ecoENERGY Innovation Initiative

Research and Development Component

Public Report

Project: Reducing the cost of in-stream tidal energy generation through comprehensive hydrodynamic site assessment.

Low-profile GPS drifter measuring flow speeds while drifting past the ecoSpray tidal energy test platform in Grand Passage, NS.

Table of Contents:

1 Summary

Our project's goal was to reduce the costs, and therefore risks, of in-stream tidal energy development through comprehensive site assessment. The Project partnered three universities —Acadia, Dalhousie and University of New Brunswick (UNB)—with three companies—Fundy Tidal Inc. (FTI), Dynamic System Analysis (DSA) and Clean Current. The project focused on the community tidal projects planned for the Digby Neck region of Nova Scotia. The Digby locations offered easily accessible sites and a range of environmental conditions. Significantly, the project's community focus allowed the growth of several small Canadian companies.

The project was successful in characterizing sites in all three Digby Neck passages and making recommendations for turbine deployments at each site. Field measurements and numerical modelling illustrated that tidal currents show large variations across a site, have high levels of turbulence and can combine with waves to produce extreme conditions. The project determined the turbine specifications for each site.

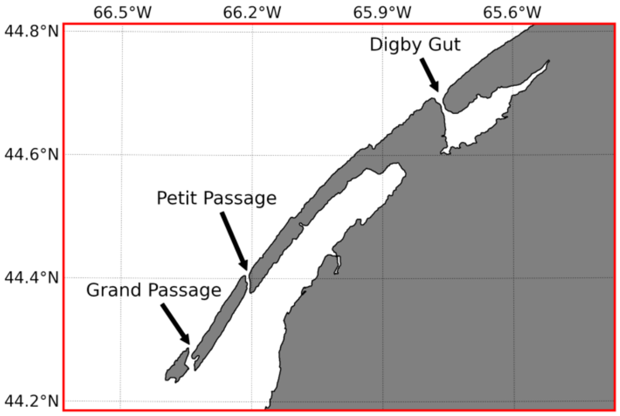
The project has successfully developed, demonstrated and validated cost-effective site assessment technologies. These include new field measurement technologies capable of characterizing the tidal flow, such as low-cost drifters to measure surface flow and multi-purposing acoustic Doppler current profilers (ADCPs) to measure turbulence and wave motion as well as long-term flow variation. Furthermore, the project developed innovative numerical models capable of analyzing spatial scales ranging from the turbine blades to the entire passages and temporal scales of a few seconds to 50 years. These numerical models were designed to be cost effective and accessible to project developers.

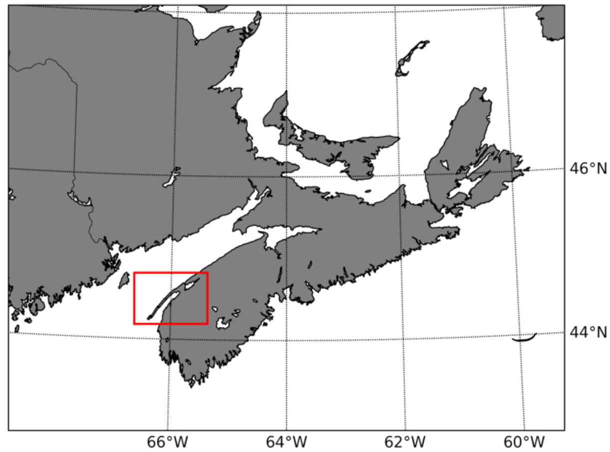
The project faced a major challenge when a turbine was not deployed in the Digby Neck passages as planned. To overcome this challenge, the project deployed the ecoSpray, a platform designed to replicate a floating turbine. Not only did the deployment of the ecoSpray allow for important field measurements of the forces on and flow around a surface platform, it demonstrated that a platform could be constructed and successfully deployed using local resources and at a reasonable cost.

Finally, the project was successful in the development of new field measurement technologies, numerical modelling software and data analysis techniques. The project partners have used these technologies to become leaders in the development of tidal energy in the Bay of Fundy. The project has fostered further academic research, created academic-industry partnerships and allowed Canadian companies to compete in the global tidal energy industry.

