HYDROELECTRIC POWER POTENTIAL
Woonsocket Falls Dam
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
This report and study project was made possible through a financial grant from

THE
UNITED STATES DEPARTMENT OF ENERGY

with the assistance of

THE
GOVERNOR'S ENERGY OFFICE
State of Rhode Island
Honorable J. Joseph Garrahy, Governor

Acknowledgement

For their many contributions, thanks are due the participants of the hydro study group. They responsibly examined complex problems and responded with either well thought out solutions or appropriate questions to better define the problem. Study group members who were not on the contract deserve specific acknowledgement for their active participation and for providing substantial useful information.

Special thanks are due Mrs. Joan Lamoureux and Mrs. Judy Howard for their diligent typing of the many drafts and final version of this document.

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. KOFEOS                LAURENS TROMP
JOHN S. KRIKORIAN, JR.         DANIEL W. URISH
PROJECT DIRECTOR

GOVERNOR'S ENERGY OFFICE

EMILIE BENOIT                     DANTE C. IONATA

PROJECT CONSULTANT

JOHN W. GRIFALCONI

JANUARY 1979

UNITED STATES DEPARTMENT OF ENERGY
STUDY PROJECT

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or assume that its use would not infringe privately owned rights.
# Hydro Electric Power Potential

**Woonsocket Falls Dam**  
**Woonsocket, Rhode Island**

## Topic List

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIST OF ILLUSTRATIONS, MAPS, GRAPHS, AND CHARTS</strong></td>
<td>i</td>
</tr>
<tr>
<td><strong>REPORT SUMMARY AND RECOMMENDATIONS</strong></td>
<td>iii</td>
</tr>
<tr>
<td>Report Summary</td>
<td>iii</td>
</tr>
<tr>
<td>Recommendations</td>
<td>viii</td>
</tr>
<tr>
<td><strong>1. INTRODUCTION</strong></td>
<td>1</td>
</tr>
<tr>
<td>1.1 Project Description</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Historical Summary</td>
<td>6</td>
</tr>
<tr>
<td>1.3 Project Benefits</td>
<td>6</td>
</tr>
<tr>
<td><strong>2. EXISTING FACILITIES AND CONDITIONS</strong></td>
<td>8</td>
</tr>
<tr>
<td>2.1 Description of Dam</td>
<td>8</td>
</tr>
<tr>
<td>2.2 Geological Description of Area</td>
<td>8</td>
</tr>
<tr>
<td>2.3 Hydrologic Conditions</td>
<td>10</td>
</tr>
<tr>
<td>2.3.1 General Hydrology</td>
<td>10</td>
</tr>
<tr>
<td>2.3.2 Flood Control</td>
<td>10</td>
</tr>
<tr>
<td>2.3.3 Hydroelectric Potential</td>
<td>13</td>
</tr>
<tr>
<td><strong>3. &quot;WHEELING&quot; OF ENERGY</strong></td>
<td>16</td>
</tr>
<tr>
<td>3.1 Wheeling Charges</td>
<td>16</td>
</tr>
<tr>
<td>3.2 Historical Summary</td>
<td>17</td>
</tr>
<tr>
<td><strong>4. PROJECT FINANCING</strong></td>
<td>18</td>
</tr>
<tr>
<td>4.1 Introduction</td>
<td>18</td>
</tr>
<tr>
<td>4.2 External Financing</td>
<td>18</td>
</tr>
<tr>
<td>4.2.1 Bonds</td>
<td>18</td>
</tr>
<tr>
<td>4.2.1.1 General Obligation and Revenue</td>
<td>19</td>
</tr>
<tr>
<td>4.2.1.1 General Obligation</td>
<td>19</td>
</tr>
<tr>
<td>4.2.1.2 Revenue</td>
<td>20</td>
</tr>
<tr>
<td>4.2.1.2 Net Interest Cost</td>
<td>23</td>
</tr>
<tr>
<td>4.2.1.3 Public Placement</td>
<td>25</td>
</tr>
<tr>
<td>4.2.1.4 Example of an Issue</td>
<td>26</td>
</tr>
<tr>
<td>4.2.1.5 The Indenture</td>
<td>27</td>
</tr>
<tr>
<td>4.2.1.6 Interest during Construction</td>
<td>29</td>
</tr>
<tr>
<td>4.2.1.7 Private versus Public Placement</td>
<td>31</td>
</tr>
<tr>
<td>4.2.2 Financing through Federal Government</td>
<td>32</td>
</tr>
<tr>
<td>4.2.3 Leasing</td>
<td>34</td>
</tr>
<tr>
<td>4.3 Internal Financing</td>
<td>35</td>
</tr>
<tr>
<td>4.4 Conclusion</td>
<td>36</td>
</tr>
</tbody>
</table>
5. GENERAL ENGINEERING

5.1 Power Station Grounding
5.2 Connection of Proposed Hydro Station to Existing Utility Network
5.3 Automation
5.4 Metering
5.5 Intake and Trash Racks
5.6 Sewer Works
5.7 Water Works
5.8 Description of Computer Model
  5.8.1 Engineering Features
  5.8.2 Cash Flow Calculation
  5.8.3 Performance Indices
  5.8.4 Optimization
    5.8.4.1 Civil Estimated Construction costs
    5.8.4.2 Electrical-Mechanical Estimated Costs
5.9 Turbogenerators
  5.9.1 Allis-Chalmers Hydroelectric Generating Units
  5.9.2 Northern Water Power Hydroelectric Generating Units
5.10 Operating and Maintenance Costs

6. FEASIBILITY SITE A

6.1 Location
6.2 Penstock
  6.2.1 Utilities in path
6.3 Power House
6.4 Feasibility with Allis-Chalmers Hydroelectric Generating Units
  6.4.1 Computer Runs, Energy sold to Utility Company
    6.4.1.1 Financial Feasibility using Nominal Data Points
    6.4.1.2 Sensitivity Study
    6.4.1.3 Optimization Study
  6.4.2 Computer Runs, Energy wheeled and sold to Utility Company
    6.4.2.1 Financial Feasibility using Nominal Data Points
    6.4.2.2 Sensitivity Study
    6.4.2.3 Optimization Study
6.5 Feasibility with Northern Water Power Hydroelectric Generating Units
  6.5.1 Computer Run, Energy sold to Utility Company
    6.5.1.1 Financial Feasibility using Nominal Data Points
  6.5.2 Computer Run, Energy wheeled and sold to Utility Company
    6.5.2.1 Financial Feasibility using Nominal Data Points
FEASIBILITY SITE B
7.1 Location
7.2 Penstock
  7.2.1 Utilities in Path
7.3 Power House
7.4 Feasibility with Allis-Chalmers
       Hydroelectric Generating Units
  7.4.1 Computer Runs, Energy sold to
       Utility Company
     7.4.1.1 Financial Feasibility using
          Nominal Data Points
     7.4.1.2 Sensitivity Study
     7.4.1.3 Optimization Study
  7.4.2 Computer Runs, Energy wheeled and
       sold to Utility Company
     7.4.2.1 Financial Feasibility using
          Nominal Data Points
     7.4.2.2 Sensitivity Study
     7.4.2.3 Optimization Study
7.5 Feasibility with Northern Water Power
       Hydroelectric Generating Units
  7.5.1 Computer Run, Energy sold to
       Utility Company
     7.5.1.1 Financial Feasibility using
          Nominal Data Points
  7.5.2 Computer Run, Energy wheeled and
       sold to Utility Company
     7.5.2.1 Financial Feasibility using
          Nominal Data Points

FEASIBILITY SITE C
8.1 Location
8.2 Power House
8.3 Feasibility with Allis-Chalmers
       Hydroelectric Generating Units
  8.3.1 Computer Run, Energy sold to
       Utility Company
     8.3.1.1 Financial Feasibility using
          Nominal Data Points
     8.3.1.2 Optimization Study
  8.3.2 Computer Run, Energy wheeled and
       sold to Utility Company
     8.3.2.1 Financial Feasibility using
          Nominal Data Points
     8.3.2.2 Optimization Study

PLANNING, PERMITS AND LEGAL FACTORS
9.1 Project Approval and Development
9.2 Federal Review
9.3 State Review
9.4 Local Review and Future Action
9.5 Legal
10. ENGINEERING AND CONSTRUCTION SCHEDULE

11. REFERENCES

<p>| APPENDIX A | Department of Environmental Management dam safety report |
| APPENDIX B | Corps of Engineers dam safety report |
| APPENDIX C | Estimated Construction Costs |
| APPENDIX D | Written Comments Concerning Wheeling and the National Energy Plan II |
| APPENDIX E | Lower Woonsocket, Flood Control, Protection Map |
| APPENDIX F | Letter Indicating Ownership of Dam |
| APPENDIX G | Project Tasks |
| APPENDIX H | Computer Program |
| APPENDIX I | Woonsocket Study Group and Hydro Participants |</p>
<table>
<thead>
<tr>
<th>TOPIC</th>
<th>FIGURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woonsocket Planning Map</td>
<td>1</td>
</tr>
<tr>
<td>Summary Chart</td>
<td>2</td>
</tr>
<tr>
<td>Woonsocket Falls Dam</td>
<td>3</td>
</tr>
<tr>
<td>Reference Map</td>
<td>4</td>
</tr>
<tr>
<td>Aerial View</td>
<td>5</td>
</tr>
<tr>
<td>Details of Dam</td>
<td>6</td>
</tr>
<tr>
<td>Flow Duration Curve</td>
<td>7</td>
</tr>
<tr>
<td>Average Hydrograph</td>
<td>8</td>
</tr>
<tr>
<td>Site Plan</td>
<td>9</td>
</tr>
<tr>
<td>Example of an Issue</td>
<td>10</td>
</tr>
<tr>
<td>Interest During Construction</td>
<td>11</td>
</tr>
<tr>
<td>Sewer and Water Works</td>
<td>12</td>
</tr>
<tr>
<td>Sewer Power Demand</td>
<td>13</td>
</tr>
<tr>
<td>Approximate Waterworks Power Demand</td>
<td>14</td>
</tr>
<tr>
<td>Block Diagram of Computer Model</td>
<td>15</td>
</tr>
<tr>
<td>Smoothed Flow Data</td>
<td>16</td>
</tr>
<tr>
<td>Allis-Chalmers Efficiency Curve</td>
<td>17</td>
</tr>
<tr>
<td>Site A</td>
<td>18</td>
</tr>
<tr>
<td>Location of Utilities</td>
<td>19</td>
</tr>
<tr>
<td>Power House, Site A</td>
<td>20</td>
</tr>
<tr>
<td>Cash Flow, Site A, A.C., Energy Sold</td>
<td>21</td>
</tr>
<tr>
<td>Sensitivity, Site A, A.C., Energy Sold</td>
<td>22</td>
</tr>
<tr>
<td>Optimization, Site A, A.C., Energy Sold</td>
<td>23</td>
</tr>
<tr>
<td>Cash Flow, Site A, A.C., Energy Wheeled</td>
<td>24</td>
</tr>
<tr>
<td>Sensitivity, Site A, A.C., Energy Wheeled</td>
<td>25</td>
</tr>
<tr>
<td>Optimization, Site A, A.C., Energy Wheeled</td>
<td>26</td>
</tr>
<tr>
<td>Cash Flow, Site A, N.W.P., Energy Sold</td>
<td>27</td>
</tr>
<tr>
<td>Cash Flow, Site A, N.W.P., Energy Wheeled</td>
<td>28</td>
</tr>
<tr>
<td>Site B</td>
<td>29</td>
</tr>
<tr>
<td>Power House, Site B</td>
<td>30</td>
</tr>
<tr>
<td>Cash Flow, Site B, A.C., Energy Sold</td>
<td>31</td>
</tr>
<tr>
<td>Sensitivity, Site B, A.C., Energy Sold</td>
<td>32</td>
</tr>
<tr>
<td>Optimization, Site B, A.C., Energy Sold</td>
<td>33</td>
</tr>
<tr>
<td>TOPIC</td>
<td>FIGURE</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Cash Flow, Site B, A.C., Energy Wheeled</td>
<td>34</td>
</tr>
<tr>
<td>Sensitivity, Site B, A.C., Energy Wheeled</td>
<td>35</td>
</tr>
<tr>
<td>Optimization, Site B, A.C., Energy Wheeled</td>
<td>36</td>
</tr>
<tr>
<td>Cash Flow, Site B, N.W.P., Energy Sold</td>
<td>37</td>
</tr>
<tr>
<td>Cash Flow, Site B, N.W.P., Energy Wheeled</td>
<td>38</td>
</tr>
<tr>
<td>Site C</td>
<td>39</td>
</tr>
<tr>
<td>Power House, Site C</td>
<td>40</td>
</tr>
<tr>
<td>Cash Flow, Site C, A.C., Energy Sold</td>
<td>41</td>
</tr>
<tr>
<td>Optimization, Site C, A.C., Energy Sold</td>
<td>42</td>
</tr>
<tr>
<td>Cash Flow, Site C, A.C., Energy Wheeled</td>
<td>43</td>
</tr>
<tr>
<td>Optimization, Site C, A.C., Energy Wheeled</td>
<td>44</td>
</tr>
<tr>
<td>Engineering and Construction Schedule</td>
<td>45</td>
</tr>
<tr>
<td>Permit and Development Chart</td>
<td>46</td>
</tr>
<tr>
<td>Estimated Construction Costs</td>
<td>47</td>
</tr>
<tr>
<td>Energy Sold to Utility Company (NEP II letter)</td>
<td>48</td>
</tr>
<tr>
<td>Energy Wheeled and Excess Sold (NEP II letter)</td>
<td>49</td>
</tr>
<tr>
<td>Woonsocket Local Protection Plan</td>
<td>50</td>
</tr>
</tbody>
</table>
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
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
### Summary Chart

#### SITE A

<table>
<thead>
<tr>
<th>UTILIZATION OF ENERGY</th>
<th>HEAD FEET</th>
<th>NOMINAL INSTALLED COST FOR 10000K SW</th>
<th>NWH/YR</th>
<th>OVERALL AVERAGE EFF.</th>
<th>$U_1($)</th>
<th>$U_2($)</th>
<th>INITIAL FIVE YEAR CASH FLOW ($1,000s)</th>
<th>OPTIMAL PLANT SIZE (KW)</th>
<th>$U_1($)</th>
<th>$U_2($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sold (1)</td>
<td>18</td>
<td>2022.2</td>
<td>5926.0</td>
<td>71.</td>
<td>2153.</td>
<td>180.</td>
<td>-274.</td>
<td>1150.</td>
<td>700.</td>
<td>2247.</td>
</tr>
<tr>
<td>A.C.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheeled (2)</td>
<td>18</td>
<td>2022.2</td>
<td>5926.0</td>
<td>71.</td>
<td>4952.</td>
<td>1694.</td>
<td>133.</td>
<td>1150.</td>
<td>1000.</td>
<td>5100.</td>
</tr>
<tr>
<td>Sold (1)</td>
<td>18</td>
<td>1800.0</td>
<td>5782.5</td>
<td>70. (3)</td>
<td>2268.</td>
<td>350.</td>
<td>-193.</td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
</tr>
<tr>
<td>N.W.P.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheeled (2)</td>
<td>18</td>
<td>1800.0</td>
<td>5782.5</td>
<td>70. (3)</td>
<td>5098.</td>
<td>1881.</td>
<td>219.</td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
</tr>
</tbody>
</table>

#### SITE B

<table>
<thead>
<tr>
<th>UTILIZATION OF ENERGY</th>
<th>HEAD FEET</th>
<th>NOMINAL INSTALLED COST FOR 10000K SW</th>
<th>NWH/YR</th>
<th>OVERALL AVERAGE EFF.</th>
<th>$U_1($)</th>
<th>$U_2($)</th>
<th>INITIAL FIVE YEAR CASH FLOW ($1,000s)</th>
<th>OPTIMAL PLANT SIZE (KW)</th>
<th>$U_1($)</th>
<th>$U_2($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.C.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheeled (2)</td>
<td>20</td>
<td>2520.0</td>
<td>6199.1</td>
<td>75.</td>
<td>4780.</td>
<td>1758.</td>
<td>36.</td>
<td>1200.</td>
<td>800.</td>
<td>4050.</td>
</tr>
<tr>
<td>Sold (1)</td>
<td>20</td>
<td>2298.0</td>
<td>6108.5</td>
<td>70. (3)</td>
<td>2014.</td>
<td>-31.</td>
<td>-374.</td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
</tr>
<tr>
<td>N.W.P.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheeled (2)</td>
<td>20</td>
<td>2298.0</td>
<td>6108.5</td>
<td>70. (3)</td>
<td>4965.</td>
<td>1567.</td>
<td>55.</td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
</tr>
</tbody>
</table>

#### SITE C

<table>
<thead>
<tr>
<th>UTILIZATION OF ENERGY</th>
<th>HEAD FEET</th>
<th>NOMINAL INSTALLED COST FOR 10000K SW</th>
<th>NWH/YR</th>
<th>OVERALL AVERAGE EFF.</th>
<th>$U_1($)</th>
<th>$U_2($)</th>
<th>INITIAL FIVE YEAR CASH FLOW ($1,000s)</th>
<th>OPTIMAL PLANT SIZE (KW)</th>
<th>$U_1($)</th>
<th>$U_2($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sold (1)</td>
<td>16</td>
<td>1643.0</td>
<td>5367.3</td>
<td>67.</td>
<td>2214.</td>
<td>418.</td>
<td>-169.</td>
<td>1050.</td>
<td>900.</td>
<td>2309.</td>
</tr>
<tr>
<td>A.C.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheeled (2)</td>
<td>16</td>
<td>1643.0</td>
<td>5367.3</td>
<td>67.</td>
<td>4884.</td>
<td>1842.</td>
<td>233.</td>
<td>1050.</td>
<td>1050.</td>
<td>4975.</td>
</tr>
</tbody>
</table>

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 hydro-electric unit.
N.W.P. = Northern Water Power hydro-electric unit.

