ecoEnergy Innovation Initiative: Wasdell Falls Hydro Power Project

Public Project Report
Project 495 MH
Wasdell Falls Limited Partnership
Washago, ON
2016

Photo 1 Wasdell Falls Hydro Power Project utilizes Run-of-River technology to produce clean power

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I. Executive Summary

Wasdell Falls Limited Partnership ("WFLP" or "Wasdell") successfully achieved Commercial Operations on December 2, 2015, as per Ontario's Feed-In Tariff which was introduced as part of the 2008 Green Energy Act, in December 2015. Wasdell is a run-of-river hydropower project with an installed capacity of 1,650 kW. The project includes three 550 kW FMJ2 Very Low Head ("VLH") turbines. This installation of MJ2 turbines is the first of its kind in North America. There are over 40 turbines currently operating across Europe. The VLH's operational parameters allow it to make use of existing infrastructure with relatively low head to generate clean, renewable energy. This type of existing water control structures are found in rivers across the country. Making use of existing infrastructure will help to reduce cost and make this type of clean, renewable and low-impact energy more affordable. Canada can build upon its long and successful history of utilizing our abundant water source to produce power.

Adaptations of the MJ2 VLH turbine were required to allow the project to function throughout the cold Canadian winters. In particular, a new extraction method was required so that the turbine could be fully extracted from the river, under hydrodynamic pressure, during icy winter conditions. Working with MJ2 and supported by a Canadian engineering firm, WFLP developed a hydraulic based extraction frame that removed the turbine on a 45^0 angle. Further adaptations included additional heating of the turbine hub and a larger flap gate to allow the flushing of debris and ice.

Many remote and northern communities are located adjacent to or in the vicinity of the type of water control structure that have the required attributes – a head range of ~2 – 5metres and a minimum flow of ~10 – 15 metre^3/second – to accommodate one or more VLH turbines. These turbines could be used to provide power to these communities that would otherwise be produced using fossil fuels such as diesel. Displacing the need to rely on fossil fuels would not only reduce, fuel costs and emissions but also increase reliability of power for communities that experience volatility in fuel supply due to difficult accessibility during certain times of the year.

Based on testing completed in Europe, the VLH turbines are considered to be fish-friendly. The turbines have a relatively large diameter which allows for relatively low RPM of the turbine. Fish are able to pass through the turbine while traveling downstream. Testing to confirm the European experience is being completed at Wasdell in partnership with Fisheries and Oceans Canada. This work has begun in summer 2017 and will take place over the next 3 years.

In addition to the benefits of the technology highlighted above, replicating this type of project will provide economic benefits to the communities through the creation of temporary construction and full-time operations jobs. The time and resources needed to replicate VLH project will also be reduced based on lessons learned at Wasdell. Proponents will not need to complete the front-end innovation that was taken on by WFLP. Also, regulators and financial institutions will have reference documentation and the ability to visit Wasdell when determining to approve or finance future VLH projects across North America.

II. Introduction

Work on the 1.65 MW Wasdell Falls Power Project ("Wasdell") Environmental Assessment (EA) started in 2007 by OEL-Hydrosys after the Wasdell Falls Power Corporation, was awarded Applicant of Record by the Ontario Ministry of Natural Resources (MNR) through the competitive site release program in 2006. The Environmental Assessment (EA) received the Notice of Completion in 2011. The EA was completed as per the Class Environmental Assessment for Waterpower Projects introduced by the Ontario Water Power Association in October 2008.

Upon completion of the EA, Wasdell was jointly purchased by Coastal Hydro Power Corp.(no longer a part of the project) and Enbridge Inc. These parties purchased the Wasdell Falls Power Corporation's assets included the existing Feed In Tariff (FIT) contract and the completed EA. A separate entity, Wasdell Falls Limited Partnership (WFLP) was formed to construct, own and operate the project upon completion.

WFLP's activities were supported by the following firms all based on Canada:

- Canadian Projects Ltd., engineering design (Alberta)
- Vic Van Isle, civil works (British Columbia)
- Marnoch Facilities Management, mechanical and electrical works (Ontario)
- Avertex Solutions, interconnection works (Ontario).
- Mecan Hydro, Extraction frame and flap gate (Quebec)
- CanMech, mechanical labout (Ontario)

Further support for the project came from MJ2, based in France, who supplied the turbines and collaborated on the innovation required to adapt the turbines for use during harsh Canadian winters. Construction on the project faced delays due to factors, including but not limited, to the re-configuration of the interconnection line and severe winter weather. Construction at Wasdell was completed in May 2015 and was immediately followed by commissioning of the turbines and control building. Commissioning was interrupted due to lack of available river flow during late summer and into early fall 2015. Wasdell achieved Commercial Operations in December 2015.

