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HYDROELECTRIC POWER POTENTIAL

Woonsocket Falls Dam 1788

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John S. Krikorian, Jr.
Project Director

The contents and recommendations contained in this report are the views and the responsibility of the University of Rhode Island Study Team and may not necessarily represent the opinion of others listed herein.

UNIVERSITY OF RHODE ISLAND
CENTER FOR ENERGY STUDIES
KINGSTON, RHODE ISLAND

HYDROELECTRIC POWER POTENTIAL

WOONSOCKET FALLS DAM
WOONSOCKET, RHODE ISLAND

UNIVERSITY OF RHODE ISLAND STUDY TEAM

JAMES C. DALY	GABRIEL LENGYEL
ROGER B. DOWDELL	MACK J. PRINCE
WILLIAM E. KELLY	SAMUEL SEELY
PETER E. KOVEOS	LAURENS TROMP
JOHN S. KRIKORIAN, JR. PROJECT DIRECTOR	DANIEL W. URISH

GOVERNOR'S ENERGY OFFICE

EMILIE BENOIT DANTE C. IONATA

PROJECT CONSULTANT

JOHN W. GRIFALCONI

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JANUARY 1979

**UNITED STATES DEPARTMENT OF ENERGY
STUDY PROJECT**

HYDRO ELECTRIC
POWER POTENTIAL
Woonsocket Falls Dam
Woonsocket, Rhode Island

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REPORT SUMMARY AND RECOMMENDATIONS

Report Summary

A relatively new flood control dam, located in the City of Woonsocket, has been studied to determine its potential for hydroelectric generation. It is expected that the proposed plant would be operated run of the river as immediate upstream storage capacity is negligible. The dam is inspected by the Army Corps of Engineers on a semi-annual basis as to operability and structural stability.

Three sites for the location of the power plant were looked at in detail. These sites are designated A, B, and C and are illustrated on the downtown Woonsocket redevelopment planning map (Figure 1).

Site A is located approximately 300 feet downstream from the dam and takes advantage of an increase in available head at the expense of a buried penstock (8 foot pipe for water flow). This site does entail the acquisition of a vacant private parcel of land.

Site B is located across the bend in the river and approximately 1200 feet downstream from the dam and takes advantage of a further increase in head at the expense of an addition to the project cost due to the increased length of the penstock. This site has the highest cost for development.

Site C is located in the river channel opposite the tainter gate on the dam's east side. This location would eliminate the need for a penstock and its associated costs; but will require detailed evaluation and approval of its

FIGURE 1

effects on flood control operations and the dam's structure by the Army Corps of Engineers. This site has the lowest cost for development.

The proposed hydro station should be operated in parallel with the existing utility system. Use of local distribution lines for "wheeling"* of energy from the hydro generator to sites where it can be best utilized has been investigated, as well as, selling all of the energy to the utility company. The municipal sewer and water works are good sites where the energy can be wheeled. Wheeling of the energy does give a significant improvement to the project's financial feasibility.

The civil, electrical, and mechanical elements of the project have been studied. To reduce operating costs and to improve financial feasibility, the plant should be fully automated and this has been assumed during the study. If only for safety purposes, control and monitoring circuits should be conveniently available for use by the Blackstone Valley Electric Company.

Semi-automatic mechanical raking equipment for the trash racks is included in the design concept. It is assumed that collected debris will be manually removed from the intake site by Woonsocket Public Works personnel utilized in a dual capacity.

*Utilizing the utility company's distribution lines, with appropriate rental fee, to transmit the energy from the dam to a site where it can best be utilized to displace high cost energy brought from the utility company.

A comprehensive computer model, that takes into account engineering, environmental, economic, and financial factors, was utilized to estimate financial feasibility of each of the three sites for various options. Output from the model is the cash flow, which is the city revenue after operating, maintenance, and loan payments have been removed from the income of the proposed hydro plant.

Summary of the feasibility assessments are tabulated in Figure 2. Conservative installed plant costs and the best available data and information, with due consideration of time and monetary constraints, were used in the model. For some of these results, a nominal generator size of 1000 KW provided a basis for comparison during each of the case studies. Power plant size that optimizes financial feasibility and their associated monetary values are indicated in the last four columns of this table. The configurations that give the best cash flow return over the short term and operating life of the power plant are:

SITE A with
energy wheeled

SITE C with
energy wheeled

Both of these have comparable financial returns and should be considered prime configurations. Site A entails the acquisition of a vacant private parcel of land and Site C is subject to detailed evaluation and approval by the Army Corps of Engineers.

Woonsocket may utilize one or a combination of several alternatives to finance this project. External financing

	UTILIZATION OF ENERGY	HEAD FEET	NOMINAL INSTALLED COST FOR 1000KW UNIT \$/KW	MWH/YR	OVERALL AVERAGE EFF. %	U_1 (\$ (\$1,000s)	U_2 (\$ (\$1,000s)	INITIAL FIVE YEAR CASH FLOW (\$1,000s)	OPTIMAL PLANT SIZE (KW) U_1 FOR U_2		U_1 (\$ (\$1,000s)	U_2 (\$ (\$1,000s)
									U_1	U_2		
SITE A	Sold ⁽¹⁾	18	2022.	5926.0	71.	2153.	180.	-274.	1150.	700.	2247.	249.
	A.C.											
	Wheeled ⁽²⁾	18	2022.	5926.0	71.	4952.	1694.	133.	1150.	1000.	5100.	1694.
	Sold ⁽¹⁾	18	1800.	5782.5	70. ⁽³⁾	2268.	350.	-193.	(4)	(4)	(4)	(4)
	N.W.P.											
	Wheeled ⁽²⁾	18	1800.	5782.5	70. ⁽³⁾	5098.	1881.	219.	(4)	(4)	(4)	(4)
SITE B	Sold ⁽¹⁾	20	2520.	6199.1	75.	1854.	-225.	-462.	1300.	500.	1969.	-33.
	A.C.											
	Wheeled ⁽²⁾	20	2520.	6199.1	75.	4780.	1358.	-36.	1200.	800.	4956.	1429.
	Sold ⁽¹⁾	20	2298.	6108.5	70. ⁽³⁾	2014.	-31.	-374.	(4)	(4)	(4)	(4)
	N.W.P.											
	Wheeled ⁽²⁾	20	2298.	6108.5	70. ⁽³⁾	4965.	1567.	55.	(4)	(4)	(4)	(4)
SITE C	Sold ⁽¹⁾	16	1643.	5567.3	67.	2254.	418.	-149.	1050.	900.	2309.	441.
	A.C.											
	Wheeled ⁽²⁾	16	1643.	5567.3	67.	4884.	1842.	233.	1050.	1050.	4975.	1860.

- (1) All of the hydro generated energy is sold to the utility company.
- (2) Hydro generated energy is wheeled to the sewer and water works with excess sold to the utility company.
- (3) No information was provided by manufacturer to obtain this value, this is an estimated data point.
- (4) Insufficient data available to determine this value.
- U_1 = Discounted cash flow sum over 35 year operating life.
- U_2 = Discounted cash flow sum over 20 year loan period.
- A.C. = Allis-Chalmers hydroelectric unit.
- N.W.P. = Northern Water Power hydroelectric unit.

Summary Chart

FIGURE 2

could consist of sales of bonds, general or revenue; financing through federal government aid, either a direct grant or loan associated with the National Energy act; or a leasing arrangement with the Blackstone Valley Electric Company. Woonsocket could consider the possibility of internal financing out of any reserves or out of current revenues through taxes.

Contacts and discussions about the project have been held with the:

- State Energy Office,
- Public Utilities Commission,
- Department of Environmental Management,
- City of Woonsocket,
- Rhode Island Water Resources Board,
- Corps of Engineers,
- Federal Energy Regulatory Commission,
- Blackstone Valley Electric Company,
- Eastern Utilities Associates

Preliminary review has indicated that the hydro facility will have a minimal impact on the environment, although Site C will have to be carefully investigated as to effect on flood control operation of the dam. Good communication with regulatory agencies in the planning stage will assist in the development of the hydroelectric facility.

Recommendations

It is recommended that:

- (1) The City of Woonsocket proceed with plans to develop one of the prime sites - Site A or Site C - with the energy being wheeled to the sewer and water works and any excess sold to the utility company.

Reasons and Comments: By decreasing electrical energy brought from, and selling excess to the utility company, the proposed hydro facility has the capability of providing a net increase in disposable funds to the city over the short and long term life of the project.

- (2) The City of Woonsocket proceed immediately to obtain the necessary permits and licenses for the project.

Reasons and Comments: The money required to satisfy the regulatory requirements appears as if it is relatively low; however, time required is relatively long. Because of potential problems regulatory aspects can cause, satisfaction of these requirements should precede a commitment to actual construction.

- (3) The Rhode Island State Energy Office explore the possibility of obtaining a demonstration grant for the project.

Reasons and Comments: The concept of wheeling, as used in the project, and its implications are somewhat unique and should provide a basis for a demonstration grant.

- (4) Funding be provided so that the computer model and, information and data input, be further refined to incorporate more details of the system. Some of these include better modelling of the demand features of the power rate structure, and inclusion of random variation in the river flow data.

Reasons and Comments: The sensitivity of optimal plant sizing, due to the effects of actual non-smooth, daily random river flow, needs to be determined. It was assumed that changes in demand charges - due to wheeling - for utility brought energy at the sewer works would not significantly change the financial feasibility of the hydro plant. This qualitative assessment could be further tested by a more detailed quantitative simulation. The impact of recent energy legislation on power rate structures is unknown at this time. Effect of demand charges were discounted by using conservative data estimates for other variables.

- (5) The power rate structures be studied to determine if they are applicable to non-utility owned, co-generation facilities.

Reasons and Comments: Utility power rate structures were not designed for co-generation and may need changes that take into account the unique capability of a co-generation facility.

1. INTRODUCTION

1.1 Project Description

The potential site is a new flood control dam located in the City of Woonsocket (Figure 3). Adjacent to the river, municipally owned land is available that is suitable for use in the development of a small hydroplant facility. The dam is intended to pass floodwaters rather than impound, upstream storage capacity is negligible. Normal stream discharge flows over the closed tainter gates. It is expected that the plant would be operated run of the river. The dam has a head of approximately 18 feet in normal operation and this is reduced when potential flooding conditions exist. Exact optimum size of generator is dependent on the constraints and options that are finally considered.

Major elements that were considered in this feasibility assessment include the engineering and technical requirements, governmental regulatory aspects, project financing, and the technical and economic relationship associated with the utility-hydro interface. Feasibility of the project will depend on the environmental factors being satisfied and the financial requirements being acceptable.

Contacts and discussions have been held with the affected institutions and personnel involved. These include the State Energy Office, Public Utilities Commission, Department of Environmental Management, City of Woonsocket, Water Resources Board, Corps of Engineers, Federal Energy Regulatory Commission, the Blackstone Valley Electric Company,

Footnotes at the end of a section are indicated by superscript ^s, those at page bottom by asterisk; references denoted by (r).

Woonsocket Falls Dam

FIGURE 3

and the service company of the Eastern Utilities Associates.

The use of Blackstone Valley's distribution lines for the "wheeling" of energy from the hydro generator to the municipal users has been looked at in detail, as well as, selling all of the energy to the utility company. The sewer works and water works are sites where the energy can be "wheeled" over the distribution system. Relative location of the dam, sewer works and waters works, are illustrated in Figure 4.

Three sites for the location of the power plant were looked at in detail (Figure 5). Site A is located approximately 300 feet downstream from the dam, and immediately south of the South Main Street bridge. Site B is approximately 900 feet east of the dam across the bend in the river. Site C is located on the east bank between the dam and South Main Street bridge and would eliminate the need for a penstock.

A comprehensive computer model has been developed to determine the financial feasibility of each of the three sites. It takes into account the engineering, environmental, economic, and financial factors. Output of the simulation is the cash flow, which is the city revenue after operating, maintenance, and loan payments have been removed from the income of the proposed hydro plant. The model has also been used to determine the optimal configuration for the total system. The best available information and data, with due consideration of time and monetary constraints involved in

Reference Map

FIGURE 4

Aerial View

FIGURE 5

completing the project, were utilized in examining the different sites and options.

1.2 Historical Summary

The dam is a relatively new flood control dam, municipally owned by the City of Woonsocket, under supervision of the Corps of Engineers. It is inspected by them on a semi-annual basis as to operability and structural stability.

The original Woonsocket Falls dam was a fixed-crest masonry structure dating back into the 1800's and was located 100 feet upstream of the South Main Street bridge. This was replaced after the flood of August 1955.

This new dam has become a major component of the Woonsocket Local Protection Plan of the Blackstone River Basin Project authorized and co-ordinated by the U. S. Army Corps of Engineers. The project was designed to protect the industrial area of Woonsocket along the Blackstone River in the 8,300 foot long section between the Massachusetts state line and the South Main Street bridge. (Appendix E). The dam is a 266 foot long concrete flood control dam equipped with four tainter gates, each 50 feet long and approximately 10 feet high.*

1.3 Project Benefits

By decreasing electrical energy brought from, and selling any excess to the utility company, the project has the capability of providing a net increase in available disposable funds to the city. These funds can be used for other activities or projects. The construction of the faci-

*Information provided by Earle F. Prout, Jr., Dams Section, R. I. D. E. N, Appendix A.

lity would provide jobs for the construction industry within the state.

The development of this hydro facility will help to overcome our dependence on imported energy supplies. Should the centralized, utility owned power plants and long distance transmission facilities be destroyed or damaged during severe man made or natural disasters, then the hydro plant will be capable of assisting in supplying emergency power to vital city services.

2. EXISTING FACILITIES AND CONDITIONS

2.1 Description of Dam

The Woonsocket Falls dam is a part of the Upper Woonsocket Flood Control Project completed in 1960. The dam is a concrete structure founded on bedrock, having four 50-foot ogee weirs with 10.1 foot high tainter gates and a short non-overflow abutment section across an abandoned canal.

The total length of the structure is about 268 feet, and the total height from bedrock channel elevation to the concrete service road on the top of the structure is about 40 feet. The concrete weir crest, or gate sill, is elevation 138.0 and the top of the closed gates is 148.1 feet. Dam details are shown in Figure 6.

The dam is intended to pass floodwaters rather than impound. Upstream storage capacity is negligible. Normal stream discharge flows over the closed tainter gates.

2.2 Geological Description of Area

The project areas consists primarily of a thin mantle of till or alluvium overlying bedrock at shallow depth, probably less than 10 feet in most locations. The dam site is a natural rapids area with exposed bedrock along the stream bed and much of the stream sides. The rock is highly fractured and foliated with an apparent dip to the east.

The water table is approximately 10-15 feet below ground surface. The natural subsurface conditions in the project area have probably been greatly modified by numerous manmade structures--building foundations, water channels,

ABUTMENT
SECTION ←

Details of Dam

FIGURE 6

and utility trenches; the detailed location and extent of many of these features, now abandoned and covered-over, is unknown.

2.3 Hydrologic Conditions

2.3.1 General Hydrology

The drainage area of the Woonsocket river above the Woonsocket Falls dam is about 404 square miles and has an average annual precipitation of 42 inches per year. River flows of record range from a maximum of 32,900 cfs in 1955 to a minimum of 21 cfs in 1934 with an average annual flow based on 48 years of record of 749 cfs. Apparent normal base flow is about 100 cfs during the dry months. Additional information on stream flow is shown in the flow duration curve in Figure 7 and the average monthly river flow plot in Figure 8, both based on 13 years of record (1965-1977) from the USGS gaging station at Woonsocket.

2.3.2 Flood Control Operations

The Woonsocket Falls River Dam is operated by the City of Woonsocket to minimize upstream river fluctuations and levels during flood periods. When the four tainter gates of the dam are in a closed position (stage 0.0 ft., or elevation 148.1 ft.), the water level upstream of the dam will fluctuate depending on the flow in the river. No gate operation is required for normal riverflows below a stage of plus 2.5 feet, equivalent to about 1,800 cfs. Above this stage, gate operation is required to control the river rise. Gates can be raised in various combinations and various settings.

Minor rises above 2.5 feet generally occur annually and

TT

Flow Duration Curve

FIGURE 7

Average Hydrograph

FIGURE 8

occasionally more than once in a year. Minor floods are expected every 2 to 3 years, and major floods (flows exceeding 7,000 cfs) may be expected once in 4 to 5 years. During a two-week period each summer, the gates are opened to allow the river to drop to weir crest level (elevation 138.0 ft.) to permit upstream maintenance.

2.3.3 Hydroelectric Potential

The hydroelectric power potential is represented by the available flow of water and the head. Since storage behind the dam is negligible, the project will operate on a run-of-river concept. A minimum required flow of 50 cfs over the dam is assumed.

Gross head at site A, approximately 300 feet downstream can vary from 14 to 24 ft. and at site B approximately 1200 ft. downstream from 22 to 32 ft., depending on the gate position and river flow. After deduction of losses for intake, pipe flow, and tail water, 18 feet of head should be available at site A, and 20 feet of head at site B, at least 75% of the time. Power will be produced only when the water is at gate top level or above.

Flow available for power is highly variable. The plant is sized to a flow of 950 cfs which will be equal or exceeded 25% of the time. Depending on the size and number of power units installed, the minimum flow at which the plant will operate will range from 320 cfs for a single unit, to 160 for multiple units. An examination of the flow duration curve (Figure 7) and average monthly flow plot (Figure 8)

shows that it may be expected that the plant will be down about 4 months/year for a single unit and about 1 month/year for multiple units due to insufficient flow.

3. "WHEELING" OF ENERGY

3.1 Wheeling Charges

Wheeling is the use of the distribution lines owned by the electric utility for the distribution of energy from the hydroelectric generator to a distant location where it can best be used. A fee is charged by the utility for this distribution service. The fee is based on expenses involved plus a fair return on the capital value of the distribution equipment. Consideration is given to the fact that only a fraction of the load on the distribution facilities is the energy being wheeled.

Wheeling allows the generated energy to replace energy used at the sewerage treatment plant and the waterworks that would otherwise have to be purchased from Blackstone Valley Electric at a rate of about 3.5¢/KW·HR. A preliminary estimate of about 0.3¢/KW·HR for wheeling charges has been calculated by the service company of Eastern Utilities Associates. Therefore, the wheeled energy has a value to the City of Woonsocket of about 3.2¢/KW·HR. This is compared to the price of about 2.0¢/KW·HR when the energy is sold directly to the utility company (Appendix D).

Utility power rate structures were not designed for cogeneration and may need changes that take into account the unique capability of a hydroelectric plant. For example, although there are many different power rate structures, they can in most cases be broken down into three generic classifi-

cations: industrial, commercial, and residential. The industrial rate, for which the sewer qualifies, is approximately .034 dollars per KWH in New England and the customer buys a relatively large amount of energy. The commercial rate is approximately .051 dollars per KWH and the customer buys less under this structure. Under the industrial rate, a facility that has energy "wheeled" to it decreases energy purchased and may find that it does not qualify anymore for the lower industrial rate for energy brought from the utility company. Under these circumstances, there could be a detrimental change in financial feasibility for a hydro co-generator.

3.2 Historical Summary

Historically, "wheeling" of energy has been utilized in the past mostly by utility companies. For example, in 1954, the U.S. Solicitor General made it possible for a nonfederal utility to use the Bonneville Power Administration's interconnected western regional power grid to transmit electric energy from a large isolated hydro facility to distant load centers (10).

There are many hydro sites where the dam and the site where energy can best be utilized, are owned by the same entity, but are located some distance apart such as the Woonsocket dam, municipal sewer and waterworks that are being studied in this feasibility assessment. Wheeling offers the advantage of avoiding possible duplication of distribution facilities and improving feasibility of projects.

4. PROJECT FINANCING

4.1 Introduction

Woonsocket may utilize one of the several alternatives available to finance capital projects. This section discusses some of the alternatives. The optimum alternative depends on many factors, some of which may be unknown at this time. An attempt is made, however, to bring forth some of the major determinants of the decision process. The alternatives discussed are:

External Financing

1. Issuing Bonds
2. Financing through Federal Government Aid
3. Leasing

Internal Financing

An additional alternative is represented by a combination of two or more of the above.

4.2 External Financing

Externally, a municipality may borrow by acquiring funds through sales of bonds and direct loans from a private source or another level of government. Alternatively, it may opt to lease the necessary equipment to complete the project. From the local government's point of view, of course, the optimum alternative would be a grant from the federal or state government.

4.2.1 Bonds

Bonds issued by municipalities may be classified in one of the following categories;

- A. General
 Regular
 Special Tax Districts

B. Revenue

Municipal Utilities

Authorities and Commissions

Non-Utility supported by special tax or rentals
of public buildings

C. Housing Authority¹

The alternatives discussed in this report are included in the General and Revenue Categories.

Municipalities are able to compete effectively in the bond market because of the tax exempt feature to the investor associated with income from their instruments. For a Rhode Island investor, for example, buying a bond from a Rhode Island municipality, the tax-free interest income, assuming no capital gains or losses, would equal:

$$r_m = r_c (1-t-.19t) = r_c (1-1.9t)$$

where r_m = yield on the municipal bond

r_c = yield on the corporate bond

t = marginal federal tax rates

Local taxes could also be incorporated in this relation. The implication of this equation is that the greater the relevant tax rate, the lower the yield on the municipal bond which the individual would accept. The greater the value of the tax exempt feature, the lower the cost of borrowing for the municipality.²

4.2.1.1 General Obligation and Revenue

4.2.1.1.1 General Obligation

The term refers to any bond for the service of which the municipality has pledged its entire tax revenue, regardless of the manner in which this revenue is raised. The quality

of a general obligation bond ultimately rests on the economic strength of the municipality. Specifically, factors affecting the quality of an issue may include:

- a. the value of taxable property
- b. the tax and assessment rates
- c. the tax collection record of the municipality
- d. the current debt of the municipality
- e. the debt service requirements
- f. the relationship of debt and debt service to revenues and operating expenses
- g. the past debt record of the municipality
- h. the per capita debt
- i. the municipality's economic resources

The ability of the local government to support a project through general obligation bonds also depends on the legal debt limits imposed by the state. To avoid these legal constraints, the municipality may divide the area into special tax districts and issue bonds supported by the property located in these districts only.

Professional rating services evaluate the relative risk of these municipal bonds by assigning them ratings. Ratings incorporate the impact of the factors indicated as affecting the quality of general obligation bonds on the issue's relative default risk. Good ratings result in a low cost of borrowed capital for the municipality. Bonds receiving a rating of Aaa, for example, may entail interest savings of .1 percent for a municipality over bonds rated Aa, the exact difference depending on the interest rate cycle. During the last few years the rating of general obligations issued by Woonsocket, Rhode Island, has fluctuated between Baa and A indicating, according to Moody's service³, that the bonds are considered medium to upper medium grade. The bonds have

received adequate interest coverage. The rating agency, however, may feel that the bonds could prove unreliable under certain circumstances in the future.

Municipalities may improve their ratings by acquiring insurance from the Municipal Bond Insurance Corporation. An issue of \$1,000,000 may bear a premium of \$15,000, the exact premium depending on the quality of the issue. Municipal bond insurance, however, improves ratings substantially in some cases signifying considerable interest savings for the issuing authority. It should be seriously considered, then, by all municipalities. As a rule of thumb, an issue expected to receive a rating lower than A should be insured.

