I believe the most difficult or perhaps expensive part of the task would involve the turbine shafts which have been cut off. It would undoubtedly be necessary to replace the shafts in order to obtain sufficient length for installing new couplings. If serious consideration is to be given to reconditioning the existing turbine units they should be removed from the turbine pits and taken to a repair facility like one of General Electric Company's Service Shops for complete disassembly and tabulation of repair costs.

In my estimation this is not the best course of action for rehabiliting Fishook River Dam. New generators and control equipment are mandatory and a significant amount of work should be planned in and around the water passages. Even if the rehabilitation costs of the existing turbine units prove to be economical the City of Park Rapids is still left with two seventy-year-old patched up turbines operating with new generators and controls. It's impossible to determine how much additional life could be put back into the existing turbine units but certainly not another seventy years.

It would be our recommendation to replace the existing turbine units with 2-vertical turbines of either francis or propeller design. Although we are requesting estimating prices on several units of about this size we believe that 2 Leffel 30" Samson units would probably be the most economical and would be able to take advantage of the flow of the Fishook River under either run of the river conditions or in a limited peaking operation. These units would provide a total of about 230 HP or approximately 170 kilowatts. There appears to be sufficient space for somewhat larger units but in our estimation would be of no advantage except for a full peaking operation.

Since we are recommending vertical units we would also recommend installing a new floor or deck over the turbine pit in order to accommodate and support the generators and associated governor and electrical control and switchgear equipment. This arrangement would require the construction of a building to protect this equipment and the use of a pre-engineered steel building can be cost effective and very practical. The most economical approach would involve the use of a right angle speed increasing gear to accommodate turbine speed of 217 RPM with a 900 RPM synchronous generator.

Fishook River Dam
Park Rapids, Minnesota (cont'd)

We were unable to make a detailed inspection of all of the water passages particularly below the turbine and into the tailrace area. In general the concrete and civil structures appeared to be in good condition and that a minimum of repairs would be necessary. The headgates on Unit #2 leaked considerably and presumably the gates for both Unit #1 and Unit #2 would have to be completely rebuilt.

To summarize we would acknowledge that the existing turbine units could probably be repaired and returned to service but we do not believe that this would be in the best long range interests of the City of Park Rapids and that the replacement of the units as outlined above would provide the city with the most cost effective means of utilizing the water power available at the Fishook River Dam.

L. D. Larson, Manager
Hydro Projects
Central Service Department

LDL/srd/3406B

MINNESOTA HISTORICAL SOCIETY
FOUNDED IN 1849
690 Cedar Street, St. Paul, Minnesota 55101 • (612) 296-612(

27 January 1982

Mr. John Gulliver
St. Anthony Falls Hydraulic Laboratory
3rd Avenue SE at Mississippi River
Minneapolis, Minnesota 55414

Dear Mr. Gulliver:

RE: Review of the historical significance of Anoka Dam (Anoka County), Fishhook River Dam (Hubbard County), Minnesota Falls Dam (Yellow Medicine County), and the Thief River Falls Dam (Pennington County).

MHS Referral File Number: M 992

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).

This review reveals that we do not have sufficient information to make specific determinations of significance on the above dams. However, we can make the following observations based on the information we have received thus far.

1. To date, we have received no data on the Anoka Dam (Anoka County). We request the opportunity to assess the historic significance of the dam should any work be proposed or considered.

2. Review of the Fishhook River Dam in Park Rapids (Hubbard County) revealed conflicting information on the date of the dam's construction and its specific uses prior to hydro-electric conversion. Current information does not address what, if any, historical links the present dam has to the earlier 19th century dam constructed on the site. Further, additional photos will be needed to assess the current dam structure and any extant generator equipment.

From the information received thus far it appears that the Fishhook River Dam and Power retains reasonable integrity. If the project is to be continued, further research to assess its historical significance should be considered.

3. Further review of the Thief River Falls Dam (Pennington County) also depends on the receipt of additional information. Photographs in the SHPO file indicate that the power house retains reasonable integrity. However, it is necessary to determine if generating equipment remains and to assess the historical significance of the site area. Should any work be proposed or considered we request the opportunity for further review once additional information is received.