Wasdell is located at the site of a historic generation facility as noted below.

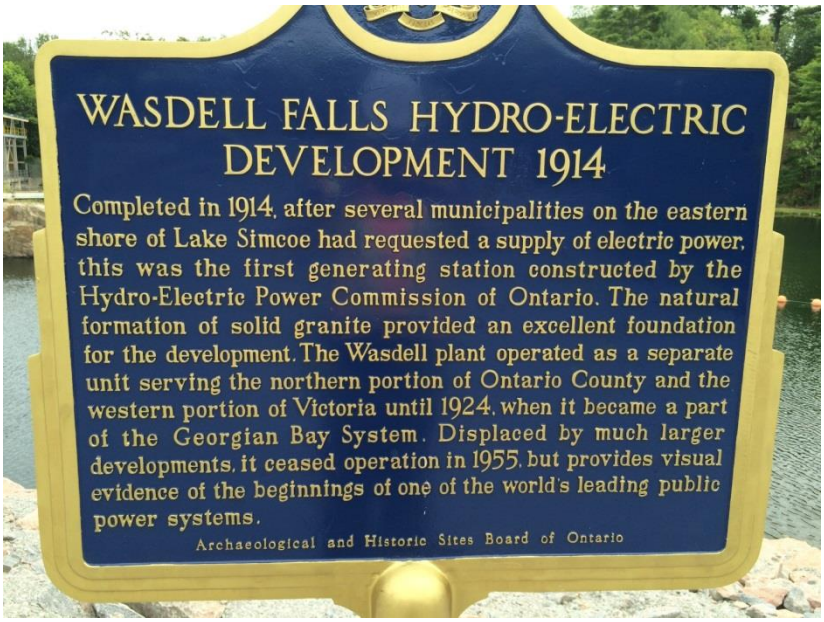

Photo 2 Wasdell Falls historic plaque

III. Background (Program background and Consortium Participant Overview

Very low head (less than 5 meters) hydropower is a clean and often low-impact source of electricity available across Canada. While Canada has a strong history in hydro power production it has generally not been economic to develop very low head hydro. The hydro-power turbines that had been widely used across Canada were not designed to capture energy from sites with low head. There are several thousand existing water control structures across the country. Even if only a portion of those have the correct characteristics of head and flow a significant amount of renewable and clean energy could be produced.

In the last decade, Canadian and French researchers and industry, with the support of the Canadian and French governments, began working on an innovative technology that would make very low head hydro more economic, and ultimately, a competitive power generation option. From this work, the Very Low Head (VLH^{TM}) turbine was created, which is designed specifically for installation into existing civil structures, minimizing: infrastructure costs; time for regulatory approvals; time to construct projects; and environmental impacts.

A French company, MJ2 Technologies, conceived the VLH^{TM} turbine design and worked with a Canadian industry partner performing the research and development work, including testing at Laval University in Québec, with funding support from NRCan. Since that time, more than 70 VLH^{TM} units are now operating or under construction in Europe, but the North American market has not been introduced to the MJ2 VLH^{TM} turbine. The Coastal Hydropower Corporation (Coastal) was able to secure funding through the ecoEnergy Innovation Initiative to undertake the work necessary to ensure the VLH turbine would operate year round in Canada. As a result, Canada is now in a position to make use of the existing infrastructure that was once considered uneconomic.

Coastal undertook a full evaluation of adaptations required for the VLH™ design to meet North America operating requirements from both an electrical and weather related standpoint. Coastal and its industry partners were able to bring years or experience of engineering design related to operating under North American standards and mitigating issues resulting from the relatively harsh winters. This experience resulted in design modifications that were published in the VLH™ Cold Climate Adaptation and Ice Study reports. The innovative modifications applied to the turbine are as follows:

- An extraction system that would allow the turbine to be fully extracted from the river, under hydrodynamic pressure, during the icy winter condition.
- Heating mechanisms for the turbine generator.
- A larger, yielding flap gate to allow the flushing of debris and ice.
- Protective matting on the draft hood to protect against ice.
- Icephobic coating for turbine frame, distributor and blades.
- Steep installation angle to ensure submergence

As a result of these innovative modifications to a French turbine which had established a new standard of efficiency in terms of power projects, Coastal and partners went ahead with the development of the 1.65 MW hydro Project at the existing Wasdell Falls dam. This project involved three modified VLH™ turbines. The VLH™ turbines are installed in a purpose designed and built flow channel to allow for ease of monitoring and testing in the years to come. Once all modifications are proven to work as expected, future projects could be built directly into the bays of existing dams or water control structures reducing project costs and overall foot-print even further.

