

# TEN MILE RIVER HYDROPOWER FEASIBILITY STUDY

*DRAFT*



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**Attachments**

- Appendix A – Preliminary Dam Inspection Report
- Appendix B – Hydrologic & Hydraulic Data
- Appendix C – Preliminary Project Configurations
- Appendix D – Natural Resource Data
- Appendix E – Economic Analysis (energy modeling, cost estimates, proformas)

## **Executive Summary**

The Essex Partnership was retained by the City of East Providence (City) to evaluate the feasibility of hydropower development at the Turner Reservoir Dam, Hunt's Mill Dam and Omega Pond Dam owned by the City on the Ten Mile River in Rhode Island. Results of the study indicate that there are three potential development configurations that could result in economically viable projects, depending on environmental requirements, these are:

1. 205 kw at Turner Reservoir Dam (Alternative A)
2. 302-500 kw at Turner Reservoir to Hunt's Mill Powerhouse (Alternative C)
3. 200-350 kw Hunt's Mill Dam to Hunt's Mill Powerhouse - historic hydro alignment (Alternative E)

While Alternative A is only marginally economic due to the limited head available at the dam, the licensing effort would be relatively straightforward. Alternatives C and E would develop more head, but would entail bypassing sections of the Ten Mile River and therefore would complicate the licensing process and involve greater regulatory risks.

Neither alternative C or E were found to be economic under the State's default instream flow standard (RI Modified Base Flow). Economic viability increased significantly when the instream flow standard was reduced to reflect potential refinements to the standard that could result from site specific analysis. These results suggest that site specific instream flow studies would be warranted if either of these alternatives were to be pursued.

Restoration of the historic hydropower configuration at Hunt's Mill which utilizes existing infrastructure appears economically promising. An optimization analysis which balances equipment selection with refined instream flow requirements could confirm this finding.

Development at Omega Pond Dam does not appear economic due primarily to very low average head conditions and associated energy potential. However, the dam is adjacent to an existing Narragansett Bay Commission pumping station; additional investigations that reduce development costs and utilize the output for the adjacent loads could improve economics.

Based on visual inspections, all three dams appear to be in good overall condition with no apparent issues that would preclude hydropower development. With proper care and maintenance the dams can reasonably be expected to continue perform as intended for many years. Published literature suggests that the hydraulic capacity of the Turner Reservoir Dam spillway may be inadequate. We recommend investigating this issue before investing significant resources in any hydropower development involving this dam.

Electrical interconnection at each of the sites would require less than one mile of upgraded (3-phase, 15-kv) service. At 15 kv the projects are not likely to overload the circuit or require additional system upgrades.

All of the findings presented herein regarding economic viability reflects a conservative all-equity analysis with no consideration of possible tax treatments or financial leveraging.

## **Introduction**

The Essex Partnership, LLC (Essex) was retained by the City of East Providence (City) to evaluate the technical and economic feasibility of developing hydropower at the Turner Reservoir, Hunt's Mill and Omega Pond Dams. This report addresses the following Feasibility Study (FS) tasks:

1. Preliminary Dam Inspections;
2. Hydrology and Hydraulic Analysis;
3. Preliminary Project Configurations;
4. Environmental Resources and Regulatory Analysis;
5. Energy Modeling and Generation Potential;
6. Cost Estimates; and
7. Economic Analysis.

For the purposes of this FS we identified preliminary project configurations and turbine equipment options designed to fit the physical characteristics of the sites. Based on the selected equipment options we developed a screening level energy model and then performed a comparative economic analysis to identify the most economically attractive development options. The economic findings presented in this report are preliminary and will likely change based on additional site specific information and more detailed analyses.

## Study Sites

All three of the dams evaluated are located on the Ten Mile River in East Providence, Rhode Island (Figure 1). The Ten Mile River watershed drains an area of approximately 52 square miles, including parts of Rhode Island and Massachusetts, before discharging to the Seekonk River. The dams evaluated in this FS are all owned by the City and are located in the lower reach of the Ten Mile River.

The City is currently working with several project partners to install fish passage at each of the sites. This evaluation includes consideration of the operational requirements of potential hydro developments for both upstream and downstream fish passage.



Figure 1: Project Locus Map. Study sites are marked with red stars.

The following sections provide brief descriptions of the study dams highlighting pertinent details associated with the hydro evaluation.

### **Turner Reservoir Dam**

The James V. Turner Reservoir Dam is the most upstream dam of the sites studied. The dam is classified by the State as an intermediate size structure with high hazard potential. Built in 1934, the 550 foot-long dam consists of two sections of earthen embankments and a 200 foot long concrete overflow spillway. A 25 foot-long concrete low level outlet abuts the right end of the spillway. The structure contains two 54-inch diameter conduits and an abandoned 66-inch diameter penstock intake. The penstock is reportedly buried under ground and runs approximately 2,400 feet along the right river bank toward the Hunt's Mill Dam downstream. The penstock was historically used for water supply however records on file at the Rhode Island Department of Environmental Management (RIDEM) indicate that this use was abandoned in 1970 due to water quality concerns.

The drainage area at the dam is 48 square miles. The impoundment has a maximum reservoir storage and surface area of 3,100 acre-feet and 390 acres, respectively. Current use of the impoundment is primarily for recreation. Efforts to restore upstream fish passage on the river will expand its use to provide spawning and rearing habitat for anadromous fishes (river herring and shad). The dam and entire reservoir shoreline is owned by the City.

### ***Hunt's Mill Dam***

The Hunt's Mill Dam is located on the Ten Mile River approximately 2,300 feet downstream of the Turner Reservoir Dam (Figure 1). The 175 foot-long dam consists of an overflow spillway at an abandoned headrace entrance. The appurtenant facilities, all abandoned, include a penstock, headrace, pumphouse, and a tailrace. The dam with impoundment storage of 140 acre-feet and surface area of 0.4 acres is classified by the State as a small size structure with low hazard potential. The dam was used for hydropower generation and public water supply from the 1930s to 1970.

A denil fish ladder is currently being installed at the right (west) side of the dam. The former intake, headrace, concrete conduit and stilling well have been removed to accommodate the fish ladder. Prior to installation of the fish ladder the headrace downstream of the entrance closure wall had a short, open flume transitioning into an underground steel penstock which leads to the pumphouse. The pumphouse contains a 144 kW vertical Francis hydro-generating unit, presently retired. The historic hydro station discharged to a now abandoned 900-foot long tailrace channel which created a 1,200 foot-long river bypass reach.

### ***Omega Pond Dam***

The Omega Pond Dam is located at the confluence of the Ten Mile and Seekonk Rivers. The 200 foot-long, 18 foot-high dam consists of an overflow spillway and abutment walls. The 112 foot-long, 15 foot-high spillway is a concrete gravity structure with downstream stone facing. The dam impoundment has a storage capacity of 280 acre-feet and a surface area of 33 acres. The impoundment is used for recreation and water supply by several adjacent industries. Downstream of Omega Dam the Ten Mile River discharges into the Seekonk River which is a tidal estuary. Consequently, tailwater levels are tidally influenced. The dam is classified by the State as a small size structure with low hazard potential.

The existing structure was built in 1918 downstream of an original timbercrib dam erected in 1883. Similar to the Turner and Hunt's Mill Dams, the Omega Pond Dam is scheduled for installation of a denil fish ladder at the right (north) side of the dam utilizing a portion of the existing spillway.

## **Preliminary Dam Inspection**

The Essex Partnership, with assistance from MBP Consulting (MBP), conducted visual inspections of the study dams in October 2010. Results of these inspections indicate that the dams are no longer being used for their originally intended uses. There are some signs of deterioration; however, with routine maintenance typical for water retaining structures, these dams could be expected to exist well into the future. There were no observed conditions that would preclude hydropower development. A complete copy of the Preliminary Inspection report is provided as Appendix A.

Suggested measures related to operation, maintenance and repair of the dams include removal of brush and trees from water retaining structures, and re-pointing of joints and voids in masonry components. Additional recommendations include repair of deteriorated spillways and retaining walls and in some cases, restoration of inoperable low-level outlets.

If developed for hydropower, jurisdiction for dam safety would transfer from RIDEM to the Federal Energy Regulatory Commission (FERC). FERC typically has more stringent safety criteria than State dam safety offices. Consideration of potential exposure of this jurisdictional transfer is important in evaluating overall project feasibility.

The Hunt's Mill and Omega Pond dams, are classified by RIDEM as low hazard structures, and thus would be strong candidates for an exemption from the requirements outlined in the Federal Power Act (FPA) Part 12 (concerning dam safety – administered by FERC). The Turner Reservoir Dam, with an existing RIDEM high hazard classification, would likely be subject to compliance with Part 12 if it were to be developed for hydropower.

Phase I (US Army Corps 1978) and Phase II (New England Engineering 1982) dam inspection reports of the Turner Reservoir Dam indicate that the existing spillway appears undersized (i.e., not able to adequately pass extreme flood flows). The Phase II analysis of the spillway's hydraulic capacity (New England Engineering 1982) included several potential structural measures to address this concern. Phase II cost estimates to implement these measures ranged from \$700,000 to \$3.5mm (escalated 2.5%/yr from 1982- 2010 dollars), depending on the alternative.

A more current and detailed analysis would be needed to determine the likely nature and cost of remedial measures needed, if any, to meet FERC Part 12 safety criteria. Before expending significant funds on hydropower development activities, it would be prudent to perform additional, site-specific hydrologic and stability analyses for the Turner Reservoir Dam. These studies and analyses could be done in conjunction with licensing efforts.



## Hydrologic Analysis

The first step in evaluating a site's hydro potential is to collect sufficient data to characterize the magnitude and variability of river flows. In the United States this is typically accomplished using average daily flow data recorded by a USGS gauge on the river being studied. If the river is ungaged or the period of record is too short (typically 30 years or more of record are required) then one or more surrogate gauges may be used.

The existing gauge on the Ten Mile River (USGS 01109403 TEN MILE R., PAWTUCKET AVE. AT E. PROVIDENCE, RI) was established in 1986. Because this gage represents a limited, 24 year period of record, additional data were obtained from the Woonasquatucket River (USGS 01114500 WOONASQUATUCKET R. AT CENTERDALE, RI) which has a 69 year period of record. Data from both gages were pro-rated to reflect the same hypothetical 50 square mile drainage area and compared to determine if the data from the Ten Mile River were representative of longer-term regional trends. The two data sets compare well (see Figure 2), suggesting that the Ten Mile River gage data set is representative of long-term hydrologic conditions. For purposes of this feasibility study flow data from the USGS gauge on the Ten Mile River were used.