2 Introduction and Background

In 2012, the Canadian Marine Renewable Energy Technology Roadmap set ambitious goals for the Canadian tidal energy industry that required Canadian developers and researchers to demonstrate commercial-scale projects, approaches and expertise in the decade following the report's release. At the same time, the Province of Nova Scotia was introducing a Community Feed-in-Tariff program that would support the development of community-owned tidal energy projects. Both initiatives recognized that to accelerate commercialization of tidal energy, the cost per kilowatt hour of tidal energy had to be reduced through experiential learning and technological advances. This project was designed to achieve this goal by conducting comprehensive hydrodynamic site assessment of the COMFIT sites awarded to FTI.





(Left) The location of the three Digby Neck passages studied in this project. (Right) The location of Digby Neck relative to the Bay of Fundy and Nova Scotia.

The three sites, Digby Gut, Grand Passage and Petit Passage (shown above), were selected by FTI because they are particularly suitable for the deployment and testing of both individual tidal energy converters (TECs) and small commercial arrays. These sites offer a range of tidal flow regimes, from energetic to very energetic, that provide an excellent testbed for developing the site assessment techniques required.

The project set out to address the major gaps in site assessment. Previous work focused only on identifying passages that had strong tidal flow and, thus, the potential to generate significant energy. This project recognized that sites must be assessed in more detail to determine how the site's characteristics affect the engineering, construction and operational costs associated with each TEC technology. By considering each site's hydrodynamics, as well as engineering and operational issues, this project's goal was to develop strategies and techniques to determine the location and layout of TEC arrays that will result in the lowest cost per kilowatt hour. However, the methods and technologies to complete such a detailed site assessment either did not exist or were prohibitively expensive. Hence, a critical component of the project was to develop and validate the field measurement and numerical modelling techniques that could produce a cost-effective and complete site assessment.

The project was conducted between January 2012 and March 2016, primarily in Nova Scotia and New Brunswick. The project partners were three universities and three companies:

- Acadia University: Led by Dr. Richard Karsten of the Acadia Tidal Energy Institute, specializing in numerical coastal oceanography
- Dalhousie University: Led by Dr. Alex Hay of the Department of Oceanography, specializing in physical oceanography and field measurements
- University of New Brunswick (UNB): Led by Drs. Andrew Gerber and Tiger Jeans of the Department of Mechanical Engineering, specializing in computational fluid dynamics (CFD) modelling of flows and structures

- Fundy Tidal Inc. (FTI): The COMFIT developer
- Dynamic System Analysis (DSA): An ocean engineering consultancy and software company
- Clean Current: A tidal turbine manufacturer

3 Project Activities

The project was broken into three broad activities: determining the natural flow conditions, modelling the performance of a TEC in these conditions and deploying the test platform.

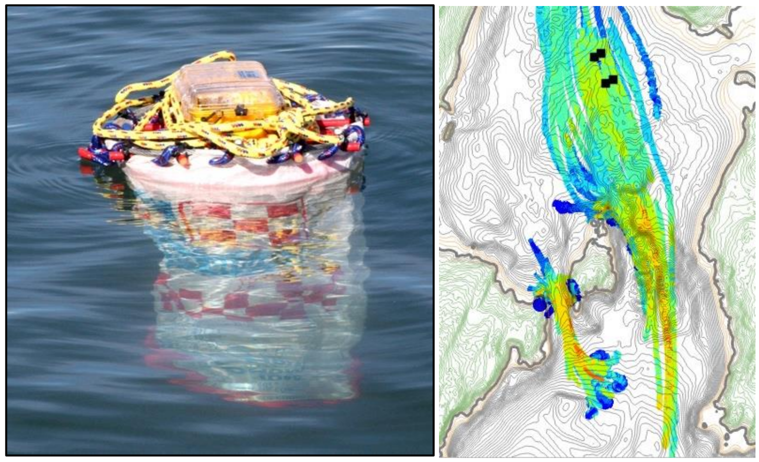
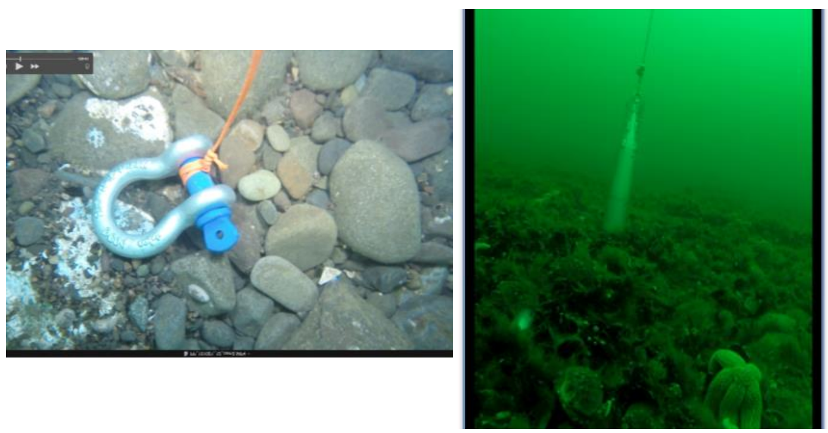
3.1 Measure and Model the Natural Flow Conditions