**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.
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.
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
FIGURE 4

Reference Map
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 facili-

*Information provided by Earle P. Prout, Jr., Dams Section, R. I. D. E. M, 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,
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
FLOW DURATION CURVE
BLACKSTONE RIVER-WOONSOCKET
DRAINAGE AREA 416 SQ. MILES
AT USGS GAGING STATIONS
1965-77

Flow Duration Curve

FIGURE 7
Average Hydrograph

FIGURE 8
occasionally more than once in a year. Minor floods are ex-
pected 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 posi-
tion 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)
Site Plan

FIGURE 9
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 Authority\(^1\)

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:

\[
r_m = r_c (1 - \tau - 0.19t) = r_c (1 - 1.9t)
\]

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 service$^3$, 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 obligation 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 projects

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. 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.

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. 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, including:

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:

1. A pledge of the entire gross revenues to bond interest and retirement.
<table>
<thead>
<tr>
<th>AMOUNT</th>
<th>MATURITY</th>
<th>INTEREST RATE</th>
<th>BOND YEARS</th>
<th>TOTAL INTEREST</th>
</tr>
</thead>
<tbody>
<tr>
<td>$100,000</td>
<td>1985</td>
<td>5.90%</td>
<td>120</td>
<td>$35,400</td>
</tr>
<tr>
<td>$100,000</td>
<td>1986</td>
<td>6.00</td>
<td>140</td>
<td>42,000</td>
</tr>
<tr>
<td>$100,000</td>
<td>1987</td>
<td>6.10</td>
<td>160</td>
<td>48,800</td>
</tr>
<tr>
<td>$100,000</td>
<td>1988</td>
<td>6.20</td>
<td>180</td>
<td>55,800</td>
</tr>
<tr>
<td>$300,000*</td>
<td>1998</td>
<td>7.20</td>
<td>1140</td>
<td>410,400</td>
</tr>
<tr>
<td>$300,000*</td>
<td>1999</td>
<td>7.30</td>
<td>1200</td>
<td>438,000</td>
</tr>
</tbody>
</table>

2940  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.


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
Interest for Two Years = \$67,100 \times 2 = \$134,200

<table>
<thead>
<tr>
<th>Year</th>
<th>Maturity</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td></td>
<td>$100,000</td>
</tr>
<tr>
<td>1986</td>
<td></td>
<td>$300,000</td>
</tr>
<tr>
<td>1987</td>
<td></td>
<td>$100,000</td>
</tr>
<tr>
<td>1988</td>
<td></td>
<td>$100,000</td>
</tr>
<tr>
<td>1989</td>
<td></td>
<td>$5,900</td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td>$6,100</td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td>$6,100</td>
</tr>
<tr>
<td>1992</td>
<td></td>
<td>$6,200</td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td>$21,900</td>
</tr>
<tr>
<td>1994</td>
<td></td>
<td>$67,700</td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td>$67,700</td>
</tr>
</tbody>
</table>
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 2% 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 advise 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 90%/n) 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.

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. 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.

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

1 Housing Authority bonds may also be examined as a special type of revenue bonds.

2 The 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.

3 See (2)

4 See (1) for discussions of some of these points.

5 For an electricity related project, for example, it could be noted that electric consumption is expected to increase by 5-6% over the next decade, compared to a 3% increase for energy in general. According to some sources, (4), the share of electricity in U.S. energy demand will increase from 28% in 1974 to 37% in 1990. Electricity prices could also be compared to other prices, both in the retail and wholesale level, to reveal any probable pricing pattern.

6 See section of the report on Financing Through Federal Government Aid.

7 Other 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.

8 See (3) for analysis of some of these factors.

9 Payment for the securities usually takes place about fifteen to thirty days after bonds are received.

10 See (2).

11 See (4), Section 402.

12 See (4), Section 403. These loans carry an interest rate of 6.875 percent. This rate may change by .25 percent each year.

13 See (4), Section 404. Another section of the Act, Section 405, establishes a program of simple and expeditions licensing procedures.

( ) refers to references in Section II.
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 is 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 13) 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

FIGURE 12
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 company.
Approximate Hourly Power Demand of Waterworks

FIGURE 14
BLOCK DIAGRAM OF MAJOR SYSTEM MODEL ELEMENTS

FIGURE 15
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 $T = \frac{1}{f_o} = \frac{2\pi}{\omega_0}$.

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 choosen 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:

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

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

\[ n = 0, \ldots, 5 \]

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 piecewise linear. An electrical efficiency of 95\(^{\circ}\) has been used. The power available from the generator is modelled as

\[ P = .0846 \text{ EFH}, \]

\[ P_e = \begin{cases} p, & p \leq p \varepsilon \\ \varepsilon, & p > p \varepsilon \end{cases} \]
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 is 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.

\[ L_a = C_c \]

\[ C_c = C_o + R_F \]

\[ P_a = \frac{L_a i^\ell}{1 - \left(\frac{1}{1+i^\ell}\right)^y} \]

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

- \( L_a \) = loan amount,
- \( C_c \) = Capital cost,
- \( i^\ell \) = 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:

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

\[ U_2 = \sum_{n=1}^{y} \frac{C_f(n)}{(1+i_d)^{n-1}} \]

\( U_1, U_2 \) = utilities,
- \( y_o \) = operating life of power plant,
- \( C_f \) = cash flow,
\[ i_d = \text{discount rate}, \]
\[ P_a = \text{annual loan payment}, \]
\[ y_f = \text{amortization period for loan}. \]

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:

\[
\text{Installed Cost Schedule} = (-0.239)(\text{CKW}) + 1166.13 + \\
+ (-0.1317)(\text{CKW}) + 778.04 + \\
+ \text{adjustment factor},
\]

\[ \text{CKW} = \text{plant size [500 KW, 1350 KW]}, \]

First term = Civil Construction Cost Schedule,

Second term = Electrical-Mechanical Cost Schedule,

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

\[
\text{Installed Cost Schedule} = DOLKW \left(1 + e^{-\frac{\text{CKW}}{300}}\right),
\]

\[ \text{CKW} = \text{plant size [1350, 2000]}, \]

\[ DOLKW = \text{plant cost for 1350 KW facility, from above}. \]
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 superficial site investigations. In unknown situations the more costly alternative was used.

The estimated costs represent January, 1979 figures accelerated by a 10 - 15% 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 hydro-electric 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°/o 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°/o 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 Tompsoon, 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 $800/yr $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
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
## Hydro-Electric Simulation Assumptions

When the powerplant is rated 1000 kW, it will generate on the average 670 kW. The average powerplant efficiency is 71% and the dam head is 18 ft. The installed plant cost is $22,000/kW and the operation life is 35 yrs. This is financed by a 20-year loan at 7.0% interest. Inflation is assumed to be 7.0% and energy inflation (the value of energy generated) is assumed to be $924,000/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 34.0 mills/kWh and 0 kWh/yr during the night at 37.0 mills/kWh.
2. The waterworks consumes 0 kWh/yr during the day at 45.3 mills/kWh for the first year and 0 kWh/yr during the night at 37.2 mills/kWh.
3. The energy sold to Blackstone Valley amounts to 2716.0 kWh/yr during the day at 24.0 mills/kWh and 3299.3 kWh/yr during the night at 19.0 mills/kWh.

During the first year the automated plant production costs are $1740. This includes a 0.0% wheeling charges to Blackstone Valley Electric for transmitting power to the regional sewer and the waterworks at a rate of 2.8 mills/kWh. The reserve fund is established for equipment replacement and unforeseen expenses. The reserve fund amounts to $9448.0, which is 4.67% of the total capital cost.

**Discount Rate: 6.25% + UTIL 1 = $215348. UTIL 2 = $179674.**

### Site A, Allis-Chalmers, Energy Sold

<table>
<thead>
<tr>
<th>Year</th>
<th>Revenue</th>
<th>Prod Cost</th>
<th>Loan Payment</th>
<th>Cash Flow</th>
<th>DCash Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>1</td>
<td>126175</td>
<td>17400</td>
<td>179057</td>
<td>-71082</td>
<td>-71082</td>
</tr>
<tr>
<td>2</td>
<td>132007</td>
<td>18618</td>
<td>179057</td>
<td>-63468</td>
<td>-59734</td>
</tr>
<tr>
<td>3</td>
<td>144458</td>
<td>19731</td>
<td>179057</td>
<td>-55321</td>
<td>-49004</td>
</tr>
<tr>
<td>4</td>
<td>154570</td>
<td>21316</td>
<td>179057</td>
<td>-46603</td>
<td>-40853</td>
</tr>
<tr>
<td>5</td>
<td>165390</td>
<td>22800</td>
<td>179057</td>
<td>-37275</td>
<td>-32949</td>
</tr>
<tr>
<td>6</td>
<td>176967</td>
<td>24404</td>
<td>179057</td>
<td>-27295</td>
<td>-20575</td>
</tr>
<tr>
<td>7</td>
<td>187354</td>
<td>26113</td>
<td>179057</td>
<td>-16613</td>
<td>-11249</td>
</tr>
<tr>
<td>8</td>
<td>205609</td>
<td>27941</td>
<td>179057</td>
<td>-51941</td>
<td>-33941</td>
</tr>
<tr>
<td>9</td>
<td>216792</td>
<td>29896</td>
<td>179057</td>
<td>7038</td>
<td>4333</td>
</tr>
<tr>
<td>10</td>
<td>231967</td>
<td>31999</td>
<td>179057</td>
<td>20121</td>
<td>11660</td>
</tr>
<tr>
<td>11</td>
<td>249205</td>
<td>34197</td>
<td>179057</td>
<td>31419</td>
<td>10269</td>
</tr>
<tr>
<td>12</td>
<td>265579</td>
<td>36624</td>
<td>179057</td>
<td>49096</td>
<td>25203</td>
</tr>
<tr>
<td>13</td>
<td>284169</td>
<td>39188</td>
<td>179057</td>
<td>65124</td>
<td>31463</td>
</tr>
<tr>
<td>14</td>
<td>304641</td>
<td>41911</td>
<td>179057</td>
<td>82273</td>
<td>37410</td>
</tr>
<tr>
<td>15</td>
<td>325346</td>
<td>44866</td>
<td>179057</td>
<td>100625</td>
<td>43062</td>
</tr>
<tr>
<td>16</td>
<td>348119</td>
<td>48007</td>
<td>179057</td>
<td>120255</td>
<td>48437</td>
</tr>
<tr>
<td>17</td>
<td>372487</td>
<td>51367</td>
<td>179057</td>
<td>141231</td>
<td>53511</td>
</tr>
<tr>
<td>18</td>
<td>399861</td>
<td>54963</td>
<td>179057</td>
<td>163741</td>
<td>58422</td>
</tr>
<tr>
<td>19</td>
<td>426460</td>
<td>58010</td>
<td>179057</td>
<td>187973</td>
<td>63042</td>
</tr>
<tr>
<td>20</td>
<td>453612</td>
<td>62927</td>
<td>179057</td>
<td>213528</td>
<td>67486</td>
</tr>
<tr>
<td>21</td>
<td>480254</td>
<td>67332</td>
<td>0</td>
<td>420922</td>
<td>125208</td>
</tr>
<tr>
<td>22</td>
<td>522431</td>
<td>72042</td>
<td>0</td>
<td>450388</td>
<td>126991</td>
</tr>
<tr>
<td>23</td>
<td>559001</td>
<td>77088</td>
<td>0</td>
<td>481913</td>
<td>126982</td>
</tr>
<tr>
<td>24</td>
<td>598131</td>
<td>82484</td>
<td>0</td>
<td>515647</td>
<td>127878</td>
</tr>
<tr>
<td>25</td>
<td>640000</td>
<td>88258</td>
<td>0</td>
<td>551742</td>
<td>128781</td>
</tr>
<tr>
<td>26</td>
<td>684800</td>
<td>94336</td>
<td>0</td>
<td>590363</td>
<td>129690</td>
</tr>
<tr>
<td>27</td>
<td>732735</td>
<td>101047</td>
<td>0</td>
<td>631688</td>
<td>130605</td>
</tr>
<tr>
<td>28</td>
<td>784026</td>
<td>108120</td>
<td>0</td>
<td>675906</td>
<td>131527</td>
</tr>
<tr>
<td>29</td>
<td>838908</td>
<td>115298</td>
<td>0</td>
<td>723219</td>
<td>132456</td>
</tr>
<tr>
<td>30</td>
<td>897631</td>
<td>123786</td>
<td>0</td>
<td>773844</td>
<td>133391</td>
</tr>
<tr>
<td>31</td>
<td>960464</td>
<td>132451</td>
<td>0</td>
<td>828013</td>
<td>134332</td>
</tr>
<tr>
<td>32</td>
<td>1027697</td>
<td>141733</td>
<td>0</td>
<td>885742</td>
<td>135291</td>
</tr>
<tr>
<td>33</td>
<td>1099634</td>
<td>151643</td>
<td>0</td>
<td>947991</td>
<td>136236</td>
</tr>
<tr>
<td>34</td>
<td>1176608</td>
<td>162258</td>
<td>0</td>
<td>1014350</td>
<td>137197</td>
</tr>
<tr>
<td>35</td>
<td>1258970</td>
<td>173161</td>
<td>0</td>
<td>1085352</td>
<td>138166</td>
</tr>
</tbody>
</table>

**Figure 21**
## SENSITIVITY ANALYSIS

<table>
<thead>
<tr>
<th>UTIL 1 in $</th>
<th>UTIL 2 in $</th>
<th>VARIABLE CHANGE</th>
<th>NOMINAL VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967357.</td>
<td>127969.</td>
<td>Inflation - 20°/o increase - 8.4°/o</td>
<td>7.0</td>
</tr>
<tr>
<td>2291561.</td>
<td>223236.</td>
<td>Inflation - 20°/o decrease - 5.6°/o</td>
<td>7.0</td>
</tr>
<tr>
<td>3499345.</td>
<td>552184.</td>
<td>Energy inflation - 20°/o increase 8.4°/o</td>
<td>7.0</td>
</tr>
<tr>
<td>1149851.</td>
<td>-138645.</td>
<td>Energy inflation - 20°/o decrease 5.6°/o</td>
<td>7.0</td>
</tr>
<tr>
<td>2153191.</td>
<td>814316.</td>
<td>Loan period - 25 yrs.</td>
<td>20 yrs.</td>
</tr>
<tr>
<td>2153198.</td>
<td>-433612.</td>
<td>Loan period - 15 yrs.</td>
<td>20 yrs.</td>
</tr>
<tr>
<td>1932711.</td>
<td>-41105.</td>
<td>Loan interest - 7.5°/o</td>
<td>6.25°/o</td>
</tr>
<tr>
<td>1749680.</td>
<td>-224136.</td>
<td>Loan interest - 8.5°/o</td>
<td>6.25°/o</td>
</tr>
<tr>
<td>2652159.</td>
<td>449932.</td>
<td>Day energy sold - 26.4 mills</td>
<td>24 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy sold - 20.9 mills</td>
<td>19 mills</td>
</tr>
<tr>
<td>1654228.</td>
<td>-90633.</td>
<td>Day energy sold - 21.6 mills</td>
<td>24 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy sold - 17.1 mills</td>
<td>19 mills</td>
</tr>
<tr>
<td>1852648.</td>
<td>16741.</td>
<td>Production cost for year 1 - $25,000</td>
<td>$17,400</td>
</tr>
<tr>
<td>2327195.</td>
<td>273539.</td>
<td>Production cost for year 1 - $13,000</td>
<td>$17,400</td>
</tr>
<tr>
<td>1804694.</td>
<td>-169122.</td>
<td>Installed plant cost - 2350 $/KWH</td>
<td>2022 $/KWH</td>
</tr>
<tr>
<td>2493321.</td>
<td>521507.</td>
<td>Installed plant cost - 1700 $/KWH</td>
<td>2022 $/KWH</td>
</tr>
<tr>
<td>1995700.</td>
<td>-201591.</td>
<td>Power plant rating - increase to 1300 KW</td>
<td>1000 KW</td>
</tr>
<tr>
<td>1676868.</td>
<td>315942.</td>
<td>Power plant rating - decrease to 600 KW</td>
<td>1000 KW</td>
</tr>
<tr>
<td>1549590.</td>
<td>110662.</td>
<td>Discount rate - 7.5°/o</td>
<td>6.25°/o</td>
</tr>
<tr>
<td>1187626.</td>
<td>65170.</td>
<td>Discount rate - 8.5°/o</td>
<td>6.25°/o</td>
</tr>
<tr>
<td>2536791.</td>
<td>386960.</td>
<td>River flow - 20°/o increase</td>
<td></td>
</tr>
<tr>
<td>1558731.</td>
<td>-142300.</td>
<td>River flow - 20°/o decrease</td>
<td></td>
</tr>
<tr>
<td>2153194.</td>
<td>179380.</td>
<td>Nominal values</td>
<td></td>
</tr>
</tbody>
</table>

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.
"Discounted Cash Flow Over Operating Life Versus Plant Size."

