IPRO 319
Feasibility Assessment for Sustainable Hydroelectric Facilities in Northeastern Illinois

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Sponsor:

Dr. Alex Tseng
Dr. Spetzler

Background:

There are thousands of dams in the United States that can create a pollution-free energy on many rivers and streams. This study will focus on Fox River, which drains 938 square miles in southeastern Wisconsin prior to entering Illinois from its headwater near Waukesha. Between the McHenry County/Wisconsin border and its junction with the Illinois River near Ottawa, the river runs for 115 miles and drains an additional 1,720 square miles. Although it is only 3% of the total area in Illinois, the watershed is home to about 450,000 people (11% of the state total); a number that is likely to increase by more than 30% over the next 20 years. The Fox River is a multi-purpose resource that contributes critical habitat for wildlife, serves as a valuable source for recreation, receives and assimilates pollutants from point and-non-point sources and provides source water for public water supplies.

Dr. Tseng and Dr. Spetzler recently suggested that the Fox River also offers an untapped resource: existing dams along the Fox River could become low impact hydroelectric facilities. On the 100-mile reach of the Fox River between McHenry and Dayton, Illinois, there are 15 dams. One of these, the Dayton dam, is a privately owned and operated hydroelectric facility. The remaining 14 dams were originally built in the 1800s to provide energy for lumber and gristmills. Although they no longer serve their original purposes, most of these dams have been maintained and could provide an opportunity for a sustainable power source.

Main Objective:

IPRO 319's objective is to determine the feasibility of converting one or more existing dams on the Fox River into low impact hydroelectric facilities based upon the project's economic viability, stakeholders, permitting, and certification processes.

Economic Team:

An essential part of this project was to determine if a hydroelectric facility on the Fox River would be economically attractive. The goal of the economic assessment team was to develop a cost/benefit analysis for the dams that were the best candidates for such a facility. An important consideration throughout the project was to balance realistic results with inherent limitations.

The first step we took was to develop a strategy for dealing with this task. Early in the project, it was apparent that the number of dams under consideration must be reduced. To accomplish this, we developed a series of filters to eliminate the weaker choices. The examination of flow duration curves from previous studies was crucial to deciding which dams had the highest potential output. In one study, we found that the height of the dam was incorrectly applied to determine its power output. The correct value to use is the head, which is the vertical difference between the head and tail waters. By making this correction, we obtained a more accurate value for the potential output using equation 1. and the duration curves provided by Naila Mahdi fig 1

$$P = \frac{Q * H}{11.8}$$

Equation 1
P= Potential Power in kilo watts
Q= the flow in cubic feet per second
H= Head
("Hydropower Engineering", by C.C. Warnick.)

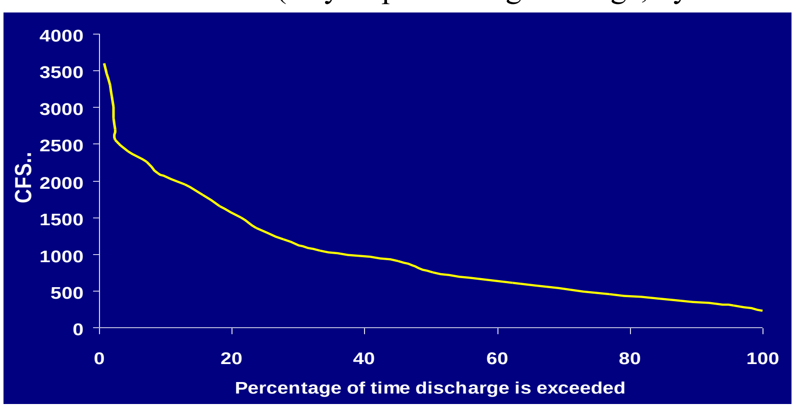

Fig1. Flow duration curve

By Naila Mahdi

An initial obstacle that we faced was the large number of factors to consider. It became apparent that it was not efficient to investigate every individual cost. As a team, we determined what was most important, and then used estimates or previous data for the rest. The investigation of possible turbines was important to the study because the turbine is one of the biggest costs. We concluded that the axial turbine was the right one for the average head size and flow rates of the dams under consideration. Table 1 shows the power out put and the estimated cost according with equation 2 and Fig 2.

