Dominica

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Prefeasibility study of the Belfast River site

NRECA Small Decentralized Hydropower (SDH) Program

Dominica: Prefeasibility study of the Belfast River site

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Small Decentralized Hydropower (SDH) Program
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Summary and conclusions

At the request of USAID/Barbados, NRECA's Principal Engineer for Small Hydropower Development traveled to Dominica to review plans for a micro-hydro demonstration project funded jointly by USAID and the Caribbean Development Bank. In the course of examining alternative project sites, he was asked to visit a potential site on the Belfast River near the Dominican Coconut Producers, Inc. (DCP) factory. DCP presently generates its own power with diesel generators at an approximate cost of US$0.14/kWh and is interested in developing the hydropower site to meet the plant's increasing need for electrical power.

From approximately 3.0 km upstream of the factory, the Belfast River runs rapidly through a narrow gorge and a series of small drops. Coutour maps indicated that within this distance the river falls over 120 m and has a catchment basin of approximately 9 km^2. Proportioning this basin size to a nearby basin that has been gauged, it was estimated that the site can yield an average flow of approximately 1.3 m^3/s.

After a field observation of the site, a proposed scheme for developing 100 m of the head and 1.2 m^3/s of the flow was considered. This scheme could produce an average output of 750 kW for a capital cost of about US$ 3 million. Assuming a load factor of 0.9 and a 30 year life, the scheme would have an 18% rate of return.

It is recommended that DCP pursue development of the Belfast site. DCP should initiate the following actions: (1) undertake initial flow measurements in the Belfast River, (2) verify data in this prefeasibility report, (3) talk to financial institutions about terms and conditions of loans, and (4) seek technical assistance for a feasibility study.

Introduction

The AID Office of Energy, Science and Technology Bureau, through its Cooperative Agreement with the National Rural Cooperative Association (NRECA), agreed to provide a small hydropower engineer to Dominica to assist the Caribbean Development Bank with its proposed micro-hydro project for the Government of Dominica. During that assignment, the engineer visited a potential hydro site on the Belfast River which could supply the electrical requirements of the Dominican Coconut Producers, Inc. (DCP) factory, a private entity.

DCP is located at the mouth of the Belfast River approximatley 5 km north of Roseau (Fig.1). The factory processes coconuts product such as rum, oils, and soap. The factory presently has two diesel generators rated at 260 kW each which supply its electrical power requirements. The factory operates 24 hours per day and generates its energy for about US$0.14/kWh. DCP is also served by the Dominican Electricity Corp. (DOMLEC) from a 11 kV tap off the main distribution line. DCP can purchase power from DOMLEC for about US$ 0.16/kWh but, for cost and reliablity reason, prefers to generate its own power.

If provided with additional energy from the proposed hydropower site DCP could produce its own caustic soda rather than import soda. For this reason, the DCP forecasts future electrical load of 900 kW at a 0.9 load factor.

The proposed hydropower scheme would consist of a diversion weir located approximately 3 km upstream of the factory, a long steel penstock leading to a power-house located approximately 1.5 km from the factory, and an 11 kV, three-phase overhead distribution line. The location of these features is sketched in Fig. 1.

