Feasibility of Low Head Hydroelectric Development

At High Falls State Park, Monroe County, Georgia

MASTER

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HYDROELECTRIC DEVELOPMENT
AT
HIGH FALLS STATE PARK
MONROE COUNTY, GEORGIA

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MAY, 1979

BY

STATE OF GEORGIA
OFFICE OF ENERGY RESOURCES AND
DEPARTMENT OF NATURAL RESOURCES

WITH
GEORGIA INSTITUTE OF TECHNOLOGY

AND

→ THE CADRE CORPORATION

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FOREWORD

The High Falls State Park low head hydroelectric feasibility study has been conducted for the State of Georgia and the U. S. Department of Energy by Georgia Institute of Technology's Engineering Experiment Station and the Cadre Corporation. The study has been funded by the Department of Energy with cost sharing from the State, Georgia Tech, and Cadre.

This report describes the technical, economic and environmental aspects of developing a hydroelectric facility that would be suitable and blend with the varying activities of the state park. Factors have been investigated that would often be less important to a private sector analysis, but which are critical to an environment where the production of power is desired, though not the primary function. The program manager for the study was Mr. Robert W. Harvey from the Georgia Office of Energy Resources. The State's Department of Natural Resources provided environmental inputs coordinated by Mr. Steve Schmidt.

The Georgia Institute of Technology had the prime responsibility for performing the study and utilized the Cadre Corporation for subcontracting assistance. The research team from Georgia Tech consisted of the following key individuals with their principal areas of contribution:

Dr. Neil B. Hilsen	Principal Investigator
Dr. George R. Fletcher	Technical Analysis and Design
Mr. M. John Moskaluk	Systems Analysis
Mr. J. Edward Jacobson	Economic Analysis
Mr. James R. Marks	Hydrologic Analysis

Important contributions were also provided by Dr. James R. Wallace and Dr. Charles S. Martin from the School of Civil Engineering in the hydrologic aspects of the study.

The Cadre Corporation was responsible for the facility design and related analysis and provided valuable inputs to the study. Key personnel were Mr. Donald D. Battles, Mr. James M. Austin and Mr. Gary C. Pool.

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EXECUTIVE SUMMARY

A source of electric power that is potentially feasible results from the use of existing dams with a low available head. Recognizing this, the U. S. Department of Energy has provided funds to the State of Georgia for conducting a feasibility study of constructing a hydroelectric generating facility at High Falls State Park. The purpose of the study has been to explore the technical, economic and environmental aspects of developing a facility that would be suitable for the multiple-purpose functions of the park. The dam was built in 1905 and used for generation purposes until 1958 when the site was abandoned due to economic problems. Due to the 20 meter maximum head limit imposed on the study, the original generating facility, which had a head of 33.5m (110 ft.), has not been assessed. Three other locations, however, have been assessed which fell within the low-head constraint.

The overall objectives of this project have been to (1) assess the feasibility of a hydropower facility at High Falls State Park from technical, environmental, and economic view points; (2) assess the economic, environmental, social, institutional, and marketing constraints and impacts that affect the development of a hydropower facility; (3) prepare a set of conceptual design drawings and specifications concerning the facility, distribution system, location, equipment size, duty cycle, and other performance parameters; (4) develop a construction schedule with estimated costs; and (5) prepare a report that provides the basis for a design proposal for the facility implementation. The park has been selected for study because it would provide a large array of variables in the technical, economic, environmental, and social aspects of revitalizing the generating potential of the Towaliga River. The overall program plan consists of: (1) site assessment; (2) facility design; (3) energy production estimates; (4) economic analysis; and (5) environmental and socio-institutional assessment.

The design concept employed for this study has taken maximum advantage of standardized and pre-engineered package systems. Specific resources, constraints, and limitations are identified and a design selected; this design is utilized to conduct further economic analyses. The key results of this study are presented briefly in the following paragraphs.

Results

A typical year of flow data has been derived to represent expected flow conditions through the life of the facility. The average flow during this typical year is 231 cfs. The monthly flow distributions have been used for analytical purposes to account for seasonal variations. The lowest month, September, has an average flow of 96 cfs while the highest month, March, has an average flow of 363 cfs.

The Department of Natural Resources (DNR) set reasonable constraints to insure compatibility of the final design with primary park functions such as fisheries management, camping and recreation, and natural and cultural resource interpretation. The primary constraints imposed are: maintain flow over spillway and falls between sun-rise and 10 pm; maintain vegetation and topography to maximum extent possible; maintain flow downstream; and design the powerhouse to be compatible with existing park structures, as well as aesthetically pleasing.

As a result of a preliminary analysis of the flow characteristics, precipitation patterns, and topography, three candidate sites have been selected with different available heads of 9.14m (30 ft.), 12.5m (41 ft.), and 20m (65.6 ft.). For a combination of reasons (environmental, historical and economic), the 9.14m (30 ft.) head site at the base of the dam has been selected. The turbine selected for this application is a 1150mm vertical axis turbine with an open flume arrangement. The generator is an 8 pole 750 rpm asynchronous machine that can deliver 597 kW at rated operating conditions. The energy will be fed into the Georgia Power Company distribution system through a substation that presently exists 150m (500 ft.) from the proposed powerhouse location. All transformer and switch gear must conform to Georgia Power specifications. It is estimated that this turbine can produce approximately 2,600,000 kWh per year subject to the seasonal variations of water flow.

The small size of this facility combined with the operating constraints defined by DNR, will result in minimal environmental impact, with only minimal variations in the present flow conditions of the reservoir and the stream. There will be no impact in the availability of the recreational uses of the park.

A cost estimate has been made based on the selected system. The result is a total project cost of \$1,050,200 or \$1,760 per kW. This amount includes costs of not drawing down the reservoir or not coordinating construction with required safety improvements to the dam. If these can be allowed, the project could realistically enjoy a savings of as much as \$150,000 of the total cost. It should be

noted that the cost of the generating equipment, installation, and utility intertie is \$411,100, which is only 40% of the total cost. This points out the economy of scale problems associated with constructing a small facility, because the non-equipment cost would be almost the same if the generating capacity were doubled or tripled.

The decision criterion for an investment such as this is whether the benefits exceed the costs, and in comparison to other projects whether the excess of benefits is greater than that of other alternative projects. The choice is made among the alternative locations and technological options. The evaluation of benefits is based on the assumption that the capital investment is made with money borrowed with general obligation bonds at the prevailing rate of interest, requiring annual payments of equal size for the term of the bond to pay it off. Costs and benefits accruing in the future are discounted at the social discount rate (assumed at a value of 5.5%).

The resulting net present value (NPV) of the stream of benefits and costs of the facility is \$110,000. The nature of the assumptions imply that this amount is a lower bound on the expected NPV of the facility. The nominal values assigned in this analysis have been derived from a very conservative viewpoint. By removing some of the less binding constraints, and by assuming a rise in energy prices of two percent per year, the net present value of the facility comes to \$441,000. However, this amount is not an extreme; the actual benefits and costs over the life of the facility may realistically be expected to exceed this NPV.

Conclusions

The analysis of this project shows the proposed hydroelectric generating facility and site to be technically, environmentally, and economically feasible. The low head hydro technology is well developed with operational equipment "off the shelf." Construction will not present a major problem or be permanently harmful to the environment. On the other hand, there are institutional concerns that bear heavily on the economic value of the proposed facility. These issues are related to how the facility would be financed and how the operation would affect the park functions and activities. Also, the head limitation imposed on this study has prevented the old powerhouse site from being considered as an available alternative. This site appears to satisfy all identified constraints and offers economic benefits far greater than the proposed facility. These factors must be addressed in more detail before the total value to the State is determined.

Therefore, the recommendation to the State of Georgia is to forego making the investment at this time in the proposed facility until the above issues are resolved.

SECTION 1

INTRODUCTION

SECTION 1

INTRODUCTION

Background

Americans have become accustomed to abundant, inexpensive energy, and thus have developed a stock of capital goods, such as homes, automobiles, and factories, which require relatively large energy inputs. However, over the past six years, recurring energy shortages of traditional fuels such as oil and gas, and subsequent energy price increases, have dramatically focused public attention on the necessity of ample energy supplies to the nation's social and economic well-being. Thus, within the past few years, both government and private industry have drastically increased efforts to seek new domestic supplies of the traditional fuels, as well as develop alternate energy technologies, such as solar, geothermal, and biomass conversion.

In the search for sources of energy to relieve our dependence on depletable fossil fuels, hydroelectric generation has received relatively little attention. Over the past two decades, environmental issues have been pushed to the forefront, preventing the development of high-head sites on undeveloped rivers, primarily because these sites tend to be scenic and desirable for natural river recreation. This, coupled with the belief that most of the desirable sites have already been exploited, has led many people to consider hydropower as having limited potential and being unworthy of further attention.

Nationally, hydropower contributes about 15% of our electric energy output. Although hydropower will never provide a large share of the national energy budget, it is apparent that we cannot rely on any single source of energy. We must pursue all sources which hold the potential of being environmentally acceptable and economically feasible. One of these potential sources results from the use of existing dams which are not being used for generating electricity and have a relatively low head available.

In order to study the potential of this energy source, the U. S. Department of Energy issued a Program Research and Development Announcement (PRDA). The objectives of the PRDA have been to evaluate and fund feasibility studies on the development of hydroelectric generation at existing small dams. It is under that PRDA that this study is undertaken.

Purpose

The purpose of this study has been to explore the technical, economic, and environmental aspects of the feasibility of constructing a hydroelectric generating facility at High Falls State Park. The Georgia Office of Energy Resources and the Georgia Department of Natural Resources have responded to DOE's PRDA based on an existing dam structure at the park. This dam has been selected for several reasons.

First, there is considerable flexibility in potential markets for the power produced. The State, which owns the dam, can generate the power and has the option of supplying its own needs or selling into the existing grid.

Second, the environmental impact of the proposed facility has been thought to be minimal. The lake is old and ecologically stable, and the facility could be designed so as to avoid damage caused by excessive lake drawdowns or downstream fluctuation. Also, the visibility and accessibility of the site would enhance the value of the project as a demonstration.

Finally, it is believed that since the park has more primary uses other than electric generation, such as fisheries management and recreation, and since much of the surrounding shoreline is privately owned, the site would provide a wide array of variables to be studied.

Objectives

The overall objectives of this project have been to (1) assess the feasibility of a hydropower facility at High Falls State Park from technical, environmental, and economic view points; (2) assess the economic, environmental, social, institutional, and marketing constraints and impacts that affect the development of a hydro-power facility; (3) prepare a set of conceptual design drawings and specifications concerning the facility, distribution system, location, equipment size, duty cycle, and other performance parameters; (4) develop a construction schedule with estimated costs; and (5) prepare a report that provides the basis for a design proposal for the facility implementation.

Specific objectives have included the careful examination of a number of factors that would often be less important, or possibly unrelated to a private sector analysis. Unlike a private site where the objective of maximizing the use of available hydropower can override other uses, the use of a public site already serving a number of public purposes necessitates the careful examination of additional purposes to insure that the original ones are not unduly compromised.

Consideration of these factors and purposes is extremely important for public site development and provides DOE with information to satisfy its objective of assessing potential energy production from low-head applications on a national basis.

Scope

The scope of the study has included the evaluation of three specific sites and the impact each would have on the environmental, economic, and technical considerations. Since the original generating facility had a head of approximately 33.5 meters (110 ft.), the 20 meter limitation in the PRDA has precluded this location from the assessment. However, a limited analysis has been conducted for this site, at no cost to DOE, because, in order to recommend a correct policy decision, a knowledge of all possible options must be available. Many constraints have been identified to define the bounds and to deal with the large array of variables involved. The design concept has taken maximum advantage of standardized and pre-engineered package systems. Three manufacturers with different designs have been studied. The market for produced power has been considered to be the Georgia Power Company, the Oglethorpe Power Corporation, and the High Falls State Park. Economic decision criteria have been established to satisfy both the Department of Energy and the State of Georgia. The Department of Natural Resources, which now manages the park in which the dam is located, is mandated by law to promote environmental protection, fisheries management, and public recreation. Thus, the situation exists in which the optimal technical configuration for power output could possibly be discounted due to its detrimental effects on legally mandated park operations.

In summary, the study has served not only to investigate the potential of the existing low-head sites, but also has considered some peculiarities involved in placing a hydro facility into an existing infrastructure where the production of power is desired but is not the primary decision element.

Overview

Section 2 presents the planning environment under which the study has been conducted and identifies the general physical and locational aspects of the State Park, the specific sites available, and the array of assumptions and constraints that have guided the analysis. The approach and decision criteria, which have been followed to choose a final design and site, are described in Section 3, and the detailed analysis of the proposed system is presented in Section 4. The conclusions and recommendations from this study are presented in Sections 5 and 6. Appendices have been used for that material which, though informative and pertinent, is not required for an understanding of the basic results of the study.

SECTION 2

PLANNING ENVIRONMENT

SECTION 2

PLANNING ENVIRONMENT

This section presents a description of the physical planning aspects of High Falls State Park, the alternative hydrofacility site locations, and the assumptions and constraints that have been needed to direct the feasibility effort. Also, the impact that the three sites have on the planning and decision process are identified. This planning information sets the stage for the subsequent analysis and selection of the alternative site and facility configuration.

HIGH FALLS STATE PARK

General Description

High Falls State Park is located approximately 50 miles south of Atlanta at Interstate Highway 75, in Monroe County, Georgia. The park contains a reservoir lake used for swimming, boating, and fishing and offers activities for camping, hiking, and picnicking. The reservoir, dam, and falls serve as the primary resources of the park. The park grounds not including the reservoir is 983 acres in size.

The site, acquired by what was in 1961 the State's Game and Fish Commission, has served an important fisheries function through its use as a testing ground for understanding fisheries management techniques as well as developing public fishing. Additionally, as a state park, the reservoir and falls system serves as a focal point for diverse recreation opportunities, natural and cultural resource interpretation and relaxation.