4.2.1.1.2 Revenue

Issuing general obligation bonds may not be feasible for the municipality because of existing economic and political difficulties. Financing may then be accomplished through revenue bonds. These bonds depend for payment and interest on income generated from some specific source, such as an electric utility, rather than the general taxing power of the municipality.

Revenue bonds appeal to the municipalities because they may enable the local government to circumvent any legal debt ceiling, attain a better rating than general obligating bonds in certain cases, and issue the bonds without referring the issue to the electorate*. Revenue bonds may also be utilized to encourage location of industry in the local area, with the ultimate objective to improve the overall economic picture,

*For Woonsocket, both Revenue and Tax Secured Bonds must be authorized by the General Assembly and then referred to the electorate.

or, in the case of authority bonds, to allow for the possibility of extending the project beyond the immediate boundaries.

Since they are supposed to be self-liquidating and financially self-supporting, revenue bonds bearing the title of municipal utility or a corporation are evaluated on the basis of the profitability of the project to be financed.

The strength of bond, then, depends among other factors, on:

- a. the degree and consistency of coverage afforded to
 - interest payments
 - debt retirement
 - operating expenses
 - depreciation
 - contingency margin
- b. order of application of revenues
- c. ability of the authority to raise rates
- d. possibility of future competition for the projects⁴

It is imperative that accurate and convincing statements are formulated with respect to the earning capacity of the product*. Demand and cost projections have to be formulated. If the demand projections reveal that the revenues generated exceed the costs after allowance for contingencies, then the issue will receive a high rating.⁵ If demand projections indicate that the revenues are inadequate, the appropriate governmental authorities have to decide whether the project deserves at least partial financial aid in the form of a grant. This will be the case if the social rate of return derived from the project is greater than the private rate. The social implications of the product, then will have to be weighted in addition to the private ones.⁶

Despite any apparent accuracy of earnings forecasts,

*Financial feasibility assessments developed in Sections 6, 7, and 8 can be used to help convince investors of the security of an issue.

revenue bonds may still be identified as risky instruments for the simple reason that the project has not even begun in some cases at the time of financing. Thus, revenue bonds may be rated below the rating of a general obligation issued by the same municipality. The cost of initially floating a revenue issue, then may be higher for the municipality than the cost of floating a general issue.

4.2.1.2 Net Interest Cost

Issuing of bonds by municipalities involves at least two types of costs.⁷ The first is the familiar interest paid to the ultimate owners of the bonds. These interest payments are usually made on a semiannual basis. If the bonds are of serial nature, with a certain part of debt coming due at pre-specified periods of time, these interest payments will be the same for bonds having the same maturity. The interest payments, however, need not be the same for bonds of differing maturities.

The second type of cost is a one-time expense paid to bond underwriters when the issue is offered. This cost is referred to as the spread. The spread represents the reward to the underwriters for undertaking the costs and risks associated with selling the issue to investors in the primary market.

Municipalities offer many of their bonds - general or revenue - on competitive bidding basis. The municipality announces its intent to issue bonds and invites bids on the bonds. The bidding notice may include any coupon rate

structure and other details of the sale. Several underwriters submit bids. The winning bid is identified by the lowest spread or net interest cost. Net interest cost is determined using the following formula:

$$\text{NIC} = \frac{\text{Total Interest Cost Over Life of Issue Minus Premium}}{\text{Total Number of Bond Years}}$$

If, for example, the bid is for 101, amounting to a premium of \$10,000 for an assumed issue, total interest is \$900,000, and the total number of bond years is 20,000 (found by multiplying the number of bonds in a maturity group by the number of years the bond will be outstanding), then

$$\text{NIC} = \frac{900,000 - 10,000}{200,000} = \frac{890,000}{200,000} = 44.5$$

If the example relates to a bond denominated at \$1,000, then the net interest cost is 4.45 percent.

To place their bid, underwriters estimate the price at which the issue can be offered to the investors. The underwriters then subtract the spread from the price expected to be paid by the investors and submit their bid. The lowest net interest cost, as noted, will determine the winning bid.

The price at which the bond is offered to the investors will depend on many factors, including⁸:

- a. the general level of bond prices
- b. the rating of the bond
- c. the maturity of the bond
- d. the type of security considered (general or revenue)
- e. the number of underwriters participating in the bidding process

The spread required by the underwriters usually ranges from under 1.0 to 2 percent of the issue and averages 1 percent

for some large issues. The spread is determined by

- a. the rating of the bond
- b. the maturity of the bond
- c. the general level of bond prices
- d. the number of underwriter bids

Furthermore, the number of underwriter bids is influenced by

- a. the size of the issue
- b. the rating of the bond
- c. the maturity of the bond
- d. the type of security considered (general/revenue)
- e. legal constraints on commercial bank underwriting of revenue bonds

The net interest cost approach to evaluating underwriters' bids may be a simple and expedient method of settling the placement process. It may be a very inefficient method, however. The possible inefficiency of the approach results from the manner in which payments enter the net interest cost calculation. The approach utilizes a discount rate equal to zero. A more realistic approach would incorporate the relevant variables in the calculation after they are properly discounted. Proper discounting may alter the ranking of bids received by the municipality. The new ranking may entail substantial cost savings to the issuing authority.

4.2.1.3 Public Placement

When bonds are offered on a negotiated, rather than competitive, basis no formal bids are submitted. Instead, the underwriters and the issuers reach an agreement on coupon payments and issue structure through negotiations. Negotiated offerings are sometimes preferred because of the specialized nature of the bonds marketed. A large number of revenue

bonds are offered in this manner.

To issue bonded debt, municipalities need appropriate legal advice. The function of legal counsel is to assist in drafting the legal opinion accompanying the bond offering. The opinion appears on issue advertisements and can be printed on the bonds. In the opinion, the lawyer is expected to make a statement about the revenues backing the issue, and the tax treatment of the issue. The lawyer will also assist the municipality in negotiating with the underwriters.

To announce the sale to the general public, the underwriting group advertises the issue in specialized bond circulars and in the financial papers. The advertisement gives a preliminary description of the bonds, including the purpose of the issue, the total amount issued, the amount due each year if the bond is serial, the coupon rate and price (or yield) for each maturity, and any call provisions.

The advertisement is usually accompanied by a separate brief article announcing the sale and providing some background, including previous comparable sales by the municipality. The advertisement usually appears in the newspapers two to three weeks before the official statement can be acquired by prospective investors. The entire process, from the decision to issue bonded debt until payment is received may take up to ninety days.⁹

4.2.1.4 Example of an Issue

The actual structure of a bond issue depends on market conditions prevailing at the time of flotation. Utilizing a set of assumptions, however, an example of an issue is

illustrated in Figure 10.

The assumptions are the following:

1. The bonds are issued on January 1, 1980.
2. Bonds receive a rating between Baa and A. Interest payments are estimated from currently outstanding bond issues of comparable quality and maturity.
3. The size of the issue is \$1,000,000.
4. Price is 100 for all bonds.
5. Denomination is \$5,000.
6. Maximum maturity is 20 years.
7. Bonds with maturities of 19 and 20 years are subject to call by the municipality according to terms agreed upon in the official statement. The call provision is advisable, since it enables the municipality to take advantage of any downward movement of interest rates in the future.
8. Coupon payments are increasing in a linear fashion.
9. Total interest is calculated assuming an effective discount rate of zero. The present value of interest payments decreases when the appropriate discount rates are utilized.

4.2.1.5 The Indenture

When the bond is finally sold to the investor, the legal agreement between the issuing authority and the bondholders is included in the indenture. The indenture contains the terms and constraints on the issue. The indenture, which may be a comprehensive document, first defines the type of the security issued. This is an especially important point in the case of revenue bonds, since the type of a bond determines the flow of funds from the issuer to the lender. Some of the common types of securities include:¹⁰

1. A pledge of the entire gross revenues to bond interest and retirement.

<u>AMOUNT</u>	<u>MATURITY</u>	<u>INTEREST RATE</u>	<u>BOND YEARS</u>	<u>TOTAL INTEREST</u>
\$100,000	1985	5.90 ^o /o	120	\$35,400
\$100,000	1986	6.00	140	42,000
\$100,000	1987	6.10	160	48,800
\$100,000	1988	6.20	180	55,800
\$300,000*	1998	7.20	1140	410,400
\$300,000*	1999	7.30	<u>1200</u> 2940	<u>438,000</u> 1,030,400

*Subject to call according to the Optimal Provisions set forth in the official statement.

Example of an Issue

FIGURE 10

2. A pledge of the entire net revenues to bond interest and retirement.
3. A pledge of a fixed percentage of the gross or net revenues.

The indenture will also include some of the following covenants:

1. The rate covenant, which explains the issuing authority's ability to vary rates.
2. Issuance of additional bids.
3. The distribution of funds among the following: operating expenses, maintenance, bond interest, expense, serial principal, sinking fund contribution, reserve fund accumulation, and others.
4. Segregation of funds into different accounts.
5. A pledge to maintain the project in good condition.
6. Provision for audits of the accounts.
7. Retention of independent engineer to monitor the project.
8. Restriction on competition to the project.
9. Negotiability of the instrument.

4.2.1.6 Interest During Construction

Once the bonds are sold and payment is received, construction of the project may begin. During construction, of course, the project experiences a net cash outflow consisting of the payment for construction and for bond interest. Under the assumed issue structure in Figure 10, the interest cost incurred during construction are shown in Figure 11. For simplicity, again, these interest costs are presented undiscounted. Also for simplicity, it is assured that interest payments of full two years are made.

The municipality, however, may decrease net interest

<u>AMOUNT</u>	<u>MATURITY</u>	<u>INTEREST PER YEAR</u>
\$100,000	1985	\$ 5,900
\$100,000	1986	6,000
\$100,000	1987	6,100
\$100,000	1988	6,200
\$300,000	1998	21,600
\$300,000	1999	<u>21,900</u>
		\$67,700

Interest for Two Years = \$67,700 x 2 = \$135,400

Interest During Construction

FIGURE 11

costs during construction if part of the borrowing funds is placed in Treasury securities. Assume, for example, that the municipality is in a position to pay for some of the costs after construction is completed. These funds may be placed in short term or long term government securities, depending on the length of construction. Investing \$500,000 of the gross proceeds in a two year security may yield as much as \$80,000 on interest. If part of it is retained for contingencies, the remaining or \$60,000, could be applied to defray a portion of interest costs. The net payments, then, may only amount to \$75,400.

4.2.1.7. Private Versus Public Placement

To this point, the analysis has assumed that the issue has been offered for public sale. If the project is one of small scale, however, the entire supporting issue may have to be sold to a single institutional investor, or to a group of such investors. This may be necessitated by the high flotation costs associated with issues below \$5,000,000. These costs vary inversely with the size of the issue. For an issue of \$1,000,000, underwriting and other expenses could exceed 2⁰/o of gross proceeds. Some underwriting firms will even flatly refuse to handle such an issue.

Private placements initially entail some savings to the issuing authority. There are no underwriting costs involved, although an underwriter may be hired to offer advice to the municipality. Private placements may also give the municipality some flexibility with respect to the timing of the

loan proceeds. The interest charged, however, may exceed charges assigned to a public offering. In addition, a private offering may include loan clauses which are stricter than those found in public offerings.

Small issues, then, may be excluded from public offerings because of high flotation costs*. If this is the case, the municipality's financial officers have to find an individual lender willing to buy the entire issue. The past financial history of the municipality, its relationship with lenders in the surrounding financial centers, and the availability of investment funds will determine the cost and terms of the loan.

4.2.2 Financing Through Federal Government Aid

If cost/return calculations conducted by the municipality indicate that the project is not financially feasible, the local authority has the option of applying for federal assistance. This assistance may be both indirect and direct.

The Public Utilities Regulatory Policy Act of 1978 sets forth certain broad energy related national purposes, one of which is to encourage the efficient use of energy resources. Under the act directives, a municipality contemplating to undertake a hydroelectric project may qualify to receive part of the \$10,000,000 allotted to defray a portion (up to 90⁰/o) of the costs of

1. studies to determine the feasibility of undertaking a project at an existing dam and
2. preparing any application for a necessary license or other federal, state and local approval respecting such a project and of participating in any administrative processing regarding any such application.

*Bonds for the hydro project would be a small issue.

Furthermore, if the project is not found feasible, the secretary shall cancel the unpaid balance and any accrued interest.¹¹

This indirect manner of financial assistance may enable municipalities to further survey all aspects of the project. It may provide the opportunity to adequately study the engineering and economic implications of the project, and persuade the eventual lenders of the project's worthiness.

In terms of direct assistance, municipalities may receive part of the \$100,000,000 in loans furnished by the Secretary of Energy to cover up to 75% of the construction costs of a hydroelectric project.¹² According to the act, every loan made shall bear interest at the rate used at the time of the loan for water resources planning projects under Section 80 of the Water Resources Development Act of 1974. The maximum maturity for these loans shall be 10 years, for feasibility studies loans, and 30 years for construction costs loans.¹³

In addition to the assistance provided by the Public Utilities Regulatory Policy Act, there is a possibility for provision of additional funds in the form of grants or loans administered by the Secretary of Energy. Federal assistance may fund projects considered marginal in the private markets. The municipality may still have to raise part of the required funds from other sources. The task of raising \$250,000 is much easier, in most cases at least, than that of raising \$1,000,000.

4.2.3 Leasing

Instead of borrowing to buy, the possibility of leasing with a probable option to buy the necessary equipment has to be considered by the project sponsor. Leasing is sometimes preferred to borrowing if it provides the lessee with flexibility in the use of the appropriate equipment or enables the lessee to avoid the risks associated with ownership. In some cases, leasing is the only available form of financing. The "borrow or lease" decision is in effect, the "not operate or lease" decision.

An adequate cost/benefit analysis of the leasing alternative has to incorporate both the financial and nonfinancial aspects of the decision. The financial aspects mainly evolve around the tax benefits passed on from the lessee to the lessor. These benefits stem principally from the investment tax credit and the deductibility of depreciation. As these benefits are furnished to the lessor, the lessee reaps the equally desirable benefits of lower rental payments. The amount of benefits the lessor actually passes to the lessee depends on the tax position of the parties involved and the discount rate utilized by each.

The nonfinancial aspects of leasing include the uncertainties associated with nonownership during the life of the lease. Quantifying these aspects is extremely difficult. Evaluating the leasing alternative, then, may become a complicated task.

Leasing to a municipality does not generate investment tax credit for the lessor. In addition, the additional

benefits derived from the deductibility of depreciation may be very small in an environment of liberal accounting practices. Rental payments, as a result, may not decrease to the extent necessary to make leasing an attractive alternative unless the discount rate utilized by the lessor is not the "appropriate" one. In the currently fast growing leasing industry, this may be the case.

In general, then, leasing does not offer for the municipality the same financial advantages it offers to other lessees. At times, however, it is the only financing alternative and also may have the advantage of reducing operating, maintenance, and administrative costs associated with operation of a small number of power plants.

4.3 Internal Financing

The municipality may attempt to finance capital projects out of reserves or out of current revenues through taxes or user charges. Alternatively, reliance on internal financing may be necessary to make part of the required interest or rental payments.

The ability of the municipality to raise funds internally depends on a variety of factors. These include the municipality's past economic record, current economic resources, tax and assessment rates, legal limitations to its tax power, tax collection record, as well as the broader economic and political realities. The weight assigned to these factors may vary over time. At the present time, for example, the decreased tolerance of the citizenry toward tax increases as expressed by resolutions similar to Proposition 13 is closely

watched by municipal officers. The current environment, then, combined with the extent to which current taxes would have to be raised to support new large capital expenditures may indicate that taxes and other forms of internal financing by themselves are not a feasible solution to the project financing question.

4.4 Conclusion

This section has discussed some of the alternatives available to a municipality in financing a new project. The most attractive alternative is a grant by the federal government. If the grant does not generate sufficient funds to cover all costs, a supplementary source of financing may be utilized. The grant may be justified if the social rate of return of the project is higher than the private (municipality) rate.

If the municipality decides to proceed with the project (without a grant), the alternatives noted may be considered individually or in combination. The optimum choice will depend to a large extent on the condition of the different markets for funds at the time of the decision. The municipal bond market, for example, may become much tighter in the near future as a result of Cleveland's financial difficulties. Similarly, the inflation rate may decline or rise depending on the policies followed by President Carter and the Federal Reserve Board. The profitability of the project may change as a result of an increase in construction costs or an increase in fuel prices. Forecasting the exact movement of all variables, and therefore engaging in speculation regarding

the feasibility of the project, is extremely risky and may even prove misleading at an early period in relation to the contemplated start of the project.

FOOTNOTES

- ¹Housing Authority bonds may also be examined as a special type of revenue bonds.
- ²The degree to which the municipality and the investor share the tax benefit depends on the maturity structure of the municipal debt and the interest rate cycle. The degree to which tax exemption reduces municipal interest cost varies inversely with both maturity and the level of interest rates. See (5), p. 195.
- ³See (2)
- ⁴See (1) for discussions of some of these points.
- ⁵For an electricity related project, for example, it could be noted that electric consumption is expected to increase by 5-6⁰/o over the next decade, compared to a 3⁰/o increase for energy in general. According to some sources, (4), the share of electricity in U.S. energy demand will increase from 28⁰/o in 1974 to 37⁰/o in 1990. Electricity prices could also be compared to other prices, both in the retail and wholesale level, to reveal any probable pricing pattern.
- ⁶See section of the report on Financing Through Federal Government Aid.
- ⁷Other costs of usually smaller magnitude include legal costs. The size and manner of payment of these costs differs from issue to issue and from municipality to municipality.
- ⁸See (3) for analysis of some of these factors.
- ⁹Payment for the securities usually takes place about fifteen to thirty days after bonds are received.
- ¹⁰See (2).
- ¹¹See (4), Section 402.
- ¹²See (4), Section 403. These loans carry an interest rate of 6.875 percent. This rate may change by .25 percent each year.
- ¹³See (4), Section 404. Another section of the Act, Section 405, establishes a program of simple and expeditious licensing procedures.

() refers to references in Section 11.

5. GENERAL ENGINEERING

5.1 Power Station Grounding

There is a need for protecting the workers and the equipment at a power station from current surges due to faults or lightning strokes. Fault currents are usually 10 to 100 times the normal current, and such a current through the grounding mat and the bulk resistance of the earth could result in dangerously high voltages. It is necessary to plan the grounding system in such a way that personnel cannot come in contact with the grounding system at any point which might prove to be dangerous.

Calculations have been carried out for embedded conductors of various sizes, shapes and configurations (6,7). For example, calculations have been completed for ground rods in parallel, as a function of rod diameter (8). Four 10' x 3/4" rods at the corners of a 10' square gives a resistance slightly less than one rod 40' long. In general, to reduce the ground resistance, one should use a large number of slender rods.

The practical problem that one faces is that of grounding the several components constituting a power plant, elements of which will be constructed on or in different materials which are seldom homogeneous. That is, some of the elements will be built on outcropping rock of fairly high resistivity with varied overburden. That part which is underground may be in rock plus clay. The switchyard would likely be on different substructure from the power house. The intake structure

is in direct contact with the large volume of water behind the dam. Hence, even if one were to use a grounding grid, the effective resistance of the several elements which are connected to the grounding grid through heavy copper conductors would in general, be different. Furthermore, the grounding grid itself might not be intimately bonded to the earth.

A detailed design for a ground system would be dependent on the specific features of the installation. Because of the relatively compact nature of the proposed Woonsocket hydro facility, a relatively simple grounding system would be adequate. A number of vertical rods on the perimeter of a square would appear to be a basic disposition to consider. Whatever the ultimate configuration, careful measurements should be made to determine the resistivities, if realistic results are to be possible.

5.2 Connection of Proposed Hydro Station to Existing Utility Network

The scheme frequently used in the past of running a hydro generating station isolated, supplying its own load, did not seem to be feasible in the case studied here. The reliability and quality of such a service in terms of frequency and voltage stability would not meet the demands of today's customers. Furthermore, the supply of energy would be subject to the variations of waterflow and it would be difficult to match exactly the demands of the load to the available power at all times. Thus, it was decided early in this study to operate the proposed hydro station in parallel with the existing utility system, because this would enable

the operator of the station to utilize fully the available power at any one time. The connection of a generating station to a power distribution system presents certain technical problems which were discussed with the representatives of Blackstone Valley Electric Company, the operator of the distribution network in the Woonsocket area. They supplied technical information and data that helped to crystallize the ideas about the proposed tie-in arrangement.

The following topics were discussed:

1. Location of the tie-in of the new station,
2. Short-circuit considerations,
3. Relay protection of the new station,
4. Load flow and voltage levels,
5. Stability of proposed generating station,
6. The choice of generators-synchronous versus induction type.

Some of these questions are closely interrelated and each topic was discussed considering the various alternatives.

This report will be limited to the presentation of the outcome of the discussions.

1. Two alternatives were considered;
 - a. Tie-in at 13.8 kV to the nearest utility substation on Sayles Street,
 - b. Construction of a new 13.8 kV line from the hydro station to the sewage plant and waterworks.

The second alternative would have had the advantage of enabling the operator of the hydro station to sell power directly to these loads and eliminate "wheeling" charges. The construction costs of the transmission line estimated at

\$35,000./mile made this alternative less economical, however, compared to "wheeling" the energy to these loads on the existing system.

Thus, alternative a) is recommended. The distances involved in this case are 1200 feet for Site A and 1800 feet for Site B.

2. The three-phase short circuit current on the 13.8 kV side of the utility's network at the present time amounts to 3800 A (900 MVA). Assuming that the size of the hydro station will be on the order of 1 MVA, the additional short circuit supplied by this unit will not exceed 10 MVA depending on the sub-transient reactance of the generators. As data are not available on this at this time, the above number is only an estimate. Generally, one can say that the short circuit current supplied by the station will not present substantial additional danger to the utility's system. Breakers in the Sayles Street substation are rated for 500 MVA interrupting capacity.

3. The following protective relays are required by the utility:

- a. Over-and-under voltage relay,
- b. Over- and under frequency relay,
- c. Directional overcurrent relay,
- d. Ground-fault relay,
- e. Negative-sequence relay,
- f. Differential relay.

Relays a. - e. are required to protect the utility's network.

against dangerous or otherwise undesirable operating conditions. Relays f. protect the generation units in case of internal faults.

4. Simple load flow studies were carried out based on data supplied by the utility. Due to the small size of the hydro generating station as compared to the load carrying capacity of the existing distribution system, the power fed into the system by the station is not expected to alter substantially the prevailing voltage levels or loading of the transmission system even at maximum output levels of the hydro station.

5. Synchronous generators can maintain synchronism with other units connected to the system if their loading does not exceed a certain stability limit. This limit depends on the electrical characteristics of the machine and tie-in line and the network configuration.

The steady-state stability of the proposed station was analyzed using typical machine data and network configurations pertinent to this case. No stability problems are expected under normal operating conditions, even at full output.

6. Induction (asynchronous) generators can be employed in case of relatively small generating stations because they cost somewhat less, require far less relaying and control equipment than synchronous machines, feed much less short circuit current back into the system in case of faults, and do not pose stability problems.