4. Review of the information on the Minnesota Falls Dam (Yellow Medicine County) indicates that the power house, operator's cottage, headgates, and original turbines have been demolished or removed. Although historically associated with one of Yellow Medicine County's early river town settlements, which is no longer extant, the integrity of the site has been compromised by the removal of the associated structures and equipment.

As stated before, should any of the above projects be considered for implementation, we request the opportunity to further review their historical significance. Prior to making a final determination, our office would like to review historic and current photos of the dams, as well as information detailing the dams' original construction, original use(s) by the area or community, and subsequent structural changes.

If you have any questions please do not hesitate to contact Dennis Gimmestad at 726-1171. 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/fr

United States Department of the Interior

FISH AND WILDLIFE SERVICE

St. Paul Field Office, Ecological Services
538 Federal Building and U.S. Court House
316 North Robert Street
St. Paul, Minnesota 55101

IN REPLY REFER TO:

February 10, 1981

Mr. Robert Knowlton
St. Anthony Falls Hydraulics Laboratory
3rd Ave. SE at the Mississippi River
Minneapolis, Minnesota 55414

Dear Mr. Knowlton:

This provides additional comments to our February 4, 1981 meeting regarding feasibility studies for the development of hydropower facilities at existing dams in Yellow Medicine, Pine, Hubbard, Stearns, Fillmore, Dakota and Goodhue Counties, Minnesota.

The Federal Energy Regulatory Commission (F.E.R.C.) will be reviewing your permit applications for these facilities, and is required to comply with provisions of the Endangered Species Act prior to taking final action regarding those applications. We are, therefore, providing you with some of the endangered species data that FERC will require in the permit applications. Listed below are endangered and threatened species whose ranges coincide with the project areas.

SPECIES	RANGE (COUNTY)
Gray Wolf	Hubbard, Pine (peripheral range)
Peregrine Falcon	Dakota, Goodhue, Pine (potential breeding range)
Bald Eagle	Hubbard (breeding range), Dakota, Goodhue (wintering range)

While the early stage of planning makes it difficult to determine possible impacts to these species, at present we do not anticipate that the proposed work will affect the species listed. However, you should be aware that these comments constitute technical assistance only, and do not fulfill the requirements of Section 7 of the Endangered Species Act, which requires FERC and other federal agencies conducting, funding or authorizing any action to inquire of the Secretary of the Interior whether federally-Listed or Proposed Species are likely to be found in the project area. That inquiry can be made by writing to the Regional Director, U.S. Fish and Wildlife Service, Federal Building, Twin Cities, MN 55111.

We look forward to continued coordination on the proposed projects.

Sincerely,

Richard F. Berry

Richard F. Berry
Field Office Supervisor

APPENDIX B

Summary of Water Chemistry and

Fishes of the Fish Hook River Watershed

Taken from

REPORT ON THE FISH HOOK RIVER WATERSHED

by J. W. Enblom
Division of Fish and Wildlife
Minnesota Department of Natural Resources

MINNESOTA NATURAL HERITAGE PROGRAM

Analysis of Seven Dam Sites for St. Anthony Falls Hydraulic Lab.
April 17, 1981

Dam I.D. Number 506 - St. Cloud

Plants

The Natural Heritage Program, at this time, has no recorded occurrences of rare or endangered animals at this site.

Animals

At present there are no recorded occurrences of priority animal elements at or nearby the site.

Plant Communities

Oak savanna - Natural Heritage Program priority plant community Talahi Park (Sec 12 T35N,R31W)

Part of the park is an oak savanna that has been managed by prescribed burning. Savanna acreage in Minnesota has been severaly reduced by agriculture and urbanization. Oak savannas with high quality prairie understories are considered high priority for protection.

Floodplain Forest - Natural Heritage Program priority plant comunity, Beaver Islands (Sec 12 T35N,R31W; Sec 24 T124N,R28W)

The Beaver Islands lie 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*).