The first objective of the project was to establish the natural flow conditions within each of the three passages through a combination of field measurements and numerical modelling.

3.1.1 Field Measurements

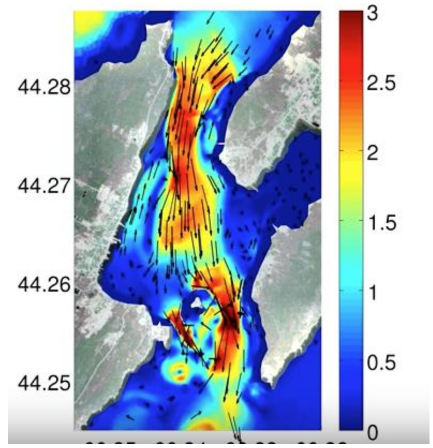
The project completed an unprecedented number of oceanographic and environmental measurements at a tidal energy site. A wide range of devices were used to measure water levels, flow velocities, surface flow, the vertical structure of the tidal flow, the variability in the flow, the bottom boundary layer dynamics and the characteristics of surface gravity waves. Many of these measurements were completed with technologies developed specifically for this project. We summarize the field measurements in the table below:

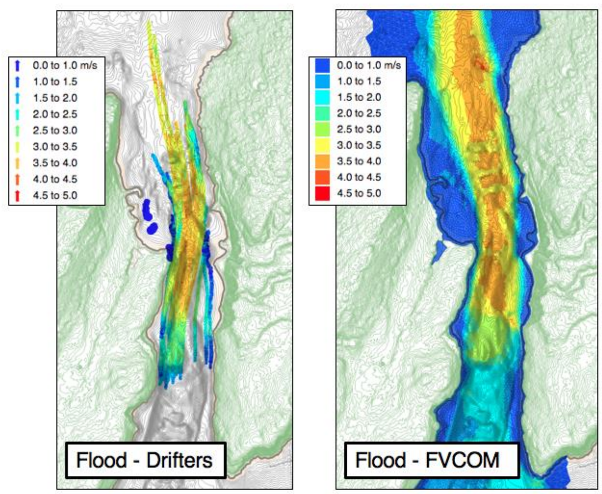
Key Flow Measurement Conducted by Dalhousie and FTI	**Picture Demonstrating R&D Technology**
ADCP deployments in all three passages for both short and longer deployments, in particular, a long-term (Aug. 2014 to Sept. 2015) deployment of an ADCP cabled to an Internet-connected shore station in Grand Passage and configured to collect wave and measure turbulence-resolving flow data.	 Deployment of an ADCP in Grand Passage (left) and the cabled ADCP several months after deployment in Grand Passage (right).
Measurements of turbulence using a state-of-the-art suite of turbulence-resolving instruments including the [Rockland Scientific] Microrider, newly developed ADCPs, single-point Nortek Vector Acoustic Doppler velocimeters, and Rockland Scientific's Vertical Microstructure Profiler (not shown).	 The Stablemoor buoy and the associated sensor suite prior to deployment in Grand Passage for the 2013 turbulence experiment. The sensors, clockwise from the upper left, are a Nortek Acoustic Doppler Velocimeter, a JTec electromagnetic flowmeter, a Nortek Acoustic Doppler Current Profiler, and the Rockland Scientific Microrider with the (white-tipped) shear probes protected by the four (black-tipped) outer steel tubes.