The park is open all year long, and the yearly attendance exceeds one million people.

Facilities

The park is served by a full-time staff of six people and increased to fifteen during seasonal months. The primary facilities consist of nearly 150 camp sites, a pioneer camp, a swimming beach, boat ramps, playground areas, shelters, a trading post and concession, and many picnicking areas. There is a 1.25 mile nature interpretive trail located near the river falls, and hiking areas exist throughout the park. Figure 2.1 shows the location of existing facilities at High Falls State Park.

Figure 2.1 High Falls State Park Facilities

History of Dam

The water power of the Towaliga River was first harnessed by a grist mill built before the Civil War. Burned by retreating Confederate soldiers, the mill was rebuilt in 1866, then sold to the Towaliga Power Company in 1898, which constructed the dam and generating facilities in 1905. The dam has not been substantially altered since then and is now 74 years old.

About 1925, the Towaliga Power Company was acquired by the Georgia Hydroelectric Company, which was in turn acquired by the Georgia Power Company in 1930. The dam and generating facilities were later sold to the Hiawassee Timber Company. The power plant was closed in 1958 due to economic problems, and in 1961, the dam site and several adjacent parcels of land were donated to the State of Georgia.

The original project was used for power generation by diversion of lake water through a canal and penstock system to a hydroelectric powerplant located ½ mile downstream.

Dam and Spillway

The present function of High Falls Dam is to impound a recreation pool as part of a park setting. The dam impounds the Towaliga River, a part of the Altamaha drainage basin, capturing a reservoir of approximately 740 acres. The dam is a stone and mortar structure placed on bedrock. The stone blocks used for construction were cut from the streambed. The dam is approximately 606 feet long and 35 feet high. The structure is built into banks on either side of the Towaliga River valley. The dam has two spillways with a total spillway length of 415 feet. The main spillway is 400 feet long, and the other is 15 feet long. Figure 2.2 shows a photograph of the spillways as they appear during strong flow conditions. The spillways are ungated continuous flow weirs. The dam has one 4-foot by 6-foot vertical lift gate controlled from the top of the dam.

The reservoir is normally operated at a pool elevation of 587.35 feet above mean sea level (msl) - the elevation of the spillway crest. All inflow to the reservoir is discharged over the two existing spillways. The dam is classified as "intermediate" in size with a normal water storage of 8,600 acre feet. The average depth of the water is only 12 feet due to a large quantity of silt which has built up over the years.

Figure 2.2 Spillways During Strong Flow Conditions

Figure 2.3 Flow over Falls

Falls

The falls result from the steep terrain of the Towaliga River below the dam. The main drop in the falls is located approximately 1,200 feet from the dam face and, at this point, is about 200 feet in width. The slope is about a 50-foot rise to a 100 foot run. These falls comprise one of the key aesthetic features of the park and can be viewed from the nature trail along the river bank. At present all of the water flowing over the spillway cascades down and through the area of the falls. When the old powerhouse was in operation below the falls, some of the spillway flow was diverted around the falls via a canal. Figure 2.3 is a photograph of the falls.

Cultural Resources

Several man-made features of the park offer important historical and archaeological resources. The dam, canal, grist mill foundation, and old powerhouse are major interpretive components of the park, and are a part of the history of the area. Figure 2.4 shows a photo of the canal and old powerhouse. The dam and grist mill foundation are shown elsewhere. Past information exists on the dam and powerhouse, but the historical significance of the grist mill is indeterminate at this time. More extensive research would be required to determine if the mill foundation currently in place belongs to a more recently constructed mill (1900's) or one built in the mid-1800's.

Archaeological significance could potentially exist at the grist mill site. Historical records indicate that Civil War, as well as traditional activities which took place on the site, could lead to important findings.

ALTERNATIVE HYDROFACILITY SITES

Three potential sites besides the original powerhouse have been selected for the location of the facility. They are shown on the site plan in figure 2.5 as being at the dam, at the site of the old grist mill, and at the base of the natural falls.

Site 1 is immediately adjacent to the dam and the canal wall near the south abutment of the dam. The exterior of the facility could be constructed so as to blend with the masonry of the dam and wall. Few, if any, trees would have to be removed from this location. The rock in which the channel has been cut is exposed at this location and appears to provide an excellent foundation for the structure. The available head at Site 1 is 30 feet (9.14m). Penstocks would be short and would

Figure 2.4 Old Powerhouse and Canal

PLAN & PROFILE - TOWALIGA RIVER FROM HIGH FALLS DAM TO OLD POWERHOUSE

SCALE: Horizontal - 1" = 100'
Vertical - 1" = 20'

ALL MEASUREMENTS APPROXIMATE

DRAWN BY: James R Marks
Georgia Tech Engineering Experiment Station -SED -STB
November 30, 1978

Plan & end elevations from site plan by
B.M. Hall & Sons, Engrs.
January 1924

Other revisions based on observations
Elevations adjusted to MSL by JRM. from USGS quad map

REVISIONS	
Added site locations	4-25-79
Added end labelling and scale	4-25-79

Figure 2.5 Site Plan Showing Alternative Sites

enter immediately into the power house from the dam. Figure 2.6 shows a photo of this site.

Site 2 is at the location of the old grist mill. This site is on the south side of the Towaliga about 420 feet downstream of the dam (see Figure 2.7 for photograph). There are no trees that would need to be removed from this site, and it may be possible to lay the penstock in the old canal except for the last 100-150 feet upstream of the hydro facility. The penstocks would thus be visible only over this relatively short distance. The available head at this location would be 41 feet (12.5m). It is possible that the old mill could be reconstructed much along its original lines and that the old mill water wheel be added as part of a demonstration project to illustrate the old and new applications of water power.

Site 3 is also on the south bank of the river, but it is considerably farther downstream than Site 2. The advantage of Site 3 is that a larger head would be available. The powerhouse could be located so that the maximum head permitted under the low head project would be realized. This head would be 65.6 feet (20m), more than twice that available at Site 1. Site 3 is just downstream of the falls and about 1,200 feet downstream of the dam. Figure 2.8 shows the approximate location of the site. Flow could be provided through the old canal except for the last 50 feet or so where the flow would be through penstocks. The configuration would be similar to that at the old powerhouse, but the diversion from the canal would be about 400 feet upstream of the old penstock entrance. Use of Site 3 would require removal of many more trees than either Site 1 or Site 2, and access and construction would be more difficult. In addition, the canal would need improvements, probably by lining with concrete. The flow would be restricted where it passes through a 30-inch culvert at the point where the park road crosses the canal. To provide the required flow, a bridge or larger culvert would have to be constructed at this location.

Overhead power lines running from the power house to the substation would provide a negative visual impact to site development. Site 1 is about 500 feet from the existing substation while Site 2 is at a distance of 250 feet, and Site 3 is about 900 feet from the substation.

In summary, Site 1, 2, and 3 would provide heads of approximately 30, 40, and 60 feet, respectively, and good rock foundations appear to exist. However, utilization of these sites would result in increasing levels of disruption and unsightly impacts with Site 3 being the most objectionable.

Figure 2.6 Site 1
Location - at the
Small Spillway of
the Dam

Figure 2.7 Site 2
Location - at the
Grist Mill (Upper
Center)

Figure 2.8 Site 3
Location - below the
Falls (Right Center)

ASSUMPTIONS AND CONSTRAINTS

The assessment has included a number of factors that would often be less important or unrelated to a private sector analysis. These factors are centered around the legal mandates of the Department of Natural Resources (DNR) which provide that sites, such as High Falls State Park, serve multiple public functions. Thus, the DNR has had to set reasonable constraints to insure compatibility of the final design with primary park functions such as fisheries management, camping and recreation, and natural and cultural resource interpretation. The constraints have been based on the best available data and represent minimums for the multiple purposes that the park serves. Where one resource management function might be unaffected by certain hydropower development actions, other functions might very well be affected. Thus, the more stringent constraint must be selected as the guide for design and operation. Constraints and assumptions have been identified to define the bounds of the study, not only for environmentally-related factors, but for institutional, hydrologic, safety and hardware implementation factors as well.

Environmental Aspects

Environmental concerns are primarily focused on the reservoir and falls as the center of the park's activities. In general, hiking along the falls and around the old mill and powerhouse sites, and swimming would be the most directly affected by the installation of a low-head hydroelectric facility.

Swimming is limited to an artificial beach constructed just above the dam. Because of the nature of its construction, a narrow shelf with a sharp drop just offshore, fluctuations in the water level of the reservoir of more than 2-3 inches would create erosion problems. Visually, such a drawdown of that magnitude would interrupt the flow of water over the 400 foot long spillway and the falls. Since these are the focal points of visual interest and, consequently, the park's major attractions, a minimum flow over the spillway and falls must be maintained at least during the hours between sun-rise and 10 P.M. In addition, because of the scenic qualities of the area, the vegetation and topography of the river's corridor at this point must be maintained as close to its natural state as possible. Thus, potential sites should focus on areas where man-made intrusions already exist.

This points up another area of concern, however - that of the historical and/or archaeological importance of these man-made intrusions. Because the dam, the grist mill foundation and the canal which is linked to the old powerhouse, are

major interpretive components of the park, alterations to the external features of these structures must be carefully weighed and professionally assessed. A reconnaissance of the sites has been performed yielding the following assessment. The historical character of the dam and spillway, in addition to the aesthetic concerns previously stated, dictate that alterations to the spillway would be unacceptable unless required for safety reasons. The archaeological impact at the dam is considered to be of low potential. The historical significance of the mill is indeterminate at this time, and the archaeological potential around the mill is considered to be high because of the relatively flat nature of the terrain. Location of the generator at Site 3, the 20-meter-head study limit set by the PRDA, would have low potential archaeological impact because the nature of the terrain is not conducive to intensive human activity. These topographical limitations continue to make it an unattractive site for intensive development because of the extensive destruction to the natural surroundings required to gain access to the site. In accordance with Federal law, a formal survey is required to insure full consideration of the cultural resources. Insufficient funds and manpower prevent such a survey at this time.

The High Falls site is a source for both recreational fishing trips and for practicing fisheries management techniques in a reservoir setting. Such techniques are not well developed because the vast majority of reservoirs are operated with other objectives as primary. Therefore, to maintain good recreational fishing at High Falls, the operation of any hydroelectric facility must be flexible to account for the evolving nature of fisheries management techniques.

In the winter, minor fluctuations in the reservoir level pose few problems for the fish population. In the spring and summer, however, drawdowns of much more than a few inches are unacceptable. Spawning takes place in the shallow shoreline areas when the water temperature reaches 70 degrees F. Fish populations would be adversely affected by drawdown in these areas. This becomes particularly crucial during the summer as the flow rate declines to its annual minimum.

In the event total renovation of the reservoir is required, however, complete draining of the water would be necessitated. The reservoir would also have to be completely drained in order to change the fish population. This would occur, for example, if an exotic species were to get into the reservoir and cause damage. Complete draining of the reservoir for these types of purposes could take anywhere from one to three months, but would be a rare occurrence.

Drawdowns of up to two-thirds of the volume of the reservoir may be needed every three years on the average. This technique is most often used to shift the population balance in favor of predators. The water level would be the lowest in October and retained at the lower elevation until February. Drawdowns of a few feet in late summer through late spring allow fishery managers to plant grasses around the edge of the lake to be flooded during early summer. This technique, used once every three years, insures excellent survival of young bass.

In designing an economically viable facility, the ability to operate with minimal disruption to the normal flow pattern provides the best assurance of compatibility with fishery management downstream. Flooding of low lying areas provides food production and nursery areas for fish; therefore, the normal flooding pattern of the stream must be maintained. Flow surges downstream must be minimized because of the scouring effects on the banks and the destruction of food sources. A minimum flow downstream from the falls must be maintained at all times to prevent shallow areas from drying out. Because insufficient data exist relating the volume of stream flow to the productivity of the stream, it is impossible at this time to estimate an acceptable minimum flow necessary to maintain a reasonable level of productivity in the stream below the falls. Such data would be time consuming and costly to generate, yet would be necessary to fully evaluate the possible impacts.

The range of sizes identified for the hydropower generator to be installed at High Falls offers no major conflicts with water supply or water quality needs, and practically no impact will be noticed far enough downstream where these factors become more crucial.

Environmental Constraints

1. Aesthetics of Hydro Facility

The hydro facility powerhouse must be constructed using natural materials which blend with the environment.

Penstocks will generally not be visible.

Transmission lines will not be more visually deleterious than at present.

2. Elevation of Reservoir

This will be maintained essentially at the height of the spillway (587.35 ft.)

3. Drawdown of Reservoir

Level of the reservoir will not be allowed to fluctuate more than 2 to 3 inches.

4. Flow over Spillway

Water flowing over spillway will be maintained at a minimum level of .1 feet between sun-rise and 10 P.M.

5. Flow over Falls

A minimum flow of 40 cfs must be maintained between sun-rise and 10 P.M.

6. Flow Downstream

At least a minimum flow must be maintained.

7. Use of Crestgates on Spillway

Alterations will not be made to the spillway except for safety reasons.

8. Fishery Management

Standard fishery management practices will continue to be maintained.

9. Historical Considerations

Only minimal disruption will be acceptable at the grist mill site.

10. Archaeological Considerations

The grist mill site should not be disturbed prior to archaeological investigations.

11. Vegetation and Topography

Must be maintained as close to the natural state as possible.

12. Recreational Use

Erosion must be prevented at the swimming beach.

Institutional Aspects

Since the proposed facility would be controlled by the Department of Natural Resources, its operation would be markedly different from the way a utility company or a private investor would operate the generator. DNR has a completely different set of priorities governing its procedures from private individuals and firms; the constitutional charter of the Department dictates its concerns, and the outlook of the administration adjusts and determines the aspects of park operation that are most important within the mission of the Department. Furthermore, income from the facility would go directly into general revenues and not to DNR.