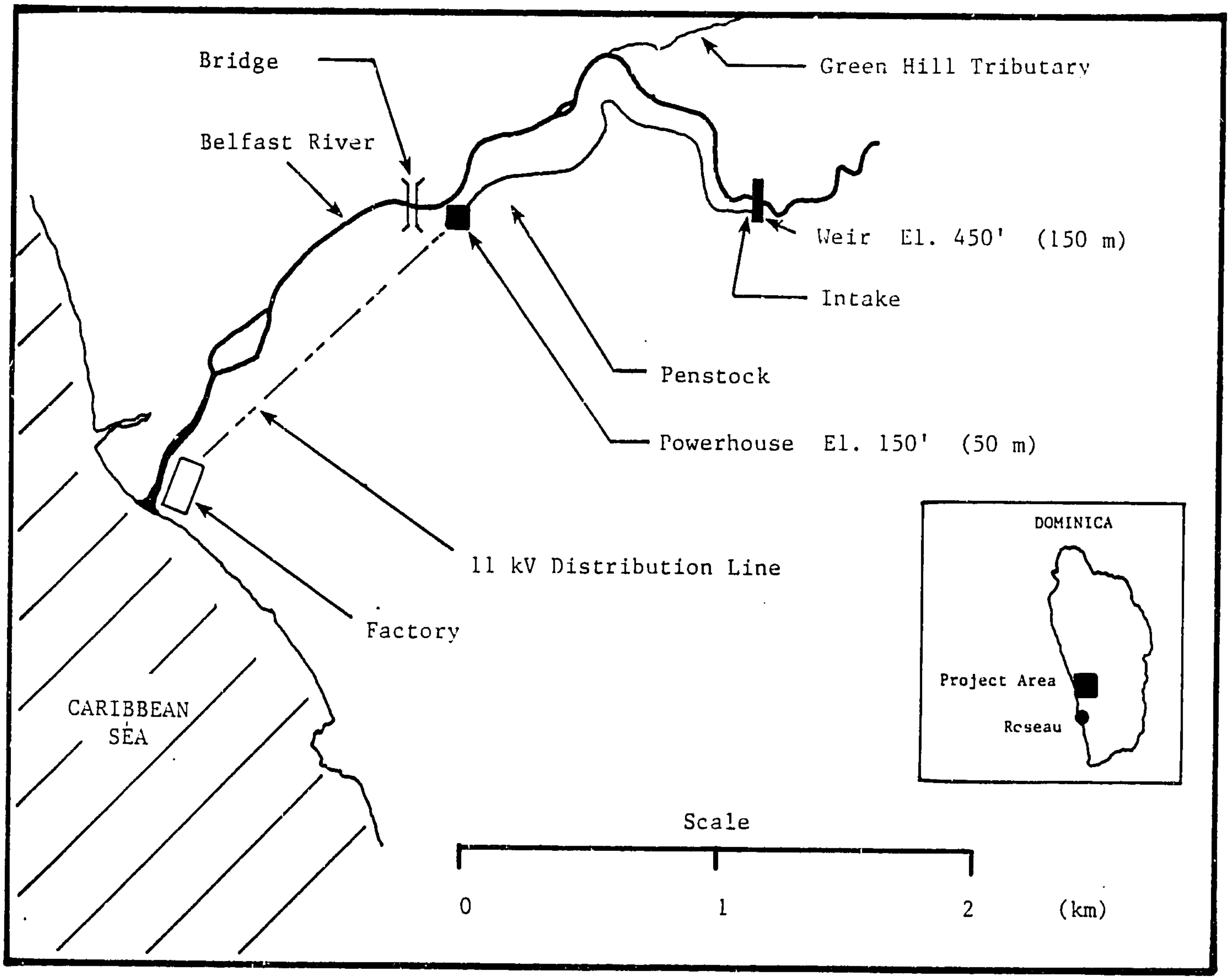

Fig. 1. Sketch of proposed layout.

Fig. 2. Dominica Coconut Producers Inc.

Site Description and proposed general layout of project

General Characteristics

The Belfast River site is located on the eastern coast of Dominica at approximately 15 22' N and 61 24" W. The general climate and rainfall characteristics of Dominica are described in reference 2. It has a marine tropical climate characterized by a wet season from May to December and a dry season from January to April. Rainfall over the island generally increases with increasing elevation and is higher on the east coast than on the west coast.

The Belfast River begins in the high mountains and flows through rugged, tropical forest areas in the central part of eastern Dominica. In the mountains, the river banks are steep and actively eroding. Large boulders are carried down the river during floodflows. No flow records are known to exist.

Hydrology

The Belfast River basin is just north of the Antrim Valley which supplies potable water for the capital of Roseau. The Antrim River was gauged for two years in the 1950s and the 4 km^2 basin yielded an average flow of 0.6 m^3/s. Assuming a similar flow regime in the Belfast River basin, the specific discharge for the basin is .15 $m^3/s/km^2$. In order to have sufficent flow to generate 750 kW with the estimated available head, the basin would have to be at least 7km^2 in size. For this reason, the diversion weir must be located below the confluence of the Belfast River and the Deux Saisons tributary. At this confluence the basin has an 9 km^2 area, which yields an average flow of 1.3 m^3/s. The drainage basin for the proposed scheme is sketched in Fig. 3.