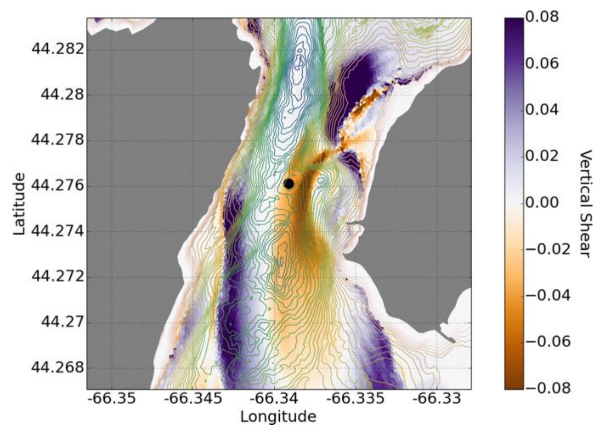
Key Flow Measurement Conducted by Dalhousie and FTI	Picture Demonstrating R&D Technology
Hundreds of surface drifts using an inexpensive, low-profile surface drifter, providing a map of the spatial variability in near-surface tidal flows, thereby addressing a limitation of bottom-mounted instruments.	 A drifter (left) and a map of ebb speed in Grand Passage from drifter data (right).
A detailed analysis of the seabed, including video imaging, grab samples, use of a dynamic penetrometer, side-scan sonar and sub-bottom profiling in all three passages. The bathymetric data was combined into a single complete high-resolution bathymetry data set for all three passages.	 An image of the sea bottom (left) and a penetrometer hitting the sea bottom after being released from a boat above (right).

3.1.2 Numerical Modelling

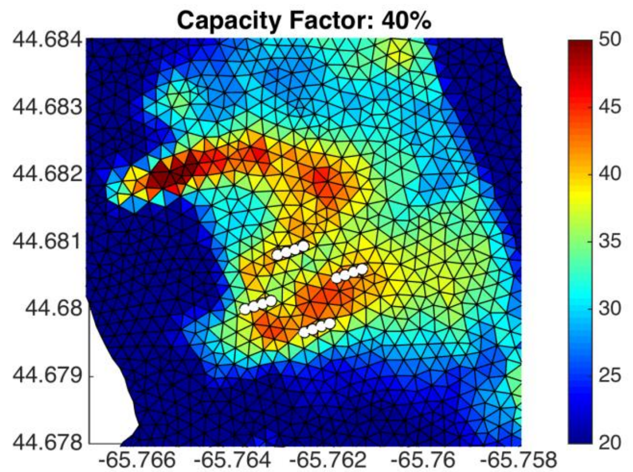
The observations were used to validate and refine Acadia's oceanographic model of the region. The numerical model was used to produce long-term, high-resolution 3D simulations of the flow at each site. As well, the project developed an innovative open-source data analysis software package, PySeidon, to analyze and compare the large amount of field and numerical data generated by the project.

<table>
<tr><th>Key Acadia Model Development</th><th>Image of Simulation Result</th></tr>
<tr><td>The model includes the high-resolution bathymetry in all three passages. The model has resolution that reaches 20 m in all three passages, capable of resolving flow on the scale of turbine sites, including high-frequency fluctuations associated with large-scale eddies and wakes.</td><td>


Animation of simulated tidal currents in Grand Passage. (click here for full animation)
</td></tr>
<tr><td>The field observations were used to validate and refine Acadia's oceanographic model of the region.</td><td>


Comparison of drifter velocities (left) with simulated velocities (right) in Petit Passage.
</td></tr>
<tr><td>The model generates accurate vertical flow profiles and can identify regions of strong shear that are unsuitable for turbine deployment.</td><td>


A map of the shear in the northern portion of Grand Passage. The region of high negative shear (orange in colour) indicated that this location was not suitable for turbine deployment and helped explain the high levels of turbulence in the region.
</td></tr>
</table>

Key Acadia Model Development	Image of Simulation Result
The simulated tidal currents from Acadia's numerical model were used to calculate the power output and capacity factors for different turbines at all locations and different depths in the passages This analysis was used to determine the financial viability of projects and determine sites requiring more in-depth site assessment.	 Numerical model results were used to predict the capacity factor of a turbine at all locations in Digby Gut. The white dots represent a turbine array that would have an overall capacity factor of 40%.