"Discounted Cash Flow Over Loan Period Versus Plant Size."

'Nominal cost is 2022, $/KW for a 1000+ KW facility.'

'X=Plant size in KW and Y=Discounted Cash Flow in Dollars.'

**SITE A, ALLIS-CHALMERS ENERGY SOLD**

**FIGURE 23**
AND 2046301.

WHEN AN11

TRANSMITTING

THIS SITE A, ENERGY

THE.

THE VALUE OF ENERGY

2021723.

THE ENERGY SOLD

THE INCLUDES

DISINFECTION

THE

THE ENERGY GENERATED.) IS ASSUMED TO BE 7.00%, YEARLY ENERGY AMOUNT 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 34.0 MIGHTS/KWH FOR THE FIRST YEAR AND 1163625. KWH/yr DURING THE NIGHT AT 34.0 MIGHTS/KWH.

(2) THE WATERWORKS CONSUMES 714688. KWH/yr DURING THE DAY AT 45.3 MIGHTS/KWH FOR THE FIRST YEAR AND 2046301. KWH/yr DURING THE NIGHT AT 37.2 MIGHTS/KWH.

(3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 216205. KWH/yr DURING THE DAY AT 24.0 MIGHTS/KWH AND 0. KWH/yr DURING THE NIGHT AT 19.0 MIGHTS/KWH.

THE CURRENT YEAR'S 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 2.90 MIGHTS/KWH.

THE RESERVE FUND 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 = $4951675. ; UTIL 2 = $1693889. **

SITE A, ENERGY WHEELED AND SOLD, ALLIS-CHALMERS

FIGURE 24
<table>
<thead>
<tr>
<th>UTIL 1 in $</th>
<th>UTIL 2 in $</th>
<th>VARIABLE CHANGE</th>
<th>NOMINAL VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4584207.</td>
<td>1591910.</td>
<td>Inflation - 20% increase</td>
<td>7.0</td>
</tr>
<tr>
<td>5225049.</td>
<td>1780337.</td>
<td>Inflation - 20% decrease</td>
<td>7.0</td>
</tr>
<tr>
<td>7233985.</td>
<td>2325742.</td>
<td>Energy inflation - 20% increase</td>
<td>7.0</td>
</tr>
<tr>
<td>9210054.</td>
<td>1154338.</td>
<td>Energy inflation - 20% decrease</td>
<td>7.0</td>
</tr>
<tr>
<td>4951377.</td>
<td>2741556.</td>
<td>Loan period - 25 yrs.</td>
<td>20 yrs.</td>
</tr>
<tr>
<td>4951385.</td>
<td>681851.</td>
<td>Loan period - 15 yrs.</td>
<td>20 yrs.</td>
</tr>
<tr>
<td>4730897.</td>
<td>1473110.</td>
<td>Loan interest - 7.5%</td>
<td>6.25%</td>
</tr>
<tr>
<td>4547866.</td>
<td>1290079.</td>
<td>Loan interest - 8.5%</td>
<td>6.25%</td>
</tr>
<tr>
<td>5047836.</td>
<td>1908137.</td>
<td>Day energy value sewer - 37.4 mills</td>
<td>34 mills</td>
</tr>
<tr>
<td>4671323.</td>
<td>1542154.</td>
<td>Night energy value sewer - 37.4 mills</td>
<td>34 mills</td>
</tr>
<tr>
<td>5300473.</td>
<td>1925795.</td>
<td>Day energy value waterworks - 49.83 mills</td>
<td>45.3 mills</td>
</tr>
<tr>
<td>4522286.</td>
<td>1461395.</td>
<td>Night energy value waterworks - 40.92 mills</td>
<td>37.2 mills</td>
</tr>
<tr>
<td>4971899.</td>
<td>1704699.</td>
<td>Day energy sold - 26.4 mills</td>
<td>24 mills</td>
</tr>
<tr>
<td>4930861.</td>
<td>1682490.</td>
<td>Night energy sold - 20.9 mills</td>
<td>19 mills</td>
</tr>
<tr>
<td>5884091.</td>
<td>1657181.</td>
<td>Day energy sold - 21.6 mills</td>
<td>24 mills</td>
</tr>
<tr>
<td>5018669.</td>
<td>1730007.</td>
<td>Night energy sold - 17.1 mills</td>
<td>19 mills</td>
</tr>
<tr>
<td>4650836.</td>
<td>1530958.</td>
<td>Wheeling charges - 3.278 mills/KWH</td>
<td>2.98 mills/KWH</td>
</tr>
<tr>
<td>5125383.</td>
<td>1787753.</td>
<td>Wheeling charges - 2.682 mills/KWH</td>
<td>2.98 mills/KWH</td>
</tr>
<tr>
<td>4602880.</td>
<td>1154093.</td>
<td>Production cost for year 1 - $25,000</td>
<td>$17,400</td>
</tr>
<tr>
<td>5297358.</td>
<td>2035721.</td>
<td>Installed plant cost - $2500/KWH</td>
<td>2022 $/KWH</td>
</tr>
<tr>
<td>4770016.</td>
<td>1299710.</td>
<td>Power plant rating - increase to 1300 KW</td>
<td>1000 KW</td>
</tr>
<tr>
<td>4064686.</td>
<td>1573621.</td>
<td>Power plant rating - decrease to 600 KW</td>
<td>1000 KW</td>
</tr>
<tr>
<td>5161641.</td>
<td>1309029.</td>
<td>Discount rate 8.5%</td>
<td>6.25%</td>
</tr>
<tr>
<td>3839952.</td>
<td>1465003.</td>
<td>Discount rate 7.5%</td>
<td>6.25%</td>
</tr>
<tr>
<td>4548772.</td>
<td>2014797.</td>
<td>River flow - 20% increase</td>
<td>20%</td>
</tr>
<tr>
<td>5055439.</td>
<td>1208764.</td>
<td>River flow - 20% decrease</td>
<td>20%</td>
</tr>
<tr>
<td>5011222.</td>
<td>1725977.</td>
<td>Power demand sewer 20% increase</td>
<td>20%</td>
</tr>
<tr>
<td>4868453.</td>
<td>1648719.</td>
<td>Power demand sewer 20% decrease</td>
<td>20%</td>
</tr>
<tr>
<td>5080473.</td>
<td>1763652.</td>
<td>Power demand waterworks 20% increase</td>
<td>20%</td>
</tr>
<tr>
<td>4818847.</td>
<td>1621846.</td>
<td>Power demand waterworks 20% decrease</td>
<td>20%</td>
</tr>
</tbody>
</table>

**SENSITIVITY ANALYSIS**

**SITE A, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD**

**FIGURE 25**
"DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE."

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

*Nominal cost is 2022. $/KW for a 1000 KW facility.*

X = FLAT SIZE 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 70°/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.
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 per kW and the operation life is 35 yrs. This is financed by a 20 yr $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 0.0 kWh/yr during the day at 34.0 mills/kWh for the first year and 0.0 kWh/yr during the night at 34.0 mills/kWh.
2. The waterworks consumes 0.0 kWh/yr during the day at 37.2 mills/kWh for the first year and 0.0 kWh/yr during the night at 37.2 mills/kWh.
3. The energy sold to Blackstone Valley amounts to 2650336 kWh/yr during the day at 43.3 mills/kWh and 3132213 kWh/yr during the night at 43.3 mills/kWh. During the first year the automated plant production costs are $17400.

This includes $0.0 wheeling charges to Blackstone Valley Electric for transmitting power to the regional sewer and the waterworks at a rate of 2.98 mills/kWh.

The reserve fund is established for equipment replacement and unforeseen expenses. The reserve fund amounts to $4979 which is 4.72% of the total capital cost.

** Discount rate: 6.25% ; Util 1 = $226.8260. ; Util 2 = $349.900. **

### Site A, Northern Water Power, Energy Sold

<table>
<thead>
<tr>
<th>YEAR</th>
<th>REVENUE</th>
<th>PROD COST</th>
<th>LOAN PAYMENT</th>
<th>CASH FLOW</th>
<th>D/CASH FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>123120</td>
<td>17400</td>
<td>160132</td>
<td>-54412</td>
<td>-54412</td>
</tr>
<tr>
<td>2</td>
<td>131738</td>
<td>18618</td>
<td>160132</td>
<td>-47012</td>
<td>-44246</td>
</tr>
<tr>
<td>3</td>
<td>140960</td>
<td>19921</td>
<td>160132</td>
<td>-39093</td>
<td>-34629</td>
</tr>
<tr>
<td>4</td>
<td>150858</td>
<td>21316</td>
<td>160132</td>
<td>-30621</td>
<td>-25529</td>
</tr>
<tr>
<td>5</td>
<td>161385</td>
<td>22808</td>
<td>160132</td>
<td>-22555</td>
<td>-16913</td>
</tr>
<tr>
<td>6</td>
<td>172682</td>
<td>24404</td>
<td>160132</td>
<td>-11855</td>
<td>-8755</td>
</tr>
<tr>
<td>7</td>
<td>184770</td>
<td>26113</td>
<td>160132</td>
<td>-1475</td>
<td>-1025</td>
</tr>
<tr>
<td>8</td>
<td>197703</td>
<td>27941</td>
<td>160132</td>
<td>9631</td>
<td>6300</td>
</tr>
<tr>
<td>9</td>
<td>211543</td>
<td>29846</td>
<td>160132</td>
<td>2194</td>
<td>13246</td>
</tr>
<tr>
<td>10</td>
<td>225351</td>
<td>31989</td>
<td>160132</td>
<td>34229</td>
<td>19835</td>
</tr>
<tr>
<td>11</td>
<td>242195</td>
<td>34238</td>
<td>160132</td>
<td>47835</td>
<td>26889</td>
</tr>
<tr>
<td>12</td>
<td>259149</td>
<td>36274</td>
<td>160132</td>
<td>52392</td>
<td>32027</td>
</tr>
<tr>
<td>13</td>
<td>277289</td>
<td>39180</td>
<td>160132</td>
<td>77969</td>
<td>37649</td>
</tr>
<tr>
<td>14</td>
<td>296699</td>
<td>41931</td>
<td>160132</td>
<td>94636</td>
<td>43031</td>
</tr>
<tr>
<td>15</td>
<td>317468</td>
<td>44866</td>
<td>160132</td>
<td>112470</td>
<td>48132</td>
</tr>
<tr>
<td>16</td>
<td>339690</td>
<td>48007</td>
<td>160132</td>
<td>131552</td>
<td>52987</td>
</tr>
<tr>
<td>17</td>
<td>363469</td>
<td>51367</td>
<td>160132</td>
<td>151969</td>
<td>57610</td>
</tr>
<tr>
<td>18</td>
<td>388911</td>
<td>54943</td>
<td>160132</td>
<td>173816</td>
<td>62016</td>
</tr>
<tr>
<td>19</td>
<td>414125</td>
<td>58810</td>
<td>160132</td>
<td>197192</td>
<td>64218</td>
</tr>
<tr>
<td>20</td>
<td>445264</td>
<td>62927</td>
<td>160132</td>
<td>222200</td>
<td>70228</td>
</tr>
<tr>
<td>21</td>
<td>476432</td>
<td>67332</td>
<td>0</td>
<td>409100</td>
<td>121691</td>
</tr>
<tr>
<td>22</td>
<td>509782</td>
<td>72045</td>
<td>0</td>
<td>437372</td>
<td>122550</td>
</tr>
<tr>
<td>23</td>
<td>545466</td>
<td>77088</td>
<td>0</td>
<td>468370</td>
<td>123415</td>
</tr>
<tr>
<td>24</td>
<td>583649</td>
<td>82494</td>
<td>0</td>
<td>501164</td>
<td>124286</td>
</tr>
<tr>
<td>25</td>
<td>624504</td>
<td>88258</td>
<td>0</td>
<td>536246</td>
<td>125164</td>
</tr>
<tr>
<td>26</td>
<td>668219</td>
<td>94436</td>
<td>0</td>
<td>573783</td>
<td>126047</td>
</tr>
<tr>
<td>27</td>
<td>714994</td>
<td>101047</td>
<td>0</td>
<td>613947</td>
<td>126937</td>
</tr>
<tr>
<td>28</td>
<td>765043</td>
<td>108120</td>
<td>0</td>
<td>656923</td>
<td>127833</td>
</tr>
<tr>
<td>29</td>
<td>818596</td>
<td>115688</td>
<td>0</td>
<td>702907</td>
<td>128736</td>
</tr>
<tr>
<td>30</td>
<td>875897</td>
<td>123786</td>
<td>0</td>
<td>752111</td>
<td>129645</td>
</tr>
<tr>
<td>31</td>
<td>937209</td>
<td>132451</td>
<td>0</td>
<td>804750</td>
<td>130560</td>
</tr>
<tr>
<td>32</td>
<td>1002814</td>
<td>141723</td>
<td>0</td>
<td>861091</td>
<td>131481</td>
</tr>
<tr>
<td>33</td>
<td>1073010</td>
<td>151643</td>
<td>0</td>
<td>921367</td>
<td>132409</td>
</tr>
<tr>
<td>34</td>
<td>1148120</td>
<td>162018</td>
<td>0</td>
<td>988282</td>
<td>133344</td>
</tr>
<tr>
<td>35</td>
<td>1228468</td>
<td>173616</td>
<td>0</td>
<td>1054871</td>
<td>134285</td>
</tr>
<tr>
<td>YEAR</td>
<td>REVENUE</td>
<td>PROD COST</td>
<td>LOAN PAYMENT</td>
<td>CASH FLOW</td>
<td>DCASH FLOW</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>-----------</td>
<td>--------------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>211491.</td>
<td>34213.</td>
<td>160132.</td>
<td>17146.</td>
<td>17146.</td>
</tr>
<tr>
<td>2</td>
<td>226295.</td>
<td>36608.</td>
<td>160132.</td>
<td>29555.</td>
<td>27816.</td>
</tr>
<tr>
<td>3</td>
<td>242135.</td>
<td>39170.</td>
<td>160132.</td>
<td>42033.</td>
<td>37942.</td>
</tr>
<tr>
<td>4</td>
<td>259085.</td>
<td>41912.</td>
<td>160132.</td>
<td>57040.</td>
<td>47555.</td>
</tr>
<tr>
<td>5</td>
<td>277221.</td>
<td>44846.</td>
<td>160132.</td>
<td>72245.</td>
<td>56686.</td>
</tr>
<tr>
<td>6</td>
<td>296262.</td>
<td>47985.</td>
<td>160132.</td>
<td>88508.</td>
<td>65364.</td>
</tr>
<tr>
<td>7</td>
<td>317390.</td>
<td>51344.</td>
<td>160132.</td>
<td>105971.</td>
<td>73617.</td>
</tr>
<tr>
<td>8</td>
<td>339607.</td>
<td>54938.</td>
<td>160132.</td>
<td>124536.</td>
<td>81470.</td>
</tr>
<tr>
<td>9</td>
<td>363379.</td>
<td>58784.</td>
<td>160132.</td>
<td>144463.</td>
<td>88946.</td>
</tr>
<tr>
<td>10</td>
<td>388815.</td>
<td>62899.</td>
<td>160132.</td>
<td>165784.</td>
<td>96070.</td>
</tr>
<tr>
<td>11</td>
<td>416032.</td>
<td>67302.</td>
<td>160132.</td>
<td>188595.</td>
<td>102861.</td>
</tr>
<tr>
<td>12</td>
<td>445154.</td>
<td>72013.</td>
<td>160132.</td>
<td>213009.</td>
<td>109313.</td>
</tr>
<tr>
<td>13</td>
<td>476315.</td>
<td>77054.</td>
<td>160132.</td>
<td>239129.</td>
<td>115529.</td>
</tr>
<tr>
<td>14</td>
<td>509656.</td>
<td>82447.</td>
<td>160132.</td>
<td>267077.</td>
<td>121411.</td>
</tr>
<tr>
<td>15</td>
<td>545332.</td>
<td>88219.</td>
<td>160132.</td>
<td>296981.</td>
<td>127095.</td>
</tr>
<tr>
<td>16</td>
<td>583505.</td>
<td>94394.</td>
<td>160132.</td>
<td>328997.</td>
<td>132507.</td>
</tr>
<tr>
<td>17</td>
<td>624350.</td>
<td>101001.</td>
<td>160132.</td>
<td>363216.</td>
<td>137692.</td>
</tr>
<tr>
<td>18</td>
<td>668054.</td>
<td>108071.</td>
<td>160132.</td>
<td>399851.</td>
<td>142663.</td>
</tr>
<tr>
<td>19</td>
<td>714818.</td>
<td>115636.</td>
<td>160132.</td>
<td>439049.</td>
<td>147435.</td>
</tr>
<tr>
<td>20</td>
<td>764855.</td>
<td>123731.</td>
<td>160132.</td>
<td>480992.</td>
<td>152018.</td>
</tr>
<tr>
<td>21</td>
<td>818394.</td>
<td>132392.</td>
<td>160132.</td>
<td>566000.</td>
<td>204059.</td>
</tr>
<tr>
<td>22</td>
<td>875681.</td>
<td>141859.</td>
<td>160132.</td>
<td>734022.</td>
<td>205499.</td>
</tr>
<tr>
<td>23</td>
<td>936978.</td>
<td>151575.</td>
<td>160132.</td>
<td>835003.</td>
<td>206950.</td>
</tr>
<tr>
<td>24</td>
<td>1002566.8</td>
<td>162186.</td>
<td>160132.</td>
<td>840381.</td>
<td>208411.</td>
</tr>
<tr>
<td>25</td>
<td>1072745.</td>
<td>173539.</td>
<td>160132.</td>
<td>899206.</td>
<td>209882.</td>
</tr>
<tr>
<td>26</td>
<td>1147837.</td>
<td>185586.</td>
<td>160132.</td>
<td>962151.</td>
<td>211344.</td>
</tr>
<tr>
<td>27</td>
<td>1228185.</td>
<td>198684.</td>
<td>160132.</td>
<td>1029501.</td>
<td>212855.</td>
</tr>
<tr>
<td>28</td>
<td>1314158.</td>
<td>212592.</td>
<td>160132.</td>
<td>1101564.</td>
<td>214358.</td>
</tr>
<tr>
<td>29</td>
<td>1406148.</td>
<td>227473.</td>
<td>160132.</td>
<td>1178074.</td>
<td>215871.</td>
</tr>
<tr>
<td>30</td>
<td>1504577.</td>
<td>243064.</td>
<td>160132.</td>
<td>1261180.</td>
<td>217395.</td>
</tr>
<tr>
<td>31</td>
<td>1609897.</td>
<td>260434.</td>
<td>160132.</td>
<td>1349462.</td>
<td>218930.</td>
</tr>
<tr>
<td>32</td>
<td>1722589.</td>
<td>278664.</td>
<td>160132.</td>
<td>1443924.</td>
<td>220475.</td>
</tr>
<tr>
<td>33</td>
<td>1843169.</td>
<td>299191.</td>
<td>160132.</td>
<td>1544998.</td>
<td>222032.</td>
</tr>
<tr>
<td>34</td>
<td>1972191.</td>
<td>319042.</td>
<td>160132.</td>
<td>1653148.</td>
<td>223599.</td>
</tr>
<tr>
<td>35</td>
<td>2110244.</td>
<td>341375.</td>
<td>160132.</td>
<td>1768868.</td>
<td>225178.</td>
</tr>
</tbody>
</table>