Dam I.D. Number 234 - Fishook River

Plants

At this time, the Natural Heritage Program has no recorded occurrences of rare or endangered plant species at this site.

Animals

The Natural Heritage Program, at this time, has no recorded occurrences of rare or endangered animals at this site. There is a great blue heron colony (150 nests) on Long Lake, approximately 2 miles east but the proposed construction should not pose any threats to this colony.

Plant Communities

At this time, the Natural Heritage Program has no recorded occurrences of priority plant communities at this site.

Dam I.D. Number 510 - Granite Falls

At this time, the Natural Heritage Program has no recorded occurrences of rare or endangered plant species at this site.

Animals

At present there are no recorded occurrences of priority animal elements at this site. Approximately 1 mile southeast of the site, however, is an occurrence record for the five-line skink (Eumeces fasciatus). In Minnesota the skink has been classified as an endangered species. The area around Granite Falls is the only area where this species is known to occur in Minnesota. The proposed dam construction, however, should not pose any problems.

Plant Communities

At this time, the Natural Heritage Program has no recorded occurrences of priority plant communities at this site.

Dam I.D. Number 513 - Kettle River

Plants

At this time, the Natural Heritage Program has no recorded occurrences of rare or endangered plant species at this site.

Animals

At present there are no recorded occurrences of priority animals at this site.

Plant Communities

At this time, the Natural Heritage Program has no recorded occurrences of priority plant communities at this site.

Dam I.D. Number 502 - Thief River Falls

Plants

At this time, the Natural Heritage Program has no recorded occurrences of rare or endangered plant species at this site.

Animals

The Natural Heritage Program, at this time, has no recorded occurrences of rare or endangered animals at this site.

The following table summarizes the water areas which have been surveyed in this watershed:

Lake Description	Wetlands Type	Number Present	Average Size (Acres)	Total Area (Acres)
Fish Lakes	V	25	460	11,508
Waterfowl	IV	9	45	403
Waterfowl-Winterkill Fish	IV & V	11	147	1,621
Total for All Areas		45		13,532

The fish lakes which were surveyed varied in size from 26.3 to 2,054 acres. Marginal (winterkill) fish and waterfowl lakes varied in size from 13.2 to 770 acres, and waterfowl lakes ranged from 12 to 82 acres.

SUMMARY OF STREAM SURVEY DATA

Fish Hook River - Hubbard County

Stream Length - 10 miles.
Average Width - 30 feet.
Source of Flow - Fish Hook Lake.
Mouth - Shell River.
Tributaries - Straight River and creek from Long Lake.
Dates of Survey - August 15-16, 1961.
Public Access - in Park Rapids, Section 24, owned by city in
Dean Park, Section 14, owned by Village of Park Rapids.
Shoreline Development - two miles at upper end is heavily developed.
From Park Rapids downstream the development is light.
Classification - warm water stream - walleye, northern pike.

Straight River - Becker and Hubbard Counties

Source of Flow - Straight Lake.
Mouth - Fish Hook River.
Stream Length - 14 miles.
Average Width - 33 feet.
Tributaries - none.
Pool Type - B_3
Stream Bank Cover - Trees and brush provide 25-50 per cent shade.
Dates of Survey - August 2-8, 1961 and August 7-8, 1947.
Public Access - at county road crossing.
Shoreline Development - There are only a few scattered farms along this stream.
Classification - cold water stream - brown and rainbow trout.

Straight Lake Creek - Becker County

Source of Flow - springs, T. 140 N., R. 37 W., S. 3.
Mouth - Straight Lake.
Tributaries - Upper Straight Creek.
Length of Flow - 2.5 miles.
Average Width - 3 feet.
Stream Bank Cover - forested, 85 per cent shade.
Public Access - at county road crossing, Sections 1-2.
Date of Survey - August 11, 1947.
Shoreline Development - none.
Classification - cold water stream - brook trout.