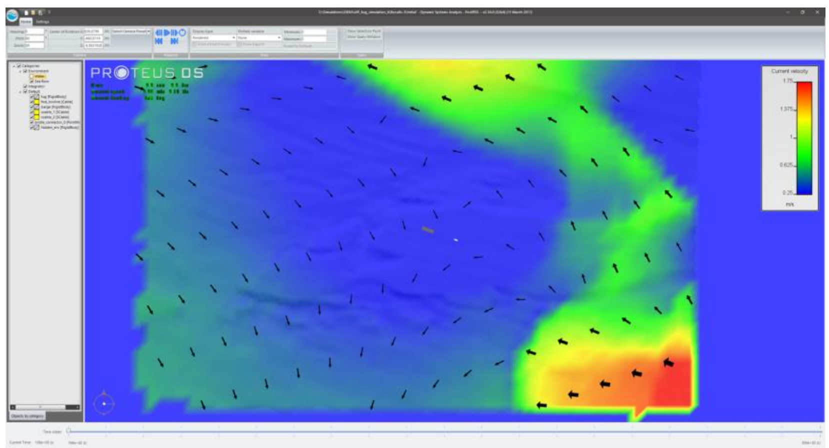
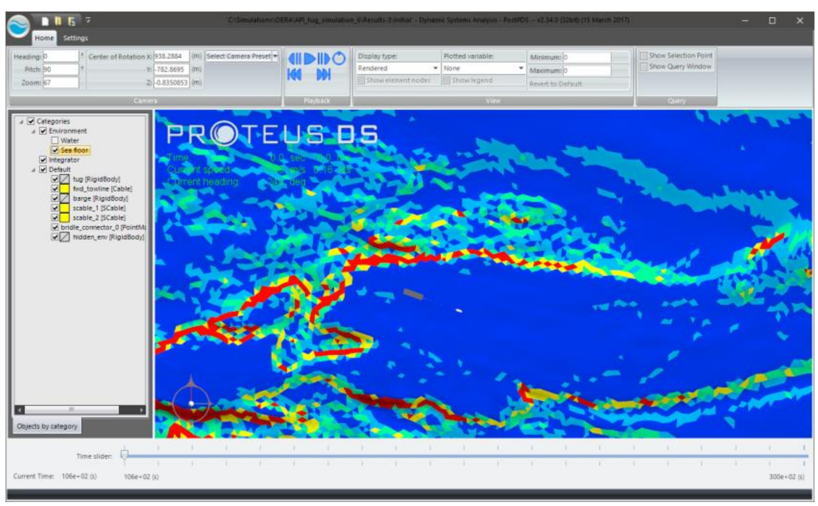
In completing the detailed site assessments, the project developed new technologies and established protocols for gathering field data and validating numerical models. The data generated was used to established that the flow regimes in Grand Passage and Digby Gut were less suitable for turbines than initial assessments indicated, while Petit Passage had flows most suitable for turbine deployments using existing commercially viable technologies. Lower flow levels near the sea bottom shifted the analysis to the performance and cost-effectiveness of surface platforms. This in turn required more detailed analysis of the uncertainty in long-term energy predictions, the high levels of turbulence in the flow and the extreme wave and storm conditions. The project's results were a reminder for the tidal energy industry that a full site assessment is required before the feasibility of a tidal project can be determined.

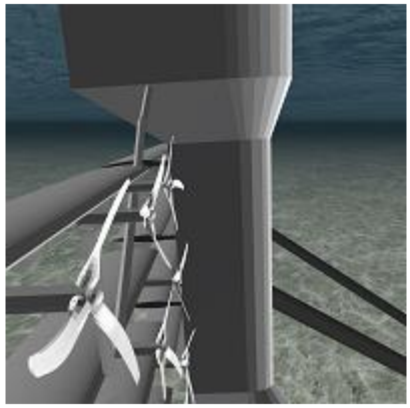
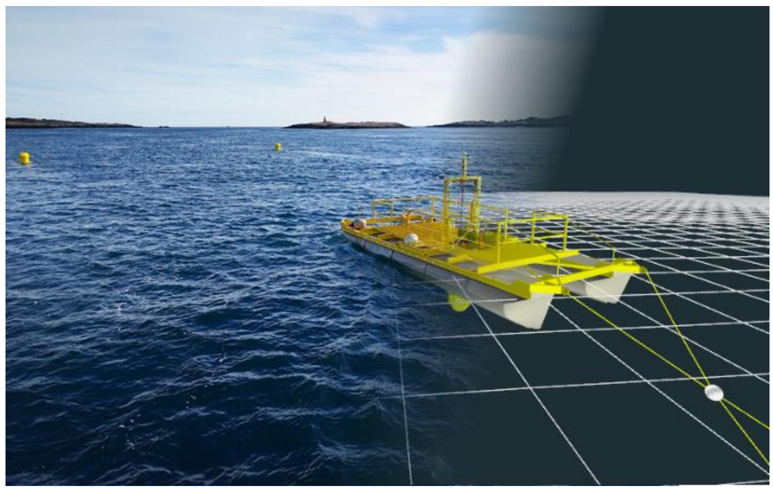
3.2 Model the Tidal Energy Converters

The second project activity was modelling specific TEC devices to estimate their power potential and suitability for deployment at the selected sites. To compete this objective, DSA, UNB, and Clean Current engineers worked closely together to model all aspects of turbine performance (other turbine technologies were assessed, but not in the same detail).

