UNIVERSITY OF MINNESOTA
ST. ANTHONY FALLS HYDRAULIC LABORATORY

Project Report No. 203

FEASIBILITY OF HYDROPOWER CAPACITY ADDITIONS AT THE GRANITE FALLS DAM MN 00510

BY

Loyal Gake, Rodrick Garver, John Gulliver
and Richard Renaud

Prepared for

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
St. Paul, Minnesota

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ACKNOWLEDGEMENTS

This study was performed under the general supervision of Professor Roger E. A. Arndt, Director of the St. Anthony Falls Hydraulic Laboratory. Alan Rindels compiled the required hydrologic information. Bob Knowlton performed the tailwater curve computations and compiled the information given in the summary of environmental impacts of the proposed development.

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I. INTRODUCTION

The Granite Falls Dam is located on the Minnesota River in Granite Falls, Minnesota. The existing dam and powerhouse were constructed by the City of Granite Falls for the generation of hydroelectric power. There are currently two open flume Leffel units with Francis turbines generating electricity in the powerhouse. Unit No. 1, installed in 1940, is rated at 345 kW with 21 ft head. Unit No. 2, installed in 1932, is rated at 260 kW with 18 ft head. The net head at the site is approximately 18 ft, so the maximum generating capacity of the existing facility is 525 kW. The purpose of this study is to assess the feasibility of augmenting the existing facility with additional capacity, or of replacing the existing units with larger turbine units.

The Granite Falls 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 Granite Falls. Authorization to begin the Granite Falls Dam hydropower feasibility study was given October 29, 1980.

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 Granite Falls Dam is located on the Minnesota River in Granite Falls, Minnesota. The existing dam and powerhouse were constructed by the City of Granite Falls for the generation of hydroelectric power. There are currently two open flume Leffel units with Francis turbines generating electricity in the powerhouse. Unit No. 1, installed in 1940, is rated at 345 kW with 21 ft head. Unit No. 2, installed in 1932, is rated at 200 kW with 18 ft head. The net head at the site is approximately 18 ft, so the maximum generating capacity of the existing facility is 525 kW. The average annual discharge of the Minnesota River at Granite Falls is 704 cfs. The Granite Falls Dam is classified as run-of-river since it has no seasonal peaking capability. There is a small amount of storage, however, which may be used for a limited amount of daily peaking.

During a field verification of the existing facility capacity the overall turbine/generator efficiencies were estimated to be 74 per cent for Unit No. 1 and 78 per cent for Unit No. 2. A 78 per cent efficiency is excellent for a 50-year old open flume Francis turbine, since 81 per cent is the maximum overall efficiency which may be expected from these units. The somewhat lower efficiency for Unit No. 1 may reflect a suspected misalignment problem. A problem of heavy bearing wear exists in Unit No. 1, and the current frequency of bearing replacement is once every two years. The most likely cause of this problem is a misaligned drive shaft.

All of the energy produced at the Granite Falls Hydropower facility is used to offset energy purchases from Northern States Power Company (NSP). The value of the hydroelectric energy, therefore, is equal to the rate at which Granite Falls purchases energy from NSP. Operation of the hydropower facility will also reduce the monthly demand charge paid by Granite Falls to NSP. An estimate of the average reduction in demand charge which may be expected in each month of the year is given in Section VI. Operating the hydropower facility in a peaking mode will transfer some energy production from off-peak to peak hours and reduce the demand charge. The contribution of peaking is described in Section VII.

The current plant operation is simply to run 1 or 2 turbine units, depending upon river discharge. If one turbine is running at full flow and water is still spilling over the flashboards, a second turbine is operated during on-peak hours. Finally, if the flow in the river exceeds the design discharge of both turbines, two turbines are run 24 hours a day.

The operational plan this study proposes is very similar to the current plant operation, with some refinements. First, the hydroplant should be operated based upon river discharge. Each afternoon a call should be made to the USGS stage-discharge gaging station in Montevideo to determine river discharge. The plant operational procedure for the next day will be based upon the river discharge. Second, any peaking operation should occur from 8 a.m. to 9 p.m., if possible, in order to reduce the demand charge paid by Granite Falls to NSP. A suggested plant operation based upon river discharge is given in Table 2.

Five project development alternatives were considered. Alternative A, "Do Nothing," is used as a base for calculating the incremental benefits of adding capacity to the existing facility. Using the proposed operational plan, the following estimates of energy production and benefits were made for the existing facility (1981 base year):

Average Annual Energy Production	2.57 GWH
Average Annual Energy Benefits	$55,500
Average Annual Demand Charge Credit	$14,500
Average Total Annual Benefits	$70,000

The annual energy production was computed with the tailwater curve which assumes the flashboards are in place at Minnesota Falls. If the flash boards at Minnesota Falls are not in place, the average annual energy production would be 2.70 GWH. Since the flashboards are in place most of the year, the first figure is more representative. The computed figures of 2.57 and 2.70 compare well with the 20-year average annual production of 2.54 GWH at the Granite Falls Dam from 1937 to 1957.

Aside from investigating and solving the cause of bearing wear, there are no real incremental costs associated with Alternative A.

Of the four development alternatives considered which increased the existing hydropower capacity, Alternative E had the best economic feasibility. Alternative E is the addition of one new unit to the existing facility, with the new unit replacing the existing flood gates. The effect of this alternative upon spillway discharge is discussed in Section VIII.C. The new unit considered for this alternative has a 72 in. fixed-blade propeller turbine and fixed guide vanes. For each value of net head, the unit has only one operating flow. The unit is therefore either "on" or "off." The design discharge is 515 cfs at 22 ft net head with a rated generator output of 812 kW. The unit is a comparatively attractive development alternative because of its simplicity and significantly lower cost. The project cost, incremental energy production, incremental benefits, and feasibility indicators for Alternative E are as follows (1981 base year):

Average Annual Incremental Energy Production	1.50 GWH
Average Annual Energy Benefit	$ 32,400
Average Annual Demand Charge Credit	$ 6,000
Total Average Annual Incremental Benefit	$ 38,400
Total Initial Cost	$807,000
Annual Incremental Benefits/Total Initial Cost	$ .048
Incremental Operation, Maintenance, and Replacement Costs	$ 10,200
Payback Period	32 years
50-year Benefit Cost Ratio	1.33
50-year Net Present Value	$472,000

III. RECOMMENDATIONS

1. The <u>feasibility</u> of hydropower capacity addition at the Granite Falls Dam is <u>positive with reservations</u>.

2. This study can make no recommendations on whether to develop or not develop additional hydropower capacity at the Granite Falls Dam. Based upon the economic assumptions given in Section IX, Development Alternative E has a payback period of 32 years with a 50-year benefit cost ratio of 1.33. The life of the facility may be expected to be 50 to 100 years. The project feasibility, however, is extremely sensitive to the assumptions made in the economic analysis, as shown in Section IX.C. The City of Granite Falls must assess the potential risks and benefits of site development before making an implementation decision.

3. A reconnaissance study should be undertaken to determine the needs and method and estimate the cost of upgrading the safety of the Granite Falls Dam.

4. A hydroplant operational plan is recommended which is very similar to the current plant operation, with some refinements to improve the daily peaking potential of the facility. The proposed operational plan is given in Section VII.

5. The cause of the heavy bearing wear in the existing Unit No. 1 should be investigated and eliminated during the design and construction of any project development.

6. Close coordination with applicable state and federal agencies in the final design phase is strongly recommended to insure that all potential environmental impacts are evaluated and mitigated.

IV. SITE CHARACTERISTICS AND EXISTING FACILITIES

A. Site Description and Location

The Granite Falls Dam is located on the Minnesota River in the City of Granite Falls (about 130 miles west of Minneapolis and St. Paul) in Section 34, T.116N., R.39W. The Minnesota Falls Dam is located 3.1 miles down river in Section 1, T.115N, R.39W [1].* The site location is given in Fig. 1.

The dam consists of a concrete gravity section with flashboards extending from the right (west) bank across the river to a point near the left bank where a short gate section and the two-unit hydroelectric power station is located. The concrete gravity section has a nominal height of 21 ft and a length of 300 ft. The gate section is 28 ft long and is equipped with four manually operated vertical lift gates 5'4" wide. The gates are currently operated with extreme difficulty [1]. Flashboards 30 in. in height are removed prior to each spring flood and replaced as soon as river discharge falls below the discharge capacity of the turbines. A site plan, dam cross section, and a front view of the spillway, and powerhouse are given in Figs. 2, 3, and 4. Photographs of the site are given in Figs. 5 and 6.

The powerhouse is integral with the dam and consists of the following two hydroturbine units.

Unit No. 1. Installed 1940.**

Leffel Sampson unit with Francis runner.

- 345 kW design output at 21 ft head and 228 cfs design discharge.
- 300 rpm
- 0.8 power factor
- 375 kva generator rating

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*Numbers in brackets indicate references in Section XII.

**Jeff Judd, Personal Communication, James Leffel & Company.

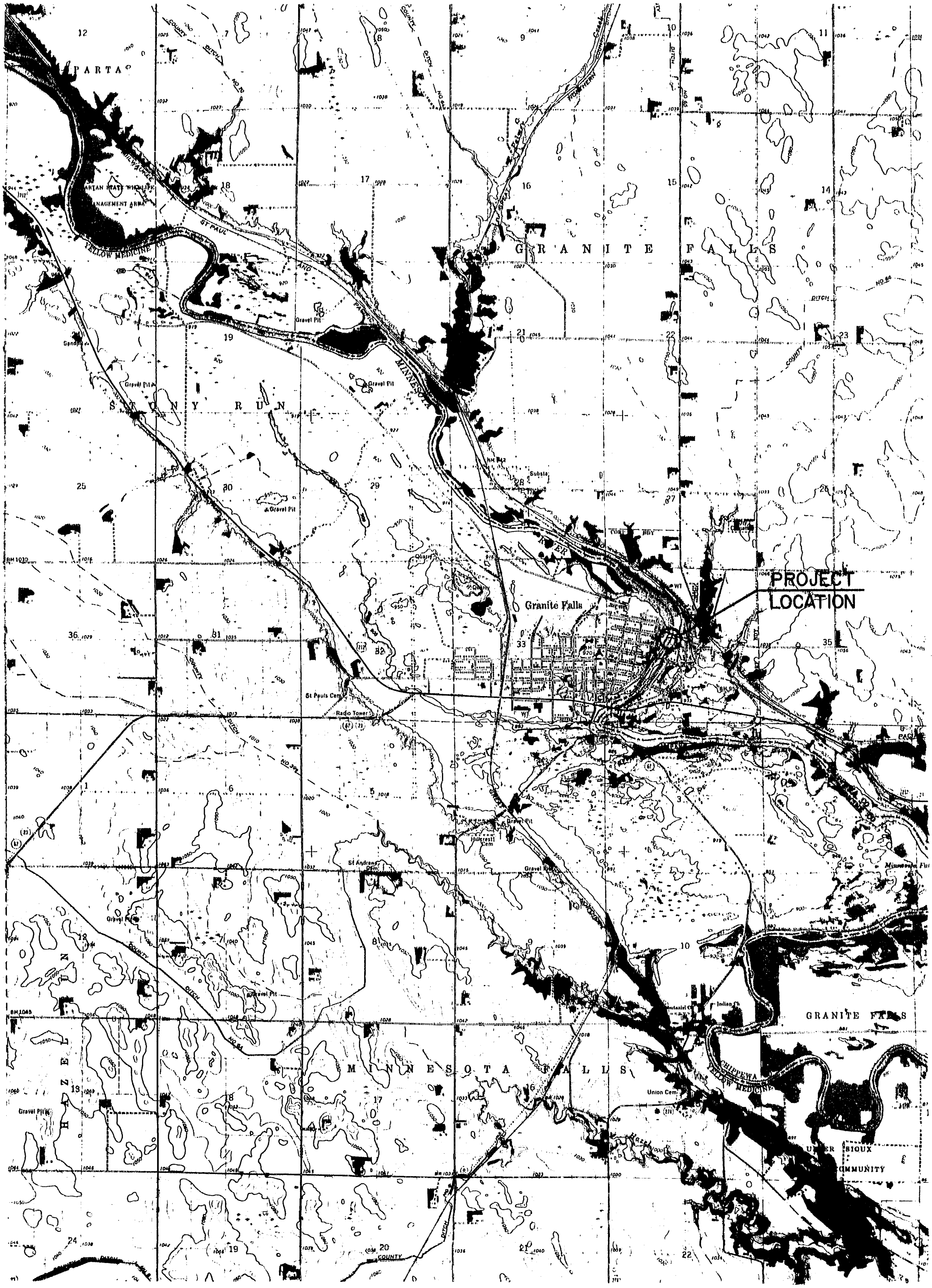


Fig. 1. Location of Granite Falls Dam on U.S.G.S. Quadrangle Map.

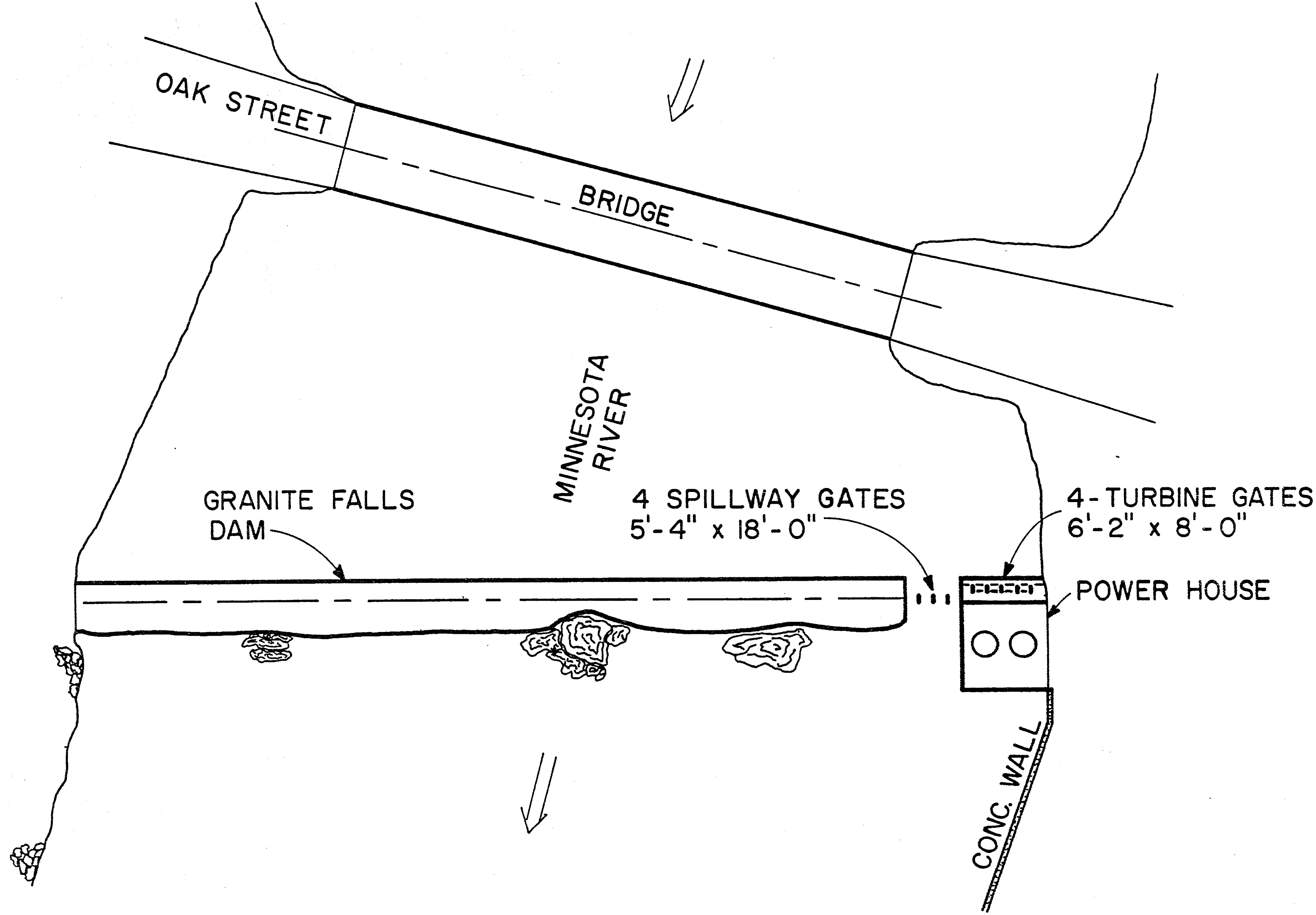


Fig. 2. Plan View of Granite Falls Dam [1].

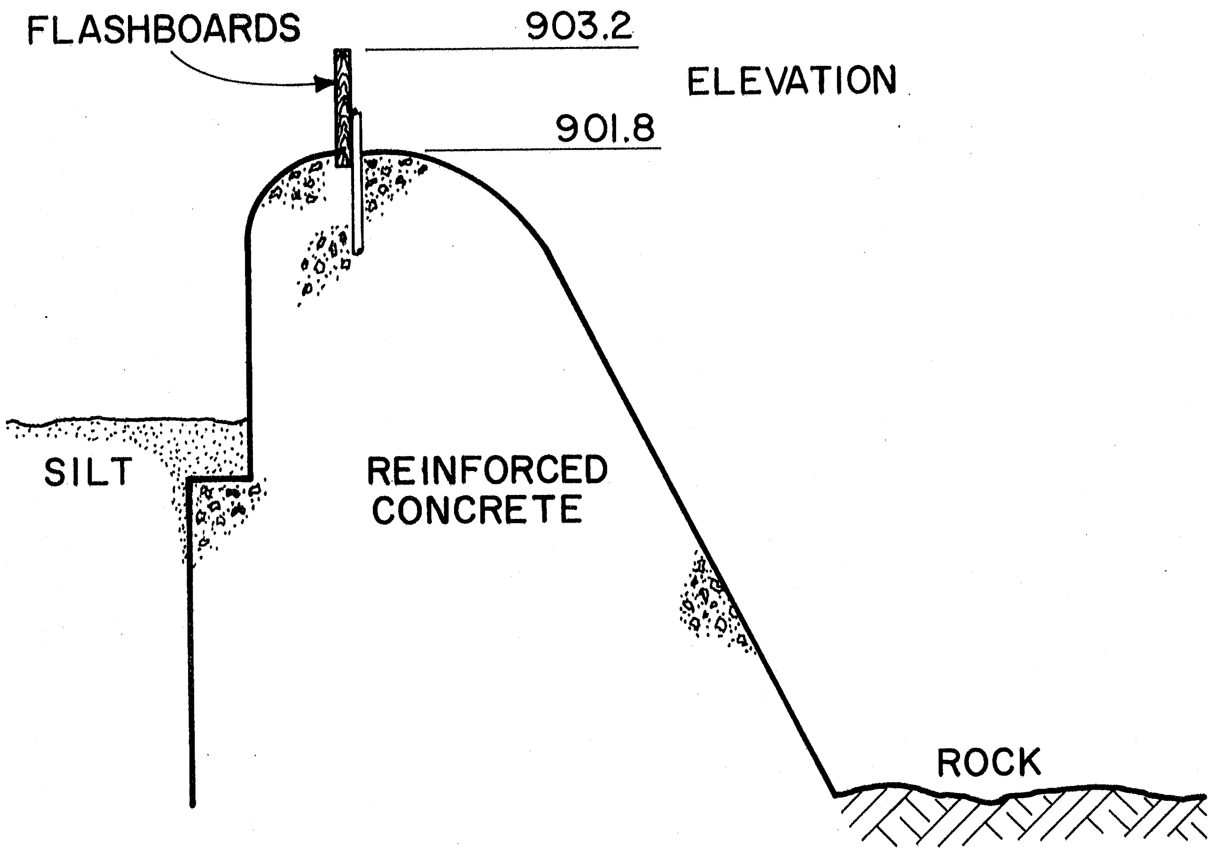
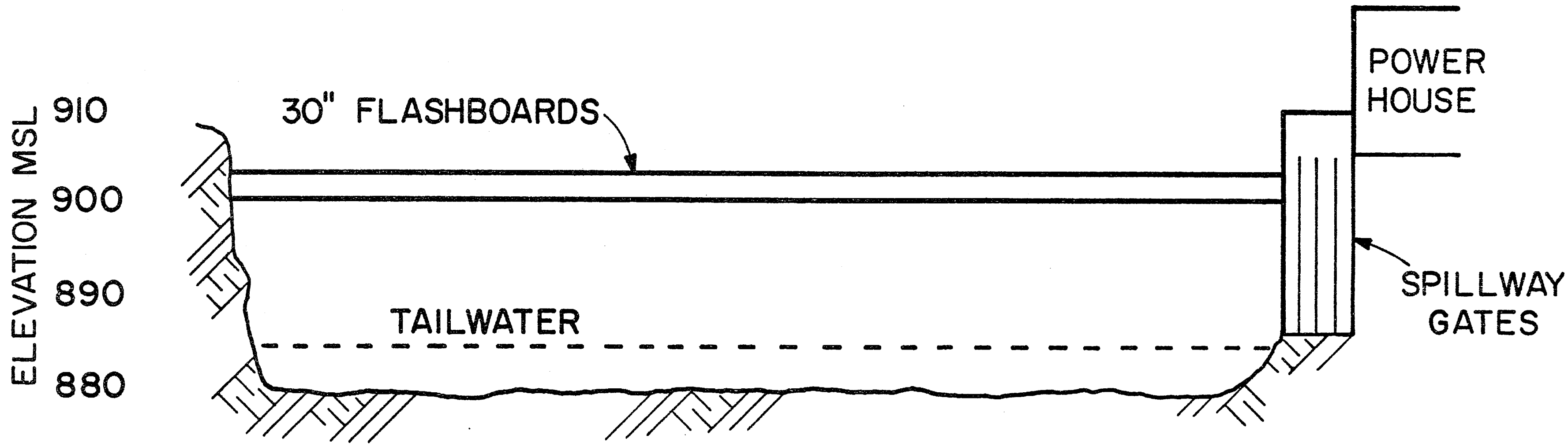


Fig. 3. Approximate Cross-Section of Granite Falls Dam [1].



GRANITE FALLS DAM
LOOKING UPSTREAM

Fig. 4. Front View of Granite Falls Dam [1].

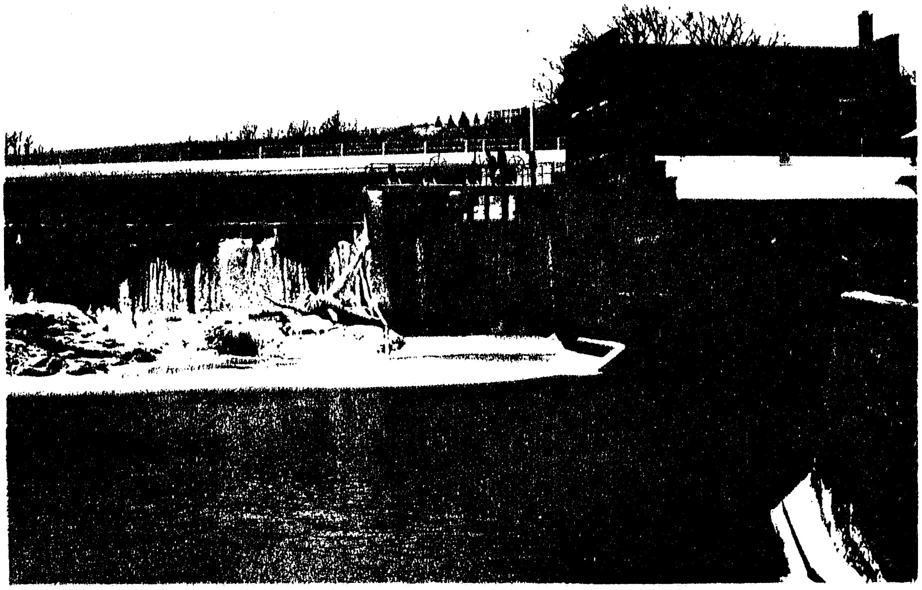


Fig. 5. View From Downstream Showing the Powerhouse, Flood Gates and the Spillway.