The photograph below shows the fore-bay of the VLH turbines with the existing dam in the background (located where the gantry structure can be seen)

Photo 3 Wasdell Falls VLH Forebay

IV. Objectives

The Project's objectives were divided in three phases. Phase 1 and 2 focused on adapting the European

turbine to the sometimes harsh winter conditions in Canada and completing the construction and commissioning of the project. The 3rd phase of the objectives focused on follow-on testing and monitoring of the turbines stated attributes and performance during winter. Further details of these objectives are presented in the table below.

Objective	Project Activity	Description
Phase 1		
1.1	Cold Climate/ North American Adaptation	Complete all design engineering on the Project. Design to include Cold Climate adaptation techniques - internal heating system, ice-phobic (hydrophobic) coating, flap or crest gates, removal under ice load, heated guide vanes – and electromechanical output enhancements needed to meet North American requirements.
1.2	Cold Climate/ North American Implementation	Work with MJ2 to incorporate all innovative design modifications into final VLH turbine specifications for manufacturing.
1.3	Permitting	Obtain required environmental approvals and construction permits.
Phase 2		
2.1	Finalize Project contracts – procurement of Project components and construction contractors.	Finalize procurement contracts for all Project components. Have all necessary contracts in place with contractors and sub-contractors.
2.2	Project Construction	Commence construction – civil works, structure works, mechanical works, electrical works, and interconnection requirements.
2.3	Project Commissioning	Energize the Project and test the power production to reach substantial completions – based upon pre-approved output levels defined with cooperation from MJ2.
Phase 3		
3.1	Fish Impact Monitoring	Conduct studies using native fish specimens to assess the fish friendliness of the VLH. The study will be developed with input from Federal and Provincial regulators, and the results will be publicly available. The aim is to create a study that can be applicable in all Canadian jurisdictions.
3.2	Project Reporting / Knowledge Transfer	Provide detailed reports to all stakeholders highlighting the Project's intended purpose, progress and outcomes. This will include monitoring the performance, efficiency and output of the VLH turbine throughout all four seasons.

V. Project Evolution

Wasdell Falls faced several barriers during it's evolution, the most substantial challenges are listed below;

Technology challenges – described in System and application below

Cold Climate Adaptation. In the photo below you can see the ice build up on the downstream side of the turbine structure and crest gate.

Photo 4 Ice Accumulation on downstream side of VLH Structure

Access to Project Financing

- Wasdell represents the first installation of the VLH turbine outside of Europe and required innovative adaptations. As a result the project was viewed as somewhat of a prototype to financial institutions and this made securing the required construction debt for the project difficult.
- WFLP needed to work closely with potential lenders and carry out extensive due diligence to provide the lender with the required confidence to provide the required debt financing.
  - With the successful completion of Wasdell there is an operating North American project that any potential capital provider can see, providing the confidence needed to move forward with financing.
  - Future proponents will need to spend much less time and effort in order to secure the required financing to complete the project. The value of this reduced time and effort will vary based on each project.

Regulatory Approvals

- Wasdell represents the first installation of the VLH turbine outside of Europe. As a result there were challenges in obtaining regulatory approvals based on North American electrical standards.
- WFLP worked closely with the design engineer, electrical consultant, electrical contractors, MJ2

and local representatives for the Electrical Safety Association (ESA) and the Canadian Standards Association (CSA) to ensure all equipment met North American standards.

- Now that all issues related to the equipment coming from Europe have been identified and mitigated, future proponents will be able to complete the regulatory requirements associated electrical safety with much less time, effort and expense.
- The value of this reduced time and effort will vary based on each installation of the VLH turbines.