Related to the control assumptions is the political arena in which decisions are made. Funding for the proposed project would be approved by a legislative decision, in a scenario that reflects a reluctance to finance through the use of debt. On the other hand, the public and many legislators and administrators desire energy independence, environmentally clean alternative sources of energy, and some of the other amenities available from the proposed facility. All capital expenditures of this magnitude must be approved by the Georgia General Assembly, and operating and maintenance costs must be provided for in the annual budgeting cycle.

It has been decided not to use the generated energy for the park or the immediate vicinity. However, it is expected that energy generated at High Falls will be readily disposed of. An arrangement has been discussed with Georgia Power Company that will assure the sale of every kWh generated at a price that depends on their marginal cost. Therefore, the demand for the facilities power is considered unlimited and does not pose a planning constraint.

The Department of Natural Resources must be careful not to breach any of the stipulations in the deed which transferred ownership of the High Falls reservoir to the State. Specifically, the deed requires that a minimum lake level of 587.35 feet above msl be maintained except when dam maintenance, repairs, or fisheries management dictates otherwise. Legislative approval or agreement from all lake front property owners would be required to change this stipulation.

Institutional Constraints

1. DNR Established Priorities

DNR has a set of priorities which must be met that concern both the decision to build the facility and the manner in which it would be run if it were built.

2. Political Decision

The decision to build the facility is a political one.

3. Legal Aspect

The legal covenant requires the lake to be primarily maintained at a level of 587.35 feet above sea level.

Safety Aspects

The High Falls dam has been classified as a "significant" hazard facility based primarily on the presence of a secondary highway bridge immediately down stream from the dam. However, the hazard classification would have been even greater, if there were permanent habitable structures in the flood plain below the dam. As a result of the the Corps of Engineers classification, Lockwood Green and Associates has been retained to perform a complete safety analysis and recommend methods of making the dam safe.

The greatest concern at this time is the possibility that the structure can overturn if flow conditions resulting from extremely high precipitation levels ($\frac{1}{2}$ the maximum probable precipitation) are reached or exceeded. A more detailed analysis of this possibility is currently underway by Lockwood Green, and specific recommendations will be made at a later date. If these levels are probable, the two basic options seem to be to either increase the mass at the base of the dam or

completely demolish and remove the dam. Another option is to lengthen the spillway to protect the dam. However, this appears unfeasible due to the existing terrain near the spillway. Recommended improvements that will most likely be made include the repair of several small leaks and outlet gates at the base of the dam.

The safety aspects related to the facility include design feature considerations that would protect the general public as well as personnel who are performing routine maintenance. Protective screens should be provided where the water is fed to the turbine inlet; and the area around the turbine outlet could be dangerous and ought to be "off limits" to the overcurious public. Railings around or on the facility should be required. Other general safety and security features, such as emergency lighting and warning signs, should be included in the final design.

Safety Constraint

A safety constraint on the design of a hydro facility has not been specifically identified in this feasibility study. It has been assumed that adequate safety features would be provided at any alternative site or for any equipment selected. It has further been assumed that the dam would remain in place with safety modifications to be recommended at a future time.

Hydrologic Aspects

The drainage area of the Towaliga River upstream of High Falls Dam covers approximately 203 square miles of gently rolling hills occupied by forest and farm land. The drainage area includes parts of Monroe, Lamar, Spaulding, Butts and Henry Counties. Surface elevations range from about 555 feet msl in the river channel just downstream from the dam to a high of about 1,000 feet msl at the upstream end of the watershed. The soils are predominatly sandy silts with medium infiltration characteristics.

Streamflow records are not available for the Towaliga River in the immediate vicinity of the dam. However, a U. S. Geological Survey Gauging Station on the Towaliga did exist in the upper part of the basin for a period of eleven years. The station was located in Butts County, where the river crosses State Highway 16, 6.5 miles west of Jackson, Georgia. The drainage area at this location is approximately 103 square miles. The altitude at this location is about 600 feet msl. The period of record is June, 1960, to September, 1971, at which time the gauge was discontinued. During this period, the average flow was 143 cfs (18.49 inches per year) or about 1.35 cfs per square mile. The maximum recorded

discharge was 7,470 cfs in March, 1973, and the minimum was 6.5 cfs in October, 1970.

To provide an estimate of the flow rates into High Falls Lake, the flow values measured at the U.S.G.S. Gauge station in the upper basin have been used. From a statistical analysis of the flow records, the flow at the dam is expected to be about 1.852 times the flow at the gauge (see Appendix A for details). Thus, all flow rates used in this report have been obtained by multiplying the measured flows by 1.852. These data have been used to generate flow frequency distributions and flow duration curves for the total period of record and for each month of the year. The average flow during this typical year is 231 cfs. The lowest month, September, has an average flow of 96 cfs while the highest month, March, has an average flow of 363 cfs.

Hydrologic Constraint

1. Available Flow

Average yearly flow of 231 cfs plus monthly variations ranging from 96 cfs to 363 cfs is used for the system design.

Technological Aspects

Manufacturers of hydroelectric equipment have standardized on three basic arrangements for small scale hydroturbines in the 750mm to 1,500mm range. They are a horizontal tube type, a vertical tube type, and a vertical open flume type. Generally, the horizontal configuration requires more building space than a vertical arrangement because the powerhouse generating equipment must be at the same level as the turbine. Vertical configurations, whether open or closed feed designs, allow the generating equipment to be located above the turbine, thus occupying less ground space and resulting in savings to required foundation work. However, if not properly designed, visual aesthetics could present a potential problem. On the other hand, more waterproofing protection is required in the horizontal arrangement if the facility is adjacent to a dam.

In evaluating available hydroelectric equipment, three different manufacturers have been contacted: Allis-Chalmers, AB Bofors-Nohab, and Ateliers Des Charmilles. The first two provided information on their standardized units for our planning purposes. Figure 2.9 shows their horizontal and vertical configurations. The third could not supply information at this time, as they are currently involved in designing their unit which will be available in the near future.

ALLIS-CHALMERS

HORIZONTAL ARRANGEMENT

BOFORS-NOHAB

HORIZONTAL ARRANGEMENT

BOFORS-NOHAB

VERTICAL ARRANGEMENT

BOFORS-NOHAB

OPEN FLUME ARRANGEMENT

Figure 2.9 Hydroelectric Equipment Manufacturers Configurations
2-17

Turbine arrangements are available with either a fixed blade runner or a variable pitch on the runner. The fixed blade arrangement will operate only when a predetermined discharge is available, while the variable arrangement operates at various loads through the discharge cycle. The variable pitch turbine costs more, but may provide a better generator match with the flow conditions.

Implementing the construction of a hydroelectric facility will surely impact the chosen site and be sensitive to its surroundings. Therefore, construction techniques, excavation, and access requirements must be carefully chosen to produce only minimum disruption to the area and result in a structure that blends with the environment.

Technological Constraints

1. Equipment Related

Horizontal or vertical tube turbine configurations will be utilized.

2. Design Requirement

Facility must blend with natural surroundings both visually and materially.

3. Construction Requirement

Construction techniques and access roads must minimize impact on area.

CONSTRAINTS VS. PROPOSED SITES

Table 2.1 shows the identified constraints that have a potential impact on the selection of each of the three proposed alternative sites. A value of 3 represents the strongest potential impact in the site selection decision. A value of 2 represents a lower potential impact and a value number 1 an even lower impact.

It can be seen that constraints related to aesthetics, historical and archaeological considerations, and design and construction techniques are the most critical in terms of selecting the specific site for the hydroelectric facility.

TABLE 2.1 Constraints vs. Sites

	Site 1 (Dam)	Site 2 (Grist Mill)	Site 3 (Falls)
Environmental Constraints			
1. Aesthetics of Facility	3	3	2
2. Elevation of Reservoir	-	-	-
3. Drawdown of Reservoir	-	-	-
4. Flow over Spillway	2	2	2
5. Flow over Falls	1	1	3
6. Flow Downstream	1	1	1
7. Use of Crestgates	2	2	2
8. Fishery Management	1	1	1
9. Historical Aspects	-	3	-
10. Archaeological Aspects	-	3	-
11. Vegetation & Topography	-	1	3
12. Recreational Use	1	1	1
Institutional Constraints			
1. DNR Priorities	2	2	2
2. Political Decision	2	2	2
3. Legal Aspect	2	2	2
Hydrology Constraints			
1. Available Flow	2	2	2
Technological Constraints			
1. Equipment	1	2	2
2. Design	3	3	2
3. Construction	3	2	3

Key: a value of 1 represents minor impact
a value of 2 represents moderate impact
a value of 3 represents major impact

SECTION 3
SYSTEM SELECTION

SECTION 3

SYSTEM SELECTION

This section describes the approach followed and analysis conducted in choosing the site, design, and facility that best meet the criteria that are established here as the basis of making a decision.

APPROACH

This study is ultimately a process of evaluation and selection. Simply, a variety of options have been weighed according to an evaluation procedure, measured against a number of constraints, and selected based on the evaluation. The basic choice rule is to pick the alternative configuration that is worth the most money, as long as it meets a number of constraining standards. Finally, depending on that money value, tempered by non-monetary observations, a choice is made whether to proceed with the project. The actual choice process is done in stages, whereby options are first eliminated if they do not meet certain minimum requirements, and then eliminated in favor of a best choice.

The selection process is outlined in Figure 3.1. The stepwise nature of the procedure is evident from the form of the flowchart. Here we shall briefly discuss the process, and then describe the manner in which the process has been applied to the analysis of the proposed High Falls installation.

The first step in the selection process is to determine acceptable sites. Obviously, the identification of potential sites assumes certain preselection by a reasonableness standard. Such potential sites are then evaluated in terms of the environmental, aesthetic, legal, engineering, and institutional constraints established earlier in the study. The options that fail to meet the constraints are eliminated at this point of the analysis. Although some minor constraints apply to the generator alternatives, the critical issues apply mainly to site selection. Having eliminated unsuitable sites, the process moves to stage two.

The next block of the flow diagram outlines an intermediate step in the determination of the value of the surviving proposed alternatives. As in the case of any evaluation procedure, the physical nature of the subject of evaluation must

Figure 3.1 System Selection Process

be identified. In this case, it is the energy production that is central to the determination of value. To calculate the likely energy output of the alternative configurations, the suitable sites and candidate generators are matched with the water flow data to provide the available electrical energy. That energy is the input into the next step of the process.

It is the energy produced by the facility that will bring in revenues. At the same time, the investment and upkeep will have a bearing on the amount and dependability of the energy supply and on the price received as well. Thus, this step calculates costs and uses these figures along with figures supplied by the prospective buyer of the energy to estimate the revenues that can be expected from the alternatives.

Having previously established that the alternative with the highest value would be chosen, the study now calculates the pertinent values (the final step in the selection process). Cost of investment, costs for operation and maintenance, and revenues over the expected lifetimes of the alternatives are compared, arriving at net present value for each option. The alternative possessing the highest is the survivor of the selection process.

The subsections that follow describe the application of this approach to the analysis of the proposed High Falls State Park hydroelectric facility.

ANALYSIS

Suitable Sites

Constraints have been identified through interviews and discussions with various individuals and organizations which would be directly impacted by the construction of a low-head hydroelectric facility. These include personnel within the Department of Natural Resources (DNR) such as Park personnel, historical, parks and recreation, and fish and wildlife; Office of Management and Budget (State of Georgia); and utility companies. The constraints established by this technique have already been discussed in Section 2. Whenever possible, the constraints are expressed in quantifiable terms; however, certain constraints are non-quantifiable. In Table 3.1, the critical constraints have been extracted, and the impact of these constraints on the potential site has been identified.

Table 3.1 Critical Constraints

SITE	CONSTRAINTS	IMPACT
Site 1 Base of Dam	Aesthetics Construction Design	Increased Cost of Design and Construction
Site 2 Old Mill	Historical Archaeological Aesthetics	Eliminate Site from Further Consideration
Site 3 Falls	Vegetation and Topography Flow over Falls	Eliminate Site from Further Consideration

For Site 1, at the base of the dam, the critical constraints are the aesthetics, construction and design. Aesthetics and design are directly tied together, and the aesthetics constraint can be satisfied by the proper design. The construction constraint is specifically related to the access to the site and the disruption of normal park facilities during the construction phase. Although these constraints will have a definite impact on the site, they can be satisfied with the proper design and construction techniques. Therefore, these constraints do not eliminate Site 1 from consideration.

Site 2, in the area of the Old Grist Mill, has four critical constraints. These are historical, archaeological, aesthetic and design. In this case, the historical, aesthetic and design constraints are very closely related, and could probably be satisfied by the proper design of the facility. However, the archaeological constraint is not so easily satisfied. This specific area has contained two gristmills which have been the center of various types of activities since before the Civil War, and the area also may contain some archaeological artifacts of the Civil War itself. In order to explore these possibilities fully, it will take a considerable expenditure of effort and possibly many years. Therefore, for the purposes of this feasibility study, this specific site has been eliminated from further consideration.

Site 3, at the falls, is particularly sensitive to the potential damage to the vegetation and topography which would be caused by heavy construction. The

existence of a facility in place may not cause a particular problem; however, the secondary construction necessary in order to gain access to the area would cause considerable damage to the natural surroundings which are so important to the operation of this park. In addition to the potential damage to the vegetation and topography, the operation of this facility would divert water around the falls. The result of this would be to reduce the flow and the natural beauty of the falls, which is one of the main attractions of the park. Thus, for this study, Site 3 has been eliminated.

Table 3.2 summarizes the selection process.