Fig. 6. View From the Right Abutment Showing the Powerhouse and the Spillway with Flashboards.

Unit No. 2. Installed 1932.*

Leffel Sampson unit with Francis runner.

- 260 kW design output at 18 ft head and 197 cfs design discharge
- 277 rpm
- 0.8 power factor
- 312 kva generator rating

A plan and cross section of Unit No. 1 are given in Fig. 7. Figure 8 gives a photograph of Unit No. 1 taken when the open flume was dewatered for bearing replacement. A photograph of the generators, governors, and control panel within the powerhouse is given in Fig. 9.

The powerhouse gate section is 30 ft long with four 6'2" wide vertical lift gates. The gates are manually operated and currently are difficult to raise. The powerhouse trash racks are in good condition. The intake gate, lift mechanisms, and trash racks are given in Fig. 10.

A visual inspection of the tailwater region indicated no problems with the powerhouse substructure. The draft tubes are in good condition, and the tie rods shown in Fig. 7 are still in place.

The City of Granite Falls is a municipal utility with its own distribution system. A 3-unit step-up transformer station is located immediately adjacent to the powerhouse. The three transformers are rated at 5000, 5600, and 7000 kva, respectively.

B. Historical Background

In the summer of 1868, T. Prentiss Hill and Robert K. Miller and their families filed a preemption claim to land adjacent to the falls on the Minnesota River with the intent of starting a flour mill. The following year they transferred their rights to Henry Hill and Orange S. Miller. Henry Hill was actually the founder of the City of Granite Falls. In 1872 the mill was put into operation [2].

The original dam was constructed on the present site in 1871 for the milling operations and was abandoned in 1905. In 1911 the City of Granite Falls constructed a new dam with hydroelectric facilities to

*Jeff Judd, Personal Communication, James Leffel and Company.

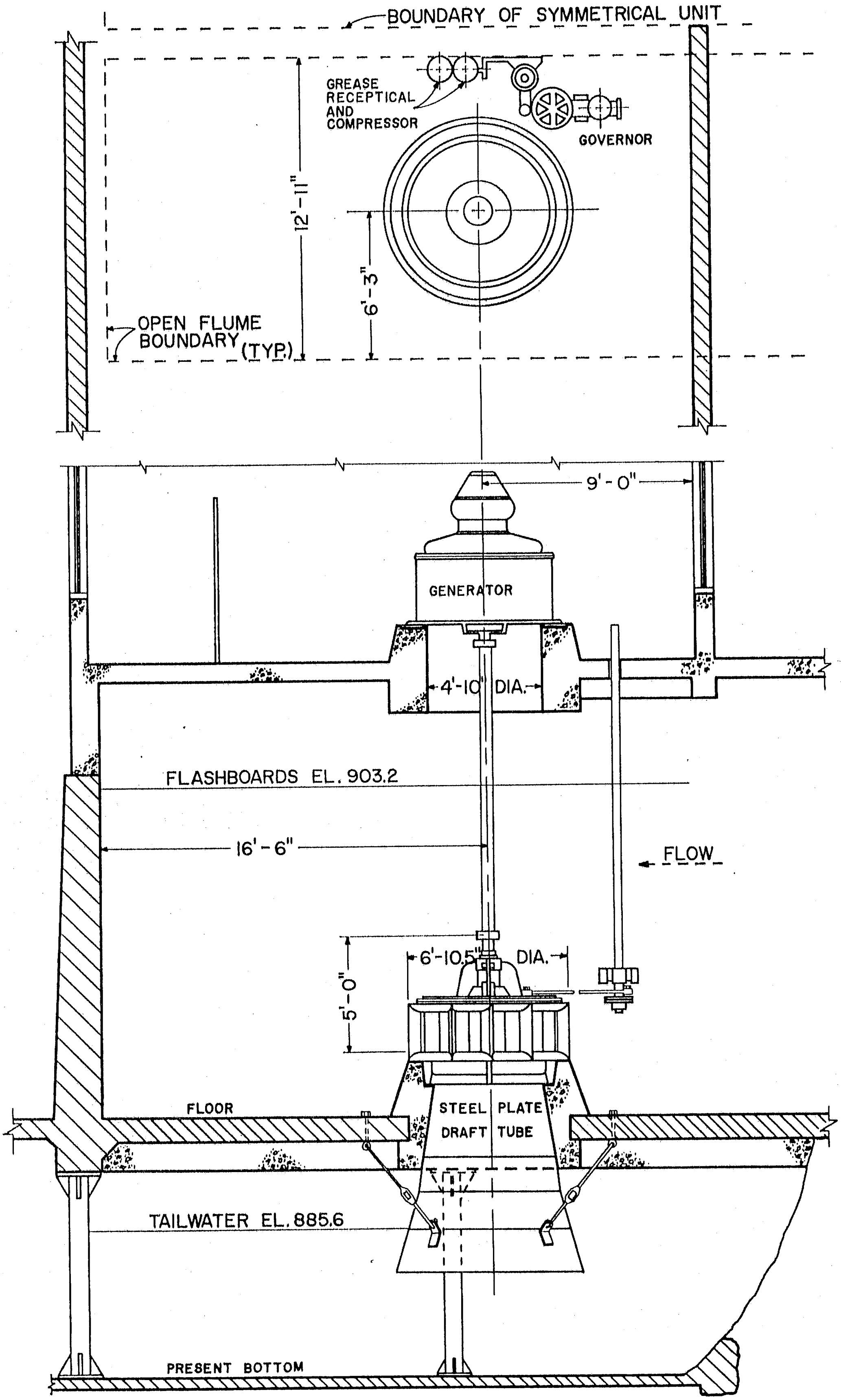


Fig. 7. No. 1 Existing Francis Turbine, Installed 1940.

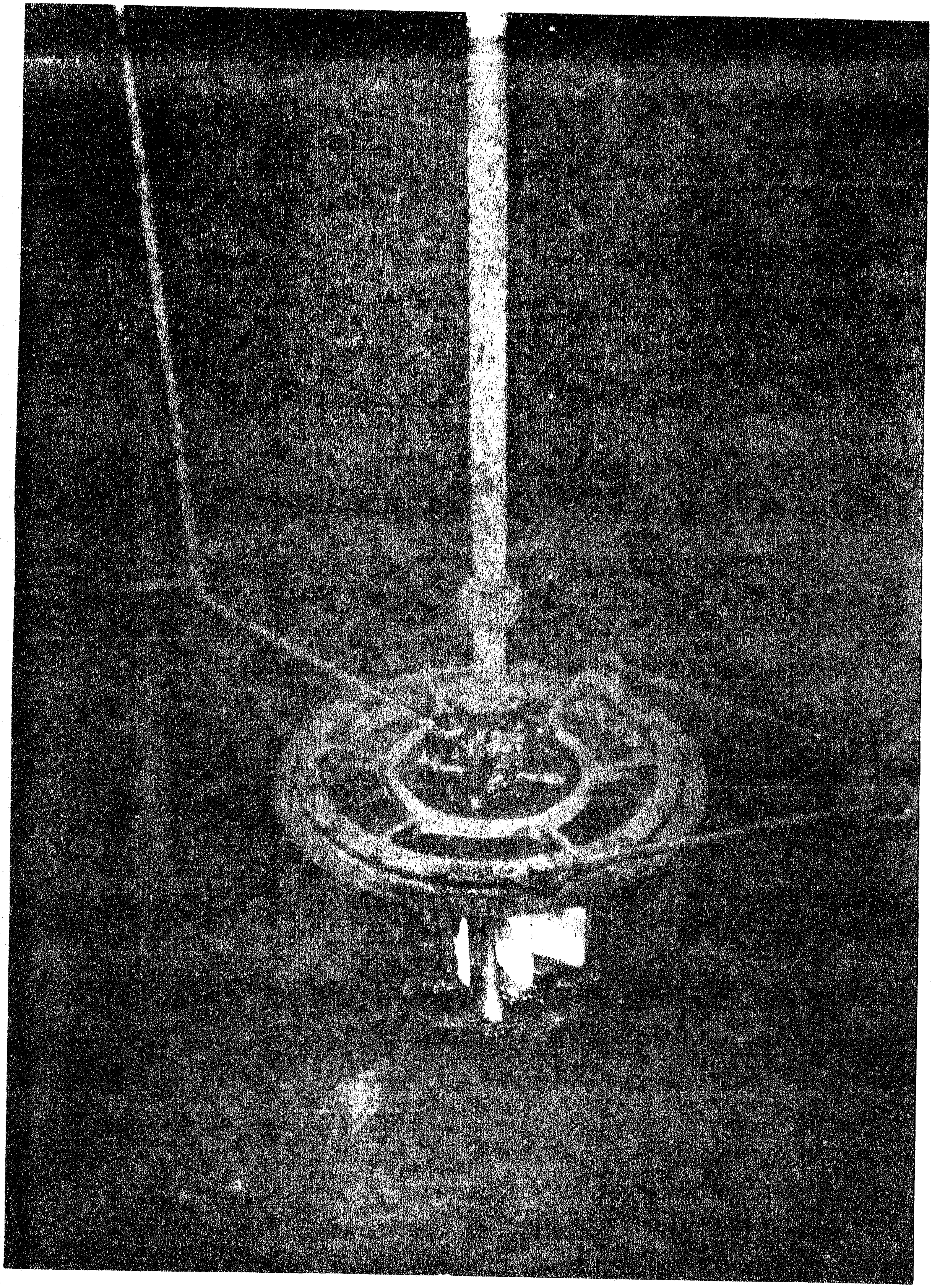


Fig. 8. 275 kW Leffel Open Flume Francis Turbine Wicket Gates, Installed 1940.

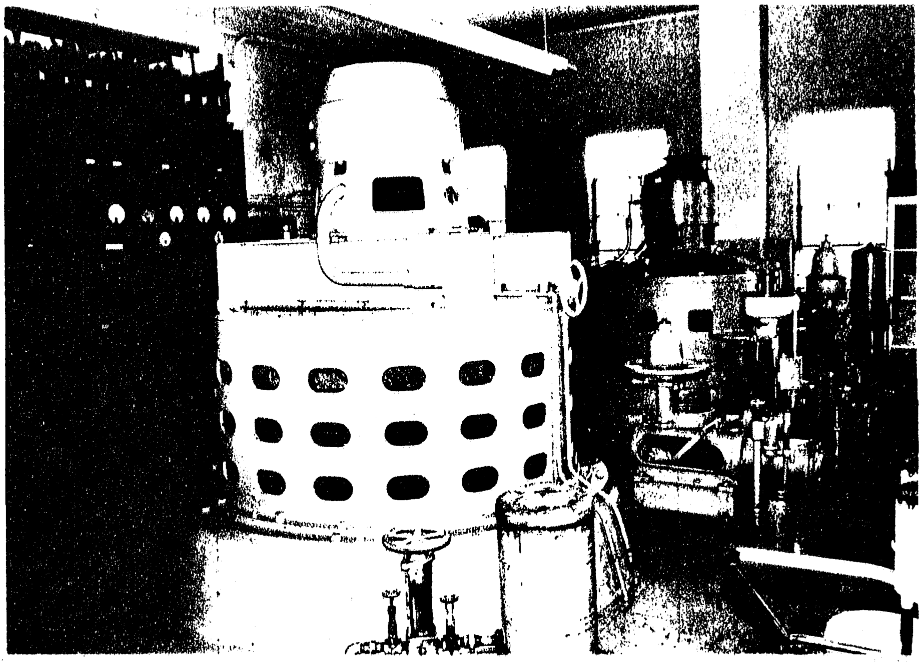


Fig. 9. Generators, Governors, and Control Panel Within the Powerhouse.

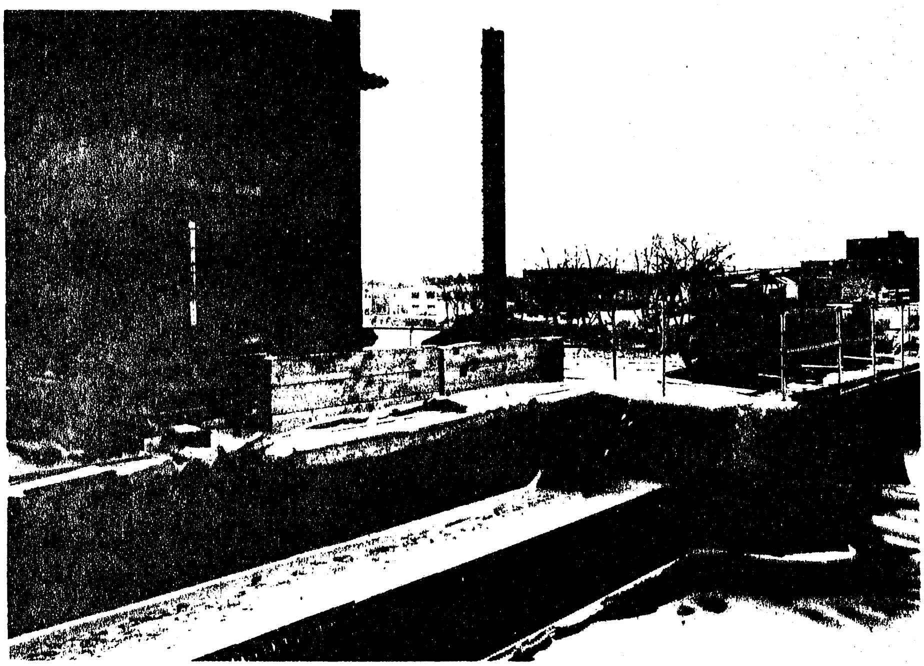


Fig. 10. Intake Gate with Left Mechanisms, Trash Racks, and Flood Gates.

supply power to supplement the three stream generators in operation since June 1892.

Through the decades the city has updated the generating facilities periodically by installing new diesel motors or new turbines. In 1929 the city reached a point where increased consumption of electric power demanded the city have greater standby generating facilities for periods when the river level was too low to generate much electricity.

In the fall of 1929 Northern States Power Company began construction of a 20,000 kW coal-fired, steam generating plant, at that time the third largest in Minnesota. This power was further augmented in 1953 by the addition of a 40,000 kW unit. In 1932 one of the original turbine/generator units was replaced with the existing Unit No. 2. In 1940, Unit No. 1 was also replaced with the other existing Leffel Sampson unit.

Under agreement with NSP, Granite Falls has continued generating as much power as it can with the hydroelectric power facility.

C. Dam Integrity

The size classification for the Granite Falls Dam is small, with a high hazard classification [1]. The following observations were made in the National Dam Safety Program report completed in October, 1978 [1].

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

2. In the absence of design or "as built" information, it is not possible to evaluate the stability of the structure against sliding or overturning. There appears to be anchorage rods exposed at the downstream base of the dam but the details are unknown and, in fact, it is not known whether they extend into the foundation. A stability computation made as a part of this investigation assuming no anchorage and with no hydrostatic

uplift pressure beneath the dam indicates that sliding is a more probable problem at the design flood than overturning. However, there is presently no visual evidence of structural or foundation inadequacy and the overall appearance of the structure is good.

3. The quality of the concrete in the dam is quite variable. The right (west) half is very bad in surface appearance. The surface scaling has exposed much reinforcing steel, both at the crest and along the downstream face of the spillway. There are large voids and exposed coarse aggregate at the horizontal joints between lifts; however, this would appear to be largely a surface condition, since there is no indication of seepage through these joints. The concrete quality of greatest concern is in the relatively thin walls of the gate structure. In an attempt to improve appearance, the concrete has been covered with a layer of shotcrete. In some sections this layer has a hollow sound when tapped, indicating poor bond and possibly voids. There is also a question on the quality of the concrete beneath the shotcrete.

   a. Gate Section

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

   b. Concrete Gravity Spillway Section

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

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

5. The entire structure is constructed of concrete founded on exposed bedrock; consequently,concern for erosion and scour protection is limited to the abutments where the ends of the structure terminate in overburden material. The left abutment is protected by approach

walls and downstream training walls of the powerhouse. The right abutment is protected by grouted riprap placed the full height of the earth slope. During major floods, such as that of the record flood in 1969, it is necessary to construct a sandbag closure between the right abutment and the approach fill of the Oak Street bridge approximately 200 ft upstream to prevent flanking of the dam by flood flows.

6. The power pool at Granite Falls is maintained 2.5 ft above the crest of the overflow spillway by installation of flashboards across the 300 ft length of the crest. These boards consist of three 2 in. x 10 in. boards 16 ft long attached to double extra strength pipe placed at 5'4" centers in holes in the concrete crest. Because of the rather unusual height of these flashboards (two ft is more common) the flow over the boards must be limited to less than 18 in. or the pipe supports will fail by bending. Also, ice must not be permitted to develop against the boards in the winter. Consequently considerable labor is expended in removing ice on a daily basis. As a matter of incidental interest, it is understood that a bubbler system for ice removal has been tried unsuccessfully. While the use of flashboards can sometimes increase flood heights if the boards remain totally or partially intact during flood flows, the experience at Granite Falls has been that the great pressure against the 30 in. height of boards invariably cause the pipes to bend down with surcharges at and above 18 inches.

In addition, the Safety Inspection Report made the following recommendations:

1. That the structural integrity of the gate structure be checked in more detail, possibly by coring or drilling into the mass to evaluate the characteristics of the concrete. With regard to the safety hazard involved in the sudden failure of the 28 ft long gate section, a flood wave of perhaps 7 ft in height could be produced if failure occurred with the gates closed. Because of the limited width of the gate section, the initial wave height would rapidly diminish as it proceeded downstream. Failure of the entire section with the gates open would produce a smaller wave.

2. That the flood carrying capacity of the natural by-pass channel west of town be maintained and increased, if possible.

3. That the gates and gate mechanism be replaced.

4. That the feasibility of increasing the flood capacity of the system should be investigated. The possibilities to be investigated would be increasing the capacity of the natural by-pass channel, increasing the height of the levee system, or increasing the capacity of the spillway.

5. Direct communication between Lac Qui Parle Dam and the city dam would be preferable, particularly since gate manipulation at the latter dam is not a push button type operation. Normally the hydraulic travel time between the two dams is approximately 36 hours.

6. That a documented operating plan be prepared and made available at the operating site.

7. That a systematic program of inspection and maintenance be established and implemented with immediate emphasis on improvement of the gate structure and related mechanical equipment.

The City of Granite Falls currently plans to consider a reconnaissance study for dam rehabilitation (Phase 2 integrity evaluation) upon completion of this feasibility study.

V. HYDRAULICS AND HYDROLOGY

A. Flow Duration and Reservoir Storage

The Granite Falls Dam MN 00510 is on the Minnesota River. The drainage area of the site is 6,370 mi^2. The discharges at the site were calculated using the following technique.

- Granite Falls Dam site has a drainage area of 6,370 mi^2.
- USGS Gage #05311000 (Mn. River at Montevideo, about 15 miles upstream of dam site) has a drainage area of 6,180 mi^2.
- USGS Gage #05325000 (Mn. River at Mankato, about 105 miles downstream) has a drainage area of 14,900 mi^2.
- Since the drainage area of Granite Falls Dam #510 is close to that of USGS Gage #05311000, the flow duration curve is calculated as

$$Q_i \text{(at the dam site)} = \frac{6370}{6180} Q_i \text{(USGS Gage \#05311000)}$$

$$= 1.03\ Q_i \text{(USGS Gage \#05311000)}$$

where Q_i = flow which is exceeded i% of the time, i.e.

Q_{10} = flow which is exceeded 10% of the time.

Application of the above formula gives the following values:

Minimum flow - no flow for several days in 1933-1934, 1936.
Maximum flow on April 12, 1969 - 36,153 cfs.
Average annual discharge 68 years of record - 704 cfs.

A flow duration curve for the Granite Falls Dam is given in Fig. 11. Flow duration curves were also computed for each month over the period of record. The results are summarized and presented on Fig. 12. This figure indicates a noticeable annual fluctuation in flow over a range of exceedence levels.

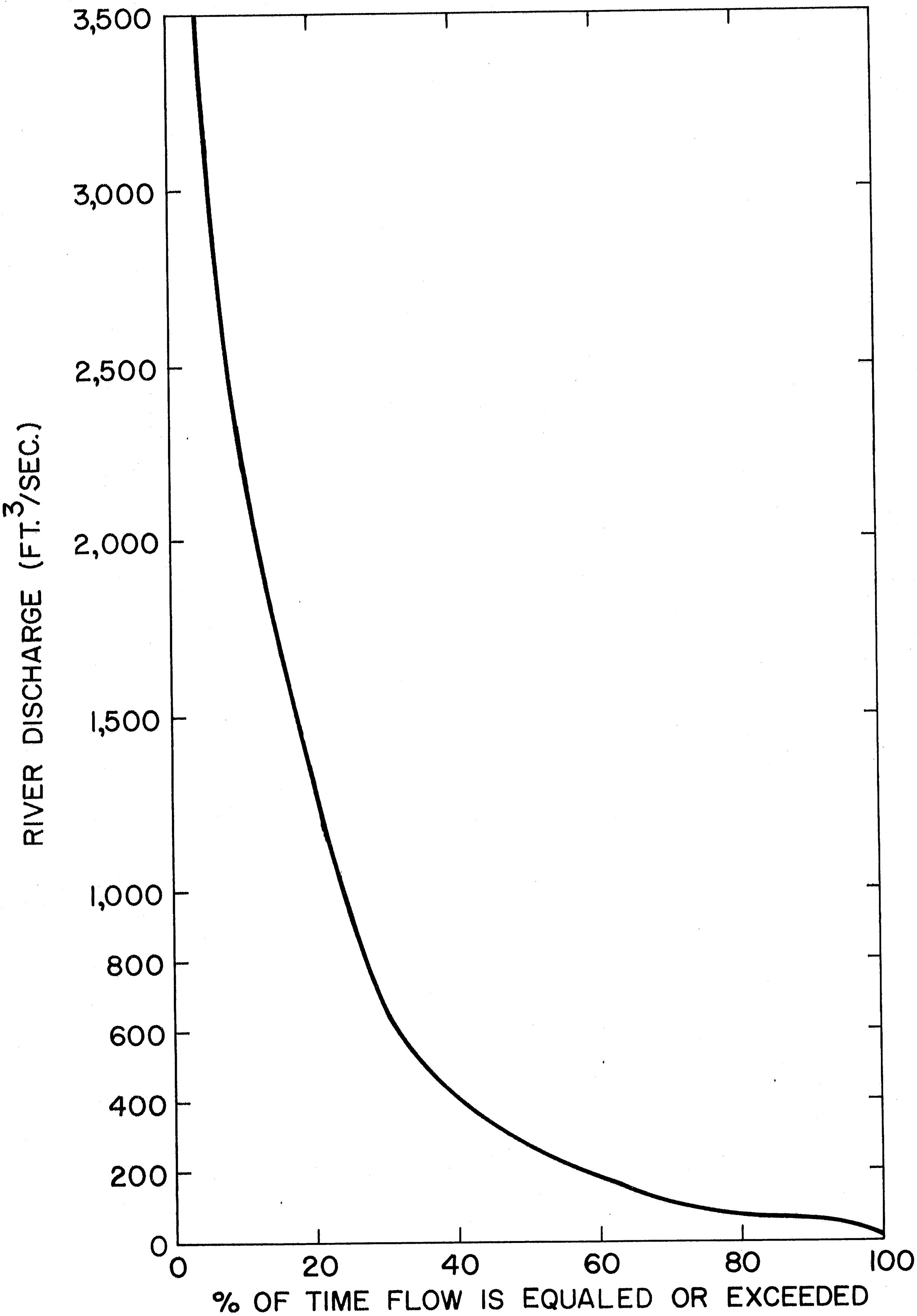


Fig. 11. Flow Duration Curve for the Granite Falls Dam.