No flow measurements were made during this prefeasibility visit.

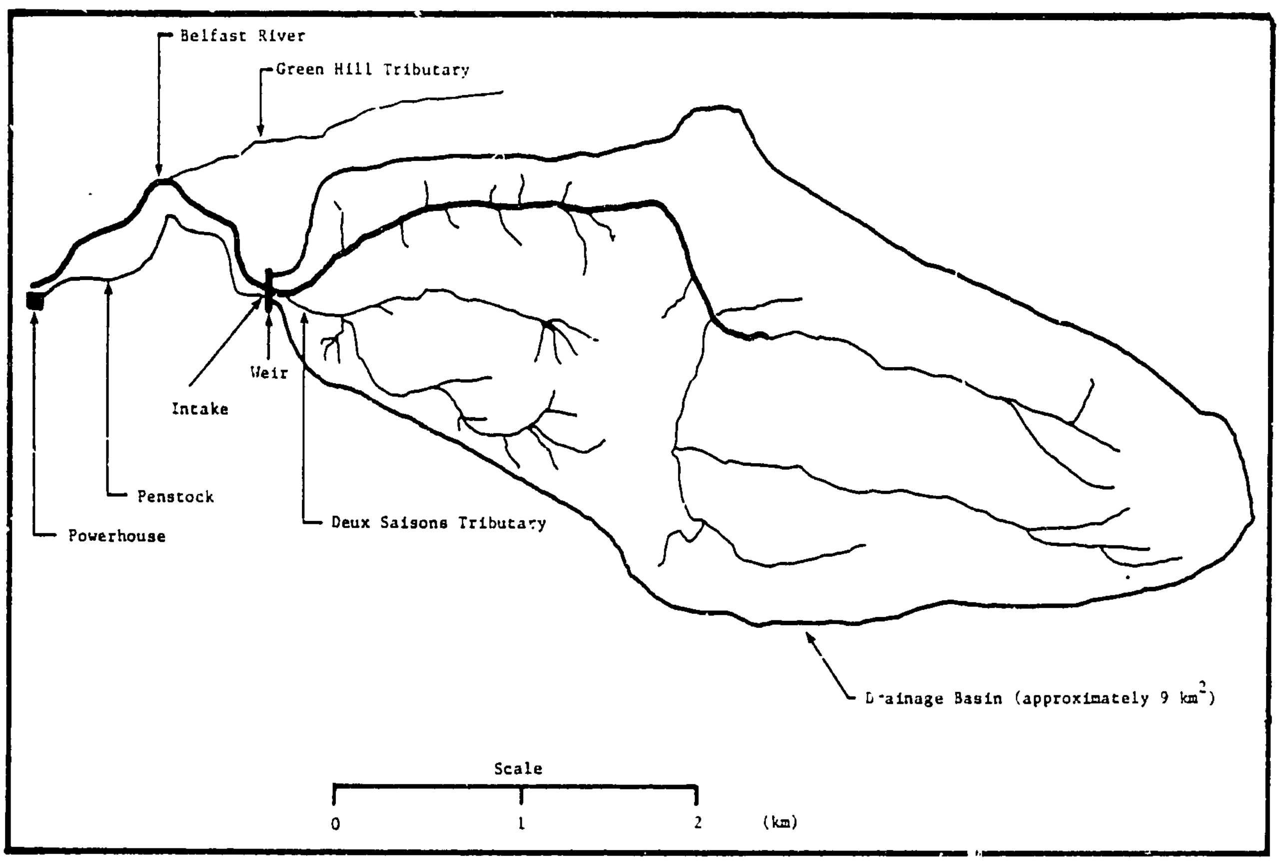

Fig. 3. Belfast River drainage basin.

Weir

The site selected for the weir is located approximately 20 m downstream of the confluence of the Belfast River and the Deux Saisons tributary. A concrete sill and flashboard type weir is recommended (Fig. 4). The concrete sill is extended across the river and keyed into the riverbed. The sill would be fitted with hinged flashboards with pins holding the flashboard sections in place. The pins would be of design strength and diameter that would cause them to bend or break during large flood flows. This would allow flood flows, which carry most of the sediment load and large boulders, to pass through the diversion structure and also wash out accumulations of sediment. A wing wall would extend from the flashboards to an impervious stratum in the riverbank. An intake located on the south wall would divert the flow to a settling area, if necessary, and then to the penstock. A picture of the proposed weir location is given in Fig. 5.