Table 3.2 Site Selection

SITE	HEAD-ft.(m)	ACCEPTABLE	REASON
Base of Dam	30 (9.14)	Yes	Design
Old Mill	41 (12.5)	No	Archaeological Impact
Falls	65.6 (20)	No	Ecological Impact
Old Powerhouse	110 (33.5)	No	Head Limitation

Energy Production

A crucial factor of hydroelectric design is the relationship between the hydrology and the equipment used to produce energy. This portion of the analysis corresponds to the second group of boxes in Figure 3.1. In general, the available flow is used to size the turbine. The approach taken for sizing the turbines in this study has been to elicit recommendations from manufacturers, based on the specific potential sites and the flow data. The characteristics of the systems or turbines recommended by the vendors have been used to estimate the energy production at the various sites. Turbines larger and smaller than those recommended have also been examined because of specific restrictions and constraints on operating conditions which were not provided to the equipment manufacturers. Data on the turbines was combined with hydrology data explained in Appendix A to estimate energy production in a method completely described in the appendix. The basic output of this set of calculations is expressed in terms of monthly energy production as well as some other items of information which are pertinent to the

operating conditions of the equipment. Figure 3.2 is a plot of the monthly energy production of a 1,150mm turbine with a variable pitch runner at 30 feet of head. Also plotted on this figure for comparison is the mean water flow that is available for each month. It is clear from this figure that the maximum energy production is during the winter and early spring months, while the late summer months will be capable of producing only about 30% of the energy that can be produced during the winter months. These monthly variations are important to later calculations of net revenue and lifecycle cost, because the energy is significantly more valuable during the summer months.

Figure 3.3 is a plot of the annual energy production as a function of turbine size over a range of 750mm to 1,750mm runner diameter. The two curves that are drawn on Figure 3.3 illustrate the difference between turbines of the same size, which have either a fixed pitch runner or a variable pitch runner. As these two curves illustrate, the variable pitch turbine is able to extract more energy from the same available flow than the fixed pitch option. Table 3.3 summarizes the energy calculations.

Table 3.3 Alternative Turbine Configurations

SITE	TURBINE SIZE (mm)	PEAK POWER (kW)	ANNUAL ENERGY (kWh)
Base of Dam	1,000 Horizontal	430	2,379,000
Base of Dam	1,250 Horizontal	660	2,727,000
Base of Dam	1,150 Vertical	597	2,622,000

Revenue

The estimate of the energy production is used to calculate the revenue from the sale of energy produced in the hydroelectric facility. The revenue from this facility is calculated by multiplying the energy produced by the price paid for the energy. The price for energy has been set through discussions with officials at the Georgia Power Company, applying a methodology of sharing of the savings. Therefore, in order to calculate the price paid for the energy, it is necessary to know the production cost of the energy. The method for calculating the price of

Figure 3.2 Energy Production by Month

Figure 3.3 Energy Production Vs. Turbine Size

the energy is to calculate the average between the Georgia Power marginal cost of production and the cost of production from the hydroelectric facility. Of course, the price received will never exceed Georgia Power's marginal cost. This method of pricing was proposed primarily to insure both parties an opportunity to share in the benefits of the hydroelectric facility. The annual revenue is used as an input to the calculation of the lifecycle cost of the system. Two very important implications of this methodology are that the revenue can be increased by providing energy when the utility marginal costs are high, and the price will increase as the utility costs increase.

Economic Analysis

The revenue received and the lifecycle cost of operating the hydroelectric facility are combined over the expected life of the equipment in order to estimate the total net present value of the project. The selection, then, is made based on the alternative that provides the highest net present value. The great difficulty is in comparing dollar payoffs of a hydroelectric facility with non-monetary payoffs of most other types of state investments.

The use of net present value over the life of the project has several potential pit-falls because it requires that several economic parameters be estimated over a long period of time. Some of these parameters are cost of capital, system life, operation and maintenance, escalation of energy costs, and inflation rate. This very important analysis is discussed in Appendix C; by selecting conservative values for the parameters, one can be reasonably sure that the results will be pessimistic. Refer to Table 3.4 for a summary of these calculations.

Table 3.4 Economic Comparison of Suitable Options

OPTION	TURBINE SIZE (mm)	INITIAL COST	COST PER kW	LEVEL- IZED ENERGY COST mil/kWh	LIFE CYCLE NPV
1	1,000 Horizontal	\$1,197,800	2,786	33.7	2,533
2	1,250 Horizontal	\$1,327,800	3,012	32.5	26,131
3	1,150 Vertical	\$1,050,200	1,759	26.9	110,157

Of the three options surviving the initial selection, option #3 is the best choice. Not only would it have the highest net present value over the system life, but it also would be selected based on other criteria that is often employed. The capital cost per unit capacity is the lowest (i.e., \$/kW), as is the levelized energy cost. Therefore, the system that was selected was the 1,150mm verticle axis turbine. A complete description of this system will be given in Section 4.

The calculation of NPV at this stage is practically free. Extensive evaluations were done for the selected system, as illustrated in Appendix C. At no cost to the Department of Energy, an analysis of the Old Powerhouse site was done; Table 3.5 illustrates the comparison among all the options. One important point that is evident from the table is that the Old Powerhouse site has excellent potential. The values shown in this table are based on superficial estimates, but the results suggest that further investigations be conducted.

Table 3.5 Comparison of Possible Options

OPTION #	SITE	TURBINE SIZE (mm)	LEVEL- IZED ENERGY COST mil/kWh	LIFE CYCLE NPV
1	Base of Dam	1,000 Horizontal	33.7	2,533
2	Base of Dam	1,250 Horizontal	32.5	26,131
3	Base of Dam	1,150 Vertical	26.9	110,157
4	Old Mill	1,250 Horizontal	26.6	163,316
5	Falls	1,250 Horizontal	22.7	392,884
6	Old Powerhouse	1,150 Vertical	11.9	1,108,903

SECTION 4

PROPOSED SYSTEM

SECTION 4

PROPOSED SYSTEM

Based on the selection process of Section 3 and the constraints that have been described in Section 2, a system and site is selected. This selection serves as a basis for a more detailed definition of the system design, and cost estimate.

DESIGN ASPECTS

Location of Proposed System

As a result of a combination of institutional, environmental, and economic considerations, the site selected is the base of the dam (Site 1). The available head from the spillway to the base of the dam is 9.14m (30 ft.). The powerhouse would be located in the river bed next to the existing canal that was once used to supply water to the old hydroelectric facility. Figure 4.1 is an artist's rendering of the proposed hydroelectric facility at the High Falls dam. This site offers several advantages. It is close to the check-in station where park personnel will have easy access to the powerhouse. Also, the existing Georgia Power substation is relatively close (approximately 150m (500 ft.)).

Description of Proposed System

The turbine selected for this application is a 1150mm vertical axis open flume type turbine. This type of turbine is selected because of a unique combination of engineering-economic, and aesthetic reasons. Figure 4.2 is a section view and Figure 4.3 is a plan view of the proposed facility from an engineering point of view. This design minimizes the modifications that would be required on the dam, and minimizes the size and environmental protection required for the powerhouse. This type of turbine design can also minimize the visual impact of the structure. It should be pointed out that the designs of this facility are schematic. Before such a facility is constructed, detailed designs must be completed. The following is a brief description of several of the major design considerations.

Figure 4.1 Artist's Rendering of Proposed High Falls Facility

Figure 4.2 Section View of Proposed Facility

4-4

INTAKE GATE

GENERATOR
CONTROL
EQUIPMENT

GENERATOR

Figure 4.3 Plan View of Proposed Facility

Modifications to High Falls Dam

Locating the powerhouse near the canal wall allows for a temporary access road to be built in the riverbed adjacent to the wall. Personnel will have access along the dam itself. The road will not be needed after construction is completed.

Headwater enters the flume through the existing spillway. A hydraulically operated inlet gate installed on the dam will control the flow.

A cofferdam will be built around the spillway to facilitate construction. A section of dam approximately 14 feet wide and 10 feet deep will be removed for installing the inlet gate and flume.

Steel pipe guard rails will be installed along the dam as protection for maintenance personnel. A steel trash rack in front of the inlet gate will prevent harmful objects from entering the flume.

Powerhouse Design

The High Falls Dam, the canal to the old hydroelectric generating plant, and the old mill strongly suggest native stone for the new plant. The form of the new plant is determined by function of the power generating equipment.

The powerhouse design presented herein attempts to minimize impact on its surroundings while at the same time asserting presence and dignity within the High Falls Dam area. Native stone will be used as a facing material on the cylindrical portion for continuity with adjacent structures and for resistance to the effects of water. The flume which makes the actual connection to the dam will be rough textured concrete which will blend with the spillway as it ages. All materials have been selected for their low-maintenance qualities.

The rugged landscape of High Falls State Park will be altered only to the extent necessary for construction. A tailwater pool must be excavated adjacent to the powerhouse.

Powerhouse Utilities

The powerhouse will require a source of power to operate the automatic controls, auxiliary turbine generator equipment and other building utilities such as lighting, heating and ventilation. Most of the hydroturbine manufacturers offer a panelboard with the transformer for this purpose as part of their standardized hydroturbine generator package. A schematic of the powerhouse service panel is given in Figure 4.4. This panel is referred to as the station service panel. Due to

Figure 4.4 Powerhouse Service Panel

the on-off cycling of the generator, the station service panel should be connected to the load side of the generator main breaker. By doing this, power will be available to operate the lights and other essential equipment whether or not the generator is producing power. Several 120 volt convenience outlets should be provided in the power house for maintenance equipment. Figure 4.5 is a plan view of the powerhouse that shows a lay-out of the major items of equipment as well as the powerhouse utilities.

1. Lighting

The powerhouse will require interior lighting for periodic maintenance and inspections. A wall switch would be provided so that the lights could be left off during normal operation and turned on only when needed. The fixture would be enclosed as gasketed to protect the lamps and to prevent moisture from entering the fixture. Refer to the area lighting plan Figure 4.6.

The powerhouse will also require outdoor lighting for safety and security. High pressure sodium lighting is recommended because it produces the most lumens per watt and has the longest lamp life. All the outdoor fixtures would be controlled by a photocell so that they would automatically turn on at night and turn off during the day.

Both the interior and outdoor lights would be connected to the station service panel so that they would operate at all times.

2. Heating

A small sized electric heater will be required to provide freeze protection for all the equipment during the winter months. The heater would be thermostatically controlled for automatic operation. The heater would be connected to the station service panel so that it could operate whether or not the generator was producing power.

3. Ventilation

An exhaust fan will be required to remove the excess heat produced by the generator. The generator in operation on a hot summer day could produce enough heat to cause false tripping of the breakers and other control equipment problems. The exhaust fan would be thermostatically controlled for automatic operation. The exhaust fan would be connected to the service panel so that it could operate at all times.

Figure 4.5 Powerhouse Equipment and Utility Layout

Figure 4.6 Powerhouse and Area Lighting Plan

Standardized Hydroturbine Generator

Manufacturers have standardized on three basic arrangements for the small scale hydroturbine. They are the horizontal tube type, the vertical tube type and the vertical open flume type. For this site with its special requirements, the open flume arrangement is chosen. The open flume arrangement will require the fewest modifications to the dam. Also, the open flume is a vertical arrangement and requires less building space for the equipment than the horizontal arrangement. Following is the equipment that comes as part of the manufacturers standardized hydroturbine generator package:

Intake Gate

The intake gate is used to control the flow of water into the turbine. The gate would be a vertical crest type gate hydraulically operated. A hydraulic pumping unit would be provided with all the necessary controls included for automatically opening and closing the gate.

Turbine

The turbine is the prime mover which converts the energy of the water to torque. The turbine consists of fabricated steel propeller type blades mounted on a steel hub.

The special requirements of this site require that the turbine be furnished with a variable pitch runner. This variable pitch runner will be hydraulically controlled from a float arrangement on the head water level.

Gear Box

The speed increaser gear ratio provides a suitable step-up ratio from the design turbine speed to the specified generator speed.

Generator

The generator is a squirrel-cage asynchronous machine type with two bearings and a standard shaft end for connection to a gearbox. The machine is screen and splash protected and cooled directly by the ambient air circulating through the frame. By means of a shaft-mounted fan, the air is drawn in through openings at one end of the machine and blown out at the other.

The generator is a 10 pole machine corresponding to a synchronous speed of 720 rpm. The asynchronous generator will always run approximately 2% greater than synchronous speed.

The machines should be supplied with special rotors, reinforced to withstand the centrifugal forces at runaway speed for at least 4 hours.

With a 30 ft. head, 275 cfs discharge, 1150 mm runner diameter, 406 rpm turbine speed and 730 rpm generator speed, the output of the generator will be 597 kw at an overall efficiency of 85.6%.

Control Equipment

Standardized control equipment mounted in a free standing cubicle is available. The cubicle contains the following:

a. Instrument unit with:

Voltmeter

Ammeter

Speed indicator

b. Operation unit with:

Pushbuttons for Start, Stop, Alarm cancellation, Blocking of start, Closing of breaker, Opening of breaker and Emergency stop;

Switches for Manual-Auto and Alarm On-Off Position indicator for the main breaker Symbolic diagram.

c. Automatic control unit:

The system is built up for automatic start and stop, initiated by switches for maximum and minimum upstream water level requirements as well as the pushbuttons of the operation unit.

d. Speed monitoring:

The speed monitoring equipment comprises an impulse band with teeth (mounted around the shaft), a pick up, an integrator, two speed monitors (100% and 115% speed) and a speed indicating instrument.

e. Annunciation:

The signal equipment comprises 3 signal relays (totally 6 signals) and an alarm relay.

f. Relay protections:

The following protections are included as standard:
overcurrent
overvoltage

reverse power

undervoltage

earth-fault (neutral point voltage)

The schematic of the generator protection system is shown in Figure 4.7.

g. Metering:

A kWh-meter is mounted inside the cubicle.

