FEASIBILITY STUDY
HYDROELECTRIC FACILITY DEVELOPMENT AT PATTISON STATE PARK
SUPERIOR, WISCONSIN

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Prepared for: Wisconsin Department of Administration
Division of Energy

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Introduction

This study shall investigate the feasibility of hydroelectric generation within the confines of the Pattison State Park. The study is delineated into six sections that examine the energy potential, technical feasibility, economic benefits, regulatory and environmental issues, cost estimates, and conclusion. Appended to this study is a RETScreen® Energy Model for Small Hydro Projects and supporting documentation.

Energy Potential

To determine the energy potential at this site it was necessary to synthesize a flow duration curve. A flow duration curve is a graphical representation of stream flow against the percent of time the indicated flow was equaled or exceeded during the period covered by the available flow data. A stream flow gauging station on the Black River near the Pattison State Park does not exist. The nearest and only USGS stream flow gauging station on the same watershed is Station 04024430 on the Nemadji River near South Superior, WI. This station is located in Douglas County @ 46^o38'00" (46.63334) N, 92^o05'38" (92.09389) W with the following characteristics:

- Drainage area: 420 mi^2
- Gauge datum: 601.13 ft. above sea level
- Calculation period: 1973-10-01 to 2006-09-30
- Type: daily-mean

In accordance to general accepted practices[1] for determining the flow at an ungauged location the following equation was used:

Q_{site} = [drainage area of site / drainage area of gauge]^n Q_{gauge}
where:
Q ≡ Flow in ft^3/s (CFS)
n ≡ exponent
The drainage area of the site is 76.7mi^2, which represents about 18% of the gauged site. Therefore, a simple relationship of 1 for the value of n can not be used since the drainage area site is not within 20% of the gauged drainage area. To determine the approximate value of n the flow across the Armco 28' x 4' gate at the Pattison Dam was determined. Using the classical formula for broad-crested weirs i.e:

$Q = CLH^{3/2}$
where:
C ≡ flow coefficient
L ≡ length of gate (ft)
H ≡ Head (ft)
Q ≡ Flow in ft^3/s

The value of C was found from test results of similar broad-crested weir data[2] that matched the characteristics of the roller gate at the dam. C = 2.64, given a head between 0.4 to 0.6 and a breadth of crest of weir at 1.5 feet. By substituting the appropriate values of the variables with:
L = 28' (from existing drawings of Armco gate)
H = 0.5' (measured value of head before contraction at gate, which also corresponds to gate opening on 6 June 2007 of 6" out of 48" available.
Observed nappe: Depressed
The flow Q was calculated to be 26.13 ft^3/s

This data was correlated with the mean discharge of Station 04024430 on the same date, which was 217 ft^3/s, to approximate the value of n as 1.24. Typical values of n range between 0.6 and 1.2 therefore, n is within the acceptable range considering the large discrepancy of drainage areas.

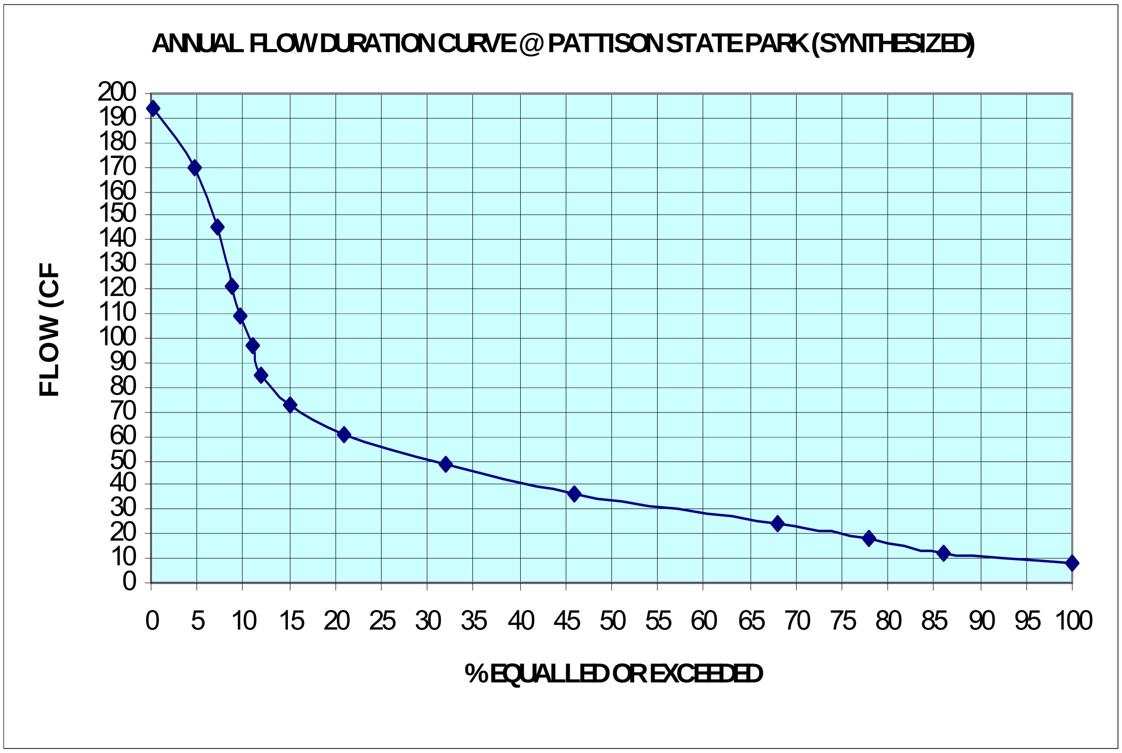
The derived equation to represent flow at the Pattison dam as a function of Q_{gauge} is:

$$Q_{site} = [0.182619^{1.24}]\, Q_{gauge}$$

TABLE 1 FLOW DURATION DATA DAILY MEAN VALUES

USGS 04024430		Pattison Synthesized		Pattison Estimated via curve fit algorithm	
CFS	% flow equaled or exceeded	Adjusted CFS	% flow equaled or exceeded	CFS Determined by formula R^2=0.982	% flow equaled or exceeded
1,600	0.3	194	0.3	209.29	0
1,400	4.7	170	4.7	151.16	5
1,200	7.1	146	7.1	109.51	10
1,000	8.8	121	8.8	80.78	15
900	9.6	109	9.6	61.90	20
800	11	97	11	50.23	25
700	12	85	12	43.58	30
600	15	73	15	40.16	35
500	21	61	21	38.53	40
400	32	49	32	37.59	45
300	46	36	46	36.56	50
200	68	24	68	34.94	55
150	78	18	78	32.45	60
100	86	12	86	29.07	65
70	100	8	100	24.93	70
				20.34	75
				15.75	80
				11.68	85
				8.75	90
				7.60	95
				8.89	100

FIGURE 1



The curve fit algorithm to best fit the flow duration curve is a 5th order polynomial. In order to increase the accuracy of the data used in the model values were entered by graphical determination due to some areas of divergence. This graphical representation is shown in the appendix of this study which includes the formula for flow as a function of % time equaled or exceeded.

Information on elevations where extracted from plans prepared by Ayres Associates, Project No. 97942 dated 11-18-98

Road Grade Elevation: 983.8
Normal Pool Elevation: 976.5
Gate Elevation: 976.5
Tail Race Slab Elevation: 964.0

The earliest plans found dated 5-6-54, drawing number 8M-228 show elevations as:

High Water Elevation: 81.5
Normal Pool Elevation: 77.5
Stream Bed Elevation: 65.0

In either case the gross head from normal pool elevation to stream bed or tail race is 12.5 feet. The dam has a 32” diameter corrugated metal low level pipe from the lake that empties into the north wall section. The flow of water through this pipe is controlled by a sluice gate mounted to the wall and operated from the platform above. This dam is classified as high hazard, but it has sufficient spillway capacity for a 1,000 year flood flow condition. The structure height of the dam is 20 ft. Other related data of the Interfalls Lake created by the Pattison Dam is:

- Area: :27.16 Acres w / islands
- Lake area: 26.7 Acres
- Lake depth:<3ft: 3%
- Lake depth >20ft: 0%
- Lake maximum depth: 13ft
- Shoreline: 1.6miles
- Volume:179.9 acre-ft

The most effective location for hydroelectric generation is directly north of the spillway gate between the dam and the Highway 35 Bridge. This location has nearly no impact on the aesthetics of the area or any structural impact on the bridge. The estimated gross head that can be obtained from this location is 12.5 feet. A purely pragmatic approach without regards to maintaining the Big Manitou Falls would be to divert the water from the lake and locate the hydroelectric facility at the bottom of the falls. This location increases the power output by a factor of about 50 times of that of the location near the dam. For obvious reason this is not an option, but a means to illustrate the effect head has on the power output. With that said, the dam site has the potential of extracting approximately 160 MWh with a design flow of 30 CFS at 12.5 feet of gross head equating to an output of 25 kW. The turbine type that best utilizes the available head and economics is a fixed blade propeller. Permissible operating range of a propeller turbine is 110% maximum and 90% minimum[3].