There are several alternate weir locations downstream of the proposed location that may simplify the penstock installation but which would sacrifice head. The elevation of the proposed weir is approximately 450 feet (150 m).

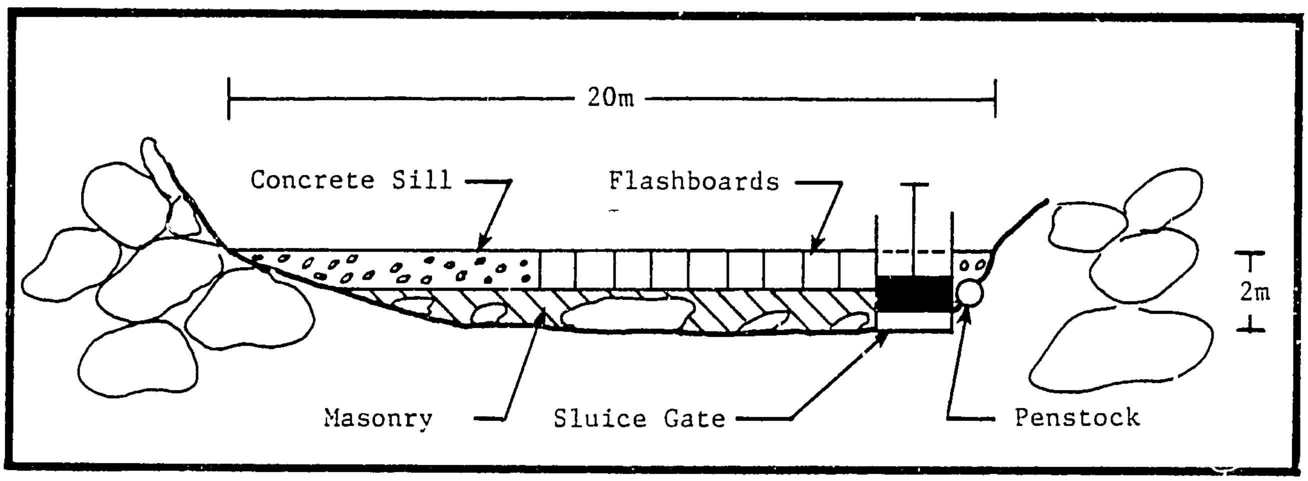

Fig. 4. Sketch of proposed Diversion Weir

Fig. 5. Location of proposed weir.

Penstock

Correct planning and installation of the conveyance system from the weir to the powerhouse will constitute the most difficult engineering problem of the project. Lined or unlined canals do not appear feasible because of the steep cliffs along the riverbanks ((see Fig. 7). Options do exist for a mix of low-pressure and high-pressure conduits with the low pressure conduits acting similar to enclosed canals. For the purposes of this prefeasilility analysis, it is assumed that a steel penstock of 0.8 m diameter and 10 mm thickness is used for the entire length.

The river profile, as derived from 1:50,000 contour maps with 50 foot contour intervals, is shown in Fig. 6 the first 350 m of penstock construction will be through presently inaccessible, difficult terrain. Bends in the penstock will require large anchors and thrust blocks. From the confluence of the Green Hill tributary, penstock construction will relatively easily.

After the confluence of the Pont Casse tributary, the riverbed slope decreases. At some point, the cost of an additional meter of penstock will not be worth the benefits gained from the additional head and energy available. For a prefeasiblity analysis, this point is estimated to be close to the point of the small confluence approximately 0.2 km upstream from the bridge (see Fig. 1). The elevation of this site is approximatley 150 (50 m).