Site Fox River	Elgin	Geneva	Stolp Isl.
Installed Capacity MW	0.405	0.99	1.06
Equipment	$ 2.1	$ 3.3	$ 4.1
Civil Work	$ 0.53	$ 0.8	$ 1.0
Total direct cost	$ 2.6	$ 4.1	$ 5.0
Contingencies	$ 0.4	$ 0.7	$ 0.8
Subtotal	$ 3.2	$ 5.1	$ 6.1
Grant from IL	$ 1	$ 1	$ 1
Total project cost	$ 2.2	$ 4.05	$ 5.2
Cost per kW (USD)	$ 4192	$ 4090	$ 4900

Table 1. Power output and cost estimates. Spreadsheet by Naila Mahdi data by Economic group.

$$C_T = 9000(KW)^{0.7} H_R^{-0.35}$$

Equation 2. Cost of turbine and generator
KW = turbine Capacity
Hr = Valid Head in meters.
("Hydropower Engineering", by C.C. Warnick.)

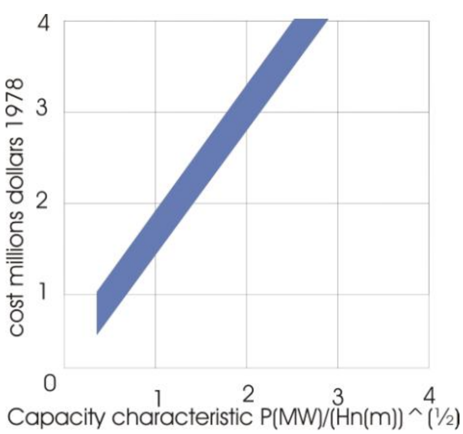

Fig 2. Cost estimate curve from finish experience.
("Hydropower Engineering", by C.C. Warnick.)

The visit from IIT alumni Dr. Alex Tseng invigorated the project. His experience in developing similar projects and his vision for the future was an inspiration. Before his visit, we didn't anticipate the project being economically attractive. He introduced us to the siphon turbine. Fig 3. This is a kind of axial turbine that utilizes suction. It is especially attractive for low-head application, because it greatly reduces the cost involved with the powerhouse.

Dr. Tseng's visit gave us an opportunity to actually tour an operating facility. This helped to give us a feel for how this project can work. During the semester, we visited both the Peru and Kankakee hydroelectric plants.