**HYDRO-ELECTRIC SIMULATION ASSUMPTIONS**

- **WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE .662. KW**
- **THE AVERAGE POWERPLANT EFFICIENCY IS 70.0%**
- **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 RE 7.002 AND ENERGY INFLATION IS ASSUMED TO BE 7.002/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 83395. 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 BLACKSTONE 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 UNFORESEEN 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 13 1/2 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
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
<table>
<thead>
<tr>
<th>YEAR</th>
<th>REVENUE</th>
<th>PROD COST</th>
<th>LOAN PAYMENT</th>
<th>CASH FLOW</th>
<th>DCASH FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>131990</td>
<td>17400</td>
<td>224185</td>
<td>-109595</td>
<td>-109595</td>
</tr>
<tr>
<td>2</td>
<td>141239</td>
<td>18618</td>
<td>224185</td>
<td>-101274</td>
<td>-95599</td>
</tr>
<tr>
<td>3</td>
<td>151115</td>
<td>19921</td>
<td>224185</td>
<td>-92992</td>
<td>-82373</td>
</tr>
<tr>
<td>4</td>
<td>161693</td>
<td>21316</td>
<td>224185</td>
<td>-83808</td>
<td>-69791</td>
</tr>
<tr>
<td>5</td>
<td>173011</td>
<td>22909</td>
<td>224185</td>
<td>-73992</td>
<td>-58051</td>
</tr>
<tr>
<td>6</td>
<td>185122</td>
<td>24404</td>
<td>224185</td>
<td>-63468</td>
<td>-46871</td>
</tr>
<tr>
<td>7</td>
<td>198080</td>
<td>26113</td>
<td>224185</td>
<td>-52217</td>
<td>-36295</td>
</tr>
<tr>
<td>8</td>
<td>211946</td>
<td>27974</td>
<td>224185</td>
<td>-40180</td>
<td>-26265</td>
</tr>
<tr>
<td>9</td>
<td>226782</td>
<td>29994</td>
<td>224185</td>
<td>-27999</td>
<td>-16608</td>
</tr>
<tr>
<td>10</td>
<td>242657</td>
<td>31989</td>
<td>224185</td>
<td>-13517</td>
<td>-7833</td>
</tr>
<tr>
<td>11</td>
<td>259643</td>
<td>34229</td>
<td>224185</td>
<td>1229</td>
<td>670</td>
</tr>
<tr>
<td>12</td>
<td>277847</td>
<td>36624</td>
<td>224185</td>
<td>107064</td>
<td>8731</td>
</tr>
<tr>
<td>13</td>
<td>297265</td>
<td>39186</td>
<td>224185</td>
<td>33892</td>
<td>16374</td>
</tr>
<tr>
<td>14</td>
<td>318073</td>
<td>41931</td>
<td>224185</td>
<td>51957</td>
<td>23625</td>
</tr>
<tr>
<td>15</td>
<td>340338</td>
<td>44866</td>
<td>224185</td>
<td>71267</td>
<td>30508</td>
</tr>
<tr>
<td>16</td>
<td>364161</td>
<td>48007</td>
<td>224185</td>
<td>91970</td>
<td>37044</td>
</tr>
<tr>
<td>17</td>
<td>389653</td>
<td>51367</td>
<td>224185</td>
<td>114100</td>
<td>43254</td>
</tr>
<tr>
<td>18</td>
<td>416920</td>
<td>54663</td>
<td>224185</td>
<td>137780</td>
<td>49159</td>
</tr>
<tr>
<td>19</td>
<td>446113</td>
<td>58810</td>
<td>224185</td>
<td>165117</td>
<td>54776</td>
</tr>
<tr>
<td>20</td>
<td>477340</td>
<td>62927</td>
<td>224185</td>
<td>190228</td>
<td>60122</td>
</tr>
<tr>
<td>21</td>
<td>510754</td>
<td>67332</td>
<td>0</td>
<td>443422</td>
<td>131901</td>
</tr>
<tr>
<td>22</td>
<td>546506</td>
<td>72045</td>
<td>0</td>
<td>474461</td>
<td>132831</td>
</tr>
<tr>
<td>23</td>
<td>594761</td>
<td>77088</td>
<td>0</td>
<td>507673</td>
<td>133769</td>
</tr>
<tr>
<td>24</td>
<td>625694</td>
<td>82484</td>
<td>0</td>
<td>543210</td>
<td>134714</td>
</tr>
<tr>
<td>25</td>
<td>669493</td>
<td>88258</td>
<td>0</td>
<td>581234</td>
<td>135665</td>
</tr>
<tr>
<td>26</td>
<td>716357</td>
<td>94436</td>
<td>0</td>
<td>623491</td>
<td>136622</td>
</tr>
<tr>
<td>27</td>
<td>766501</td>
<td>101047</td>
<td>0</td>
<td>665455</td>
<td>137587</td>
</tr>
<tr>
<td>28</td>
<td>820156</td>
<td>108120</td>
<td>0</td>
<td>712036</td>
<td>138558</td>
</tr>
<tr>
<td>29</td>
<td>877567</td>
<td>115688</td>
<td>0</td>
<td>761078</td>
<td>139536</td>
</tr>
<tr>
<td>30</td>
<td>938994</td>
<td>123786</td>
<td>0</td>
<td>815209</td>
<td>140521</td>
</tr>
<tr>
<td>31</td>
<td>1004725</td>
<td>132451</td>
<td>0</td>
<td>872274</td>
<td>141513</td>
</tr>
<tr>
<td>32</td>
<td>1075055</td>
<td>141723</td>
<td>0</td>
<td>933332</td>
<td>142512</td>
</tr>
<tr>
<td>33</td>
<td>1150308</td>
<td>151643</td>
<td>0</td>
<td>998665</td>
<td>143519</td>
</tr>
<tr>
<td>34</td>
<td>1330829</td>
<td>162550</td>
<td>0</td>
<td>1060570</td>
<td>144531</td>
</tr>
<tr>
<td>35</td>
<td>1316997</td>
<td>173616</td>
<td>0</td>
<td>1143370</td>
<td>145551</td>
</tr>
</tbody>
</table>

HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 710. KW.
The average powerplant efficiency is 75.5% 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
$220000. 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 Blackstone Valley Electric for
Transmitting power to the regional sewer and the Waterworks at a rate of 2.9MILLS/KWH.
The reserve fund is established for equipment replacement and unforeseen expenses.
The reserve fund amounts to 115665. WHICH IS 4.5% OF THE TOTAL CAPITAL COST.

** Discount rate: 6.25% ; UTIL 1 = $1054005. ; UTIL 2 = $ -225320. **

SITE B, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 31
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

<table>
<thead>
<tr>
<th>UTIL 1 in $</th>
<th>UTIL 2 in $</th>
<th>VARIABLE CHANGE</th>
<th>NOMINAL VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1668367.</td>
<td>-276732.</td>
<td>Inflation &gt; 20°/o increase &gt; 8.4°/o</td>
<td>7.0</td>
</tr>
<tr>
<td>1992369.</td>
<td>-181464.</td>
<td>Inflation &gt; 20°/o decrease &gt; 5.6°/o</td>
<td>7.0</td>
</tr>
<tr>
<td>326190.</td>
<td>164663.</td>
<td>Energy inflation &gt; 20°/o increase 8.4°/o</td>
<td>7.0</td>
</tr>
<tr>
<td>804423.</td>
<td>-558001.</td>
<td>Energy inflation &gt; 20°/o decrease 5.6°/o</td>
<td>7.0</td>
</tr>
<tr>
<td>1854001.</td>
<td>443355.</td>
<td>Loan period &gt; 25 yrs.</td>
<td>20 yrs.</td>
</tr>
<tr>
<td>1854009.</td>
<td>-871079.</td>
<td>Loan period &gt; 15 yrs.</td>
<td>20 yrs.</td>
</tr>
<tr>
<td>1579217.</td>
<td>-500108.</td>
<td>Loan interest &gt; 7.5°/o</td>
<td>6.25°/o</td>
</tr>
<tr>
<td>1351110.</td>
<td>-728217.</td>
<td>Loan interest &gt; 8.5°/o</td>
<td>6.25°/o</td>
</tr>
<tr>
<td>2373562.</td>
<td>57135.</td>
<td>Day energy sold &gt; 26.4 mills</td>
<td>24 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy sold &gt; 20.9 mills</td>
<td>19 mills</td>
</tr>
<tr>
<td>1352045.</td>
<td>507776.</td>
<td>Day energy sold &gt; 21.6 mills</td>
<td>24 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy sold &gt; 17.1 mills</td>
<td>19 mills</td>
</tr>
<tr>
<td>1553459.</td>
<td>-387959.</td>
<td>Production cost for year 1 &gt; $25,000</td>
<td>$17,400</td>
</tr>
<tr>
<td>2028005.</td>
<td>-131161.</td>
<td>Production cost for year 1 &gt; $13,000</td>
<td>$17,400</td>
</tr>
<tr>
<td>1450254.</td>
<td>-629073.</td>
<td>Installed plant cost &gt; 2900 $/KWH</td>
<td>2520 $/KWH</td>
</tr>
<tr>
<td>2406507.</td>
<td>327183.</td>
<td>Installed plant cost &gt; 2000 $/KWH</td>
<td>2520 $/KWH</td>
</tr>
<tr>
<td>1815840.</td>
<td>-614554.</td>
<td>Power plant rating &gt; 30°/o increase</td>
<td>1000 kw</td>
</tr>
<tr>
<td>1465397.</td>
<td>55937.</td>
<td>Power plant rating &gt; 40°/o decrease</td>
<td>1000 kw</td>
</tr>
<tr>
<td>1232275.</td>
<td>-263370.</td>
<td>Discount rate &gt; 7.5°/o</td>
<td>6.25°/o</td>
</tr>
<tr>
<td>894945.</td>
<td>-287514.</td>
<td>Discount rate &gt; 8.5°/o</td>
<td>8.5°/o</td>
</tr>
<tr>
<td>2276897.</td>
<td>3524.</td>
<td>River flow &gt; 20°/o increase</td>
<td></td>
</tr>
<tr>
<td>1382097.</td>
<td>-513159.</td>
<td>River flow &gt; 20°/o decrease</td>
<td></td>
</tr>
<tr>
<td>1384005.</td>
<td>-223520.</td>
<td>Nominal Values</td>
<td></td>
</tr>
</tbody>
</table>