3.2.1 Modelling Supporting Structures

The focus of DSA's research was evaluating how turbines, their supporting structures and platforms and their mooring systems behave in tidal environments found in the outer Bay of Fundy. The initial phase of research focused on enhancing the ProteusDS software to be able to predict loads and motions of tidal platforms. Reducing the size and weight of platforms will directly reduce capital (installation) and maintenance costs. Sizing of structures directly depends on the site assessment (seabed wind, wave and current) information at a given site.

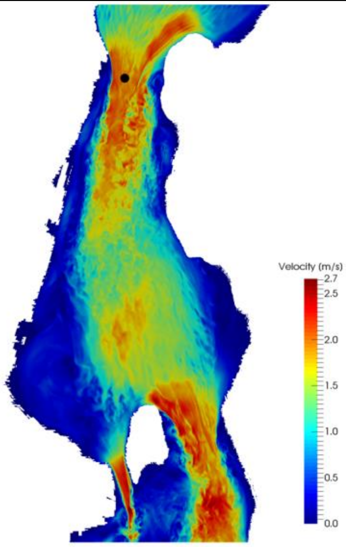
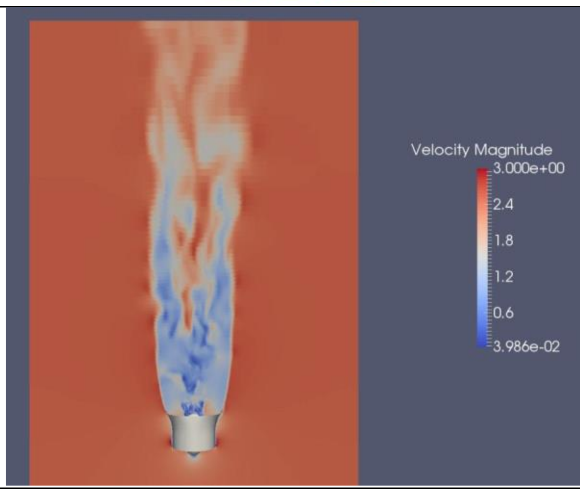
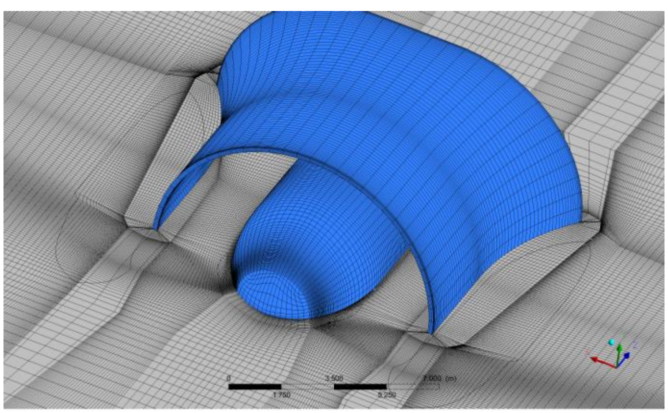
DSA Key R&D Activities	Picture Demonstrating R&D Technology
Anchoring and foundation calculations were performed and anchors tested.	
The use of 3D spatially and temporally varying current modeling in the ProteusDS software, including the ability to visualize these flows.	
Bathymetry analysis capability added to the ProteusDS software, allowing anchor locations to be selected based on seabed slopes and exclusion zones. Criteria for selection of anchor locations were researched.	

DSA Key R&D Activities	Picture Demonstrating R&D Technology
Turbine modelling with the use of a “turbine” numerical model in ProteusDS added and refined.	
Models of mooring systems and power cables completed in the ProteusDS software, with the result being the deployment of a platform and spread mooring system in Grand passage. Data was collected that will validate the numerical model.	