VI. Description of System and Its Application

The Very Low Head (VLH) turbine was developed in France in 2004 with the intent to capture the energy at existing river hydraulic structures with very low water level differential from upstream to downstream (i.e. very low head). Although there are several technologies that allow the exploitation of low heads, most are uneconomic due to the high civil structure costs, large environmental impacts and low efficiencies. The VLH turbine design is applicable at sites where the head is the range of 1.4 to 4.2 m. Within this head range the VLH turbine was developed to be integrated into, or adjacent to, the civil works of existing hydraulic structures such as diversion weirs, navigation locks, drop structures, small dams and spillways. These hydraulic structures are usually found on rivers, lakes and canals for water level control, flood management or water diversion but commonly do not have hydropower facilities or provisions for hydropower installation. Deployment opportunities abound in Canada with an estimated 80,000 existing structures within North America for possible low-head hydro development. Integrating the turbines into existing structures such as these greatly minimizes the cost of the civil works, significantly diminishes environmental impacts and reduces the effort to obtain regulatory approval, design and build the facility in comparison to conventional applications.

The VLH is an integrated turbine-generator set, incorporating a Kaplan runner with eight adjustable blades, a distributor composed of 18 fixed guide-vanes separated by radial trash rack bars, a permanent magnet generator directly coupled to the runner, and an automatic trash rack cleaner mounted on the nose of the distributor. The unit is intended to be mounted in an inclined position, with the turbine between 30° and 50° from horizontal. This holistic design is compact and aimed at decreasing intake and outlet structure size by maximizing the diameter of the turbine runner. Figure 2 shows the VLH schematic.

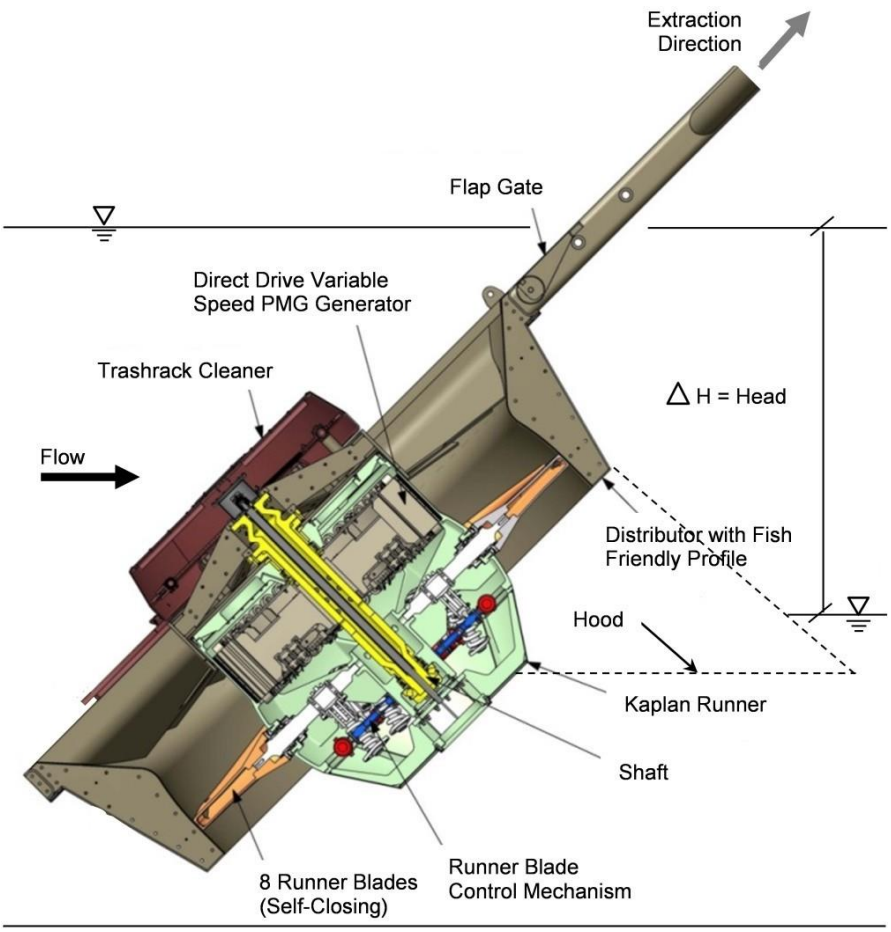

Figure 1: Very Low Head Turbine (VLH) Schematic (MJ2 2011, CPL 2013).