Turbine-generator

It is proposed that two Francis turbines coupled to synchronous generators be installed in the powerhouse. Installing two Francis units will allow operation of the plant down to 20% of the design flow. Another alternative is to install three or more Pelton units. The

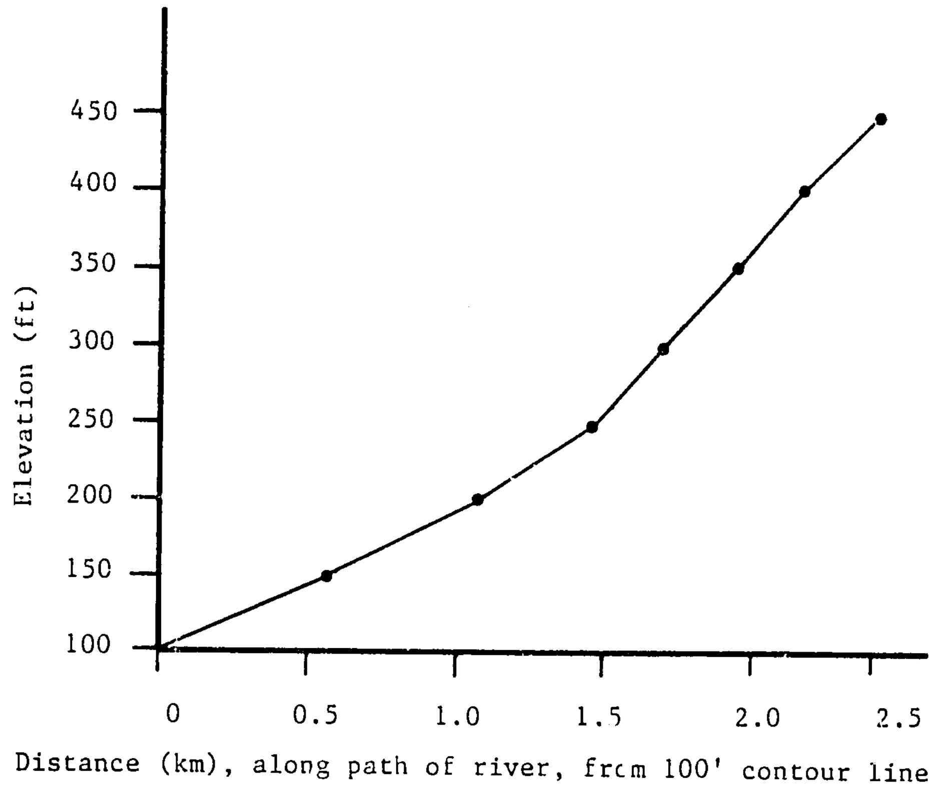

Fig. 6. Belfast River bed profile.

advantage of the Francis turbines is that fewer turbines will be required and the advantage of the Pelton units is that they can operate at lower flows without cavitating. In either case, the base of the penstock would be designed to accommodate two or more turbines. The generators would be three-phase 440 V.

Electrical distribution

Electrical power from the generator would be transformed from 440 V to 11 kV and delivered to the factory on three-phase, grounded neutral, wood pole overhead lines built to DOMLEC standards. DCP presently owns its 11 kv to 440 V step-down transformers. The proposed powerhouse is approximately 1.2 km from the factory substation.

Energy potential

The power potential (P) can be estimated by the equation:

$$P = 7.5 (Q) (H) \text{ kW}$$

where Q is the design flow and H the gross head. For the Belfast River, this yields:

$$P = 7.5 (1.2) (100) \text{ kW}$$

$$P = 900\text{kW}$$

Since $1.3 m^3/s$ is not available year round, a design flow of $1.2 m^3/s$ is used and an average capacity of 750 kW is used to for estimating the potential energy. The annual energy production from the hydropower units available for use is:

$$E = \text{kW (load factor) (plant availability) (hours per year)}$$

$$= 750\ (0.9)\ (0.95)\ (8{,}760)$$

$$= 5{,}617{,}350 \text{kWh/year, or,}$$

$$= \underline{5{,}600{,}000 \text{kWh/year.}}$$

Fig. 7. River banks along the proposed penstock route. Note steep cliffs to the left.

Cost estimates

The cost estimates presented in this section are only preliminary. They are not based on actual projects in Dominica and should be adjusted accordingly before a decision is made to move ahead with a feasibility study. The unit costs presented in these estimates are best guesses based on data from the U.S. and other countries. All cost are given in U.S. dollars.