Switchgear

The switchgear comprises three cubicles; one apparatus cubicle, one intermediate cable cubicle and one circuit breaker cubicle.

a. The apparatus cubicle contains:

1 Station service panel with three phase and single phase circuit breakers.

3 Voltage transformers for relay protection.

1 Dry insulated station service transformer-15 KVA.

b. The cable cubicle contains attachments and anchoring bars for cables coming from below.

c. The circuit breaker cubicle contains:

1 Motor-operated air circuit breaker. The breaker has shunt trip and closing coils.

6 Current transformers for relay protections.

3 Current transformers for measuring.

A separate box with a neutral point resistor.

Also, batteries and charging equipment are included separately for tripping the generator main breaker under fault conditions.

Connection to Power Company Grid

Connection of a low head hydroelectric facility to a power company grid must incorporate two primary considerations. The first is the protection of the equipment from damage by the grid and second, to protect the grid from damage by the foreign power source. In the immediate vicinity of High Falls, there are two utility systems that could serve as potential customers for the sale of hydroelectric energy, Oglethorpe Power Corporation and Georgia Power Company. Both of these utilities were contacted and cooperated with this study. The utility interface was defined based on supplying energy to the Georgia Power system because (1) there is

a Georgia Power substation within 150m (500 ft.) from the proposed facility, and (2) Georgia Power had already established the technical requirements of cogeneration facilities, and was able to provide specific technical and cost information.

Energy will enter the utility grid via the 12.47 kV radial distribution line. The equipment required for this purpose consists of step-up transformers, secondary circuit breakers, and protective relays. This equipment, shown schematically in Figure 4.8, will be located in the existing Georgia Power substation. The energy will be transmitted from the hydroelectric facility to the substation through a cable that will be enclosed in a 4" conduit fastened to the face of the dam and then underground to the substation. Figure 4.9 illustrates the relationship between the hydroelectric facility and the utility substation as well as the routing of the feeder cable.

License Requirements

Prior to the development of low-head hydropower at High Falls, an application will have to be submitted to the Federal Energy Regulatory Commission (FERC) for a license to construct the facility (CFR 18, Chapter 1, Part 4, 4.30-4.86). Requirements for applying vary depending on the size of the facility. High Falls would fit in the 2,000 hp or less category since it will generate less than 600 hp. This permits the submission of application of less detail.

Briefly, the points which must be covered in the application include 1) a concise general description, including that of location; 2) the proposed use or market for power; 3) the securing of the necessary State permits; and 4) the effect on fish and wildlife resources, and proposals for measures considered necessary to conserve and, if possible, to enhance fish and wildlife resources. Adequate graphic exhibits are also required. Because the license constitutes federal involvement, a determination of the eligibility of properties for the National Register of Historic Places must be undertaken. (Under the State Antiquities Act, a survey may be requested by the Senate Historical Commission for action affecting State property).

After the application is received, a hearing may be ordered by the Commission either on its own accord or on the motion of any party of interest. If the application is approved and a license is granted, the licensee may proceed. A license is generally granted for thirty to forty years. Upon completion of the project, the licensee must file a cost statement with the FERC giving the actual cost of the project.

DEVICE NUMBER	FUNCTION
27	UNDERVOLTAGE RELAY
47	PHASE-SEQUENCE VOLTAGE RELAY
51	A-C TIME OVERCURRENT RELAY
59	OVERVOLTAGE RELAY
62	TIME-DELAY RELAY
81	FREQUENCY RELAY

Figure 4.8 Schematic of Substation Equipment
For Utility Intertie

Figure 4.9 Routing of Feeder Cable to Substation

The FERC has additional requirements to be fulfilled after project construction. One is the payment of an annual charge to the FERC to cover the costs of administration. This charge is levied in proportion to horsepower. Another requirement is the complete inspection of the dam and facility (excluding transmission lines and generating equipment) at least every five years. Alterations to the facility are subject to approval of an amendment to the license.

CONSTRUCTION ASPECTS

Construction Cost Estimate

The Construction Cost Estimate, Table 4.1, presents the estimated cost of constructing a hydroelectric facility at High Falls State Park. Several factors that contribute to these costs require additional explanation and are discussed in the following paragraphs.

Working within a functioning recreational area, and especially during the peak season of park use, presents special problems to the contractors such as safety precautions and construction site access by workmen and vehicles. These translate into increasing project costs.

Sitework is the most critical cost factor affecting construction. Heavy rock excavation will be required for foundations and construction of a tailrace. Blasting is prohibited near the dam, and access road construction represents a substantial cost prerequisite to rock excavation and actual construction.

Modifications to the dam depend on access to the dam's surface approximately 15 feet below spillway elevation. This cost estimate assumes a cofferdam to be constructed around the present spillway during demolition and construction. A cost saving alternative would be to lower the lake elevation until demolition on the dam has been accomplished and the intake gate installed. This could be accomplished in a 4 to 6 week period.

Table 4.1 Construction Cost Estimate for Proposed Facility

Site Work	\$ 96,000
Demolition	10,000
Cofferdam	50,000
Concrete	100,000
Masonry	15,000

Table 4.1 Construction Cost Estimate for Proposed Facility (Continued)

Metal	7,500
Moisture Protection	10,000
Door	300
Painting	500
Heating & Ventilation	2,800
Electrical	3,000
Hydroelectric Generating Unit	280,000
Installation of Hydroelectric Generating Unit	<u>80,000</u>
Subtotal	\$ 655,100
Contractor's Overhead & Profit	<u>140,000</u>
Total Construction Estimate	\$ 795,100
Contingency	42,000
Georgia Power Equipment & Powerline	51,100
Design Fees, Tests, Survey, Soil Investigations & Other Professional Services	<u>162,000</u>
Total Project Estimate	\$1,050,200

The installation cost of the hydroelectric generating unit includes all the labor, tools, contractor equipment and miscellaneous materials required to install the turbine, gear box, generator, control equipment, switch gear unit and intake gate. This cost includes all the labor and materials to completely wire up the generator, switchgear, and controls and to install hydraulic equipment, lines, and controls for the intake gate.

Contractor's overhead and profit is computed at approximately 20% of the estimated construction cost. A contingency fund of approximately 5% of the total construction estimate is included to cover unforeseen expenses during design and construction phases. A fund equal to approximately 20% of the total construction estimate is included to cover costs of professional design services, subsurface investigations, structural analyses of the dam, equipment and system start up and testing.

Design and Construction Schedule

The primary considerations for construction at High Falls State Park are the lead time required in obtaining licenses and having to restrict construction to sum-

mer and fall. Assuming a 13 month total design/construction period and establishing November 1 as the date of substantial completion, design work must begin November 1 of the previous year.

Shortly after beginning design, an order for a hydroelectric generating unit will be placed. This would be a competitive bid process to ensure getting the lowest cost. Particulars of the successful supplier will have to be known early in the design process.

The construction sequence is predicated upon constructing during summer and fall when water is at a minimum. Excessive amounts of water in the immediate area present hazards to construction. Neither construction of the powerhouse nor modifications to the dam can commence until an access road is completed.

A total construction time of approximately 7 months will be required to erect the powerhouse and install the hydroelectric equipment. Coordination between these two activities is of utmost importance. Delays in either can seriously impact the schedule.

After substantial completion of all construction activities has been accomplished, testing of equipment will begin. Full power production should be available by mid-November in time for increased water flow. The proposed schedule is illustrated in Figure 4.10.

OPERATION ASPECTS

Operation

The low-head hydroelectric facility must be able to operate in an automatic, unattended mode. This will be necessary in order to operate the facility within the present capabilities of the High Falls Park staff. The Park staff will be capable of manually operating the equipment and of performing certain routine, maintenance procedures; however, it will not be feasible to train personnel that will be dedicated to the operation of the hydroelectric facility. This degree of automation is possible with a small hydroelectric equipment of the type proposed for use in this facility.

Automatic controls will be capable of responding to the flow conditions of the river to provide as much power as possible during the time of day that the energy has the most value and still maintain a specified minimum reservoir level. The primary result of operating the system in this manner is that the facility does not produce as much energy as is possible. This can be translated directly into economic results which will be discussed later.

Figure 4.10 Design and Construction Schedule

One concern that has been expressed by Park and Fish and Wildlife personnel is the potential "rapid" fluctuations in the reservoir level that may result from a hydroelectric facility. This does not appear to be a problem. The turbine that is proposed in this report is a 1,150mm turbine that has a flow of 275 cfs at rated output, and with a variable pitch impeller, the flow can be varied from 90 cfs to a maximum of 275 cfs. Since the reservoir covers an area of 740 acres, the hydroelectric facility can vary the level of the reservoir, in the worst case (i.e., no incoming flow), from from 0.01 ft/h (1/8 in/h) to a maximum of 0.03 ft/h (3/8 in/h). However, from a realistic point of view, the fluctuation from the hydroelectric facility will not be perceptible.

Energy Production Analysis

At the normal operating head of 9.14m (30 ft.), the 1,150mm vertical axis will produce 597 kW with a discharge of 7.79 m³/s (275 cfs). It is estimated, by means of the model described in Appendix B, that this turbine will produce approximately 2,600,000 kWh per year. For comparative purposes, the total energy consumed by High Falls Park is only 230,000 kWh per year. The energy production is seasonal and depends directly on the flow of the river which is described in Appendix A. Table 4.2 is a summary of the estimated energy production by month and annually.

Table 4.2 Estimated Energy Production

<u>MONTH</u>	<u>ENERGY OUTPUT kWh</u>
January	334109.54
February	313911.80
March	382711.34
April	324814.57
May	262804.54
June	187721.12
July	177571.05
August	122889.87
September	63605.16
October	104713.78

Table 4.2 Estimated Energy Production (Continued)

<u>MONTH</u>	<u>ENERGY OUTPUT kWh</u>
November	136599.39
December	<u>210920.08</u>
Annual	2622372.24

From an operational point of view, it is possible to increase energy production by changing the operating rules. As discussed in Section 2, the operation of the facility will be subject to the constraints that (1) the level of the reservoir must be at least 587.35 feet (i.e., the level of the spillway), and (2) flow must be maintained over the spillway for aesthetic reasons. The spillway flow requirement is satisfied by defining the level of the reservoir as 0.1 feet above the spillway, which implies that approximately 50 cfs of the mean 271 cfs is unavailable for energy production. As energy becomes more and more valuable during the summer and early fall, it will be possible to utilize some of this flow to produce more energy. Figure 4.11 is a plot of annual energy production as a function of the minimum allowable reservoir elevation. As can be seen in this figure, the energy production can be increased by approximately 30 percent by not requiring .1 feet of water to be maintained over the spillway. Additional gains in energy production can be made by allowing the reservoir to be drawn down below the spillway. Operationally, it could be important to have the ability to use the water to produce energy when it is needed most. In other words, the use of the reservoir as a storage facility.

Economic Analysis

The total project cost is \$1,050,200 or \$1,760 per kW (see Table 4.1). This amount includes several costs that are related to satisfying existing constraints. For example, if the reservoir can be drawn down during construction, the need for a coffer dam would be eliminated, thus saving approximately \$50,000. Also, if construction of the facility can be coordinated with the safety improvements the State must make to the dam, savings from shared heavy equipment, access roads, and labor will result. This saving would be as much as \$100,000. It should be noted that the cost of the generating equipment, installation, and utility intertie is \$411,100, which is only 40% of the total cost. This points out the economy of scale

Figure 4.11 Impact of Reservoir Drawdown

problems associated with constructing a small facility, because the non-equipment cost would be almost the same if the generating capacity is doubled or tripled.

The decision criterion for an investment such as this is whether the benefits exceed the costs, and in comparison to other projects whether the excess of benefits is greater than that of other alternative projects. The choice is made among the alternative locations and technological options. The evaluation of benefits is based on the assumption that the capital investment is made with money borrowed with general obligation bonds at the prevailing rate of interest, requiring annual payments of equal size for the term of the bond to pay it off. Costs and benefits accruing in the future are discounted at the social discount rate (assumed at a value of 5.5%).

The State of Georgia has historically borrowed money with a levelized debt service. Thus, \$1,050,200 borrowed at 5.5% interest may be paid back in equal installments of \$68,492. Because of the effects of inflation, the real value of that amount is smaller every year. That is, the dollar amount remains constant while the buying power of the dollar decreases.

The nominal values assigned in this analysis are derived from a very conservative viewpoint. The growth in the price of energy is likely to be positive due to rising costs in the utility industry. The imposition of a social discount rate of 5.5% reduces the evaluation of benefits. Finally, the life span of the facility will probably be more than 30 years. The price per kWh, calculated in real terms, will likely be contracted in nominal dollars and thus be larger than included in the model. The net present value of the stream of benefits and costs of the facility under these conditions is \$110,000. The nature of the assumptions imply that this amount is a lower bound on the expected NPV of the facility. By removing some of the less binding constraints, and by assuming a rise in energy prices of two percent per year, the net present value of the facility comes to \$441,000. This amount is not an extreme; there are still constraints and assumptions that could realistically be modified to result in higher net present value. Nominal parameter values are given in Table 4.3. All dollar amounts in this table are in real terms or constant dollars.

Table 4.3. Nominal Parameter Values

<u>Variable</u>	<u>Value (in real terms or constant dollars)</u>
Initial capital expense	\$1,050,200
General obligation bond rate	5.5%

Table 4.3 Nominal Parameter Values (Continued)

<u>Variable</u>	<u>Value (in Real Terms or Constant Dollars)</u>
Operating and Maintenance Cost	\$170/mo = \$2,040/year
Annual generation	2,622,000 kWh
Social discount rate	5.5%
Average cost of Georgia Power's displaced energy	22.8 mils/kWh in 1978
Price paid by Georgia Power for energy produced	Slightly lower than cost of displaced energy
Growth of price of energy	Average just under zero over 30 years

The economic analysis is discussed in more detail, including a sensitivity analysis, in Appendix C.