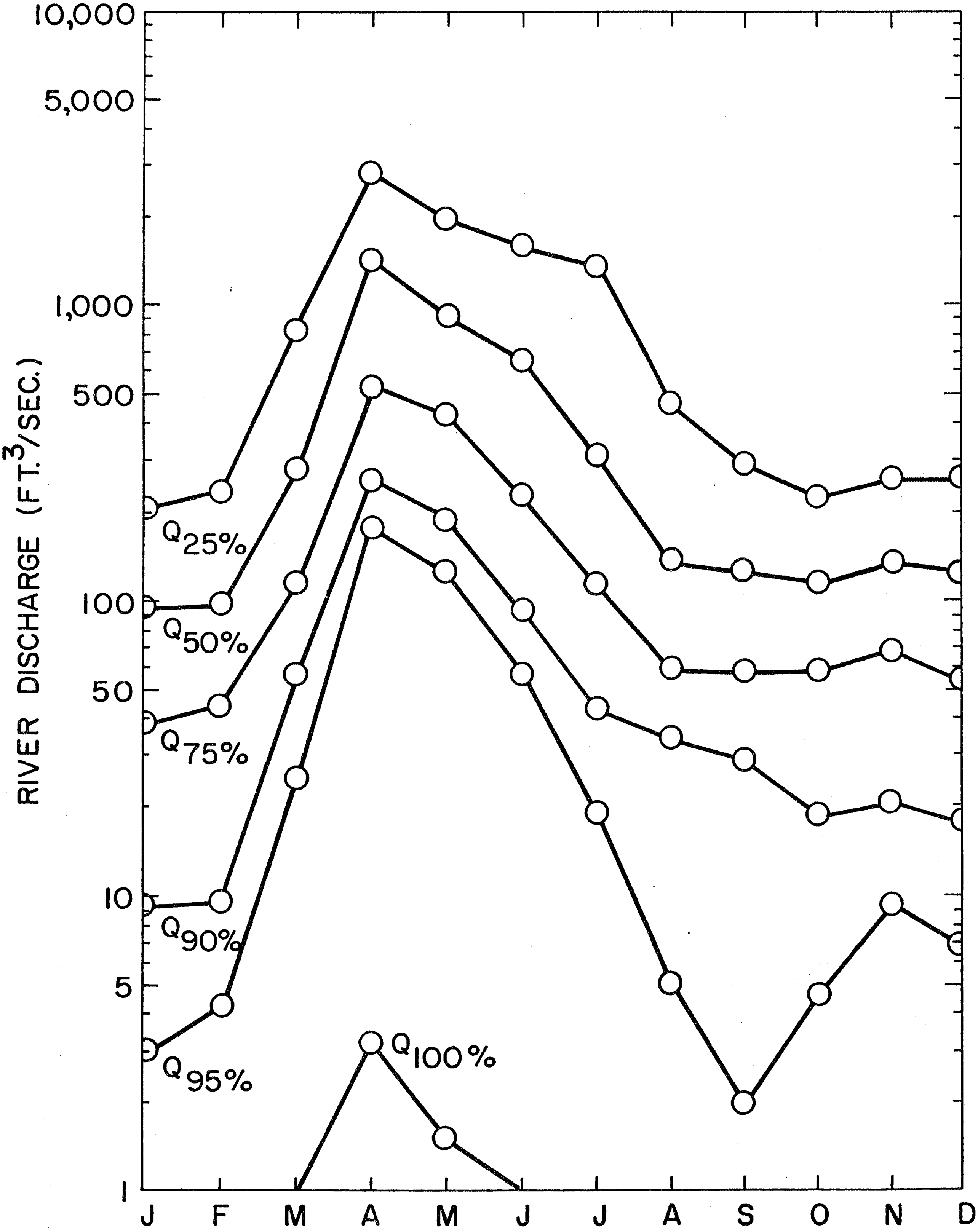


Fig. 12. Summary of Monthly Flow Duration Curves for the Granite Falls Dam. Q_{25}% = flow which is equaled or excluded 25% of the time.

The dryest year of record occurred in 1934 with an average annual discharge of 4.4 cfs. The wettest year was experienced in 1952. The flow duration curve for that year is given in Fig. 13.

The Granite Falls Dam is classified as run-of-river since it has no seasonal peaking capability. There is a small amount of storage, however, which may be used for a limited amount of daily peaking. The advantage to daily peaking during low flow periods will be discussed in Section VI. An operational scheme which includes a limited amount of daily peaking will be proposed in Section VII. In this section the amount of storage available for peaking will be determined with a simplified analysis.

The reservoir behind the Granite Falls Dam is approximately 3.5 miles in length with a mean depth of 6 ft. A surface wave, therefore, will transverse the reservoir in approximately 21.4 minutes. This means that the reservoir water surface may be assumed level during drawdown since the time-of-travel for a disturbance is large compared to the time scale of interest for peaking (12 to 15 hours).

Reservoir storage was determined by calculations on the cross-sectional areas given in Ref. [3]. The result of the analysis is the total storage versus headwater elevation curve given in Fig. 14. From this figure the total volume available versus drawdown from the top of the flashboards was computed. The results given in Fig. 15 will be used in Section VII to estimate the daily peaking capabilities of the Granite Falls Dam.

B. Headwater and Tailwater Elevations

A survey taken on April 29, 1981, indicated that the elevation of the spillway crest is 900.8 ft above mean sea level (msl), and that the top of the flashboards are at elevation 903.2 ft msl. These values are different from those previously reported [1] which were 901.3 and 904.1 ft msl, respectively.

The headwater elevation curve given in Fig. 16 was developed using the weir equation and the Rehbock formula for weir coefficient [4]. Headwater elevation is assumed to be at flashboard crest when river discharge equals turbine design discharge.

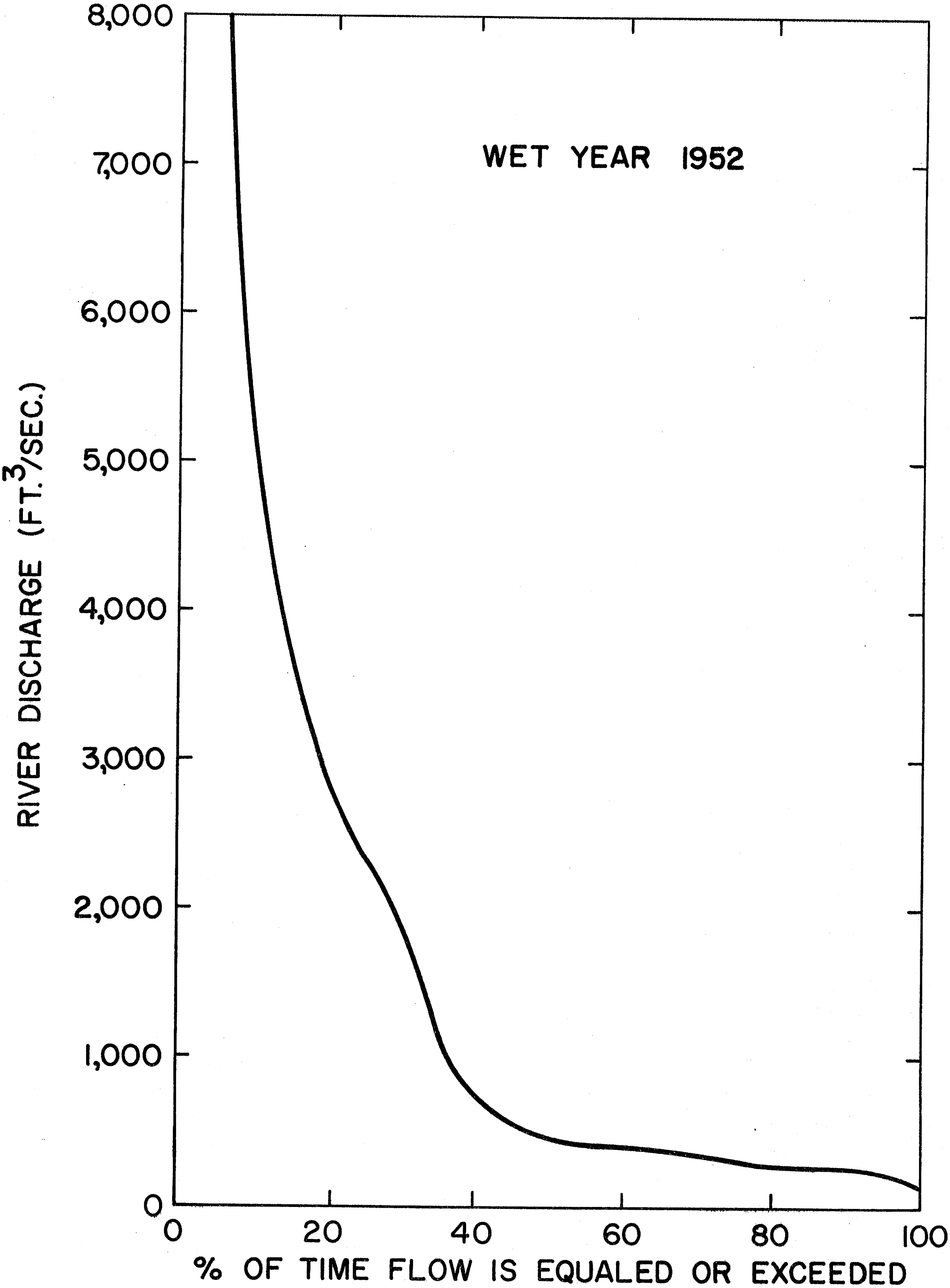


Fig. 13. Flow Duration Curve for Wettest Year of Record; 1952.

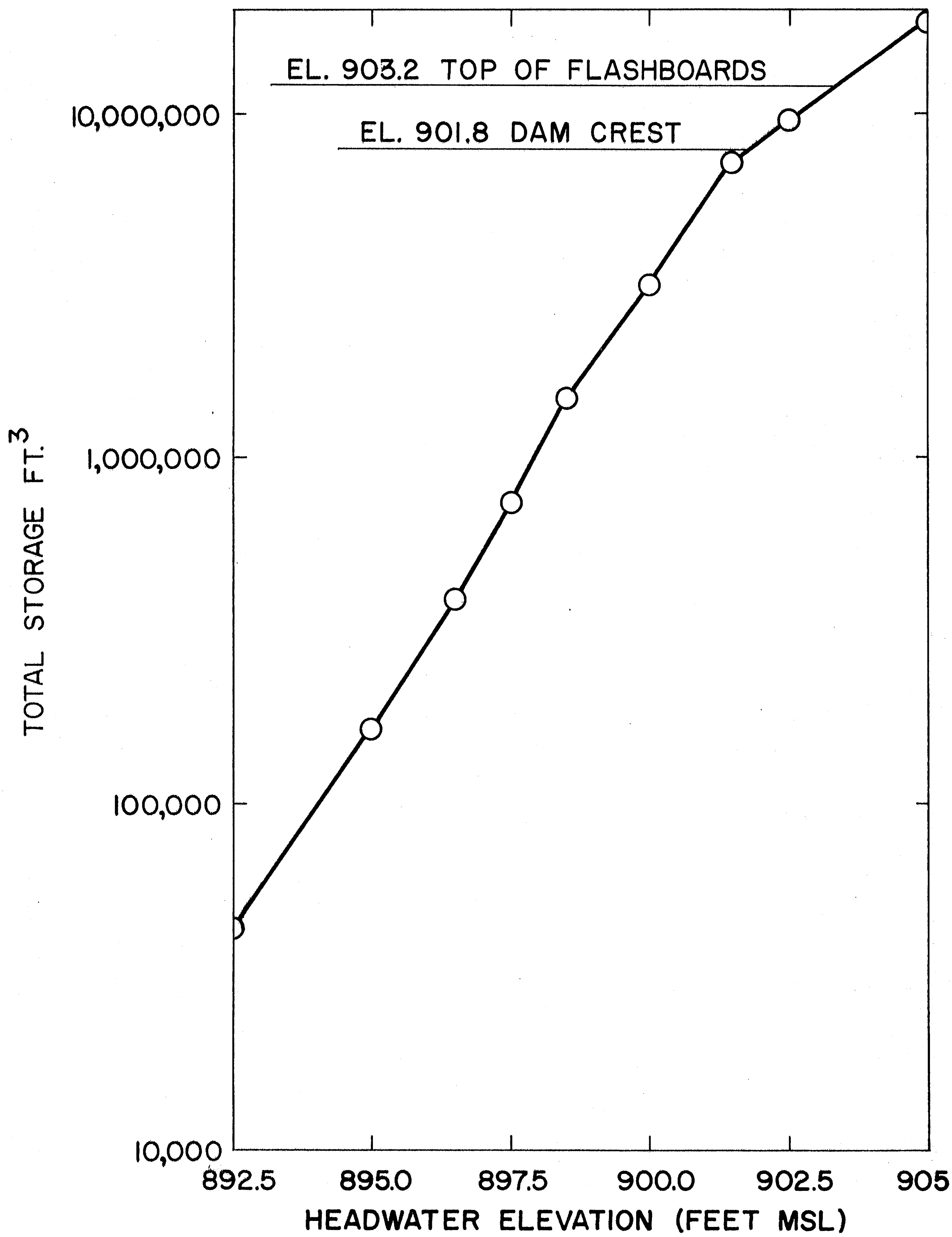


Fig. 14. Reservoir Storage Volume at the Granite Falls Dam versus Headwater Elevation.

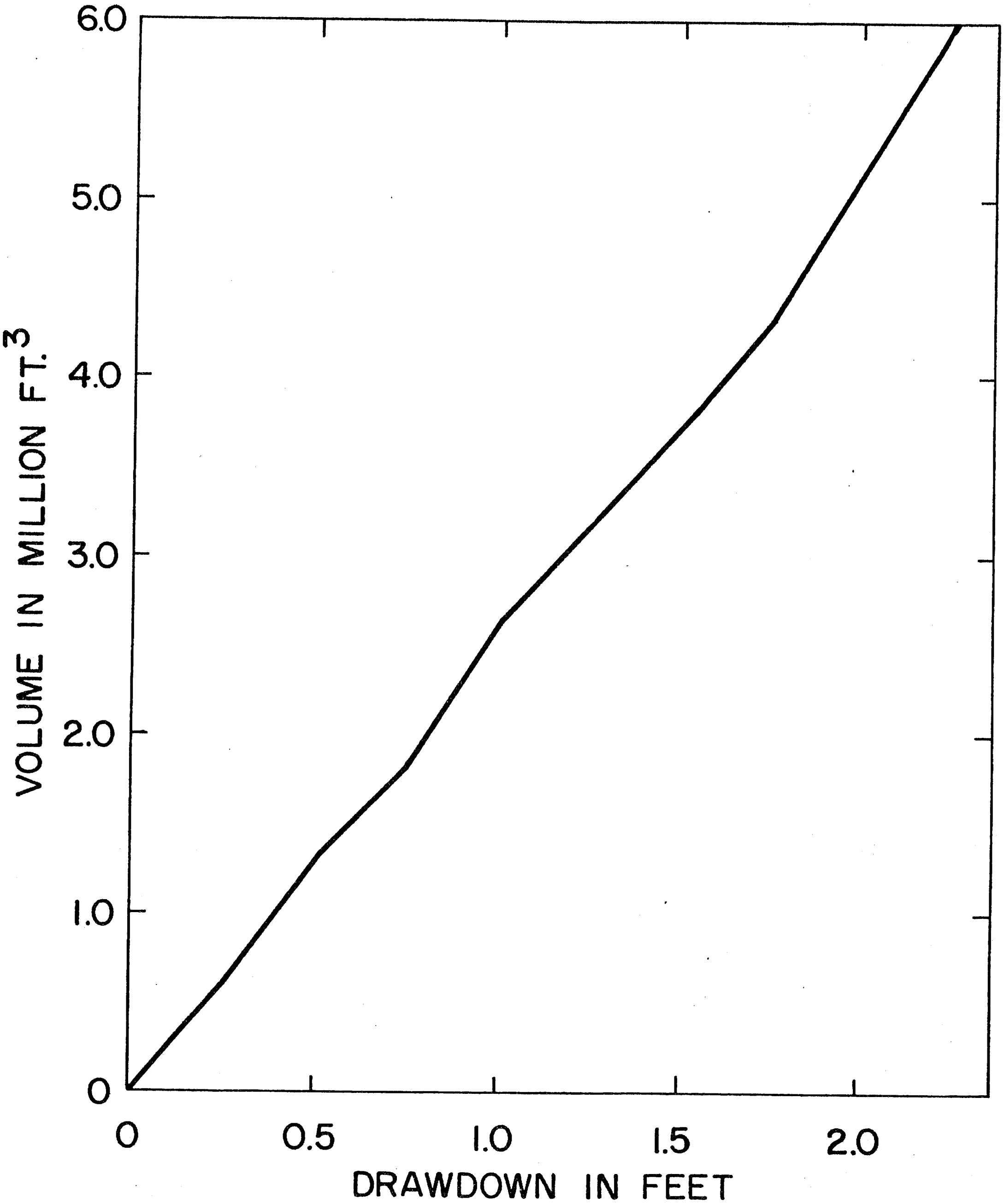


Fig. 15. Volume Available for a Given Drawdown from the Top of the Flashboards at the Granite Falls Dam.

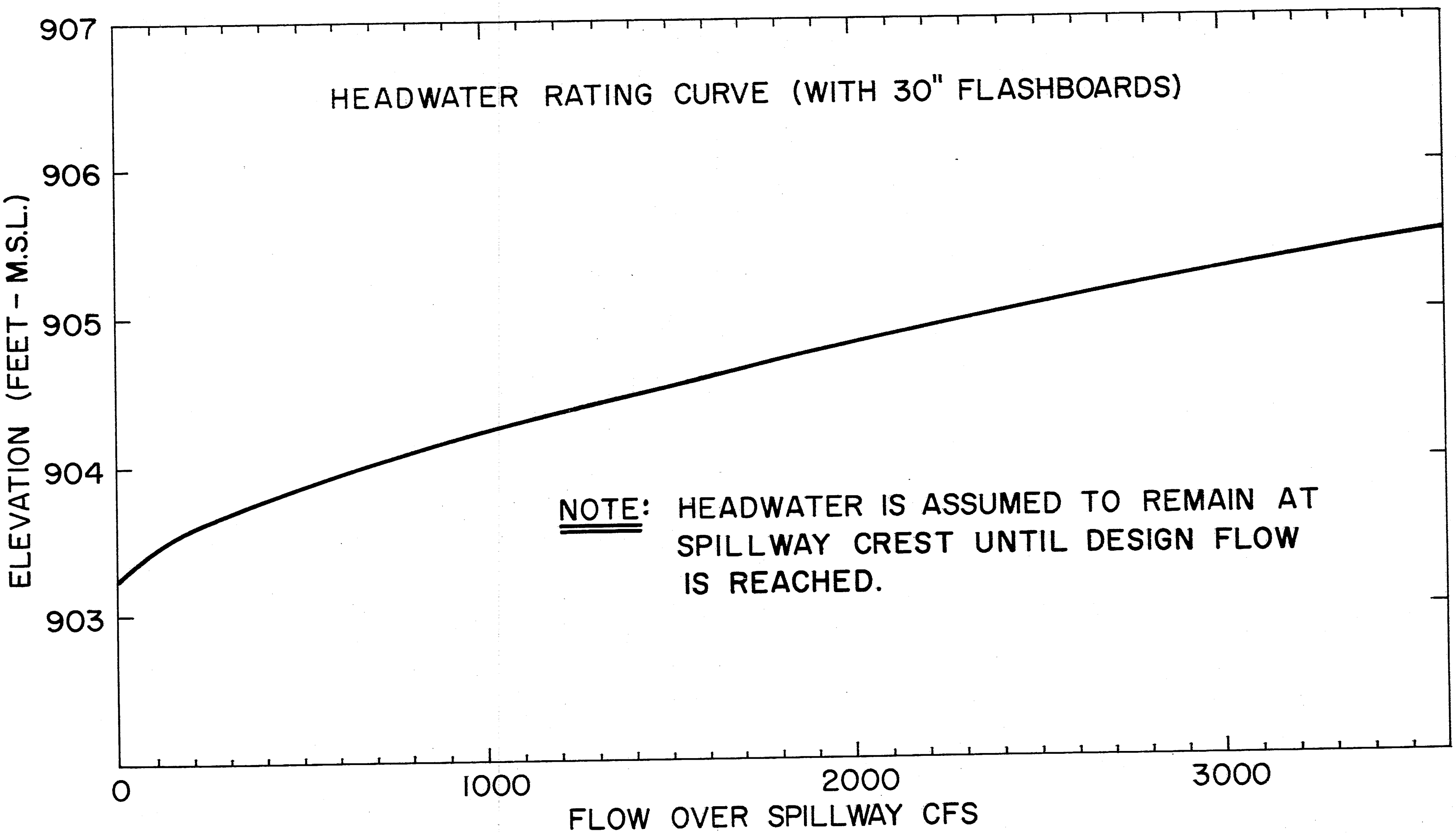


Fig. 16. Headwater Elevation versus Spillway Discharge for the Granite Falls Dam.

The tailwater curve given in Fig. 17 was determined by backwater curve computations from Minnesota Falls to Granite Falls with the HEC 2 computer program. Cross-sectional data was obtained from Barr Engineering. The two curves correspond to the use of 14 in. flashboards at Minnesota Falls by Northern States Power Company. The one data point is from the field survey taken on April 29, 1981, when the flashboards were up at Minnesota Falls. The excellent agreement with the computed tailwater elevations is an indication that the computed curves are accurate at low river discharges.

It should be noted that the headwater and tailwater curves included herein indicate that the gross head available at the Granite Falls Dam never reaches the 21 ft design head. A design head of 18 ft would be more appropriate.