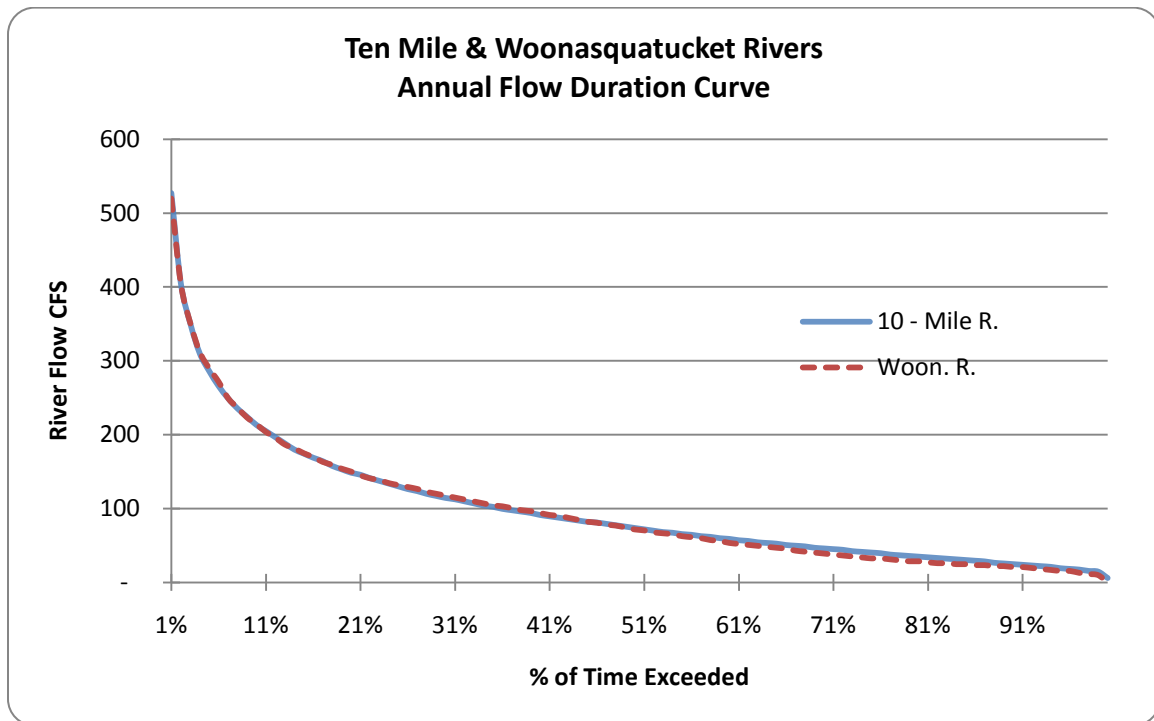


Figure 2: Annual flow exceedance curves (Ten Mile & Woonasquatucket Rivers).

Referring to Figure 2, above, some initial approximations can be made regarding the hydraulic capacity (or turbine size) for hydropower development. Although the graph is a simple plot of river flows (Y-axis) verses % of time the flow is exceeded (X-axis) it provides a good overall picture of the relationship between the magnitude of river flows and their variability over an average flow year.

For example, the 25% exceedance flow is approximately 132 cfs. This means that the river will have a flow of 132 cfs (or higher) 25% of the time, or 2,190 hours in an average year (25% of 8,760 hours/year). Installing a hydro turbine(s) with this hydraulic capacity would utilize river flows up 132 cfs. Flows in excess of 132 cfs would be spilled over the dam – without generating any power. Increasing the hydraulic capacity to 500 cfs would allow the turbine to utilize flows up to 500 cfs. One percent of the time (87.6 hours/yr) river flows would exceed 500 cfs and the additional water would be spilled.

Installing a larger turbine, however, may not necessarily optimize the hydro potential of the site. Depending upon the type of turbine used, the minimum operating point ranges from 10% to 20% of the hydraulic capacity (maximum operating point). Francis turbines, such as the existing unit at Hunt's Mill, typically have a minimum operating point around 20% of hydraulic capacity. For the 500 cfs turbine mentioned above, this means the minimum operating point would be approximately 100 cfs. Referring to Figure 2, above, all of the river flows below 100 cfs would not be utilized for energy production.

Other factors to consider when configuring a project and selecting an installed capacity are seasonal operating restrictions to provide adequate protection of environmental resource (i.e., fish passage, water quality and instream flow concerns). As described in the Environmental Inventory section, Rhode Island has a standard instream flow requirement to protect instream resources. On an average monthly basis the minimum stream flow requirement at the three study sites would be approximately 70 cfs. If the project configuration involved a bypass reach – the first 70 cfs of river flows would have to be released at the dam – and would not be available for generation. Referring once again to Figure 2, this would have the effect of moving the X-axis up 70 cfs, which would make the flow duration curve much steeper. To address these factors in our energy calculations monthly flow exceedance relationships were developed. Using these data the energy model was run on a monthly basis to capture the seasonal variations in environmental flow requirements (fish passage and instream flows).

## Project Configurations & Site Hydraulics

As part of this FS we evaluated several different project configurations. Each potential configuration developed a unique head characteristic. In general more head will provide more power. However, there are environmental and economic trade-offs that need to be considered as part of the evaluation. Additional detail on the configurations and specific trade-offs is provided in subsequent sections.

Figure 3 presents a simple line diagram of the study area which schematically represents the project configuration options evaluated. The gross hydraulic head developed under each of these configurations is tabulated in the table on the following page. The ID nomenclature provided in Figure 3 corresponds to ID values in the head data table.

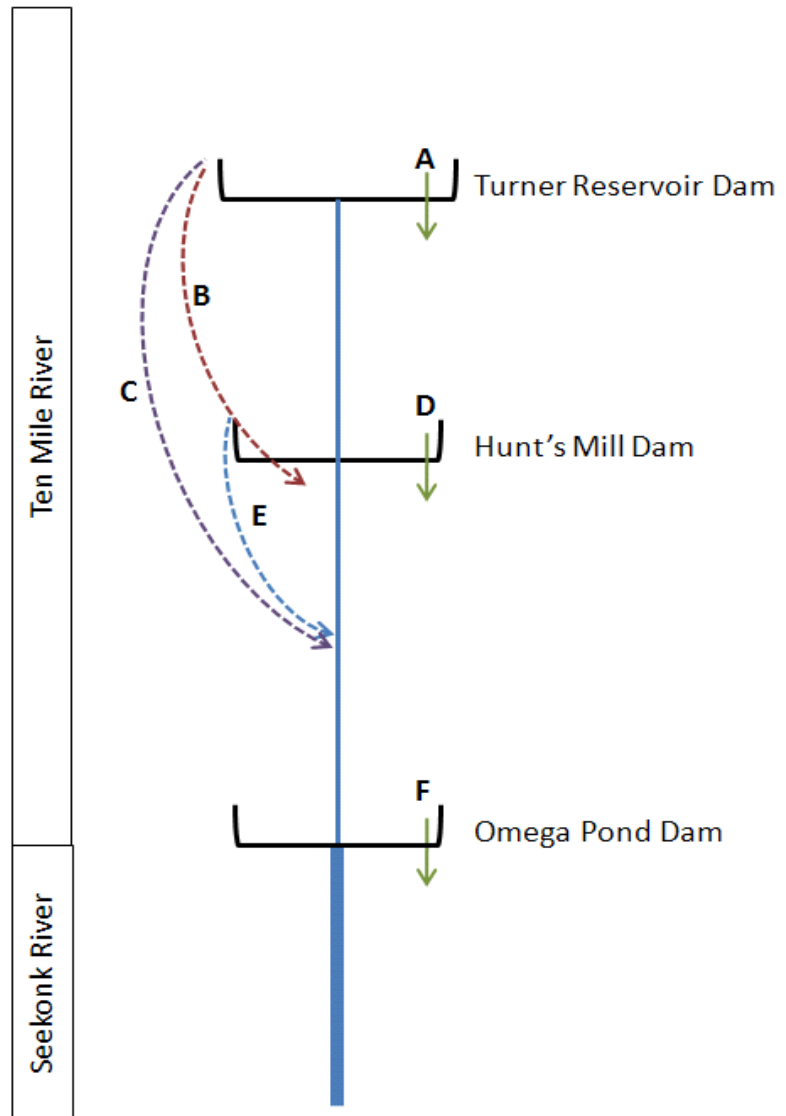


Figure 3: Schematic of configurations evaluated.

In order to determine the hydraulic head at each site field measurements were taken of water surface elevations upstream and downstream of each dam were taken during the preliminary dam inspections. The field measurements were taken using an assumed local datum at each dam to determine hydraulic head. This survey approach however, using a local datum at each dam, is not applicable for determining head between adjacent dams.

To address this data gap, we reviewed Corps fish passage plans and reports, the 1980 Hydro Feasibility Study (Maguire), and the FEMA FIS flood profiles to obtain elevations

along the river between Turners and Hunt’s Mill. Ultimately the FIS profiles were used to estimate available head due to various inconsistencies in some of the reported elevation data (i.e., the Corps reported tailwater elevations at Turner below headwater elevations at Hunt’s Mill). The estimated tailwater elevations result in calculated hydraulic head values which closely agree with previous assessments of hydraulic head between the two sites (Maguire 1980), as well as the cumulative head generated between alternatives A and E. Gross hydraulic head values for each of the project configurations evaluated as part of this FS are tabulated below.

ID	Description of Project Configuration	Gross Head
A	Turner Reservoir Dam <ul style="list-style-type: none"> <li>• Intake &amp; discharge at spillway; no bypass<sup>1</sup> reach</li> </ul>	14.5
B	Turner - Hunt's Mill Dam <ul style="list-style-type: none"> <li>• Intake at Turner Res. with discharge at toe of Hunt’s Mill spillway</li> <li>• Develops head between two sites</li> <li>• Creates 2,300 ft long bypass reach</li> </ul>	22
C	Turner - Hunt's Mill Powerhouse <ul style="list-style-type: none"> <li>• Intake at Turner Res. with discharge through historic Hunt’s Mill tailrace</li> <li>• Develops the maximum head between two sites</li> <li>• Creates 3,500 ft long bypass</li> </ul>	38
D	Hunt's Mill Dam <ul style="list-style-type: none"> <li>• Intake &amp; discharge at spillway; no bypass reach</li> </ul>	8.5
E	Hunt's Mill Dam – Hunt’s Mill Powerhouse <ul style="list-style-type: none"> <li>• Intake at spillway, discharge through historic tailrace</li> <li>• Redevelops historic head</li> <li>• Creates 1,200 foot long bypass reach</li> <li>• Restores/upgrades existing historic turbine and tailrace</li> </ul>	23.5
F	Omega Pond Dam <ul style="list-style-type: none"> <li>• Intake &amp; discharge at spillway; no bypass reach</li> <li>• Actual head fluctuates through tidal action</li> </ul>	8

A simple linear relationship was used to develop corresponding headwater and tailwater elevations for flows on the Ten Mile ranging from 0 to 1,000 CFS. To be conservative we assumed gross head (headwater elevation – tailwater elevation) decreased by 1.5-feet over this range of river flows.