Current operating procedures require the water level of Interfalls Lake to be lowered 30 inches typically starting the first week in October. The drawdown under normal fall low flow conditions is 16 inches per day in four inch increments at approximately two hour intervals. Under abnormally high water conditions the gate may be lowered as much as six inches per operation per hour.

Refilling the impoundment generally takes place when the snowmelt runoff has diminished and grading of the beach area has been completed. The occurrence of this is ordinarily in late April. The rate of filling will depend upon the volume of water passing through the spillway. This rate of filling shall be in two hour intervals with the gate raised no more than eight inches per lift. However, raising the gate shall not reduce the flow to less than four inches over the top the gate.

Based on the above information provided by the Wisconsin Department of Natural Resources the power output of the hydroelectric facility will be impacted by the existing operation plan. In order to maximize the efficiency of the turbine for the two operating heads a manually adjustable blade pitch is proposed. Unit output during the lowered head times shall be reduced by approximately 28%. Table 2 illustrates the flow and the number of days that are affected by this operational procedure.

TABLE 2 Mean Monthly Flow with Days @ 10 Feet of Gross Head

Month	USGS 04024430 Monthly Mean Flow (CFS)	Pattison Synthesized Monthly Mean Flow (CFS)	Days /Month	Days @ 10 feet Head
January	83	10	31	31
February	99	12	28	28
March	435	53	31	31
April	1380	168	30	23
May	604	73	31	0
June	468	57	30	0
July	339	41	31	0
August	207	25	31	0
September	300	36	30	0
October	319	39	31	24
November	293	36	30	30
December	140	17	31	31
Annual Mean	388.92	47.23		
Total			365	198
% time @ 10' Head:	54.25%			

A weighted average of the flow and head was calculated to view the impact on energy output. Table 3 illustrates that the energy split is nearly 50% / 50% although the percentage of time operated at the 10 feet head level is 54.25%.

TABLE 3 Monthly Energy Output %

Month	Weighted average 10' Head	Weighted average 12.5' Head
January	1.81%	
February	1.95%	
March	9.50%	
April	22.36%	6.80%
May		13.19%
June		9.89%
July		7.40%
August		4.52%
September		6.34%
October	5.39%	1.57%
November	6.19%	
December	3.06%	
Total Average	50.27%	49.72%

The weighted average of the gross head is 11.14 feet. The hydraulic model (Pattison RET **Iteration 1**) has been adjusted to reflect this gross head resulting in an annual energy output of approximately 139 MWh and plant capacity of 22 kW. This model shall be used to estimate the basic economics of the project without regards for other restraints.

Technical Feasibility

A sketch of one of the possible locations is shown below. The sketch is for illustrative purposes only and is not to scale.