Photo 5 Wasdell Falls Downstream of VLH Structure

Over thirty-five (35) VLH units have been successfully deployed across Europe since March 2007, but units have yet to be deployed in North America, mainly due to different hydraulic, environmental, electrical and societal requirements. It is well recognized that even if an otherwise worthy technical solution cannot meet all of the necessary technical and regulatory requirements it will not be successfully deployed. Hence, deployment of the VLH turbine in Canada had multiple challenges and required considerable technical research to adapt the turbine to meet North American requirements. Consequently, the first North American VLH deployment is now underway at the historic site of Wasdell Falls in Ontario, Canada.

VII. Results

Project Achievements

Achievement 1 Successfully Achieved Commercial Operations

- WFLP successfully completed the permitting, financing, construction and commissioning of Wasdell In December 2015. This included meeting all the requirements of the Feed-in-Tariff program as governed by the Independent Electricity Systems Operator (formerly the Ontario Power Authority) and achieving Commercial Operations.
- Achieving Commercial Operations demonstrates that making use of existing water control structures to generate clean, renewable, reliable electricity is feasible and achievable when private and public organizations work together. This project has been producing this clean energy since August of 2015 and will continue doing so for decades to come.

Achievement 2 Cold Climate Turbine Adaptation

- WFLP was able to collaborate with the European turbine manufacturer/supplier, Canadian engineers and post-secondary institutions to adapt the existing VLH turbine that had shown the ability to efficiently produce power from low head run-of-river project site. The adaptation focused on modifying the existing technology so that it could continue to safely and effectively operate during the winter months.
- This successful collaboration has resulted in a turbine frame, an extraction system and a project concept that can be replicated throughout Canada, including remote northern locations to provide reliable, decentralized power.

Achievement 3 Working with Local Community and Contractors

- When possible, WFLP engaged contractors from the Washago, Ontario area during the construction and commissioning of Wasdell. This included the lead Mechanical and Electrical contractor and the Interconnection line contractors. The sub-contractors used were also from the local area. WFLP also actively engaged the residents upstream and downstream of the Wasdell Falls dam.

Technology Development Objectives

- Wasdell will serve as a demonstration for the innovative cold climate adaptations of the pre-existing VLH turbine technology. These cold climate adaptations will allow renewable energy to

be produced efficiently throughout the year from low head hydro power sites across North America.

- The design efforts resulting from the collaboration and innovation between WFLP, MJ2 and others and implemented at Wasdell have produced a technology that can make low head hydro projects economically viable. Wasdell represents a real application of the cold climate modifications including the extraction frame mechanism, additional turbine heating and insulation and larger flap gate to manage the additional debris. Future proponents and their engineers can use Wasdell as an indication of what is possible and what needs to done in order to take advantage of the numerous existing water control structures for the production of clean, renewable energy.
- These technology advancements will make once uneconomic low head hydro projects feasible. There are thousands of existing water control structures across Canada and the United States. While not all of these structures would have the optimal head and flow characteristics for a VLH project, studies have shown there is a potential to install over 1,100 M of capacity in Canada and estimates for annual production from similar sites in the United States have exceeded 73 TeraWatt Hours (TWh).

VIII. Lessons Learned

Potential for Replication

- Future low head hydro projects, and in particular those using VLH turbines, can build from the lessons learned at Wasdell and expect lower project costs on a $/MW of installed capacity basis.
- Replications of low head projects similar to Wasdell can expect to see reduced costs and fewer barriers to entry in the following key areas:
    - Engineering investigation and design
    - Financing due diligence and investigation
    - Regulatory review and approval

IX. Benefits

Renewable Energy Generation

- The 1.65MW installed capacity of Wasdell is expected to produce approximately 8,500MWh annually. This represents an annual Capacity Factor of roughly 59%.

  Status
  - The full benefit of this will be clear after Wasdell has had a chance to produce consistently for a full year.

GHG Reduction

- Producing a clean energy at Wasdell will displace the need to consume fossil fuels for thermal based electricity generation. To estimate the volume of fossil fuel displaced, an intensity factor that quantifies the GHGs associated with producing every kWh was calculated. Assuming Ontario's GHG Factor is 160grams CO2equivalent/kWh, Wasdell will be displacing 1,360 tonne of CO2equivalent annually.

  Status
  - The full benefit of this will be clear after Wasdell has had a chance to produce consistently for a full year.

Cost Reduction for Future Projects

- Future North American projects that make use of the VLH project should see a significant reduction in engineering design costs as much of the innovative design needed to properly adapt these turbines has already been completed. The incremental costs associated with

engineering and design, financing, permitting and construction as a first of its kind project will also be reduced or avoided.

Status

- The dollar value of cost reductions will depend on the project size.