A detailed economic and technical comparison between the

synchronous and asynchronous alternatives was not carried out because suppliers declined to quote prices on asynchronous units. Synchronous machines in turn have the advantage of being able to supply reactive power which induction units are unable to do. Furthermore, it seems that the additional technical problems associated with the use of synchronous units can be easily overcome at a slight increase in cost.

In summary, it is proposed that the hydro station be tied through a transformer and a short overhead line to the 13.8 kV bus of the utility's Sayles Street substation. Synchronous generating units should be used with the protective relaying discussed under 3. It must be noted that the units should be able to run under automatic control, be brought from standstill to synchronism without the assistance of an operator, and be disconnected from the system if necessary by remote tripping.

5.3 Automation

The power plant has been assumed to be fully automated to reduce operating costs and consequently, improve financial feasibility. Push button start and stop operation is relatively easy to implement. Some packaged hydro plants are being sold that are fully automated. Control and monitoring circuits should also be conveniently available for use by the Blackstone Valley Electric Company - if only for safety purposes.

5.4 Metering

If all of the generated energy is sold to the utility

company, then only metering of energy from the hydro plant will be required. Should energy be "wheeled", then time of day metering of the hydro plant, sewer works, and waterworks may be necessary. Data collection should be computerized to improve reliability and efficiency of the accounting of energy generated, used, and wheeled.

5.5 Intake and Trash Rack

The proposed intake consists of a reinforced concrete bay with trash rack and stopgate and is located on the east bank on city land approximately 100 feet upstream from the dam. The intake area will be covered and protected by chain link fence.

River water passing to the turbines must be screened of foreign material larger than about 3 inches. This necessitates the installation of steel bar screens in conjunction with the intake structure. Minimizing head loss through these constricted openings will be a major design and maintenance consideration.

The trash rack for the proposed project will be approximately 40 feet in length to limit head loss due to flow velocity, and consists of removable sections. Design must be adequate to withstand complete blockage due to debris or ice. Cleaning of racks may require extensive attention during 1 to 2 months during early fall then there is leaf build-up on the rack. Mechanical raking equipment is included in the project concept. It is assumed that collected debris will be manually removed from the intake site. Ice, particularly

frazil and anchor ice, which can collect and clog the entire depth of rack, is a potential problem a month or so during the winter. Because of the assumed limited nature of this problem no provision is made in the proposed project for automatic control of icing.

5.6 Sewer Works

A regional sewerage treatment plant (Figure 12) is operated by the City of Woonsocket. Its location is indicated in Figure 4 and is about 1.2 miles from the dam. When in full operation, it will have a demand capacity of 4 Megawatts. The present nature of the demand can be seen from the characteristics shown in Figure 13. This represents the average hourly demand for the two week period from October 27, 1978 to November 10, 1978. The data shows that the sewerage treatment plant consumed at least 550 KW of electricity twenty-four hours a day during this period. The sewerage treatment plant could absorb at least half of the energy generated by the Woonsocket dam. In the future when the sewerage treatment plant demand for electricity increases, it could absorb a larger portion of the power generated. The sewer works has been assumed to be close to full operation when the hydro plant comes on line.

5.7 Water Works

A water pumping station (Figure 12) is operated by the City of Woonsocket. Its location is indicated in Figure 4 and is about 1.7 miles from the dam. This installation provides water for the residents of the city. During the period

Sewage Treatment Plant

Water Treatment Plant

Average Hourly Power Demand for the
Waste Treatment Plant

FIGURE 13

of one year it consumes 3,500,000 KW-hr of electrical energy. This is a little more than half of the energy that could be generated by the Woonsocket dam. The waterworks pays a modified time-of-day rate for the electric energy it uses. Because the cost of energy is high, at times, no pumping is done for two hours in the afternoon. About $3/4$ of the energy is used during 13 hours at night in order to take advantage of lower time-of-day rates. It is evident that the demand of electricity by the waterworks can be controlled, with consumption delayed for a few hours if it is economical. Approximate power demand for the waterworks is illustrated in Figure 14.

5.8 Description of Computer Model

A block diagram of a model for a run of the river hydro-electric facility is shown in Figure 15. The system model involves the interaction of engineering, environmental, economic, and financial factors. Yearly cash flow and utility calculations (performance functions) are the primary output. Several options are available for use in the model, the primary ones are:

1. The hydro-electric generator is connected in parallel with the local utility company's system with excess energy sold to the utility company.

2. The installed hydro power plant is rated less than 1500 KW and is primarily used to supply energy to the water pumping division and the waste treatment plant (sewer) of the city of Woonsocket, with excess energy sold to the utility

Approximate Hourly Power Demand
of Waterworks

FIGURE 14

company. The local utility distribution lines are used to transport the generated energy and in exchange, a wheeling fee is paid to the utility company.

5.8.1 Engineering Features

The major engineering elements included in the model (9) are dam head, monthly river flow, power plant rating and power plant efficiency schedule. The output for an electrical generator is calculated from these inputs. To avoid the discontinuities in the river flow data, a least square approximation was obtained. This smoothing approximation is an internal element of the model. It was assumed that the river flow is a periodic function and thus can be represented by a Fourier series. It is well known that the minimum mean square error in approximating a periodic function by a finite Fourier series is obtained by truncating the infinite series for that function. A periodic function $f(t)$ can be represented by:

$$f(t) \approx \frac{A_0}{2} + \sum_{k=1}^n A_k \cos k\omega_0 t + \sum_{k=1}^n B_k \sin k\omega_0 t$$

where the period is $T = \frac{1}{f_0} = \frac{2\pi}{\omega_0}$.

The task is to select values for the coefficients A_k , B_k and the number of terms in order to obtain the desired smoothing. An appropriate number of terms are selected to provide an accurate approximation yet still remove the effects of the monthly discontinuities in the river flow data. The coefficient for the trigonometric series can be chosen by a

procedure devised by Joseph B. Fourier (1758-1830).

$$A_k = \frac{2}{T} \int_0^T f(t) \cos k\omega_0 t \, dt$$

$$B_k = \frac{2}{T} \int_0^T f(t) \sin k\omega_0 t \, dt$$

It was determined that six terms gave reasonably good smoothing. The coefficients were calculated as follows:

$$A_n = \frac{1}{6} \sum_{m=1}^{12} \text{flow}(m) \cos[2\pi n(m-0.5)/12]$$

$$B_n = \frac{1}{6} \sum_{m=1}^{12} \text{flow}(m) \sin[2\pi n(m-0.5)/12]$$

$$n = 0, \dots, 5$$

Comparing coefficients A_k , B_k with A_n , B_n we find with the period $T = 12$ (12 months),

$$f(t) = \text{flow}(m)$$

$$k\omega_0 t = \frac{2\pi k}{T} (m - .5)$$

A computer plot of the least square approximation of the river flow is shown in Figure 16.

The turbine efficiency curve and the electrical efficiency of the generator determines the efficiency schedule. A non-linear turbine efficiency curve is converted to piece wise linear. An electrical efficiency of 95% has been used. The power available from the generator is modelled as

$$P = .0846 EFH,$$

$$P_e = \begin{bmatrix} P, & P \leq P_g \\ P_g, & P > P_g \end{bmatrix}$$

YMIN= 5.000E+01
YMAX= 1.700E+03

X= 1.000E+00	Y= 8.906E+02
X= 2.000E+00	Y= 8.536E+02
X= 3.000E+00	Y= 8.239E+02
X= 4.000E+00	Y= 8.200E+02
X= 5.000E+00	Y= 8.552E+02
X= 6.000E+00	Y= 9.340E+02
X= 7.000E+00	Y= 1.050E+03
X= 8.000E+00	Y= 1.188E+03
X= 9.000E+00	Y= 1.326E+03
X= 1.000E+01	Y= 1.441E+03
X= 1.100E+01	Y= 1.515E+03
X= 1.200E+01	Y= 1.539E+03
X= 1.300E+01	Y= 1.511E+03
X= 1.400E+01	Y= 1.442E+03
X= 1.500E+01	Y= 1.344E+03
X= 1.600E+01	Y= 1.236E+03
X= 1.700E+01	Y= 1.129E+03
X= 1.800E+01	Y= 1.033E+03
X= 1.900E+01	Y= 9.506E+02
X= 2.000E+01	Y= 8.778E+02
X= 2.100E+01	Y= 8.093E+02
X= 2.200E+01	Y= 7.391E+02
X= 2.300E+01	Y= 6.637E+02
X= 2.400E+01	Y= 5.829E+02
X= 2.500E+01	Y= 4.997E+02
X= 2.600E+01	Y= 4.191E+02
X= 2.700E+01	Y= 3.465E+02
X= 2.800E+01	Y= 2.858E+02
X= 2.900E+01	Y= 2.387E+02
X= 3.000E+01	Y= 2.050E+02
X= 3.100E+01	Y= 1.831E+02
X= 3.200E+01	Y= 1.707E+02
X= 3.300E+01	Y= 1.662E+02
X= 3.400E+01	Y= 1.684E+02
X= 3.500E+01	Y= 1.767E+02
X= 3.600E+01	Y= 1.904E+02
X= 3.700E+01	Y= 2.083E+02
X= 3.800E+01	Y= 2.284E+02
X= 3.900E+01	Y= 2.490E+02
X= 4.000E+01	Y= 2.691E+02
X= 4.100E+01	Y= 2.897E+02
X= 4.200E+01	Y= 3.139E+02
X= 4.300E+01	Y= 3.467E+02
X= 4.400E+01	Y= 3.935E+02
X= 4.500E+01	Y= 4.579E+02
X= 4.600E+01	Y= 5.398E+02
X= 4.700E+01	Y= 6.342E+02
X= 4.800E+01	Y= 7.312E+02
X= 4.900E+01	Y= 8.181E+02
X= 5.000E+01	Y= 8.824E+02
X= 5.100E+01	Y= 9.156E+02
X= 5.200E+01	Y= 9.160E+02

SMOOTHING OF THE RIVERFLOW DATA ON A WEEKLY BASIS.FLOW IS IN CU-FEET/SEC.

FIGURE 16

where, P = available water power,
 P_e = available power from electric generator,
 P_g = generator name plate rating,
 E = efficiency,
 F = flow in cubic feet per second,
 H = head in feet.

5.8.2 Cash Flow Calculation

The revenue for the yearly energy displaced and sold is determined from the average hourly power demand of the waste treatment plant and the waterworks division, the available power, and the utility power rate structure. A yearly adjustment for energy cost increases is made. The cash flow is calculated from the yearly revenue, production costs and loan payment;

$$C_f(n) = R - P_c - P_a,$$

n = year n ,

C_f = cash flow,

R = revenue,

P_c = Production costs,

P_a = Annual loan payment.

The yearly production costs includes wheeling charges paid to the local utility company with adjustments for inflation.

$$P_c(n) = P_c(1)(1 + i_f)^{n-1}, \quad i_f = \text{inflation growth rate.}$$

The loan payment is for a loan equal to the capital cost. A reserve fund is established which is approximately equal to

the total operating expenses for a 6 month period. The reserve fund is part of the capital cost.

$$L_a = C_c$$

$$C_c = C_o + R_F$$

$$P_a = \frac{L_a i_\ell}{1 - \left(\frac{1}{1+i_\ell}\right)^{y_\ell}}$$

$$R_F + [P_c - W_c] = \frac{C_o i_\ell}{1 - \left(\frac{1}{1+i_\ell}\right)^{y_\ell}}$$

L_a = loan amount,

W_c = wheeling costs

C_c = Capital cost,

i_ℓ = loan interest rate,

C_p = original capital cost,

R_f = reserve fund for 6 month period,

P_a = annual loan payment.

5.8.3 Performance Indices

To indicate the financial feasibility, suitable utility functions (Performance Indices) are defined. For this study two utility functions are used in the model:

$$U_1 = \sum_{n=1}^{y_o} \frac{C_f(n)}{(1+i_d)^{n-1}}$$

$$U_2 = \sum_{n=1}^{y_\ell} \frac{C_f(n)}{(1+i_d)^{n-1}}$$

U_1, U_2 = utilities,

y_o = operating life of power plant,

C_f = cash flow,

i_d = discount rate,

P_a = annual loan payment,

y_ℓ = amortization period for loan.

The appropriate discount rate and utility function depends on the social, economic and financial system used by the city.

5.8.4 Optimization

The two utility functions are obtained as a function of plant size. From this, the power plant size that will maximize financial feasibility is determined. An installed cost schedule was obtained using available data and is used in the optimization study; the cost schedule is:

$$\begin{aligned} \text{Installed Cost} \\ \text{Schedule} &= (-.239)(CKW) + 1166.13 + \\ &\quad + (-.1317)(CKW) + 778.04 + \\ &\quad + \text{adjustment factor,} \end{aligned}$$

CKW = plant size [500 KW, 1350 KW],

First term = Civil Construction Cost Schedule,

Second term = Electrical-Mechanical Cost Schedule,

Adjustment Factor = Used to set desired cost for 1000 KW facility.

$$\begin{aligned} \text{Installed Cost} \\ \text{Schedule} &= DOLKWW(1. + e^{\frac{-CKW}{300}}), \end{aligned}$$

CKW = plant size [1350, 2000],

$DOLKWW$ = plant cost for 1350 KW facility, from above.

5.8.4.1 Civil Estimated Construction Costs (Appendix C)

Estimated construction costs for the civil cost schedule are based on unit costs described in standard estimating guides to the extent possible. In some instances, namely the penstock pipe, the estimated cost is based on manufacturer quotes.

Quantities were developed from preliminary design concepts using limited available subsurface information for route and site conditions. This was supplemented by surficial site investigations. In unknown situations the more costly alternative was used.

The estimated costs represent January, 1979 figures accelerated by a 10 - 15⁰/o contingency because of the conceptual stage of design. As design progresses to specific locations and better known conditions, and certain major cost items such as the semi-automatic trash racks are better defined, this contingency may be reduced.

5.8.4.2 Electrical-Mechanical Estimated Costs (Appendix C)

Electrical-mechanical estimated costs for that part of the cost schedule were based on packaged Allis-Chalmers units. Northern Water Power did not respond with sufficient information to assist with the development of the cost schedule.

5.9 Turbogenerators

Allis-Chalmers and Northern Water Power were contacted to determine their manufacturing capability and the type of units and services that they provide.

5.9.1 Allis-Chalmers Hydroelectric Generating Units

Allis-Chalmers has started to produce standardized hydroelectric generating units. These units include:

- . Inlet valve
- . Hydraulic Turbine (tube turbine)
- . Gear unit
- . Generator
- . Governor/controller
- . Electrical controls
- . Transformer

They believe the best way to economically produce such units is by selling a standard package of equipment. Several conversations were held with the personnel at Allis-Chalmers.

An operating tube turbine in Norwich, Connecticut, built by Allis-Chalmers, was examined and comprehensive discussions with operating and maintenance personnel yielded useful information. This unit was fully automated and was recommended.

The turbine-generator considered included a synchronous generator and tube turbine with adjustable runner blades. According to the manufacturer, this combination provides the best operating features and efficiency at the lowest cost. The efficiency curve utilized in the computer model is illustrated in Figure 17.

The manufacturer stated that the combination of adjustable runner blades and adjustable wicket gates (Kaplan turbine) with its approximately 75% increase in turbine costs does not appear to be justified for most applications.

Efficiency Curve

FIGURE 17

For the Woonsocket dam, they proposed:

"one horizontal hydraulic adjustable four-blade, fixed vane, standard 2500 mm TUBE turbine rated to develop 1275 KW under a net head of 5.5 meters (18 feet). Their optimum turbine size and output under varying flow conditions was based on a flow equaled or exceeded approximately 25% of the time. In this case a rough estimate of 950 cubic feet per second was made. The turbine may be operated at a flow as low as 1/3 full load discharge. Maximum unit centerline elevation above tailwater is limited to 4 meters.

Coupled to the turbine shaft would be a speed increaser capable of stepping the turbine output speed to a generator speed of 900 RPM.

Connected between the high speed side of the speed increaser and the generator is an air operated disconnect clutch. Should the turbine runaway to 25% overspeed, the clutch would disconnect, protecting the generator.

The generator proposed is a horizontal synchronous type operating at a 60 cycle synchronous speed of 900 RPM, 1125 RPM overspeed, and 4160 volts."

Additional accessories include intake butterfly valve, oil pressure system, governor and controls. Their preliminary price to design and manufacture one of these standardized units was \$774,000.

For many of the options studied in the feasibility assessment, the 1275 KW was close to the optimum size obtained with the detailed computer model. However, to provide a basis for comparison during each of the case studies, a nominal generator size of 1000 KW was used. Optimization curves were obtained to include the 1275 KW unit recommended by Allis-Chalmers.

5.9.2 Northern Water Power Hydroelectric Generating Units

Northern Water Power is a small and young company which at the writing of this report, was undergoing a reorganization. Because they are a young company, this necessitated

a closer look at the kind of services they perform and the manner in which they accomplish their contracted tasks.

Six companies were contacted from a list of recent clients shown in a Northern Water Power brochure. The responses to our inquiries varied from favorable to enthusiastic. To quote from a conversation with the superintendent of Stevens and Thompson, a paper mill in New York where NWP installed a new 800 KW turbine with automatic shutdown and manual start, "NWP bid was 1/3 of everybody else's, the turbine is running for 24 hrs/day, we have had absolutely no trouble and are very happy with what they have done." This is the only installation which does compare favorably in size and scope desired for the Woonsocket installation.

Several of the recent clients contacted had engineering studies prepared by NWP. One of the companies, Crown Zellerbach Corp., requested NWP to make an engineering study to put their facility into operation; however Westinghouse was selected to do the reconditioning. Nevertheless, NWP supplied special bearings etc., at a price of \$1600.

A 1920 Lombard turbine was put into operation by NWP for the Allen Rogers Corporation. The turbine was a small one, 96 KVA and the major reconditioning involved only the governor. They considered NWP very knowledgeable and the company was extremely pleased with their work.

Their engineering capabilities and water power know-how appear to be excellent and for this reason, they should be considered as possible general contractors or as general

manager of the project should it become a reality. Their manufacturing capability may need further development.

Information available from Northern Water Power was not as complete as that obtained from Allis-Chalmers. They suggested three vertical units, 300 KW each, at a roughly estimated cost of 450 dollars per kilowatt for a complete package. No other details were available. Total plant size was 900 KW.

During the case studies, to provide a basis for comparison, a nominal generator size of 1000 KW was used for the Northern Water Power unit.

5.10 Operating and Maintenance Costs

Estimates of operating and maintenance costs (part of the production costs) are based on conversations with operating personnel of four hydro units in Norwich, Connecticut, and the experiences of a utility company in Canada that owns a large number of small hydro plants. Operating and maintenance costs for these machines in Canada were approximately \$8000 per unit (12). For the proposed Woonsocket hydro station, operating and maintenance costs have been estimated as:

1. Operating the automated hydro unit plus trash removal assuming Woonsocket Public Works personnel utilized in a dual capacity with other responsibilities - 26 man-weeks at \$400/week	\$10,400/yr
2. Outside maintenance specialists for major problems - 5 man-weeks at \$800/week	4,000/yr
3. Oil, grease, etc, parts for minor repairs	2,200/yr
4. Water, heat, telephone lines, light for power house building	<u>800/yr</u>
	\$17,400/yr

A reserve fund has also been established to assist with repairs and is approximately equal to total operating expenses for a 6 month period. This reserve fund has been included in the capital cost.

6. FEASIBILITY SITE A

6.1 Location

Site A, as shown in Figure 18, is located on the east bank of the river approximately 300 feet down stream from the dam, and immediately south of the South Main Street bridge. The location is an undeveloped privately owned parcel of land (Lot 21, Plot 14). The elevation of the site is about 148 feet, approximately 22 feet above the river bed. The upper 10 to 15 feet of material at the site appears to consist of undefined fill and rubble; the power plant will be founded on the underlying bedrock.

6.2 Penstock

The proposed penstock consists of 8 foot diameter reinforced concrete pipe fitted with "O" ring seals. The pipe will be set in select granular fill placed in the excavated bedrock. Excavation in the rock will be under wet conditions because of ground water flow from the rock fractures. Finished grade pipe cover will be approximately 10 feet. The length of run to Site A is about 420 feet. Flow shutoff control will be by stopgate at the upper end and butterfly valve immediately before the turbine.

6.2.1 Utilities in Path

A major construction consideration is the avoidance of disruption to existing utilities. Based on available plans, it appears the penstock will pass below existing water, storm drain and sanitary sewer lines. Route A will cross the 15" mill water line, a 15" storm drain system, a 12" water line

Site A

FIGURE 18

and possibly an old 8" sanitary sewer. None of these utilities appears to be a problem if the contractor is prudent. Special care must be taken with regard to any nearby gas or electric utilities. The location of some utilities are shown in Figure 19.

6.3 Power House

The proposed power house is a 2,000 square foot reinforced concrete structure. Basic utilities consisting of lights, power, heat, water and telephone will be included. The roof will be removable and set at approximately ground level to permit mobile crane access to power unit components. The centerline of the single power unit should be no higher than approximately 10 feet above tailwater. If multiple smaller units are selected, the centerline elevation would be located about 4 feet lower for greater efficiency. Entrance to the power house will be at elevation 138, which will allow 14 feet freeboard for flood protection. A butterfly valve will be installed in the structure immediately above the turbine. The tailwater discharge area will be protected by concrete abutments. An artist's rendition of the proposed power house is illustrated in Figure 20.

6.4 Feasibility with Allis-Chalmers Hydroelectric Generating Units

6.4.1 Computer Runs, Energy Sold to Utility Company

This case study includes the Allis-Chalmers hydroelectric unit at Site A along with the assumption that all of the energy is sold to the utility company.

Location of Utilities

FIGURE 19

Power House - A

FIGURE 20

6.4.1.1 Financial Feasibility using Nominal Data Points

Available information was utilized in obtaining a best estimate of the appropriate data input variables for the computer model. Results of this simulation are indicated in Figure 21 with the assumptions and data inputs indicated on the bottom of the computer printout. River flow data is that obtained previously in Figure 16.

The column of interest is the CASH FLOW column that indicates the city revenue after operating, maintenance, and loan payments have been removed from hydro income. The REVENUE column is the money received by the city from the utility company.

6.4.1.2 Sensitivity Study

As many of the data input variables for the case study are based on estimates or subject to future change, a sensitivity analysis of the results provides useful information. The two utility functions (Performance Index) used in the sensitivity study are:

Utility 1 = Discounted Cash Flow Sum over
Operating Life,

Utility 2 = Discounted Cash Flow Sum over
Loan Period.

The nominal data set is that used in the case study. Figure 22 illustrates the utility values for single variable changes.