SITE B, ALLIS-CHALMERS, ENERGY SOLD

**FIGURE 32**
"DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE."

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

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

SITE B, ALLIS-CHALMERS, ENERGY SOLD

FIGURE 33
<table>
<thead>
<tr>
<th>YEAR</th>
<th>REVENUE</th>
<th>PROD CUST</th>
<th>LOAN PAYMENT</th>
<th>CASH FLOW</th>
<th>DCASH FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>1</td>
<td>223765.</td>
<td>35190.</td>
<td>224185.</td>
<td>-35611.</td>
<td>-35611.</td>
</tr>
<tr>
<td>2</td>
<td>239428.</td>
<td>37654.</td>
<td>224185.</td>
<td>-22411.</td>
<td>-21092.</td>
</tr>
<tr>
<td>3</td>
<td>256180.</td>
<td>40289.</td>
<td>224185.</td>
<td>-8286.</td>
<td>-7340.</td>
</tr>
<tr>
<td>4</td>
<td>274121.</td>
<td>43109.</td>
<td>224185.</td>
<td>5691.</td>
<td>4080.</td>
</tr>
<tr>
<td>5</td>
<td>293230.</td>
<td>46127.</td>
<td>224185.</td>
<td>22997.</td>
<td>18045.</td>
</tr>
<tr>
<td>6</td>
<td>313841.</td>
<td>49356.</td>
<td>224185.</td>
<td>40300.</td>
<td>29762.</td>
</tr>
<tr>
<td>7</td>
<td>335810.</td>
<td>52811.</td>
<td>224185.</td>
<td>58814.</td>
<td>40800.</td>
</tr>
<tr>
<td>8</td>
<td>359316.</td>
<td>56508.</td>
<td>224185.</td>
<td>78634.</td>
<td>51434.</td>
</tr>
<tr>
<td>9</td>
<td>384468.</td>
<td>60463.</td>
<td>224185.</td>
<td>99820.</td>
<td>61459.</td>
</tr>
<tr>
<td>10</td>
<td>411381.</td>
<td>64696.</td>
<td>224185.</td>
<td>122500.</td>
<td>70987.</td>
</tr>
<tr>
<td>11</td>
<td>440717.</td>
<td>69274.</td>
<td>224185.</td>
<td>146768.</td>
<td>80494.</td>
</tr>
<tr>
<td>12</td>
<td>470989.</td>
<td>74070.</td>
<td>224185.</td>
<td>172734.</td>
<td>90667.</td>
</tr>
<tr>
<td>13</td>
<td>503958.</td>
<td>79255.</td>
<td>224185.</td>
<td>200050.</td>
<td>100875.</td>
</tr>
<tr>
<td>14</td>
<td>539235.</td>
<td>84802.</td>
<td>224185.</td>
<td>230247.</td>
<td>104694.</td>
</tr>
<tr>
<td>15</td>
<td>576798.</td>
<td>90239.</td>
<td>224185.</td>
<td>262057.</td>
<td>112149.</td>
</tr>
<tr>
<td>16</td>
<td>617369.</td>
<td>97090.</td>
<td>224185.</td>
<td>296094.</td>
<td>119262.</td>
</tr>
<tr>
<td>17</td>
<td>660584.</td>
<td>103886.</td>
<td>224185.</td>
<td>332513.</td>
<td>126053.</td>
</tr>
<tr>
<td>18</td>
<td>706825.</td>
<td>111158.</td>
<td>224185.</td>
<td>371482.</td>
<td>132542.</td>
</tr>
<tr>
<td>19</td>
<td>752033.</td>
<td>118939.</td>
<td>224185.</td>
<td>413178.</td>
<td>138747.</td>
</tr>
<tr>
<td>20</td>
<td>809243.</td>
<td>127265.</td>
<td>224185.</td>
<td>457979.</td>
<td>144866.</td>
</tr>
<tr>
<td>21</td>
<td>865890.</td>
<td>136174.</td>
<td>0.</td>
<td>729717.</td>
<td>217062.</td>
</tr>
<tr>
<td>22</td>
<td>926502.</td>
<td>145706.</td>
<td>0.</td>
<td>780796.</td>
<td>218594.</td>
</tr>
<tr>
<td>23</td>
<td>991395.</td>
<td>155905.</td>
<td>0.</td>
<td>835452.</td>
<td>220137.</td>
</tr>
<tr>
<td>24</td>
<td>1060751.</td>
<td>166818.</td>
<td>0.</td>
<td>893933.</td>
<td>221691.</td>
</tr>
<tr>
<td>25</td>
<td>1135003.</td>
<td>178495.</td>
<td>0.</td>
<td>956508.</td>
<td>223256.</td>
</tr>
<tr>
<td>26</td>
<td>1214452.</td>
<td>190250.</td>
<td>0.</td>
<td>1023462.</td>
<td>224812.</td>
</tr>
<tr>
<td>27</td>
<td>1299444.</td>
<td>204359.</td>
<td>0.</td>
<td>1095104.</td>
<td>226419.</td>
</tr>
<tr>
<td>28</td>
<td>1390426.</td>
<td>218644.</td>
<td>0.</td>
<td>1171761.</td>
<td>228018.</td>
</tr>
<tr>
<td>29</td>
<td>1487759.</td>
<td>233971.</td>
<td>0.</td>
<td>1253784.</td>
<td>229627.</td>
</tr>
<tr>
<td>30</td>
<td>1591897.</td>
<td>250348.</td>
<td>0.</td>
<td>1341548.</td>
<td>231248.</td>
</tr>
<tr>
<td>31</td>
<td>1703329.</td>
<td>267873.</td>
<td>0.</td>
<td>1435456.</td>
<td>232801.</td>
</tr>
<tr>
<td>32</td>
<td>1822562.</td>
<td>286624.</td>
<td>0.</td>
<td>1535938.</td>
<td>234525.</td>
</tr>
<tr>
<td>33</td>
<td>1950140.</td>
<td>306657.</td>
<td>0.</td>
<td>1643452.</td>
<td>236180.</td>
</tr>
<tr>
<td>34</td>
<td>2086449.</td>
<td>328155.</td>
<td>0.</td>
<td>1758493.</td>
<td>237848.</td>
</tr>
<tr>
<td>35</td>
<td>2232713.</td>
<td>351126.</td>
<td>0.</td>
<td>1881587.</td>
<td>239527.</td>
</tr>
</tbody>
</table>

**HYDRO-ELECTRIC SIMULATION ASSUMPTIONS**

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 710. KW
THE AVERAGE POWERPLANT EFFICIENCY IS 75.0% 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 INFLATION (THE VALUE OF ENERGY GENERATED IS ASSUMED TO BE 7.00% YEARLY. ENERGY INFLATION) 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 34.0 HILLS/KWH FOR THE FIRST YEAR AND 1219675. KWH/YR DURING THE NIGHT AT 34.0 HILLS/KWH.
(2) THE WATERWORKS CONSUMES 747362. KWH/YR DURING THE DAY AT 45.3 HILLS/KWH FOR THE FIRST YEAR AND 2138171. KWH/YR DURING THE NIGHT AT 37.2 HILLS/KWH.
(3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 229238 KWH/YR DURING THE DAY AT 24.0 HILLS/KWH AND 115665 KWH/YR DURING THE NIGHT AT 19.0 HILLS/KWH.
DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE $ 35190.
THIS INCLUDES $17790. WHEELING CHARGES TO BLACKSTONE VALLEY ELECTRIC FOR TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98 HILLS/KWH.
THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORESEEN 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

<table>
<thead>
<tr>
<th>UTIL 1 in $</th>
<th>UTIL 2 in $</th>
<th>Variable Change</th>
<th>Nominal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4404333</td>
<td>1253962</td>
<td>Inflation $&gt;$ 20(^\circ)/o increase $&gt;$ 8.4(^\circ)/o</td>
<td>7.0</td>
</tr>
<tr>
<td>5059604</td>
<td>1446632</td>
<td>Inflation $&gt;$ 20(^\circ)/o decrease $&gt;$ 5.6(^\circ)/o</td>
<td>7.0</td>
</tr>
<tr>
<td>7167100</td>
<td>2019085</td>
<td>Energy inflation $&gt;$ 20(^\circ)/o increase 8.4(^\circ)/o</td>
<td>7.0</td>
</tr>
<tr>
<td>300394</td>
<td>793939</td>
<td>Energy inflation $&gt;$ 20(^\circ)/o decrease 5.6(^\circ)/o</td>
<td>7.0</td>
</tr>
<tr>
<td>4779768</td>
<td>2458668</td>
<td>Loan period $&gt;$ 25 yrs.</td>
<td>20 yrs.</td>
</tr>
<tr>
<td>4779780</td>
<td>295245</td>
<td>Loan period $&gt;$ 15 yrs.</td>
<td>20 yrs.</td>
</tr>
<tr>
<td>4504988</td>
<td>1083150</td>
<td>Loan interest $&gt;$ 7.5(^\circ)/o</td>
<td>6.25(^\circ)/o</td>
</tr>
<tr>
<td>4276880</td>
<td>859044</td>
<td>Loan interest $&gt;$ 8.5(^\circ)/o</td>
<td>6.75(^\circ)/o</td>
</tr>
<tr>
<td>5194470</td>
<td>1582349</td>
<td>Day energy value sewer $&gt;$ 37.4 mills</td>
<td>34 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy value sewer $&gt;$ 37.4 mills</td>
<td>34 mills</td>
</tr>
<tr>
<td>4487039</td>
<td>1199527</td>
<td>Day energy value sewer $&gt;$ 31.6 mills</td>
<td>34 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy value sewer $&gt;$ 31.6 mills</td>
<td>34 mills</td>
</tr>
<tr>
<td>5228203</td>
<td>1600600</td>
<td>Day energy value waterworks $&gt;$ 49.83 mills</td>
<td>45.3 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy value waterworks $&gt;$ 40.92 mills</td>
<td>37.2 mills</td>
</tr>
<tr>
<td>4331350</td>
<td>1115275</td>
<td>Day energy value waterworks $&gt;$ 40.77 mills</td>
<td>45.3 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy value waterworks $&gt;$ 33.48 mills</td>
<td>37.2 mills</td>
</tr>
<tr>
<td>4401531</td>
<td>1369710</td>
<td>Day energy sold $&gt;$ 26.4 mills</td>
<td>24 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy sold $&gt;$ 20.9 mills</td>
<td>19 mills</td>
</tr>
<tr>
<td>4758018</td>
<td>1346163</td>
<td>Day energy sold $&gt;$ 21.6 mills</td>
<td>24 mills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Night energy sold $&gt;$ 17.1 mills</td>
<td>19 mills</td>
</tr>
<tr>
<td>4709423</td>
<td>1319866</td>
<td>Wheeling charges $&gt;$ 3.278 mills/KWH</td>
<td>2.98 mills/KWH</td>
</tr>
<tr>
<td>4850126</td>
<td>1396007</td>
<td>Wheeling charges $&gt;$ 2.682 mills/KWH</td>
<td>2.98 mills/KWH</td>
</tr>
<tr>
<td>4479226</td>
<td>1193298</td>
<td>Production cost for year 1 $&gt;$ $25,000</td>
<td>$17,400</td>
</tr>
<tr>
<td>4953775</td>
<td>1452095</td>
<td>Production cost for year 2 $&gt;$ $13,000</td>
<td>$17,400</td>
</tr>
<tr>
<td>4376024</td>
<td>954186</td>
<td>Installed plant cost $&gt;$ 2900 $$/KWH</td>
<td>2520 $$/KWH</td>
</tr>
<tr>
<td>5332276</td>
<td>1910438</td>
<td>Installed plant cost $&gt;$ 2000 $$/KWH</td>
<td>2520 $$/KWH</td>
</tr>
<tr>
<td>4786230</td>
<td>992850</td>
<td>Power plant rating $&gt;$ 30(^\circ)/o increase</td>
<td>1000 KW</td>
</tr>
<tr>
<td>3851771</td>
<td>1347196</td>
<td>Power plant rating $&gt;$ 40(^\circ)/o decrease</td>
<td>1000 KW</td>
</tr>
<tr>
<td>3647071</td>
<td>1152527</td>
<td>Discount rate 7.5(^\circ)/o</td>
<td>6.25(^\circ)/o</td>
</tr>
<tr>
<td>2938967</td>
<td>1013061</td>
<td>Discount rate 8.5(^\circ)/o</td>
<td>6.25(^\circ)/o</td>
</tr>
<tr>
<td>5442277</td>
<td>1716445</td>
<td>River flow $&gt;$ 20(^\circ)/o increase</td>
<td></td>
</tr>
<tr>
<td>3952427</td>
<td>910223</td>
<td>River flow $&gt;$ 20(^\circ)/o decrease</td>
<td></td>
</tr>
<tr>
<td>4843217</td>
<td>1392269</td>
<td>Power demand sewer $&gt;$ 20(^\circ)/o increase</td>
<td></td>
</tr>
<tr>
<td>4692677</td>
<td>1110803</td>
<td>Power demand sewer $&gt;$ 20(^\circ)/o decrease</td>
<td></td>
</tr>
<tr>
<td>4912858</td>
<td>1431037</td>
<td>Power demand waterworks $&gt;$ 20(^\circ)/o increase</td>
<td></td>
</tr>
<tr>
<td>4641080</td>
<td>1282884</td>
<td>Power demand waterworks $&gt;$ 20(^\circ)/o decrease</td>
<td></td>
</tr>
</tbody>
</table>

### Site B, Allis-Chalmers, Energy Wheeled and Sold

**Figure 35**
"DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE."

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

"NOMINAL COST IS 2520. $/KW FOR A 1000. KW FACILITY."

"X=PLANT SIZE 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
HYDRO-ELECTRIC SIMULATION ASSUMPTIONS

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 699. KW.

THE AVERAGE POWERPLANT EFFICIENCY IS 70.0, 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
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 34.0 MILLS/KWH.

(2) THE WATERWORKS CONSUMES 0. KWH/YR DURING THE NIGHT AT 37.2 MILLS/KWH.

(3) THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 2799771 KWH/YR DURING THE DAY
AT 24.0 MILLS/KWH, AND 3308822 KWH/YR DURING THE NIGHT AT 29.9 MILLS/KWH.

DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE $17400.
THIS INCLUDES 0. WHEELING CHARGES TO BLACKSTONE VALLEY ELECTRIC FOR
TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.98 MILLS/KWH.
THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORESEEN 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.
### 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 $2298000. #/KWH and the operation life is 35 yrs. This is financed by a 20yr 8.2298000. 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 34.0 MILLS/KWH and 1103400. KWH/YR during the night at 34.0 MILLS/KWH.
2. The waterworks consumes 942052. KWH/YR during the day at 45.3 MILLS/KWH and 2205415. KWH/YR during the night at 37.2 MILLS/KWH.
3. The energy sold to Blackstone Valley amounts to 1937597. KWH/YR during the day at 19.0 MILLS/KWH and 0. KWH/YR during the night at 19.0 MILLS/KWH.

During the first year the automated plant production costs are $35025. This includes $17625. wheeling charges to Blackstone Valley Electric for transmitting power to the regional sewer and the waterworks at a rate of 3.99 MILLS/KWH.