C. Spillway Design Flood

The dam is located in a portion of the river valley where substantial flood flows by-pass the main channel through an overflow channel west of the city. Prior to 1969 the total river flow that could be discharged without significant flood damage was approximately 13,000 cfs. This non-damaging flow capacity has been increased by construction of a levee along the right bank from the Oak Street bridge (200 ft upstream from the dam) to a location 13,000 ft upstream from the dam. The levee was constructed to a height to contain the record flood of 43,400 cfs. Of this flow the spillway is capable of 36,800 cfs, with 31,800 cfs passing over the spillway crest and 5,000 cfs passing through the flood gate section. Hydrologic studies indicate that the record flood has about a 1 per cent chance of recurring in any given year and that much larger floods are possible in the future [1].

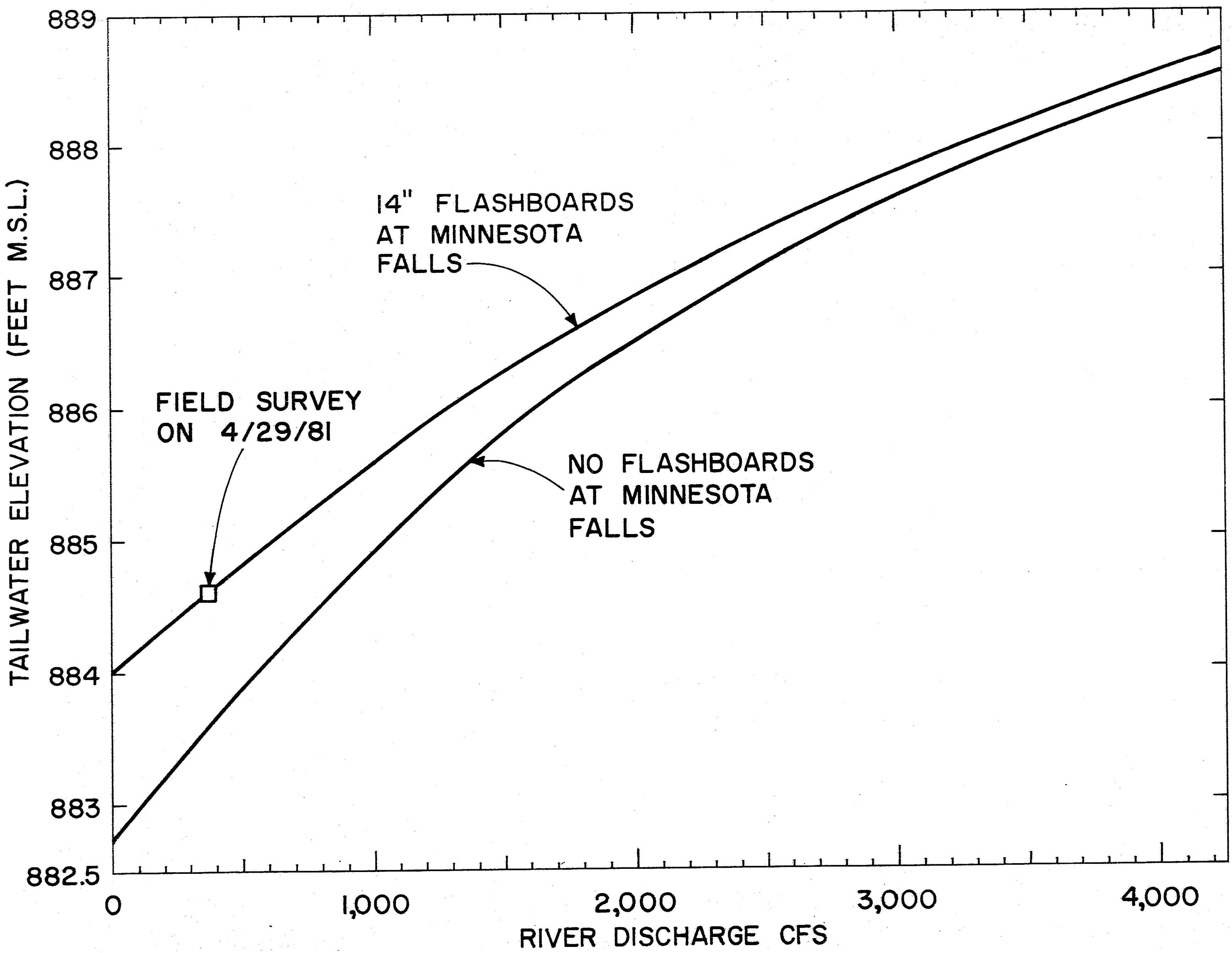


Fig. 17. Tailwater Elevation versus River Discharge for the Granite Falls Dam.

VI. CURRENT POWER PRODUCTION AND DEMAND

A. Current Demand

The City of Granite Falls is a municipal utility with its own distribution system. The peak demand in 1980 was 5777 kW at 5:30 p.m. on September 8. The minimum demand of 665 kW occurred at 3:30 a.m. on May 19. All power generated by a hydropower facility will therefore be used to offset power purchases from NSP by the Granite Falls Municipal Utility. The demand pattern is relatively constant throughout the year, with a small increase in demand in July and August, corresponding to an increase in the use of air conditioners.

The typical daily demand curve given in Fig. 18 indicates that the demand is relatively constant throughout the daytime period (8 a.m. through 8 p.m.)

B. Current Production

The capacity of the existing Granite Falls hydropower facility is 550 kW generator output. As noted in Section V, however, the design head of the facility should be 18 ft, rather than 21 ft. Therefore, the design capacity is never achieved. During a field verification of facility capacity performed on April 29, 1981, gross head was measured at 17.8 ft and both turbine units were operated at full capacity. The resulting generator output was 235 kW for Unit 1 and 230 kW for Unit 2. Design flow for each unit obtained from the James Leffel & Co. was then adjusted to represent the maximum possible flow through the two turbines. Finally, using the measured gross head, measured generator output, and design flow at 17.8 ft head, the turbine/generator unit efficiencies were calculated to be 74 per cent for Unit No. 1 and 78 per cent for Unit No. 2. A 78 per cent overall efficiency is excellent for a 50-year old open flume Francis turbine, since 81 per cent is the maximum efficiency which may be expected from these units. The somewhat lower efficiency for

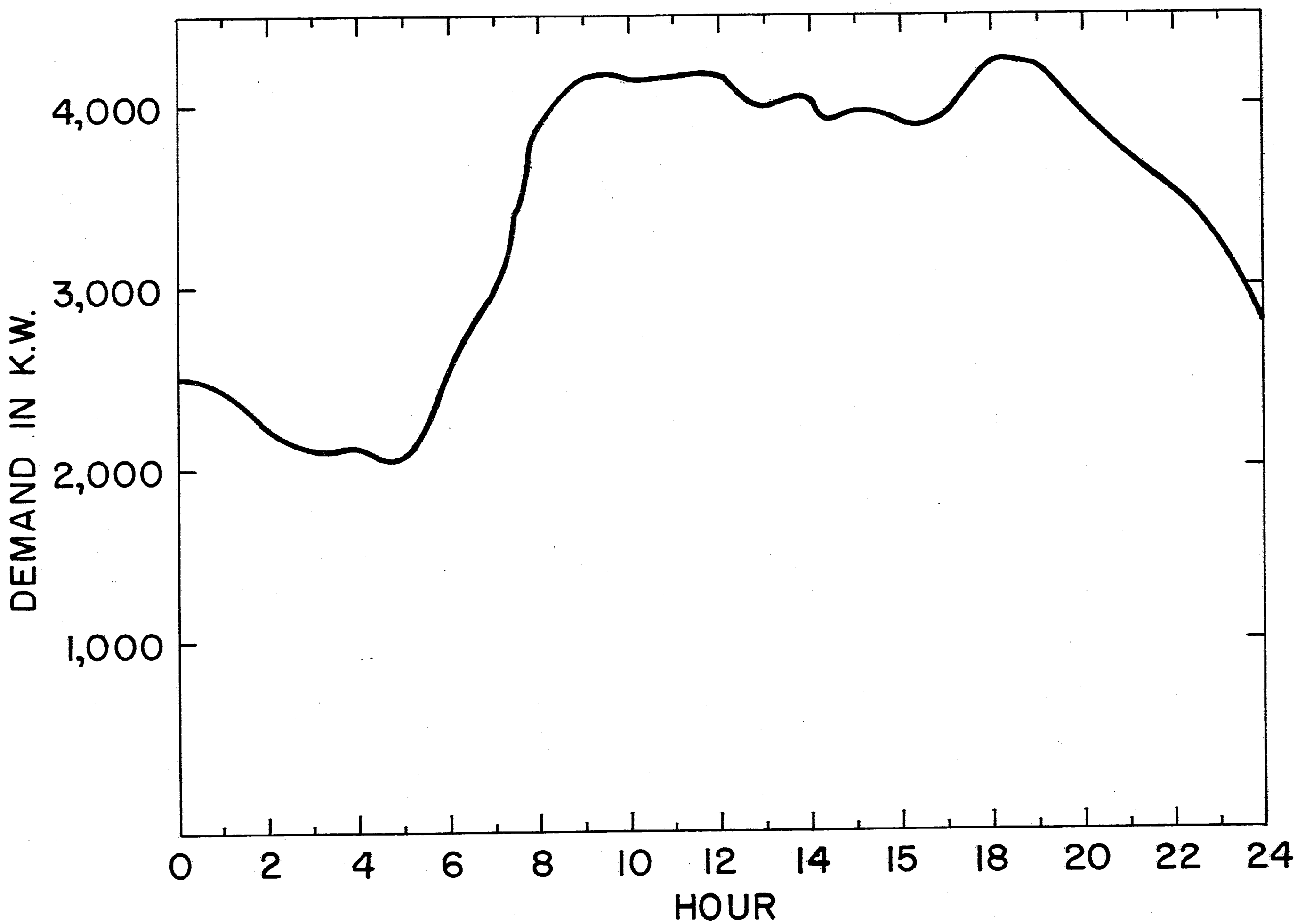


Fig. 18. Demand Curve for the Granite Falls Utility on a Typical Day (January 8, 1980).

Unit No. 1 may reflect a suspected misalignment problem for that unit which is described in Section VIII.A. The field verification indicates that, except for the suspected misalignment, the existing units are in excellent condition. The turbine runners do not appear to be exposed to an excessive amount of cavitation, either. During three site visits, there was never any audible indication of cavitation noise.

The average annual energy production through the twenty years from 1937 to 1957, when the existing units were relatively new, was 2.544 GWH. This trend continued through the early seventies until various interruptions resulted in a lower energy production. The annual energy production from 1970 through September, 1979, is given in Table 1. Bridge construction and drought created a four year drop-off in energy production from 1974 through 1977. In 1978, 1979, and 1980 there was excessive bearing wear in Unit No. 1, requiring periodic (semi-annual) bearing replacement. This problem is addressed in Section VIII.A. New bearings were installed in December, 1980. As of April, 1981, both units were operating at a relatively high efficiency.

TABLE 1. Annual Generation of Electricity by Granite Falls Hydroelectric Facility, 1970 through September, 1979

Year	Annual Energy Generated (GWH)	Notes
1970	2.49	
1971	2.71	
1972	2.87	
1973	2.29	
1974	1.35	Bridge Construction
1975	1.93	Bridge Construction
1976	.90	Drought
1977	.86	Drought
1978	1.56	
1979 (through Sept.)	1.65	

C. Value of Energy and Power

All of the energy produced at the Granite Falls hydropower facility is used to offset energy purchases from Northern States Power Company (NSP). The value of the hydroelectric energy, therefore, is equal to the rate at which Granite Falls purchases energy from NSP.

The current contract between Granite Falls and NSP has an energy charge of 1.447 cents/kWH plus a fuel adjustment which is tied into NSP's fuel costs. Granite Falls' average cost of energy with fuel adjustmetn in 1980 was 1.7 cents/kWH.

Granite Falls also pays a monthly demand charge to NSP which is based upon the greatest 15 minute average demand in each month. The present contract demand charge is $4.25 per kW.

NSP has recently filed for a rate increase subject to approval by the Federal Energy Regulatory Commission. The proposed rates are:

Energy Charge:

2.68 cents/kWH for peak hours

2.019 cents/kWH for off-peak hours

Demand Charge:

$4.60/kW/month

Peak hours are 8 a.m. to 8 p.m., Monday through Friday, excluding official holidays. The energy charge is set such that the fuel adjustment charge would be approximately zero in January, 1982.

All calculations in this study are based upon July, 1981, dollars. The July, 1981, energy value used in the economic analysis in Section IX is found as follows:

1. The energy charge proposed by NSP is assumed to be that applicable to energy plus fuel adjustment in January, 1982.
2. If there is no daily peaking at the hydroplant, the average charge for energy offset by hydropower would be 2.25 cents/kWH in January, 1982.
3. Assuming a 9 per cent annual energy escalation rate, the July, 1981, energy value is

$$\frac{2.25}{(1.09)^{\frac{1}{2}}} = 2.16 \text{ cents/kWH.}$$

An energy value of 2.16 cents/kWH (July 1981 base) will be used in the economic analysis in Section IX.

Operating the hydropower facility in a peaking mode will transfer some energy production from off-peak to peak hours and reduce the demand charge. The contribution of peaking will be described in Section VII.

Operation of the hydropower facility will also reduce the monthly demand charge paid by Granite Falls to NSP. An estimate of the average reduction in demand charge which may be expected in each month of the year was made by the following method:

1. For each month of the year and twenty years of record (1961-1980), the minimum flow of the month at the Granite Falls Dam was divided by the average flow of that month to give a minimum flow factor which indicates the variation of flow in that month.

2. For each month the mean minimum flow factor was determined over the twenty year period.

3. The mean flow over the period of record for each month was multiplied times the mean minimum flow factor for that month to give the dependable flow which may be used to compute a reduction in demand charge.

The above method should give a slightly conservative estimate of the reduction in demand charge which may be expected from a hydropower facility. This reduction in demand charge will herein be called capacity credit.

VII. CURRENT AND PROPOSED OPERATIONAL SCHEMES

The Granite Falls hydropower facility is currently operated through the combined effort of several city personnel. There is at least one person on duty at the adjacent water treatment plant 24 hours a day. A secondary responsibility of city personnel is the operation and maintenance of the hydropower plant. Wicket gate control, gage readings, and power peaking are all manual operations.

Any change in the position of the vertical lift gates at the powerhouse or the flood gates requires a crew of several men due to the deteriorated condition of the gate hoists. Gate changes, however, are infrequent. The powerhouse gates are (or should be) closed only for machinery maintenance and repair. The flood gates are opened during periods of high river discharge and also to flush out sediment which has deposited near the powerhouse intakes. During periods of extreme low flow or during repairs to the dam, the pool must be maintained not lower than 1 ft below the concrete spillway crest to permit continued withdrawal of water from the reservoir for municipal water supply [2].

The current plant operation is simply to run 1 or 2 turbine units, depending upon river discharge. If one turbine is running at full flow and water is still spilling over the flashboards, a second turbine is operated during on-peak hours. Finally, if the flow in the river exceeds the design discharge of both turbines, two turbines are run 24 hours a day.

The operatioal plan this study proposes is very similar to the current plant operation, with some refinements. First, the hydroplant should be operated based upon river discharge. Each afternoon a call should be made to the USGS stage-discharge gaging station in Montevideo to determine river discharge. The plant operational procedure for the next day will be based upon that river discharge. Second, any peaking operation should occur from 8 a.m. to 9 p.m., if possible, in order to reduce the demand charge paid by Granite Falls to NSP (once the river discharge has been determined). A suggested plant operating procedure is given in Table 2.

The operating procedure given in Table 2 assumes a maximum reservoir drawdown of 1.2 ft below the top of the flashboards. The procedure has been formulated based upon the reservoir storage and tailwater elevations computed in Section V. If the operation procedure is implemented, small adjustments in the figures will be required if spillage over the flashboards occurs or the desired drawdown during peaking is not achieved. If two units are running simultaneously, they should be run at approximately the same output to obtain maximum overall plant efficiency. (This is the case because the two turbine units are similar in size.)

TABLE 2. Suggested Operating Procedure for the Existing Granite Falls Hydropower Facility

River Discharge in cfs (Q)	Off-Peak (9 p.m. → 8 a.m.) Power Production in kW (P_A)	On-Peak (8 a.m. → 9 p.m.) Power Production in kW (P_B)
0 to 60	No Operation	One unit at full discharge for $\frac{24Q}{200}$ hours
60 to 110	No Operation	$P_B = 2.18\ Q$
110 to 400	$P_A = 1.18\ Q$ to prevent spillage	$P_B = 1.18\ Q + 70$
Above 400	Full open	Full open

VIII. PROJECT DEVELOPMENT ALTERNATIVES

In this section the costs and expected annual incremental energy production of four development alternatives for the Granite Falls hydropower facility are considered. These alternatives were assessed by using the "Do Nothing" alternative as a base. The increase in benefits supplied by each alternative has been defined as incremental. Project development alternatives were formulated in the following manner:

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

- The expected annual energy production was computed for each of the five development alternatives using flow duration, headwater, tailwater information, and turbine performance curves.

- The income generated by displacing energy to be bought from NSP and reducing the monthly demand charge was computed by the method described in Section VI.C.

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

- When electrical equipment costs were not included in the turbine/generator cost estimates, these costs were estimated based upon information obtained from a well-known generator/switchgear/controls manufacturer. Electrical equipment costs include switchgear, transformer, control switchboard, wire and cable system, and conduit, grounding, and lighting.

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

- Miscellaneous power plant equipment costs were estimated according to guidelines in Ref. [5]. Equipment for ventilation, fire protection, communication, and turbine/generator bearing cooling water are included in this category. The cost estimates include 15 per cent for freight and installation. The July 1978 cost base was escalated to July 1981 according to the Consumer Price Index.

- A 15 per cent contingency was applied to freight, miscellaneous equipment, and installation costs excluding turbines, generators, and electrical equipment. A manufacturer's contingency had already been applied to the excluded items.

- A multiplier of 20 per cent was applied to the final project cost for engineering, construction management, and other costs [5]. These costs include expenditures for license and permit application, preliminary and final design, construction management, and administration.

- Annual O.M.&R costs were computed using the technique described in Ref. [5]. For development Alternatives C, D, and E, the technique was modified to engird an incremental analysis, i.e. annual incremental O.M.&R costs were computed by figuring the costs for the entire proposed power plant minus the figured costs for the existing installation.

A. Alternative A: Do Nothing

Calling Alternative A "Do Nothing" might be misleading, for certain assumptions have been applied. The turbine/generators are assumed to be in good operating condition. In addition, the operational scheme prescribed in Section VII is assumed. The validity of this assumption was strengthened by the field verification test for overall powerplant efficiency described in Section VI.

A problem of heavy bearing wear exists in Unit No. 1. The current frequency of bearing replacement is approximately once every two years. The suspected cause of the problem is a misaligned turbine drive shaft. It is strongly recommended that this problem be fully investigated and eliminated during design and construction of any project development alternative. The lower overall efficiency of Unit No. 1, noted in Section VI, could be caused by this misalignment problem.

Aside from investigating and solving the cause of bearing wear, there are no real costs associated with Alternative A. This alternative is included to provide a base for estimating the incremental benefits of the other development alternatives, i.e. the actual benefits of each alternative are those beyond what is already provided by Alternative A. All income and energy production values given in Alternatives B through E will be the incremental amount above that of Alternative A.

The proposed operational plan for Alternative A is very similar to that currently in use, as described in Section VII. Using this operational plan the estimated annual energy production and benefits are (1981 base year):

Average Annual Energy Production (GWH)	2.57
Average Annual Energy Benefits ($)	$55,500
Average Annual Demand Charge Credit ($)	$14,500
Average Total Annual Benefits ($)	$70,000

The annual energy production was computed with the tailwater curve which assumes the flashboards are in place at Minnesota Falls. If the flashboards at Minnesota Falls are not in place, the average annual energy production would be 2.70 GWH. Since the flashboards are in place most of the year, the first figure is more representative. The computed figures of 2.57 and 2.70 compare well with the 20-year average annual production of 2.54 GWH at the Granite Falls Dam.

B. Alternative B: Replacement with Two 1650 mm Vertical Units*

Alternative B is to replace the existing turbine units with two vertical open flume tubular units. Each tubular unit has a 1650 mm adjustable propeller runner and fixed guide vanes. The design discharge of each unit is 500 cfs at 20 ft head with a minimum discharge of 150 cfs and a rated generator output of 700 kW. A plan and section view of a preliminary layout are given in Figs. 19 and 20.

There is currently no information in the literature which may be used to specify submergence of the bell mouth intake with confidence. The possible need of vortex suppression devices should be considered upon project design, if this alternative is selected.

The cost estimates for Alternative B are as follows:

Alternative B Cost Estimates (1981 Base Year)

1.	Construction Costs (Including Gates)	$ 253,000
2.	Turbine/Generator Package* (Includes speed increasers, blade positioners, alarms, and instrumentation)	1,000,000
3.	Electrical Equipment**	150,000
4.	Freight	15,000
5.	Installation	150,000
6.	Miscellaneous Plant Equipment	71,000
7.	15% Contingency on Items 4 through 6	35,000
8.	Engineering, Construction Management, etc.	334,000
	Total Initial Cost	$2,008,000

As stated previously, the true benefits of Alternative B are the incremental benefits beyond the existing installation, Alternative A. These benefits are (1981 base year):

Average Annual Incremental Energy Production	1.61 GWH
Average Annual Incremental Energy Benefits	$ 35,800
Average Annual Incremental Demand Charge Credit	$ 6,800
Total Average Annual Incremental Benefit	$ 41,600

The incremental annual operation, maintenance, and replacement costs for this alternative are estimated at $17,700 (1981 Base Year) [5].

*Based on cost estimates obtained from Dominion Bridge-Sulzer, Inc.
**Based on cost estimates obtained from Brown-Baveri, Inc.