<sup>1</sup> A bypass reach is used to describe a section of a watercourse that is subjected to diversion of all or part of the natural flows to accommodate other uses. Reductions in the flows in the bypass reach can be detrimental to the riparian ecosystem health.

## **Hunt's Mill Options**

In addition to configuration D, tabulated above, we explored three additional options for redeveloping the site:

1. *Hunt's Mill New* - install all new modern equipment, either in the existing powerhouse or in a new powerhouse adjacent to the existing powerhouse building;
2. *Hunt's Mill Repowered* - upgrade the existing unit with modern equipment (see detailed description below);
3. *Hunt's Mill Restored* – restore the existing turbine and generator to their original, as-new operating condition.

Each of these options was modeled for water withdrawn from Turner Reservoir (Alternative C) and for water withdrawn from the Hunt's Mill Dam (Alternative E).

The following section briefly describes the existing Hunt's Mill hydroelectric unit as well as repowering and restoration options.

### **Existing Unit**

The existing Hunt's Mill unit is a 1924 vertical Francis turbine manufactured by the James Leffel Company. The turbine is installed in a vertical cylindrical steel pressure case and discharges into a vertical steel draft cone. Relevant photographs from our October 13, 2010 site visit are presented on the following pages. In general the equipment is inoperable and would require a significant amount of work to return to reliable operation. The runner (waterwheel, or rotating part of the turbine) and draft cone were not accessible during our site visit. A more detailed inspection would be required to better ascertain the condition of the equipment and develop a firm scope of work for restoration.

Although hydro equipment manufactured during the 1920's tended to be robust, performance typically falls way short of current technology. Modern designs typically offer a broader operating range, substantially higher efficiencies and increased output. Given the age and apparent amount of work that would be required to restore the existing Leffel unit, installation of a new, modern designed turbine (Repowering) is likely to provide the most beneficial reuse of existing infrastructure.

### **Hunt's Mill Repowering**

Repowering typically involves selecting an existing turbine design that best fits the setting and existing water passages at the site. For purposes of developing performance

parameters and preparing cost estimates, we assumed the following scope of work for repowering:

1. Remove the existing turbine (wicket gate assembly and runner);
2. Repair and paint the steel pressure case and draft cone;
3. Rework the turbine/generator shaft, machine the couplings and line bore and install fitted new coupling bolts;;
4. Install a new Wicket gate assembly (stay vanes, headcover and wicket gates);
5. Install a new, modern design runner;
6. Replace the existing governor with a new, solid state gate actuator;
7. Rewind the existing generator;
8. Install new electrical controls and switchgear.

### **Hunt's Mill Restoration**

We also developed preliminary cost estimates for restoring the unit to its original, as-new operating condition. While this would not be an optimal alternative from an energy production perspective, it represents an historic preservation case if that were to become the primary objective of the project. As mentioned above, a more thorough inspection would be required to ascertain the scope of work required to refurbish the unit. For purposes of this FS we assumed the following work would be required:

1. Remove the existing turbine (wicket gate assembly and runner);
2. Repair and paint the steel pressure case and draft cone;
3. Rework the turbine/generator shaft, machine the couplings and line bore and install fitted new coupling bolts;
4. Rework the wicket gate assembly and install new stay vanes, headcover and wicket gates identical to the existing equipment;
5. Obtain the original runner design from Leffel or make a pattern of the existing runner blades and fabricate a new runner identical to the existing;
6. Rewind the existing generator;
7. Replace the existing governor with a new, solid state gate actuator. Restoring the existing governor may be cost prohibitive but it could be cleaned and left in place for educational and display purposes.
8. Install new electrical controls and switchgear. For personnel safety and protection of the equipment we do not recommend restoring the original controls and switchgear. However, the existing electrical gear could be cleaned and left in place for educational and display purposes.



*Figure 4. Existing Hunt's Mill Generator and Governor*



*Figure 5. Steel penstock and Vertical Pressure Case*



*Figure 6. Headcover, Stay Vanes and Wicket Gate Assembly*



## **Environmental Resources & Regulatory Analysis**

Hydropower projects are typically licensed and permitted in a manner conditioned to avoid, minimize, and reduce adverse environmental impacts. To that end many modern hydropower developments are configured to allow for eventual certification by the Low Impact Hydropower Institute (LIHI). LIHI certification evaluates candidate projects against ten criteria reflecting sensitive environmental resources. In many states LIHI certification is a requirement to participate in Renewable Energy Certificate (REC) markets and therefore provides an economic incentive. Typical issues include, but are not limited to; stream flows, water quality, fish passage and protection, cultural and historic resources, recreation, and consistency with watershed management goals. Additional detail on the LIHI certification program is available at <http://www.lowimpacthydro.org>.

In recognition of the LIHI criteria, this study includes project configurations designed to avoid and minimize adverse impacts to sensitive resources. Examples of these provisions include; utilization of existing dams and impoundments, reduced flow allowances for fish passage, turbine discharges sited to eliminate bypass channels or provisions for instream flows, and turbine selection to address biological and architectural considerations. The scope of this FS also includes evaluation of several project configurations (B, C, and E) that may not be considered strong candidates for LIHI certification due to significant bypass reaches. In these cases operational adjustments were made to anticipate regulatory conditions on project operations for protection of environmental resources. Additional protection, mitigation and enhancement (PM&E) measures would likely be identified and incorporated on a site specific basis during regulatory processing.

The following sections provide additional detail on the environmental resources present in the study area as well as a discussion of the regulatory requirements and relative level of risk and complexity associated with each configuration evaluated.

### ***Environmental Inventory***

Several sources of information were reviewed to gain a better understanding of existing environmental resources in the study area. These sources included, but were not limited to; RIDEM fisheries data, water quality monitoring data, fish passage plans and permitting materials, and Rhode Island and Massachusetts Geographic Information Systems. The figure below was compiled using publically available GIS-based data from RI and MA; it illustrates the location of regulated and/or sensitive resources in relation to the study sites. More detailed resource mapping is provided in Appendix D.

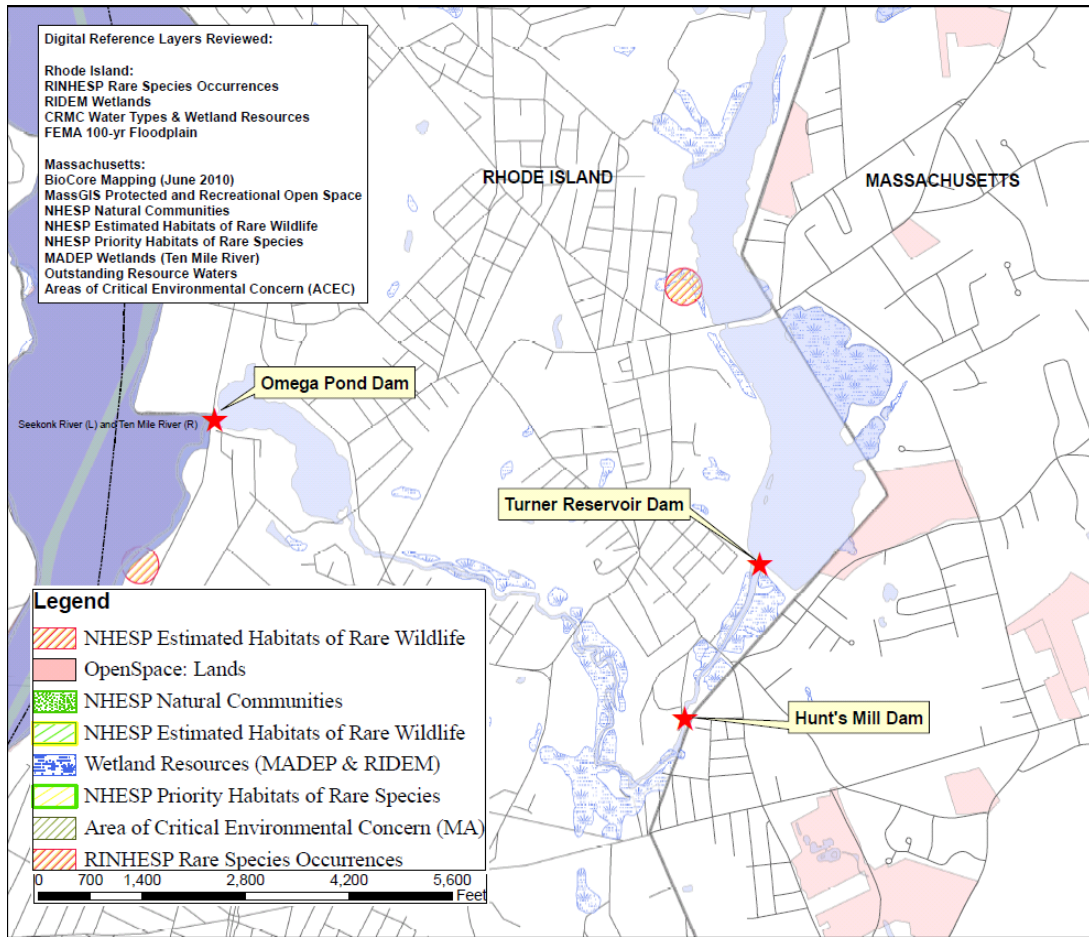


Figure 7: Environmental Resources Inventory Map of the Study Area. More detailed mapping is provided in Appendix D.

Based on observations made during site visits, GIS-based natural resource mapping, preliminary discussions with regulators and experience with similar projects, there are several environmental resource areas that would need to be addressed during the development of hydropower at the site. The following sections provide additional detail on these resources, potential implications for project development, and possible resolution and/or mitigation strategies.

### ***Aquatic Resources***

Diverting portions of river flows for hydropower generation can potentially have adverse impacts on the aquatic environment. Any variation in river flows and water surface elevations associated with project operations would need to be evaluated to determine the extent and severity of potential environmental impacts.