Picture 1. Kankakee Hydroelectric power plant
1.2 MW

Picture 2. City of Peru Hydroelectric
8 MW

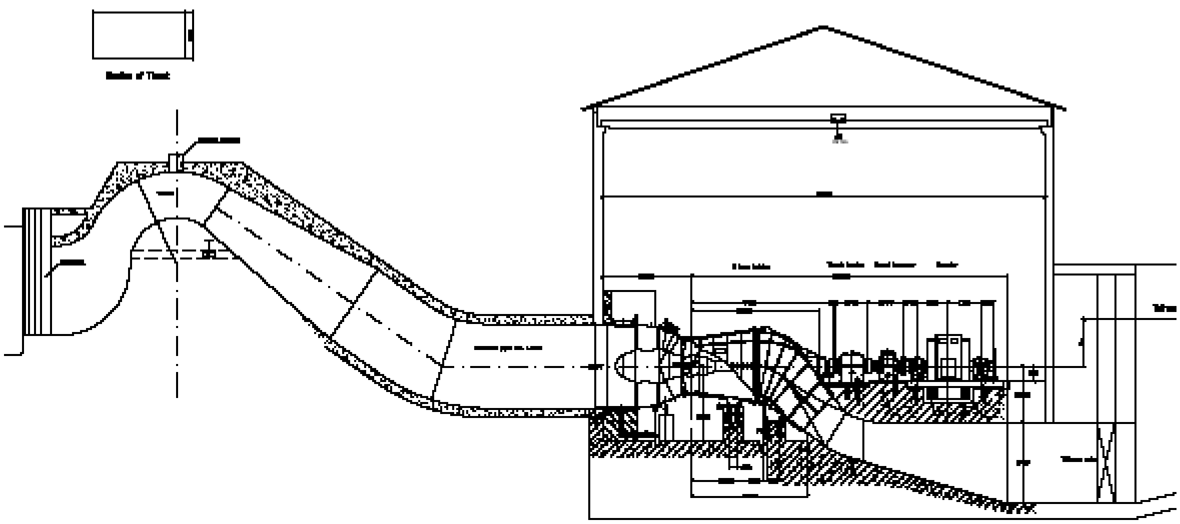

Fig 3. Siphon intake with an S type turbine. Provided by Dr Tseng

When we were satisfied with our research, we developed a cost report for our three best candidates: Elgin (pictures 3and 4), Geneva, and Stolp Island. Since these sites were very similar, we choose to focus our efforts on Elgin, as our research had produced the most accurate data for that site. This included blueprints for the dam as well as the feasibility study that was done by North American Hydro., the operating company of the Dayton hydroelectric facility. That report helped us estimate certain costs. Upon consultation with Dr. Tseng, we determined that the report had greatly overestimated some of the costs.

Picture 3. Elgin dam.

Picture 4. Elgin Dam.

The cost benefit study was based in Elgin data. We used a cash flow diagram fig 4 And equations 3 and 4.

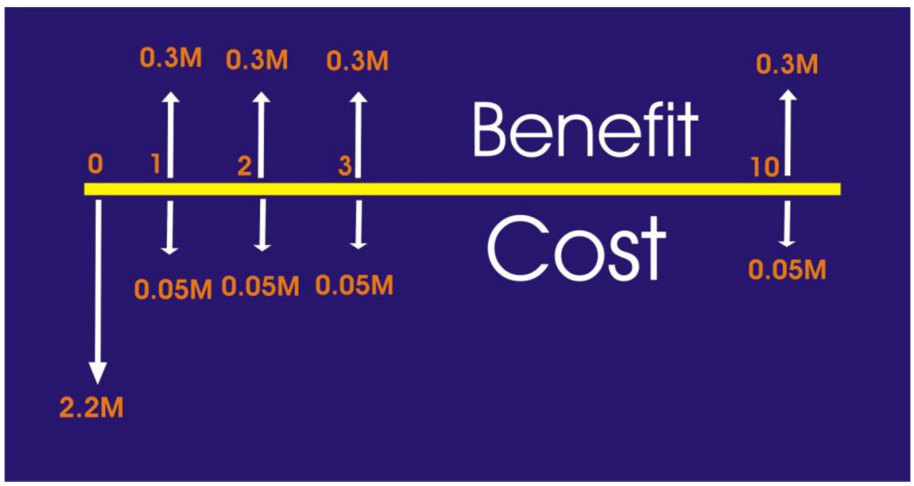

Fig 4. Cash Flow diagram for ten years.

$$Cost = 2.2M + 0.05M\frac{(1+i)^n - i}{i(1+i)^n}$$

Equation 3. 2.2M = out-front cost
0.05M = annual cost
i = interest rate =5.25%
n = number of years (10years)

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$$Benefit = 0.3M\frac{(1+i)^n - i}{i(1+i)^n}$$

Equation 4. 0.3M = annual benefit based on purchase agreement of 8.3 cents per KW-h
i = interest rate =5.25%
n = number of years (10years)

The benefit over cost ratio for the project must be over one in order to be feasible. The ratio with the parameters specified above is 0.8. It means it is not feasible. However we could do a linear relation between the purchase agreement (cost per KW-h) and the ratio in order to find the minimum price for the electricity produced by the hydroelectric facility. Fig 5 shows the graph of this linear relation and we found that 10 cents per KW-h will give a benefit cost ratio of 1.