Environmental Analysis

The small size of this facility combined with the operating constraints defined by DNR, will result in minimal environmental impact, with only minimal variations in the present flow conditions of the reservoir and the stream. There will be no impact in the availability of the recreational uses of the park. The facility will be constructed in the river bed in such a way that the historical features of the old mill site and the canal are not disturbed. Only the immediate area of the facility will display the effects of a modification of the existing flow patterns. It is anticipated that the park will broaden its interpretative presentations to include the proposed low-head facility.

The location of the proposed hydroelectric generator adjacent to the High Falls Dam appears to produce the fewest conflicts with the environmental constraints outlined in Section 2. Both visual and operational factors are addressed by this design to the degree that the basic concept fits within the guidelines that DNR has proposed.

Use of the secondary spillway, altered to permit greater flow, is preferable to either altering the main spillway or cutting into the base of the dam. Because the axis of the turbine/generator facility will be constructed in a vertical manner adjacent to the dam and will be covered with natural stone, its visual impact seems to be acceptable. In addition, the uniformity of materials in constructing the facility, aids in blending the facility with the existing dam. The final selection of

materials for covering the structure would have to be approved by DNR. Power lines will play a low profile by being placed in a conduit along the dam and underground from the dam to the power substation. The tail water pool will be designed to blend with the surrounding structures and riverbed. Despite the use of the tailwater pool, concern exists over the impact of scouring in the immediate area of the turbine outlet. Since this facility configuration utilizes the secondary spillway, the function of troughs which presently feed water from the reservoir into the old headrace must be maintained. This flow of water is required to prevent the stagnation of the water in the canal and to maintain the water level.

Safety factors are an important consideration because of the accessible public nature of the immediate area. The flume which feeds water from the reservoir to the turbine, should be protected to prevent someone from accidentally falling into it. Railings will flank the catwalk to the powerhouse. A more effective fence and gate than at present should be placed on the dam to improve security for the facility. However, access to the edge of the main spillway should be maintained. Another area which could pose safety problems for the over-curious public is the immediate area of the tail water. Although swimming and wading is not permitted in this area, it may be necessary to take special precautions to prevent unauthorized access to this area.

The operating scenario proposed for the facility reflects the constraints outlined in Section 2. The maintenance of a minimum flow of 40 cfs at all times meets both the visual requirement of water over the spillway and the requirement of keeping a continuous flow of water downstream. This operating scenario has the minimal impact on reservoir pool fluctuations well within the limits set by DNR. Flow fluctuations downstream during the low flow periods will vary between 40 cfs and 180 cfs under this scenario. Because of the dissipating action of the tailwater pool and the falls, the down stream impact of the fluctuation should not be significant. It should be reiterated, however, that the relationship between streamflow and productivity is not fully understood, and that the operation scenario would have to be monitored.

Institutional Aspects

Because of the high degree of automation projected for this facility, the impact on the management of the park is expected to be minimal. The on-site presence of DNR personnel would permit rudimentary checks on the operation of the facility. Should DNR needs require, these individuals would have to be familiar with the procedures required to establish manual control of the facility.

It is expected that the addition of this facility to the park would broaden the interpretative features present. A progression of water use technology for power generation can be illustrated through using the old mill foundation, the old powerhouse and the new low-head hydroelectric facility. Since visitation is already high at the park due to its proximity to an interstate, significant increases in attendance are not expected.

SECTION 5

CONCLUSIONS AND
RECOMMENDATIONS

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

The analysis of this project shows the feasibility of low head hydroelectric development at High Falls State Park. The three sites that have been considered are technically and economically feasible; but only the proposed site at the dam is environmentally feasible. Therefore, this site would normally be recommended for implementation. However, several institutional issues exist that must be addressed in more detail and resolved before a final recommendation can be made.

For the proposed site, the following major conclusions are listed:

- (1) The site is technically feasible.
- (2) Hydroelectric equipment is available to satisfy the design requirement.
- (3) Construction will not present a major problem.
- (4) A feasible arrangement is possible for the consumption of all produced power.
- (6) Operation of other park activities will be minimally disrupted.
- (7) Both visual and operational constraints are within the state guidelines.
- (8) The benefits are greater than the costs and, thus, the facility is economically feasible.

The location of the powerhouse at the dam has resulted in the selection of a vertical axis turbine. This type of equipment is well developed with standardized units currently available. Construction will not present a major problem, as access to the site is convenient, and the design is uncomplicated. The total energy that is produced will be sold to the Georgia Power Company. The amount is roughly 10 times greater than the park consumes, and an increment will be bought back to satisfy the demand. This arrangement provides a cost effective method of operation that will be easy to implement.

The proposed facility minimizes the environmental impact on the natural park setting through a design that is functional and aesthetically pleasing. The facility will not interfere with other park uses and should enhance the overall value and attraction of the park as a demonstration project.

The benefits have been shown to exceed the costs for the proposed investment, and it is, therefore, economically feasible. The facility does better than break even, and, according to the established criteria, if the benefits exceed the costs in present values, then the project is to be undertaken. The evaluation has been performed using very conservative values for the cost parameters. Therefore, the actual economic value should be substantially higher than estimated. In addition, the non-monetary benefits of the project indicate that it is advisable.

Institutional concerns, on the other hand, also bear heavily on the economic value of the proposed facility. Issues exist related to how the facility would be financed and how it would be operated to blend with the many activities of the park. If the project is to be undertaken, the likely procedure would be for the legislature to permit the Department of Natural Resources to issue a general obligation bond and simultaneously to establish line items for servicing the debt and for operation and maintenance. Income from the facility would become a part of general revenues of the State; thus, there would be only the most tenuous relationship between the agency responsible for operating the facility and the income and associated incentives that the facility would generate.

A second point is related to the operational aspects of the facility as a potential impact to other park activities. Concern still exists about the affect that streamflow fluctuations could possibly have on fish and wildlife productivity.

Third is the issue related to the head limitation imposed on this study which prevented the old powerhouse site from being considered as an available alternative. This site appears to be within the identified constraints and would offer economic benefits far greater than the proposed facility.

These issues must be addressed before the total value to the State can be determined. Therefore, the research team recommends that the State of Georgia postpone making the decision on the proposed investment at this time until the above issues are resolved.

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APPENDIX A

HYDROLOGIC ANALYSIS

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APPENDIX A

HYDROLOGIC ANALYSIS

Purpose

A set of important inputs to the projection of benefits of energy production for the High Falls Dam results from a hydrologic analysis of the expected streamflow. The best source of streamflow records is the U. S. Geological Survey (USGS), which maintains a large network of various types of streamflow gauging stations. Unfortunately, data is not available directly for the dam site itself, but there has been a gauge upstream in the past. An additional problem is the fact that all data is in the past, while we are interested in the future. Therefore, it has been necessary to expand available data to the site of interest and also into the future.

Existing Database

From June, 1960, to September, 1971, the USGS operated a continuous stage recording gauge at a site approximately 4 miles upstream of High Falls Dam on the Towaliga River at Georgia Highway 16; station #02211300 (USGS, 1971)¹. These data have been obtained in punched card form from the USGS for use in the hydrological analysis. During this period the average flow was 143 cfs or about 1.35 cfs per square mile. The maximum discharge was 7470 cfs in March, 1973, and the minimum was 6.5 cfs in October, 1970.

A statistical analysis of flow records in this region of Georgia (Carter, 1970)² shows that the annual discharge in a river is related to the drainage area according to the formula:

$$\frac{Q1}{Q2} = \frac{A1}{A2}^b$$

Q1 = annual flow for drainage area A1
Q2 = annual flow for drainage area A2
b = regression coefficient

-
1. USGS, Surface Water Records for Georgia, annual issues for water years 1960-1971.
 2. Carter, R. F., Evaluation of the Surface Water Data Program in Georgia, USGS Open File Report, Atlanta, Georgia, 1970.

For this area, $b = 0.908$. The two drainage areas have been measured by planimeter from USGS maps (see Figure A.1; USGS 1:250000 series, Atlanta) and have been found to be 103 mi^2 for the gauge and reservoir, respectively. If these values are used in the equation, it yields the equation:

$$Q_2 = 1.852 (Q_1),$$

which has been used to expand all the streamflow data.

Time Projection of Data

As has been mentioned, the data available is for the period 1960-71. In projecting future operation of a hydroelectric facility, projections of future streamflows are needed. There is good reason to suspect that the data available are typical of long-term averages. A check of records from other long term gauging stations in this region of Georgia has shown that, during the 1960 through 1970 period, the average flows were approximately equal to the long-term (30-50 year) average. Also, there is no known intensive development planned for this area. Therefore, no adjustment for wet or dry periods has been made to the measured flows on the Towaliga River.

Derivation of Typical Year Data

In using the simulation model (see Appendix B), runs have been made with only one typical year of data to be able to test a large number of alternatives. The differences between months, which are regular from year to year, have been kept to reflect wet and dry seasons. However, day-to-day differences should not be important if measured over many years. There is no reason to expect a different flow on one day (at least within a month) than on another day. Still, day-to-day differences in flow can influence the operation of a reservoir, and they tend to follow patterns as discussed below.

In order to smooth out random fluctuations, the data have been summarized. Flow increments of 10 cfs have been established up to 2,000 cfs, and the number of days in each flow range has been summed for each month and for the overall year. This flow frequency distribution for the overall year is shown in Fig. A.2. A cumulative distribution (flow duration curve) has also been generated. The flow-duration curve gives the number of days with flow expected greater than a given flow. The overall year flow-duration curve is shown in Fig. A.3.

A-4

Figure A.2 Flow Frequency Distribution
for Typical Year

Figure A.3 Flow Duration Curve
for Typical Year

Typical Year Developed

If rescaled, the frequency distribution may be thought of as a probability distribution and the flow duration curve as a cumulative probability distribution. In constructing a typical year, the concern is to get data points which all have an equal probability of occurrence. If the value of flow for 1, 2, 3, . . . , n days is taken from the flow duration curve, then this goal is met, since the days on this curve correspond to cumulative probability. This method has been used to represent flows for each month.

As mentioned earlier, the relationship of day-to-day flow values could potentially affect the operation of a hydroelectric facility. For instance, if a period of heavy flows is followed by light flows, the reservoir will be at a high level and a good deal of water is lost over the spillway and not utilized for power generation. On the other hand, if a period of light flows is followed by a buildup to heavier flows, the operation can handle more of the water for power generation.

The flow duration curve presents flows which follow a decending pattern each month. Since some of a previous day's flow is stored by the reservoir for future use, this unrealistic pattern may adversely affect the simulation results. Normally, streamflow follows a pattern of quick increase followed by more gradual decrease. This is illustrated by a plot of streamflow versus time, called a hydrograph, and is shown in Fig. A.4. Since accurate daily forecasts of future flow data cannot be predicted, the data has been randomly arranged within each month. Figures A.5 through A.16 show flow frequency distributions for each month. Flow duration curves for each month are shown in Figs. A.17 through A.28.

Figure A.4 Typical Hydrograph (Linsley, 1975)¹

1. Linsley, Kohler, and Paulhus, Hydrology for Engineers, McGraw-Hill, 2nd Edition, p. 234, 1975.

Figure A.5 - Flow Frequency-January

Figure A.6-Flow Frequency-February

Figure A.7 - Flow Frequency-March

Figure A.8 - Flow Frequency - April

Figure A.9 - Flow Frequency-May

Figure A.10 - Flow Frequency-June

Figure A.11 - Flow Frequency-July

Figure A.12 - Flow Frequency-August

Figure A.13 - Flow Frequency-September

Figure A.14 - Flow Frequency-October

Figure A.15 - Flow Frequency-November

Figure A.16 - Flow Frequency-December

Figure A.17 - Flow Duration-January

Figure A.18 - Flow Duration-February

Figure A.19 - Flow Duration-March

Figure A.20 - Flow Duration-April

Figure A.21 - Flow Duration-May

Figure A.22 - Flow Duration-June

Figure A.23 - Flow Duration-July

Figure A.24 - Flow Duration-August

Figure A.25 - Flow Duration-September

Figure A.26 - Flow Duration-October

Figure A.27 - Flow Duration-November

Figure A.28 - Flow Duration-December

APPENDIX B
SIMULATION PROCESS

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Simulation Process	B-1

APPENDIX B

SIMULATION PROCESS

Introduction

The projected energy outputs for alternative hydroelectric plants configurations have been computed using an iterative computer simulation model. The basis for the simulation is the maintenance of a water-budget for the reservoir. The model makes it possible to account for the operation of the facility. the basic features of this model are discussed in the following paragraphs.

Simulation Process

The simulation is based on a water-budget for the reservoir. This simply means that water that comes in must either go out or cause the quantity of water stored in the reservoir to change. This can be expressed as:

$$\Delta S = \Sigma I - \Sigma O \quad (B.1)$$

where ΔS = change in volume of water stored
 ΣI = volume of inflow from all sources, including but not limited to:

- 1) streamflow
- 2) groundwater flows
- 3) direct precipitation
- 4) overland flow

ΣO = volume of outflow from all sources, including but not limited to:

- 1) streamflow
- 2) infiltration
- 3) evaporation

In this program, we have only considered streamflow input and output as significant. In this case, output streamflow is composed of flow over the spillway of the dam and flow through the turbines. The streamflow is an input and depends on meteorological conditions to which simulation must respond. The methods used for obtaining these flows is described in Appendix A.

The input flow to the reservoir is considered as a given. The outflow over the spillway is a function of the height of the water over the spillway and its length:

$$Q = CLH^{3/2} \quad (B.2)$$

where Q = spillway flow in cfs;
 C = coefficient of discharge (4.01 in this case);
 L = length of spillway in feet;
 H = height of water over spillway in feet.

Our water-budget does not directly give us the water level; rather, it gives us reservoir storage (or at least changes in storage). However, reservoir level and relative storage have been related by using contour maps. The method involves measuring the area in square miles enclosed by different contour lines, including that of the reservoir surface (587' msl). By doing this, it is possible to relate the change in reservoir level to the change in storage. The additional volume is calculated by the average end-area method used in earthwork calculations. The following relationship is obtained by regression:

$$H = 587.33 + 0.001055S \quad (B.3)$$

Here S is storage relative to the spillway level, rather than total reservoir storage, since this value is not known. The units of S are acre-feet, a common volume unit in hydrology, which means an acre of water one foot deep. The equation extrapolates below 587', but this range should not be reached, and even if it were, the height variations are small so that not much error would be probable.