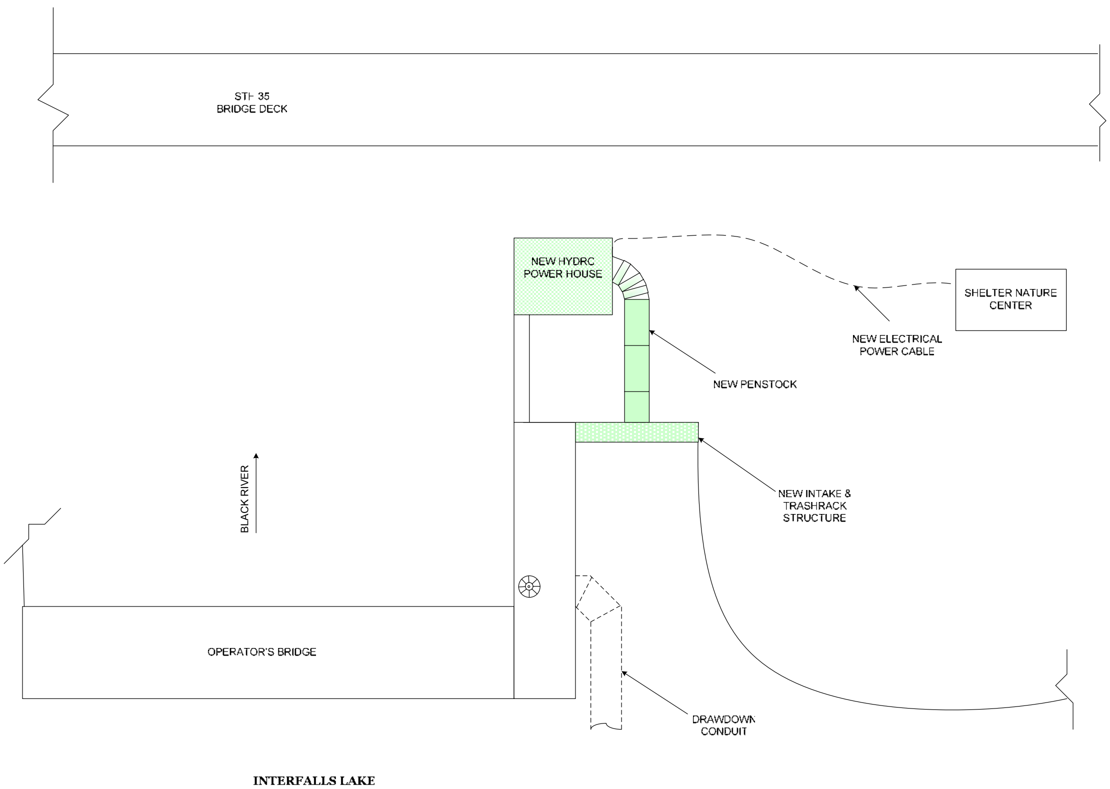


FIGURE 2 **PROPOSED HYDROELECTRIC FACILITY LAYOUT (not to scale)**

The proposed facility shall require modifications to the existing dam. This shall entail the addition of an intake structure with walkway, head gate, and trashrack for debris removal. Water shall be conveyed to the power house via a 32 inch diameter penstock. The penstock shall deliver the water to the turbine equipped with wicket gates for flow control. The water through the turbine is discharged by way of a draft tube into the tailrace. Due to the normal low tailrace water elevation a plunge pool shall be necessary.

Several turbine manufactures were contacted as shown in Table 4. The investigation also reviewed some newer technologies, but found that they were not into commercial operation. Therefore, data used in the study was based on a turbine being supplied by Canadian Hydro Components Ltd (CHC). The turbine efficiency information used the standard efficiency curve data from the model and then modified per information supplied by CHC. This turbine is a 500mm diameter model with a manually adjustable pitch blade to accommodate the 10 to 12.5 feet gross head variation. The manufacturer initially calculates the speed of the turbine will be 720 r.p.m., meaning that the generator could be direct connected to the turbine.

TABLE 4 Turbine Manufacturer List

No.	Manufacturer	Comments
1	American Hydro Corp. 135 Stonewood Rd., P.O. Box 3628 York, PA 17402 USA	Unit too small for this manufacturer.
2	Canadian Hydro Components Ltd. 16 Main St., P.O. Box 640 Almonte, ON K0A 1A0 Canada	Proposed an adjustable propeller turbine.
3	HydroGeneration Ltd. Wimberley Mills, Knapp Lane Brimscombe, Stroud, Gloucestershire GL5 2TH UK	Pending
4	Dependable Turbine Ltd. 17930 Roan Place Surrey, BC V3S 5K1 Canada	Does not have a standard unit to fit this application.
5	The James Leffel & Co. 1978 Commerce Circle Springfield, OH 45504 USA	Proposing a propeller or Francis turbine.
6	VA Tech Hydro 115 Central Avenue West Caldwell, NJ 07006 USA	Unit too small for this manufacturer. Recommended Canadian Hydro Components Ltd.

An induction generator is proposed for this site due to the generator size, lower cost, and simplicity in operation. The generator shall be designed to operate connected to the utility grid. No isolated operation is anticipated, since the firm capacity is between 2 and 3 kW.

The building housing the turbine / generator shall contain low voltage switchgear, a hydraulic actuator for the turbine's wicket gates, control and protection panel, isolation transformer, auxiliaries, and ventilation equipment. The location of the building will require it to be a masonry structure.