6.4.1.3 Optimization Study

It was assumed that pondage was not available for use by the facility. By making use of a suitable utility function (Utility 1, Utility 2 in Section 6.4.1.2), a power plant

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	126175.	17400.	179857.	-71082.	-71082.
2	135007.	18618.	179857.	-63468.	-59734.
3	144458.	19921.	179857.	-55321.	-49004.
4	154570.	21316.	179857.	-46603.	-38853.
5	165390.	22808.	179857.	-37275.	-29249.
6	176967.	24404.	179857.	-27295.	-20157.
7	189354.	26113.	179857.	-16615.	-11549.
8	202609.	27941.	179857.	-5189.	-3394.
9	216792.	29896.	179857.	7038.	4333.
10	231967.	31989.	179857.	20121.	11660.
11	248205.	34228.	179857.	34119.	18609.
12	265579.	36624.	179857.	49098.	25203.
13	284169.	39188.	179857.	65124.	31463.
14	304061.	41931.	179857.	82273.	37410.
15	325345.	44866.	179857.	100622.	43062.
16	348119.	48007.	179857.	120255.	48437.
17	372487.	51367.	179857.	141263.	53551.
18	398561.	54963.	179857.	163741.	58422.
19	426460.	58810.	179857.	187793.	63062.
20	456312.	62927.	179857.	213528.	67486.
21	488254.	67332.	0.	420922.	125208.
22	522431.	72045.	0.	450386.	126091.
23	559001.	77088.	0.	481913.	126982.
24	598131.	82484.	0.	515647.	127878.
25	640000.	88258.	0.	551742.	128781.
26	684800.	94436.	0.	590363.	129690.
27	732735.	101047.	0.	631688.	130605.
28	784026.	108120.	0.	675906.	131527.
29	838908.	115688.	0.	723219.	132456.
30	897631.	123786.	0.	773844.	133391.
31	960464.	132451.	0.	828013.	134332.
32	1027697.	141723.	0.	885974.	135281.
33	1099634.	151643.	0.	947991.	136236.
34	1176608.	162258.	0.	1014350.	137197.
35	1258970.	173616.	0.	1085353.	138166.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 678. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 71.2 AND THE DAM HEAD IS 18. FT. THE INSTALLED PLANT
 COST IS 2022. \$/KW AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 2021723. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED .) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 5926033.KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT;
 (1) THE REGIONAL SEWER CONSUMES 0. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 0. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 2716099.KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 3209934. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 17400.
 THIS INCLUDES \$ 0. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO \$ 94428. WHICH IS 4.67 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$2153489. , UTIL 2 = \$ 179674. **

SITE A, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 21

SENSITIVITY ANALYSIS

UTIL 1 in \$	UTIL 2 in \$	VARIABLE CHANGE	NOMINAL VALUE
1967557.	127969.	Inflation → 20°/o increase → 8.4°/o	7.0
2291561.	223236.	Inflation → 20°/o decrease → 5.6°/o	7.0
3499345.	552184.	Energy inflation → 20°/o increase 8.4°/o	7.0
1149851.	-138645.	Energy inflation → 20°/o decrease 5.6°/o	7.0
2153191.	814316.	Loan period → 25 yrs.	20 yrs.
2153198.	-433612.	Loan period → 15 yrs.	20 yrs.
1932711.	-41105.	Loan interest → 7.5°/o	6.25°/o
1749680.	-224136.	Loan interest → 8.5°/o	6.25°/o
2652159.	449392.	Day energy sold → 26.4 mills	24 mills
		Night energy sold → 20.9 mills	19 mills
1654228.	-90633.	Day energy sold → 21.6 mills	24 mills
		Night energy sold → 17.1 mills	19 mills
1852648.	16741.	Production cost for year 1 → \$25,000	\$17,400
2327195.	273539.	Production cost for year 1 → \$13,000	\$17,400
1804694.	-169122.	Installed plant cost → 2350 \$/KWH	2022 \$/KWH
2495321.	521507.	Installed plant cost → 1700 \$/KWH	2022 \$/KWH
1995700.	-201591.	Power plant rating → increase to 1300 KW	1000 KW
1676868.	315942.	Power plant rating → decrease to 600 KW	1000 KW
1549590.	110662.	Discount rate → 7.5°/o	6.25°/o
1187626.	65170.	Discount rate → 8.5°/o	6.25°/o
2536791.	386960.	River flow → 20°/o increase	
1558751.	-142300.	River flow → 20°/o decrease	
2153194.	179380.	Nominal values	

SITE A, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 22

size can be selected to maximize either Utility 1 or Utility 2. In performing this study, cost data (dollars per Kilowatt) has been assumed to be dependent on plant size. Optimization curves about the nominal value of \$2022/KW are illustrated in Figure 23.

6.4.2 Computer Runs, Energy wheeled and sold to Utility Company

This case study includes the Allis-Chalmers hydro-electric unit at Site A along with the assumption that the energy is wheeled to the Sewer and Water works and excess energy is sold to the utility company. Power demand data for the sewer is illustrated in Figure 13 and approximate demand data for the water works is illustrated in Figure 14.

6.4.2.1 Financial Feasibility using Nominal Data Points

Results of this simulation are indicated in Figure 24. See Section 6.4.1.1.

6.4.2.2 Sensitivity Study

Figure 25 illustrates the utility values for single variable changes. See Section 6.4.1.2.

6.4.2.3 Optimization Study

Optimization curves about the nominal value of \$2022/KW are illustrated in Figure 26. See Section 6.4.1.3.

6.5 Feasibility with Northern Water Power Hydroelectric Generating Units

6.5.1 Computer Run, Energy sold to Utility Company

This case study includes the Northern Water Power units at Site A along with the assumption that all of the energy is sold to the utility company.

YMIN= 1.000E+04
YMAX= 2.247E+06

DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE.

YMIN= 1.000E+04
YMAX= 2.489E+05

DISCOUNTED CASH FLOW OVER LOAN PERIOD VERSUS PLANT SIZE.

* NOMINAL COST IS 2022. \$/KW FOR A 1000. KW FACILITY.*

* X=PLANTSIZE IN KW AND Y=DISCOUNTED CASH FLOW IN DOLLARS.*

SITE A, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 23

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	213949.	34415.	179857.	-324.	-324.
2	228925.	36824.	179857.	12244.	11524.
3	244950.	39402.	179857.	25691.	22757.
4	262096.	42160.	179857.	40079.	33414.
5	280443.	45111.	179857.	55475.	43529.
6	300074.	48269.	179857.	71948.	53134.
7	321079.	51648.	179857.	89574.	62260.
8	343554.	55263.	179857.	108434.	70936.
9	367603.	59132.	179857.	128614.	79188.
10	393335.	63271.	179857.	150207.	87043.
11	420868.	67700.	179857.	173311.	94524.
12	450328.	72439.	179857.	198033.	101654.
13	481851.	77509.	179857.	224485.	108454.
14	515580.	82935.	179857.	252788.	114944.
15	551671.	88740.	179857.	283073.	121143.
16	590287.	94952.	179857.	315478.	127069.
17	631607.	101599.	179857.	350152.	132739.
18	675819.	108710.	179857.	387252.	138168.
19	723126.	116320.	179857.	426949.	143371.
20	773745.	124462.	179857.	469426.	148363.
21	827907.	133175.	0.	694732.	206655.
22	885860.	142497.	0.	743363.	208114.
23	947870.	152472.	0.	795398.	209583.
24	1014220.	163145.	0.	851076.	211063.
25	1085215.	174565.	0.	910650.	212553.
26	1161179.	186784.	0.	974395.	214053.
27	1242461.	199859.	0.	1042602.	215564.
28	1329433.	213849.	0.	1115584.	217086.
29	1422493.	228818.	0.	1193674.	218618.
30	1522066.	244835.	0.	1277230.	220162.
31	1628611.	261974.	0.	1366637.	221716.
32	1742613.	280312.	0.	1462301.	223281.
33	1864594.	299933.	0.	1564660.	224857.
34	1995115.	320929.	0.	1674186.	226444.
35	2134773.	343394.	0.	1791379.	228043.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 678. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 71.2% AND THE DAM HEAD IS 18. FT. THE INSTALLED PLANT
 COST IS 2022. \$/KW, AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 2021723. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 5926025. KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT:
 (1) THE REGIONAL SEWER CONSUMES 1785026. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 1163625. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 714868. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 2046301. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 216205. KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 0. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 34415.
 THIS INCLUDES \$17015. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO \$ 94428. WHICH IS 4.67 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$4951676. , UTIL 2 = \$ 1693889. **

SITE A, ENERGY WHEELED AND SOLD, ALLIS-CHALMERS

FIGURE 24

SENSITIVITY ANALYSIS

UTIL 1 in \$	UTIL 2 in \$	VARIABLE CHANGE	NOMINAL VALUE
4584207.	1591910.	Inflation - 20°/o increase	7.0
5225049.	1780337.	Inflation - 20°/o decrease	7.0
7233985.	2325742.	Energy inflation - 20°/o increase	7.0
3250054.	1154338.	Energy inflation - 20°/o decrease	7.0
4951377.	2741556.	Loan period - 25 yrs.	20 yrs.
4951385.	681851.	Loan period - 15 yrs.	20 yrs.
4730897.	1473110.	Loan interest - 7.5°/o	6.25°/o
4547866.	1290079.	Loan interest - 8.5°/o	6.25°/o
5347836.	1908134.	Day energy value sewer - 37.4 mills	34 mills
		Night energy value sewer - 37.4 mills	34 mills
4671525.	1542154.	Day energy value sewer - 31.6 mills	34 mills
		Night energy value sewer - 31.6 mills	34 mills
5380473.	1925795.	Day energy value waterworks - 49.83 mills	45.3 mills
		Night energy value waterworks - 40.92 mills	37.2 mills
4522286.	1461395.	Day energy value waterworks - 40.77 mills	45.3 mills
		Night energy value waterworks - 33.48 mills	37.2 mills
4971899.	1704699.	Day energy sold - 26.4 mills	24 mills
		Night energy sold - 20.9 mills	19 mills
4930861.	1682490.	Day energy sold - 21.6 mills	24 mills
		Night energy sold - 17.1 mills	19 mills
4884091.	1657181.	Wheeling charges - 3.278 mills/KWH	2.98 mills/KWH
5018669.	1730007.	Wheeling charges - 2.682 mills/KWH	2.98 mills/KWH
4650836.	1530958.	Production cost for year 1 - \$25,000	\$17,400
5125383.	1787753.	Production cost for year 1 - \$13,000	\$17,400
4602880.	1345093.	Installed plant cost - 2350 \$/KWH	2022 \$/KWH
5292508.	2035721.	Installed plant cost - 1700 \$/KWH	2022 \$/KWH
4770016.	1299710.	Power plant rating - increase to 1300 KW	1000 KW
4004686.	1575621.	Power plant rating - decrease to 600 KW	1000 KW
3161641.	1309029.	Discount rate 8.5°/o	6.25°/o
3839952.	1465005.	Discount rate 7.5°/o	6.25°/o
5544872.	2014757.	River flow - 20°/o increase	
4055439.	1208764.	River flow - 20°/o decrease	
5011222.	1725977.	Power demand sewer 20°/o increase	
4868453.	1648719.	Power demand sewer 20°/o decrease	
5080473.	1763452.	Power demand waterworks 20°/o increase	
4818794.	1621846.	Power demand waterworks 20°/o decrease	
4951381.	1693594.	Nominal Values	

SITE A, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD

FIGURE 25

YMIN= 1.000E+04
YMAX= 5.100E+06

DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE.

YMIN= 1.000E+04
YMAX= 1.694E+06

DISCOUNTED CASH FLOW OVER LOAN PERIOD VERSUS PLANT SIZE.

* NOMINAL COST IS 2022. \$/KW FOR A 1000. KW FACILITY.*
* X=PLANTSIZE IN KW AND Y=DISCOUNTED CASH FLOW IN DOLLARS.*

SITE A, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD

FIGURE 26

6.5.1.1 Financial Feasibility using Nominal Data Points

Available data for this case study was not as good as that for the Allis-Chalmers unit (6.4.1.1); consequently, results will not be as useful. The available information, however, was used to obtain a result from the computer model.

Results of this simulation are indicated in Figure 27 with the assumptions and data inputs indicated on the bottom of the computer printout. River flow data is that obtained previously in Figure 16. A constant estimated efficiency of 70⁰/o was used.

The column of interest is the CASH FLOW column that indicates the city revenue after operating, maintenance, and loan payments have been removed from hydro income. The REVENUE column is the money received by the city from the utility company.

6.5.2 Computer Run, Energy Wheeled and sold to Utility Company

This case study includes the Norther Water Power hydro-electric unit at Site A along with the assumption that the energy is wheeled to the Sewer and Water works and excess energy is sold to the utility company. Available data was not as complete as for the Allis-Chalmers unit.

6.5.2.1 Financial Feasibility using Nominal Data Points

Results of this simulation are indicated in Figure 28. See Section 6.5.1.1.

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	123120.	17400.	160132.	-54412.	-54412.
2	131738.	18618.	160132.	-47012.	-44246.
3	140960.	19921.	160132.	-39093.	-34629.
4	150827.	21316.	160132.	-30621.	-25529.
5	161385.	22808.	160132.	-21555.	-16913.
6	172682.	24404.	160132.	-11855.	-8755.
7	184770.	26113.	160132.	-1475.	-1025.
8	197703.	27941.	160132.	9631.	6300.
9	211543.	29896.	160132.	21514.	13246.
10	226351.	31989.	160132.	34229.	19835.
11	242195.	34228.	160132.	47835.	26089.
12	259149.	36624.	160132.	62392.	32027.
13	277289.	39188.	160132.	77969.	37669.
14	296699.	41931.	160132.	94636.	43031.
15	317468.	44866.	160132.	112470.	48132.
16	339690.	48007.	160132.	131552.	52987.
17	363469.	51367.	160132.	151969.	57610.
18	388911.	54963.	160132.	173816.	62016.
19	416135.	58810.	160132.	197192.	66218.
20	445264.	62927.	160132.	222205.	70228.
21	476432.	67332.	0.	409100.	121691.
22	509782.	72045.	0.	437737.	122550.
23	545466.	77088.	0.	468378.	123415.
24	583649.	82484.	0.	501164.	124286.
25	624504.	88258.	0.	536246.	125164.
26	668219.	94436.	0.	573783.	126047.
27	714994.	101047.	0.	613947.	126937.
28	765043.	108120.	0.	656923.	127833.
29	818596.	115688.	0.	702907.	128736.
30	875897.	123786.	0.	752111.	129645.
31	937209.	132451.	0.	804758.	130560.
32	1002814.	141723.	0.	861091.	131481.
33	1073010.	151643.	0.	921367.	132409.
34	1148120.	162258.	0.	985862.	133344.
35	1228488.	173616.	0.	1054871.	134285.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 662. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 70.% AND THE DAM HEAD IS 18. FT. THE INSTALLED PLANT
 COST IS 1800. \$/KW AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 1800000. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 5782549.KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT:
 (1) THE REGIONAL SEWER CONSUMES 0. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 0. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 2650336.KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 3132213. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 17400.
 THIS INCLUDES \$ 0. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO\$ 84979.WHICH IS 4.72 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$2268260. , UTIL 2 = \$ 349880. **

SITE A, NORTHERN WATER POWER, ENERGY SOLD

FIGURE 27

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	211491.	34213.	160132.	17146.	17146.
2	226295.	36608.	160132.	29555.	27816.
3	242135.	39170.	160132.	42833.	37942.
4	259085.	41912.	160132.	57040.	47555.
5	277221.	44846.	160132.	72242.	56686.
6	296626.	47985.	160132.	88508.	65364.
7	317390.	51344.	160132.	105913.	73617.
8	339607.	54938.	160132.	124536.	81470.
9	363379.	58784.	160132.	144463.	88946.
10	388815.	62899.	160132.	165784.	96070.
11	416032.	67302.	160132.	188598.	102861.
12	445154.	72013.	160132.	213009.	109341.
13	476315.	77054.	160132.	239129.	115529.
14	509656.	82447.	160132.	267077.	121441.
15	545332.	88219.	160132.	296981.	127095.
16	583505.	94394.	160132.	328979.	132507.
17	624350.	101001.	160132.	363216.	137692.
18	668054.	108071.	160132.	399851.	142663.
19	714818.	115636.	160132.	439049.	147435.
20	764855.	123731.	160132.	480992.	152018.
21	818394.	132392.	0.	686002.	204059.
22	875681.	141659.	0.	734022.	205499.
23	936978.	151575.	0.	785403.	206950.
24	1002566.	162186.	0.	840381.	208411.
25	1072745.	173539.	0.	899206.	209882.
26	1147837.	185686.	0.	962151.	211363.
27	1228185.	198684.	0.	1029501.	212855.
28	1314158.	212592.	0.	1101566.	214358.
29	1406148.	227473.	0.	1178674.	215871.
30	1504577.	243396.	0.	1261180.	217395.
31	1609897.	260434.	0.	1349462.	218930.
32	1722589.	278664.	0.	1443924.	220475.
33	1843169.	298171.	0.	1544998.	222032.
34	1972191.	319042.	0.	1653148.	223599.
35	2110244.	341375.	0.	1768868.	225178.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 662. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 70.2% AND THE DAM HEAD IS 18. FT. THE INSTALLED PLANT
 COST IS 1800. \$/KW, AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 1800000. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED .) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 5782544.KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT:
 (1) THE REGIONAL SEWER CONSUMES 1675737. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 986572. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 833995. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 2145637. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 140606.KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 0. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 34213.
 THIS INCLUDES \$16813. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO\$ 84979.WHICH IS 4.72 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$5098039. , UTIL 2 = \$ 1881192. **

SITE A, NORTHERN WATER POWER, ENERGY WHEELED AND SOLD

FIGURE 28

7. FEASIBILITY SITE B

7.1 Location

Site B, as shown in Figure 29 , is located approximately 900 feet east of the dam across the bend in the river and approximately 1200 feet downstream from the dam. The site is city owned land, but is about 14 feet lower than Site A and may be subject to flooding under extreme conditions; this concern may be overcome by siting the structure as high as possible. The elevation of the site is about 134 feet, approximately 16 feet above the river bed. The upper 10 feet of material at the site appears to be unconsolidated alluvium or glacial outwash sediments. Below this, bedrock is assumed; the power plant will be founded on bedrock.

7.2 Penstock

The proposed penstock is an 8 foot diameter reinforced concrete pipe with "O" ring seals. The pipe will be set in select granular fill placed in the excavated bedrock. Excavation in the rock will be under wet conditions because of ground water flow from the rock fractures. Finished grade pipe cover will vary from about 10 feet at the upper end of the line to about 5 feet at the lower end. The length of run to Site B is about 900 feet. Flow shutoff will be by stopgate at the upper end and butterfly valve immediately before the turbine.

7.2.1 Utilities in Path

The proximity and crossing of utilities will be a major construction problem along Route B. It is envisioned that

Site B

FIGURE 29

the route will parallel the route of the new sanitary sewer line from River Street to Armory Street as shown in Figure 19. It will cross the 15" mill water line, an 18" storm drain, a 12" water line, an 8" and a 24" sanitary sewer line, a water main, and a 12" gas main. In addition, an existing underground telephone cable will have to be temporarily re-located. The blasting for rock excavation and the digging will necessitate special care by the contractor. Special precautions should be taken with regard to nearby gas or electric utilities. A detailed determination of the exact location of affected utilities must be included in the engineering portion of this project if Route B is selected.

7.3 Power House

The proposed power house is a 2,000 square foot reinforced concrete structure projecting above ground. Basic utilities-consisting of lights, power, heat, water and telephone-will be included. The roof will be removable to permit mobile crane access to power unit components. The centerline of the single unit should be no higher than approximately 10 feet above low tailwater elevation. If multiple smaller units are selected, the centerline elevation will be about 4 feet lower for greater efficiency. A butterfly valve will be installed in the structure immediately above the turbine. The tailwater discharge area will be protected by concrete. An artist's rendition of the proposed power house is illustrated in Figure 30.

Power House - B

FIGURE 30

7.4 Feasibility with Allis-Chalmers Hydroelectric Generating Units

7.4.1 Computer Runs, Energy Sold to Utility Company

This case study includes the Allis-Chalmers hydroelectric unit at Site B along with the assumption that all of the energy is sold to the utility company.

7.4.1.1 Financial Feasibility using Nominal Data Points

Available information was utilized in obtaining a best estimate of the appropriate data input variables for the computer model. Results of this simulation are indicated in Figure 31 with the assumptions and data inputs indicated on the bottom of the computer printout. River flow data is that obtained previously in Figure 16.

The column of interest is the CASH FLOW column that indicates the city revenue after operating, maintenance, and loan payments have been removed from hydro income. The REVENUE column is the money received by the city from the utility company.

7.4.1.2 Sensitivity Study

Many of the data input variables for the case study are based on estimates or subject to future change; therefore, a sensitivity analysis of the results was obtained to provide useful information. The two utility function (Performance Index) used in the sensitivity study are:

Utility 1 = Discounted Cash Flow Sum over
Operating Life

Utility 2 = Discounted Cash Flow Sum over
Loan Period

The nominal data set is that used in the cash study. Figure

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	131990.	17400.	224185.	-109595.	-109595.
2	141229.	18618.	224185.	-101574.	-95599.
3	151115.	19721.	224185.	-92992.	-82373.
4	161693.	21316.	224185.	-83808.	-69871.
5	173011.	22808.	224185.	-73982.	-58051.
6	185122.	24404.	224185.	-63468.	-46871.
7	198080.	26113.	224185.	-52217.	-36295.
8	211946.	27941.	224185.	-40180.	-26285.
9	226782.	29896.	224185.	-27299.	-16808.
10	242657.	31989.	224185.	-13517.	-7833.
11	259643.	34228.	224185.	1229.	670.
12	277817.	36624.	224185.	17008.	8731.
13	297265.	39188.	224185.	33892.	16374.
14	318073.	41931.	224185.	51957.	23625.
15	340338.	44866.	224185.	71287.	30508.
16	364161.	48007.	224185.	91970.	37044.
17	389653.	51367.	224185.	114100.	43254.
18	416928.	54963.	224185.	137780.	49159.
19	446113.	58810.	224185.	163117.	54776.
20	477340.	62927.	224185.	190228.	60122.
21	510754.	67332.	0.	443422.	131901.
22	546506.	72045.	0.	474461.	132831.
23	584761.	77088.	0.	507673.	133769.
24	625694.	82484.	0.	543210.	134714.
25	669493.	88258.	0.	581234.	135665.
26	716357.	94436.	0.	621921.	136622.
27	766501.	101047.	0.	665455.	137587.
28	820156.	108120.	0.	712036.	138558.
29	877567.	115688.	0.	761878.	139536.
30	938996.	123786.	0.	815209.	140521.
31	1004725.	132451.	0.	872274.	141513.
32	1075055.	141723.	0.	933332.	142512.
33	1150308.	151643.	0.	998665.	143518.
34	1230829.	162258.	0.	1068570.	144531.
35	1316987.	173616.	0.	1143370.	145551.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 710. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 75.% AND THE DAM HEAD IS 20. FT. THE INSTALLED PLANT
 COST IS 2520. \$/KW. AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 2520000. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED .) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 6199120.KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT;
 (1) THE REGIONAL SEWER CONSUMES 0. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 0. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 2841263.KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 3357857. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 17400.
 THIS INCLUDES \$ 0. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO \$ 115665. WHICH IS 4.59 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$1854005. , UTIL 2 = \$ -225320. **

SITE B, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 31

32 illustrates the utility values for single variable changes.