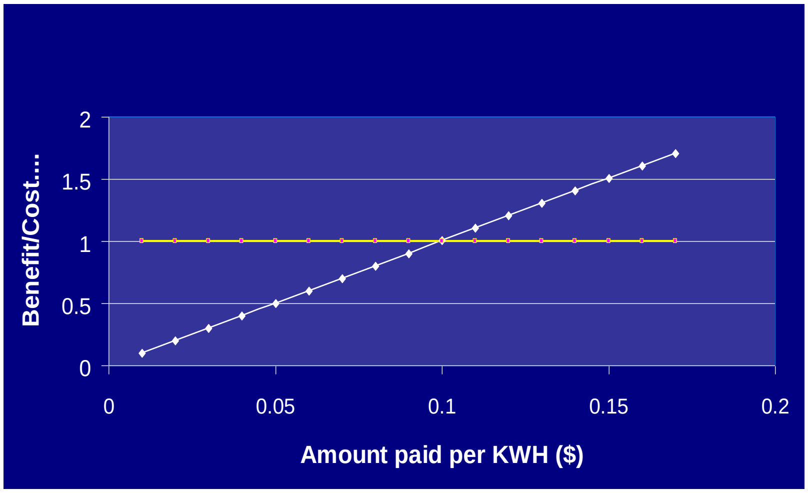

Fig 5. Benefit -Cost ratio Vs cost per KW-h

Overall we functioned very well as a team throughout the project. We tackled problems together as they arose. By respecting each other's opinions, we were able to take the best course of action when decisions needed to be made. By working together, we accomplished more than we could have individually.

Our conclusion is that in the present economic climate, and with the standard procedures for developing hydroelectric facilities this project is not feasible. In addition, there are more factors to consider than simply economics as the other groups determined. There are many reasons to implement this project, even if it is only to break even. There are several alternative to make this project to be feasible one of them is to increase the cost of electricity produce by the facilities. In a ten-year time frame, with an investment return rate of 5.25%, we forecast breaking even if our electricity produced is sold for $0.10 per KW-hour. Another possibility is to reduce costs by implementing siphon turbines suggested by Dr Tseng and developing new procedures to place this equipment more efficiently and less expensive. An additional advantage of this new approach is that the powerhouse could be avoided.

References:

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2.) Dayton, http://nwis.waterdata.usgs.gov/nwis/discharge/?site_no=05552500 ;
3.) Algonquin, http://nwis.waterdata.usgs.gov/nwis/discharge/?site_no=05550000 ;
4.) South Elgin, http://nwis.waterdata.usgs.gov/nwis/discharge/?site_no=05551000 . www.vatech.hydro.com
5.) Repair and rehabilitation of Kimball Street dam city of Elgin, Illinois (blueprints). Department of public Works Engineering division. 150 Dexter Court Elgin, IL. July 1998
6.) Feasibility assessment for low hydroelectric facilities on the Fox River in northeast Illinois, A project of the Energy and Sustainability Center at IIT, By

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8.) Laymans's guidebook on how to develop a small hydro site. Celso Penche. Published Books DG XVII. 1997.
9.) Hydropower engineering / C.C. Warnick in collaboration with Howard A. Mayo, James L. Carson, Lee H. Sheldon. Warnick, C. C., 1920 Englewood Cliffs, NJ : Prentice-Hall, c1984.
10.) Hydropower engineering handbook / John S. Gulliver, editor in chief, Roger E. A. Arndt, editor in chief. New York : McGraw-Hill, c1991.
11.) Hydroelectricity / Diane Gibson. Gibson, Diane, 1966- New ed., 1st pbk. ed. North Mankato, Minn. : Smart Apple Media, 2005.

Stakeholders Team:

The main groups that were addressed by the stakeholders team were the environmental groups, dam owners, and utility companies.

First we identified the environmental groups who had stakes along the Fox River. It was found that there were many different organizations who wanted a say in the future of the Fox River, especially the dams along the river. The vast majority of these groups were against having dams along the Fox River, not necessarily having hydroelectric facilities put on the dams, but having the dams on the river in general. The stakeholder group identified the problems, identified what the environmental groups wanted to see happen, and made recommendations on how to appease them.

There were two main reasons why the groups were against the existence of the dams, the first being the destruction of the ecosystem. Organizations like Fox River Ecosystem Partnership and Friends of the Fox River feel that the dams lower the water quality of the river, allowing sediment to build up behind the dams. The Friends of the Fox River did an extensive study to see if the environmental problems were caused by having the dams on the Fox River and concluded that some of the problems were in fact from the dams themselves (1). One source causing the lower water quality is the pooling of water behind the dams. This allows for algae growth, which causes bad odor, green coloring, and a lack of O_2. The lack of O_2 can lead to the death of living organisms, such as the fish. The dams also disrupt the upstream and downstream flow of organisms, especially for fish.