There are several standard approaches for protecting aquatic resources. Operation of the project in a “run-of-river” mode (i.e., inflows equal outflows) without storage or ponding

is generally considered the least disruptive operational mode and is a requirement for LIHI certification.

Rhode Island has developed a standard approach for protecting instream resources from proposed diversions and withdrawals known as the Rhode Island Modified Base Flow Methodology (Richardson 2005). This method prescribes minimum flow requirements to approximate natural flow conditions and is intended to provide stream flows adequate to protect aquatic resources. The standards are based on the size of the drainage area at the location of the proposed impact and vary by season (monthly intervals). Alternatives B, C, and E would discharge flows used for generation downstream of the intake points (creating a bypass reach) these alternatives would likely be subject to an instream flow requirement. Alternatives A, D, and E would discharge at the base of the spillway (and would not bypass the river) we have assumed that they would not be subject to an instream flow requirement (aside from provisions to maintain fishway operations).

In today's regulatory climate almost any project with a bypass reach will be subject to an instream flow requirement to protect aquatic resources. These requirements reduce the volume of water available to the turbine thereby reducing generation potential (see Energy Modeling). Site specific studies can be used to propose modified instream flow requirements as an alternative to accepting the standard, desk-top instream flow settings. Based on our experiences the trade-off in upfront study costs and back end generation gains is often justified (see Energy Modeling).

### ***Fisheries***

The Ten Mile River in the study area is classified as a Class B warm water fishery by the RIDEM. According to RIDEM and Corps fish survey data the following species occur in the river and impoundments within the study area (Appendix D).

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#### **Warm Water Fish Assemblage of the Ten Mile River**

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Yellow perch	Pumpkin seed
Redfin pickerel	Yellow bullhead
Largemouth bass	Golden shiner
Bluegill	American eel
White perch	Black crappie
White sucker	White catfish

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Standard conditions for the licensing and permitting of hydropower projects typically include provisions for providing safe passage for migratory and resident fishes occurring in the vicinity of a project. There are currently efforts underway at each dam to install upstream fish passage for migratory populations of blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*) and American shad (*Alosa sapidissima*) as well as American eel (*Anguilla rostrata*). Additional information on the Ten Mile River fish passage restoration program can be found on the Corps' project website (<http://www.nae.usace.army.mil/projects/ri/tenmile/10mile.htm>).

Downstream passage for most fish species will be accomplished via notches in the project spillways (outmigrant notch). Downstream passage/protection for adult eels usually focuses on conditions near the project intake and can include restrictions to intake approach velocities, bar rack angles or spacing, and reduced operation during migration periods to avoid impacts associated with impingement on the racks and injury and mortality due to turbine passage.

From a hydropower perspective, development at dams with existing provisions for fish passage presents a double edged sword. As a positive, a potential project does not have to bear the capital expense of designing and installing passage facilities. The drawback is that the design may not necessarily have been conceived to be compatible with hydropower and can constrain design options.

Regardless of the design focus, a hydropower project with fish passage requirements needs to consider operational practices that facilitate passage. These provisions include; providing adequate flows to the ladder and outmigrant notch to ensure proper functionality (fish ladder flows) as well as provisions for flows near the fish ladder entrance to ensure that migrating fish can locate and use the facility (attraction flows). These flow requirements are seasonal, corresponding to key biological requirements (bioperiods), and result in a reduction in flows available for generation.

Provisions for eel and fish passage/protection have been included as part of the energy modeling and economic analysis conducted for this study.

### ***Water Quality***

The Turner Reservoir is on Rhode Island's list of impaired waters due to lead, copper, phosphorous, coliform bacteria and dissolved oxygen levels. Assessments of water quality in the study area completed by the Corps indicate that water quality is generally acceptable to support aquatic life. The RIDEM is currently in the process of developing a Total Maximum Daily Load (TMDL) model for the river focused primarily on metals and nutrient pollution. A water quality monitoring program has been in place on the river since 2007 to support development of the TMDL. Preliminary review of water quality data provided by RIDEM support the assessment that the Turner Reservoir and Omega Pond experience seasonal dissolved oxygen impairments. RIDEM summaries of the water quality monitoring program for 2007 and 2009 are provided in Appendix D.

As water flows over a dam's spillway it is aerated. Routing flows through a hydroelectric turbine resulting in less flow over the spillway can reduce aeration and impact dissolved oxygen levels in the water, particularly if dissolved oxygen levels are already low. Provisions for instream flows (discussed above) can help to minimize and/or mitigate for such impacts.

It is common for regulators to request a commitment from project operators to have no impact on baseline (pre-project) water quality conditions. Since water quality is already a concern in the study area, it is very likely that potential water quality impacts will be

raised as an issue during licensing and permitting efforts. We have included provisions for environmental studies (including water quality modeling) in our cost estimates to address such issues. Possible resolution strategies can include: provisions for instream flows (over the dam) to maintain water quality, real-time water quality monitoring and operational adjustments, and/or provisions for aeration of flows through the turbine. The history of water quality issues at the Turner Reservoir is expected to require additional analysis and consultations.

### ***Wetlands / Floodplains***

Wetland resources in the vicinity of the project are generally confined to the river channel and associated floodplains (RIDEM and wetland data available through RIGIS). Turner Reservoir and Omega Pond have wetland complexes consisting of emergent, scrub-shrub and forested wetland types which occur along the impoundment shorelines. Operating the project in a run-of-river mode will avoid impacts to upstream wetlands associated with water level fluctuations in the headpond. Alternatives which include installation of a penstock from the Turner to Hunt's Mill sites would likely include some impacts to wetlands along the penstock alignment as well as floodplain wetlands located between Turner Reservoir and Hunt's Mill (see Appendix D).

The hydraulic capacity of the Turner Reservoir spillway is currently limited. Development which further reduces this capacity would be expected to trigger some concerns and possibly require mitigation of lost flood conveyance or storage functions.

Costs and provisions for wetland and flood impact assessments as well as an allowance for some mitigation measures that may be required for development activities have been included in the cost estimates and economic analyses where appropriate.

### ***Rare, Threatened & Endangered Species***

The Rhode Island Natural Heritage and Endangered Species Program (NHESP) recognize a small area on the northwest shore of the Turner Reservoir impoundment as a known occurrence for a rare species (Appendix D). Considering the location of the occurrence in relation to the potential project and the nature of run-of-river hydropower projects, it is unlikely that normal project operations would impact this resource. Depending on specific ecological requirements of the rare species, it is possible that avoidance and mitigation measures associated with potential impacts from construction related activities may be required.

### ***Cultural / Historic Resources***

Considering the industrial history of the Ten Mile River watershed and the project sites there may be potential impacts to cultural and/or historic resources from project development. Coordination with the State Historic Preservation Office (SHPO) and Native American tribal nations is a requirement during project licensing and permitting proceedings. Depending on the identification and determination of resource significance

there is potential for both direct and indirect impacts from project related activities. Mitigation options are varied and depend on the specific situation and resource. Potential outcomes can include archival documentation of significant resources and/or interpretive signage and displays.

***Recreational Resources***

FERC licensing/exemption may require making accommodations for recreational use of project lands. Provisions for public access can be negotiated with local and state agencies charged with providing recreational facilities in the area. Previous and on-going efforts by the City to enhance recreational opportunities may be used to (at least partially) address this issue. We have included provisions in the economic analysis for additional assessments and consultations in relation to recreational resources during project licensing and permitting.

## **Regulatory Analysis**

Taking environmental impacts into account during the preliminary planning stages of hydropower development can help to avoid a contentious regulatory proceeding. Since a portion of the Turner Reservoir is in or abuts the State of Massachusetts we assume that some coordination and approvals with regulators in that State would be required to develop hydropower at that site. The following regulatory approvals are anticipated for hydropower development on the Ten Mile River:

- Federal:
  - Federal Energy Regulatory Commission (FERC)
    - Federal Power Act (FPA) Part 1 - license or exemption from licensing
  - Corps Dredge and Fill Permit – Clean Water Act Section 404
  - Coastal Zone Management Act – Consistency Review (Omega Pond only)
- State of Rhode Island:
  - Wetlands Permit – insignificant alteration or permit to alter
  - Water Quality Certificate (WQC) – Clean Water Act Section 401
  - Historic Preservation – Section 106
- State of Massachusetts (Turner Reservoir Only):
  - Wetlands Protection Act – Order of Conditions
  - Natural Heritage and Endangered Species Program – Review

Typically hydropower projects take 3-5 years to license and permit. A significant portion of this time is dictated by statutory requirements for both public and agency review and comment of the proposed project associated with FERC processing. Low impact design and operating protocols as well as early outreach and coordination with regulators and other stakeholders can reduce the time and complexity of the process. Projects with more contentious resource concerns can take longer than 5 years and require significant time and capital to complete.

Since each of the projects is currently owned by the City we would recommend pursuing an exemption from FERC licensing. This provision allows entities with all the ownership rights to develop operate and maintain small hydropower projects to obtain approval in perpetuity (does not require re-licensing). In order to obtain an exemption a project must meet several eligibility criteria, including; operate in run of river mode, have less than 5 MW of installed capacity, and demonstrate all ownership and control rights to develop, operate and maintain the project.

There is an outside chance that redevelopment of the Hunt's Mill site can be relieved of some of the FERC processing burden due to its historic use for hydropower if it is found to be outside of FERC's jurisdiction. According to FERC guidelines (unless a project has a valid pre-1920 federal permit), non-federal hydroelectric projects are jurisdictional if:

1. The project is located on navigable waters of the United States.
2. The project occupies public lands or reservations of the United States.
3. The project utilizes surplus water or waterpower from a federal dam.
4. The project is located on a body of water over which Congress has Commerce Clause jurisdiction, project construction occurred on or after August 26, 1935, and the project affects the interests of interstate or foreign commerce.

Because generation would feed into the existing interstate transmission system it is unlikely that the project would be found non-jurisdictional (fails test #4). However a request for a jurisdictional determination is fairly simple and straight forward with no penalties related to the decision.

Each of the project configurations evaluated in this FS has a unique combination of regulatory risk and complexity depending on the specific development requirements and nexus with sensitive resources. The following table summarizes the key drivers of relative regulatory risks and complexity associated with each of the evaluated configurations.