The reserve fund is established for equipment replacement and unforeseen expenses. The reserve fund amounts to $566518 which is 4.62% of the total capital cost.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>REVENUE</th>
<th>PROD COST</th>
<th>LOAN PAYMENT</th>
<th>CASH FLOW</th>
<th>D.CASH FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0</td>
<td>1.00</td>
<td>35025.00</td>
<td>204435.00</td>
<td>-17137.00</td>
<td>-17137.00</td>
</tr>
<tr>
<td>1</td>
<td>2.00</td>
<td>37477.00</td>
<td>204435.00</td>
<td>-4026.00</td>
<td>-3789.00</td>
</tr>
<tr>
<td>2</td>
<td>3.00</td>
<td>40101.00</td>
<td>204435.00</td>
<td>10003.00</td>
<td>8861.00</td>
</tr>
<tr>
<td>3</td>
<td>4.00</td>
<td>42908.00</td>
<td>204435.00</td>
<td>25014.00</td>
<td>20854.00</td>
</tr>
<tr>
<td>4</td>
<td>5.00</td>
<td>43075.00</td>
<td>204435.00</td>
<td>41025.00</td>
<td>32306.00</td>
</tr>
<tr>
<td>5</td>
<td>6.00</td>
<td>49125.00</td>
<td>204435.00</td>
<td>58261.00</td>
<td>43026.00</td>
</tr>
<tr>
<td>6</td>
<td>7.00</td>
<td>52564.00</td>
<td>204435.00</td>
<td>76469.00</td>
<td>53277.00</td>
</tr>
<tr>
<td>7</td>
<td>8.00</td>
<td>56242.00</td>
<td>204435.00</td>
<td>96325.00</td>
<td>63014.00</td>
</tr>
<tr>
<td>8</td>
<td>9.00</td>
<td>60180.00</td>
<td>204435.00</td>
<td>117328.00</td>
<td>72220.00</td>
</tr>
<tr>
<td>9</td>
<td>10.00</td>
<td>64393.00</td>
<td>204435.00</td>
<td>139905.00</td>
<td>81073.00</td>
</tr>
<tr>
<td>10</td>
<td>11.00</td>
<td>68900.00</td>
<td>204435.00</td>
<td>164008.00</td>
<td>89450.00</td>
</tr>
<tr>
<td>11</td>
<td>12.00</td>
<td>73729.00</td>
<td>204435.00</td>
<td>189799.00</td>
<td>97427.00</td>
</tr>
<tr>
<td>12</td>
<td>13.00</td>
<td>78804.00</td>
<td>204435.00</td>
<td>217395.00</td>
<td>105029.00</td>
</tr>
<tr>
<td>13</td>
<td>14.00</td>
<td>84405.00</td>
<td>204435.00</td>
<td>246923.00</td>
<td>112277.00</td>
</tr>
<tr>
<td>14</td>
<td>15.00</td>
<td>90314.00</td>
<td>204435.00</td>
<td>278518.00</td>
<td>119194.00</td>
</tr>
<tr>
<td>15</td>
<td>16.00</td>
<td>96436.00</td>
<td>204435.00</td>
<td>314325.00</td>
<td>125799.00</td>
</tr>
<tr>
<td>16</td>
<td>17.00</td>
<td>103400.00</td>
<td>204435.00</td>
<td>348499.00</td>
<td>132112.00</td>
</tr>
<tr>
<td>17</td>
<td>18.00</td>
<td>110439.00</td>
<td>204435.00</td>
<td>387203.00</td>
<td>138151.00</td>
</tr>
<tr>
<td>18</td>
<td>19.00</td>
<td>116383.00</td>
<td>204435.00</td>
<td>428617.00</td>
<td>143931.00</td>
</tr>
<tr>
<td>19</td>
<td>20.00</td>
<td>122669.00</td>
<td>204435.00</td>
<td>472930.00</td>
<td>149470.00</td>
</tr>
<tr>
<td>20</td>
<td>21.00</td>
<td>128936.00</td>
<td>204435.00</td>
<td>519468.00</td>
<td>154760.00</td>
</tr>
<tr>
<td>21</td>
<td>22.00</td>
<td>135553.00</td>
<td>204435.00</td>
<td>569791.00</td>
<td>160194.00</td>
</tr>
<tr>
<td>22</td>
<td>23.00</td>
<td>140024.00</td>
<td>204435.00</td>
<td>625515.00</td>
<td>165650.00</td>
</tr>
<tr>
<td>23</td>
<td>24.00</td>
<td>155175.00</td>
<td>204435.00</td>
<td>692901.00</td>
<td>171648.00</td>
</tr>
<tr>
<td>24</td>
<td>25.00</td>
<td>160030.00</td>
<td>204435.00</td>
<td>767886.00</td>
<td>177692.00</td>
</tr>
<tr>
<td>25</td>
<td>26.00</td>
<td>166660.00</td>
<td>204435.00</td>
<td>850308.00</td>
<td>184474.00</td>
</tr>
<tr>
<td>26</td>
<td>27.00</td>
<td>177660.00</td>
<td>204435.00</td>
<td>950823.00</td>
<td>191746.00</td>
</tr>
<tr>
<td>27</td>
<td>28.00</td>
<td>190096.00</td>
<td>204435.00</td>
<td>1016540.00</td>
<td>203131.00</td>
</tr>
<tr>
<td>28</td>
<td>29.00</td>
<td>220003.00</td>
<td>204435.00</td>
<td>1107697.00</td>
<td>210888.00</td>
</tr>
<tr>
<td>29</td>
<td>30.00</td>
<td>225481.00</td>
<td>204435.00</td>
<td>1216841.00</td>
<td>217546.00</td>
</tr>
<tr>
<td>30</td>
<td>31.00</td>
<td>238107.00</td>
<td>204435.00</td>
<td>1295304.00</td>
<td>222074.00</td>
</tr>
<tr>
<td>31</td>
<td>32.00</td>
<td>249177.00</td>
<td>204435.00</td>
<td>1332475.00</td>
<td>225848.00</td>
</tr>
<tr>
<td>32</td>
<td>33.00</td>
<td>256366.00</td>
<td>204435.00</td>
<td>1423745.00</td>
<td>231305.00</td>
</tr>
<tr>
<td>33</td>
<td>34.00</td>
<td>265282.00</td>
<td>204435.00</td>
<td>1525549.00</td>
<td>236893.00</td>
</tr>
<tr>
<td>34</td>
<td>35.00</td>
<td>270522.00</td>
<td>204435.00</td>
<td>1632334.00</td>
<td>242538.00</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>272319.00</td>
<td>204435.00</td>
<td>1746599.00</td>
<td>248239.00</td>
</tr>
</tbody>
</table>

**Discount Rate: 6.25%**

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
HYDRO-ELECTRIC SIMULATION ASSUMPTIONS:

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 637. KW.
THE AVERAGE POWERPLANT EFFICIENCY IS 67.0% AND THE DAM HEAD IS 16. FT. THE INSTALLED PLANT
COST IS 1643.0/KW AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
* 1643.0/. 17400.0. 0. 0. 0. 0.
# 17400.0. 0. 0. 0. 0. 0.
# 0. 0. 0. 0. 0. 0.
# 0. 0. 0. 0. 0. 0.
# 0. 0. 0. 0. 0. 0.
# 0. 0. 0. 0. 0. 0.
# 0. 0. 0. 0. 0. 0.
# 0. 0. 0. 0. 0. 0.
The INSTALLED PLAN'T COST IS 16243.00. THE PRICE OF ENERGY GENERATED (THE VALUE OF ENERGY GENERATED) IS ASSUMED TO BE 7.00%. YEARLY ENERGY AMOUNTS TO 5567397.KW/H.
REVENUE REPRESENTS THE MARKET VALUE OF THE ELECTRICITY GENERATED. IT IS ASSUMED THAT:
1. THE REGIONAL SEWER CONSUMES 0.0 KWH/yr DURING THE DAY AT 34.0 M/L/KWH. FOR THE FIRST YEAR
AND 0.0 KWH/yr DURING THE NIGHT AT 19.0 M/L/KWH.
2. THE WATERWORKS CONSUMES 0.0 KWH/yr DURING THE DAY AT 45.0 M/L/KWH. FOR THE FIRST YEAR
AND 0.0 KWH/yr DURING THE NIGHT AT 25.0 M/L/KWH.
3. THE ENERGY SOLD TO BLACKSTONE VALLEY AMOUNTS TO 2551723 KWH/yr DURING THE DAY AT 24.0 M/L/KWH.
DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE $17400.0. THIS INCLUDES 0. WHEELING CHARGES TO BLACKSTONE VALLEY ELECTRIC FOR TRANSMITTING POWER TO THE REGIONAL SEWER AND THE WATERWORKS AT A RATE OF 2.9 M/L/KWH.
THE RESERVE FUND IS ESTABLISHED FOR EQUIPMENT REPLACEMENT AND UNFORESEEN EXPENSES.
THE RESERVE FUND AMOUNTS TO 70111. WHICH IS 4.77% OF THE TOTAL CAPITAL COST.
** DISCOUNT RATE: 6.25% ; UTIL 1 = 42534.00 ; UTIL 2 = 418304.00 ; 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.
"DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE."

*NOMINAL COST IS 164.8% 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
<table>
<thead>
<tr>
<th>YEAR</th>
<th>REVENUE</th>
<th>PROD COST</th>
<th>LOAN PAYMENT</th>
<th>CASH FLOW</th>
<th>DCASH FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>1</td>
<td>201,070.</td>
<td>3,341.7</td>
<td>146,188.</td>
<td>21,465.</td>
<td>21,465.</td>
</tr>
<tr>
<td>2</td>
<td>215,145.</td>
<td>3,576.5</td>
<td>146,188.</td>
<td>33,201.</td>
<td>31,248.</td>
</tr>
<tr>
<td>3</td>
<td>230,205.</td>
<td>3,802.9</td>
<td>146,188.</td>
<td>45,258.</td>
<td>40,533.</td>
</tr>
<tr>
<td>4</td>
<td>246,320.</td>
<td>4,093.8</td>
<td>146,188.</td>
<td>57,914.</td>
<td>49,356.</td>
</tr>
<tr>
<td>5</td>
<td>263,562.</td>
<td>4,303.0</td>
<td>146,188.</td>
<td>73,571.</td>
<td>57,728.</td>
</tr>
<tr>
<td>6</td>
<td>282,011.</td>
<td>4,606.9</td>
<td>146,188.</td>
<td>80,254.</td>
<td>65,693.</td>
</tr>
<tr>
<td>7</td>
<td>301,752.</td>
<td>4,911.5</td>
<td>146,188.</td>
<td>97,938.</td>
<td>73,270.</td>
</tr>
<tr>
<td>8</td>
<td>323,874.</td>
<td>5,366.1</td>
<td>146,188.</td>
<td>116,622.</td>
<td>80,841.</td>
</tr>
<tr>
<td>9</td>
<td>345,475.</td>
<td>5,741.7</td>
<td>146,188.</td>
<td>135,308.</td>
<td>87,350.</td>
</tr>
<tr>
<td>10</td>
<td>367,650.</td>
<td>6,134.6</td>
<td>146,188.</td>
<td>154,994.</td>
<td>93,897.</td>
</tr>
<tr>
<td>11</td>
<td>392,234.</td>
<td>6,542.9</td>
<td>146,188.</td>
<td>174,680.</td>
<td>100,440.</td>
</tr>
<tr>
<td>12</td>
<td>422,221.</td>
<td>7,033.8</td>
<td>146,188.</td>
<td>194,366.</td>
<td>106,100.</td>
</tr>
<tr>
<td>13</td>
<td>452,846.</td>
<td>7,526.2</td>
<td>146,188.</td>
<td>214,052.</td>
<td>111,793.</td>
</tr>
<tr>
<td>14</td>
<td>484,545.</td>
<td>8,030.3</td>
<td>146,188.</td>
<td>233,738.</td>
<td>117,475.</td>
</tr>
<tr>
<td>15</td>
<td>518,463.</td>
<td>8,616.7</td>
<td>146,188.</td>
<td>253,424.</td>
<td>123,158.</td>
</tr>
<tr>
<td>16</td>
<td>554,755.</td>
<td>9,219.9</td>
<td>146,188.</td>
<td>273,110.</td>
<td>128,842.</td>
</tr>
<tr>
<td>17</td>
<td>593,508.</td>
<td>9,865.2</td>
<td>146,188.</td>
<td>292,796.</td>
<td>134,526.</td>
</tr>
<tr>
<td>18</td>
<td>635,139.</td>
<td>10,526.8</td>
<td>146,188.</td>
<td>312,482.</td>
<td>140,210.</td>
</tr>
<tr>
<td>19</td>
<td>679,958.</td>
<td>11,294.7</td>
<td>146,188.</td>
<td>332,168.</td>
<td>145,935.</td>
</tr>
<tr>
<td>20</td>
<td>727,170.</td>
<td>12,085.3</td>
<td>146,188.</td>
<td>351,854.</td>
<td>151,659.</td>
</tr>
<tr>
<td>21</td>
<td>778,072.</td>
<td>12,913.3</td>
<td>146,188.</td>
<td>371,540.</td>
<td>157,383.</td>
</tr>
<tr>
<td>22</td>
<td>832,536.</td>
<td>13,834.5</td>
<td>146,188.</td>
<td>391,226.</td>
<td>163,107.</td>
</tr>
<tr>
<td>23</td>
<td>890,013.</td>
<td>14,805.0</td>
<td>146,188.</td>
<td>410,912.</td>
<td>168,831.</td>
</tr>
<tr>
<td>24</td>
<td>953,170.</td>
<td>15,841.4</td>
<td>146,188.</td>
<td>430,598.</td>
<td>174,555.</td>
</tr>
<tr>
<td>25</td>
<td>1,019,891.</td>
<td>16,950.2</td>
<td>146,188.</td>
<td>450,284.</td>
<td>180,279.</td>
</tr>
<tr>
<td>26</td>
<td>1,091,283.</td>
<td>18,136.0</td>
<td>146,188.</td>
<td>470,970.</td>
<td>185,993.</td>
</tr>
<tr>
<td>27</td>
<td>1,167,672.</td>
<td>19,406.3</td>
<td>146,188.</td>
<td>500,656.</td>
<td>191,707.</td>
</tr>
<tr>
<td>28</td>
<td>1,249,409.</td>
<td>20,764.7</td>
<td>146,188.</td>
<td>530,342.</td>
<td>197,421.</td>
</tr>
<tr>
<td>29</td>
<td>1,336,867.</td>
<td>22,123.1</td>
<td>146,188.</td>
<td>560,028.</td>
<td>203,135.</td>
</tr>
<tr>
<td>30</td>
<td>1,430,447.</td>
<td>23,577.5</td>
<td>146,188.</td>
<td>589,714.</td>
<td>208,849.</td>
</tr>
<tr>
<td>31</td>
<td>1,530,577.</td>
<td>25,047.7</td>
<td>146,188.</td>
<td>619,400.</td>
<td>214,563.</td>
</tr>
<tr>
<td>32</td>
<td>1,637,717.</td>
<td>26,527.3</td>
<td>146,188.</td>
<td>649,086.</td>
<td>220,277.</td>
</tr>
<tr>
<td>33</td>
<td>1,752,357.</td>
<td>28,013.6</td>
<td>146,188.</td>
<td>678,772.</td>
<td>225,991.</td>
</tr>
<tr>
<td>34</td>
<td>1,875,021.</td>
<td>31,622.0</td>
<td>146,188.</td>
<td>708,458.</td>
<td>231,705.</td>
</tr>
<tr>
<td>35</td>
<td>2,006,271.</td>
<td>33,343.6</td>
<td>146,188.</td>
<td>738,144.</td>
<td>237,419.</td>
</tr>
</tbody>
</table>

**HYDRO-ELECTRIC SIMULATION ASSUMPTIONS**

WHEN THE POWERPLANT IS RATED 1000. KW IT WILL GENERATE ON THE AVERAGE 637. KW
THE AVERAGE POWERPLANT EFFICIENCY IS 67.0% AND THE DAM HEAD IS 16. FT. THE INSTALLED PLANT
COST IS 1443. $/KW AND THE OPERATION LIFE IS 35 YRS. THIS IS FINANCED BY A 20YR
LOAN AT 7.00% 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 1693222. 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 1930218. 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 905447. KWH/YR DURING THE NIGHT AT 19.0MILLS/KWH.
DURING THE FIRST YEAR THE AUTOMATED PLANT PRODUCTION COSTS ARE $ 33417.
THIS INCLUDES $10017. WHEELING CHARGES TO BLACK STONE VALLEY ELECTRIC FOR
TRANSMITTING POWER TO THE REGIOINAL SEWER AND THE WATERWORKS AT A RATE OF 2.90MILLS/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% I UTIL 1 = $.486971. I UTIL 2 = $.184176. I UTIL 3 = .0.63**

SITE C, ALLIS-CHALMERS, ENERGY WHEELED AND SOLD

**FIGURE 43**
"DISCOUNTED CASH FLOW OVER OPERATING LIFE VERSUS PLANT SIZE."

"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 now 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 whose 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.
APPRAISAL OF EXISTING INFORMATION
(ENGINEERING, FINANCIAL,
ENVIRONMENTAL, REGULATORY)
DECISION (GO - NO GO)
POWER STUDIES
PREPARATION OF PROJECT CONTRACTUAL
DOCUMENTS: FINANCING, UTILITY
COMPANY-HYDRO RELATIONSHIP,
CONSTRUCTION CONTRACT
DETAILED ENGINEERING DESIGN AND
ESTIMATES
OBTAINING LICENSES AND PERMITS
BIDDING FOR PRIME CONTRACTOR
CONSTRUCTION AND DELIVERY OF
HYDROTURBINE
EXCAVATION, CONSTRUCTION, AND
INSTALLATION OF PENSTOCK, INTAKE
STRUCTURE, POWERHOUSE, INSTALLATION
OF TURBOGENERATOR, SWITCHGEAR,
ELECTRICAL AND MECHANICAL ACCESSORIES.
TESTING AND STARTUP
PROJECT MONITORING

Schedule

FIGURE 45
Flow Chart
11. REFERENCES


APPENDIX A

Department of Environmental Management
dam safety report
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 its 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 its safety and structural stability, this office considers the subject dam "unique" in its 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.
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 its 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 separate 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
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,

[Signature]
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:** [X] Semi-Annual Staff  
**River Basin:** Blackstone  
**Date of Inspection:** 17 May 1978

<table>
<thead>
<tr>
<th>Feature</th>
<th>Sat</th>
<th>Unsat</th>
<th>Deficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PUMPING STATIONS - STRUCTURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERIOR</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXTERIOR</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PUMPS - MOTORS - ENGINES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRIAL OPERATED</td>
<td>X</td>
<td></td>
<td>Comment #1</td>
</tr>
<tr>
<td>GENERAL CONDITION</td>
<td>X</td>
<td></td>
<td>Comment #2</td>
</tr>
<tr>
<td>POWER SOURCE</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INSULATION TESTS</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>METAL INTAKES/OUTLETS</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GATE VALVES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GATES - DRAINAGE STRUCTURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRIAL OPERATED</td>
<td>X</td>
<td></td>
<td>Comment #3</td>
</tr>
<tr>
<td>GENERAL CONDITION</td>
<td>X</td>
<td></td>
<td>Comment #4</td>
</tr>
<tr>
<td>LUBRICATION</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DIKES - DAMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GENERAL CONDITION</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLOPES/erosion</td>
<td>X</td>
<td></td>
<td>Comment #5</td>
</tr>
<tr>
<td>SAND BOILS/CAVING</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRESPASSING</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLOPE PROTECTION</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRAINS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STOP-LOGS - LOG BOOM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONDITION OF LOGS</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVAILABILITY OF LOGS</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGHWAY SLOTS</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STORAGE FACILITIES</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CHANNELS - OUTLET WORKS CHANNEL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BANKS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DISTRIBUTION CONTROL</strong></td>
<td></td>
<td></td>
<td>Comment #6</td>
</tr>
</tbody>
</table>