Groups like the Illinois Smallmouth Alliance take special concern with problems associated with fish because they hurt their recreation, the second reason why the organizations are against the dams (3). When the ecosystems of the fishes are disrupted then they have trouble reproducing, which means less fish for the fisherman to catch. Another recreational issue identified by the Fox River Ecosystem Partnership is the danger for canoeists traveling the river. Only the Straton dam has a lock system allowing for boats to travel from downstream to upstream, the rest have water flowing over the top of the dam. If a canoeist is unaware they might go over the edge, which can lead to fatalities as occurred several time at the Elgin dam. Also, with the lower water qualities due to the dams, many people will not swim in the water reducing the recreation along the Fox River more.

In 1998 the Fox River Ecosystem Partnership made an action plan called "Integrated Management Plan for the Fox River Watershed in Illinois" to improve the Fox River, which many environmental organization signed. Some of the signers were the Sierra Club, Valley of Fox Group, Water Sentinels Project, Max McGraw Wildlife Foundation, Friends of the Fox River, and the Illinois Smallmouth Alliance (2). The plan called for three main recommendations related to the dams. The first was the recommendation of removing or modifying the dams to improve fish migration and non-motorized boating safety. They felt that the river would most be benefited by the removal of the dams, however, if this was not possible then they wanted the dams to incorporate technology to improve the environment (2). For example, to help fish migration they felt fish passages should be installed and to establish portages to help non-motorized boats to move up and downstream. The second was to utilize the existing dam area, if it were safe and accessible (2). This basically is to determine where they can establish more sites for recreation, such as, canoeing and fishing. The last recommendation was to discourage the construction of new dams and on-line detention for storm water and flood control (2). The groups felt that these would contribute even more to the already existing problems along the Fox River.

After considering the issues brought forth by the environmental groups and how the hydroelectric dam project could gain their support, the stakeholder group came up with some recommendations. The first was to put a fish passage in the design plan when the facility is built. This, however, was found to be too expensive, ranging from $250,000 to $4,000,000. Therefore, to try and appease the environmental organizations the stakeholder group recommended a fish friendly turbine that would not disrupt the fish environment. The true reaction of the environmental organizations can not truly be understood until a detailed plan of building the hydroelectric facility is completed and studies to see the environmental impact concluded. However, utilizing the existing dams to produce electricity and incorporating fish friendly technology will help push them to be in favor of the project.

The next step was to find out who owned the dams we were looking at. The Geneva dam is owned by the state. To gain approval for building on a state owned dam you must submit forms to the U.S. Army Corp of Engineers, Illinois Department of Natural Resources / Office of Water Resources, Illinois Environmental Protection Agency, Federal Energy Regulatory Commission, and U.S. Department of Interior. The city owned dams are the north Elgin and Stolp Island West. Elgin has done several studies in the past to see if the could put their dam to use by turning it into a hydroelectric facility, but with little success. Their interest in hydro power is a good sign as they are still interested in this type of project. The city indicated that if we were able to propose a feasible project they would be in favor of the conversion. The dam in Aurora is more complicated. Stolp Island happens to be a historic area. Therefore any modification of the dam would have to be accompanied by a plan to make the facility blend in with the historic monuments of the area. Although the city is interested in the concept of hydro power, the added costs of modifying the appearance of the newly installed structure could make the project too expensive. Since the greatest support for hydro power is in Elgin we feel that is the best place to get support for our project.

Finally we looked at who powers each city. This study is important because we need to know to whom we are selling the power we are producing. In Elgin and Aurora ComEd provides power. To sell power to ComEd we would need to negotiate a power purchase agreement, or PPA. Although ComEd was unable to give us an estimate PPA for our project we were able to estimate one for our economic assessment. Unlike Elgin and Aurora, Geneva purchases its own power. That means we would be able to sell our power directly to the city. Also the city is looking to invest in such projects that produce power within the city. Finding the amount that the produced power can be sold for is very important because, this number determines the revenue produced by the facility, which in turn dictates whether or not the project is economically feasible.