Since inflow and spillway outflow are now determined, the only unknown left in the water budget is the turbine flow. This is determined by the type of turbine under consideration. The turbine can operate either in a fixed pitch or variable pitch mode. In the fixed pitch mode, the turbine will operate properly at only one flowrate. If the turbine can operate at this flow for the whole hour without excessive drawdown, then full-hour operation is possible. If not, only partial hour or no operation is possible. On the other hand, the flowrate for a variable pitch turbine can be adjusted to the available water flows. In this model, the variable pitch formula was:

$$Q_{\text{turb}} = Q_I - Q_{\text{spill}} - 11469 \times H_{\text{minimum}} \quad (B.4)$$

This is so that the turbine can operate without drawing the reservoir level down below its minimum. The turbine also must operate at no less than 30% of full rated flow or be shut down.

Once the turbine flow and duration are determined, the energy output can be calculated. The instantaneous power output is:

$$P = C Q_{\text{turb}} \Delta H \quad (\text{B.5})$$

$$C = \text{coefficient} = C' \times E_{\text{turb}} \times E_{\text{pipe}} \times E_{\text{variable speed}} \quad (\text{B.6})$$

where: $C' = 0.0846$

E_{turb} = turbine efficiency

E_{pipe} = efficiency factor for pipe based on head loss

$E_{\text{variable speed}}$ = efficiency reduction factor for variable pitch turbines, decreases with decreasing % of full load;

Q_{turb} = turbine flow (cfs)

ΔH = power head (ft.)

P = power in kW

If the length of operation is known (T), then:

$$\text{ENERGY (in kWh)} = PT \quad (\text{B.7})$$

The simulation is based on hourly iterations within each day. The spillway flow is assumed constant over the hour and the inflow is assumed constant for each day. A flowchart of the iteration process appears as figure B.1.

There are simplified methods of extrapolating data from one site to another for similar or identical turbine configurations. The energy produced from a turbine is directly proportional to the product of the flow through the turbine and the head available to the turbine. The turbine, by nature, is basically a constant volume machine. Since water is effectively incompressible, the flow through the turbine would be almost identical, regardless of the head available to the turbine (assuming the speed is the same). Therefore, if the energy production of a specific site is known, and it is desired to compare one potential site against the other, the energy production can be estimated, since the energy production is proportional to the head available at each site. Although this technique is not completely rigorous, it is an excellent approximation and comparisons can be made by using simple arithmetic.

Figure B.1. Flow Chart of Iteration Process

APPENDIX C
ECONOMIC ANALYSIS

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APPENDIX C

ECONOMIC ANALYSIS

Introduction

The economic analysis of this project is done on two levels, more or less concurrently. The decisions to be made are whether or not to pursue the construction of the hydroelectric facility, and if so, which of the many optional configurations of generators to choose. It is obvious that the selection of options must begin before the analysis of economic feasibility, since that selection may in itself bear on the feasibility. In short, the decision whether to proceed is made by applying cost-benefit analysis, and the selection of alternative configuration is made on the basis of a marginal analysis. Both decisions are tested with a sensitivity analysis.

The analysis requires decision criteria, established prior to the analysis, in order to draw consistent, meaningful policy conclusions. The criteria for the decisions made here result from explicitly stated policy and from implicit values reaching the project team. Using the decision criteria, the foremost standard is that, measured in dollars, benefits exceed costs for the project, but attached to that standard is the question of identifying to whom the benefits accrue and by whom the costs are born.

Costs and Benefits

The pecuniary costs of the project derive from two sources, capital on the one hand and operation and maintenance on the other. Capital costs include the prices paid for the machinery and buildings, improvements to the dam and spillways, and design and engineering services. The State of Georgia makes very few capital investments that are expected to pay for themselves through revenues; thus amortization is not part of the States accounting vocabulary. However, the State has been known to borrow to finance Stone Mountain Park, the World Congress Center, and some other ventures, and the market rate at the time of this writing was estimated by the State Auditor's office to be 5.5% per annum, paid over a 20 year or longer term, in equal dollar installments each year. Of course, inflationary effects are to reduce the burden of the annual payment. Operating and maintenance impose periodic costs on the project in more or less equal annual

payments. O&M will actually be very small for the first year--under warranty, slightly larger but falling for the next few years as the benefits of learning are enjoyed, and slowly rising towards a maximum as the facility ages.

Pecuniary benefits arise from the sale of electrical energy to Georgia Power Company, or to the Oglethorpe Power Corporation. Or the park could use the energy to displace what it consumes and then sell the excess. (The latter case has been seen to be unacceptable at the present time due to the cost of distribution facilities.) The magnitude of the benefits derive from the price the utility company is willing to pay for energy. Georgia Power Company has proposed to "share the savings" with the State of Georgia. In other words, Georgia Power would pay the average of the cost of energy at the hydro facility and their system lambda or marginal cost of energy. If the cost of energy should be greater at the park's generator than in the Georgia Power system, then the company would pay a fraction, nominally set at 95%, of the company's marginal cost.

Besides pecuniary costs and benefits there are benefits that are more or less easily measured, but not in dollars, and there are costs and benefits that are not at all measurable. Quantifiable costs include the number of tourists greater or fewer who will visit the park because of the generator or its physical effects, the changes in flora and fauna because of changes in water flow, and so forth. Intangibles on the other hand, include such effects as whether a dam with a hydrofacility is prettier or uglier than one without, who the visitors to the park are, and the identity of the recipients of benefits and the bearers of costs. This last point--the distributional effects will be discussed further in this appendix in the section dealing with cost-benefit analysis. The major intangible, nearly impossible to value, but of crucial importance in the decision process, is the degree of energy independence afforded by generating facilities such as the one under consideration here.

Rate of Inflation and Social Discount Rate

The assumptions underlying the analysis are based on the identified constraints and on a realistic outlook concerning the economic parameters. The rate of inflation is expected to level out at about 5% after falling from the current rates of around 10%. The assumption is made that the State of Georgia would be willing and able to issue a general obligation bond in the amount of the capital investment for a thirty year term. The real price of displaced energy is assumed to rise at a rate close to zero for most of the project's life, after actually falling for the first couple of years. To be sure, the assumptions are extremely conservative; the

values representing these assignments are enumerated in the section on Data and Results.

The establishment of a valid social discount rate for analytical purposes is an exercise fraught with dangers. When projects are going to be compared, it is difficult to resolve the choice of discount rate. One point is essential: if the agency doing the comparing is going to pay for the chosen alternative, then a uniform discount rate applies; otherwise, any comparisons are academic, and the ultimate sponsoring agency applies the appropriate social discount rate within its purview.

The assignment of a number to the rate of social discount depends on a relative valuation of the present vis-a-vis the future, as evaluated by the current generation and by all other affected generations as well. Needless to say, there is no way to poll the inhabitants of the future, and we must use our own judgment. Furthermore, depending on the way a project is paid for, the group that is paying the most, in dollars or in environmental damage or in whatever measure, must be considered with the greatest weight in the assignment of a value to the social discount rate. Ultimately, we resort to using the opportunity cost of capital as the appropriate rate, more because it is handy than because it is right.

Cost-Benefit Analysis

The application of cost-benefit analysis is to determine if the benefits of the project exceed the costs. In the case of the High Falls Park hydroelectric facility, only the economic costs and benefits have been taken explicitly into account, since the aesthetic, environmental, and recreational aspects of the analysis have been done by establishing limiting values for certain of the variables of the calculations in order not to exceed the perceived thresholds and constraints of the local residents and the Georgia Department of Natural Resources. For example, it was decided beforehand that the level of the lake may not fluctuate more than a predetermined amount; thus, the possibility of extra storage capacity or of drawing down the lake is severely limited. The decision is ultimately made by choosing the alternative generating facility that maximizes the present value of net economic benefits over the lifetime of the proposed installation.

The benefits of the facility are measured in revenues. Depending on the final agreement as to the use or sale of electricity, the generator will bring in revenues both for its capacity to provide power and for its ability to supply energy. Both factors are taken into account, either by using a variable rate for energy provided or by using a power premium. The costs of the facility are due to operating and maintenance over the life of the facility and to the initial cost of the capital tied

up in the generators and peripheral equipment such as transmission or interties with the utility company. Furthermore, some of the benefits and costs accrue on a monthly basis, and some annually. Thus, the analysis is computationally involved if not conceptually sophisticated.

The following is a list of the variables that are involved in the computation of values:

b = borrowing rate for capital expenditures (annual)

C = capital costs (paid at $i=0$)

CA_j = annualized capital costs corrected for inflation (debt service) in year j

ce_j = coal escalation rate from year j to $j+1$

d = social discount rate (monthly)

da = social discount rate (annual)

DE_i = utility system lambda (marginal cost of energy displaced by out put of hydro facility) in month i

ge_j = growth rate of energy costs from year j to $j + 1$

gp = growth rate of premium for power capacity (annual)

h = growth rate of operating & maintenance costs (annual)

i = month index, ranging from 0 through n

j = year index, ranging from 0 through m

KW = quantity of power capacity

KWH_i = quantity of energy sold in month i

$KWHA_j$ = quantity of energy sold or produced in year j

m = lifetime of the facility in years

M_i = operating and maintenance costs in month i

M_o = basic or initial operating and maintenance costs per month

MA_j = operating and maintenance costs during year j

n = lifetime of the facility in months = $12m$

PE_i = price paid by utility per kWh of energy in month i

PP_i = premium paid by utility per kW of power capacity in month i

R_i = revenue from sale of electricity in month i

RE_i = revenue from sale of energy in month i

RP_i = revenue from sale of power in month i

TC_j = total costs of facility in year j

where the assumption is made that receipts and payments occur at the end of the time indicated; e.g., O&M costs for April are paid at the end of April. Further-

more, all figures are in constant dollars, in order to remove the distortions of inflation, or in the case of rates of increase, in terms of real increase, not inflated. E.g., 18 mils per kWh in 1985 is 18 non-inflated mils; if a cost rises one percent from year to year it is one percent not including any effect that inflation might have.

The calculation of net present value of the facility, then, is to complete the following:

$$NPV = \sum_{i=1}^{360} (R_i - M_i)/(1 + d)^i - \sum_{j=1}^{30} CA_j/(1 + da)^j \quad (C.1)$$

where the components of the expression are explained below:

$$\begin{aligned} R_i &= RE_i + RP_i \\ &= (PE_i)(KWH_i) + (PP_i)(KW) \end{aligned} \quad (C.2)$$

In other words, the net present value of the facility is the discounted sum of the difference between revenues and costs over the lifetime, net of the capital investment cost. In order to calculate the figures on a month-by-month basis, growth rates and other adjustments must be made.

In the calculation of RE_i , the value of KWH_i comes from the capacity of the generating facility, combined with the operating philosophy of the administration. That is, given certain constraints, KWH_i will be one set of figures, but under other circumstances it may be another set with the evergy for some months being higher or lower. The price of energy, PE_i , is calculated from the system lambda of the power company and the average cost per kilowatt hour of producing evergy at the facility. On a share the savings principle, Georgia Power Company has agreed to pay the average of their marginal cost of displaced energy (lambda) and the facility's average annual cost per kWh of generation, up to some fraction of the Company's marginal cost. Thus,

$$PE = \frac{DE + TC/KWHA}{2}, \quad (C.3)$$

as long as the average is less than DP by, say, 5 per cent. However, since the price of displaced energy depends on other prices, themselves changing from year to year,

$$PE_i = \frac{DE_i + TC_j/KWHA_j}{2} \quad (C.4)$$

where month i is a month in year j . $TC_j/KWHA_j$ is the per kilowatt hour cost of generating electricity at the hydro facility during year j . DE_i is the cost of displaced energy during month i ; actually, the cost will change over the month and over each day within the month, but for this analysis, the monthly weighted average is used for simplicity.

The two factors in the numerator of the expression must be calculated for each time period. The price of displaced energy depends on the cost of inputs that are used to generate that energy. Thus, we need some sort of indicator of the magnitude of the changes in the cost from year to year. According to Georgia Power Company, the cost of displaced energy will rise at least as much as the contribution to that cost of coal inputs. Since coal makes up about 85 per cent of the marginal cost of energy, and the other inputs are expected to rise at the same rate as inflation, the rate of increase in DP will be at least

$$ge_j = (ce_j)(0.85) \quad (C.5)$$

Therefore, the relation among the successive DE values is

$$DE_i = (DE_{i-12})(1 + ge_j) \quad (C.6)$$

where i is a month in year j . Total costs in year j are calculated according to an accounting scheme that annualizes the up-front capital costs evenly over the life of the facility, and adds the O&M costs:

$$TC_j = CA_j + MA_j \quad (C.7)$$

where MA_j is the sum over the 12 months of year j of the M_i values, and CA_j is calculated from the following accounting identity to derive its nominal value:

$$C = \sum_{j=0}^{29} \frac{CA}{(1 + b)^j} \quad (C.8)$$

The problem here is that CA, the nominal annualized capital cost is derived from the annual repayment cost in dollars to service the general obligation debt. In fact, the dollar value is irrelevant, since inflation makes it worth continually less; we let CA_j be the annualized cost corrected for inflation:

$$CA_j = \frac{(CA_{j-1})}{(1 + \text{rate of inflation in year } j-1)} \quad (C.9)$$

The second term in the original calculation RP_i depends on the price of power and the power capacity. And the price of power depends on the escalation rate, so that

$$PP_i = (PP_{i-12})(1 + gp) \quad , \quad (C.10)$$

where the price is constant for all months of a given year. In the present calculation, this is academic, since power capacity is not being bought; however, the calculation of net present value requires the ability to include the figure if a different sales arrangement should be worked out.