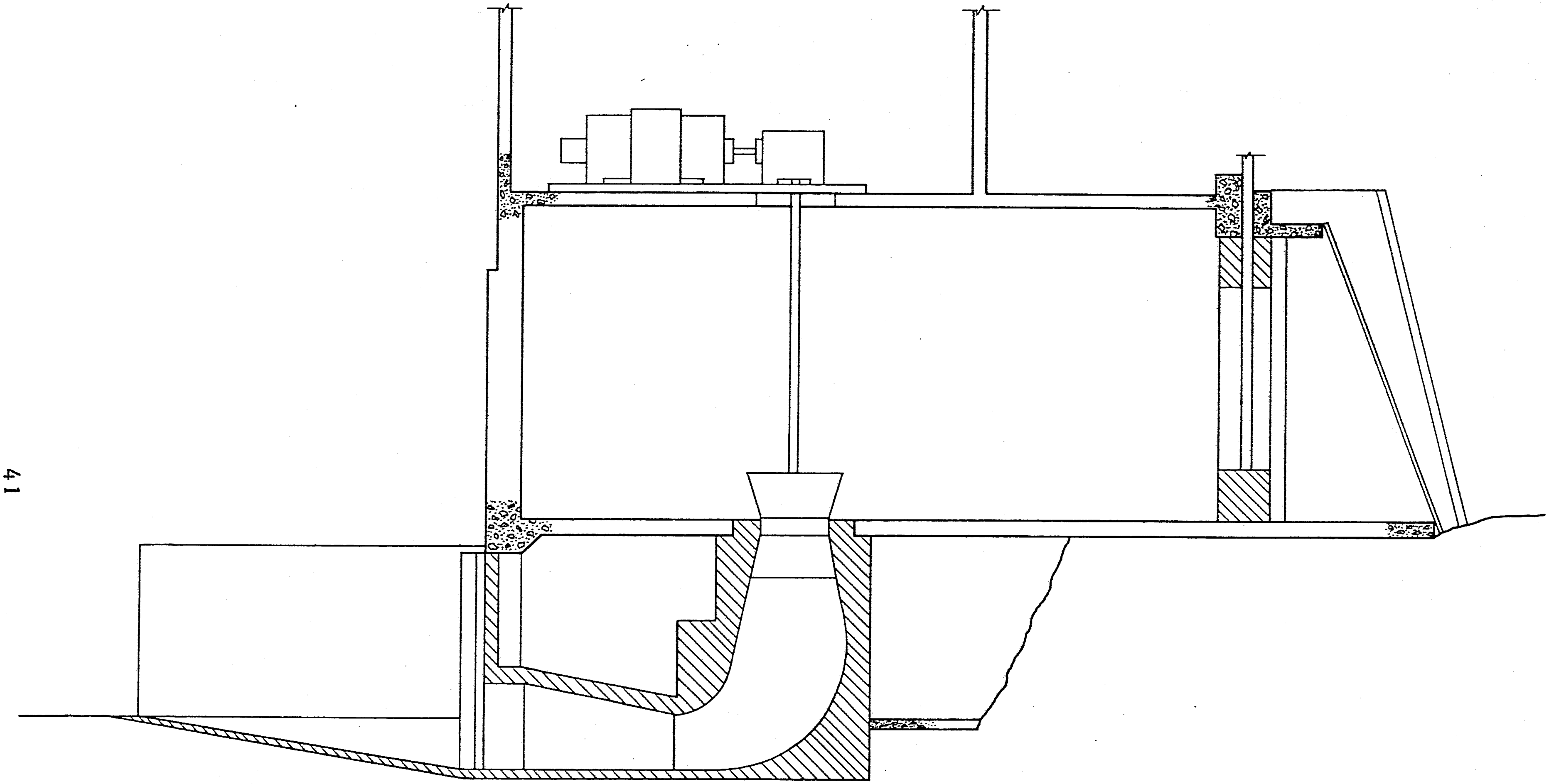


Fig. 19. Section View of Alternative B: Replacement With Two 1650 mm Vertical Units.

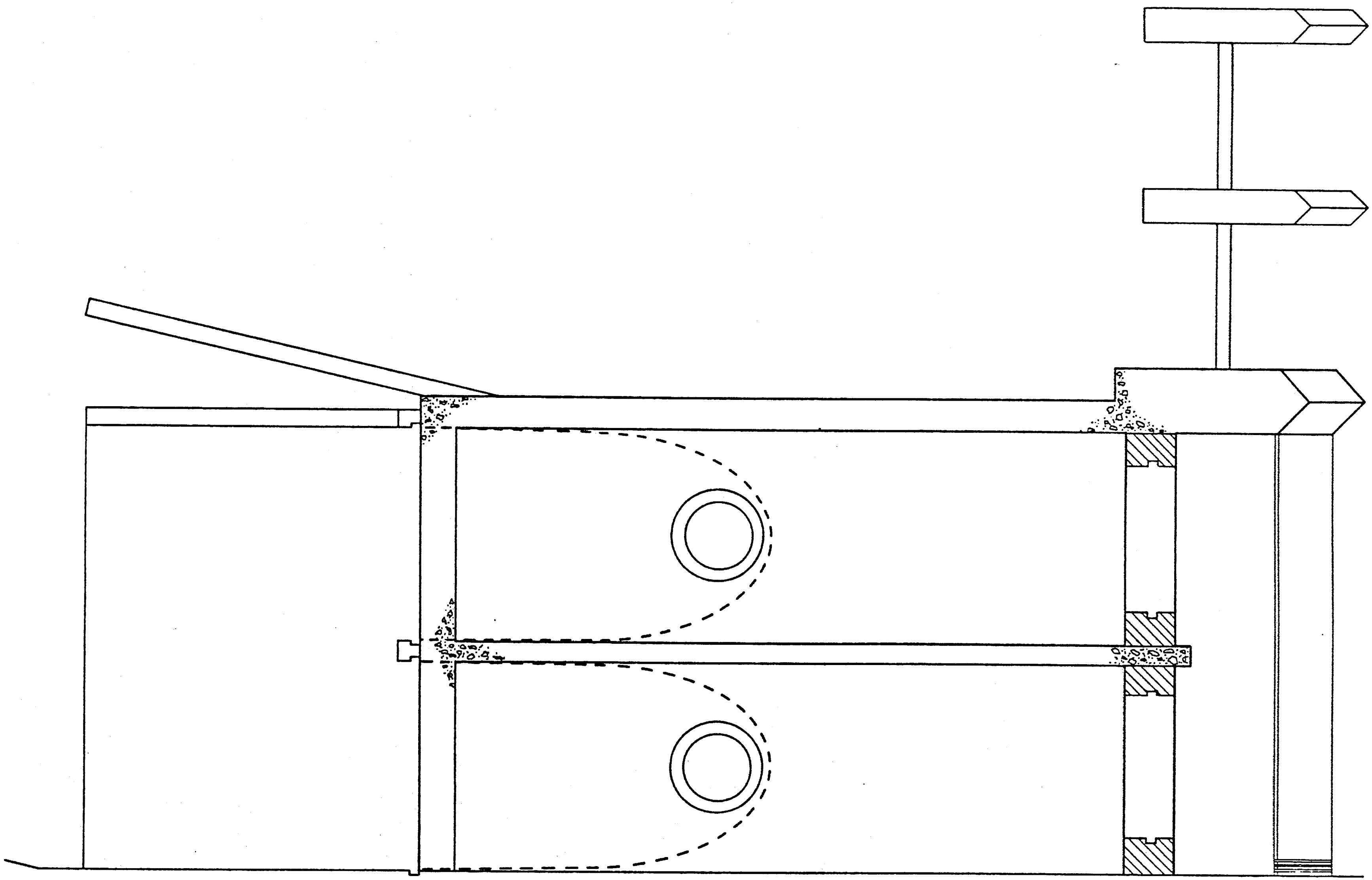


Fig. 20. Plan View of Alternative B: Replacement With Two 1650 mm Vertical Units.

C. Alternative C: Addition of One 1750 mm Horizontal Unit*

Alternative C is the addition of one horizontal tubular unit to the existing facility. The existing powerhouse and turbine units will remain intact and in operation. The new unit would be placed in the flood gate section immediately to the west of the existing powerhouse. The new unit considered has a 1750 mm variable-blade propeller turbine and fixed guide vanes. Design discharge is 641 cfs at 21 ft net head. Minimum discharge is 228 cfs. Rated generator output is 905 kW. A plan and section view of a preliminary layout are given in Figs. 21 and 22.

One disadvantage to Alternative C (as well as Alternatives D and E) is that the unit replaces the existing flood gates. The existing flood gates currently contribute 5000 cfs to the maximum spillway capacity of 41,500 cfs. The current spillway capacity, however, is still well below the design flood for the spillway. The City of Granite Falls will be considering means of increasing the spillway capacity, and new, enlarged flood gates are a possibility. Any proposed hydropower development should coincide with plans for increasing spillway capacity. One option, which will not improve spillway discharge capacity, is to rebuild the existing flood gates adjacent to the new powerhouse. An approximate cost of rebuilding the existing flood gates is $200,000.

For Alternatives C, D, and E, turbine/generator package and electrical equipment were obtained as one cost estimate. The turbine/generator package for these three alternatives includes:

- An intake roller gate with hydraulic cylinder operator
- Turbine
- Gear speed increaser
- Couplings
- Induction generator
- Blade positioner (for adjustable-blade units)
- Hydraulic power unit for operating intake gates and blade positioners
- Indoor protection and control cabinet
- Outdoor switchgear

---

*Based on a cost estimate and other information supplied by Allis-Chalmers.

- Outdoor step-up transformer
- Outdoor disconnect switch

The cost estimates for Alternative C are as follows:

Alternative C Cost Estimates (1981 Base Year)

1.	Construction Costs	$ 152,000
2.	Turbine/Generator/Electrical Equipment Package*	649,000
3.	Freight	10,000
4.	Installation	97,000
5.	Miscellaneous Plant Equipment	59,000
6.	15% Contingency on Items 3 through 5	25,000
7.	Engineering, Construction Management, etc.	198,000
	Total Initial Cost	$1,190,000

The incremental energy production and benefits for Alternative C are (1981 base year):

Average Annual Incremental Energy Production	1.69 GWH
Average Annual Energy Benefit	$ 36,500
Average Annual Demand Charge Credit	$ 7,300
Total Average Annual Incremental Benefit	$ 43,800

The incremental annual operation, maintenance, and replacement costs for this alternative are estimated to be $12,200 (1981 Base Year) [5].

D. Alternative D: Addition of One 2250 mm Horizontal Unit*

As with Alternative C, Alternative D is the addition of one new unit to the existing facility, with the new unit placed within the existing flood gate section. The effect of this alternative upon spillway discharge capacity is discussed in Section VIII.C. The new unit considered for this alternative has a 2250 mm variable-blade propeller turbine and fixed guide vanes. Design discharge is 1053 cfs at 21 ft net head. Minimum discharge is 374 cfs. Rated generator output is 1500 kW. The configurations of Alternative C and Alternative D are virtually the same, differing primarily

*Based on cost estimates obtained from Allis-Chalmers.

in size. Therefore, the plan and section views for Alternative C, Figs. 21 and 22, may be considered representative for those of Alternative D. Alternative D will have greater excavation and structural costs, and therefore a greater overall cost.

The cost estimates for Alternative D are as follows:

Alternative D Cost Estimates (1981 Base Year)

1.	Construction Costs	$ 196,000
2.	Turbine/Generator/Electrical Equipment Package*	903,000
3.	Freight	15,000
4.	Installation	135,000
5.	Miscellaneous Plant Equipment	72,000
6.	15% Contingency on Items 3, 4, and 5	33,000
7.	Engineering, Construction Management, etc.	271,000
	Total Initial Cost	$1,625,000

The incremental energy production and benefits for Alternative D are (1981 base year):

Average Annual Incremental Energy Production	2.44 GWH
Average Annual Energy Benefit	$52,700
Average Annual Demand Charge Credit	$10,000
Total Average Annual Incremental Benefit	$62,700

The incremental annual operation, maintenance, and replacement costs for this alternative are estimated to be $19,000 (1981 Base Year) [5].

E. Alternative E: Addition of One 72 in. Inclined Unit*

As with Alternatives C and D, Alternative E is the addition of one new unit to the existing facility, with the new unit replacing the existing flood gates. The effect of this alternative upon spillway discharge is discussed in Section VIII.C. The new unit considered for this alternative has a 72 in. fixed-blade propeller turbine and fixed guide vanes. For each value of net head, the unit has only one operating flow. The unit is therefore either "on" or "off." The design discharge is 515 cfs

*Based on cost estimates from Allis-Chalmers

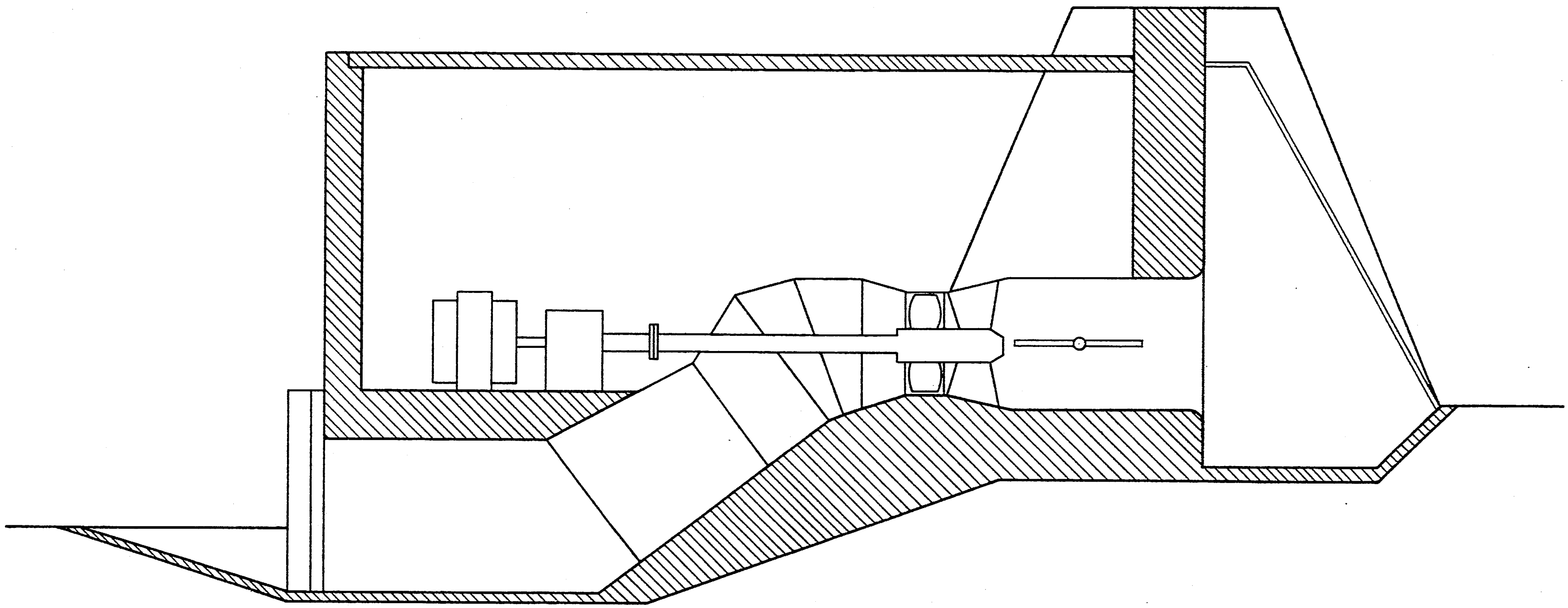


Fig. 21. Section View of Alternative C: Addition of One Horizontal Tubular Unit With 1750 mm Runner Diameter.

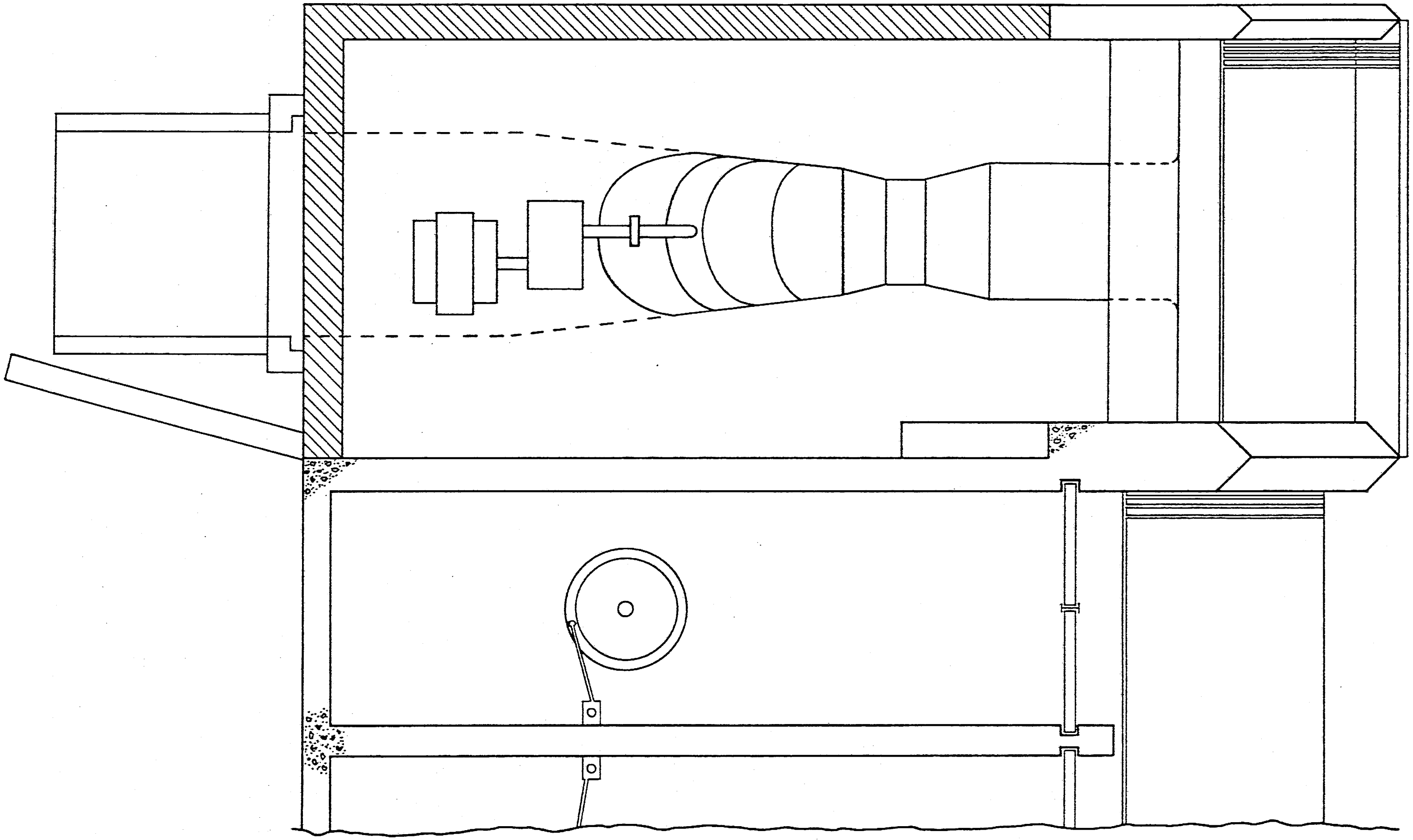


Fig. 22. Plan View of Alternative C: Addition of One Horizontal Tubular Unit With 1750 mm Runner Diameter. The Existing Powerhouse is Shown at the Bottom of the Figure.

at 22 ft net head with a rated generator output of 812 kW. The unit is a relatively attractive development alternative because of its simplicity and significantly lower cost. Plan and section views of a preliminary layout are given in Figs. 23 and 24.

The cost estimates for Alternative E are as follows:

Alternative E Cost Estimates (1981 Base Year)

1.	Construction Costs	$137,000
2.	Turbine/Generator/Electrical Equipment Package*	391,000
3.	Freight	10,000
4.	Installation	59,000
5.	Miscellaneous Plant Equipment	57,000
6.	15% Contingency on Items 3, 4, and 5	19,000
7.	Engineering, Construction Management, etc.	134,000
	Total Initial Cost	$807,000

The incremental energy production and benefits for Alternative E are (1981 Base Year):

Average Annual Incremental Energy Production	1.50 GWH
Average Annual Energy Benefit	$32,400
Average Annual Demand Charge Credit	$ 6,000
Total Average Annual Incremental Benefit	$38,400

The incremental annual operation, maintenance, and replacement costs for this alternative are estimated to be $10,200 (1981 Base Year) [5].

F. Other Development Alternatives

There are other turbine manufacturers marketing turbines in the United States which are applicable to the Granite Falls Dam. Axel-Johnson, Inc. (kMW unit), Kraerner-Moss (Sørumsand-Verksted unit), the James Leffel and Co., and Voest-Alpine are all marketing tubular units with standardized design which are compatible with Alternatives B, C, and D. Allis-Chalmers and Dominion Bridge-Sulzer, Inc. also produce units which are compatible with Alternatives B, C, and D. The Neyrpic right-angle drive units, manufactured in the United States by Hydro Energy Systems, Inc., are a fixed-blade propeller turbine designed to fulfill the same market as the Allis-Chalmers Mini Tube

*Based on cost estimates from Allis-Chalmers.

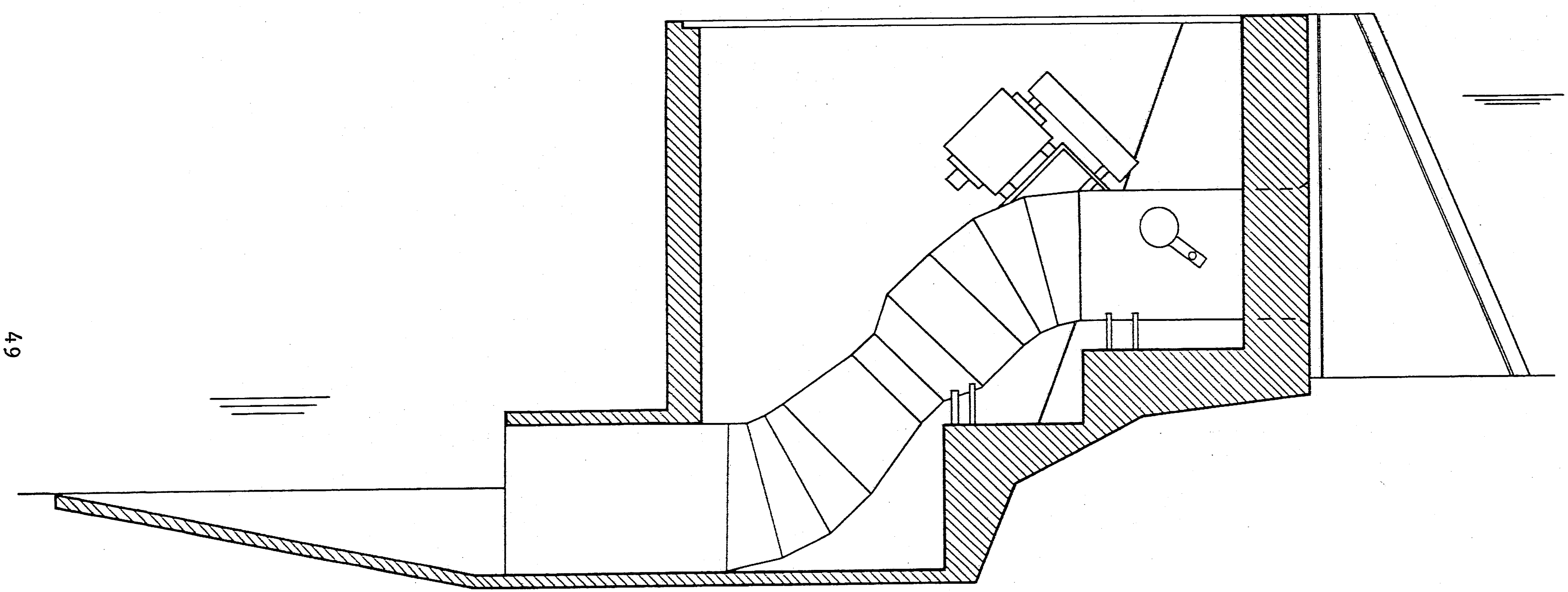


Fig. 23. Section View of Alternative E: Addition of One 72 in. Inclined Unit.