In conclusion there is no reason, from a stakeholder's assessment, that this project could not be completed. There is enough support for our evdever to come to fruition, as long as the numbers add up and the government approves.

References:

1.) Friends of the Fox River. Water Quality Issues of the Fox River. www.friendsofthefoxriver.org/wq-table.htm.
2.) Fox River Ecosystem Partnership. "Integrated Management Plan for the Fox River Watershed in Illinois." http://foxriverecosystem.org/management_plan.htm#Recommendation%20CriteriaFRE_IMPLAN.pdf
3.) Illinois Smallmouth Alliance. www.illinoissmallmouthalliance.com

Acknowledgments:

Special thanks go to John M Loete (Director of Public Works, Elgin) and Ken Schroth (Director Public Works, Aurora) for there help in determining city support for a hydroelectric facility.

Permitting Team:

With any kind of operation, permits need to be obtained. The operation of a small hydroelectric generator is no different. There are five government agencies that need to be appeased in order to continue operation: U.S. Army Corp of Engineers, Illinois Department of Natural Resources / Office of Water Resources, Illinois Environmental Protection Agency, Federal Energy Regulatory Commission, and U.S. Department of Interior. The purpose of the permitting group is to study the permitting process and to come up with an estimated timeline. The research method we used was mainly a search and research. We searched for handbooks for the various government agencies

Based on information found through various websites and different case studies, we can conclude that the average time to complete the permitting process for operating a small hydroelectric generator is about 4 years.

References:

1.) FERC website: www.ferc.gov
2.) USACE website: www.usace.army.mil
3.) IDNR/OWR website: dnr.state.il.us/owr
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5.) IEPA website: www.epa.state.il.us

Acknowledgments:

Special thanks go to Naila Mahdi for her help in searching for resources and Dr. Alex Tseg for sharing his expertise.

Certification:

Small low-impact hydroelectric is a novel idea in Illinois. The goal of the certification team was to determine what if certification was need and the requirements for certification. First we looked at low-impact certification. A nonprofit organization, Low Impact Hydro Institute (LIHI), gives certification to hydroelectric dams that meet eight criteria. The criteria sets standards for river flows, water quality, fish passage and protection, watershed protection, threatened and endangered species protection, cultural resource protection, recreation, and facilities recommended for removal.

The biggest obstacle for the certification team was determining if certification was required for this project. The next step to solving the puzzle was learning about the Illinois Sustainable Energy Plan. The plan calls for at least 2% of energy to come from renewable sources in 2006, an increase of at least 1% each year until 2012 when at least 8% of energy should be from renewable sources. Wind power is seen as having the most potential and being the most economically feasible; therefore, it is recommended that at least 75% of renewable energy is from wind sources. Hydropower on existing dams is included in the plan. Our project hopes to show that small low-impact hydropower is another unused resource in Illinois.

We looked at obtaining certification from Green-e. Green-e certifies energy as being green, or environmentally friendly. The requirements for Green-e are hydropower under 30 megawatts or certified by LIHI. We would be producing much less than 30 megawatts; therefore, certification by LIHI is not needed. It was also found that green certification is for utilities. We do not need to apply for the certification, but our product would be able to be used toward certification for a utility.

In conclusion, certification is not required at this time. We have considered the criteria for certification; so that if in the future certification is needed it will be possible.

References:

1.) http://www.lowimpacthydro.org/
2.) http://green-e.org/
3.) http://www.eere.energy.gov/RE/hydro_enviro.html
4.) http://www.commerce.state.il.us/dceo/Bureaus/Energy_Recycling/
5.) http://www.epa.gov/greenpower/

Conclusion:

In the end we have found that it is not economically feasible at this time, although we feel there are more reasons than profit to continue, such as environmental preservation and sustainable energy development. The next step is to continue research to try and find more economic ways to complete this kind of project. Once the research is complete then investors must be found to fund the project and owner support must be identified, then the permitting process can begin.