Upper Straight Creek - Becker County

Source of Flow - springs, T. 141 N., R. 37 W., S. 25.
Mouth - Straight Lake Creek.
Tributaries - none.
Length of Flow - 4 miles.
Average Width - 10 feet.
Public Access - county road right-of-way, Section 6.
Stream Bank Cover - forested, 60 per cent shade.
Date of Survey - August 11, 1947.
Shoreline Development - none.
Classification - cold water stream - brown trout.

Dinner Creek - Becker County

Source of Flow - Kane (Hemphill) Lake.
Mouth - Two Inlets Lake.
Length of Flow - six miles.
Average Width - four feet.
Stream Bank Cover - forested, provides 30-40 per cent shade.
Public Access - at county road crossings, Sections 2 and 11.
Shoreline Development - none.
Classification - warm water stream - minnow.

WATER CHEMISTRY

The chemical analyses were made of water samples collected from lakes during the survey of this watershed. These present a general picture of the chemical quality of the water, but it should be pointed out that this is subject to some variation because the chemistry of any water is subject to some short-term variation, and any single analysis can be considered a temporary resultant of many interacting factors. Those factors are: 1) those related to chemical and physical nature of the watershed and lake bed, 2) those related to water supply and loss, and 3) those related to the complicated biological and chemical system within the water itself (Moyle, 1956).[1] Most of the chemical constituents in lake waters are carried in from surrounding land by surface or ground waters, and the analyses therefore reflect the nature of watershed soils - an expression mostly of calcium and magnesium carbonates.

Waters from many of the lakes were analyzed in the field for total alkalinity - a test expressing concentrations of calcium and magnesium carbonate or "temporary hardness" - and more detailed analyses made on surface-water samples from 22 of the lakes that were sent into the St. Paul laboratory. The latter were all analyzed for total alkalinity, and 17 of them analyzed for sulphate ion, total phosphorus, and total nitrogen (Table XII).

Total alkalinity analyses ranged from 55.0 to 207.5 p.p.m. All but three of the lakes were above 100 p.p.m., and none in the soft-water range below 40 p.p.m. The mean for the series analyzed in the field was 134.4 p.p.m., and for the laboratory series 129.3 p.p.m. They are typical hard and moderately hard carbonate waters.

Sulphate ion concentrations ranged from 0.0 to 8.0 p.p.m., all low, differentiating these lakes from the sulphate prairie waters farther west.

Total phosphorus analyses ranged from 0.011 to 0.057 p.p.m. with a mean of 0.039. Total nitrogen (as determined by Kjeldahl analyses) ranged from 0.16 to 1.25 p.p.m. with a mean of 0.82 p.p.m. These waters can be characterized as having moderate or good, but not excessive, phosphorus and nitrogen fertility.

Secchi disc readings which indicate depth of light penetration because of turbidity and color also provide an indirect indication of the fertility of water. They ranged from 4.0 feet to 19 feet with a mean for 24 lakes tested of 10.45 feet. These indicate quite clear waters of moderate or good fertility, but not of excessive fertility or high turbidity.

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[1] Moyle, John B., 1956. Relationship between the Chemistry of Minnesota Surface Waters and Wildlife Management. Journal of Wildlife Management, Vol. 20, No. 3.