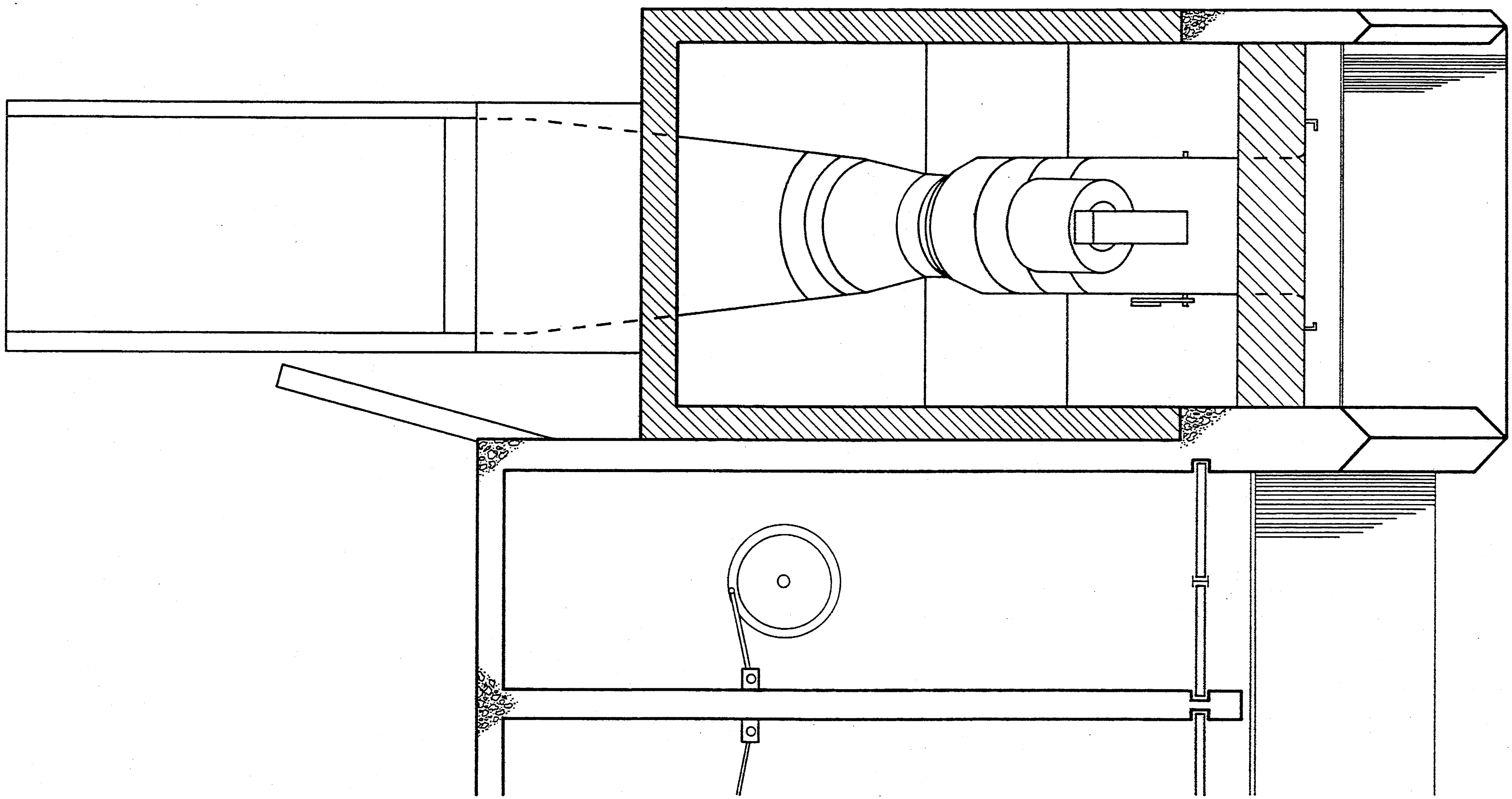


Fig. 24. Plan View of Alternative E: Addition of One 72 in. Inclined Unit.

of Alternative E. The right-angle drive unit may be inclined, however, the configuration would differ significantly from that given in Figs. 23 and 24. These manufacturers should be contacted during 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.

G. Summary of Project Development Alternatives

There is a significant difference between the total initial project cost of the four development alternatives which included new turbine/ generator units. These differences are illustrated in Table 3. Also given in Table 3 is the ratio of annual benefit to total initial project cost (not to be confused with the "benefit-cost ratio"). Choosing the alternative with the largest value of this ratio is the same as choosing the largest benefit-cost ratio or the minimum payback period. It is a relatively conservative feasibility indicator, however, since it does not always correspond to the maximum benefits minus costs.

TABLE 3. Comparison of the Incremental Benefits and Energy Production and of Total Initial Project Costs for Development Alternatives B, C, D, and E (1981 Base Year)

Development Alternative:	B	C	D	E
Average Annual Incremental Energy Production (GWH)	1.61	1.69	2.44	1.50
Total Average Annual Incremental Benefits ($)	41,600	43,800	62,700	38,400
Total Initial Cost ($)	2,008,000	1,190,000	1,625,000	807,000
Annual Incremental Benefits/ Total Initial Cost	.021	.037	.039	.048

IX. ECONOMIC ANALYSIS

A. Background and Assumptions

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

1. Economic Feasibility Indicators.

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

The first year cost of power is the cost of debt service, operation and maintenance, and other costs divided by the average annual energy production.

The benefit-cost ratio is the present worth of project benefits divided by the present worth of initial project costs and annual costs.

$$B/C = \frac{\sum_{i=0}^{n} B_i/(1 + d)^i}{C_i + \sum_{i=0}^{n} OMi/(1 + d)^i} \qquad (2)$$

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:

$$NPV = \sum_{i=0}^{n} NB_i/(1 + d)^i \qquad (3)$$

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).

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

2. Assumptions

The following assumptions are incorporated into the economic analysis:

- The economic life of the project is assumed to be 50 years. For this reason the initial project cost will be amortized over a 50-year period.
- 11 per cent interest rate. Interest rates on tax-exempt bonds have been climbing since the beginning of 1980. As of July 1981, Moody's A-rated municipal bond index had stabilized at approximately 11 per cent [6].

  Historically, A-rated tax-exempt bonds have been near the rate of inflation. The recent tax cuts, however, have diminished 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 per cent*.

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

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

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

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

B. Comparison of Project Development Alternatives.

The cost and benefit streams for development Alternatives B, C, D, and E are given in Tables 4, 5, 6, and 7. Alternative E produces the earliest positive cash flow, becoming positive after the thirteenth year. Development Alternatives C and D become positive after 16 years. The longest time of negative cash flow is 25 years with Alternative B.

The first year cost of power, benefit-cost ratio, net percent value, internal rate of return, and payback period for each of the development Alternatives are compared using the incremental approach in Table 8. A 35-year and 50-year project economic life were used. The useful life of a hydropower facility is anywhere from 50 to 100 years. The 50-year project economic life is used herein because it corresponds more closely to the useful life of any proposed facility.

TABLE 8. First Year Cost of Power, Benefit-Cost Ratio, Net Present Value and Payback Period for Granite Falls Dam Development Alternatives B, C, D, and E.

	Development Alternatives			
	B	C	D	E
First Year Cost of Power ($/kWH)	0.149	.085	.081	.066
35-Year Project Economic Life:				
Benefit-Cost Ratio	0.5	0.87	0.88	1.06
Net Present Value (Millions $, 1981 Base Year)	-1.43	-0.24	-0.30	.08
50-Year Project Economic Life				
Benefit-Cost Ratio	0.65	1.10	1.10	1.33
Net Present Value (Million $, 1981 Base Year)	-1.14	0.20	.30	.47
Payback Period (Years)	over 50	44	43	32

TABLE 4. Cost and Benefit Streams for Development Alternative B, at the Granite Falls Dam Base year for present worth = 1981. Two-year construction period. 11 per cent interest rate. 9 per cent escalation rates. All figures are in dollars.

Annual Incremental Operation, Maintenance and Replacement Cost (1981 Base Year) = <u>$17,000</u>

Year	Debt Service	O & M Costs	Gross Income and Tax Benefits	Present Worths Benefits	Present Worths Costs	Present Worths Cash Flow	Net Present Value
1	111042	0	0	0	101873	-101873	-101873
2	222083	0	0	0	186923	-186923	-288796
3	222083	22922	53842	41576	189189	-147613	-436409
4	222083	24985	58688	41576	175029	-133453	-569863
5	222083	27234	63970	41576	162039	-120463	-690325
6	222083	29685	69727	41576	150121	-108545	-798870
7	222083	32356	76003	41576	139187	-97611	-896482
8	222083	35268	82843	41576	129156	-87580	-984062
9	222083	38443	90299	41576	119953	-78377	-1062439
10	222083	41902	98426	41576	111510	-69934	-1132373
11	222083	45674	107284	41576	103765	-62189	-1194562
12	222083	49784	116939	41576	96658	-55082	-1249644
13	222083	54265	127464	41576	90139	-48563	-1298207
14	222083	59149	138936	41576	84158	-42582	-1340789
15	222083	64472	151440	41576	78670	-37094	-1377883
16	222083	70274	165069	41576	73636	-32060	-1409943
17	222083	76599	179926	41576	69017	-27441	-1437385
18	222083	83493	196119	41576	64780	-23204	-1460589
19	222083	91007	213770	41576	60893	-19317	-1479906
20	222083	99198	233009	41576	57327	-15751	-1495656
21	222083	108126	253980	41576	54055	-12479	-1508135
22	222083	117857	276838	41576	51053	-9477	-1517612
23	222083	129464	301753	41576	48299	-6723	-1524335
24	222083	140026	328911	41576	45772	-4196	-1528531
25	222083	152629	358513	41576	43455	-1879	-1530410
26	222083	166365	390779	41576	41328	248	-1530162
27	222083	181338	425950	41576	39377	2199	-1527963
28	222083	197658	464285	41576	37587	3989	-1523974
29	222083	215448	506071	41576	35945	5631	-1518343
30	222083	234838	551617	41576	34439	7137	-1511206
31	222083	255973	601263	41576	33057	8519	-1502686
32	222083	279011	655376	41576	31789	9787	-1492899
33	222083	304122	714360	41576	30625	10951	-1481948
34	222083	331493	778652	41576	29558	12018	-1469930
35	222083	361327	848731	41576	28579	12997	-1456933
36	222083	393847	925117	41576	27681	13895	-1443038
37	222083	429293	1008377	41576	26857	14719	-1428319
38	222083	467929	1099131	41576	26101	15475	-1412843
39	222083	510043	1198053	41576	25407	16169	-1396674
40	222083	555947	1305878	41576	24771	16805	-1379869
41	222083	605982	1423407	41576	24187	17389	-1362480
42	222083	660520	1551514	41576	23651	17925	-1344555
43	222083	719967	1691150	41576	23160	18416	-1326139
44	222083	784764	1843353	41576	22709	18867	-1307272
45	222083	855393	2009255	41576	22295	19281	-1287991
46	222083	932378	2190088	41576	21916	19660	-1268331
47	222083	1016292	2387196	41576	21568	20008	-1248323
48	222083	1107759	2602044	41576	21248	20328	-1227995
49	222083	1207457	2836228	41576	20955	20621	-1207375
50	222083	1316128	3091488	41576	20687	20889	-1186485
51	111042	1434580	3369722	41576	19070	22506	-1163979
52	0	1563692	3672997	41576	17700	23876	-1140103

Payback period = over 50 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $1,428,319
Benefit Cost Ratio = .50

Economic Analysis for a Project Life of 50 Years
Present Net Value = $1,140,103
Benefit Cost Ratio = .65

TABLE 5. Cost and Benefit Streams for Development Alternative C, at the Granite Falls Dam Base year for present worth = 1981. Two-year construction period. 11 per cent interest rate. 9 per cent escalation rates. All figures are in dollars.

Annual Incremental Operation, Maintenance and Replacement Cost (1981 Base Year) = $12,200

Year	Debt Service	O & M Costs	Gross Income and Tax Benefits	Present Worths Benefits	Present Worths Costs	Cash Flow	Net Present Value
1	65807	0	0	0	60373	-60373	-60373
2	131613	0	0	0	110776	-110776	-171149
3	131613	15799	56727	43804	113829	-70025	-241175
4	131613	17221	61833	43804	105438	-61634	-302809
5	131613	18771	67398	43804	97739	-53935	-356744
6	131613	20461	73464	43804	90677	-46873	-403617
7	131613	22302	80075	43804	84197	-40393	-444010
8	131613	24309	87282	43804	78252	-34448	-478458
9	131613	26497	95138	43804	72798	-28994	-507452
10	131613	28882	103700	43804	67795	-23991	-531443
11	131613	31481	113033	43804	63204	-19400	-550843
12	131613	34315	123206	43804	58993	-15189	-566032
13	131613	37403	134295	43804	55129	-11325	-577358
14	131613	40769	146381	43804	51585	-7781	-585138
15	131613	44438	159555	43804	48333	-4529	-589667
16	131613	48438	173915	43804	45349	-1545	-591213
17	131613	52797	189568	43804	42612	1192	-590021
18	131613	57549	206629	43804	40101	3703	-586318
19	131613	62728	225225	43804	37797	6007	-580311
20	131613	68374	245496	43804	35684	8120	-572191
21	131613	74527	267590	43804	33745	10059	-562132
22	131613	81235	291673	43804	31966	11838	-550294
23	131613	88546	317924	43804	30334	13470	-536824
24	131613	96515	346537	43804	28837	14967	-521856
25	131613	105202	377725	43804	27463	16341	-505515
26	131613	114670	411721	43804	26203	17601	-487914
27	131613	124990	448776	43804	25046	18758	-469156
28	131613	136239	489165	43804	23986	19818	-449338
29	131613	148501	533190	43804	23013	20791	-428547
30	131613	161866	581177	43804	22120	21684	-406862
31	131613	176434	633483	43804	21301	22503	-384359
32	131613	192313	690497	43804	20549	23255	-361105
33	131613	209621	752642	43804	19860	23944	-337160
34	131613	228487	820379	43804	19227	24577	-312584
35	131613	249050	894213	43804	18647	25157	-287427
36	131613	271465	974693	43804	18115	25689	-261738
37	131613	295897	1062415	43804	17626	26178	-235561
38	131613	322528	1158032	43804	17178	26626	-208935
39	131613	351555	1262255	43804	16767	27037	-181898
40	131613	383195	1375858	43804	16390	27414	-154485
41	131613	417682	1499685	43804	16044	27760	-126725
42	131613	455274	1634657	43804	15727	28077	-98648
43	131613	496249	1781776	43804	15436	28368	-70279
44	131613	540911	1942136	43804	15168	28636	-41644
45	131613	589593	2116928	43804	14923	28881	-12763
46	131613	642656	2307452	43804	14699	29105	16342
47	131613	700495	2515123	43804	14492	29312	45654
48	131613	763540	2741484	43804	14303	29501	75155
49	131613	832258	2988217	43804	14129	29675	104830
50	131613	907162	3257157	43804	13970	29834	134664
51	65807	988806	3550301	43804	13012	30792	165456
52	0	1077799	3869828	43804	12200	31604	197060

Payback period = 44 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $235,561
Benefit Cost Ratio = .87

Economic Analysis for a Project Life of 50 Years
Present Net Value = $197,060
Benefit Cost Ratio = 1.10

TABLE 6. Cost and Benefit Streams for Development Alternative D, at the Granite Falls Dam Base year for present worth = 1981. Two-year construction period. 11 per cent interest rate. 9 per cent escalation rates.

Annual Incremental Operation, Maintenance and Replacement Cost (1981 Base Year) = $19,000

Year	Debt Service	O & M Costs	Gross Income and Tax Benefits	Present Worths Benefits	Present Worths Costs	Present Worths Cash Flow	Net Present Value
1	89862	0	0	0	82442	-82442	-82442
2	179724	0	0	0	151270	-151270	-233712
3	179724	24606	81203	62704	157780	-95076	-328788
4	179724	26820	88512	62704	146321	-83617	-412405
5	179724	29234	96478	62704	135808	-73104	-485509
6	179724	31865	105161	62704	126163	-63459	-548968
7	179724	34733	114625	62704	117315	-54611	-603579
8	179724	37859	124942	62704	109197	-46493	-650072
9	179724	41266	136186	62704	101750	-39046	-689118
10	179724	44980	148443	62704	94917	-32213	-721332
11	179724	49028	161803	62704	88649	-25945	-747276
12	179724	53441	176365	62704	82898	-20194	-767470
13	179724	58250	192238	62704	77622	-14918	-782389
14	179724	63493	209540	62704	72782	-10078	-792466
15	179724	69207	228398	62704	68341	-5637	-798103
16	179724	75436	248954	62704	64267	-1563	-799666
17	179724	82225	271360	62704	60529	2175	-797492
18	179724	89625	295782	62704	57100	5604	-791888
19	179724	97692	322403	62704	53954	8750	-783138
20	179724	106484	351419	62704	51068	11636	-771503
21	179724	116067	383047	62704	48420	14284	-757219
22	179724	126513	417521	62704	45991	16713	-740506
23	179724	137900	455098	62704	43763	18941	-721565
24	179724	150311	496057	62704	41718	20986	-700579
25	179724	163839	540702	62704	39842	22862	-677717
26	179724	178584	589365	62704	38121	24583	-653134
27	179724	194657	642408	62704	36542	26162	-626973
28	179724	212176	700224	62704	35094	27610	-599363
29	179724	231271	763245	62704	33765	28939	-570424
30	179724	252086	831937	62704	32546	30158	-540266
31	179724	274774	906811	62704	31428	31276	-508989
32	179724	299503	988424	62704	30401	32303	-476687
33	179724	326459	1077382	62704	29460	33244	-443443
34	179724	355840	1174346	62704	28596	34108	-409335
35	179724	387865	1280037	62704	27804	34900	-374435
36	179724	422773	1395241	62704	27077	35627	-338808
37	179724	460823	1520812	62704	26410	36294	-302514
38	179724	502297	1657686	62704	25798	36906	-265608
39	179724	547504	1806877	62704	25237	37467	-228141
40	179724	596779	1969496	62704	24722	37982	-190159
41	179724	650489	2146751	62704	24250	38454	-151705
42	179724	709033	2339959	62704	23816	38888	-112817
43	179724	772846	2550555	62704	23418	39286	-73531
44	179724	842402	2780105	62704	23054	39650	-33881
45	179724	918218	3030314	62704	22719	39985	6104
46	179724	1000858	3303042	62704	22412	40292	46396
47	179724	1090935	3600316	62704	22130	40574	86970
48	179724	1189120	3924345	62704	21872	40832	127803
49	179724	1296140	4277536	62704	21635	41069	168872
50	179724	1412793	4662514	62704	21417	41287	210159
51	89862	1539944	5082140	62704	20109	42595	252754
52	0	1678539	5539533	62704	19000	43704	296458

Payback period = 43 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $302,514
Benefit Cost Ratio = .88

Economic Analysis for a Project Life of 50 Years
Present Net Value = $296,458
Benefit Cost Ratio = 1.10

TABLE 7. Cost and Benefit Streams for Development Alternative E, at the Granite Falls Dam Base year for present worth = 1981. Two-year construction period. 11 per cent interest rate, 9 per cent escalation rates.

Annual Incremental Operation, Maintenance and Replacement Cost (1981 Base Year) = $10,200

Year	Debt Service	O & M Costs	Gross Income and Tax Benefits	Present Worths Benefits	Present Worths Costs	Present Worths Cash Flow	Net Present Value
1	44627	0	0	0	40942	-40942	-40942
2	89254	0	0	0	75123	-75123	-116065
3	89254	13209	49729	38400	79120	-40720	-156785
4	89254	14398	54205	38400	73429	-35029	-191815
5	89254	15694	59083	38400	68209	-29809	-221623
6	89254	17106	64401	38400	63419	-25019	-246642
7	89254	18646	70197	38400	59025	-20625	-267267
8	89254	20324	76514	38400	54993	-16593	-283860
9	89254	22153	83401	38400	51295	-12895	-296755
10	89254	24147	90907	38400	47902	-9502	-306257
11	89254	26320	99088	38400	44789	-6389	-312646
12	89254	28689	108006	38400	41933	-3533	-316178
13	89254	31271	117727	38400	39313	-913	-317091
14	89254	34086	128322	38400	36909	1491	-315600
15	89254	37153	139871	38400	34704	3696	-311903
16	89254	40497	152460	38400	32680	5720	-306184
17	89254	44142	166181	38400	30824	7576	-298608
18	89254	48115	181137	38400	29121	9279	-289329
19	89254	52445	197440	38400	27559	10841	-278488
20	89254	57165	215209	38400	26126	12274	-266213
21	89254	62310	234578	38400	24811	13589	-252624
22	89254	67918	255690	38400	23604	14796	-237828
23	89254	74030	278702	38400	22497	15903	-221926
24	89254	80693	303786	38400	21482	16918	-205008
25	89254	87955	331126	38400	20551	17849	-187158
26	89254	95871	360928	38400	19696	18704	-168454
27	89254	104500	393411	38400	18912	19488	-148966
28	89254	113905	428818	38400	18193	20207	-128759
29	89254	124156	467412	38400	17533	20867	-107891
30	89254	135330	509479	38400	16927	21473	-86418
31	89254	147510	555332	38400	16372	22028	-64390
32	89254	160786	605312	38400	15862	22538	-41852
33	89254	175257	659790	38400	15395	23005	-18847
34	89254	191030	719171	38400	14966	23434	4587
35	89254	208222	783896	38400	14572	23828	28415
36	89254	226962	854447	38400	14211	24189	52604
37	89254	247389	931347	38400	13880	24520	77124
38	89254	269654	1015169	38400	13576	24824	101948
39	89254	293923	1106534	38400	13297	25103	127051
40	89254	320376	1206122	38400	13042	25358	152409
41	89254	349210	1314673	38400	12807	25593	178002
42	89254	380639	1432993	38400	12592	25808	203810
43	89254	414896	1561963	38400	12394	26006	229816
44	89254	452237	1702539	38400	12213	26187	256003
45	89254	492938	1855768	38400	12047	26353	282356
46	89254	537303	2022787	38400	11894	26506	308862
47	89254	585660	2204838	38400	11754	26646	335507
48	89254	638369	2403273	38400	11626	26774	362281
49	89254	695823	2619568	38400	11508	26892	389173
50	89254	758447	2855329	38400	11400	27000	416172
51	44627	826707	3112308	38400	10751	27649	443822
52	0	901111	3392416	38400	10200	28200	472022

Payback period = 32 years

Economic Analysis for a Project Life of 35 Years
Present Net Value = $77,124
Benefit Cost Ratio = 1.06

Economic Analysis for a Project Life of 50 Years
Present Net Value = $472,022
Benefit Cost Ratio = 1.33

C. Sensitivity Analysis

Sensitivity analysis investigates the impact of variations in project parameters and economic assumptions on the feasibility indicators. The analysis will determine the sensitivity of the feasibility indicators to important project parameters and assumptions.

Alternative E appears to give superior economic feasibility indicators. Therefore, Alternative E will be used in developing the sensitivity analysis.

1. Loss of Demand Charge Credit

A significant component of the incremental income is the demand charge credit. It is highly unlikely that a complete loss of demand charge credit will ever be experienced, but for the sake of comparison, the worst case of complete loss or demand charge credit, is presented. The impact of the loss of demand charge credit on various feasibility indicators is given in Table 9 for Development Alternative E. Alternative E1 is the same as Alternative E described in Section VIII.E. Alternative E2 is without demand charge credit.

TABLE 9. Benefit-Cost Ratio, Net Present Value and Payback Period for Development Alternative E With and Without Demand Charge Credit, Granite Falls Dam.