7.4.1.3 Optimization Study

It was assumed that pondage was not available for use by the facility. By making use of a suitable utility function (Utility 1, Utility 2 in Section 7.4.1.2), a power plant size can be selected to maximize either Utility 1 or Utility 2. In performing this study, cost data (dollars per Kilowatt) has been assumed to be dependent on plant size. Optimization curves about the nominal value of \$2520/KW are illustrated in Figure 33.

7.4.2 Computer Runs, Energy Wheeled and sold to Utility Company

This case study includes the Allis-Chalmers hydroelectric unit at Site B along with the assumption that the energy is wheeled to the Sewer and Water works and excess energy is sold to the utility company. Power demand data for the sewer is illustrated in Figure 13 and demand data for the water works is illustrated in Figure 14.

7.4.2.1 Financial Feasibility using Nominal Data Points

Results of this simulation are indicated in Figure 34. See Section 7.4.1.1.

7.4.2.2 Sensitivity Study

Figure 35 illustrates the utility values for single variable changes. See Section 7.4.1.2.

7.4.2.3 Optimization Study

Optimization curves about the nominal value of \$2520/KW are illustrated in Figure 36. See Section 7.4.1.3.

SENSITIVITY ANALYSIS

UTIL 1 in \$	UTIL 2 in \$	VARIABLE CHANGE	NOMINAL VALUE
1668367.	-276732.	Inflation > 20°/o increase > 8.4°/o	7.0
1992369.	-181464.	Inflation > 20°/o decrease > 5.6°/o	7.0
326190.	164663.	Energy inflation > 20°/o increase 8.4°/o	7.0
804423.	-558001.	Energy inflation > 20°/o decrease 5.6°/o	7.0
1854001.	443555.	Loan period > 25 yrs.	20 yrs.
1854009.	-871079.	Loan period > 15 yrs.	20 yrs.
1579217.	-500108.	Loan interest > 7.5°/o	6.25°/o
1351110.	-728217.	Loan interest > 8.5°/o	6.25°/o
2375962.	57135.	Day energy sold > 26.4 mills	24 mills
		Night energy sold > 20.9 mills	19 mills
1332045.	-507776.	Day energy sold > 21.6 mills	24 mills
		Night energy sold > 17.1 mills	19 mills
1553459.	-387959.	Production cost for year 1 > \$25,000	\$17,400
2028005.	-131161.	Production cost for year 1 > \$13,000	\$17,400
1450254.	-629073.	Installed plant cost > 2900 \$/KWH	2520 \$/KWH
2406507.	327183.	Installed plant cost > 2000 \$/KWH	2520 \$/KWH
1815840.	-614554.	Power plant rating > 30°/o increase	1000 KW
1465597.	55937.	Power plant rating > 40°/o decrease	1000 KW
1252275.	-263570.	Discount rate > 7.5°/o	6.25°/o
894945.	-287514.	Discount rate > 8.5°/o	
2276897.	3524.	River flow > 20°/o increase	
1322097.	-513159.	River flow > 20°/o decrease	
1854005.	-225320.	Nominal Values	

SITE B, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 32

YMIN= 1.000E+04
YMAX= 1.969E+06

X= 5.000E+02	Y= 1.158E+06
X= 5.500E+02	Y= 1.267E+06
X= 6.000E+02	Y= 1.371E+06
X= 6.500E+02	Y= 1.467E+06
X= 7.000E+02	Y= 1.560E+06
X= 7.500E+02	Y= 1.648E+06
X= 8.000E+02	Y= 1.732E+06
X= 8.500E+02	Y= 1.725E+06
X= 9.000E+02	Y= 1.772E+06
X= 9.500E+02	Y= 1.785E+06
X= 1.000E+03	Y= 1.854E+06
X= 1.050E+03	Y= 1.852E+06
X= 1.100E+03	Y= 1.917E+06
X= 1.150E+03	Y= 1.935E+06
X= 1.200E+03	Y= 1.953E+06
X= 1.250E+03	Y= 1.948E+06
X= 1.300E+03	Y= 1.969E+06
X= 1.350E+03	Y= 1.886E+06
X= 1.400E+03	Y= 1.844E+06
X= 1.450E+03	Y= 1.693E+06
X= 1.500E+03	Y= 1.639E+06
X= 1.550E+03	Y= 1.525E+06
X= 1.600E+03	Y= 1.455E+06

"DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE."

YMIN= -1.086E+06
YMAX= -3.269E+04

X= 5.000E+02	Y=-3.269E+04
X= 5.500E+02	Y=-3.498E+04
X= 6.000E+02	Y=-3.876E+04
X= 6.500E+02	Y=-4.572E+04
X= 7.000E+02	Y=-5.391E+04
X= 7.500E+02	Y=-6.352E+04
X= 8.000E+02	Y=-7.449E+04
X= 8.500E+02	Y=-1.337E+05
X= 9.000E+02	Y=-1.630E+05
X= 9.500E+02	Y=-2.102E+05
X= 1.000E+03	Y=-2.255E+05
X= 1.050E+03	Y=-2.786E+05
X= 1.100E+03	Y=-2.943E+05
X= 1.150E+03	Y=-3.345E+05
X= 1.200E+03	Y=-3.740E+05
X= 1.250E+03	Y=-4.253E+05
X= 1.300E+03	Y=-4.610E+05
X= 1.350E+03	Y=-5.699E+05
X= 1.400E+03	Y=-6.489E+05
X= 1.450E+03	Y=-7.870E+05
X= 1.500E+03	Y=-8.728E+05
X= 1.550E+03	Y=-9.911E+05
X= 1.600E+03	Y=-1.086E+06

"DISCOUNTED CASH FLOW OVER LOAN PERIOD VERSUS PLANT SIZE."

* NOMINAL COST IS 2520. \$/KW FOR A 1000. KW FACILITY.
* X=PLANTSIZE IN KW AND Y=DISCOUNTED CASH FLOW IN DOLLARS.*

SITE B, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 33

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	223765.	35190.	224185.	-35611.	-35611.
2	239428.	37654.	224185.	-22411.	-21092.
3	256188.	40289.	224185.	-8286.	-7340.
4	274121.	43109.	224185.	6827.	5691.
5	293309.	46127.	224185.	22997.	18045.
6	313841.	49356.	224185.	40300.	29762.
7	335810.	52811.	224185.	58814.	40880.
8	359316.	56508.	224185.	78624.	51434.
9	384468.	60463.	224185.	99820.	61459.
10	411381.	64696.	224185.	122500.	70987.
11	440177.	69224.	224185.	146768.	80047.
12	470989.	74070.	224185.	172734.	88667.
13	503958.	79255.	224185.	200518.	96875.
14	539235.	84802.	224185.	230247.	104694.
15	576981.	90738.	224185.	262057.	112149.
16	617369.	97090.	224185.	296094.	119262.
17	660584.	103886.	224185.	332513.	126053.
18	706825.	111158.	224185.	371482.	132542.
19	756303.	118939.	224185.	413178.	138747.
20	809243.	127265.	224185.	457793.	144686.
21	865890.	136174.	0.	729717.	217062.
22	926502.	145706.	0.	780796.	218594.
23	991357.	155905.	0.	835452.	220137.
24	1060751.	166818.	0.	893933.	221691.
25	1135003.	178495.	0.	956508.	223256.
26	1214452.	190990.	0.	1023462.	224832.
27	1299464.	204359.	0.	1095104.	226419.
28	1390426.	218664.	0.	1171761.	228018.
29	1487755.	233971.	0.	1253784.	229627.
30	1591897.	250348.	0.	1341548.	231248.
31	1703329.	267873.	0.	1435456.	232881.
32	1822562.	286624.	0.	1535938.	234525.
33	1950140.	306687.	0.	1643452.	236180.
34	2086649.	328155.	0.	1758493.	237848.
35	2232713.	351126.	0.	1881587.	239527.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 710. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 75.% AND THE DAM HEAD IS 20. FT. THE INSTALLED PLANT
 COST IS 2520. \$/KW, AND THE OPERATION LIFE IS 35. YRS. THIS IS FINANCED BY A 20YR
 \$ 2520000. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 6199109. KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT:
 (1) THE REGIONAL SEWER CONSUMES 1864663. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 1219675. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 747362. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 2138171. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 229238. KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 0. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 35190.
 THIS INCLUDES \$17790. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO \$ 115665. WHICH IS 4.59 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$4779775. , UTIL 2 = \$ 1357937. **

SITE B, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD

FIGURE 34

SENSITIVITY ANALYSIS

UTIL 1 in \$	UTIL 2 in \$	VARIABLE CHANGE	NOMINAL VALUE
4404333.	1253962.	Inflation > 20°/o increase > 8.4°/o	7.0
5059604.	1446632.	Inflation > 20°/o decrease > 5.6°/o	7.0
7167100.	2019085.	Energy inflation > 20°/o increase 8.4°/o	7.0
3000394.	793939.	Energy inflation > 20°/o decrease 5.6°/o	7.0
4779768.	2458668.	Loan period > 25 yrs.	20 yrs.
4779780.	295245.	Loan period > 15 yrs.	20 yrs.
4504988.	1083150.	Loan interest > 7.5°/o	6.25°/o
4276880.	855042.	Loan interest > 8.5°/o	6.25°/o
5194470.	1582349.	Day energy value sewer > 37.4 mills	34 mills
		Night energy value sewer > 37.4 mills	34 mills
4487039.	1199527.	Day energy value sewer 31.6 mills	34 mills
		Night energy value sewer > 31.6 mills	34 mills
5228203.	1600600.	Day energy value waterworks > 49.83 mills	45.3 mills
		Night energy value waterworks > 40.92 mills	37.2 mills
4331350.	1115275.	Day energy value waterworks > 40.77 mills	45.3 mills
		Night energy value waterworks > 33.48 mills	37.2 mills
4301531.	1369710.	Day energy sold > 26.4 mills	24 mills
		Night energy sold > 20.9 mills	19 mills
4758018.	1346163.	Day energy sold > 21.6 mills	24 mills
		Night energy sold > 17.1 mills	19 mills
4709423.	1319866.	Wheeling charges > 3.278 mills/KWH	2.98 mills/KWH
4850126.	1396007.	Wheeling charges > 2.682 mills/KWH	2.98 mills/KWH
4479226.	1195298.	Production cost for year 1 > \$25,000	\$17,400
4953775.	1452095.	Production cost for year 2 > \$13,000	\$17,400
4376024.	954186.	Installed plant cost > 2900 \$/KWH	2520 \$/KWH
5332276.	1910438.	Installed plant cost > 2000 \$/KWH	2520 \$/KWH
4786230.	992850.	Power plant rating > 30°/o increase	1000 KW
3851771.	1347196.	Power plant rating > 40°/o decrease	1000 KW
3647071.	1152527.	Discount rate 7.5°/o	6.25°/o
2958967.	1013061.	Discount rate 8.5°/o	6.25°/o
5442277.	1716445.	River flow > 20°/o increase	
3952427.	910223.	River flow > 20°/o decrease	
4843217.	1392269.	Power demand sewer > 20°/o increase	
4692677.	1310805.	Power demand sewer > 20°/o decrease	
4912858.	1431037.	Power demand waterworks > 20°/o increase	
4641080.	1282884.	Power demand waterworks > 20°/o decrease	
4779775.	1357937.	Nominal Values	

SITE B, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD

FIGURE 35

YMIN= 1.000E+04
YMAX= 4.956E+06

X= 5.000E+02	Y= 3.304E+06
X= 5.500E+02	Y= 3.542E+06
X= 6.000E+02	Y= 3.757E+06
X= 6.500E+02	Y= 3.956E+06
X= 7.000E+02	Y= 4.148E+06
X= 7.500E+02	Y= 4.333E+06
X= 8.000E+02	Y= 4.510E+06
X= 8.500E+02	Y= 4.527E+06
X= 9.000E+02	Y= 4.632E+06
X= 9.500E+02	Y= 4.656E+06
X= 1.000E+03	Y= 4.780E+06
X= 1.050E+03	Y= 4.779E+06
X= 1.100E+03	Y= 4.896E+06
X= 1.150E+03	Y= 4.936E+06
X= 1.200E+03	Y= 4.956E+06
X= 1.250E+03	Y= 4.922E+06
X= 1.300E+03	Y= 4.940E+06
X= 1.350E+03	Y= 4.821E+06
X= 1.400E+03	Y= 4.774E+06
X= 1.450E+03	Y= 4.552E+06
X= 1.500E+03	Y= 4.494E+06
X= 1.550E+03	Y= 4.341E+06
X= 1.600E+03	Y= 4.267E+06

DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE.

YMIN= 1.000E+04
YMAX= 1.429E+06

X= 5.000E+02	Y= 1.128E+06
X= 5.500E+02	Y= 1.196E+06
X= 6.000E+02	Y= 1.252E+06
X= 6.500E+02	Y= 1.301E+06
X= 7.000E+02	Y= 1.347E+06
X= 7.500E+02	Y= 1.389E+06
X= 8.000E+02	Y= 1.429E+06
X= 8.500E+02	Y= 1.382E+06
X= 9.000E+02	Y= 1.384E+06
X= 9.500E+02	Y= 1.344E+06
X= 1.000E+03	Y= 1.358E+06
X= 1.050E+03	Y= 1.305E+06
X= 1.100E+03	Y= 1.318E+06
X= 1.150E+03	Y= 1.289E+06
X= 1.200E+03	Y= 1.251E+06
X= 1.250E+03	Y= 1.184E+06
X= 1.300E+03	Y= 1.146E+06
X= 1.350E+03	Y= 1.018E+06
X= 1.400E+03	Y= 9.366E+05
X= 1.450E+03	Y= 7.600E+05
X= 1.500E+03	Y= 6.723E+05
X= 1.550E+03	Y= 5.322E+05
X= 1.600E+03	Y= 4.354E+05

DISCOUNTED CASH FLOW OVER LOAN PERIOD VERSUS PLANT SIZE.

* NOMINAL COST IS 2520. \$/KW FOR A 1000. KW FACILITY.*
* X=PLANTSIZE IN KW AND Y=DISCOUNTED CASH FLOW IN DOLLARS.*

SITE B, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD

FIGURE 36

7.5 Feasibility with Northern Water Power Hydroelectric Generating Units

7.5.1 Computer Run, Energy sold to Utility Company

This case study includes the Northern Water Power units at Site B along with the assumption that all of the energy is sold to the utility company.

7.5.1.1 Financial Feasibility using Nominal Data Points

Available data for this case study was not as good as that available for the Allis-Chalmers unit (7.4.1.1); consequently, results will not be as useful. The available information, however, was used to obtain a result from the computer model.

Results of this simulation are indicated in Figure 37 with the assumptions and data inputs indicated on the bottom of the computer printout. River flow data is that obtained previously in Figure 16. A constant estimated efficiency of 70% was used.

The column of interest is the CASH FLOW column that indicates the city revenue after operating, maintenance, and loan payments have been removed from hydro income. The REVENUE column is the money received by the city from the utility company.

7.5.2 Computer Run, Energy Wheeled and Sold to Utility Company

This case study includes the Northern Water Power hydroelectric unit at Site B along with the assumption that the energy is wheeled to the Sewer and Water works and excess energy is sold to the utility company. Power demand data

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	130062.	17400.	204435.	-91773.	-91773.
2	139166.	18618.	204435.	-83887.	-78952.
3	148908.	19921.	204435.	-75449.	-66833.
4	159331.	21316.	204435.	-66420.	-55375.
5	170485.	22808.	204435.	-56759.	-44537.
6	182418.	24404.	204435.	-46421.	-34283.
7	195188.	26113.	204435.	-35360.	-24578.
8	208851.	27941.	204435.	-23525.	-15390.
9	223470.	29896.	204435.	-10861.	-6687.
10	239113.	31989.	204435.	2689.	1558.
11	255851.	34228.	204435.	17187.	9374.
12	273760.	36624.	204435.	32701.	16786.
13	292924.	39188.	204435.	49300.	23818.
14	313428.	41931.	204435.	67062.	30493.
15	335368.	44866.	204435.	86066.	36833.
16	358844.	48007.	204435.	106401.	42857.
17	383962.	51367.	204435.	128160.	48584.
18	410840.	54963.	204435.	151441.	54033.
19	439598.	58810.	204435.	176352.	59220.
20	470370.	62927.	204435.	203007.	64161.
21	503295.	67332.	0.	435963.	129682.
22	538525.	72045.	0.	466480.	130597.
23	576222.	77088.	0.	499134.	131519.
24	616557.	82484.	0.	534073.	132448.
25	659716.	88258.	0.	571458.	133383.
26	705896.	94436.	0.	611459.	134324.
27	755308.	101047.	0.	654261.	135272.
28	808179.	108120.	0.	700059.	136227.
29	864751.	115688.	0.	749063.	137189.
30	925284.	123786.	0.	801497.	138157.
31	990053.	132451.	0.	857602.	139133.
32	1059356.	141723.	0.	917633.	140115.
33	1133510.	151643.	0.	981867.	141104.
34	1212855.	162258.	0.	1050596.	142100.
35	1297755.	173616.	0.	1124138.	143103.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 699. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 70.% AND THE DAM HEAD IS 20. FT. THE INSTALLED PLANT
 COST IS 2298. \$/KW AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 2298000. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 6108593.KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT:
 (1) THE REGIONAL SEWER CONSUMES 0. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 0. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 2799771.KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 3308822. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 17400.
 THIS INCLUDES \$ 0. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO \$ 106212. WHICH IS 4.62 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$2013657. , UTIL 2 = \$ -30691. **

SITE B, NORTHERN WATER POWER, ENERGY SOLD

FIGURE 37

for the sewer is illustrated in Figure 13 and demand data for the water works is illustrated in Figure 14. Available data was not as complete as for the Allis-Chalmers unit.

7.5.2.1 Financial Feasibility using Nominal Data Points

Results of this simulation are indicated in Figure 38.

See Section 7.5.1.1.

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	222324.	35025.	204435.	-17137.	-17137.
2	237887.	37477.	204435.	-4026.	-3789.
3	254539.	40101.	204435.	10003.	8861.
4	272357.	42908.	204435.	25014.	20854.
5	291422.	45911.	204435.	41075.	32230.
6	311821.	49125.	204435.	58261.	43026.
7	333648.	52564.	204435.	76649.	53277.
8	357004.	56243.	204435.	96325.	63014.
9	381994.	60180.	204435.	117378.	72270.
10	408733.	64393.	204435.	139905.	81073.
11	437344.	68900.	204435.	164008.	89450.
12	467958.	73723.	204435.	189799.	97427.
13	500714.	78884.	204435.	217395.	105029.
14	535764.	84405.	204435.	246923.	112277.
15	573267.	90314.	204435.	278518.	119194.
16	613396.	96636.	204435.	312325.	125799.
17	656333.	103400.	204435.	348498.	132112.
18	702276.	110638.	204435.	387203.	138151.
19	751435.	118383.	204435.	428617.	143931.
20	804035.	126669.	204435.	472930.	149470.
21	860317.	135536.	0.	724781.	215594.
22	920539.	145024.	0.	775515.	217116.
23	984976.	155175.	0.	829801.	218648.
24	1053924.	166038.	0.	887886.	220192.
25	1127698.	177660.	0.	950038.	221746.
26	1206636.	190096.	0.	1016540.	223311.
27	1291100.	203403.	0.	1087697.	224888.
28	1381477.	217641.	0.	1163836.	226476.
29	1478180.	232876.	0.	1245304.	228074.
30	1581652.	249177.	0.	1332475.	229684.
31	1692366.	266619.	0.	1425746.	231305.
32	1810832.	285282.	0.	1525549.	232939.
33	1937587.	305252.	0.	1632334.	234583.
34	2073219.	326620.	0.	1746599.	236239.
35	2218344.	349483.	0.	1868861.	237907.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 699. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 70.% AND THE DAM HEAD IS 20. FT. THE INSTALLED PLANT
 COST IS 2298. \$/KW, AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 2298000. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED .) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 6108587. KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT;
 (1) THE REGIONAL SEWER CONSUMES 1763728. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 1103400. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 842052. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 2205415. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 193994. KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 0. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 35025.
 THIS INCLUDES \$17625. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO \$ 106212. WHICH IS 4.62 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$4965211. , UTIL 2 = \$ 1566518. **

SITE B, NORTHERN WATER POWER, ENERGY WHEELED AND SOLD

FIGURE 38

8. FEASIBILITY SITE C

8.1 Location

Site C, as shown in Figure 39, is located on the east bank between the dam and South Main Street bridge. This site would eliminate the need for a penstock by utilizing the direct flow from one of the four dam tainter gates. The basic structure would project from the east bank approximately 30 feet (single power unit) to 40 feet (two power units) and be built into the channel bedrock. Tailwater would be in the east channel immediately north of the bridge. This site would eliminate the high penstock costs, the potential utilities problems, road and area reconstruction costs and the land acquisition associated with sites A and B. Because of the upstream location, available gross head is less than other sites, but compensated in part by eliminating a penstock head loss; estimated net head for Site C is 16 feet as compared with 18 feet for Site A. While this site may have merit because of the reduction of civil costs, a detailed evaluation of its effect on flood control operations is required before it can be seriously considered. Close cooperation with the Army Corps of Engineers would assist with the evaluation of this site.

8.2 Power House

The proposed power house is a 2,000 square foot reinforced concrete structure integral with the east end of the dam and keyed into the bedrock. The existing east tainter gate would be utilized for inflow control, with the water

Site C

FIGURE 39

passing under the open tainter gate directly to the intake area. A semi-automatic trash rack structure will be located immediately over the power house intake. A butterfly valve(s) is included in the proposed power house immediately above the turbine. An overflow spillway on the west side of the intake provides additional control. The main roof of the power house will be removable to permit mobile crane access to power unit components. The roof will be at existing street level with power house access also at street level through a superstructure entranceway. The centerline of the power unit(s) will be at about elevation 135, approximately 5 feet above tailwater. The tailwater discharge area will be protected by concrete abutments. An artist's rendition of the proposed power house is illustrated in Figure 40.

8.3 Feasibility with Allis-Chalmers Hydroelectric Generating Units

8.3.1 Computer Run, Energy Sold to Utility Company

This case study assumes that all of the energy is sold to the utility company and a packaged Allis-Chalmers unit is installed at Site C.

8.3.1.1 Financial Feasibility using Nominal Data Points

Results of this simulation are in Figure 41. The column of interest is the CASH FLOW column. This shows the city revenue after operating, maintenance, and loan payments have been removed from hydro income. REVENUE column is the money received by the city from the utility company.