For the purpose of this analysis, “risk” is a qualitative measure of the likelihood of receiving a FERC license/exemption with favorable conditions. A “low” risk reflects a relatively high probability of receiving a license or exemption as designed. A “medium” risk implies that there is a greater than 50% chance of having to do extra studies and receiving a license/exemption with conditions that adversely affect project economics. A “high” risk implies the likelihood of having to do additional environmental studies and potentially receiving onerous license conditions.

Complexity here relates to the regulatory process and the degree of difficult (typically measured in time and money) associated with obtaining the license/exemption. Similar to “risk”, a “low” complexity implies a relatively straightforward regulatory process. A “medium” complexity implies that there will likely be extra consultations required and possibly more time and costs than a simple project. A “high” complexity implies that the process will likely involve numerous stakeholders and be protracted.



ID	Summary of Key Regulatory Drivers	Risk	Complexity
A	<p><b>Turner Reservoir Dam</b></p> <ul style="list-style-type: none"> <li>No bypass reach</li> <li>Significant water quality (D.O.) issues</li> <li>Dam safety (FERC)</li> </ul>	Medium	Medium
B	<p><b>Turner – Hunt's Mill Dam</b></p> <ul style="list-style-type: none"> <li>Creates 2,300 ft long bypass reach and associated instream flow concerns</li> <li>Turner Res. Fish ladder attraction flow issues</li> <li>Significant water quality (D.O.) issues</li> <li>Wetland impacts from penstock construction and modified bypass reach flows</li> </ul>	Medium	High
C	<p><b>Turner - Hunt's Mill Powerhouse</b></p> <ul style="list-style-type: none"> <li>Creates 3,500 ft long bypass and associated instream flow concerns</li> <li>Turner Res &amp; Hunt's Mill fish ladders attraction flow issues</li> <li>Significant water quality (D.O.) issues</li> <li>Wetland impacts from penstock construction and modified bypass reach flows</li> </ul>	High	High
D	<p><b>Hunt's Mill Dam</b></p> <ul style="list-style-type: none"> <li>No bypass reach</li> <li>Potential water quality (D.O.) concerns</li> </ul>	Low	Low
E	<p><b>Hunt's Mill Dam – Hunt's Mill Powerhouse</b></p> <ul style="list-style-type: none"> <li>Creates 1,200 foot long bypass reach and associated instream flow concerns</li> <li>Hunt's Mill fish ladder attraction flow issues</li> <li>Potential water quality (D.O.) concerns</li> <li>Wetland impacts from tailrace restoration</li> </ul>	Medium	Medium
F	<p><b>Omega Pond Dam</b></p> <ul style="list-style-type: none"> <li>No bypass reach</li> <li>Potential water quality (D.O.) concerns</li> </ul>	Low	Low

## Preliminary Energy Modeling & Generation Potential

The following section briefly describes the energy model developed for estimating generation potential and how the model was used to begin the process of optimizing the development of the various configurations outlined above.

### ***Energy Modeling***

A monthly flow duration model was developed to estimate installed capacity and energy production for the various alternatives at each site. Major components of the model include: hydrology (river flows); site hydraulic characteristics (head); equipment performance; and potential license mandated operating conditions to protect environmental resources.

Hydrology data were developed as described in the Hydrologic Analysis section. Other physical site characteristics including information on the hydraulic head at each site are described in the Project Configurations & Site Hydraulics section.

For equipment performance characteristics, the proprietary turbine design software “TRBNPRO” was used to develop equipment configurations, sizes and performance characteristics. Typically axial flow (propeller) turbines are best suited for the range of heads at the three sites (6-ft. to 36-ft). Given the wide range of flows on the Ten Mile, a double regulated axial flow turbine (Kaplan) will provide much higher efficiency than a fixed-blade turbine over the entire operating range. Therefore, for all cases involving new equipment, we assumed double regulated axial flow turbines would be used.

For the Hunt’s Mill site (Alternatives C and E) we modeled two special cases using the existing vertical Francis turbine arrangement. As previously described, one scenario involves designing and installing a new runner to increase efficiency and output. The other scenario replicates the existing turbine design. Based on our experience refurbishing hydro units we developed preliminary work scopes which included installing a new Francis turbine assembly (runner, headcover and wickets gates) in the existing water passages (cylindrical pressure case and conical draft tube). Using TRBNPRO we developed a modern design Francis runner to fit the following parameters of the existing Hunt’s Mill configuration:

<b><i>Speed</i></b>	225 RPM
<b><i>Runner Diameter</i></b>	Approximately 1 meter
<b><i>Runner Setting</i></b>	13-ft above tailwater
<b><i>Gross Head</i></b>	23.5 feet

Typical efficiency curves for Kaplan and (modern design) Francis units are shown in the graph below. For all alternatives modeled we assumed an overall generator efficiency of 95% for the conversion of mechanical power to electrical power.

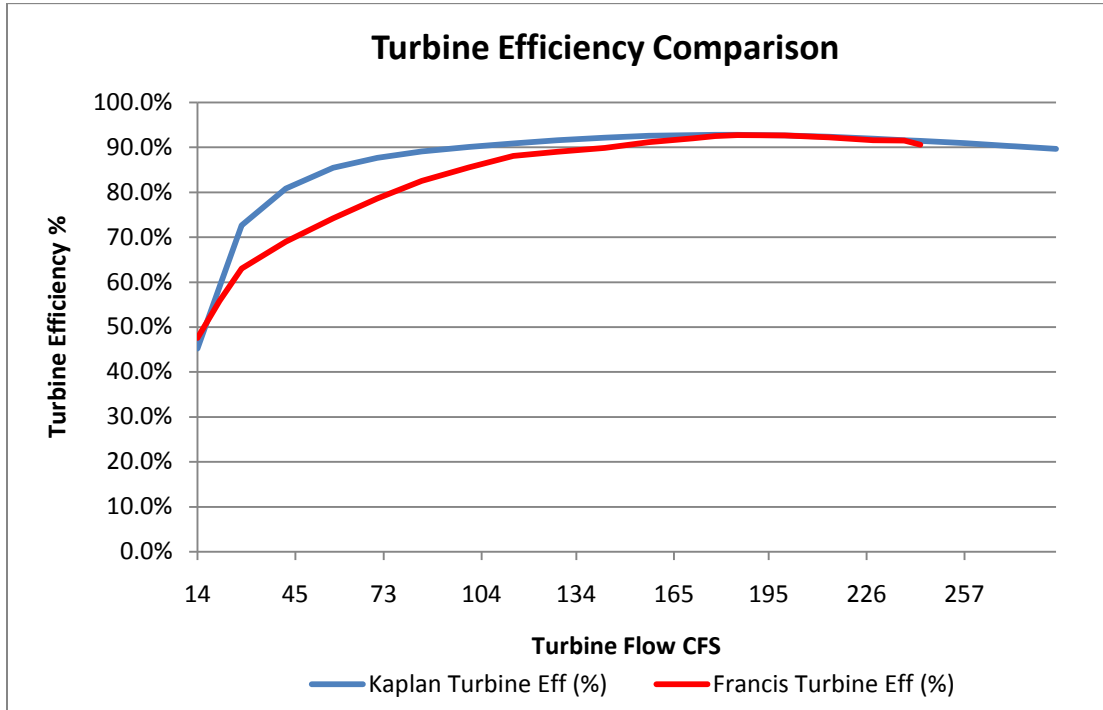


Figure 8. Francis and Double Regulated Kaplan Efficiency Curves

Various license conditions typically associated with hydro projects affect operation of the project and hence, energy production. Specific license conditions for the Ten Mile River would likely include seasonally adjusted minimum flows to maintain aquatic habitat conditions in the bypass reach, minimum flows over the dam for aeration and dissolved oxygen, fishery flows for upstream passage (attraction water and fish ladder flows) and fishery flows for downstream passage. Based on the results of our preliminary regulatory review we developed a range of anticipated license conditions for the three sites and incorporated them into the energy model. In most cases this resulted in a reduction in the amount of flow available for energy production (see Energy Estimates section).

Using the above information we calculated the gross energy production on a monthly basis and then totaled the results to develop annual estimates for each alternative. Gross generation was reduced by 5% for planned and unplanned outages and by an additional 1% for station service consumption to develop estimates of net energy production.

## Determining Installed Capacity

Results from the energy model were used to make a preliminary determination of the optimal installed hydraulic capacity at each site. Curves were developed for each site that plot annual energy production in megawatt hours (MWH) as a function of installed hydraulic capacity (flow to the turbine in cubic feet per second [cfs]), as shown below for Alternative A.

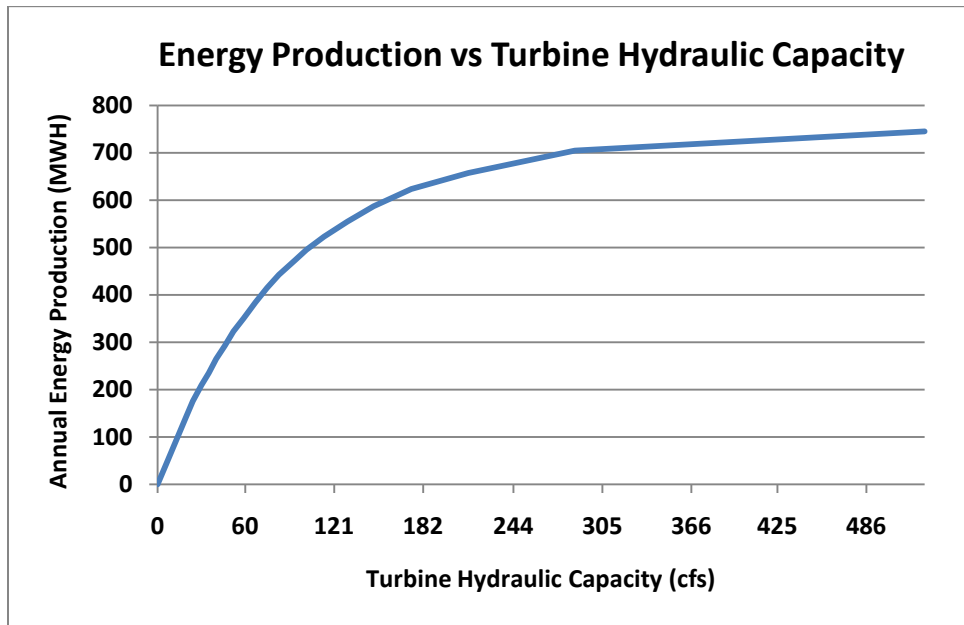


Figure 9. Annual energy production as a function of turbine hydraulic capacity for Alternative A

These curves were used in conjunction with other model outputs, particularly the calculated capacity factor<sup>2</sup> for each installed capacity. Smaller turbines (designed to operate in the lower range of the flow exceedance curve – see Figure 2) would run frequently, but would generate a relatively small amount of energy leaving a significant portion of the site’s energy potential undeveloped.