ED FORM JAN 66 513  121
<table>
<thead>
<tr>
<th>Feature</th>
<th>Sat</th>
<th>Uns</th>
<th>Deficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONCRETE STRUCTURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Settlement</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joints</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Drains</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>MISCELLANEOUS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency Operation Plan</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency Equipment</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-Annual Report</td>
<td>X</td>
<td></td>
<td>Comment #7</td>
</tr>
</tbody>
</table>

**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 Unsatisfactory, Indicate Specific Deficiencies. Indicate if Not Applicable.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Inspected By: Typed Name &amp; Title</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Paul H. Cooper, Jr. Civil Engineer</td>
<td></td>
</tr>
</tbody>
</table>
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 fastend 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 make 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 ½ 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
<table>
<thead>
<tr>
<th>ITEMS</th>
<th>SITE A ($1,000s)</th>
<th>SITE B ($1,000s)</th>
<th>SITE C ($1,000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penstock (buried 8 ft. diameter reinforced concrete pipe)</td>
<td>310.8</td>
<td>310.8</td>
<td>678.</td>
</tr>
<tr>
<td>Site Work (road reconstruction, utilities relocation/repair, ground restoration, and landscaping)</td>
<td>58.3</td>
<td>58.3</td>
<td>105.6</td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td><strong>806.1</strong></td>
<td><strong>816.6</strong></td>
<td><strong>1220.6</strong></td>
</tr>
<tr>
<td>Engineering (12%o)</td>
<td>96.7</td>
<td>98.</td>
<td>146.5</td>
</tr>
<tr>
<td>Land Acquisition</td>
<td>24.</td>
<td>24.</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL CIVIL WORKS</strong></td>
<td><strong>926.8</strong></td>
<td><strong>938.6</strong></td>
<td><strong>1367.1</strong></td>
</tr>
<tr>
<td>Electrical, Mechanical (turbo-generator, controls switchgear, metering, circuit breakers, transformers, protective relaying, bus, cable, and connections)</td>
<td>760.</td>
<td>559.5</td>
<td>764.</td>
</tr>
<tr>
<td>Engineering - Electrical, Mechanical-(12%o)</td>
<td>91.</td>
<td>67.1</td>
<td>92.</td>
</tr>
<tr>
<td>Licensing, Permitting and Legal</td>
<td>19.8</td>
<td>19.8</td>
<td>19.8</td>
</tr>
<tr>
<td>Interest during Construction</td>
<td>130.</td>
<td>130.</td>
<td>162.</td>
</tr>
<tr>
<td>Reserve Fund</td>
<td>94.4</td>
<td>85.</td>
<td>115.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2022.</strong></td>
<td><strong>1800.</strong></td>
<td><strong>2520.</strong></td>
</tr>
</tbody>
</table>

A.C. = Allis-Chalmers Hydroelectric Unit  
N.W.P. = Northern Water Power Hydroelectric Unit
APPENDIX D

Written Comments Concerning Wheeling and the National Energy Plan II
NEP - 11

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 - 11, 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 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.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>REVENUE</th>
<th>PROD COST</th>
<th>LOAN PAYMENT</th>
<th>CASH FLOW</th>
<th>DCASH FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1</td>
<td>142140</td>
<td>23000</td>
<td>150714</td>
<td>-31575</td>
<td>-31575</td>
</tr>
<tr>
<td>2</td>
<td>150997</td>
<td>24245</td>
<td>150714</td>
<td>-24100</td>
<td>-22104</td>
</tr>
<tr>
<td>3</td>
<td>150501</td>
<td>25660</td>
<td>150714</td>
<td>-17097</td>
<td>-14197</td>
</tr>
<tr>
<td>4</td>
<td>167361</td>
<td>27007</td>
<td>150714</td>
<td>-10341</td>
<td>-7366</td>
</tr>
<tr>
<td>5</td>
<td>176254</td>
<td>30069</td>
<td>150714</td>
<td>-2562</td>
<td>-1559</td>
</tr>
<tr>
<td>6</td>
<td>184722</td>
<td>30769</td>
<td>150714</td>
<td>5970</td>
<td>3336</td>
</tr>
<tr>
<td>7</td>
<td>197105</td>
<td>31713</td>
<td>150714</td>
<td>14670</td>
<td>7436</td>
</tr>
<tr>
<td>8</td>
<td>208143</td>
<td>33155</td>
<td>150714</td>
<td>23971</td>
<td>10843</td>
</tr>
<tr>
<td>9</td>
<td>219799</td>
<td>35270</td>
<td>150714</td>
<td>33707</td>
<td>13646</td>
</tr>
<tr>
<td>10</td>
<td>232107</td>
<td>37239</td>
<td>150714</td>
<td>44154</td>
<td>15923</td>
</tr>
<tr>
<td>11</td>
<td>245105</td>
<td>39951</td>
<td>150714</td>
<td>55104</td>
<td>17742</td>
</tr>
<tr>
<td>12</td>
<td>258031</td>
<td>42448</td>
<td>150714</td>
<td>66669</td>
<td>19166</td>
</tr>
<tr>
<td>13</td>
<td>273326</td>
<td>43727</td>
<td>150714</td>
<td>70884</td>
<td>20240</td>
</tr>
<tr>
<td>14</td>
<td>280632</td>
<td>46132</td>
<td>150714</td>
<td>91785</td>
<td>21035</td>
</tr>
<tr>
<td>15</td>
<td>304795</td>
<td>48758</td>
<td>150714</td>
<td>105411</td>
<td>21569</td>
</tr>
<tr>
<td>16</td>
<td>321083</td>
<td>51346</td>
<td>150714</td>
<td>119003</td>
<td>21888</td>
</tr>
<tr>
<td>17</td>
<td>339800</td>
<td>54176</td>
<td>150714</td>
<td>135003</td>
<td>22622</td>
</tr>
<tr>
<td>18</td>
<td>358721</td>
<td>57150</td>
<td>150714</td>
<td>151000</td>
<td>22901</td>
</tr>
<tr>
<td>19</td>
<td>377021</td>
<td>60293</td>
<td>150714</td>
<td>166014</td>
<td>21048</td>
</tr>
<tr>
<td>20</td>
<td>400246</td>
<td>63609</td>
<td>150714</td>
<td>102723</td>
<td>21587</td>
</tr>
<tr>
<td>21</td>
<td>422657</td>
<td>67107</td>
<td>150714</td>
<td>204030</td>
<td>21235</td>
</tr>
<tr>
<td>22</td>
<td>446320</td>
<td>70790</td>
<td>150714</td>
<td>224816</td>
<td>20809</td>
</tr>
<tr>
<td>23</td>
<td>471322</td>
<td>74692</td>
<td>150714</td>
<td>245916</td>
<td>20323</td>
</tr>
<tr>
<td>24</td>
<td>497716</td>
<td>79000</td>
<td>150714</td>
<td>268520</td>
<td>19790</td>
</tr>
<tr>
<td>25</td>
<td>522807</td>
<td>83111</td>
<td>150714</td>
<td>291739</td>
<td>19230</td>
</tr>
<tr>
<td>26</td>
<td>555020</td>
<td>87076</td>
<td>150714</td>
<td>467314</td>
<td>27409</td>
</tr>
<tr>
<td>27</td>
<td>580101</td>
<td>92350</td>
<td>150714</td>
<td>493711</td>
<td>25923</td>
</tr>
<tr>
<td>28</td>
<td>614223</td>
<td>97619</td>
<td>150714</td>
<td>523363</td>
<td>24446</td>
</tr>
<tr>
<td>29</td>
<td>651301</td>
<td>102990</td>
<td>150714</td>
<td>555059</td>
<td>23053</td>
</tr>
<tr>
<td>30</td>
<td>690102</td>
<td>108622</td>
<td>150714</td>
<td>581529</td>
<td>21740</td>
</tr>
<tr>
<td>31</td>
<td>728031</td>
<td>114628</td>
<td>150714</td>
<td>614203</td>
<td>20501</td>
</tr>
<tr>
<td>32</td>
<td>764946</td>
<td>120733</td>
<td>150714</td>
<td>647913</td>
<td>19333</td>
</tr>
<tr>
<td>33</td>
<td>812745</td>
<td>127584</td>
<td>150714</td>
<td>685162</td>
<td>18231</td>
</tr>
<tr>
<td>34</td>
<td>858529</td>
<td>134601</td>
<td>150714</td>
<td>723658</td>
<td>17193</td>
</tr>
<tr>
<td>35</td>
<td>906321</td>
<td>142004</td>
<td>150714</td>
<td>764317</td>
<td>16213</td>
</tr>
</tbody>
</table>

**HYDRO-ELECTRIC SIMULATION ASSUMPTIONS**

WHEN THE PLANT IS RAISED TO 1000, KW IT WILL GENERATE ON THE AVERAGE 729, KW.
THE AVERAGE POWERPLANT EFFICIENCY IS 79%, AND THE DAM HEAD IS 180 FT. THE INSTALLED PLANT
COST IS $2,100,000, AND THE OPERATING LIFE IS 45 YEARS. THIS IS FINANCED BY A 25 YEAR
CITY REVENUE AFTER OPERATING, MAINTENANCE, AND LOAN PAYMENTS HAVE BEEN REMOVED FROM HYDRO

**Energy Sold to Utility Company**

**Figure 1**

**Figure 46**
<table>
<thead>
<tr>
<th>YEAR</th>
<th>REVENUE</th>
<th>PROD COST</th>
<th>LOAN PAYMENT</th>
<th>CASH FLOW</th>
<th>DCASH FLOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>214151</td>
<td>39423.00</td>
<td>150714.25</td>
<td>24014.25</td>
<td>24014.25</td>
</tr>
<tr>
<td>2</td>
<td>226143</td>
<td>41591.77</td>
<td>150714.25</td>
<td>33838.25</td>
<td>30212.50</td>
</tr>
<tr>
<td>3</td>
<td>238807</td>
<td>43799.54</td>
<td>150714.25</td>
<td>44214.25</td>
<td>35247.50</td>
</tr>
<tr>
<td>4</td>
<td>252180</td>
<td>46279.31</td>
<td>150714.25</td>
<td>56284.25</td>
<td>39272.50</td>
</tr>
<tr>
<td>5</td>
<td>266302</td>
<td>48638.08</td>
<td>150714.25</td>
<td>67750.25</td>
<td>42421.50</td>
</tr>
<tr>
<td>6</td>
<td>281215</td>
<td>51524.85</td>
<td>150714.25</td>
<td>78977.25</td>
<td>44814.50</td>
</tr>
<tr>
<td>7</td>
<td>297443</td>
<td>54592.62</td>
<td>150714.25</td>
<td>91891.25</td>
<td>46555.50</td>
</tr>
<tr>
<td>8</td>
<td>297443</td>
<td>53741.39</td>
<td>150714.25</td>
<td>95531.25</td>
<td>47737.50</td>
</tr>
<tr>
<td>9</td>
<td>313594</td>
<td>60502.15</td>
<td>150714.25</td>
<td>119938.25</td>
<td>48441.50</td>
</tr>
<tr>
<td>10</td>
<td>349598</td>
<td>63829.92</td>
<td>150714.25</td>
<td>133138.25</td>
<td>47386.50</td>
</tr>
<tr>
<td>11</td>
<td>364281</td>
<td>67340.69</td>
<td>150714.25</td>
<td>146338.25</td>
<td>46321.50</td>
</tr>
<tr>
<td>12</td>
<td>389761</td>
<td>71043.45</td>
<td>150714.25</td>
<td>159538.25</td>
<td>44855.50</td>
</tr>
<tr>
<td>13</td>
<td>411798</td>
<td>74950.21</td>
<td>150714.25</td>
<td>172738.25</td>
<td>47776.50</td>
</tr>
<tr>
<td>14</td>
<td>434859</td>
<td>79766.97</td>
<td>150714.25</td>
<td>186138.25</td>
<td>44997.50</td>
</tr>
<tr>
<td>15</td>
<td>459211</td>
<td>84422.73</td>
<td>150714.25</td>
<td>200538.25</td>
<td>46055.50</td>
</tr>
<tr>
<td>16</td>
<td>484926</td>
<td>89010.49</td>
<td>150714.25</td>
<td>215938.25</td>
<td>44980.50</td>
</tr>
<tr>
<td>17</td>
<td>512081</td>
<td>92850.25</td>
<td>150714.25</td>
<td>231338.25</td>
<td>43801.50</td>
</tr>
<tr>
<td>18</td>
<td>540758</td>
<td>97957.01</td>
<td>150714.25</td>
<td>246738.25</td>
<td>42541.50</td>
</tr>
<tr>
<td>19</td>
<td>571040</td>
<td>103344.77</td>
<td>150714.25</td>
<td>262138.25</td>
<td>41220.50</td>
</tr>
<tr>
<td>20</td>
<td>603018</td>
<td>109028.53</td>
<td>150714.25</td>
<td>277538.25</td>
<td>39857.50</td>
</tr>
<tr>
<td>21</td>
<td>636786</td>
<td>115025.29</td>
<td>150714.25</td>
<td>292938.25</td>
<td>38445.50</td>
</tr>
<tr>
<td>22</td>
<td>672446</td>
<td>121351.05</td>
<td>150714.25</td>
<td>308338.25</td>
<td>37059.50</td>
</tr>
<tr>
<td>23</td>
<td>710103</td>
<td>128025.81</td>
<td>150714.25</td>
<td>323738.25</td>
<td>35649.50</td>
</tr>
<tr>
<td>24</td>
<td>749868</td>
<td>135064.57</td>
<td>150714.25</td>
<td>339138.25</td>
<td>34244.50</td>
</tr>
<tr>
<td>25</td>
<td>791860</td>
<td>142495.33</td>
<td>150714.25</td>
<td>354538.25</td>
<td>32852.50</td>
</tr>
<tr>
<td>26</td>
<td>836204</td>
<td>150332.09</td>
<td>150714.25</td>
<td>369938.25</td>
<td>31461.50</td>
</tr>
<tr>
<td>27</td>
<td>883031</td>
<td>158331.85</td>
<td>150714.25</td>
<td>385338.25</td>
<td>29070.50</td>
</tr>
<tr>
<td>28</td>
<td>932480</td>
<td>167322.61</td>
<td>150714.25</td>
<td>399738.25</td>
<td>26680.50</td>
</tr>
<tr>
<td>29</td>
<td>984699</td>
<td>176526.37</td>
<td>150714.25</td>
<td>415138.25</td>
<td>24300.50</td>
</tr>
<tr>
<td>30</td>
<td>1039614</td>
<td>185234.13</td>
<td>150714.25</td>
<td>430538.25</td>
<td>21919.50</td>
</tr>
<tr>
<td>31</td>
<td>1098073</td>
<td>194741.90</td>
<td>150714.25</td>
<td>445938.25</td>
<td>19539.50</td>
</tr>
<tr>
<td>32</td>
<td>1159563</td>
<td>204249.66</td>
<td>150714.25</td>
<td>461338.25</td>
<td>17158.50</td>
</tr>
<tr>
<td>33</td>
<td>1224498</td>
<td>213864.42</td>
<td>150714.25</td>
<td>476738.25</td>
<td>14777.50</td>
</tr>
<tr>
<td>34</td>
<td>1293070</td>
<td>223511.18</td>
<td>150714.25</td>
<td>492138.25</td>
<td>12397.50</td>
</tr>
<tr>
<td>35</td>
<td>1365481</td>
<td>234400.00</td>
<td>150714.25</td>
<td>507538.25</td>
<td>9917.50</td>
</tr>
</tbody>
</table>

**HYDRO-ELECTRIC SIMULATION ASSUMPTIONS**

- The powerplant is rated at 1000 kW, it will generate on the average 729 kW.
- The utility company will sell the electricity with an estimated rate of 0.62 Mils/KWh.
- The cost of replacement for equipment is assumed to be 65.64% of the initial plant cost.
- The operation life of the powerplant is 35 years.
- The simulations were conducted for the first year.
- The initial interest rate is assumed to be 5.50%.
- Energy inflation is assumed to be 5.60% per year.
- The regional sewer consumes 3389563.00 KWh during the first year.
- The waterworks consumes 1072613.00 KWh during the first year.
- The energy sold to Blackstone Valley amounts to 853409.00 KWh during the first year.
- The regional sewer should be replaced every 5 years and the waterworks every 10 years.