8.3.1.2 Optimization Study

Optimization curves about the nominal value of \$1643/KW

Power House - C

FIGURE 40

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	118539.	17400.	146188.	-45049.	-45049.
2	126837.	18618.	146188.	-37969.	-35736.
3	135715.	19921.	146188.	-30394.	-26924.
4	145215.	21316.	146188.	-22289.	-18582.
5	155380.	22808.	146188.	-13616.	-10684.
6	166257.	24404.	146188.	-4336.	-3202.
7	177895.	26113.	146188.	5594.	3888.
8	190347.	27941.	146188.	16219.	10610.
9	203672.	29896.	146188.	27587.	16985.
10	217929.	31989.	146188.	39751.	23035.
11	233184.	34228.	146188.	52767.	28779.
12	249506.	36624.	146188.	66694.	34235.
13	266972.	39188.	146188.	81596.	39421.
14	285660.	41931.	146188.	97540.	44352.
15	305656.	44866.	146188.	114601.	49044.
16	327051.	48007.	146188.	132856.	53512.
17	349945.	51367.	146188.	152389.	57769.
18	374441.	54963.	146188.	173290.	61828.
19	400652.	58810.	146188.	195653.	65701.
20	428697.	62927.	146188.	219581.	69399.
21	458705.	67332.	0.	391373.	116418.
22	490814.	72045.	0.	418769.	117240.
23	525171.	77088.	0.	448083.	118068.
24	561933.	82484.	0.	479448.	118901.
25	601268.	88258.	0.	513010.	119740.
26	643356.	94436.	0.	548920.	120586.
27	688391.	101047.	0.	587344.	121437.
28	736578.	108120.	0.	628458.	122294.
29	788138.	115688.	0.	672450.	123157.
30	843307.	123786.	0.	719521.	124027.
31	902338.	132451.	0.	769887.	124902.
32	965502.	141723.	0.	823779.	125784.
33	1033086.	151643.	0.	881443.	126672.
34	1105401.	162258.	0.	943143.	127566.
35	1182779.	173616.	0.	1009163.	128467.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS.

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 637. KW.
 THE AVERAGE POWERPLANT EFFICIENCY IS 67.2% AND THE DAM HEAD IS 16. FT. THE INSTALLED PLANT
 COST IS 1643. \$/KW AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 1643261. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED .) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 5567397.KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT;
 (1) THE REGIONAL SEWER CONSUMES 0. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 0. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 0. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR.
 AND 0. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 2551723.KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 3015674. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 17400.
 THIS INCLUDES \$ 0. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO\$ 78311.WHICH IS 4.77 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$2253639. , UTIL 2 = \$ 418384. , UTIL 3 = 0.14 **

SITE C, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 41

are obtained in Figure 42.

8.3.2 Computer Run, Energy Wheeled and Sold to the Utility Company

It is assumed that a packaged Allis-Chalmers unit is installed at Site C and that generated energy is wheeled to the sewer and water works with any excess sold to the utility company.

8.3.2.1 Financial Feasibility using Nominal Data Points

Results of this simulation are in Figure 43. The CASH FLOW column is the column of interest.

8.3.2.2 Optimization Study

Using the nominal value of \$1643/KW, optimization curves are obtained in Figure 44.

YMIN= 1.000E+04
YMAX= 2.309E+06

X= 5.000E+02	Y= 1.440E+06
X= 5.500E+02	Y= 1.575E+06
X= 6.000E+02	Y= 1.704E+06
X= 6.500E+02	Y= 1.828E+06
X= 7.000E+02	Y= 1.854E+06
X= 7.500E+02	Y= 1.945E+06
X= 8.000E+02	Y= 2.028E+06
X= 8.500E+02	Y= 2.078E+06
X= 9.000E+02	Y= 2.177E+06
X= 9.500E+02	Y= 2.209E+06
X= 1.000E+03	Y= 2.253E+06
X= 1.050E+03	Y= 2.309E+06
X= 1.100E+03	Y= 2.301E+06
X= 1.150E+03	Y= 2.232E+06
X= 1.200E+03	Y= 2.241E+06
X= 1.250E+03	Y= 2.202E+06
X= 1.300E+03	Y= 2.198E+06
X= 1.350E+03	Y= 2.170E+06
X= 1.400E+03	Y= 2.043E+06
X= 1.450E+03	Y= 2.006E+06
X= 1.500E+03	Y= 1.963E+06
X= 1.550E+03	Y= 1.918E+06
X= 1.600E+03	Y= 1.813E+06

DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE.

YMIN= 1.000E+04
YMAX= 4.408E+05

X= 5.000E+02	Y= 3.336E+05
X= 5.500E+02	Y= 3.669E+05
X= 6.000E+02	Y= 3.982E+05
X= 6.500E+02	Y= 4.271E+05
X= 7.000E+02	Y= 4.043E+05
X= 7.500E+02	Y= 4.176E+05
X= 8.000E+02	Y= 4.273E+05
X= 8.500E+02	Y= 4.205E+05
X= 9.000E+02	Y= 4.408E+05
X= 9.500E+02	Y= 4.258E+05
X= 1.000E+03	Y= 4.182E+05
X= 1.050E+03	Y= 4.176E+05
X= 1.100E+03	Y= 3.835E+05
X= 1.150E+03	Y= 3.178E+05
X= 1.200E+03	Y= 2.947E+05
X= 1.250E+03	Y= 2.465E+05
X= 1.300E+03	Y= 2.183E+05
X= 1.350E+03	Y= 1.669E+05
X= 1.400E+03	Y= 6.279E+04
X= 1.450E+03	Y= 6.858E+03
X= 1.500E+03	Y= -5.215E+04
X= 1.550E+03	Y= -1.125E+05
X= 1.600E+03	Y= -2.053E+05

DISCOUNTED CASH FLOW OVER LOAN PERIOD VERSUS PLANT SIZE.

* NOMINAL COST IS 1643. \$/KW FOR A 1000. KW FACILITY.*
* X=PLANT SIZE IN KW AND Y=DISCOUNTED CASH FLOW IN DOLLARS.*

SITE C, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 42

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	201070.	33417.	146188.	21465.	21465.
2	215145.	35756.	146188.	33201.	31248.
3	230205.	38259.	146188.	45758.	40533.
4	246320.	40938.	146188.	59194.	49350.
5	263562.	43803.	146188.	73571.	57728.
6	282011.	46869.	146188.	88954.	65693.
7	301752.	50150.	146188.	105413.	73270.
8	322874.	53661.	146188.	123025.	80481.
9	345475.	57417.	146188.	141870.	87350.
10	369658.	61436.	146188.	162034.	93897.
11	395534.	65736.	146188.	183609.	100140.
12	423221.	70338.	146188.	206695.	106100.
13	452846.	75262.	146188.	231397.	111793.
14	484545.	80530.	146188.	257827.	117235.
15	518463.	86167.	146188.	286108.	122442.
16	554755.	92199.	146188.	316369.	127428.
17	593588.	98652.	146188.	348747.	132207.
18	635139.	105558.	146188.	383393.	136791.
19	679598.	112947.	146188.	420463.	141193.
20	727170.	120853.	146188.	460129.	145424.
21	778072.	129313.	0.	648759.	192980.
22	832536.	138365.	0.	694171.	194342.
23	890813.	148050.	0.	742763.	195714.
24	953170.	158414.	0.	794756.	197096.
25	1019891.	169502.	0.	850389.	198487.
26	1091283.	181368.	0.	909915.	199888.
27	1167672.	194063.	0.	973609.	201299.
28	1249409.	207647.	0.	1041762.	202721.
29	1336867.	222183.	0.	1114684.	204151.
30	1430447.	237735.	0.	1192711.	205593.
31	1530577.	254377.	0.	1276200.	207044.
32	1637717.	272183.	0.	1365533.	208506.
33	1752357.	291236.	0.	1461121.	209978.
34	1875021.	311622.	0.	1563398.	211460.
35	2006271.	333436.	0.	1672835.	212953.

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 637. KW
 THE AVERAGE POWERPLANT EFFICIENCY IS 67.2% AND THE DAM HEAD IS 16. FT. THE INSTALLED PLANT
 COST IS 1643. \$/KW. AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
 \$ 1643261. LOAN AT 6.25% INTEREST. INFLATION IS ASSUMED TO BE 7.00% AND ENERGY INFLATION
 (THE VALUE OF ENERGY GENERATED .) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 5567390.KWH.
 REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT;
 (1) THE REGIONAL SEWER CONSUMES 1693122. KWH/YR DURING THE DAY AT 34.0MILLS/KWH FOR THE FIRST YEAR
 AND 1085447. KWH/YR DURING THE NIGHT AT 34.0MILLS/KWH.
 (2) THE WATERWORKS CONSUMES 666127. KWH/YR DURING THE DAY AT 45.3MILLS/KWH FOR THE FIRST YEAR
 AND 1930219. KWH/YR DURING THE NIGHT AT 37.2MILLS/KWH.
 (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 192476.KWH/YR DURING THE DAY AT 24.0MILLS/KWH
 AND 0. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
 DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 33417.
 THIS INCLUDES \$16017. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
 TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILLS/KWH.
 THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
 THE RESERVE FUND AMOUNTS TO \$ 78311. WHICH IS 4.77 % OF THE TOTAL CAPITAL COST.

** DISCOUNT RATE: 6.25% ; UTIL 1 = \$4883971. , UTIL 2 = \$ 1841767. , UTIL 3 = 0.63 **

SITE C, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD

FIGURE 43

YMIN= 1.000E+04
YMAX= 4.975E+06

DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE.

YMIN= 1.000E+04
YMAX= 1.860E+06

DISCOUNTED CASH FLOW OVER LOAN PERIOD VERSUS PLANT SIZE.

* NOMINAL COST IS 1643. \$/KW FOR A 1000. KW FACILITY.*
* X=PLANTSIZE IN KW AND Y=DISCOUNTED CASH FLOW IN DOLLARS.*

SITE C, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD

FIGURE 44

9. PLANNING PERMITS & LEGAL FACTORS

9.1 Project Approval and Development

Although the basic technology, construction and operation of a hydro electric project has been well known, the current process needed to approve and develop small hydro installations is a new procedure.

New environmental policies, regulations and shifts in public sensitivity are not the only changes that face such a project. The general move to large-scale sources of power, fossil, nuclear and hydro, has meant that most development and experience in this field do not apply particularly well to the small-scale project.

Four factors that should facilitate approval and development of small-scale hydro electric generation at the Woonsocket, Rhode Island location include:

1. General public support for the development of alternative sources of energy, especially if cost and payback are reasonable - as appears to be the case at the Woonsocket Falls site.
2. Government interest and initiative, both nationally and in the state, in encouraging innovation in energy supply and related conservation.
3. Small environmental impact, if any, from the construction and operation of the hydro facility and its "run of the river" mode.
4. Increasing costs of electricity and new larger uses of such power, such as in the new Woonsocket sewage treatment plant.

9.2 Federal Review

The United States Department of Energy (DOE) governs the licensing of hydro projects through the Federal Energy Regulatory Commission which developed a streamlined permitting procedure in 1978 for small hydro projects. This new shortened approval process provides for review of such proposals by the federal government and local agencies that have been designated for the particular state involved.

The federal permit review process requires that the different agencies designated must consider and comment on each specific project pending approval. The length of time for such review, however, can not be accurately estimated as each agency has not been mandated to perform such a procedure within a specified time period. Since the review and approval process has actually started, subsequent projects should benefit from the experience.

1978 federal energy legislation, enacted into law after the new small hydro permit process went into effect, should help to facilitate the review process and improve the prospects for such projects.

Good communication between agencies and sponsor is an important need in light of the variety of agencies and interests concerned. Experience during the preparation of this Woonsocket hydro study proved the value of communication and cooperative assistance throughout the progress of the work. A cross section of these organizations that helped in this process indicates those who will be also concerned in

the future: U.S. Department of Energy and its component the Federal Energy Regulatory Commission, the Environmental Protection Administration, the U. S. Army Corps of Engineers, the Fish and Wildlife Service and the New England River Basins Commission reflect national and regional interest.

Other examples on a state and local level that demonstrate the usefulness of exchanging information and ideas are meetings attended by representatives of various groups including: R. I. Department of Environmental Management, the Governor's Energy Office, the Public Utilities Commission and Division of Public Utilities and Motor Vehicles, and the R. I. Water Resources Board. The City of Woonsocket Planning and Development Department, Department of Public Works, the Mayor and other City departments. Private organizations, and their representatives, such as the Blackstone Valley Electric Company and the Woonsocket Historical Society, also have shown how the "give and take" of good communication can build the solid understanding needed for project review.

Environmental impact of the Woonsocket hydro project would provide little justification for special studies: No water would be permanently diverted from the river, nor should the operation affect the normal changes in the river level. Minor construction for the power house and the "penstock" would have little effect on the surroundings. No existing buildings would be taken. In fact, one of the alternative proposals (Site A) would be located where a previous water-powered mill was situated. This project would

also install a water intake in the same general area above the dam where the original canal by-pass intake had existed for well over one hundred years prior to the new dam construction in the late 1950's.

Preliminary review by staff of the state's Department of Environmental Management appear to confirm the minimal impact of the project on the environment. Other positive aspects of the proposal that have been mentioned are the reduction of air pollution and possible hazards from sources of power other than hydro and also the excellent condition of the dam itself. The dam structure was constructed about twenty years ago under the supervision of the U. S. Army Corps of Engineers and is regularly inspected as part of the city's flood control system.

9.3 State Review

Rhode Island agencies concerned with the development and operation of a small hydro electric plant include:

- Governor's Energy Office
- Public Utilities Commission
- Department of Environmental Management
- Department of Economic Development
- State-wide Planning Program
- Water Resources Board

Both the Public Utilities Commission (PUC) and the Department of Environmental Management (DEM) have specific review and control over the installation. The PUC reviews the project as a source of electricity. The state DEM works in cooperation with other state and federal agencies and will be strongly influenced by the new 1979 regulations of the U. S. Council on Environmental Quality that calls for a

greatly simplified but effective review of environmental considerations. The agencies have provided cooperative assistance in the development of this cost-benefit study concerned with the dam.

9.4 Local Review and Future Action

The public nature of the Woonsocket project brings more people and agencies into the review process. This should not weaken but rather strengthen the base for such a venture. With greater public and agency participation, there should be a better opportunity for understanding and cooperative efforts if a decision is made to use such a new source of energy.

The Mayor and the City Council are specifically responsible for reviewing and approving any alterations or projects that are related to the Flood Control System constructed by the Corps of Engineers. This review would be handled through the regular process of City government and is due to the fact that the flood control system became the property of the city when completed by the Corps.

Zoning and Planning approval offer few problems as construction would be on public property in areas already zoned for public use or industry.

Building Permit Approval of construction would consist of trench work, pipe installation and the building of a power house. The building design must be reviewed as to both structural safety and stability in relation to the river and possible floods.

Local Utility (Blackstone Valley Electric) would also be a local (non-public) agency who's approval must be obtained when connecting with their transmission facilities.

Future Action: This section should help regulatory agencies and the public decide on future action concerning this hydro facility. Future action by agencies to simplify procedures and encourage timely decisions for the judicious use of this resource will benefit the community's interests and long term economy.

9.5 Legal

At this point, there seem to be no legal impediments to the development of hydroelectric power at Woonsocket Falls.

The City of Woonsocket has clear title (Appendix F) to Woonsocket Falls dam, and therefore, according to the Rhode Island Mill Act, has a right to maintain the dam without "molestations". See R. I. General Laws 46-18-1 et. seq.

It is well settled in Rhode Island that a riparian owner is entitled to reasonable use of a water course. Thus, to the extent that it owns water rights to the Blackstone River, the City of Woonsocket is entitled to reasonable use of the river.

What constitutes reasonable use is determined on a case by case basis. Since this facility will be "run of the river", it is not anticipated that the waters of the Blackstone will be put to an unreasonable use.

Routine legal matters which may arise concerning contracts, purchase and sale agreements, title searches, water rights, etc. could easily be handled by the City Solicitor of Woonsocket.

10. ENGINEERING AND CONSTRUCTION SCHEDULE

Figure 45 represents the best estimate of project scheduling assuming few delays. The schedule presumes that reviews, approvals and funding will be accomplished reasonably quickly. Especially critical to the timing is early funding and contracting for detailed engineering and design. Optimistically, the project could be a reality within three years from the time this feasibility study first receives an official review and appraisal.

ENGINEERING AND CONSTRUCTION SCHEDULE

Schedule

FIGURE 45

MUNICIPAL SMALL HYDRO Permit & Development Chart~

Flow Chart

FIGURE 46

11. REFERENCES

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12. "New England - Eastern Canadian Provinces Conference on Alternative Energy -- Hydro Workshop, Proceedings", New England Regional Commission, Boston, Mass., April 22-28, 1978.

APPENDIX A

Department of Environmental Management
dam safety report

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

Department of Environmental Management
DIVISION OF LAND RESOURCES
83 Park Street
Providence, R. I. 02903

January 5, 1979

Woonsocket Falls Dam,
Water Power Study
College of Engineering
University of Rhode Island
Kingston, Rhode Island 02881

Attention: Mr. John W. Grifalconi

Dear Mr. Grifalconi;

This letter is in reference to the current investigation into the possible development of hydro-electric power facilities at the Woonsocket Falls Dam, R.I. Dam #56, being conducted jointly by the University of Rhode Island and the Rhode Island State Energy Office and your recent inquiry as to this dam's relative safety.

The Department of Environmental Management, as you know, has the responsibility for aspects of safety and environmental impact of dams within the State and is currently working in a co-operative effort with the U. S. Army Corps of Engineers on the National Program of Inspection of Dams, Public Law #92-367.

Under the guidelines of this national program, a priority basis for the selection of dams to be included in the program has been established wherein all dams within each State are classified in accordance with size and hazard potential.

Dams covered under the program include all structures over twenty-five feet high and impounding over fifteen acre-feet of water, and/or over six feet high and impounding over fifty acre-feet of water. The hazards pertain to potential loss of human life or property damage in the area downstream of the dam in the event of failure or misoperation of the dam or it's appurtenant facilities.

Although the Woonsocket Falls Dam does not fall within any of the "size" criteria of the national inspection program and has not been scheduled for special investigation relative to it's safety and structural stability, this office considers the subject dam "unique" in it's inventory of dams within the State for the following reason:

The original Woonsocket Falls Dam, a fixed-crest masonry structure dating back into the 1800's and located about 100 feet upstream of the South Main Street bridge, was removed and replaced subsequent to the disastrous flood of August, 1955 as a major component of the Woonsocket Local Protection Plan of the Blackstone River Basin Project, authorized and co-ordinated by the U. S. Army Corps of Engineers.

Mr. John W. Grifalconi
University of Rhode Island
Page 2.

January 5, 1979

The project was designed to protect the industrial area of Woonsocket along the Blackstone River in the 8300-foot long section between the Massachusetts State line and the South Main Street bridge and included the replacement of the original dam with a new 266-foot long concrete flood control dam equipped with four tainter gates, each fifty feet long and approximately ten feet high.

This new facility (1960), although municipally owned by the City of Woonsocket, is under the constant and direct supervision of the Corps of Engineers and is regularly inspected and evaluated by them on a semi-annual basis as to it's operability and structural stability.

Therefore, after advisement of these above noted facts from the Corps of Engineers, this office has no reason to doubt the structural integrity of this facility and considers the structure safe, negating the need for a seperate and additional safety inspection at this time.

I trust this information is sufficient for your present purposes. Please inform this office if we can be of further assistance in this matter as we look forward to continued co-operation with you in this very worthwhile effort.

Very truly yours;

Earle F. Prout, Jr.

Earle F. Prout, Jr.
Dams Section

APPENDIX B

Corps of Engineers dam safety report

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDPL-H

2 January 1979

Dr. John Grifalconi
University of Rhode Island
Kingston, R. I. 02881

Dear Dr. Grifalconi:

In compliance with your verbal request at the meeting at the Flood Control Project in Woonsocket, Rhode Island on 12 December 1978, there is forwarded herewith one copy of Inspection Report for the facility, dated 17 May 1978.

Sincerely yours,

JOSEPH L. IGNAZIO
Chief, Planning Division

1 Incl. as stated

LOCAL FLOOD PROTECTION PROJECT INSPECTION REPORT

Project: Upper Woonsocket

Maintaining Agency: City of Woonsocket, DPW

Type Inspection: ☒ Semi-Annual Staff ☐ 90 Day Interim

River Basin: Blackstone

Date of Inspection: 17 May 1978

Feature	Sat	Unsat	Deficiencies
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PUMPING STATIONS - STRUCTURES

INTERIOR	X		
EXTERIOR	X		

PUMPS - MOTORS - ENGINES

TRIAL OPERATED		X	Comment #1
GENERAL CONDITION	X		Comment #2
POWER SOURCE	X		
INSULATION TESTS	X		
METAL INTAKES/OUTLETS	X		
GATE VALVES	X		

GATES - DRAINAGE STRUCTURES

TRIAL OPERATED	X		Comment #3
GENERAL CONDITION	X		
LUBRICATION	X		Comment #4

DIKES - DAMS

GENERAL CONDITION	X		
SLOPES/EROSION	X		Comment #5
SAND BOILS/CAVING	X		
TRESPASSING	X		
SLOPE PROTECTION	X		
DRAINS	X		

STOP-LOGS - LOG BOOM

CONDITION OF LOGS	X		
AVAILABILITY OF LOGS	X		
HIGHWAY SLOPS	X		
STORAGE FACILITIES	X		

CHANNELS - OUTLET WORKS CHANNEL

BANKS	X		
OR FLOOD CONTROL	X		Comment #6

Feature	Sat	Unsat	Deficiencies
---------	-----	-------	--------------

CONCRETE STRUCTURES			
SURFACE	X		
SETTLEMENT	X		
JOINTS	X		
DRAINS	X		

MISCELLANEOUS			
EMERGENCY OPER. PLAN	X		
EMERGENCY EQUIPMENT	X		
SEMI-ANNUAL REPORT		X	Comment #7

Inspection Party:

Mr. Steven Milewski, City Inspector, City of Woonsocket
 Mr. Hedley Patterson, Division Engineer, City of Woonsocket
 Mr. John Clarkin, Project Manager, West Hill Dam
 Mr. George A. Laraway, Reservoir Control Center, Corps of Engineers
 Mr. Paul Cooper, Operations Division, Corps of Engineers

Photographs Taken:

None

Remarks & Additional Comments:

(Indicate Here Observations, Discussions, Specific Feature Deficiencies, Recommendations and any other pertinent information. Use Continuation Sheet if necessary.)

See Attached Sheet

ALL APPLICABLE ITEMS. IF UNSAT INDICATE SPECIFIC DEFICIENCIES. INDICATE IF NOT APPLICABLE.

DATE	INSPECTED BY: TYPED NAME & TITLE PAUL H. COOPER, JR. Civil Engineer	SIGNATURE
------	---	-----------

UPPER WOONSOCKET LOCAL PROTECTION
PROJECT INSPECTION REPORT

17 May 1978

Comment #1 - The engines at the Singleton Street Pumping Station could not be tested since the batteries were at the maintenance garage being charged. The batteries should be kept at the pumping station so that the engines may be test run periodically. Operation of the engines at frequent intervals will keep the batteries charged and allow inspection of the engines so that necessary repairs may be made before pumping operations are required.

The standby generator at the dam was tested and operated satisfactorily.

Comment #2 - The protective cages over the drive shaft and coupling between the pump and the right angle gear are not properly fastened and should be repaired.

Comment #3 - Tainter gate #1 was tested and operated satisfactorily.

During the inspection, the problem with the operation of the gates which occurred last winter was discussed. It appears that the gates could not be operated because of the excessive buildup of ice on the radial arms, girders and stiffeners on the downstream side of the gates. The ice is the result of spray from the water flowing over the tops of the tainter gates which made the gates too heavy for the motors to lift.