Referring to Figure 9, incrementally increasing the turbine size from ‘zero’ provides a “one for one” gain in energy production along the steep part of the curve. Absent any limiting license conditions, the costs associated with installing larger equipment are compensated for by the additional energy production and associated revenues. For hydraulic capacities greater than 60 cfs the curve begins to flatten out; indicating that incremental increases in equipment size (to capture the additional hydraulic capacity)

<sup>2</sup>Capacity Factor is the amount of energy a unit or plant actually produces over a specific time period divided by the amount of energy the unit would have produced if it operated 100% of the time. For example a 1MW project (1,000 kW) producing 4,380 MWH of energy a year would have a Capacity Factor of 50% (4,380 MWH/(1 MW x 8,760 hours)). Capacity Factor is frequently used in the power industry as a measure of a plant (or individual unit’s) utilization. For the 50% Capacity Factor example, above, the plant would be used 50% of the year and ‘sit’ idle 50% of the time.

result in smaller incremental gains in energy production. Beyond 305 cfs the curve is nearly horizontal. Increasing the installed capacity from 305 cfs to 486 cfs (62%) produces only a 50 MWH increase (7%) in energy production.

For conventional hydroelectric projects in the Northeast United States the optimal installed capacity is usually in the transition area between the steep and flat portions of the curve. Our experience with hydroelectric projects in the Northeast also suggests that a Capacity Factor in the range of 40% appears to be the limiting value for successful development (in other words, installing capacity that sits idle 60% or more of the time typically is not economic). Applying these two criteria to Alternative A suggests an installed capacity in the range of 115 cfs would be optimal for Turner.

### ***Energy Estimates***

Using the approach described above, installed capacities were selected, and preliminary energy production estimates generated for each project configuration. For configurations that involve bypass reaches (i.e. Alternatives B, C, and E), three different installed capacities were selected reflecting three different potential instream flow requirements. Annual energy production estimates for each site configuration are shown in the table below.

#### ***Preliminary Annual Energy Production Estimates***

<i>Site</i>	<i>Head (FT)</i>	<i>Annual Energy Potential (MWH)</i>		
		<i>Standard Instream Flows</i>	<i>Half Instream Flows</i>	<i>No Instream Flows</i>
<b>Turner</b>				
A	14.5	720	same	same
B	22.0	460	630	1,050
C	38.0	830	1,140	1,890
<b>Hunt's</b>				
D	8.5	400	same	same
E	23.5	520	720	1,180
<b>Omega</b>				
F	8.0	380	same	same

Energy production estimates range from 380 to 1,890 MWH depending on the site and the instream flow scenario. Estimates for Alternatives A, D, and F are the same for each Instream Flow scenario because these alternatives involve releasing water directly below the dam and therefore will not require instream flow releases. It is possible that the regulatory agencies may require some flow be released over the spillway (not run through the turbine) to maintain dissolved oxygen levels in the river, or for aesthetic purposes.

For those alternatives with bypass reaches (B, C, and E) assumptions regarding instream flows have a significant impact on energy production (see table above). This impact is shown graphically in Figure 10 below, which illustrates the difference in power production potential with and without the Rhode Island Modified Base Flow standard.

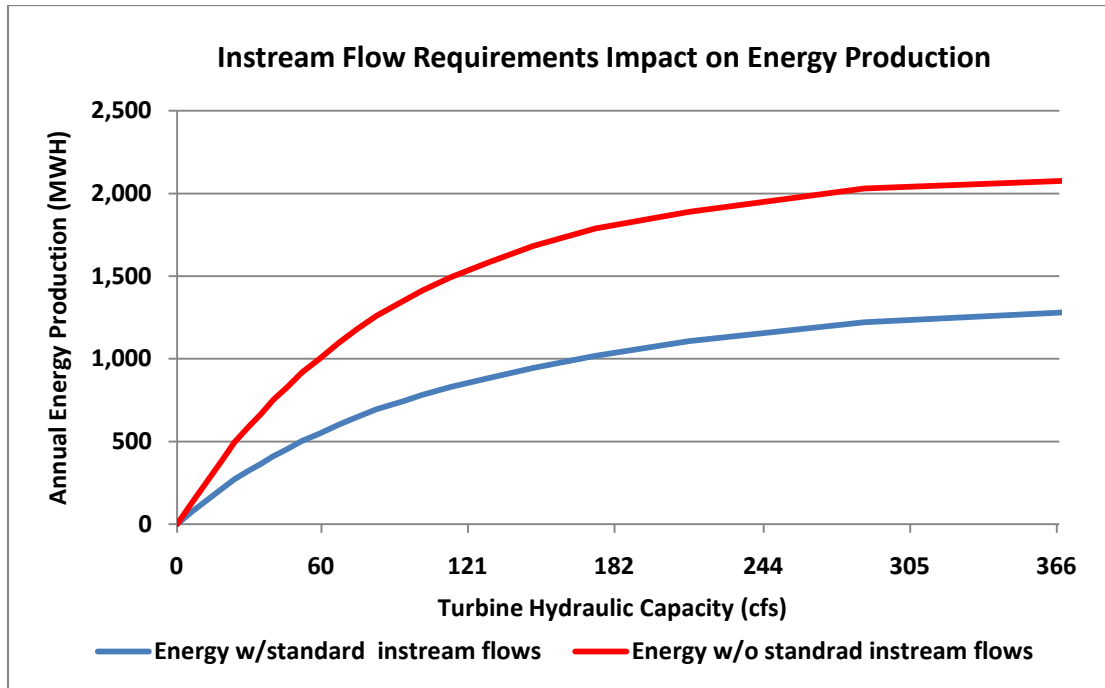


Figure 10: Comparison of installed capacity and annual energy production (using Alternative C as an example).

While it is not realistic to assume a development with no instream flow requirement, the analysis provides a basis for comparison and illustrates the potential up-side that could be achieved by conducting site-specific studies to establish a site-based compliance standard. The analysis also underscores the value of working with the State to develop site-specific instream flows that very likely would be less than the standard desk-top approach.

The existing Rhode Island Modified Base Flow Methodology is extremely conservative and in some cases reflects a requirement of more water in the river than currently occurs under natural, unregulated conditions. The energy estimates shown with the assumption of “half instream flows” reflect a “middle of the road” approximation of what may be possible if site-specific studies were conducted to determine a resource specific instream flow requirement.

## Equipment Selection

The following briefly describes the turbine equipment selected and evaluated for each of the sites and configurations considered. For the purpose of this study, we evaluated new turbine equipment as well as options for repowering or restoring the existing turbine and generator equipment at Hunt's Mill (as described below).

### Double Regulated Bulb Turbines

For those alternatives that would involve installation of a new powerhouse located at an existing dam (Alternatives A, B, D, and F), we assumed horizontal, double regulated Kaplan turbines (commonly referred to as Bulb Turbines).

Benefits of this equipment option include; potential for eliminating a bypass reach and associated turbine flow restrictions, high energy conversion efficiency (~92%) and the ability to operate efficiently over a broader range of flow conditions. Drawbacks associated with these units compared to simpler equipment such as Siphon turbines include higher equipment costs and typically more civil construction requirements. Based on our recent experience with similar low head projects in Rhode Island, Bulb turbines tend to be more economic than other simpler options. The additional energy production achieved by the more efficient bulb turbines helps offset other fixed development costs such as licensing. A typical cross section of a bulb unit installation is shown below.

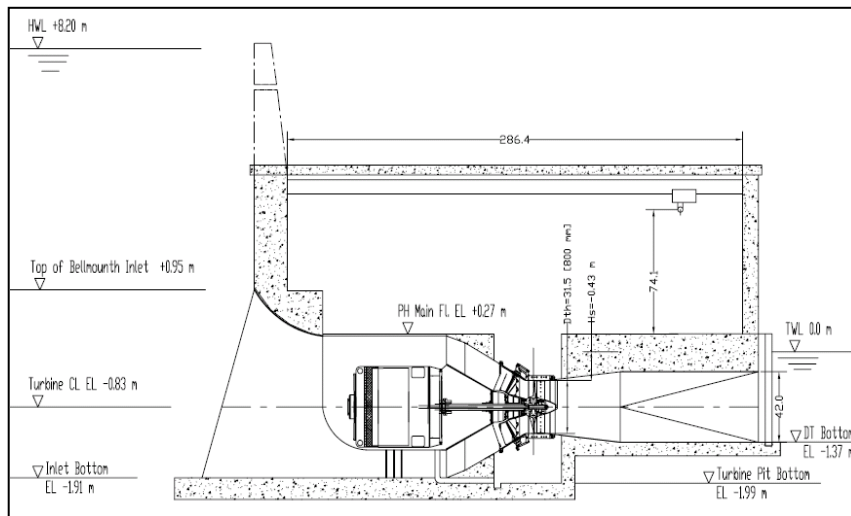


Figure 11. Schematic of a typical bulb turbine installation.

Depending on the site, and assumed instream flow scenario (which affects the assumed hydraulic design capacity); we selected different turbine runner diameters to optimize the utilization of the units given the site characteristics and available flow for generation.

## Vertical Kaplan and Francis Turbines – Hunt’s Mill

Three equipment alternatives were considered for the Hunts Mill site:

1. New double regulated vertical Kaplan turbine,
2. Repowered Francis turbine, and
3. Restored Francis turbine.

New development assumes installation of a new, state-of-the-art double regulated vertical Kaplan turbine and associated generator set. This alternative represents the greatest energy production at the site because of the efficiency benefits associated with new technology. The repowered Francis alternative costs less than the new Kaplan alternative and produces almost as much energy. A typical cross section of a vertical Francis unit installation is shown below.