3.2.2 CFD Modelling

UNB enhanced their EXN/Aero software to model a TEC device imbedded in fully unsteady turbulent flow field generated by their high-resolution model of Grand Passage. UNB researchers further developed their EXN/Aero software to model the turbulent tidal flow and the performance of the Clean Current turbine. The major results are discussed in the table below:

Images from CFD Simulations	UNB Key R&D activities
	Tidal flows are highly turbulent, making it difficult to deploy turbines reliably. Supercomputer calculations (a portion is shown just below the surface of the water at depth relevant to a turbine) allow designers to understand this behaviour in great detail. Supercomputing-based fluid flow simulation programs (such as EXN/Aero)

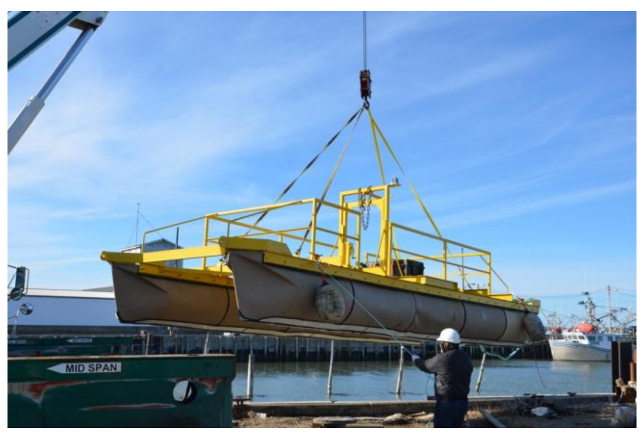
<table>
<tr><th>Images from CFD Simulations</th><th>UNB Key R&D activities</th></tr>
<tr><td>
</td><td>allow for three-dimensional predictions of the flow field. Results are shown for Grand Passage at ebb tide.</td></tr>
<tr><td>
</td><td>The turbulent flow passing through a turbine is shown while extracting power from the flow. Approximate models are being developed to include in larger models, as shown above. The turbine would be contained within the size of the black dot in the image above.</td></tr>
<tr><td></td><td>Computer models of turbine geometry, used in the models above, are highly realistic, allowing designers to test the performance of various configurations.</td></tr>
</table>

The project completed a full analysis of possible deployments of the Clean Current turbines at sites in Grand Passage and Digby Gut. The improvements in the numerical models were used throughout the rest of the project, as well as in other tidal energy analysis. However, the results were not positive for the Clean Current technology. It was determined that it was not economically feasible to deploy the turbines at the proposed sites. Again, this repeated the cautionary message for the tidal energy industry that technology must be designed for specific site conditions.

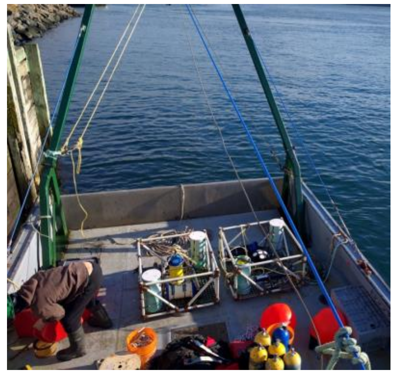
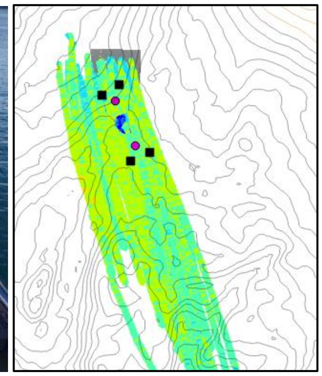
Meeting this objective had important impacts for the project and the tidal energy industry. It established that it is possible to reduce the uncertainty in power performance and cost analysis of an in-stream tidal project through careful site assessment. In terms of future tidal energy projects in the Digby area, the results established that Petit Passage was the most promising site for development due to more energetic flow at the site. The data was combined with an improved numerical modelling of the flow to address the economic feasibility of projects and, in particular, the feasibility of turbines deployed on surface platforms. DSA improved their ProteusDS software modelling of moored platforms and used the model to determine how the costs of the platforms and mooring can be reduced.