The next term in the calculation of NPV is the O&M costs. We have determined that the influences on those costs are two-fold. First there are factors that derive from familiarity with the facility and from the age of the facility. Familiarity will tend to decrease costs for the same operations, while age will tend to increase costs. Second, there is expected to be an annual growth rate in costs, due, for example, to labor contracts or price rises in components of replacement parts. The value is calculated as follows:

$$M_i = (1 + h)^j (M_0) (0.02e^{-0.1(i-2)} + 0.007e^{0.03(i-6)}) \quad , \quad (C.11)$$

where the exponential function is only an example of the familiarity-age factor.

The final factor in the calculation is the social discount rate, d . There are a number of rationalizations, justifications, and arguments concerning the choice of an appropriate social discount rate, and we do not intend to resolve the issue in this study. We do work on the assumption that d is less than the prevailing rate of interest in the marketplace and probably equal to the passbook interest rate.

Since the sum is monthly, the relationship between the discount rate and the annual social discount rate--the rate that is most likely to be expressed--is as follows:

$$d = \frac{12}{\sqrt{(1 + da) - 1}} \quad (C.12)$$

As a result of comparing net present values of the alternative site/facility combinations, the best alternative could be chosen. The results are outlined in the section of this appendix called "Data and Results." Of the options, the best has been subjected to further scrutiny in a sensitivity analysis.

Sensitivity Analysis

If the controlling variables were to take on values different from those assigned here, then the results of our calculations would change. The sensitivity of our calculated results is scrutinized by assigning alternative values to some of the inputs to see what happens to the output, net present value of the facility. Some of the variables will probably not change at all while others may be capable of varying over a wide range. We examine the effects only of realistic variations in the values of control variables.

In particular, the amount of energy available, the annual rise in the price the utility company would be willing to pay for displaced energy, the borrowing rate, the social discount rate, and the operating lifetime of the facility are all values that are very uncertain. It is essential to look at what happens to the decision variables as a result of variations in those control variables. Ideally, also, it would be useful to consider the results of simultaneous distortions in more than one control variable at a time.

The amount of energy available from the facility depends largely upon nature, but partly on environmental and aesthetic policy. As a result, a policy decision could significantly alter the amount of energy generated. The constraints on energy derive from the amount of water flow that is available for generation. More water flow implies a change in the amount of water over the spillway, the level of the lake, and the consequences of those changes on sporting, visual effect, environment, and safety.

The price that the utility company will pay for energy, or for power capacity, depends on the marginal costs of energy in the company, the contract worked out between the Department of Natural Resources and the company, and the costs of

producing energy at the hydroelectric facility. The company's marginal costs depend heavily on the configuration of the system -- i.e., which units are used for peaking capacity -- and on the price of fuels.

The rate at which money can be borrowed, or the rate at which a capital investment is amortized over its lifetime, an elusive value even for private firms, is very difficult to determine for the State of Georgia, not inclined to issue bonds. One could choose the rate at which it could borrow if it chose to, the opportunity cost of capital, the social discount rate, or some other value. Difficulties arise in measuring the opportunity cost of capital, since alternative uses of capital in the state may have paybacks that are difficult or impossible to measure. The social discount rate has its own problems, discussed next.

The appropriate value for the social discount rate is a figure that has troubled economists and policy makers since before the concept was even identified by social scientists. Some of the same alternatives are available for the selection of social discount rate as for the borrowing or amortization rate just discussed. It is plagued by the imposition of a value system, however. The rate implies the degree to which the current generation is preferable to the next generation; needless to say, the spokesmen for the future generations are not articulate, but at the same time we hesitate to value ourselves too highly. Under the best of conditions, the policy maker imposes his values on the selection of discount rate, but when the policy maker is choosing for a democratic entity, there is no fool-proof way of making the selection.

The lifetime of the hydroelectric facility is projected to be about thirty years, but there is clear evidence that the life span of such a facility can be much longer. To do sensitivity analysis on length of life would perturb many of the calculations, resulting in unclear outputs. For example, whereas an increased life-span would give the owner windfall profits from the 31st year onward, if it had been known earlier that the facility would last so long, the greater life span would have had to be taken into consideration in the calculation of the price paid for energy. Since windfalls cannot be taken into account, we have decided not to include life span among the variables on which sensitivity analysis will be run.

In short, sensitivity analysis looks at the output values that are associated with alternative levels of the input variables. It is an exercise in "what would happen if . . ." The level of analysis permits only a partial analysis, in the sense of looking at one input-output relation at a time. In reality, there is reason to believe that if one of the inputs were to be different, then others would be different as well. The complexities of such calculations are obvious.

Data and Results

The first step in the economic analysis is to calculate the present value of the alternatives that are available. Such a calculation has been done for each site and for each generator turbine choice. The results are summarized in the accompanying Table C.1. In this calculation, a simplified discounting scheme has been used. The complex arithmetic outlined previously under "Cost Benefit Analysis" has been deemed unnecessary for the preliminary choice of alternative facilities. For this calculation, it is assumed that all costs and benefits occur at the end of the year.

Table C.1 Net Present Value of Alternative Configurations

	TURBINE OPTION	SITE OPTION	NET PRESENT VALUE
1.	1,000mm Horizontal	Base of Dam	\$ -2,533
2.	1,250mm Horizontal	Base of Dam	\$ 26,131
3.	1,150mm Vertical	Base of Dam	\$ 110,157
4.	1,250mm Horizontal	Old Mill	\$ 163,316
5.	1,250mm Horizontal	Falls	\$ 392,884
6.	1,150mm Vertical	Old Powerhouse	\$1,108,903

Of the six options that were technologically feasible within the physical constraints, only the first three may be considered. Option number four is unacceptable for archaeological reasons. The fifth option is unacceptable on ecological grounds. Option six is outside the head limitations of the study, since it enjoys a total head of about 110 feet or 33.5 meters. Since the calculation of its NPV was practically free, the research team has carried it out for the Old Powerhouse option without cost. We have included it for information purposes. Of the remaining alternatives, number three is clearly the superior.

After the choice of alternatives is made, the sensitivity of that choice to perturbations in the control variables will determine the strength of that decision. If mild variances in the control variables cause the selection to flop from one choice to another, then more analysis must be done, or some other choice criteria must be added. In the case of this problem, the controlling variables are not economic but institutional. Thus, varying the economic parameters would have

little if any effect on the choice among alternatives. Therefore, in the interest of economic efficiency, the exercise has not been undertaken.

The calculation of present value of the selected alternative hydroelectric facility is based on the following values assigned to the various aspects of costs and benefits:

$$\begin{aligned} b &= 0.055 \\ C &= \$1,050,200 \\ ce_j &= \begin{aligned} &-.027 \text{ in } 1980 \\ &-.013 \text{ in } 1981 \\ &+.007 \text{ in } 1982 \\ &-.002 \text{ in } 1983 \\ &-.022 \text{ in } 1984 \\ &-.015 \text{ in } 1985 \\ &+.032 \text{ in } 1986 \\ &-.002 \text{ in } 1987 \\ &+.003 \text{ in } 1988 \\ &+.033 \text{ in } 1989 \\ &+.020 \text{ in } 1990 \\ &0.00 \text{ in } 1991 \\ &0.00 \text{ in each year through lifespan of installation} \end{aligned} \\ da &= 0.055 \\ DE_i &= \begin{aligned} &\$0.02175 \text{ in January, 1978} \\ &0.02797 \text{ in February, 1978} \\ &0.02985 \text{ in March, 1978} \\ &0.01914 \text{ in April, 1978} \\ &0.01994 \text{ in May, 1978} \\ &0.02022 \text{ in June, 1978} \\ &0.02626 \text{ in July, 1978} \\ &0.02454 \text{ in August, 1978} \\ &0.02331 \text{ in September, 1978} \\ &0.01512 \text{ in October, 1978} \\ &0.01614 \text{ in November, 1978} \\ &0.01599 \text{ in December, 1978} \end{aligned} \\ h &= 0.00 \end{aligned}$$

KW = 597

KWH_i = 334,110 in January
313,912 in February
382,711 in March
324,815 in April
262,805 in May
187,721 in June
177,571 in July
122,890 in August
63,605 in September
104,714 in October
136,599 in November
210,920 in December

KWHA_j = 2,622,373

m = 30

M₀ = \$170

PP_i = \$0

Other variables are calculated from these. These figures for DE are calculated according to a weighted average that assumes 14 hours of peak and 10 hours of valley per day. In addition, we assume:

Inflation rate = 10% in 1980

10% in 1981

9% in 1982

8% in 1983

7% in 1984

7% in 1985

6% in 1986

5% in 1987 and throughout the lifetime of the facility.

Since the total capital cost is \$1,050,200, to be borrowed over 30 years at 5.5% per annum, the annual debt service will come to \$68,492. The annualized capital cost of energy generated is 26.1 mills per kilowatt hour. O&M costs are about 0.8 mills per kWh. Using the method described in the "Cost Benefit Analysis" section, the net present value of the facility is calculated to be \$131,682 under the very conservative conditions established for this analysis.

The calculation of a benefit cost ratio in this context is problematic. A benefit cost ratio is of little or no decision value unless capital is insufficient to

build all the projects under consideration. In fact, the State of Georgia has no other projects under consideration for which benefits can be easily monetized and compared to the project under discussion. Thus, the issue is moot. If another agency were going to consider paying for the project out of a limited budget, then it might want to use the benefit cost ratios to decide among those cost effective projects at its disposal. In such a case, the ratio must be calculated with values discounted to the same point in history, preferably the present, using the same discount rate for all alternatives; it is not likely that all contractors will have used the same discount rate.

With all the caveats expressed, the benefit cost ratio for this project is calculated to be:

$$\begin{aligned}
 B/C &= \frac{\text{PV of revenues}}{\text{PV of O\&M} + \text{PV of debt service}} \\
 &= \frac{711,516}{30,389 + 549,445} \\
 &= 1.23 \qquad \qquad \qquad (C.13)
 \end{aligned}$$

Results of the computations are sensitive to changes in the control variables, but in every case, reasonable levels of these variables make the facility entirely cost effective. Sensitivity analysis has been done on the results for the chosen option, by varying one input at a time. That is, the effects of only one control variable is considered while all others are held at their nominal value as listed previously in this section. The approach is called partial analysis. In the following paragraphs, the sensitivities are reported. Recall that the base level net present value of the facility is \$131,682.

Although the office of the Auditor of the State of Georgia has estimated the general obligation bond rate to be 5.5% as of this writing, it is not out of the question that the rate will rise over the near term. On the other hand, it is not likely to fall. Thus we examined the effect on the net present value of the proposed facility of bond rates of 6%, 6.5%, and 7%. Leaving all other variables at their nominal levels, the results are as follows:

At a bond rate of 6%, the NPV would be: \$111,960.

At a bond rate of 6.5%, the NPV would be: \$ 91,387.

At a bond rate of 7%, the NPV would be: \$ 69,890.

The discount rate, assigned by a rather arbitrary means, could well be lower or higher than the nominal level set in our calculation of net present value. It would not be unreasonable to assign it a negative value, but we have considered values between 2% and 9%, giving the following results:

At a social discount rate of 9%, the NPV would be: \$ 77,678.

At a social discount rate of 7%, the NPV would be: \$103,970.

At a social discount rate of 4%, the NPV would be: \$169,279.

At a social discount rate of 2%, the NPV would be: \$242,076.

The environmental constraints placed on the operation of the hydroelectric facility include the requirement that water be permitted to spill over the dam at all times during the day, including the dry season, which coincides with the tourist season. If the limitation were removed, the summer and early fall months would enjoy greatly increased generating potential. If the facility were to operate more nearly to capacity during the dry season, the NPV of the facility would be \$208,784.

Finally, it is not all unrealistic to expect the cost of energy displaced by this facility to rise at a moderate rate. Of course, the utility company's system lambda depends on a number of factors including fuel and facility mixes; we have considered a 2% per annum rise in that marginal value to be within the bounds of reason. If that were the case, the NPV of the facility would be \$253,505.

APPENDIX D

DNR
ORGANIZATIONAL
STRUCTURE

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DNR ORGANIZATIONAL STRUCTURE

Created in 1972 by the combination of thirty-three separate agencies into one administrative unit, the Department of Natural Resources was given the responsibility for developing a comprehensive resource management program (exclusive of forestry and agriculture). The mission of the Department is to manage, guide, and promote the wise use of the State's natural, historical, and recreational resources for the benefit of Georgia's present and future generations.

The Divisions most concerned with the operation of a High Falls Hydro-electric Facility, should it become operational, are the Parks, Recreation, and Historic Sites Division, the Game and Fish Division, the Environmental Protection Division, and the Office of the Commissioner. Within each of these Divisions, only a few sections would be directly involved. Their responsibilities are outlined below.

Because of the day-to-day involvement of the Parks, Recreation, and Historic Sites Division at High Falls State Park, the Operations Section, including the Programming Unit, of that division would experience the most visible contact. The use of the Park's facilities, the interpretation of both the historical and natural features, and the overall aesthetic character of the Park must integrate easily with any new activity or facility in the park. In a role removed from the Park's daily operations, the Historic Preservation Section identifies, inventories, and recommends sites to be placed on the National Register of Historic Places. Their concern for State-owned historic sites involves them in any impact which the hydropower unit would have on the park's cultural and historic resources.

Activities of the Fisheries Management Section of the Game and Fish Division include supervision of fresh water fish populations and comprehensive stocking programs in impounded waters and warmwater and coldwater streams. High Falls State Park is a source for testing and understanding reservoir management techniques.

The Environmental Protection Division's Water Protection Branch is concerned with the quality of water for downstream users.

Coordination of interdivisional projects is the function of the Office of the Commissioner. Divisional input is secured and any potential conflicts are resolved.