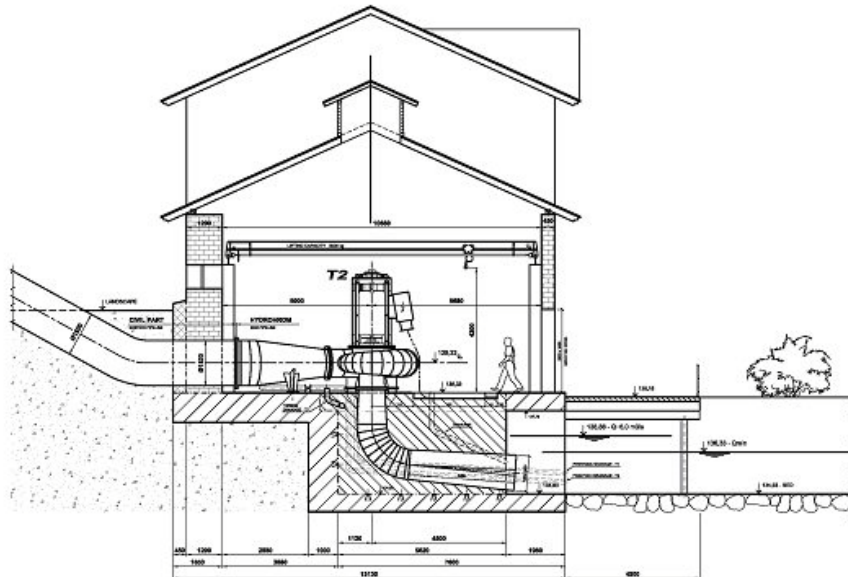


Figure 12. Schematic of a typical Francis turbine installation.

The Repowered case assumes that the existing turbine would be replaced with a modern Francis runner as described in more detail in the Hunt’s Refurbishment section of this report. Under this alternative, the energy production potential of the site would be higher than the existing nameplate due to the efficiency benefits of the modern design runner.

Under the Restored case, we have assumed that the existing unit at Hunt’s Mill would be restored to its original operating condition. Under this alternative the installed capacity would be approximately the same as the unit’s existing generator nameplate rating (approximately 150 kw) and that the unit would produce approximately 450 MWH per year of energy. To verify the accuracy of our energy model, we calibrated the model input to reflect a headloss condition and equipment efficiency reflective of the existing configuration and equipment (3-ft maximum headloss and a peak efficiency of 80%) and



calculated the installed kW capacity. Our modeled estimates were very close to the nameplate rating on the existing generator (147 vs. 144 kW). This tended to confirm the calibration of our preliminary energy model.

We did not run a Restored case for Alternative C (water delivered from Turner Reservoir to Hunt's Mill) because published reports indicate that the existing equipment was designed for 23.5-ft. of hydraulic head. It is difficult to predict how or if the unit would operate under a significantly larger head (38-ft.).

## Electrical Interconnection

All of the hydro development options studied will require interconnection to the National Grid distribution system (the grid). Based on our preliminary electrical analysis each generating unit will require a 3-phase 15 kv class distribution line. The connection to National Grid will require a sectionalizing switch at the point of interconnection, three single phase pole mounted step-down transformers, and a 15 kv fused disconnecting switch. Each generator will also require its own set of service switchgear including a main disconnecting switch, generator breaker and branch circuit breakers.

Existing service at the Turner and Hunt’s Mills sites is currently single phase (220v/110v). Interconnection of hydroelectric generators would require approximately .33 and .52 miles (respectively), of upgraded (3-phase, 15-kv) service. Interconnection at the Omega Pond site could be accomplished through the installation of approximately two new utility poles to a nearby (0.05 miles) 3-phase service associated with a Narragansett Bay Commission (NBC) sewage pumping station.

At 15 kv, the projects would add approximately 8 amps to the existing distribution lines and are not likely to overload the circuit or require additional upgrades. Conceptual alignments for the interconnections are included in the Preliminary Project Configurations provided in Appendix C.

Tabulated below are preliminary costs estimates to complete the interconnections at each site. These estimates are included in the economic analysis provided in subsequent sections.

<i>Item / Description</i>	<i>Turner Res.</i>	<i>Hunt’s Mill</i>	<i>Omega Pond</i>
13.8 kv Overhead Distribution Line	\$33,000	\$52,000	\$5,000
13.8 kv Sectionalizers	\$10,000	\$10,000	\$10,000
13.8 kv Pole-Mounted Transformers	\$30,000	\$30,000	\$30,000
13.8 kv Fused Disconnecting Switch	\$10,000	\$10,000	\$10,000
Service Switchgear	\$20,000	\$20,000	\$20,000
<b>TOTAL</b>	<b>\$103,000</b>	<b>\$122,000</b>	<b>\$75,000</b>

## Cost Estimates

Estimates for each of the alternatives were developed to reflect initial investment requirements. The cost estimates include the following specific items; civil/construction, dam repairs, licensing and permitting, equipment and controls, electrical interconnection, routine operations & maintenance and maintenance overhauls. The cost estimates also include provisions for Owner's administrative costs, legal review and counsel, as well as engineering design. A 20% contingency was added to all cost estimates cover unknowns and reflects our confidence level in the numbers at this phase of the analysis.

The civil structural costs for each alternative were derived from our recent experience at similar projects. Powerhouse civil costs for each specific alternative were calculated based on the equipment and water passage size requirements. All of the alternatives considered include an allowance for an automated trashrake at the project intake.

Cost estimates for dam repairs were developed based on the results of the preliminary dam inspection. These estimates reflect costs to bring the dams up to current standards. Provisions for on-going dam maintenance were not included as they were considered to be required whether the hydro projects are pursued or not. Costs estimates for potential dam safety remediation were not included in the economic analysis because the likelihood and exact nature of the remedial measures that may be required by FERC, if any, will depend on the findings of more detailed analysis.

Requirements for water passages (penstock sizes) to deliver water to the turbines were determined by establishing an acceptable design head loss. Since head loss is a function of velocity squared, increasing the size of water passages results in lower headlosses. For this study we sized penstock diameters based on an acceptable maximum water passage velocity of 8 feet per second (fps). Prices for the various penstock sizes were derived from vendor quotes received within the last two years for similar projects.

Equipment cost estimates are based on our experience at similar recently completed projects. Allowances were made for auxiliary electrical and auxiliary mechanical equipment. Cost for turbine/generator packages were developed using vendors quotes received within the past two years. The quotes were adjusted to fit alternative specific equipment size and configuration.

Itemized cost estimates for interconnection were developed for each site. The estimates take into account the length of the interconnecting power line, recent equipment quotes from vendors and our recent experience interconnecting projects with National Grid.

Regulatory processing cost estimates include FERC licensing as well as other non-FERC permits (i.e., Water Quality Certificate, Wetlands, etc.). Alternatives with higher complexity and/or risk were adjusted to reflect efforts to address resource concerns such as instream flows, water quality concerns, or wetland impacts. A summary of regulatory costs by alternative is tabulated below.

Alts.	Key Regulatory Drivers	Consultations (yrs)	Studies (yrs)	Regulatory Costs (\$1,000's)
A, D, F	<ul style="list-style-type: none"> <li>No bypass reach;</li> <li>No stream flow concerns, and;</li> <li>No wetland concerns.</li> </ul>	2	0.5	\$288
B, E	<ul style="list-style-type: none"> <li>Creation of bypass reach;</li> <li>Wetland impacts, and;</li> <li>Assumes acceptance of State instream flow standard.</li> </ul>	2	2	\$400
C	<ul style="list-style-type: none"> <li>Longest bypass reach;</li> <li>Highest wetland impacts, and;</li> <li>Assumes acceptance of State instream flow standard.</li> </ul>	3	2	\$450
B, E	<ul style="list-style-type: none"> <li>Creation of bypass reach;</li> <li>Wetland impacts,</li> <li>Assumes completion of site specific studies to modify instream flow standard.</li> </ul>	3	2.5	\$488
C	<ul style="list-style-type: none"> <li>Longest bypass reach;</li> <li>More Wetland Impacts, and;</li> <li>Assumes completion of site specific studies to modify instream flow standard.</li> </ul>	3	3	\$525

For alternatives that do not entail bypass reaches and penstocks (A, D, and F), we assumed minimal studies and 2 years of agency/stakeholder consultations for a total licensing and permitting cost of \$288,000. For alternatives that involve bypass reaches and wetland impacts, we assumed greater study and consultation costs resulting in a total estimated licensing and permitting cost of \$400,000 to \$488,000, depending on whether the standard RI Modified Aquatic Base Flow is accepted or site-specific instream flow studies are assumed. For Alternative C, that involves a longer bypass reach and penstock, including greater potential wetland impacts, we assumed further increases in study and consultation costs resulting in a total estimated licensing and permitting cost of \$450,000 to \$525,000 for the standard RI Modified Base Flow and site-specific instream flow cases respectively.

All cost estimates were developed based on the assumption that sites would be developed individually. Pursuing multiple sites as part of a portfolio development would likely result in economy of scale benefits.

Detailed cost estimates for each alternative are provided in Appendix E, including details on the powerhouse, water passage and equipment cost estimate calculations.

## Economic Analysis

A discounted cash flow analysis was used to evaluate the economic performance of the projects over a 20 year study period. A residual value was added to the last year of the study to incorporate the long-term, intrinsic value of the project. The model reflects a cash-on-cash, pre- tax position, as a result the predicted performance tends to be conservative. Key assumptions used in the model are listed below, detailed descriptions of the preliminary cost estimates, expected revenues, and modeled development scenarios are provided in Appendix E.

#	Input	Model Assumption
1	O&M	1.5¢/KWH
2	Payment in lieu of Property Taxes	1.5% of initial investment
3	Major maintenance	\$50k in years 5 & 15, \$125k in years 10 & 20
4	Energy Rate	\$125/MWH
5	Renewable Energy Certificates	\$25/MWH
6	State Grants	25 % of Initial Investment
7	Federal Grants	15% of Initial Investment
8	Residual Value	Net cash flow last year of study divided by the growth rate
9	Initial Investment Contingency	20% of total development costs
10	Discount Rate	5%
11	Escalation Rate	2.5%/ yr Applies to all recurring revenues and costs (O&M, insurance, energy rate, etc.)
12	Study Period	20 years