Land	10,000
Weir (20m long @ $3,000/m)	60,000
Intake structure, stoplogs, trashracks sediment basin, and sluice gates	20,000
Penstock (0.8 m diameter, 10 mm thick)	
1100 m @ $600/m	660,000
700 m @ $500/m	350,000
Thrust blocks	60,000
Turbine-generators; two Francis units with control and switchgear (900kW @ $950/kW	855,000
Powerhouse (80m^2 @ $1000/m^2)	80,000
Access road (2km @$6,000/Km)	12,000
Distribution (2km @ $12,000/km)	24,000
Substation; pad mounted transformers; (7 - 300 kVA transformers 11 kV-440 v	72,000
Contractor mobilization	10,000
Subtotal	2,203,000
Interest during construction @ 15%	
Engineering fee @ 10%	
Contingencies @ 15%	881,000
Total	3,084,000

The line item for contractor moblization is required since no construction contractor with the necessary experience is headquartered in Dominica and the selected firm will be required to move personnel, facilities, and equipment onto the island.

The "interest during construction" item assumes that the site can be constructed in two years and interest charges on advanced loan funds will be equivalent to 15% of the construction cost. This item will, of course, be sensitive to the prevailing interest rates.

Financial analysis

Since the source of funding for the Belfast River project is not known, several assumptions must be made to estimate the financial soundness of the project. It is assumed that project funding needs are approximately US$ 3,000,000, that the funds can be borrowed at 15% interest for a 20 year period, that the O&M requirements are 3% of the capital requirements per year, and that taxes and depreciation are about 5% of the capital requirements per year. Using a capital recovery factor of 0.16, the annual cost of the installation is 0.24 times the capital requirements of $3,000,000, or $720,000 per year. Using an energy production rate of 5,600,000 kWh/year, then the average cost per kWh is $ 0.13. After the loan is paid off, the annual cost will drop to $240,000/year and the unit cost will drop to about $ 0.04/kWh.

Comparing the estimated cost of $ 0.13/kWh with the present cost to DCP for electrical energy of $ 0.14/kWh gives a favorable indication of the benefits of the hydropower installation. If it is further assumed that financial benefits of the installation are equal to the value of the diesel energy potentially displaced at $ 0.14/kWh and that the diesel units will not have to be replaced after ten years of service, then the annual costs and benefits can be estimated and the rate of return on the investment calculated. Assuming a 30 year project life, such an analysis yields a rate of return of 18%.

A key factor in this analysis is the assumed high load factor of 0.9. This high value is used because the factory operates 24 hours a day and, once provided with hydroelectric energy, DCP can use any off-peak energy to produce its own caustic soda and salt.

The Belfast River project is similar to projects in other countries, including the U.S., in that its feasibility is largely a function of interest rates. If funds can be obtained at 10% interest, then the corresponding unit cost is appromimately $ 0.10/kWh until the loan is paid off. It is recognized that this preliminary financial analysis is not complete, that cash flows were not generated and discounted, that loan terms will probably be different from assumed values, and that "real" diesel costs will rise. Other ecomonic benefits derived from hydropower such as reliability of supply, improvement of balance of payments, etc. also were not considered. However, this preliminary analysis does indicate that the project is worth further consideration.

Feasibility study

This preliminary study of the Belfast River site suggests that the project should be investigated further. As the next step, it is recommended that the DCP first verify and adjust the figures in this report as appropriate. If the site is still attractive, DCP should seek an expression of interest from a financing institution and determine potential loan conditions. Then it should seek technical assistance for conducting a feasibility study.

Issues to be considered during the feasibility study include technical, financial and institutional aspects. Some of these issues are:

Techncial

Hydrology (lack of flow data)
Soil stability
Alternate layouts (penstock, turbine type powerhouse, etc.)

Financial

Future market of DCP's products
Potential future uses of hydropower and its value
Economic value of non-monetary benefits

Institutional

DOMLEC's role (grid interconnection)
Government support of the project
Water rights, land acquisition, etc.

References

1. Creager, William; Justin, Joel; Hydroelectric Handbook, John Wiley and Sons, 1950.

2. Lawrence, Walter; Folts, Jeff; and Oberg, Keith; "Dominica: An Assessment of Small Hydroelectric Potential," NRECA. January 1982.