	Demand Charge Alternatives	
35-Year Project Economic Life	With,E1	Without,E2
Benefit-Cost Ratio	1.06	0.90
Net Present Value (Million $, 1981 Base Year)	0.077	-0.133
50-Year Project Economic Life		
Benefit-Cost Ratio	1.33	1.12
Net Present Value (Million $, 1981 Base Year)	0.472	0.172
Payback Period (years)	32	42

2. Variation of Project Cost.

Because the scope of this study is to assess the feasibility of developing a site and is not a final design, variation of costs should be considered. This segment on the sensitivity analysis deals with initial costs 20 per cent greater (Alternative E3) and 20 per cent less (Alternative E4) than the original initial cost listed in Alternative E. The effects of this variation on the various feasibility indicators are given in Table 10.

TABLE 10. Benefit-Cost Ratio, Net Present Value and Payback Period at Different Initial Project Costs for Development Alternative E, Granite Falls Dam.

	Development Alternatives		
	E1	E3	E4
Initial Project Cost (Million $, 1981 Base Yr)	.807	.968	.645
35-Year Project Economic Life:			
Benefit-Cost Ratio	1.06	0.93	1.24
Net Present Value (Million $, 1981 Base Yr)	.077	-.104	.260
50-Year Project Economic Life:			
Benefit-Cost Ratio	1.33	1.17	1.52
Net Present Value (Million $, 1981 Base Yr)	.472	.285	.660
Payback Period (years)	32	40	24

3. Discount and Escalation Rates.

Economic feasibility is extremely sensitive to discount and escalation rates. The economic feasibility indicators for Alternative E are given in Table 11 for various combinations of interest discount and escalation rates.

TABLE 11. Benefit-Cost Ratio, Net Present Value and Payback Period at the Original Plus Seven Other Combinations of Interest and Escalation Rates for Development Alternative E, Granite Falls Dam.

	Alternatives			
	E1	E5	E6	E7
Interest Rate (5)	11	9	7	5
Escalation Rate for Energy Value (5)	9	9	9	9
Escalation Rate for O&M (%)	9	9	9	9
Discount Rate (%)	9	9	9	9
35-Year Project Economic Life:				
Benefit-Cost Ratio	1.06	1.21	1.41	1.66
Net Present Value (Million $, 1981 Base Yr)	0.077	0.236	0.391	0.536
50-Year Project Economic Life:				
Benefit-Cost Ratio	1.33	1.50	1.71	1.97
Net Present Value (Million $, 1981 Base Yr)	0.472	0.636	0.795	0.945
Payback Period (years)	32	25	18	12

	Alternatives				
	E8	E9	E10	E11	E12
Interest Rate (%)	9	11	11	11	11
Escalation Rate for Energy Value (%)	11	11	11	9	9
Escalation Rate for O&M (%)	11	11	9	11	9
Discount Rate (%)	11	11	9	11	11
35-Year Project Economic Life:					
Benefit-Cost Ratio	1.37	1.21	1.55	0.86	.94
Net Present Value (Million $, 1981 Base Yr)	0.365	0.233	0.699	-0.161	-.056
50-Year Project Economic Life:					
Benefit-Cost Ratio	1.68	1.50	2.26	0.94	1.11
Net Present Value (Million $, 1981 Base Yr)	0.777	0.643	1.83	-0.072	.118
Payback Period (years)	21	26	22	over 50	40

In all but two cases, energy escalation rates and the escalation rate for operation, maintenance, and replacement were adjudged to be equal.

Development Alternatives E5, E6, and E7 reflect the change in economic feasibility indicators as the cost of borrowing (interest rate) decreases. Alternatives E8 and E9 indicate the result of simultaneous higher energy and O&M escalation rates at two different interest rates. Development Alternatives E10 and E11 illustrate the impact of different energy and O&M escalation rates on the economic feasibility indicators. Alternative E10 can be interpreted to represent an energy value which increases at a greater rate than inflation. Alternative E11 can be interpreted to represent an energy value which increases at a lower rate than inflation. Finally, Alternative E12 indicates the proposed development feasibility when discount rate is chosen to be equal to the loan interest rate.

4. 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 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.

The technique used in computing the annual O.M.&R cost for development Alternative E, as well as C and D, was an incremental one described in Section VIII. The result of this approach was a significant annual O.M.&R cost over and above the computed annual O.M.&R costs for the existing facility. This approach appears to be conservative,and the predicted annual incremental O.M.&.R costs are more likely high than low. Because the existing units are currently in operation, the incremental operational cost for additional capacity may be negligible. For this reason the economic feasibility indications of two lower annual incremental O.M.&R costs are presented in Table 12, while the results are given of only one higher cost. Alternative E13 represents the effect of a 20 per cent increase in the annual incremental O.M.&R cost of E1. E14 and E15 reflect a 20 per cent and 40 per cent decrease, respectively.

TABLE 12. Benefit-Cost Ratio, Net Present Value and Payback Period at Different Annual Incremental Operation, Maintenance, and Replacement Costs for Development Alternative E, Granite Falls Dam.

	Development Alternatives			
	E1	E13	E14	E15
Operation, Maintenance and Replacement Cost ($, 1981 Base Year)	$10,200	$12,200	$8,200	$6,100
<u>35-Year Project Economic Life</u>:				
Benefit-Cost Ratio	1.06	1.01	1.12	1.2
Net Present Value (Million $, 1981 Base Year)	.077	.007	.147	.221
<u>50-Year Project Economic Life</u>:				
Benefit-Cost Ratio	1.33	1.24	1.42	1.54
Net Present Value (Million $, 1981 Base Year)	.472	.372	.572	.677
Payback Period (Years)	32	35	30	27

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, in general, the potential environmental impacts of small-scale hydrpower plants at existing dam sites. The goal of this section is to determine the potential impacts in accordance with the Federal Energy Regulatory Commission's (FERC) requirements for the filing of a Short-Form Minor License for hydroelectric power development.

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

1. Run-of-River. Hydropower plants which have insufficient reservoir storage for seasonal peaking are classified as run-of-river. This category includes facilities which have enough reservoir storage for peaking on a daily basis. We prefer to differentiate between these two subcategories with the terms "strict run-of-river" and "daily storage."

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

The following effects are considered important in the operation of a run-of-river site.

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

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

Other construction activities which could have an adverse effect upon the environment include dredging and dust control. This is most easily controlled by installing a cofferdam to reduce excessively turbid releases to the stream. Land use impacts that should be addressed concern the fact that powerhouses and dams alter the general scenery along a river, displace streamside vegetation, and present obstacles to terrestrial wildlife species [7]. Indirect impacts of small-scale hydropower may lead to new opportunities and responsibilities for supporting recreational, commercial, agricultural, or residential activity [7].

There are also several other considerations for which the degree of severity or applicability must be determined on a site-specific basis. These considerations include powerline construction, noise reduction, earthwork, historical and archaeological significance, endangered species (plants and animals), recreation (parks, canoe routes, etc.), and aesthetic quality. Also of prime importance in determining impacts would be the designation of a river or stream as a Wild and Scenic River on either a state or federal basis. There are usually no impacts incurred due to the dam itself since the impoundments have been in place for a long period of time. It is therefore likely that environmental modifications have already taken place [7].

An effective means of screening the site-specific environmental impacts is by utilizing an environmental impact matrix as shown in Fig. 25 [8] for the Granite Falls Dam. The facility will be operated as run-of-river with a possible 1.2 ft reservoir drawdown below the flashboards.

● SIGNIFICANT IMPACT

◉ LIMITED IMPACT

□ INSIGNIFICANT OR NO IMPACT

Natural Factors

Proposed Activities		Terrestrial: Soils	Terrestrial: Land Form	Hydrological: Surface Water Levels	Hydrological: Surface Water Quality	Hydrological: Underground Water Quality	Hydrological: Well Water Supply	Biological: Vegetation	Biological: Fish and Aquatic Wildlife	Biological: Birds	Biological: Terrestrial Wildlife	Atmospheric: Air Quality	
Construction	Earthwork Clearing/Grading/Excav.				◉			◉	◉				
Construction	Demolition/Disposal				◉								
Construction	Interim Flood Control												
Construction	Coffer Dam/Dewatering			◉	◉			◉	◉				
Construction	Heavy Equipment Use		◉										
Construction	Material Transp./Storage												
Construction	Temporary Structures and Facilities												
Construction	Worker and Equip. Access												
Construction	Worker Influx												
Physical Plant & Operation	Permanent Structures & Facilities												
Physical Plant & Operation	Electric Distrib. Circuits												
Physical Plant & Operation	Electric Generation												
Physical Plant & Operation	Flow Control		◉	●	◉			◉	◉				
Physical Plant & Operation	Impound, Management			◉	◉				◉				
Physical Plant & Operation	Worker & Equip. Access												
Physical Plant & Operation	Security & Safety												

Cultural Factors – Social

Proposed Activities		Scenic Views & Vistas	Open Space Qualities	Historical Archeological Sites	Rare and Unique Species	Health and Safety	Ambient Noise Level	Residential Activity
Construction	Earthwork Clearing/Grading/Excav.						◉	
Construction	Demolition/Disposal	◉					◉	
Construction	Interim Flood Control							
Construction	Coffer Dam/Dewatering							
Construction	Heavy Equipment Use						◉	
Construction	Material Transp./Storage							
Construction	Temporary Structures and Facilities							
Construction	Worker and Equip. Access							
Construction	Worker Influx							
Physical Plant & Operation	Permanent Structures & Facilities							
Physical Plant & Operation	Electric Distrib. Circuits							
Physical Plant & Operation	Electric Generation							
Physical Plant & Operation	Flow Control							
Physical Plant & Operation	Impound, Management							
Physical Plant & Operation	Worker & Equip. Access							
Physical Plant & Operation	Security & Safety							

Cultural Factors – Economic and Land Use – Land Value

Proposed Activities		Employment (Short Term)	Employment (Long Term)	Housing (Short Term)	Housing (Long Term)	Local Government Fiscal Effects	Business Activity	Land Use – Land Value: Agricultural	Residential	Commercial	Industrial	Open Space
Construction	Earthwork Clearing/Grading/Excav.											
Construction	Demolition/Disposal											
Construction	Interim Flood Control											
Construction	Coffer Dam/Dewatering											
Construction	Heavy Equipment Use											
Construction	Material Transp./Storage											
Construction	Temporary Structures and Facilities											
Construction	Worker and Equip. Access											
Construction	Worker Influx											
Physical Plant & Operation	Permanent Structures & Facilities											
Physical Plant & Operation	Electric Distrib. Circuits											
Physical Plant & Operation	Electric Generation											
Physical Plant & Operation	Flow Control											
Physical Plant & Operation	Impound, Management											
Physical Plant & Operation	Worker & Equip. Access											
Physical Plant & Operation	Security & Safety											

Cultural Factors – Infrastructure and Recreation

Proposed Activities		Infrastructure: Transportation	Infrastructure: Utilities	Infrastructure: Waste Disposal	Infrastructure: Government Services	Recreation: Hunting	Recreation: Fishing	Recreation: Boating	Recreation: Swimming	Recreation: Picnicking	Recreation: Hiking-Biking
Construction	Earthwork Clearing/Grading/Excav.			◉			◉				
Construction	Demolition/Disposal			◉							
Construction	Interim Flood Control										
Construction	Coffer Dam/Dewatering						◉	◉			
Construction	Heavy Equipment Use										
Construction	Material Transp./Storage										
Construction	Temporary Structures and Facilities										
Construction	Worker and Equip. Access										
Construction	Worker Influx										
Physical Plant & Operation	Permanent Structures & Facilities										
Physical Plant & Operation	Electric Distrib. Circuits										
Physical Plant & Operation	Electric Generation		◉								
Physical Plant & Operation	Flow Control						◉	◉			
Physical Plant & Operation	Impound, Management										
Physical Plant & Operation	Worker & Equip. Access										
Physical Plant & Operation	Security & Safety										

Fig. 25. Environmental Impact Matrix for the Proposed Hydropower Development at the Granite Falls Dam.

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 the 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" [9].

The City of Granite Falls has two options in complying with FERC requirements. The first is to file an "Application for Amendment of Licence," with a revised Exhibit L (plans and specs). No environmental report is specifically required but may be requested by the FERC. The second option is to file for an exemption from licensing. The exemption will specifically require an environmental report; however, annual license fees and periodic review and renewal are not required with an exemption. The disadvantage to an exemption is that it provides no legal protection from downstream or upstream developments which may harm power production. Regardless of which FERC licensing option is followed, some State of Minnesota permits will require an environmental analysis.

The contents of an environmental report should include [9]:

(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.

(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 Instream 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 [10]. Water fluctuation due to peaking operations may be of differing amplitude or frequency than normal seasonal fluctuations, adversely affecting fauna and flora adapted to seasonal cycles [11]. 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 [11]. These effects upon the reservoir apply mainly to hydropower installations which operate on a "seasonal peaking" basis, and are not of concern to run-of-river installations.

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 regulated flow. Areas formerly with minimal or no sedimentation farther downstream may begin to fill with sediment [12].

Hildebrand, et al [12] have stated that, "These changes in the physical environment can alter the composition and abundance of biota comprising tailwater communities. A reduction in benthic invertebrate diversity could occur as a result of the displacement of species unable to withstand high and variable current velocities or to exist in habitats where the composition of the substrate has been modified by the fluctuating flow regime. Fish species diversity and relative abundance might change for the same reasons (e.g. reduction or modification of spawning habitat) or as a result of the availability of food resources (e.g. reduced benthic production). Plant communities would also be affected by the increase in flow fluctuations, decreased bed stability, and elevated turbidity levels, which could reduce both aquatic macrophyte (vascular plants) and periphyton (primarily attached algae) production. The composition of riparian vegetation could be altered by a decrease in bank stability and modification of flooding cycles (i.e. a change in the time of occurrence, frequency, duration, and amplitude of flood flows). Such changes could, in turn, affect wildlife populations that are dependent upon riparian resources" [12]. It must be emphasized, however, that these impacts are not likely to be significant at run-of-river operations.

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 [8]. A strict run-of-river hydroelectric plant would operate according to the natural stream flows, and the operation of the plant would not alter the normal downstream flows.

If peaking is considered a possibility, there are criterion 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 [13] indicates that the absolute minimum acceptable streamflow is 10 per cent 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" [13].

With higher percentages of average annual flow (i.e. 30%) at the base flow will sustain good survival habitat for most aquatic life forms [13]. However, since flows naturally drop to low levels, a regulated stream with a minimum flow at 10 per cent of the average annual flow will occasionally provide some enhancement over a natural flow regimen [13].

Hildebrand, et al [12] have stated that "operation of small hydroelectric facilities in a store-and-release mode may dewater a section of the river below the dam during periods of water storage. Prolonged periods of greatly reduced or no flow decrease the wetted perimeter (available habitat) of the tailwaters, thus potentially reducing the diversity and standing crop of benthic invertebrates and fishes. Sharp reduction in flow can, in some cases, result in mortality due to stranding and desiccation. Inadequate streamflow can adversely affect spawning success and the incubation of eggs. The rate of migration can also be altered by unnatural discharge regimes and extended periods of inadequate streamflow" [12].

Mitigation of low flow impacts can be achieved by maintaining minimum flows. In strict run-of-river plants the minimum flow released will be the same as the natural flow so that no new impacts will be imposed upon the upstream and downstream environments. Potentially, there are two major problems associated with implementing instream flows: (1) economic penalties associated with meeting the specified flow requirements, and (2) difficulties associated with determining adequate instream flows [11]. The above mentioned guidelines based upon percentages of average annual flow may be used in determining minimum flows for seasonal peaking plants. There are currently no general minimum flow criteria for hydropower plants which operated on a daily store-release mode. The most important consideration for plants with this operational mode is that tailwater elevation should not be allowed to drop to an exceedingly low elevation.

Granite Falls Dam - Water Level Fluctuations and Instream Flows

The Granite Falls hydropower facility has been operated with daily peaking for over 50 years. Headwater drawdown equal to and greater than 2 ft is common throughout the hydroplant's operating history. There is also a history of allowing no flow through the dam for extended periods of time (e.g. 2→3 days). The river has long since adapted to the fluctuations in water level and flow caused by peaking, and the proposed development will not greatly alter the traditional hydroplant operation.

The daily peaking operation does not greatly alter the tailwater elevation because the tailwater stream reach is impounded by the Minnesota Falls Dam, 2 miles downstream. At low flows discharge at the Granite Falls Dam is essentially from one reservoir to another, i.e. from the Granite Falls reservoir to the Minnesota Falls reservoir. After an initial 6 in. decrease in tailwater elevation, the response of the tailwater surface level to a complete elimination of discharge through the hydroplant is on the order of one day. The minimum tailwater elevation is that of the Minnesota Falls spillway crest, which would still expose only a small portion of the littoral zone.

The Minnesota Department of Natural Resources is currently conducting a study of "Stream Flow Methodology on the Minnesota River" which may establish criteria on daily fluctuations of water level and instream flows.

D. Water Quality

"Developing new sites or retrofitting existing sites for hydroelectric generation can alter water quality in both the impoundment and the tailwaters. The significance of this issue is primarily dependent upon operation of the facility, thermal stratification of the impoundment, and the location (depth) of the outlet. Most projects operated in a run-of-river mode will have only limited pondage, thus strong stratification will be unlikely due to short water detention time. Projects with existing dams that are operated in this manner would not be expected to significantly alter the water quality of the river over that which existed prior to retrofitting the dam for power production" [12].

Potential water quality consideration in tailwaters below dams include:

1) Alteration of temperature regimes,
2) Reduced turbidity,
3) Changes in dissolved oxygen,
4) Increases in the dissolved form of some metals, and
5) Altered nutrient and organic matter regimes [11].

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

High concentrations of suspended sediments are also possible behind an impoundment. The result in turbidity would reduce the sunlight entering a stream or impoundment and thus reduce biological production. Such turbidity could adversely affect fish and other aquatic life [7]. However, this would not pose a problem at sites where an existing dam has been in place for many years (since the environment would already have been adjusted). The volume of water released at a run-of-river facility depends upon the natural flows and therefore would not alter the stream's ability to dissolve possible contaminants already being released downstream of the site.

Water Quality - Granite Falls Dam

The most noticeable physical aspect of Minnesota River water is its turbidity. Silt has always been common in the entire Minnesota River and most of its tributaries. The very name "Minnesota" means slightly-cloudy water in the Dakota language.

At periods of low flow or during the winter months the water reaches its maximum clarity and will be transparent to a depth of perhaps 3 ft, but rarely more. At normal to high flows the light penetration may be as little as 6 to 12 in. [14].

The main source of the turbidity is the colloidal clay found throughout most of the Minnesota River watershed. It is exposed in deeply eroded gullies and on exposed bluffs where standard erosion correction methods are often not applicable, economical, or practical. The SCS (Soil Conservation Service) is working toward the stabilization of top soil in the agricultural areas in the watershed by introduction and teaching of modern farming and soil erosion control techniques [14].

Another suspected cause of turbidity is the heavy carp population. It is probable that the carp present in the river are responsible for some of the water turbidity, especially in the summer and early autumn months when the water is warm and carp are feeding heavily [14].

A general comparison of water qualities from three Minnesota rivers, the Minnesota River, the St. Croix River and the Red River of the North, is given in the Appendix. An additional table on water quality gives a further chemical breakdown of the Minnesota River. Also given in the Appendix is a section entitled "Interpretation of Data," taken from a biennial report published by the Minnesota Water Pollution Control Commission entitled, "Water Quality Sampling Program." This section gives an excellent account of the meaning of the data presented in the water quality tables.

In general, the water of the Minnesota River is very hard, having both a high temporary or carbonate hardness (as shown by total alkalinity analysis) and high permanent or sulfate hardness as indicated by earlier analyses by the U. S. Geological Survey (USGS). Sulfate analyses reported by the USGS averaged 178 parts per million with a range of 76 to 383. The water also has high nutrient concentrations as indicated by analyses for both phosphorous and nitrogenous compounds.

During the period of observation (July 14 - August 12, 1965) three of the 55 stations supported light growth of higher aquatic vegetation. All of these stations were in the upper reaches of the river. Arrowhead (Sagittaria) and water smartweed (Polygonum) were observed. The high turbidity of the water discourages growth of both higher aquatic plants and algae. During prolonged low water stages in the upper Minnesota River, it is believed that the water would clear and the bottom stabilize long enough to allow some plant growth. Water chemistry tests show the quality of water present in the Minnesota River is capable of supporting such growth. However, it is doubtful that higher aquatic plants would do well in the face of the heavy, rough fish population present in the river. Under favorable conditions such as clear water, extensive algal blooms might develop. Preliminary investigations by the Minnesota Research and Planning Section indicate that phosphorous is the key element in promoting algal growth. In most southern Minnesota lakes a total phosphorous reading of over 0.1 ppm usually means algal problems. Water chemistry tests of Minnesota River water show readings well above this level.

Heavy siltation, such as is found in the Minnesota River, is known to inhibit reproduction, feeding, and general well being of many game fish [14].

Municipal and industrial pollution, while not a pressing problem on most of the upper river, is suspected of being a factor in the fish kills that have occurred during winter months between New Ulm and Mankato. Fish kills due to low oxygen during winter months have not been reported or observed above New Ulm [14].

While some of Minnesota's finer game fish such as smallmouth bass and northern pike are habitants in this river, they play a minor role in the sport fishery. Stretches of the river influenced by pollution, such as suspended solids, degraded wastes, and other foreign materials will not support a fishable population of many kinds of game fish. A few walleye, however, are found in some of the polluted areas.

No information is available as to what effects, if any, pollution is having on the bottom fauna in the river [14].

The Granite Falls Dam reservoir has a low storage capacity and a corresponding small hydraulic residence time. At the normal storage capacity of 10 million cubic feet, and the average annual stream discharge (700 cfs), the hydraulic residence time of the reservoir is only four hours. At 40 cfs, the flow exceeded 95 per cent of the time, the reservoir hydraulic residence time is still only three days. In addition, reservoir depth at the spillway was measured to be only 9 ft [1]. With the short hydraulic residence time and shallow reservoir depth at the Granite Falls Dam, a strong thermal stratification is unlikely during operating periods. It is therefore unlikely that the dissolved oxygen concentrations of the reservoir will be depleted during facility operation. The water quality problems associated with dissolved oxygen depletion, such as high nutrient levels, heavy metal and toxics released from reservoir sediments, and high biochemical oxygen demand, will not occur. In addition, the facility intakes will take water from the complete water column.

This will eliminate the possibility of selective withdrawal of cold hypolimnetic water. The facility will not significantly alter the natural downstream temperature regime.

E. Fish Passage Through Hydraulic Turbines

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

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

The mortality of fish passing through hydraulic turbines has been shown to correspond to various turbine characteristics [15]. For example, the survival of fish was found to be at a maximum when the turbine was operated at maximum efficiency. Furthermore, fish survival is greater when cavitation is eliminated in turbine operation.

Most of the new turbine designs have not been tested for fish mortality. However, many of the newer designs are of the propeller type. Studies have been conducted on similar turbines in the past. The results indicated that of the many factors affecting fish passage through turbines, "... cavitation is believed to be the most serious. Decapitation and the production of 'pulpy' tissues and internal hemorrages 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" [15]. 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 Granite Falls Dam, because the pressure changes are not as severe. Recent tests have indicated fingerling survival rates as high as 97 per cent for low-head hydropower facilities*.