Economic Benefits

The park is serviced by 7 separate electrical services provided by East Central Energy of Braham, Minnesota. The services are listed as:

Meter No.	Description
2012626-00	Shower Building
2012625-00	Pump House
2012629-00	Shelter Building
2012632-00	Shop
2012899-00	Office
2012948-00	Forestry Garage
2060500-01	6294

According to State Park Officials the estimated yearly energy consumption is 48,000 kWh. This appears to be a valid estimate of usage and is in line with Table 5 data. In the calendar year from January 2006 to December 2006 the total usage was 48,120 kWh. Unless the park is planning on an expansion, a conservative estimate of energy usage has been taken at 50,000 kWh per year. Therefore, the proposed hydroelectric plant would be possible, on average, to sell back into the grid 89 MWh (139 – 50 MWh) of energy and eliminate its electrical cost, except for the cost of basic service of $14.00 / month x 7 meters x 12 months which equals $1,176.00 annually.

In discussions with Mr. Greg Kvasnicka of East Central Energy (ECE) there is an agreement for distributed generation in place as directed by the Wisconsin Public Service Commission (WI PSC) to buy back power at the current blended rate of 9.27 cents /kWh for single phase power and 5.84 cents for three phase power provided the system is rated under 20 kW. To take advantage of net metering "average retail rate" the system output would have to be fed through one of the existing services at the park. There is a one time charge of $400 for the net metering package and a meeting with ECE's engineering department would have to take place to insure the existing infrastructure is adequate.

If the park wishes to sell power greater than 20 kW than a negotiated rate with Great River Energy of Minnesota would need to take place. The power output as determined from the first energy model (RET Iteration 1) is 22 kW, the model was adjusted to produce 20 KW in the final analysis (RET Final). From past experience a negotiated rate (typically a utility's avoided cost rate) will not be as good as the net metering rate offered by ECE. Therefore, it is best to limit the output to be in compliance with the 20 kW or less distributed generation interconnection agreement. This will also eliminate the additional cost for interconnecting the generator at 7.2 kV into the distribution system. The impact by reducing the power output will be about 6 MWh (139-133 MWH) per year.

Based on this finding the hydroelectric facility could be connected to the Shelter Nature Center via a low voltage (240 V) underground cable. The current delivered from the generator would be approximately 90 amperes and would be adequate for a standard 100 Ampere service.

TABLE 5 Energy Usages at Pattison State Park (Jan-2005 through Aug-2007)

Service Meter	2012625	2060500	2012948	2012899	2012632	2012629	2012626	Total
	Usage (kWh)							
Aug-07	861	128	64	1494	327	1324	6640	
Jul-07	722	107	64	1146	241	985	5200	
Jun-07	545	56	74	738	230	721	4160	
May-07	219	16	96	426	200	39	0	
Apr-07	107	36	107	369	169	22	0	
Mar-07	67	84	96	406	194	37	0	
Feb-07	80	46	117	470	224	0	0	
Jan-07	111	24	116	406	191	2	0	
Dec-06	217	29	127	380	197	0	400	
Nov-06	293	8	117	414	208	10	480	
Nov-06		6						
Oct-06	564	29	75	691	206	559	5440	
Sep-06	775	95	50	1097	244	1204	4800	
Total	4561	664	1103	8037	2631	4903	27120	49019
Aug-06	953	132	64	1924	294	1266	6560	
Jul-06	770	66	49	1302	223	1151	5520	
Jun-06	513		48	763	232	932	2160	
May-06	172		58	396	186	79	400	
Apr-06	142		84	325	191	63	0	
Mar-06	107		86	374	227	43	0	
Feb-06	137		94	333	206	0	0	
Jan-06	142		90	336	212	0	0	
Dec-05	167		65	372	228	1	240	
Nov-05	312		44	406	195	31	720	
Oct-05	519		71	757	249	59	4160	
Sep-05	766		74	1059	294	1151	5280	
Total	4700	198	827	8347	2737	4776	25040	46625
Aug-05	864		78	1921	339	1379	6800	
Jul-05	633		61	1078	278	1157	4560	
Jun-05	351		80	800	239	740	3520	
May-05	182		128	572	313	43	320	
Apr-05	167		108	380	215	21	160	
Mar-05	86		105	312	205	0	0	
Feb-05	125		112	451	332	5	0	
Jan-05	249		107	420	267	1	0	
Total for 8 months	2657	0	779	5934	2188	3346	15360	
Estimated total	3985.5	0	1168.5	8901	3282	5019	23040	45396
Three year average								47013

The Wisconsin Act 141 compels the State of Wisconsin to lead in the purchasing of renewable electricity. It mandates that 10% of all electricity used by state agencies comes from renewable resources by 31 December 2007. This shall increase to 20 percent by the end of December 2011 (Wis. Stat. 16.75(12)(b), 2005. These goals were established for the overall consumption of electricity at state government facilities, but each facility individually is not required to meet this objective.