Reduced Regulatory Burden

- Future VLH project Proponents and Regulators will benefit from having Wasdell on record with the various levels of government that reviewed all aspects of the project during the permitting process. The infrastructure owners (e.g. Parks Canada, MNR, and Ontario Ministry of the Environment (MOE))will have the ability to review existing documentation and discuss with engineers who have direct experience reviewing and approving the civil engineering plan for a similar style project. Regulators with a focus on the fisheries and waterways, the Department of Fisheries & Oceans and Transport Canada respectively, can also build from discussions and decisions regarding intake channel and tailrace velocities, and other potential impacts to fish and fish habitat resulting from the installation of the VLH turbines.

  Status

  - The full extent of these savings will be made clear once a project similar to Wasdell is proposed.

MNR Decreased Cost and Increased Revenue

- As a condition to leasing the project lands from the MNR, WFLP is responsible for all operation and maintenance of the Wasdell Falls Dam. WFLP has been operating the dam and managing upstream water levels since the start of construction. The MNR no longer needs to budget the time and resources for the Wasdell Falls Dam. Governments, at the Federal and Provincial level are always under pressure to reduce costs. Partnering with more proponents on projects like this will allow the MNR to focus its resources on other important matters. Additionally, MNR will be receiving royalties from the power production.

  Status

  - The MNR has already been able to take advantage of the additional resources available resulting from being relieved of the Wasdell Falls Dam. Royalty revenues will be received as per the terms of the Crown Land Water Power Lease

Jobs Created – Construction and Operations

- During the busiest periods of construction there were 10-20 full time workers at the project site and another 5-10 working on the interconnection line route. The project also required a dedicated Development Manager and full-time Operator from WFLP. WFLP will employ a team of Operators to oversee the power generation facility and the Wasdell Falls Dam. Going forward, WFLP will require the services of local electricians, millwrights, crane operators and other general contractors intermittently through the 40+ year project term. MJ2 has also

established a presence in Ontario to support the Wasdell project and pursue future opportunities to install the VLH turbines.

Status

- All economic benefits generated by jobs created during construction have been realized by the individuals and organization that provided serve. Going forward, WFLP will require the services of local millwrights, crane operators and other general contractors intermittently through the 40+ year project term.

X. Future Potential

- Wasdell will serve as a demonstration for the innovative cold climate adaptations of the pre-existing VLH turbine technology. These cold climate adaptations will allow renewable energy to be produced efficiently throughout the year from low head hydro power sites across North America.
- The design efforts resulting from the collaboration and innovation between WFLP, MJ2 and others and implemented at Wasdell have produced a technology that can make low head hydro projects economically viable. Wasdell represents a real application of the cold climate modifications including the extraction frame mechanism, additional turbine heating and insulation and larger flap gate to manage the additional debris. Future proponents and their engineers can use Wasdell as an indication of what is possible and what needs to done in order to take advantage of the numerous existing water control structures for the production of clean, renewable energy.
- These technology advancements will make once uneconomic low head hydro projects feasible. There are thousands of existing water control structures across Canada and the United States. While not all of these structures would have the optimal head and flow characteristics for a VLH project, studies have shown there is a potential to install over 1,100 M of capacity in Canada and estimates for annual production from similar sites in the United States have exceeded 73 TerraWatt Hours (TWh).

XI. Next Steps

- Collaboration with Department of Fisheries and Oceans on conducting a study to determine the impact to fish passing through the VLH structure.
- Refinement of extraction structure and processes
- Design refinements based on learnings from Wasdell Falls Construction and Operations experience

XII. Conclusions

The successful completion of all the terms and conditions required to achieve Commercial Operations under Ontario's Feed-in-Tariff is the most significant outcome for this demonstration project. By

achieving Commercial Operations at Wasdell, a certain amount of risk for future projects has been mitigated. Additional outcomes include the lessons learned by the proponent, the power development industry, regulators and financial institutions. These lessons learned will allow replication of Wasdell to be completed with greater efficiency and over a shorter period of time.

Now that Wasdell has proven that low head hydro power projects are feasible from and economic and technological standpoint it is expected that this type of project will be replicated in the future. Governments at every level are under increasing pressure to reduce overall GHG emissions and increase the penetration of renewable energy into current power generation portfolios. Taking advantage of existing water control structures, that have the required characteristics for low head hydro power generation, can help government achieve their environmental goals with low-impact projects that provide economic benefits to proponents, contractors and potential remote communities.