Table 4 - Water Chemistry of Lakes in the Fish Hook Watershed

Lake Name	Total Alkalinity (Field)	Total Alkalinity (Laboratory)	Sulphate Ion	Total Phosphorus	Total Nitrogen	Secchi Disc Readings (Feet)
Bad Medicine	117.5	105.00	0.5	0.043	0.16	18.0
Bass	135.0	119.00	0.0	0.039	0.84	6.0
Blue	-	150.25				18.5
Boot	-	150.00				
Cedar	120.0	105.0	2.0	0.045	0.95	8.0
Coon	67.5	55.00	0.5	0.011	0.73	15.0
Cox	122.5	106.00	3.5	0.057	0.96	5.0
Dinner	185.0	173.00	2.0	0.018	0.47	8.0
Little Dinner	207.5					7.0
Eagle	175.0					11.0
Fish Hook		142.50				16.5
Gardner	105.0	104.00	0.5	0.057	1.07	4.0
Hungry Man	87.5					13.0
Island	180.0	173.00	0.5	0.052	0.87	10.0
Little Mantrap	175.0	128.00	0.5	0.051	0.89	19.0
Long		132.50				11.0
Long Lost	120.0	100.00	0.5	0.043	0.42	18.0
Pickerel	125.0	96.00	0.5	0.034	1.25	6.0
Portage		142.50				6.0
Potato		183.50				12.75
Rice	187.5	170.00	1.0	0.043	1.20	2.0
Skunk	62.5	55.00	0.5	0.052	1.06	14.0
Straight		175.00	8.0	0.011	0.21	9.0
Sweitzer	112.0	105.0	1.0	0.032	1.24	7.0
Two Inlets		175.0				6.0

FISHES OF THE FISH HOOK RIVER WATERSHED

The lakes in the Fish Hook Watershed are of three main ecological types. These are the walleye-centrarchid lakes, centrarchid lakes, and bullhead lakes. The walleye-centrarchid lakes are moderately fertile, hardwater lakes which are medium in size. They contain a wide range of species of fish. The centrarchid lakes are medium to small-sized lakes. These are sometimes very weedy, fertile lakes. The predominant species of fish taken include northern pike, bluegills, pumpkinseed, largemouth bass, rock bass, and black crappie. The bullhead-type lakes are shallow, seldom exceeding twenty feet in depth. These are lakes in which winterkills promote the dominance of bullheads. Other species of fish usually found in these lakes are northern pike and some panfish. A total of 48 species of fish were taken during the biological surveys of the lakes and streams in this watershed. A list of the fishes of the Fish Hook watershed which includes their common and scientific names is shown in Table 5.

Table 5 - Fishes of the Fish Hook River Watershed

Common Name	Scientific Name
Bowfin	*Amia calva*
Tullibee	*Coregonus artedii*
Whitefish	*Coregonus peaformis*
Brown trout	*Salmo trutta*
Rainbow trout	*Salmo gairdneri*
White sucker	*Catostomus commersoni*
Northern redhorse	*Moxostoma macrolepidotum*
Hornyhead chub	*Hybopsis biguttata*
Blacknose dace	*Rhinichthys atratulus*
Longnose dace	*Rhinichthys cataractae*
Creek chub	*Semotilus atromaculatus*
Pearl dace	*Semotilus margarita*
Northern redbelly dace	*Chrosomus eos*
Golden shiner	*Notemigonus crysoleucas*
River shiner	*Notropis blennius*
Common shiner	*Notropis cornutus*
Emerald shiner	*Notropis atherinoides*
Rosyface shiner	*Notropis rubellus*
Spottail shiner	*Notropis hudsonius*
Bigmouth shiner	*Notropis dorsalis*
Blackchin shiner	*Notropis heterodon*
Mimic shiner	*Notropis volucellus*
Blacknose shiner	*Notropis heterolepis*
Brassy minnow	*Hybognathus hankinsoni*
Silvery minnow	*Hybognathus nuchalis*
Fathead minnow	*Pimephales promelas*
Bluntnose minnow	*Pimephales notatus*
Black bullhead	*Ictalurus melas*
Brown bullhead	*Ictalurus nebulosus*
Yellow bullhead	*Ictalurus natalis*
Tadpole madtom	*Noturus gyrinus*
Northern pike	*Esox lucius*
Banded killifish	*Fundulus diaphanus*
Yellow perch	*Perca flavescens*
Walleye	*Stixostedion vitreum*
Logperch	*Percina caprodes*
Johnny darter	*Etheostoma nigrum*
Iowa darter	*Etheostoma exile*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Rock bass	*Ambloplites rupestris*
Black crappie	*Pomoxis nigromaculatus*
Mottled muddler	*Cottus bairdi*
Stickleback	*Eucalia inconstans*
Burbot	*Lota lota*

Table 6. Occurrence of Species of Fish by Lakes, Fish Hook River Watershed (Excepting Small Fishes Such as Minnows, Darters, etc.)