Act 141 defines water power as a “renewable resource”, so the proposed hydroelectric facility at the Pattison State Park would comply. The legislature also specifies that the renewable electricity can come from renewable resources owned by the state and produced for use in the state agency (Wis. Stat. 16.75(12)(c), 2005.

A review of subsection (d) of Wis. Stat. 16.75(12) permits any or all state agencies (as represented by DOA) not to purchase or generate electricity from a renewable resource if “the generation or purchase is not deemed feasible or cost effective”.

Regulatory and Environmental Issues

Determination of whether this proposed hydroelectric project should have Federal Energy Regulatory Commission (FERC) licensing requirements is explained as follows:

Section 23(b)(1) of the FPA (Federal Power Act) requires that each non-federal hydroelectric project, except those with pre-1920 federal permits that are still valid, must be licensed if it: (1) is located on navigable waters of the United States; (2) occupies lands of the United States; (3) uses surplus water or water power from a government dam; or (4) is located on a body of water over which Congress has Commerce Clause jurisdiction, was constructed or modified after August 25, 1935, and affects interstate or foreign commerce. An owner of a proposed hydroelectric project must file a Declaration of Intention with the Commission to determine if the proposed project requires licensing. The owner of an unlicensed operating hydroelectric project would file a Petition for Declaratory Order. If the owner of a potential project does not want a jurisdictional determination, he must either file an application for a preliminary permit or file an application for a license or exemption. The DHAC (Division of Hydropower Administration and Compliance) determines jurisdiction for unlicensed projects.

The proposed Pattison Hydroelectric Project would not have any of the 4 items mentioned above to be true statements; therefore no federal licensing would be required. The next step would be to have the State of Wisconsin prepare and file a Preliminary Permit Application. The content of a Preliminary Permit Application must include an initial statement, a verification statement, and four numbered exhibits. An excerpt from the “Hydroelectric Project Handbook for Filing other than Licenses and Exemptions” by FERC, April 2001 is shown below illustrating the inclusions.

The initial statement must contain information about the applicant, the project, the requested term of the permit, affected political jurisdictions, and a verification of the facts presented. 18 CFR 4.32 and 4.81(a)

The verification statement contains the signature of a Notary Public or other authorized official verifying that the information contained in the application is true. 18 CFR 4.32 (a)(4)

Exhibit 1 must describe the proposed project. The description contains four items: (1) a characterization of the project structures, reservoir, and transmission facilities; (2) estimates of energy and capacity; (3) identification of affected United States lands; and (4) other information demonstrating how the proposed development of the water resource would be in the public interest. 18 CFR 4.81(b)

Exhibit 2 must describe project studies, either completed or planned, for assessing project feasibility, determining environmental impacts, and preparing the application. When the proposed project involves constructing a new dam, additional detail must be included about proposed test pits, borings or other foundation explorations, with particular regard to reducing adverse environmental impact during the explorations. 18 CFR 4.81(c)

Exhibit 3 is a statement of costs and financing that must provide an estimate of the costs of doing the project studies described in Exhibit 2, the source of funding for these studies, and a description of the anticipated market for the power to be generated by the proposed project. 18 CFR 4.81(d)

Exhibit 4 must include maps that clearly show the location of the project, the location and relationship of the principal project features, a proposed boundary for the project, and any areas with special protected status under the National Wild and Scenic River System or Wilderness Act. 18 CFR 4.81(e)

Due to the size of the proposed project and the economics that are disclosed later in this study, it is most likely that the state would be the only interested party. This would also be a project that would be self regulated by the state.

Interfalls Lake is predominately populated with fish species such as suckers, minnows, and bullheads. The lake is almost void of gaming species and no stocking program is currently in place. It is not anticipated that the proposed hydroelectric facility would impact any desirable fish population.