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

Fish Passage Through Hydraulic Turbines - Granite Falls Dam

The hydroelectric plant at Granite Falls is currently in operation. Therefore, any change in plant operation or turbine units will have a limited impact upon fish mortality.

"It is important to put turbine related fish mortality at conventional hydroelectric facilities into perspective. Turbine related mortality is only one of many causes of mortality to downstream migrating juveniles as a result of hydropower development; other factors affecting survival are spillways, downstream passage facilities, predation, and delay in migration" [16]. With the trash racks currently in place, only the smallest juveniles are capable of being passed through the turbines. All downstream migrants which are too large to pass through the trash racks will be passed over the spillway (as has been done historically).

Most fish in the Minnesota River are sedentary. However, fish which do enter the turbine may be subject to mechanical injury with the turbine runner or internal injury due to pressure changes. However, it is known that the highest fish survival rates occur when the turbine is operated at maximum efficiency. This condition is a goal which will be strived for

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

in the operation of the plant since it will produce the most efficient power production from a given stream flow. Problems encountered by fish due to cavitation will also be minimized when the turbine is operated at maximum efficiency.

The above results were obtained from tests on older model turbines. "The relationship of studies conducted to date on the newer turbine designs, which are currently being installed in small-scale hydropower operations, is unclear; more data need to be obtained or more modern small-scale prototypes" [16]. The turbines which are being considered for installation at Granite Falls do not appear to pose any significant problems to fish passage.

Impingement against the trash racks is another potential source of fish mortality at the Granite Falls Dam. At design discharge, the average velocity through the existing trash racks is 1.1 ft/sec. The average velocity through trash racks at a new powerhouse may be as high as 2.5 ft/sec. Neither of these trash rack velocities will cause severe fish impingement problems, but some limited fish impingement may occur.

F. Construction Impacts

In some circumstances, it is possible that the impacts due to construction activities may be greater than impacts associated with normal plant operation [16]. The primary construction impacts are related to dredging and disposal of dredged material. An analysis of the accumulated sediments should be taken to determine whether or not the sediment contains large amount 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 [12].

The physical effects due to dredging operations include resuspension of sediments, changes in water circulation patterns, changes in particle size and porosity of sediment, mobilization into the water column of nutrients,and contaminants present in resuspended sediments [11]. Potential adverse impacts to biological systems as a result of dredging operations include loss of primary production and stress to fish due to increased turbidity, destruction of benthic habitat, and secondary effects on aquatic biota from resuspension of nutrients, heavy metals or toxic contaminants,and disposal of dredged material [11].

Dumping the spoil on the river's bank might result in sediment runoff and possibly toxic pollution where chemicals are found in the dredged spoil. On the other hand, dredged spoil might well be used in nearby landfill projects which pose no threat to either the terrestrial or aquatic environments [7]. If the sediments at the site are highly contaminated, it may be necessary to use specialized dredging equipment and upland disposal which may result in high transportation costs [8].

"Disturbance of bottom sediments may result in changes in the species composition, distribution, and abundance of benthic invertebrates. Resuspension of sediments during reservoir dredging operations or runoff from the disposal site, if located adjacent to the reservoir, can increase silt deposition below the dam. Biological consequences could include (1) destruction of fish spawning areas, (2) alteration of benthic invertebrate habitats, and (3) smothering of mussels, submerged macrophytes, benthic algae, and invertebrates" [12].

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

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

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

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

Construction Impacts - Granite Falls Dam

The effect of construction activities would be temporary but could have potentially adverse impacts to the environment. The most significant problem which could occur during construction activities would be an adverse effect on water quality. All necessary precautions should be taken so that no excessively turbid water is released to the stream. Of prime importance is the fact that construction should be scheduled such that there will be a minimal effect on fish spawning season. If a lowering of water surface level is required for construction purposes, it should be done in such a way as to not interfere with the operations of the Granite Falls Municipal water supply or the NSP power plant. Also, a construction period water level fluctuation should be done as to not interfere with the littoral zone ecosystem. All necessary state and federal permits should be obtained. A consultation with these agencies well in advance of scheduled construction is advised to insure that all regulations will be followed and to prevent delay in the project.

Fish species and diversity taken above and below the Granite Falls Dam through electro-fishing are given in Tables 13 and 14 [14]. There are limitations to the information given in these tables because the method is only applicable to a depth of 8 ft, and there were locations which exceed this depth, especially behind the reservoir. In all cases both river discharge and turbidity were high, which makes it even more difficult to obtain a representative fish sample. These three obstacles account for the fact that no catfish were taken through electro-fishing from the Granite Falls Dam reservoir even though there is an established catfish sport fishery in this stretch of the river [14].

Tables 13 and 14 also give the spawning season for each fish species. Many construction activities involve excavation and dredging. Cofferdams around the construction area will minimize the impact of these construction activities. Turbid water should not be released during fish spawning season. In addition, dredging activities should be such that no municipal water supplies are contaminated. This study recommends that construction activities be timed to minimize the release of turbid water during April and May, the most critical fish spawning period for the Minnesota River at Granite Falls.

Testing and/or sampling of the sediment should be taken to determine its physical, chemical, and biological characteristics to make a proper determination of adverse effects caused by sediment resuspension. A suitable disposal site for the dredge material should also be chosen.

Close coordination with state agencies is a necessity to insure that all regulations and restrictions are met.

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

TABLE 13. Species and Diversity of Fishery Taken Upstream of Granite Falls Dam to 8 ft Stream Depth [13]

Species*	Total No.	Per Cent Composition	Spawning Season
Carp	122	78.2	Mid-May
Bigmouth-Buffalo	12		April-May
Quillback	10	6.4	--
Walleye	3	1.9	Spring shortly after spring thaw
Northern Pike	3	1.9	April-early May
Northern Redhorse	2	1.1	Late May-Early June
Silver Redhorse	2	1.1	Late May-Early June
Golden Redhorse	1	0.6	Late May-Early June
Sheepshead	1	0.6	May-June

TABLE 14. Species and Diversity of Fishery Taken Downstream of Granite Falls Dam to 5 ft Stream Depth [13]

Species*	Total No.	Per Cent Composition	Spawning Season
Carp	522	59.7	Mid-May
Quillback	136	15.5	--
Redhorse	72	8.2	Late May-Early June
Silver Redhorse	52	5.9	Late May-Early June
Bigmouth Buffalo	25	2.9	April-May
Walleye	26	3.0	Spring shortly after thaw
Channel catfish	9	2.0	April-May
Northern Pike	4	0.5	April-early May
Sauger	5	0.6	April-May
Shortnose gar	5	0.6	June
Sheepshead	3	0.3	May-June
Smallmouth bass	3	0.3	May-July
White bass	1	0.3	May-June
Mooneye	3	0.3	May-June
Gizzard shad	3	0.2	May-June
Goldeye	2	0.2	May-June
Hogsucker	2	0.1	May-June
Golden redhorse	1	0.1	Late May-Early July
White sucker	1	0.1	Mid-May

Location: Downstream of Granite Falls Dam

*Bullheads were not recorded.

affected. "Many older hydropower sites, while not of national significance, have played an important role in the local history of an area and thus important enough to stimulate local concerns. Additions and other needed alterations of the exterior of a structure should be designed in keeping with the historic and aesthetic value of an area, especially if other historic structures are in the close proximity" [18]. Sites on the National Register of Historic Places are given special protection by federal law. Therefore, it is important to review each site for potential archeological, cultural, and historic significance.

Correspondence with the Minnesota Historical Commission, given in the Appendix, indicates that the Yellow Medicine County has not been surveyed for historic standing structures. The Minnesota Historical Society should be contacted before any changes to the existing powerhouse structure are undertaken.

H. Endangered Species

"The development of sites with existing dams could be expected to have less of an impact on populations of threatened or endangered species because the degree of habitat alteration would, in most cases, be less than usually associated with the construction of new dam/impoundment systems. Retrofitting existing dams, however, could significantly affect the mussel fauna of a river or stream where the existence of small undeveloped dams has actually enhanced these populations. These dams function as silt traps and thus have reduced downstream siltation in rivers and streams that had previously been degraded by heavy sediment loads from erosion and runoff in the watershed. As a result, remnant mussel populations often exist in the spillways below such dams. These populations are frequently the only remaining mussels in these rivers or streams and often consist of threatened or endangered species. When the dams are retrofitted for hydroelectric power production, dredging and water level fluctuations could adversely affect these species" [10].

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

Endangered Species - Granite Falls Dam

There are no endangered animal species identified by the U. S. Fish and Wildlife that will be affected by the Granite Falls project. The Minnesota Natural Heritage Program (Minnesota Department of Natural Resources) has surveyed the project area and determined the five-line skink (*Eumeces fasciatus*), a lizard that constitutes the family Scincidae, as an endangered species of the area. The proposed hydropower project, however, should not pose any threat to the skink. In addition, the Minnesota Natural Heritage Program concluded that there is no occurrence of priority plant communities at this site. Therefore, the operation of the Granite Falls plant will not interfere with any endangered plant or animal species.

I. Recreation - Granite Falls Dam

Landforms surrounding the Minnesota River possess a wide variety of natural amenities that make the Granite Falls portion of the river a valuable natural and scientific area. Perhaps the most important features of scientific interest in this shoreland area are the unique geologic formations, specifically the outcrops of granite rock. Some outcrops, more than three billion years old, are the oldest rocks found in North America.

The Minnesota River valley provides areas for hunting, fishing, and many other recreational activities. In addition to the abundant fish and wildlife, the Minnesota River has many parks and accesses along its banks. In the Granite Falls region there is the Spartan State Wildlife Management Area and the Granite Falls Memorial Park [19].

The Minnesota, a gentle river interrupted by few rapids, is one of the few canoeable waters of any kind in that part of the state, underscored by the rivers value as a recreational resource.

Because of the Minnesota River's rich resources it has been placed under the State Wild and Scenic River Act from Lac Qui Parle Dam to Franklin. This reach includes the Granite Falls Dam.

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

J. Agency Contacts/Correspondence

Close coordination with public agencies is essential early in the developmental phases of the project to assure that regulatory requirements and acceptable policies become known. "Both beneficial and adverse effects of small hydropower development will be a function of project design and operation as well as the nature of the existing environment that will be altered. Successful mitigation of adverse effects associated with such development will depend upon (1) accurate prediction of the magnitude of adverse impacts and (2) early awareness of potentially significant 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" [10].

It should be noted that mitigation of impacts at existing dam sites should be viewed in the context of an already perturbed environment [20]. 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" [8].

The various stage contact agencies, as well as letters of correspondence, are included on the following pages [21].

STATE AGENCIES TO BE CONTACTED FOR SMALL HYDROPOWER DEVELOPMENT

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

      The decision to issue single permit is made on a site specific basis.
   d. Generally DNR requires permits for raising or lowering of spillway level, fluctuating water level,and discharge which are different than historical records, dam modification, dredging and disposal of dredged material (spoil), shore protection, riprap, shoreline excavation, partial or complete drainage, water level control structure, stream or channel enlargement , or relocation.
2. MINNESOTA POLLUTION CONTROL AGENCY
   a. Inquiries to the Director, Attn: Permit Section - Water Quality
   b. The 1977 Clean Water Act gives authority to the MPCA to certify hydropower projects. This MPCA Certification is a prerequisite for permitting by FERC, COE, Coast Guard or any other Federal Agency issuing permits of this type.
   c. The MPCA has authority to become the primary agency issuing NPDES (National Pollutant Discharge Elimination Systems) permits,

replacing FERC, Corps, etc., but has not exercised this authority. They may possibly do so in the future.

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

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

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

a. Power Plant Siting

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

b. Environmental Planning

Current Rules

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

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

<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.

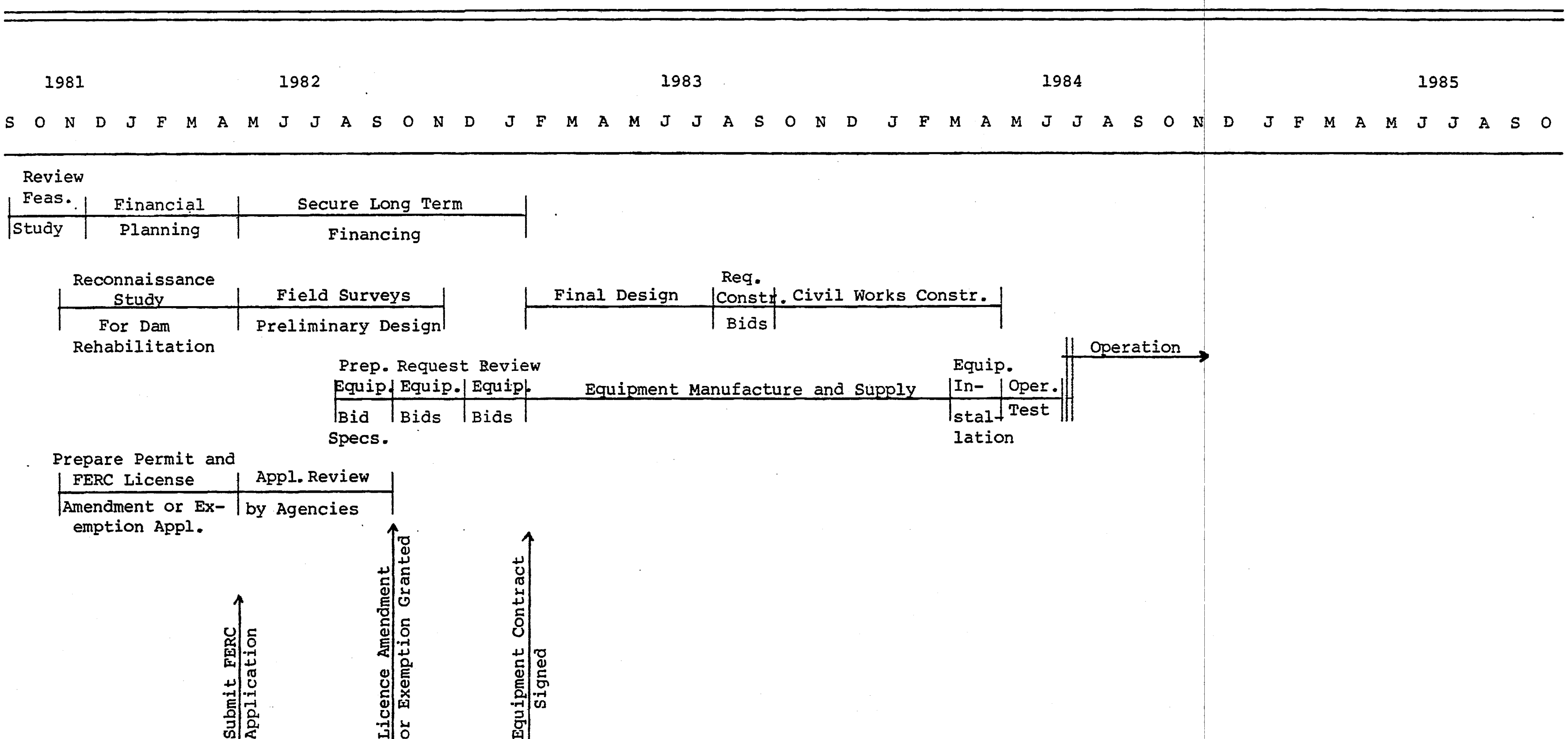
XI. PROJECT FINANCING AND IMPLEMENTATION

There are two types of project financing which are being considered for the development of additional power capacity at the Granite Falls Dam. The first is to issue Municipal tax-exempt bonds. The City of Granite Falls has an A-bond rating. As of July 24, 1981, Moody's Tax-Exempt Market Index was 11.20 per cent for A-rated bonds.

A second option is to obtain federal loans or loan guarantees to finance the project. The most likely source of federal funding for the City of Granite Falls is the Farmers Home Administration (Fm HA). Under the Rural Energy Initiative the Fm HA had offered 30 year, 5 per cent loans for small scale hydropower development. The availability of this funding, however, is currently in doubt.

Table 15 gives a proposed project implementation schedule for the timely development of the site. This schedule is likely to be revised at later stages of project development. The project implementation schedule assumes tax-exempt bonds will be issued by the City of Granite Falls for project development.

TABLE 15. Suggested Project Implementation Schedule for Development of Additional Hydropower Capacity at the Granite Falls Dam



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APPENDIX

Comparative water quality of the St. Croix River, Red River of the North, and Minnesota River during spring flows*

	St. Croix River Osceola, Wis.	Red River of the North Breckenridge, Minn.	Minnesota River Courtland, Minn.
Flow (cfs)	11,100.00	679.00	2300.00
Date collected	4-17-62	4-22-63	3-26-63
Water temperature (°F)	41°	41°	34°
Total Coliform Group Count (MPN/100 ml.)***	200.00	400.00	2300.00
Suspended solids	7.60	32.00	190.00
Suspended Volatile Matter	4.40	13.00	160.00
Turbidity value	10.00	20.00	100.00
pH value	8.20	8.60	—
Chlorides	1.90	18.00	8.00
Dissolved oxygen	11.50	14.50	16.00
5 day B.O.D.	5.50	7.50	11.00
P. (Phosphorus)	—	0.19	0.45
NH_3 (Ammonia)	0.20	0.06	0.80

* Results in mg/liter (PPM) except where noted.

** See Interpretation of Data, page 42 of Appendix for explanation of meaning of above data.

*** MPN: Most Probable Number

Comparative water quality of the St. Croix River, Red River of the North, and Minnesota River during fall flows*

	St. Croix River Osceola, Wis.	Red River Breckenridge, Minn.	Minnesota River Courtland, Minn.
Flow (cfs)	3,440.0	544.00	2600.00
Date collected	9-10-62	10-1-62	9-19-62
Water temperature (°F)	64°	60°	---
Total Coliform Group Organisms (MPN/100 ml.)**	200.0	780.00	33,000.00
Suspended solids	5.6	44.00	53.00
Suspended Volatile Matter	2.8	12.00	11.00
Turbidity value	15.0	19.00	30.00
pH value	7.5	8.40	7.90
Chlorides	4.0	10.00	5.00
Dissolved oxygen	7.0	8.80	10.10
5 day B.O.D.	1.3	6.50	4.30
Phosphorus	---	0.20	0.28
NH_3 (Ammonia)	less than .1	0.16	0.08

* All results in mg/liter (parts per million) except where noted.

** MPN: Most Probable Number

Chemical analyses of three water samples taken at different locations from the Minnesota River. All analyses in parts per million

	Granite Falls 8-13-65	New Ulm 8-13-65	Mankato 8-13-65
Total alkalinity	248.000	270.000	285.000
Total phosphorus	0.170	0.158	0.158
CO_2 (carbon dioxide)	28.000	35.000	15.000
Ammonia	0.000	0.015	0.000
Total Kjeldahl Nitrogen	3.450	1.130	1.350
Nitrites	0.071	0.030	0.024
Nitrates	0.092	0.000	0.000
Total Nitrogen	3.573	1.160	1.374

Interpretation of Data

Total Coliform Group Organisms

The total coliform group of organisms by definition includes all of the aerobic and faculative anaerobic, gram negative, non-spore forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35° C. This group commonly includes the Escherichia coli which are normal inhabitants of the intestines of all warm-blooded animals and the Aerobacter Aerogenes which are often found in the soil, or other non-fecal vegetable matter. The total coliform group is ordinarily used as a general indicator of the possible presence of mammalian fecal material (sewage) and therefore, by inference, of the possible presence of human pathogens. Where intimate contact is made with the water, it is generally recommended by public health authorities that the total coliform group organisms in the water should not exceed 1,000 MPN* per 100 ml.

Suspended Solids

Suspended solids are the main cause of turbidity and discoloration in water although there often is no direct correlation. Discoloration is esthetically offensive, and in highly turbid waters the penetration of sunlight may be reduced so as to interfere with the production of oxygen by photosynthesis. Suspended solids in large amounts may create sludge deposits and blanket spawning beds or other desirable bottom areas.

Suspended Volatile Matter

Suspended volatile matter is used an an indication of the decomposibility of suspended matter, such as the organic solids associated with sewage or industrial wastes. Suspended volatile solids have in general the same pollutional effects in a stream as indicated above for total suspended solids, plus the attributes of consuming dissolved oxygen from the water and releasing noxious and toxic gas.

Turbidity Value

A condition due to fine material in suspension which may not be of sufficient size to be seen as individual particles by the naked eye, but which reduces the passage of light through liquid. High turbidity is undesirable in natural waters particularly those which are used for recreation. It is esthetically objectionable and in extreme cases may even be a hazard to the safety of others.

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* MPN - Most Probable Number

Chlorides

Chlorides are universally present in sewage and many industrial wastes. In large amounts they may give a salty taste to drinking water. The U.S. Public Health Service (1961) Drinking Water Standards recommend that the chloride content not exceed 250 parts per million. Chlorides are not removed by any conventional sewage or waste treatment processes, and are therefore used as a general indicator of the presence of domestic or industrial effluents.

Biochemical Oxygen Demand, 5-Day

This is an arbitrary or empirical measure of the quantity of material in the stream which under specified conditions will take dissolved oxygen from the water. The 5-day demand at 20° C. is the accepted primary indicator of water pollution from the viewpoint of measuring the load on the oxygen resources of a stream.

Phosphorus and Nitrogen

Phosphorus is an essential nutrient for algae and weed growths.* It is generally considered to be the limiting element in the development of such nuisance blooms or growths in the absence of manmade pollution. Nitrogen is also very important as a nutrient but some forms of algae can take nitrogen directly from the air while phosphorus can be obtained only from the water.

Ammonia

Nitrogen is an essential constituent of all living organisms. In the decomposition of organic matter it undergoes changes from complex proteins through amino acids to ammonia, nitrites and nitrates. In low concentrations ammonia acts as a nutrient and may stimulate nuisance algae blooms and weed growths. In high concentrations it may have a serious toxic effect upon fish and other aquatic fauna. Ammonia is commonly found in waters which are heavily polluted with sewage or other organic wastes, and it is thus considered a general indicator of recent organic pollution.

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* 0.10 ppm is sufficient phosphorus to produce heavy algae blooms.

MINNESOTA HISTORICAL SOCIETY
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5 June 1981

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

Dear Mr. Gulliver:

RE: Review of the historical significance of Granite Falls Dam (Yellow Medicine County) and Kettle Falls Dam (Pine Co.)

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 Pine County was recently surveyed for historic standing structures. As a result of this survey, the Kettle Falls dam was identified and listed as an inventory structure. Although it has historic value, it was determined at this time that it was not eligible for inclusion on the National Register of Historic Places. However, it is our opinion that the structure should be re-evaluated in the future.

With regard to the Granite Falls dam, our records indicate that Yellow Medicine County has not yet been surveyed, and, therefore, we have not assessed the historical or architectural significance of the structure. From the information that you have provided, it appears that like the Kettle Falls dam it is of historic interest, but it may not be eligible for inclusion on the National Register of Historic Places. However, prior to making a final determination, our office would like to review the photos of the original dam construction, and photos of the present dam.

This information should be submitted to Ms. Susan Hedin, Environmental Assessment Officer, State Historic Preservation Office, 240 Summit Avenue, St. Paul, MN 55102, (612) 296-0103.

Thank you for your attention to cultural resources in your planning process.

Sincerely,

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

RWF/sl