**Discount Rate:** 12.00%  
**Utility 1:** 86857.00  
**Utility 2:** 1035993.00  
**Utility 3:** 0.27

Energy Wheeled and Excess sold to Utility Company

**Figure 2**

**Figure 49**
APPENDIX E

Lower Woonsocket, Flood Control, Protection Map
BLACKSTONE RIVER FLOOD CONTROL
LOWER WOONSOCKET LOCAL PROTECTION PROJECT
PROJECT PLAN
BLACKSTONE, MILL & PETERS RIVERS, RHODE ISLAND
30 JUNE 1974
SCALE IN FEET
1" = 2000 FEET
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION. CORPS OF ENGINEERS
WALTHAM, MASS

FIGURE 50
APPENDIX F

Letter Indicating Ownership of Dam
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,

[Signature]
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 70%. 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:

<table>
<thead>
<tr>
<th></th>
<th>$/KWH (yr)</th>
<th>$/KWH (35 yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site A</td>
<td>.81</td>
<td>.023</td>
</tr>
<tr>
<td>Site C</td>
<td>.74</td>
<td>.021</td>
</tr>
</tbody>
</table>

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 assessment 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
PROGRAM SEWER
   1 DIMENSION DD(50)
   10 * SWD(1,1) IS TOTAL KWH/YR USED DURING THE DAY BY THE SEWER
   20 * SWH(1,1) IS TOTAL KWH/YR USED AT NIGHT BY THE SEWER
   30 * WDD(1,1) IS TOTAL KWH/YR USED DURING THE DAY AND WDH(1,1) IS TOTAL KWH/YR USED DURING THE NIGHT BY THE WATERWORKS
   40 DIMENSION SWD(52,2),WDD(52,2)
   50 DIMENSION SWH(52,2),WDH(52,2)
   60 DIMENSION AF(14),BF(14),FLOW(52)
   70 DIMENSION PW(52),APW(52),FLOW(52)
   80 DIMENSION CAFL(50),A(132)
   90 DIMENSION DCAFL(50)
  100 DATA DCAFL/50*0.0/
  110 DIMENSION EFFIC(50)
  120 DATA EFFIC/50*0.0/
  130 BKWH IS AN ARRAY FOR THE AMOUNT OF ENERGY SOLD TO THE POWER COMPANY DURING THE DAY.
  140 CKWH IS AN ARRAY FOR THE AMOUNT OF ENERGY SOLD TO THE POWER COMPANY AT NIGHT.
  150 DIMENSION BKWH(52,2),CKWH(52,2)
  160 DIMENSION PWRUA(24,2)
  170 DIMENSION PWRUA2(24,2)
  180 DIMENSION AF(14,0.0)/
  190 DIMENSION BF(14,0.0)/
  200 DATA FLOW/52*0.0/
  210 DIMENSION EFFIC(24)
  220 DATA EFFIC/24*0.0/
  230 SKWH IS AN ARRAY FOR THE AMOUNT OF ENERGY SOLD TO THE POWER COMPANY DURING THE DAY.
  240 CKWH IS AN ARRAY FOR THE AMOUNT OF ENERGY SOLD TO THE POWER COMPANY AT NIGHT.
  250 DIMENSION SKWH(52,2),CKWH(52,2)
  260 DIMENSION PWRUA(24,2)
  270 DIMENSION PWRUA2(24,2)
  280 DATA AF/14*0.0/
  290 DATA BF/14*0.0/
  300 DATA LBO/14*0.0/
  310 DATA DCAFL/50*0.0/
  320 DATA EFFIC/50*0.0/
  330 SEWER POWER DEMAND ON AN HOURLY BASIS FOR WORKDAY AND NONWORKDAY
  360 615.,608.,607.,593.,607.,623.,642.,660.,672. /
  370 WATERWORKS POWER DEMAND ON AN HOURLY BASIS FOR WORKDAY AND NON-WORKDAY
  380 DATA PWRUA2/11#211.,13#560.92.,11#211.,13#560.92./
  390 DD 183 N=1,24
  400 PWRUA(N)=PWRUA(N)*1.0
  410 PWRUA2(N)=PWRUA2(N)*1.0
  420 183 CONTINUE
  430 DD 186 N=1,24
  440 PWRUA(N)=PWRUA(N)*1.0
  450 PWRUA2(N)=PWRUA2(N)*1.0
  460 186 CONTINUE
  470 DATA WBD/HEAD/240.,2G./
  480 DATA CAB/660000.,0.01/
  500 349.,596.,941./
  510 DD S=1,12
  520 FLOW(I)=FLOW(I)-50.
  530 25 CONTINUE
  540 DATA DISC/AINF,BINF,AINF+NY/6.25,0.07,0.35,35/  
  550 DISC=6.25
  560 DATA B4=8,20.,625/  
  570 DATA BL=4.900
  580 WRITE(S#4,590)
  590 READ(S#4,P MAX,EF MAX)
  600 FLOW=P MAX/(EF MAX*HEAD#0.0846008#0.01)
  610 DD S=1,6
  620 DD S=1,12
lin 650 thru 1270

650  FN=N
660  FN=M
670  TPI=2.141593
680  AF(N)=AF(N)+((FLOW(N))*COS(TPI*(FN-1.))*(FM-.5)/12.))/6.
690  BF(N)=BF(N)+((FLOW(N))*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  * LEAST APPROXIMATION OF THE FLOW(SMOOTHING).
790  30 CONTINUE
800  DO 37 N=1,52
810  DO 36 N=1,5
820  FN=N
830  FH=M
840  FLOWB(N)=FLOWB(N)+AF(N+1)*COS(FH*TPIS(FN-1.))/12.)
850  CONTINUE
860  FLOWB(N)=FLOWB(N)+AF(1)
870  31 CONTINUE
880  * CALCULATION OF THE AVAILABLE POWER.
890  37 CONTINUE
900  DO 18 N=1,52
910  IF(FLOWB(N).GE.FLOWH) GO TO 1
920  IF(FLOWB(N).GE.FLOWH*.8) GO TO 2
930  IF(FLOWB(N).GE.FLOWH*.9) GO TO 3
940  IF(FLOWB(N).GE.FLOWH*.935) GO TO 4
950  IF(FLOWB(N).GE.FLOWH*.995) GO TO 5
960  EFFIC(N)=0
970  GO TO 6
980  1 EFFIC(N)=0.955
990  2 EFFIC(N)=0.955*(10*FLOWB(N)/FLOWH+82.)
1000  GO TO 6
1010  3 EFFIC(N)=0.955*(100/5)*FLOWB(N)/FLOWH+67)
1020  GO TO 6
1030  4 EFFIC(N)=0.955*(40*FLOWB(N)/FLOWH+65.)
1040  GO TO 6
1050  5 EFFIC(N)=0.955*(500/7.5)*FLOWB(N)/FLOWH+55.)
1060  6 EFFIC(N)=0.955*(500/7.5)*FLOWB(N)/FLOWH+55.)
1070  10 CONTINUE
1080  18 CONTINUE
1090  13 AL=AL-1
1100  13 INSTALLED PLANT COST
1120  DOLLW=2520.+AL*50.
1130  13 PLANT COST WITHOUT RSFUND.
1140  DOLL=2404.7276
1150  AWMAX=0.0
1160  AAMAX=0.0
1170  BCMAX=0.0
1180  BWMAX=0.0
1190  CDMA=0.0
1200  CMAX=0.0
1210  DEMAX=0.0
1220  DDMAX=0.0
1230  WHM=0
1240  WHP=0
1250  WHCOST=0
POWER PLANT RATING

\[ CKW = 1000 + ALL\times S. \]

INSTALLED PLANT COST SCHEDULE

\[ DOKW = DOLKW \times (1 + \exp((-CKW)/125)) \]

\[ C = DOLKW \times CKW \]

\[ U = 0.0191781 \times WDY \]

\[ HD = U \times (365 - WDY) \]

UPPER BOUND ON THE AMOUNT OF POWER THAT CAN BE GENERATED.

\[ \text{IF}(CKW - PW(N)) > 0 \]

APW(N) = PW(N)

AP = AP + APW(N)

EF = EF + EFFIC(N)

\[ \text{CU} = AP / CKW \]

\[ \text{BKWH(N,J)} = 0.0 \]

\[ \text{CSWH(N,J)} = 0.0 \]

\[ \text{SWN(N,J)} = 0.0 \]

\[ \text{UUN(N,J)} = 0.0 \]

\[ \text{ENCB = 0.024} \]

\[ \text{ENCC = 0.034} \]

\[ \text{ENCN = 0.034} \]

\[ \text{WCHAK = 2.98} \]

\[ \text{ENS = 1000.} \]
**CALCULATION OF AMOUNT OF ENERGY SOLD TO THE SEWER, WATERWORKS AND THE POWER COMPANY ON A WEEKLY BASIS.**

1780 ENWD=ENCWD#1000.
1790 ENWN=ENCWN#1000.
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 LK=N+6
1850 IF(LK.GE.10) GO TO 234
1860 IF(LK-7).LT.234+332+332
1870 232 EPW=APW(M)-PWRUA2(N,J)
1880 IF(EPLJ2.LE.O) GO TO 233
1890 WWD(M,J)=APW(H)*WWD(H,J)
1900 EPW=APW(M)-PWRUA2(N,J)
1910 IF(EPLJ2.LE.O) GO TO 233
1920 WWD(M,J)=APW(H)*WWD(H,J)
1930 EPW=APW(M)-PWRUA2(N,J)
1940 IF(EPLJ2.LE.O) GO TO 233
1950 WWD(M,J)=APW(H)*WWD(H,J)
1960 EPW=APW(M)-PWRUA2(N,J)
1970 IF(EPLJ2.LE.O) GO TO 233
1980 WWD(M,J)=APW(H)*WWD(H,J)
1990 * CALCULATION OF THE YEARLY ENERGY SOLD.
2000 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2010 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2020 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2030 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2040 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2050 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2060 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2070 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2080 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2090 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2100 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2110 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2120 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2130 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2140 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2150 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2160 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2170 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2180 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2190 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2200 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2210 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2220 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2230 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2240 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2250 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2260 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2270 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2280 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2290 SWD(1,J)=SWD(1,J)+SWD(M,J)+SWD(H,J)
2300 * CALCULATION OF THE YEARLY ENERGY SOLD.
CALCULATION OF THE TOTAL WHEELING COSTS.

\[ WHCOST = SWN(1:1) + SWD(1:1) + WWI(1:1) + WWN(1:1) \]

GO TO 2000

WRITE(6,1030)

WRITE(6,1000) SWD(lrl),SWN(lrl)

WRITE(6,902) FORMAT(' THE YEARLY ENERGY IS ')

FORMAT(' THE SEWER DAY ')

WRITE(6,902) WATERWORKS DAY

ASSOC=1000*17.4+WHCOST

AMAINT=0

PASS=ASSOC

SUMRR=0

R=0.0

NYD=DNY

PAUSE

WRITE(6,93)

WRITE(6,94)

96 CONTINUE

PAUSE

WRITE(6,93)

WRITE(6,94)

97 CONTINUE

AL=LOAN

P=BL*C*((1.+BL)**AL)/((1.+BL)**AL)-1.0

Cl=DOL*1000.

P=BL*Cl*((1.+BL)**AL)/((1.+BL)**AL)-1.0

RF=(17400.0/PI)/2.

PER=(RF/C)**100.

PPP=P

DO 290 N=1:NUMYR

BN=N-1

LOAN INTEREST.

AINT=C*BL*((1.+BL)**BN)-((F*(((1.+BL)*BN)-1.)))/1.0

PROFA=PROFA-AINT

IF(N-LOAN)262*262*266

2820 262 BN=BN-1

2830 * LOAN INTEREST.

2840 * AINT=C*BL*((1.+BL)**BN)-((F*(((1.+BL)*BN)-1.)))/1.0

2850 PROFA=PROFA-AINT

2860 GO TO 268

2880 266 AINT=0.0

2890 P=0.0

2900 268 PROFA=PROFA

2910 * LOAN INTEREST.

2920 * AINT=C*BL*((1.+BL)**BN)-((F*(((1.+BL)*BN)-1.)))/1.0

2930 PROFA=PROFA-AINT

2940 GO TO 268

2960 266 AINT=0.0

2970 P=0.0

2980 268 PROFA=PROFA

2990 * LOAN INTEREST.

2800 * AINT=C*BL*((1.+BL)**BN)-((F*(((1.+BL)*BN)-1.)))/1.0

2810 PROFA=PROFA-AINT

2820 GO TO 268

2840 266 AINT=0.0

2850 P=0.0

2860 268 PROFA=PROFA

2870 * LOAN INTEREST.

2880 * AINT=C*BL*((1.+BL)**BN)-((F*(((1.+BL)*BN)-1.)))/1.0

2890 PROFA=PROFA-AINT

2900 GO TO 268

2920 266 AINT=0.0

2930 P=0.0

2940 268 PROFA=PROFA

2950 * LOAN INTEREST.

2960 * AINT=C*BL*((1.+BL)**BN)-((F*(((1.+BL)*BN)-1.)))/1.0

2970 PROFA=PROFA-AINT

2980 GO TO 268

2990 266 AINT=0.0

3000 P=0.0

3010 268 PROFA=PROFA
lin 2930 thru 3590
2930 PP=P-AINT
2940 CAFL(N)=PROF8+G-PP
2950 AN=N-1
2960 DCAFL(N)=CAFL(N)/((1.+DSC*.01))**AN.
2970 SSS=ASSOC/(1.+AINF)
2980 AMA=AMAINT/(1.+AINF)
2990 * PRODUCTION COSTS.
3000 WRITE(6.275) N,YRT,PROD,P,CAFL(N),DCAFL(N)
3010 90 CONTINUE
3020 * TAKING ENERGY INFLATION INTO ACCOUNT.
3030 ENCU=ENCW*(1.+BINF)
3040 ENCWD=ENCWD*(((1.+BINF))
3050 ENC=ENCW*(1.+BINF)
3060 ENCC=ENCW*(1.+BINF)
3070 ENC=ENCW*(1.+BINF)
3080 ENCSN-ENCSN*(1.+BINF)
3090 RB=0.0
3100 R=RB
3110 GO TO 471
3120 370 DO 390 N=1,NUMYR
3130 AN=N
3140 SUM=CAFL(N)/((1.+R)**AN)
3150 SUMR=SUM+SUMR
3160 DYDT=0.0
3170 DO 397 N=1,NUMYR
3180 AN=N
3190 SUM=CAFL(N)/((1.+R)**(AN+1.))
3200 ST2=2-SUMR
3210 SUMR=0.0
3220 D1R=0.0
3230 IF(ABS(R-RB)<.0000025)475~476~475
3240 476 UTIA=SUMR
3250 ANN=LOAN
3260 UTIB=SUMR/(ANN*PPP)
3270 475 CONTINUE
3280 FV=SUHRR
3290 UTIC=SUHRR/(ANN*PPP)
3300 470 RC=##100.
3310 A(L)=RC
3320 471 CONTINUE
3330 *
3340 * UTILITY CALCULATIONS.
3350 DO 475 N=1,NUMYR
3360 AN=N-1
3370 SUM=CAFL(N)/((1.+DSC*.01))**AN
3380 SUMR=SUM+SUMR
3390 IF(N=LOAN)475,476,475
3400 UTIA=SUMR
3410 476 UTIB=SUMR/(ANN*PPP)
3420 475 CONTINUE
3430 PV=SUMR
3440 UTIC=SUMR/(ANN*PPP)
3450 SUMR=0.0
3460 CW=CCC/CKW
3470 *
3480 * AVERAGE UTILIZATION.
3490 PAKN=AKWCKW
3500 PLL=DL*100.
3510 PAINF=AINF*100.
3520 PBINF=INF*100.
3530 NWY=WDY
3540 *
3550 * PRODUCTION COST FOR THE FIRST YEAR.
4430 CONTINUE
4440 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

150.
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 Program
Thomus 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. Lamotheux
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