Name of Lake	Tullibee	Common Sucker	Redhorse	Golden Shiner	Black Bullhead	Brown Bullhead	Yellow Bullhead	Northern Pike	Yellow Perch	Walleye	Smallmouth Bass	Largemouth Bass	Pumpkinseed	Bluegill	Rock Bass	Black Crappie
Bad Medicine	x	x				x		x	x	x	x	x	x	x	x	x
Bass		x				x		x	x			x	x	x		x
Blue	x	x	x			x		x	x	x		x	x	x	x	x
Boot		x				x		x	x	x		x	x	x	x	x
Cedar		x							x							
Coon				x		x		x				x		x		x
Cox						x		x				x		x		
Dinner		x				x	x	x	x	x		x	x	x	x	x
Little Dinner		x				x		x	x				x		x	
Eagle	x	x	x			x	x	x	x	x		x	x	x	x	x
Fish Hook	x	x	x		x	x	x	x	x	x		x	x	x	x	x
Hungry Man		x						x								
Island	x	x	x			x	x	x	x	x			x	x	x	x
Long	x	x	x				x	x	x	x		x	x	x	x	x
Long Lost		x						x	x			x	x	x		
Little Mantrap		x			x	x		x	x	x		x	x	x	x	x
Pickerel		x				x		x	x				x			x
Portage		x		x		x	x	x	x	x		x	x	x	x	x
Potato	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Rice		x				x		x	x				x			
Skunk		x		x				x	x	x			x	x	x	
Straight	x	x				x		x	x	x		x	x	x	x	x
Sweitzer		x				x	x	x	x	x			x			
Two Inlets	x	x	x	x		x	x	x	x	x		x	x	x	x	x

Fishing pressure has estimated during 1961 on sixteen of the better fish lakes in the Fish Hook Watershed. These estimates were obtained by a combination of aerial and ground counts. A total of 27 aerial counts and 18 ground counts were made on each lake during the summer fishing season. The estimated fishing pressure ranged from 2,516 to 79,173 manhours (Table 7). Considering the difference in lake size, the fishing pressure varied from 8.1 to 69.2 man-hours per acre. The median was 31.6 man-hours. The average number of anglers per boat ranged from 1.93 to 2.73, depending on the lake. The median number of anglers per boat for all lakes was 2.13.

A creel census contained information from 727 fishermen (267 contacts). The length of fishing trips varied from 1.5 to 8.0 hours with the median about 4.15 hours. Species and number of fish taken by these anglers varied from lake to lake as would be expected. The bluegill was the species listed most frequently with the following mentioned in order of abundance: northern pike, walleye, largemouth bass, crappie, perch, pumpkinseed, and rock bass. A survey of resort operators at the end of the fishing season listed eight kinds of fish as being taken by angling in the following order: northern pike, panfish, crappie, largemouth bass, walleye, rock bass, perch, and bullhead. Although the ranking according to the resort survey varies from that obtained by the creel census, they are actually very similar.

Two aerial fish house counts were made during the winter of 1961-62 (Table 8). These were compared to similar counts made during the winters of 1951-52 and 1952-53. On the six lakes which were subject to fish house counts in all three winters, there was a 36 per cent increase in fish houses from 1951-52 to 1952-53 and a 27 per cent increase from 1952-53 to 1961-62. This latter increase might have been greater but heavy snow cover and flooding kept many houses off the lakes during 1961-62.

Table 6A. Fishing Success for Various Species of Fish as Rated by Resort Owners in the Fish Hook River Watershed

Species	1st	2nd	3rd	4th	5th	Rating
Northern pike	11	6	8	4	1	1st
Panfish	10	4	1	4	2	2nd
Crappie	3	8	6	4	2	3rd
Largemouth bass	2	8	8	5	2	4th
Walleye	2	3	6	7	8	5th
Rock bass	1	2	1	2	1	6th
Perch	2				2	7th
Bullhead					2	8th