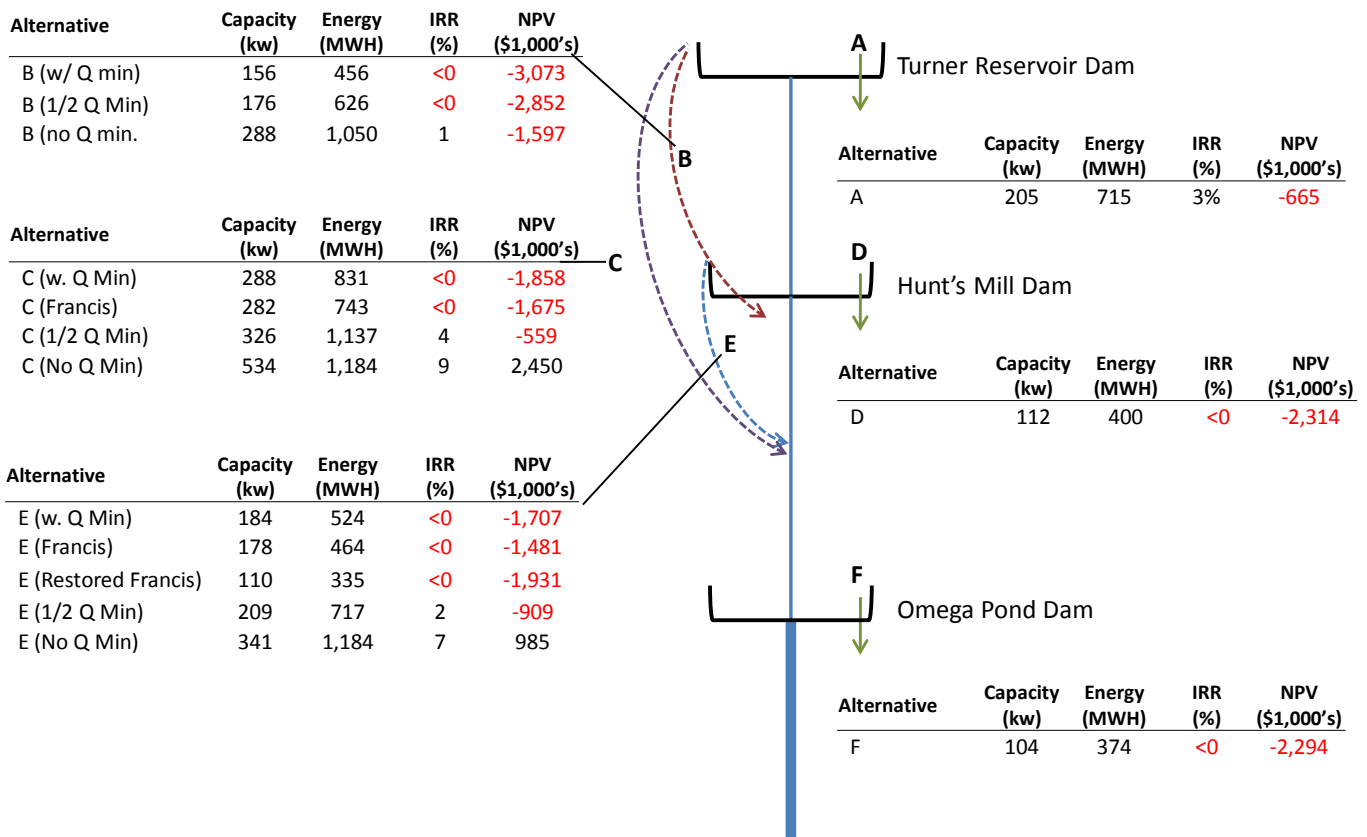
Full proformas were prepared for each alternative (Appendix E). The proformas include cost estimates for development (construction, equipment, licensing & permitting, etc.), estimates of energy production and associated revenues, and operations and maintenance costs. Based on discussions with resource agency staff and our experience with other hydropower developments, we identified environmental concerns and developed operational scenarios to reflect likely requirements for environmental protection, mitigation and enhancement measures (PM&E). Additional PM&E measures should be evaluated and incorporated on a site specific basis if development of any of the sites is pursued.

From a pure economic perspective, the preliminary results suggest that projects with a positive Net Present Value (NPV) or a positive IRR may be economically viable. The

pre-tax, all equity analysis tends to be conservative. Our experience with similar projects suggests that refining the analysis to: 1) include low cost debt (such as municipal bonds and/or Economic Development Commission loans); and 2) capture available tax benefits (Investment Tax Credits [ITC], Modified Accelerated Cost Recovery System [MACRS], etc.) tends to increase the returns on investment and make projects more attractive.

Proforma results for each of the site configurations are summarized in the tables below. For alternatives B, C, and E, which would entail bypass reaches, results are shown for multiple instream flow scenarios. Alternatives A, D, and F would be designed to capture a larger portion of river flows with only minor deductions for fish passage requirements. These alternatives would release water directly below the dams and likely would not require significant instream flows.

### ECONOMIC SUMMARIES BY ALTERNATIVE



\* Q Min refers to the Standard RI Instream Flow requirement. Model sensitivities that assume modified Q Min requirements are noted using this shorthand.

Based on the economic input assumptions used (as described above), alternatives A, C, and E represent potentially viable options, depending on regulatory requirements.

Alternative A, which would entail constructing a turbine at the Turner Reservoir Dam, provides a slightly positive Internal Rate of Return (3%) on a cash-on-cash basis. The alternative captures a large percentage of flow (would be less constrained by environmental requirements) with a relatively moderate amount of head (14.5 feet). The Net Present Value (NPV) is slightly negative because the rate of return is less than the assumed discount rate of 5%, suggesting that revenues would not quite cover the City's cost of money (on an all-equity basis).

Alternative C, which would involve diverting water from Turner Reservoir to the historic Hunt's Mill powerhouse represents the greatest amount of head (38 feet) but is not economically attractive under the RI Modified Base Flow scenario because the instream flow requirement significantly limits the amount of flow available to the turbine for generation. Under the "half min flow" scenario the alternative becomes more attractive (due to the availability of more flow) providing an IRR of 4% and a slightly negative NPV. Under the "no min flow" scenario, the value of Alternative C increases significantly providing a 9% IRR and a positive NPV of over \$2.4 million. This suggests that there is significant upside potential associated with this alternative if the instream flow requirements can be reduced through site-specific studies and agency consultations.

Alternative E, which would utilize the historic hydropower alignment diverting water from the Hunt's Mill Dam to the old Hunt's Mill powerhouse, provides a 2% IRR under the "half min flow" scenario and a 7% IRR, with just under a \$1 million NPV, under the "no min flow" scenario. As with Alternative C, results suggest that there is significant upside potential if the instream flow requirements can be reduced.

Development at Omega Pond Dam (Alternative F) does not appear economically viable, largely because of low average head (8 feet).

Of the potentially attractive alternatives, Alternative A represents the easiest and quickest option from a regulatory processing and regulatory risk perspective. The alternative does not involve a bypass reach or any penstock alignment issues. Uncertainties associated with FERC dam safety should be investigated further.

Alternative E reflects the next best option in terms of regulatory process and risk. The alternative would be more complicated and take more time than Alternative A due to the bypass reach and wetland impacts associated with restoring the historic Hunt's Mill Powerhouse tailrace.

Alternative C would be the most complex with the greatest amount of regulatory risk because of its long bypass reach and penstock, including wetland impacts along the river (depending on the instream flow), along the penstock route, and associated with the restoration of the historic Hunt's Mill powerhouse tailrace.

Of the options evaluated for the Hunt's Mill powerhouse site, Alternative E which would redevelop the existing powerhouse with a new, modern designed turbine appears to hold the most promise. A significant upside to this configuration is the potential reuse of existing civil features and infrastructure. Model results indicate that the economics of this alternative are sensitive to instream flow standards suggesting that environmental flows are a significant factor in overall economics. A more detailed optimization analysis of this alternative which would refine and balance generating equipment options with instream flow requirements is a logical next step.



## Summary of Findings

Key findings from the feasibility study are summarized below. Findings regarding economic viability reflect an all-equity analysis with no consideration of possible tax treatments or financial leveraging. This approach tends to be conservative. Where there was uncertainty, we also tended to make somewhat conservative assumptions to help avoid unpleasant surprises.

### Dam Conditions and Suitability for Hydro Development

- The existing dams appear to be in good overall condition. Based on visual inspections, there appears to be nothing that would preclude hydropower development. With proper care and maintenance customary to the hydro industry, all three dams can reasonably be expected to last a long time (i.e., equal to or greater than life of the hydro project).
- Published reports indicate that the hydraulic capacity of the Turner Reservoir Dam spillway may be inadequate. This issue should be investigated further, to verify this condition and identify remedial measures and costs to address any deficiencies before investing significant resources in any hydropower development.

### Electrical Interconnections

- Interconnection of hydroelectric generators at each of the sites would require less than one mile of upgraded (3-phase, 15-kv) service.
- At 15 kv, the projects would add approximately 8 amps to the existing distribution lines and are not likely to overload the circuit or require any significant upgrades.

### Developments Integral with Dam (No Bypass)

- Generating potential (function of head and flow) appears to be the single most significant limiting factor associated with options to develop hydropower directly at the dams. Only Turner Reservoir Dam (Alternative, A), appears potentially economic.

Alt	Head	IRR
A	14.5-ft	3%
D	8.5	<0
F	8.0	<0

- Development of configurations involving less than 10-ft of head does not appear economic as they do not produce enough revenues to offset threshold development costs.
- Developments that are integral with a dam would not entail a river bypass reach and thus would not be subject to minimum instream flow requirements, with the exception of small releases to accommodate fish passage and water quality. These developments are able to utilize more of the river's available flow and would generally be easier and quicker to license.

### **Development of Combined Sites (River Bypass)**

- None of the alternatives involving a river bypass reach are attractive with full RIDEM standard minimum flow requirements.
- With half of RIDEM standard minimum flow, two Alternatives, C & E appear potentially attractive.
- With no minimum flow, Alternatives C & E become very attractive. These results suggest that spending money to conduct site specific instream flow and water quality studies would be warranted to establish a minimum flow less than the RIDEM standard.
- Alternative C (Turner to Hunt's Mill powerhouse) is slightly more attractive than Alternative E (historic Hunt's mill alignment), but has over twice the bypass reach and twice the wetland impact. Because of potential environmental concerns, Alternative C would likely take longer to license and would involve a higher degree of risk.
- A reasonable strategy would be to proceed with Alternative E as the preferred option (possibly in combination with Alternative A). If studies and agency consultations indicate that a 'reasonable' minimum flow is possible for Alternative C, it could become the preferred option.

### **Re-Development of Hunt's Mill**

- Repowering the existing hydropower unit at Hunt's Mill with a modern design Francis runner appears slightly more attractive than constructing a new powerhouse with a new Kaplan unit. This approach takes advantage of existing infrastructure, avoids the cost of powerhouse construction, and reflects lower overall equipment cost.
- A logical next step would be to conduct an optimization analysis to further refine and balance equipment options with respect to instream flow requirements.

### **Omega (Alternative F)**

- As a stand-alone redevelopment, Omega Pond Dam does not appear economic.
- Additional analyses that look more specifically at a combined development, including factors such as load proximity and refined equipment selection could affect these preliminary results and may be warranted.