The spray could be substantially reduced by regulating the gates. It is recommended that during periods of cold weather two gates, preferably adjacent, be raised to an opening of about $\frac{1}{2}$ foot each, to maintain a water level upstream of about 148.1 feet msl. or the tops of the closed gates. This procedure should substantially reduce the spray and subsequent ice buildup. No gate changes would have to be made for minor fluctuations in river levels.

In addition, it is recommended that all the electrical and mechanical equipment on the dam be thoroughly checked. These checks should include the operation of the gate heaters, motor winding heaters, gate brake assemblies and limit switches. Insulation resistance should be measured for all circuits, and electrical features, and the gear units should be checked for proper tooth contact. These tests and inspection are outlined in the project operation and maintenance and should be performed as described therein.

Comment #4 - The missing grease caps have been replaced and the shafts have been greased.

Comment #5 - Riprap has been replaced on the slopes of the dike in the vicinity of the Singleton Street Pumping Station.

Comment #6 - Sand and silt in the intake to the Singleton Street Pumping Station should be removed.

Comment #7 - Interim reports should be submitted in February and August each year.

APPENDIX C
Estimated Construction Costs

ITEMS (Including Contingency) (1,000 KW Unit)	SITE A		SITE B		SITE C
	A.C.	N.W.P.	A.C.	N.W.P.	A.C.
	(\$1,000s)	(\$1,000s)	(\$1,000s)	(\$1,000s)	(\$1,000s)
Intake Structure (trash racks, waterway, headgate, valve, fence, etc.)	210.	210.	210.	210.	210.
Penstock (buried 8 ft. diameter reinforced concrete pipe)	310.8	310.8	678.	678.	0
Power House (2000 square foot reinforced concrete structure with utilities and controls, valve, tailrace, security features, and equipment installation)	227.	237.5	227.	237.5	227
Site Work (road reconstruction, utilities relocation/repair, ground restoration, and landscaping)	58.3	58.3	105.6	105.6	88.8
SUBTOTAL	806.1	816.6	1220.6	1231.1	525.8
Engineering (12 ⁰ /o)	96.7	98.	146.5	147.7	63.1
Land Acquisition	24.	24.	0	0	0
TOTAL CIVIL WORKS	926.8	938.6	1367.1	1378.8	588.9
Electrical, Mechanical (turbo-generator, controls switchgear, metering, circuit breakers, transformers, protective relaying, bus, cable, and connections)	760.	559.5	764.	564.	760.
Engineering - Electrical, Mechanical-(12 ⁰ /o)	91.	67.1	92.	67.7	91.
Licensing, Permitting and Legal	19.8	19.8	19.8	19.8	19.8
Interest during Construction	130.	130.	162.	162.	105.5
Reserve Fund	94.4	85.	115.	106.	78.1
TOTAL	2022.	1800.	2520.	2298.	1643.
A.C. =	Allis-Chalmers Hydroelectric Unit				
N.W.P. =	Northern Water Power Hydroelectric Unit				

Costs

ESTIMATED CONSTRUCTION COSTS

FIGURE 47

APPENDIX D

Written Comments Concerning Wheeling
and the National Energy Plan II

UNIVERSITY OF RHODE ISLAND
KINGSTON, R. I. 02881

Department of Electrical Engineering • Kelley Hall • 401-792-2505

NEP - II

December 27, 1978

William P. White
Department of Energy
Office of Policy and Evaluation
Forrestal Building
Washington, D.C. 20585

Dear Sir:

This is in response to the Department of Energy's request for written comments regarding the next National Energy Plan. In summary, with regard to NEP - II, we believe that it is desirable to have an interpretation or addition to the National Energy Act to provide the Federal Energy Regulatory Commission with the authority to order the "wheeling" of energy between a co-generator or small power producer and the site where it can best be utilized. An ongoing study at the University of Rhode Island from which the enclosed material was obtained shows that "wheeling" can improve financial feasibility when compared to the case where all of the energy is sold to the utility company.

Should you require further information about our activities, do not hesitate to get in touch.

Sincerely,

John S. Krikorian, Jr.

JSK/ba

Enclosure

cc: E. Benoit, R.I. State Energy Office
J. Daly, Electrical Engineering, University of Rhode Island
D. Day, Special Assistant to Region I
Representative, DOE Boston
R. Foust, Legislative Aide to Senator Pell
M. McLatchy, Energy and Technology Div., DOE Idaho Falls

RECOMMENDATIONS FOR NEP II

James C. Daly and John S. Krikorian, Jr.
Department of Electrical Engineering
University of Rhode Island
Kingston, Rhode Island 02881

In drafting legislation for NEP II two points should be considered. The first is that the provisions of the Public Utility Act of 1978 encouraging low-head hydroelectric development should be retained and strengthened in future legislation.

The second point is that consideration should be given to "local wheeling" of energy. This will have a significant impact on the economics of small power production.

Wheeling is the use of the transmission lines owned by the electric utility for the transmission of energy from the power producer to a distant location where it can best be used. A fee is charged by the utility for this transmission service. The fee is based on expenses involved plus a fair return on the capital value of the transmission equipment. Consideration is given to the fact that only a fraction of the load on the transmission facilities is the energy being wheeled.

Historically, wheeling of energy has been utilized in the past mostly by utility companies. For example, in 1954, the U. S. Solicitor General made it possible for a nonfederal utility to use the Bonneville Power Administration's interconnected western regional power grid to transmit electric energy from a large isolated hydro facility to distant load centers.

Wheeling allows the generated energy to replace energy used by a small power producer at a remote location that would otherwise have to be purchased from the electric utility at a rate of about 3.5¢/KW·hr. in New England. A preliminary estimate of about 0.3¢/KW·hr. for wheeling charges has been calculated. Therefore, the wheeled energy has a value to the small power producer of about 3.2¢/KW·hr. This is compared to the price of about 2.0¢/KW·hr. when the energy is sold directly to the utility company.

There are many cases where a dam site or small power producer and the site where the energy can best be utilized are owned by the same entity, but are located some distance apart. Municipally-owned dams are an example. Municipalities use power at locations distant from the generator, such as water pumping stations, schools, and sewerage treatment plants. Many industrially-owned generating sites are also at locations that are separated from sites where the owner can best utilize the energy. An ongoing study at the University of Rhode Island has shown that "wheeling" of energy can improve financial feasibility when compared to the case where all the energy is sold to the utility company.

It is not immediately apparent to us that the "wheeling" provisions of the Public Utility Regulatory Policy Act of 1978 are sufficiently broad to cover this situation. We believe that it is desirable to have an interpretation or addition to the National Energy Act to provide the Federal Energy Regulatory Commission with the authority to order the "wheeling"

of energy between a co-generator or small power producer and the site where it can best be utilized.

The benefits of wheeling can be seen in the case study shown in Figures 1 and 2. These are preliminary results of an engineering and economic feasibility study of the use of a flood~~ed~~ control dam owned by the City of Woonsocket, Rhode Island on the Blackstone River at Woonsocket for the generation of electrical energy. While the results are preliminary, the advantage of wheeling is clear. The generator has a rated capacity of one Megawatt. The benefits of wheeling can be seen in the differences in the cash flow between Figure 1 where the energy is sold to the utility company, and Figure 2 where the energy is wheeled and used by the City of Woonsocket at a sewerage treatment plant and the water works. The cash flow is the revenue after operating, maintenance and loan payments have been removed from income. With wheeling the first year cash flow is \$24,014.- this is a surplus. With no wheeling, when the energy is sold to the utility company, the first year cash flow is -\$31,575. This is a deficit indicating poor economic prospects without wheeling.

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0	0.	0.	0.	0.	0.
1	142140.	23000.	150714.	-31575.	-31575.
2	150099.	24265.	150714.	-24800.	-22214.
3	158505.	25600.	150714.	-17809.	-14197.
4	167301.	27007.	150714.	-10341.	-7360.
5	176754.	28493.	150714.	-2453.	-1559.
6	186652.	30060.	150714.	5878.	3336.
7	197105.	31713.	150714.	14678.	7436.
8	208143.	33457.	150714.	23971.	10843.
9	219799.	35270.	150714.	33707.	13646.
10	232107.	37239.	150714.	44154.	15923.
11	245105.	39287.	150714.	55104.	17742.
12	258831.	41448.	150714.	66669.	19166.
13	273326.	43727.	150714.	78884.	20248.
14	288632.	46132.	150714.	91785.	21035.
15	304795.	48670.	150714.	105411.	21569.
16	321863.	51346.	150714.	119803.	21888.
17	339808.	54170.	150714.	135003.	22022.
18	358721.	57150.	150714.	151050.	22001.
19	379021.	60293.	150714.	168014.	21848.
20	400246.	63609.	150714.	185723.	21587.
21	422659.	67107.	150714.	204830.	21235.
22	446320.	70798.	150714.	224816.	20809.
23	471322.	74692.	150714.	245916.	20323.
24	497716.	78800.	150714.	268202.	19790.
25	525587.	83134.	150714.	291739.	19220.
26	555020.	87706.	0.	467314.	27489.
27	586101.	92530.	0.	493571.	25923.
28	618922.	97619.	0.	521303.	24446.
29	653581.	102980.	0.	550593.	23053.
30	690182.	108652.	0.	581529.	21740.
31	728831.	114628.	0.	614203.	20501.
32	769646.	120933.	0.	648713.	19333.
33	812745.	127584.	0.	685162.	18231.
34	858209.	134601.	0.	723658.	17193.
35	906321.	142004.	0.	764317.	16213.

SITE A
ALL OF THE ENERGY
IS SOLD TO THE UTILITY
COMPANY

CITY REVENUE AFTER
OPERATING, MAINTENANCE,
AND LOAN PAYMENTS HAVE
BEEN REMOVED FROM HYDRO
INCOME

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 729. KW
THE AVERAGE POWERPLANT EFFICIENCY IS 79.2% AND THE DAM HEAD IS 18. FT. THE INSTALLED PLANT
COST IS 1680. \$/KW. AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 25YR
\$ 1680000. LOAN AT 7.50% INTEREST. INFLATION IS ASSUMED TO BE 5.50% AND ENERGY INFLATION
(THE VALUE OF ENERGY GENERATED) IS ASSUMED TO BE 5.60% YEARLY ENERGY AMOUNTS TO 6364457. KWH
REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT
(1) THE REGIONAL SEWER CONSUMES 0. KWH/YR DURING THE DAY AT 34.0MILS/KWH
FOR THE FIRST YEAR AND 0. KWH/YR DURING THE NIGHT AT 34.0MILS/KWH
FIRST YEAR; (2) THE WATERWORKS CONSUMES 0. KWH/YR DURING THE DAY AT 47.0MILS/KWH
FOR THE FIRST YEAR AND 0. KWH/YR DURING THE NIGHT AT 40.0MILS/KWH
FOR THE FIRST YEAR; (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 4242973. KWH/YR
DURING THE DAY AT 24.0MILS/KWH AND 2121484. KWH/YR DURING THE NIGHT AT 19.0MILS/KWH.
DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 23000.
THIS INCLUDES \$ 0. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF
2.98MILS/KWH.
THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.
DURING THE FIRST YEAR THE RESERVE FUND PAYMENT AMOUNTS TO \$ 86857. WHICH IS
5.17% OF THE COST OF INSTALLATION

** DISCOUNT RATE: 12.00% ; UTIL 1 = \$ 498002. , UTIL 2 = \$ 284762. , UTIL 3 = 0.08 **

Energy Sold to Utility Company

Figure 1
FIGURE 48

YEAR	REVENUE	PROD COST	LOAN PAYMENT	CASH FLOW	DCASH FLOW
0.	0.	0.	0.	0.	0.
1	214151.	39423.	150714.	24014.	24014.
2	226143.	41591.	150714.	33838.	30212.
3	238807.	43879.	150714.	44214.	35247.
4	252180.	46392.	150714.	55174.	39272.
5	266302.	48838.	150714.	66750.	42421.
6	281215.	51524.	150714.	78977.	44814.
7	296963.	54358.	150714.	91891.	46555.
8	313593.	57347.	150714.	105531.	47737.
9	331154.	60502.	150714.	119938.	48441.
10	349698.	63829.	150714.	135155.	48738.
11	369281.	67340.	150714.	151228.	48691.
12	389961.	71043.	150714.	168204.	48355.
13	411798.	74950.	150714.	186134.	47776.
14	434839.	79073.	150714.	205072.	46997.
15	459211.	83422.	150714.	225075.	46055.
16	484926.	88010.	150714.	246202.	44980.
17	512081.	92850.	150714.	268517.	43801.
18	540758.	97957.	150714.	292087.	42541.
19	571040.	103344.	150714.	316981.	41220.
20	603018.	109028.	150714.	343275.	39857.
21	636786.	115025.	150714.	371048.	38465.
22	672446.	121351.	150714.	400381.	37059.
23	710103.	128025.	150714.	431363.	35649.
24	749868.	135066.	150714.	464088.	34244.
25	791860.	142495.	150714.	498651.	32852.
26	836204.	150332.	0.	685872.	40345.
27	883031.	158600.	0.	724431.	38048.
28	932480.	167323.	0.	765157.	35881.
29	984699.	176526.	0.	808173.	33838.
30	1039841.	186234.	0.	853607.	31911.
31	1098072.	196477.	0.	901595.	30093.
32	1159563.	207283.	0.	952280.	28380.
33	1224498.	218684.	0.	1005814.	26763.
34	1293070.	230711.	0.	1062358.	25239.
35	1365481.	243400.	0.	1122080.	23802.

SITE A

ENERGY IS "WHEELED" TO THE SEWER AND. WATER WORKS WITH ANY EXCESS SOLD TO THE UTILITY COMPANY

UTILIZING THE UTILITY COMPANY'S POWER LINES WITH APPROPRIATE RENTAL FEE, TO TRANSMIT THE ENERGY FROM THE DAM TO A SITE WHERE IT CAN BEST BE UTILIZED

CITY REVENUE AFTER OPERATING, MAINTENANCE, AND LOAN PAYMENTS HAVE BEEN REMOVED FROM HYDRO INCOME

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 729. KW THE AVERAGE POWERPLANT EFFICIENCY IS 79.2 AND THE DAM HEAD IS 18. FT. THE INSTALLED PLANT COST IS 1680. \$/KW AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 25YR \$ 1680000. LOAN AT 7.50% INTEREST. INFLATION IS ASSUMED TO BE 5.50% AND ENERGY INFLATION (THE VALUE OF ENERGY GENERATED) IS ASSUMED TO BE 5.60% YEARLY ENERGY AMOUNTS TO 6364456.KWH REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT (1) THE REGIONAL SEWER CONSUMES 3389563. KWH/YR DURING THE DAY AT 34.0MILS/KWH FOR THE FIRST YEAR AND 1072613. KWH/YR DURING THE NIGHT AT 34.0MILS/KWH FIRST YEAR; (2) THE WATERWORKS CONSUMES 0. KWH/YR DURING THE DAY AT 47.0MILS/KWH FOR THE FIRST YEAR AND 1048871. KWH/YR DURING THE NIGHT AT 40.0MILS/KWH FOR THE FIRST YEAR; (3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 853409. KWH/YR DURING THE DAY AT 24.0MILS/KWH AND 0. KWH/YR DURING THE NIGHT AT 19.0MILS/KWH. DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE \$ 39423. THIS INCLUDES \$16423. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98MILS/KWH. THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES. DURING THE FIRST YEAR THE RESERVE FUND PAYMENT AMOUNTS TO \$ 86857. WHICH IS 5.17% OF THE COST OF INSTALLATION

** DISCOUNT RATE: 12.00% ; UTIL 1 = \$1350288. , UTIL 2 = \$ 1035993. , UTIL 3 = 0.27 **

Energy Wheeled and Excess sold to Utility Company

Figure 2
FIGURE 49

APPENDIX E

Lower Woonsocket, Flood Control, Protection Map

FIGURE 50

APPENDIX F

Letter Indicating Ownership of Dam

CITY OF WOONSOCKET RHODE ISLAND

DEPARTMENT OF PLANNING AND DEVELOPMENT

OFFICE OF THE DIRECTOR

TEL 762-6400
AREA CODE 401

February 13, 1978

TO WHOM IT MAY CONCERN:

In conjunction with the Woonsocket City Solicitor, this Office has examined the ownership of Lot 19, Plat 14 (Woonsocket Flood Control Dam) and Lot 25, Plat 14 (Municipal Parking Lot) and we find that both properties are in the ownership of the City of Woonsocket having been deeded to the City in a proper and correct way.

Deeds and other further legal documentations can be provided upon request.

Sincerely,

Robert L. Bendick, Jr.
Director

RLB/a

APPENDIX G
Project Tasks

PROJECT TASKS

1. The expected power plant configuration is a tube turbine driving a synchronous generator with a capacity of approximately 1100 KW. See also Section 5 and Figure 2.
2. The power plant is expected to perform at an overall average efficiency of around 70⁰%. It is expected that the plant would be operated run of the river, as immediate upstream storage capacity is negligible. Estimated average annual energy production is 5900 MWH/yr. See also Figure 2 and Section 1.1.
3. No impact on other perceived water resource needs are expected. See also Sections 1.1, 2, and 9.
4. Two options are available for marketing power:
 - a. All of the energy is sold to the utility company.
 - b. Energy is wheeled to the sewer and water works with excess sold to the utility company.

See also the Report Summary and Section 3.

5. Regulatory aspects are discussed in Section 9.
6. Capital investment per installed kilowatt and return on investment are indicated in Figure 2. For the prime configurations - Site A, C with energy wheeled - total cost per KWH are estimated as:

	\$/KWH(yr)	\$/KWH(35 yr)
Site A	.81	.023
Site C	.74	.021

7. Annual operation and maintenance costs are estimated in Section 5.10.
8. Anticipated project life has been conservatively assumed to be 35 years; although, we are aware of many old units, 50-60 years old.
9. See Section 2 and 9 for an initial assessemnt of the environmental impact and socio-institutional factors.
10. With regard to potential safety hazards; penstock construction should be careful to avoid any dangerous underground utilities. Site C is located in the river channel close to the dam and care must be taken to avoid damage to the dam or detrimental effects to flood control operations. See also the Report Summary, Sections 2, 6.2.1, 7.2.1, and 8, Appendix A and B.

11. Engineering acceptability of the proposed sites are described in Sections 2, 6, 7, and 8.
12. Availability of suitable mechanical and electrical equipment is described in Section 5.
13. A development plan for putting power on-line is illustrated in Section 10.

APPENDIX H
Computer Program

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11n 100 thru 640
100 DIMENSION DD(50)
110 SWD(1,1) IS TOTAL KWH/YR USED DURING THE DAY BY THE SEWER
120 SWN(1,1) IS TOTAL KWH/YR USED AT NIGHT BY THE SEWER
130 WWD(1,1) IS TOTAL KWH/YR USED DURING THE DAY AND WWN(1,1) IS TOTAL KW/YR USED DURING THE NIGHT BY THE WATERWOR
KS
140 DIMENSION SWD(52,2),WWD(52,2)
150 DIMENSION SWN(52,2),WWN(52,2)
160 DIMENSION AF(14),BF(14),FLOWB(52)
170 DIMENSION PW(52),APW(52),FLOW(12)
180 DIMENSION CAFL(50),A(132)
190 DIMENSION DCAFL(50)
200 DATA DCAFL/50*0.0/
210 DIMENSION EFFIC(52)
220 DATA EFFIC/52*0.0/
230
240 BKWH IS AN ARRAY FOR THE AMOUNT OF ENERGY SOLD TO THE POWER COMPANY DURING THE DAY.
250 CKWH IS AN ARRAY FOR THE AMOUNT OF ENERGY SOLD TO THE POWER COMPANY AT NIGHT.
260 DIMENSION BKWH(52,2),CKWH(52,2)
270 DIMENSION PWRUA(24,2)
280 DIMENSION PWRUA2(24,2)
290 DATA AF/14*0.0/
300 DATA BF/14*0.0/
310 DATA FLOWB/52*0.0/
320
330 SEWER POWER DEMAND ON AN HOURLY BASIS FOR WORKDAY AND NONWORKDAY
340 DATA PWRUA/680.,709.,719.,703.,678.,677.,678.,697.,663.,2*656.,664.,640.,627.,624.,615.,608.,607.,X
350 593.,607.,623.,642.,660.,672.,680.,709.,719.,703.,678.,677.,678.,697.,663.,656.,656.,664.,640.,627.,624.,X
360 615.,608.,607.,593.,607.,623.,642.,660.,672./
370
380 WATERWORKS POWER DEMAND ON AN HOURLY BASIS FOR WORKDAY AND NON-WORKDAY
390 DATA PWRUA2/11*211.,13*560.92,11*211.,13*560.92/
420 DO 183 N=1,24
430 PWRUA(N,1)=PWRUA(N,1)*1.0
440 PWRUA2(N,1)=PWRUA2(N,1)*1.0
450 183 CONTINUE
460 DO 186 N=1,24
470 PWRJA(N,2)=PWRUA(N,2)*1.0
480 PWRUA2(N,2)=PWRUA2(N,2)*1.0
490 186 CONTINUE
500 DATA WDY,HEAD/240.,20./
510 DATA CABLE,FEE/60000.,0.01/
520 DATA FLOW/888.,1094.,1585.,1316.,934.,599.,309.,210.,271.,X
530 349.,596.,941./
540 DO 25 I=1,12
550 FLOW(I)=FLOW(I)-50.
560 25 CONTINUE
570 DATA DISC,AINF,BINF,DNY,NUMYR/6.25,.07,.07,35.,35/
580 DSC=6.25
590 DATA LOAN,BL/20.,.0625/
600 226 CONTINUE
605 WRITE(6,900)
610 READ(5,*) PMAX, EFMAX
620 FLOWM=PMAX/(EFMAX*HEAD*0.0846008*0.01)
630 DO 35 N=1,6
640 DO 35 M=1,12

```

lin 650 thru 1270