The proposed hydroelectric facility would have little impact on the natural scenic beauty, since the location preliminarily selected is between the dam near the spillway gate and the state highway 35 bridge. Although, this area selected is not a primary scenic area it could provide an educational attraction for the park visitors in renewable energy.

Cost Estimates

The cost of the proposed project was performed via the RETScreen modeling software and check against estimated costs of the electro-mechanical equipment. The model appears to be within an acceptable cost for conventional hydroelectric technology. To develop this project an initial cost of $311,267 was estimated. The cost analysis section of the RETScreen program provides a detailed schedule of initial and reoccurring costs. The final version of this analysis should be used, since iteration 1 of the model does not take into consideration the restrictions on output to achieve a higher buy back rate. A detailed engineering specification would be necessary to more fully develop the actual cost by way of a bidding process for the equipment and civil works to be performed.

The cost analysis assumed that the state would file the required FERC documents and because of their limited scope, the cost of development was reduced by 50% of what the model calculated. It was also assumed that the O&M (Operation and Maintenance) would be performed mainly by existing personnel. The cost of the plant included a fully automated run-of-the-river project except for the cleaning of the trashracks and operation of the spillway gates during times that the flow exceeds the capacity of the hydroelectric plant. During periods of high flows there may be overtime wages paid to keep the trash racks clean. CHC was contacted to determine the period and cost for a turbine overhauls in the period cost category. The generator overhaul was estimated for a rewind and the stator core was assumed to be reusable after 25 year of service. Costs associated with overhauls are assumed to be preformed by outside service firms.

A financial summary has been provided that assumes that the state will issue a bond to fully fund the project. The assumptions made on the financial parameters are:

- Debt (Bond) interest rate: 4.5%
- Debt (Bond) term: 25 years
- Energy cost escalation rate: 4.0%
- Inflation: 2.5%
- Discount rate: 5.0%
- Project life: 40 years
- Incentives/Grants: None

Conclusion

The proposed hydroelectric facility has shown to be technically feasible and financially a project with a net present value (NPV) of a minus ($98,820.00). It will take approximately 38 years before this project will generate a positive cash flow. A sensitivity analysis was performed and it indicated that if the initial costs were reduced by approximately 34% or $100,000 the project would add value to the State of Wisconsin. Reduction in cost can be accomplished via grants or incentives or by exploring new turbine technologies with substantially lower costs. As a reference a manually adjustable blade propeller turbine for this project is approximately $80,000.00. One of these new technologies uses a polymer molded turbine. Initial information on this technology shows an output of 16.19 kW @ 12.5’ of gross head, therefore the efficiency is substantially less than conventional technology. Also the expected life of a polymer turbine is not known at this time.

Other sensitivity scenarios were performed and the major impact to financial success of this proposed project is the avoided cost of energy or buy back rate ($/kWh) and the amount of renewable energy delivered (MWh).

When the state has a choice between two mutually exclusive alternatives, the one yielding the higher NPV should be selected. The following table sums up the NPVs in various situations.

Table 6 Net Present Value Decision Table

If...	It means...	Then...
NPV > 0	the investment would add value to the state	the project may be accepted
NPV < 0	the investment would subtract value from the state	the project should be rejected
NPV = 0	the investment would neither gain nor lose value for the state	One should be indifferent in the decision whether to accept or reject the project. This project adds no monetary value. Decision should be based on other criteria, e.g. strategic positioning or other factors not explicitly included in the calculation.

In summary, at the present time, the financial aspects of the proposed hydroelectric project are not positive. If the buy back rate would increase significantly or the overall cost would drop substantially the financials would change to a point that the project should be reexamined on a financial basis.

This study has only examined the technical and financial aspects of generating hydroelectric power at the Pattison State Park. No other factors have been included in this report. The information obtained in this study has been acquired from a variety of sources both public and private, which are believed to be accurate. A detailed cost analysis has not been preformed; therefore the cost has been estimated via modeling software specifically designed for small hydroelectric power plant analysis.

[1] John S. Gulliver, Roger E. A. Arndt, "Hydropower Engineering Handbook", 1991, pp.2.16 -2.19
[2] Horace Williams King, " Handbook of Hydraulic, for the solution of hydraulic problems", third edition, 1939, p.164 table 51
[3] United States Department of the Interior, Bureau of Reclamation, "Selecting Hydraulic Reaction Turbines"