```

650      FN=N
660      FM=M
670      TPI=2.*3.141593
680      AF(N)=AF(N)+(FLOW(M)*COS(TPI*(FN-1.)*(FM-.5)/12.))/6.
690      BF(N)=BF(N)+(FLOW(M)*SIN(TPI*(FN-1.)*(FM-.5)/12.))/6.
700  35  CONTINUE
710      AF(1)=AF(1)/2.
720      AF(1)=AF(1)*1.
730      DO 316 N=1,5
740      GAIN=1.0
750      AF(N+1)=AF(N+1)*GAIN
760      BF(N+1)=BF(N+1)*GAIN
770  316  CONTINUE
780
790      LEAST APPROXIMATION OF THE FLOW(SMOOTHING).
800      DO 37 N=1,52
810      DO 36 M=1,5
820      FN=N
830      FM=M
840      FLOWB(N)=FLOWB(N)+AF(M+1)*COS(FM*TPI*(FN-.5)/52.)+BF(M+1)*SIN(FM*TPI*(FN-.5)/52.)
850  36  CONTINUE
860      FLOWB(N)=FLOWB(N)+AF(1)
870
880      CALCULATION OF THE AVAILABLE POWER.
890  37  CONTINUE
900      DO 18 N=1,52
910      IF(FLOWB(N).GE.FLOWM) GO TO 1
920      IF(FLOWB(N).GE.FLOWM*.8) GO TO 2
930      IF(FLOWB(N).GE.FLOWM*.5) GO TO 3
940      IF(FLOWB(N).GE.FLOWM*.375) GO TO 4
950      IF(FLOWB(N).GE.FLOWM*.3) GO TO 5
960      EFFIC(N)=0
970      GO TO 6
980  1  EFFIC(N)=0.95*92
990      GO TO 6
1000  2  EFFIC(N)=0.95*((10*FLOWB(N))/FLOWM+82.)
1010      GO TO 6
1020  3  EFFIC(N)=0.95*((100/5)*FLOWB(N)/FLOWM+76.67)
1030      GO TO 6
1040  4  EFFIC(N)=0.95*(40*FLOWB(N)/FLOWM+65.)
1050      GO TO 6
1060  5  EFFIC(N)=0.95*((500/7.5)*FLOWB(N)/FLOWM+55.)
1070  6  PW(N)=FLOWB(N)*EFFIC(N)*HEAD*.0846008*.01
1080  18  CONTINUE
1090      L=1
1100  13  AL=L-1
1110      INSTALLED PLANT COST
1120      DOLKW=2520.+AL*50.
1130      PLANT COST WITHOUT RSFUND.
1140      DOL=2404.72773
1150      ABMAX=0.0
1160      AAMAX=0.0
1170      BCMAX=0.0
1180      BBMAX=0.0
1190      CDMAX=0.0
1200      CCMAX=0.0
1210      DEMAX=0.0
1220      DDMAX=0.0
1230      WHA=0
1240      WHE=0
1250      WHCOST=0
```

```

lin 1250 thru 1750
1250      WMCOST=0
1260      LLL=1
1270      14 ALLL=LLL-1
1280      POWER PLANT RATING
1290      CKW=1000.+ALLL*5.
1300      INSTALLED PLANT COST SCHEDULE
1310      DOKWW=DOLKW*(1.+EXP((-CKW)/125.))
1320      C=DOLKW*CKW
1330      CCC=C
1340      WDM=.0191781*WDY
1350      HDM=.0191781*(365.-WDY)
1360
1370      UPPER BOUND ON THE AMOUNT OF POWER THAT CAN BE GENERATED.
1380      19 DO 26 N=1,52
1390      IF(CKW-PW(N))24,20,20
1400      20 APW(N)=PW(N)
1410      GO TO 26
1420      24 APW(N)=CKW
1430      26 CONTINUE
1440      AP=0.0
1450      EF=0.0
1460
1470      CALCULATION OF THE AVERAGE UTILAZATION SEE PAKW LATER IN THE PROGRAM.
1480      DO 34 N=1,52
1490      AP=AP+APW(N)
1500      EF=EF+EFFIC(N)
1510      34 CONTINUE
1520      AP=AP/52.
1530      EF=EF/52.
1540      AKW=AP/CKW
1550      DO 225 J=1,2
1560      DO 225 N=1,52
1570      SWD(N,J)=0.0
1580      WWD(N,J)=0.0
1590      SWN(N,J)=0.0
1600      WWN(N,J)=0.0
1610      CKWH(N,J)=0.0
1620      BKWH(N,J)=0.0
1630      225 CONTINUE
1640      WHA=DISA*CABLE*0.15*1.0
1650      WHB=DISB*CABLE*0.15*1.0
1660      ENCB=0.024
1670      ENCC=0.019
1680      ENCB=ENCB*1000.
1690      ENCC=ENCC*1000.
1700      ENCW=0.0372
1710      ENCWD=0.0453
1720      ENCSI=0.034
1730      ENCSN=0.034
1740      WCHAR=2.98
1750      ENS=ENCSI*1000.

```

```

lin 1760 thru 2300
1760 ENSN=ENCSN*1000.
1770 ENWD=ENCWD*1000.
1780 ENWN=ENCW*1000.
1790 .
1800 * CALCULATION OF AMOUNT OF ENERGY SOLD TO THE SEWER, WATERWORKS AND THE POWER COMPANY ON A WEEKLY BASIS.
1810 DO 60 J=1,2
1820 DO 60 M=1,52
1830 DO 60 N=1,24
1840 LX=N+6
1850 IF(LX.GE.18) GO TO 234
1860 IF(LX-7) 234,232,232
1870 232 EPW=APW(M)-PWRUA2(N,J)
1880 IF(EPW.GE.0) GO TO 233
1890 WWD(M,J)=APW(M)+WWD(M,J)
1900 GO TO 60
1910 233 WWD(M,J)=WWD(M,J)+PWRUA2(N,J)
1920 EPW2=EPW-PWRUA(N,J)
1930 IF(EPW2.LE.0) GO TO 237
1940 SWD(M,J)=SWD(M,J)+PWRUA(N,J)
1950 BKWH(M,J)=BKWH(M,J)+EPW2
1960 GO TO 60
1970 237 SWD(M,J)=SWD(M,J)+EPW
1980 GO TO 60
1990 234 EPW=APW(M)-PWRUA2(N,J)
2000 IF(EPW.GT.0) GO TO 236
2010 WORKS=APW(M)
2020 WWN(M,J)=WORKS+WWN(M,J)
2030 GO TO 60
2040 236 IF(PWRUA(N,J).LT.EPW) GO TO 235
2050 SWN(M,J)=SWN(M,J)+EPW
2060 WWN(M,J)=WWN(M,J)+PWRUA2(N,J)
2070 GO TO 60
2080 235 EPW1=EPW-PWRUA(N,J)
2090 WWN(M,J)=WWN(M,J)+PWRUA2(N,J)
2100 SWN(M,J)=SWN(M,J)+PWRUA(N,J)
2110 CKWH(M,J)=CKWH(M,J)+EPW1
2120 60 CONTINUE
2130 DO 243 J=1,2
2140 DO 243 M=1,51
2150 SWD(1,J)=SWD(1,J)+SWD(M+1,J)
2160 WWD(1,J)=WWD(1,J)+WWD(M+1,J)
2170 SWN(1,J)=SWN(1,J)+SWN(M+1,J)
2180 WWN(1,J)=WWN(1,J)+WWN(M+1,J)
2190 CKWH(1,J)=CKWH(1,J)+CKWH(M+1,J)
2200 BKWH(1,J)=BKWH(1,J)+BKWH(M+1,J)
2210 243 CONTINUE
2220 .
2230 * CALCULATION OF THE YEARLY ENERGY SOLD.
2240 SWD(1,1)=WDM*SWD(1,1)+HDM*SWD(1,2)
2250 SWN(1,1)=WDM*SWN(1,1)+HDM*SWN(1,2)
2260 WWD(1,1)=WDM*WWD(1,1)+HDM*WWD(1,2)
2270 WWN(1,1)=WDM*WWN(1,1)+HDM*WWN(1,2)
2280 CKWH(1,1)=WDM*CKWH(1,1)+HDM*CKWH(1,2)
2290 BKWH(1,1)=WDM*BKWH(1,1)+HDM*BKWH(1,2)
2300 YEN=SWD(1,1)+SWN(1,1)+WWD(1,1)+WWN(1,1)+CKWH(1,1)+BKWH(1,1)

```

lin 2310 thru 2950

2310 *
2320 * CALCULATION OF THE TOTAL WHEELING COSTS.
2330 WHCOST=(SWN(1,1)+SWD(1,1)+WWD(1,1)+WWN(1,1))*0.00298
2334 GO TO 2000
2340 WRITE(6,1030)
2350 WRITE(6,1000) SWD(1,1),SWN(1,1)
2360 WRITE(6,1020) WWD(1,1),WWN(1,1)
2370 1030 FORMAT(' ',' THE YEARLY ENERGY IS ')
2380 1000 FORMAT(' ',' THE SEWER DAY ',F9.0,' KWH',' NITE ',F9.0,' KWH')
2390 1020 FORMAT(' ',' WATERWORKS DAY ',F9.0,' KWH',' NITE ',F9.0,' KWH')
2400 2000 DACC=0.
2410 *
2420 * WHEELING COST INCLUDED AS PART OF THE PRODUCTION COSTS.
2430 ASSOC=1000*17.4+WHCOST
2440 AMAINT=0.0
2450 PASS=ASSOC
2460 PAMA=AMAIN
2470 SUMRR=0.0
2480 R=0.0
2490 NYD=DNY
2500
2510 * PAUSE 96 CONTINUE
2520 WRITE(6,93)
2530 WRITE(6,94)
2540 * 97 CONTINUE
2550 AL=LOAN
2560 *
2570 * LOAN PAYMENT.
2580 P=BL*C*((1.+BL)**AL)/(((1.+BL)**AL)-1.)
2590 C1=DOL*1000.
2600 P1=BL*C1*((1.+BL)**AL)/(((1.+BL)**AL)-1.)
2605 * RESERVE FUND
2610 RF=(17400.+P1)/2.
2620 PER=(RF/C)*100.
2630 PPP=P
2640 DO 290 N=1,NUMYR
2650 *
2660 * REVENUE CALCULATION
2670 YRT=SWD(1,1)*ENCSD+SWN(1,1)*ENCSN+WWD(1,1)*ENCWDZ
2680 +WWN(1,1)*ENCW+BKWH(1,1)*ENCB+CKWH(1,1)*ENCC
2690 IF(N-NYD)145,145,150
2710 145 D=0.0
2720 GO TO 220
2730 150 D=0.0
2740 GO TO 220
2750 220 BA=YRT-D
2760 BB=BA-ASSOC
2770 ASSOC=ASSOC*(1.+AINF)
2780 BC=BB-AMAIN
2790 AMAINT=AMAIN*(1.+AINF)
2800 PROFA=BC
2810 IF(N-LOAN)262,262,266
2820 262 BN=N-1
2830 *
2840 * LOAN INTEREST.
2850 AINT=C*BL*((1.+BL)**BN)-((P*(((1.+BL)**BN)-1.))/1.)
2860 PROFA=PROFA-AINT
2870 GO TO 268
2880 266 AINT=0.0
2890 P=0.0
2900 268 PROFB=PROFA
2910 *
2920 * LOAN PRINCIPAL

```

lin 2930 thru 3590
2930 PP=P-AINT
2940 CAFL(N)=PROFB+D-PP
2950 AN=N-1
2960 DCAFL(N)=CAFL(N)/((1.+(DSC*.01))**AN)
2970 ASS=ASSOC/(1.+AINF)
2980 AMA=AMAIN/(1.+AINF)
2990
3000 PRODUCTION COSTS.
3010 PROD=ASS+AMA
3030 WRITE(6,275) N,YRT,PROD,P,CAFL(N),DCAFL(N)
3040 98 CONTINUE
3050
3060 TAKING ENERGY INFLATION INTO ACCOUNT.
3070 ENCW=ENCW*(1.+BINF)
3080 ENCWD=ENCWD*(1.+BINF)
3090 ENCB=ENCB*(1.+BINF)
3100 ENCC=ENCC*(1.+BINF)
3110 ENCS=ENCS*(1.+BINF)
3120 290 ENCSN=ENCSN*(1.+BINF)
3130
3140 RB=0.0
3150 R=RB
3160 GO TO 471
3170 370 DO 390 N=1,NUMYR
3180 AN=N
3190 SUMR=CAFL(N)/((1.+R)**AN)
3200 390 SUMRR=SUMR+SUMRR
3210 DYDT=0.0
3220 DO 397 N=1,NUMYR
3230 AN=N
3240 397 DYDT=DYDT+CAFL(N)*AN/((1.+R)**(AN+1.))
3250 ST2=C-SUMRR
3260 SUMRR=0.0
3270 R=RB-ST2/DYDT
3280 IF (ABS(R-RB)-.0000025) 470,470,450
3290 450 RB=R
3300 GO TO 370
3310 470 RC=R*100.
3320 A(L)=RC
3330 471 CONTINUE
3340
3350 UTILITY CALCULATIONS.
3360 DO 475 N=1,NUMYR
3370 AN=N-1
3380 SUMR=CAFL(N)/((1.+(DISC*.01))**AN)
3390 SUMRR=SUMR+SUMRR
3400 IF (N-LOAN) 475,476,475
3410 476 UTIA=SUMRR
3420 ANN=LOAN
3430 UTIB=SUMRR/(ANN*PPP)
3440 475 CONTINUE
3450 PV=SUMRR
3460 UTIC=SUMRR/(ANN*PPP)
3470 SUMRR=0.0
3480 CW=CCC/CKW
3490
3500 AVERAGE UTILIZATION.
3510 FAKW=AKW*CKW
3520 BLL=BL*100.
3530 PAINF=AINF*100.
3540 PBINF=BINF*100.
3550 NWDY=WDY
3560
3570 PRODUCTION COST FOR THE FIRST YEAR.

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3580 PASAM=PASS+PAMA.
3590 HEADM=HEAD*.0254*12.
3600 WRITE(6,496)
3610 WRITE(6,3000) CKW,PAKW
3620 WRITE(6,3010) EF,HEAD
3630 WRITE(6,3020) CW,NUMYR,LOAN
3640 WRITE(6,3030) C,BLL,PAINF
3650 WRITE(6,3040) PBINF,YEN
3660 WRITE(6,3050)
3670 WRITE(6,3060) SWD(1,1),ENS
3680 WRITE(6,3070) SWN(1,1),ENSN
3690 WRITE(6,3080) WWD(1,1),ENWD
3700 WRITE(6,3070) WWN(1,1),ENWN
3710 WRITE(6,3090) BKWH(1,1),ENCRB
3720 WRITE(6,3070) CKWH(1,1),ENCCC
3730 WRITE(6,4010) PASAM
3740 WRITE(6,4020) WHCOST
3750 WRITE(6,4030) WCHAR
3770 WRITE(6,4050)
3780 WRITE(6,4060) RF,PER
3800 WRITE(6,503) DISC,PV,UTIA,UTIB
3810 600 CONTINUE
3820 900 FORMAT('0','ENTER PLANT SIZE AND MAX EFFICIENCY FOR ALLIS CHALMERS EFFIC=87.4''')
3830 3000 FORMAT(' ',13X,'WHEN THE POWERPLANT IS RATED ',F7.0,' KW IT WILL GENERATE ON THE AVERAGE ',F7.0,' KW')
3840 3010 FORMAT(' ',13X,'THE AVERAGE POWERPLANT EFFICIENCY IS ',F4.0,'% AND THE DAM HEAD IS ',F4.0,' FT. THE INSTALLED PLANT')
3850 3020 FORMAT(' ',13X,'COST IS ',F5.0,' $/KW,AND THE OPERATION LIFE IS ',I3,' YRS. THIS IS FINANCED BY A ',I3,'YR')
3860 3030 FORMAT(' ',13X,'$',F8.0,' LOAN AT',F5.2,'% INTEREST. INFLATION IS ASSUMED TO BE ',F5.2,'% AND ENERGY INFLATIO N')
3870 3040 FORMAT(14X,52H( THE VALUE OF ENERGY GENERATED .) IS ASSUMED TO BE ,F5.2,2HX.,24HYEARLY ENERGY AMOUNTS TO ,F12 .0,4HKWH.)
3880 3050 FORMAT(' ',13X,'REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED.IT IS ASSUMED THAT;')
3890 3060 FORMAT(' ',13X,'(1) THE REGIONAL SEWER CONSUMES ',F10.0,' KWH/YR DURING THE DAY AT ',F5.1,'MILLS/KWH FOR THE FIRST YEAR')
3900 3070 FORMAT(' ',13X,'AND ',F10.0,' KWH/YR DURING THE NIGHT AT ',F5.1,'MILLS/KWH.')
3910 3080 FORMAT(' ',13X,'(2) THE WATERWORKS CONSUMES ',F10.0,' KWH/YR DURING THE DAY AT ',F5.1,'MILLS/KWH FOR THE FIRS T YEAR')
3920 3090 FORMAT(' ',13X,'(3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO',F10.0,'KWH/YR DURING THE DAY AT',X
3921 F5.1,'MILLS/KWH')
3930 4000 FORMAT(' ',13X,'DURING THE DAY AT',F5.1,'MILLS/KWH AND ',F10.0,' KWH/YR DURING THE NIGHT AT ',F5.1,'MILLS/KWH. ')
3940 4010 FORMAT(' ',13X,'DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE $',F7.0)
3950 4020 FORMAT(' ',13X,'THIS INCLUDES $',F6.0,' WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR')
3960 4030 FORMAT(' ',13X,'TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF',F7.2,'MILLS/KWH.')
3970 4040 FORMAT(' ',13X,F7.2,'MILLS/KWH.')
3980 4050 FORMAT(' ',13X,'THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORSEEN EXPENSES.')
3990 4060 FORMAT(' ',13X,'THE RESERVE FUND AMOUNTS TO$ ',F7.0,'WHICH IS ',F4.2,' % OF THE TOTAL CAPITAL COST.')
4000 4070 FORMAT(' ',13X,F4.2,' % OF THE TOTAL CAPITAL COST')
4010 92 FORMAT(9X,4HYEAR,6X,6HDEPREC,3X,9HPRDD COST,4X,8HMARG REV,3X,9HLOAN PRNC,X
4020 4X,8HLOAN INT,3X,9HCASH FLOW,5X,7HFED TAX,3X,9HSTATE TAX)
4030 93 FORMAT(26X,4HYEAR,4X,8HREVENUE ,3X,9HPRDD COST,1X,X
4040 3X,12HLOAN PAYMENT,4X,9HCASH FLOW,4X,10HDCASH FLOW,/)
4050 94 FORMAT(27X,1H0,12X,2H0.,10X,2H0.,10X,2H0.,13X,2H0.)
4060 95 FORMAT(/,10X,1H0,12X,2H0.,10X,2H0.,10X,2H0.,10X,2H0.,10X,2H0.,F12.0,F12.0)
4070 274 FORMAT(8X,I3,2X,F12.0,F12.0,F12.0,F12.0,F12.0,F12.0,F12.0,F12.0)
4080 275 FORMAT(25X,I3,2X,F12.0,F12.0,F12.0,3X,F12.0,3X,F12.0,3X,F12.0)
4090 481 FORMAT(30X,16HLOAN AMOUNT IS $,F8.0)
4100 496 FORMAT(/,41X,37HHYDRO-ELECTRIC SIMULATION ASSUMPTIONS,/)
4110 485 FORMAT(/,28X,35H****>>>> CASH FLOW SUM, DISCOUNTED ,F5.2,7HX, IS $,F8.0,9H <<<<****)
4120 486 FORMAT(28X,24H****>>>> UTILITY 1 = $,F7.0,16H UTILITY 2 = ,F7.4,10H <<<<****,//////////)
4130 503 FORMAT(/,16X,19H** DISCOUNT RATE: ,F5.2,14HX ; UTIL 1 = $,F8.0,13H , UTIL 2 = $,%
4140 F10.0,12H , UTIL 3 = ,F5.2,4H **,//////////)
4150 515 FORMAT(E15.7)
4160 PAUSE
4170

```

516 CONTINUE

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4430 490 CONTINUE
4440 500 CALL OPEN(9,'DROIA','OUTPUT')
4450      WRITE(9,515) (A(I),I=1,132)
4460      CALL CLOSE(9)
4470      STOP
4480      END
```

APPENDIX I

Woonsocket Study Group and Hydro Participants

STUDY GROUP

Emilie Benoit, Governor's Energy Office
James Daly, University of Rhode Island
Ralph DeVivo, Blackstone Valley Electric Company
Roger Dowdell, University of Rhode Island
William Falcone, R. I. Water Resources Board
William Foster, Governor's Energy Office
John Gmeiner, Eastern Utilities Associates
John Grifalconi, Consultant
Douglas Hartley, R. I. Division of Public Utilities and Motor
Carriers
Dante Ionata, Governor's Energy Office
Peter Janaros, Department of Environmental Management
Edward Kehoe, R. I. Division of Public Utilities and Motor
Carriers
Peter Koveos, University of Rhode Island
John Krikorian, Jr., Project Director, University of Rhode Island
Gabriel Lengyel, University of Rhode Island
Joel Mathews, City of Woonsocket
Mack Prince, University of Rhode Island
Earle Prout, Jr., R. I. Department of Environmental Management
Robert Russ, R. I. Resources Board
Samuel Seely, University of Rhode Island
Ralph Thompson, University of Rhode Island
Laurens Tromp, University of Rhode Island
Dan Urish, University of Rhode Island
C. J. Wilson, University of Rhode Island
Mason Wilson, University of Rhode Island

HYDROELECTRIC POWER POTENTIAL
Woonsocket Falls Dam, Rhode Island
University of R. I. DOE Study of
Cost/Benefit and Alternatives

Partial list of organizations and people that helped Study
in addition to basic Study Team and members of Study Group

Blackstone Valley Electric Co.
and Eastern Utilities Associates

Edward W. Cushing, Jr.
John F. Duffy, Jr.
Daniel McConaghy
Stanley S. Ribb

City of Woonsocket, R. I.

Daniel Baudouin
Hon. Gerard J. Bouley
N. David Bouley
Russell Horne
Ernest R. Lafond
James Marvel
Makram Megalli
Edgar G. Parenteau
Hedley Patterson
John Poblocki
Marcel M. Valois

Essex Associates

Lawrence, Massachusetts
Gordon Marker

New England Regional Commission

Gordon L. Deane
W. Robert Keating

New England River Basins
Commission

Terry Gould
Thomas Klock

R.I. Governor's Energy Office

Robert Coffey
William Ferguson

R.I. Governor's Policy Staff

Theodore F. Green, III
Thomas Mailhot
Arthur Marcos
Anne D. Stubbs

R.I. Department of Economic
Development

Gordon Byrd
Jerome Lessuck
Charles Vernon

R.I. Department of
Environmental Management

Victor A. Bell
Robert L. Bendick
Dawn E. Giles
R. Daniel Prentiss
W. Edward Wood

R.I. Public Utilities Commission

Edward F. Burke
Eleanor L. Miller
John J. Wrenn
John J. Callahan

R.I. Statewide Planning Program

Roland J. Frappier
Susan P. Mossison
Daniel W. Varin

R.I. Areawide Waste Treatment
Treatment Program

Thomas Brueckner
Terry Hartt

R.I. Water Resources Board

Peter Calise

University of Rhode Island

Robert Commerford
William R. Ferrante
Robert H. Goff
Richard Hellman
John J. Kupa
Joan D. Lamoureux
Frank Newman
Virginia O'Brien
Charles Polk
Raymond Stockard

Woonsocket Historical Society

Dr. and Mrs. Alton Thomas

Other Persons in Rhode Island

Mr. and Mrs. Wm. Johnson
Arthur Kirk
Henry A. Walker

. . . list of organizations and people that help Study (cont.)

U.S. Army Corps of Engineers

James Callahan
Col. John Chandler
E. P. Gould
Joseph L. Ignazio
John W. Leslie
Leo Millette

U. S. Department of Energy

James C. Bresse
Duane Day
Richard McDonald
Michael J. McLatchy
Joseph M. Pecoraro

U. S. Environmental Protection

Administration

Eric Schneider
Donald Smith

U. S. Federal Energy -
Regulatory Commission

Edward A. Abrams
Ronald A. Corso
Martin Inwald
Fred Springer

U. S. General Accounting Office

David C. Dorpfeld

U.S. Senator Claiborne Pell
and Staff

Robert S. Foust