3.3 Deploying the ecoSpray: A Floating Tidal Turbine Platform

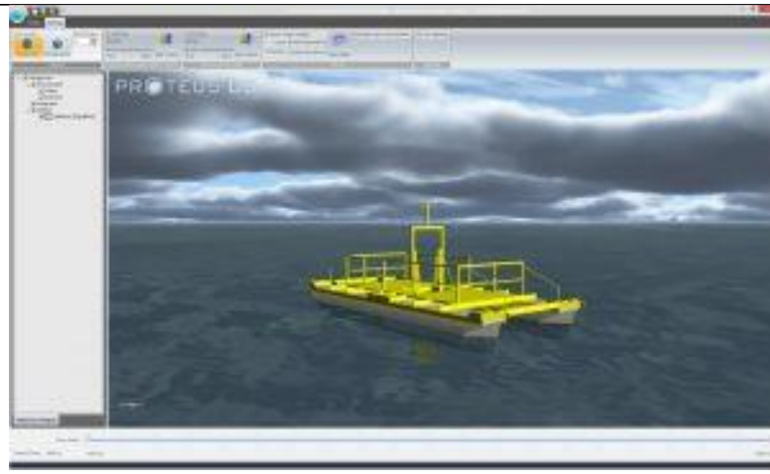
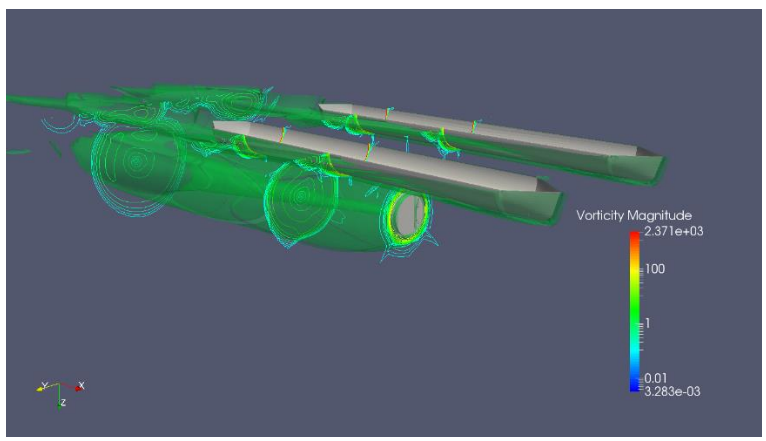
During the final phase of the project, the partners, led by DSA, focused on using the lessons learned regarding moorings and platforms to design, deploy, monitor and recover a floating tidal energy research platform called the ecoSpray.

EcoSpray Deployment Activities	**Picture Demonstrating Activity**
The ecoSpray was a community project. Local fabricators Bear River Plastics and Clare Machine Works constructed the platform. Local fishers were consulted to help select the deployment location, determine navigational marking and assist with the deployment.	 *Meeting with local fishers to discuss connecting platform with anchors.*
The ecoSpray was lowered to the water on February 29, 2016 by Clare Machine Works near Meteghan, NS. A local boat from Freeport towed it to Grand Passage for deployment.	 *Deployment of ecoSpray platform.*

EcoSpray Deployment Activities	**Picture Demonstrating Activity**
The “Spray,” a local ferry providing access to Brier Island since 1978, was used in conjunction with an excavator to deploy 6 tonne anchor blocks. This involved the project team collaborating with the Nova Scotia Department of Transportation for the deployment. DSA and FTI installed an accurate positioning system on the ferry to assist with deploying the anchor blocks within a few metres of the target positions.	 *Excavator loaded onto the “Spray” ferry for anchor deployment.*
Marker buoys with flashing lights were used to mark the site location and were deployed with the anchors.	 Launching 6 tonne anchor, with attached marker buoy.
Local lobster boats and fishers were used to deploy the mooring chains and platform. Diver Mike Huntley and the fishers connected the mooring chains to the anchors. The local boats then positioned the platform and connected the mooring chains.	 Picture of boat “Island Rebel” during connection of platform with anchors.

EcoSpray Deployment Activities	Picture Demonstrating Activity
Once the platform was in place, ADCPs were deployed upstream and downstream of the platform to capture wave and current conditions. An anemometer measured wind speed on the platform. An inertial measurement unit with GPS antennas was used to measure the position and motion of the ecoSpray platform. Drifters were released upstream of the ecoSpray to map the surface flow around the platform.	  (Left) ADCP frames ready for deployment upstream and downstream of the platform. (Right) Drifter tracks past the ecoSpray.

Video of ecoSpray platform. *(click here for full video)*

Key ecoSpray Modelling Development	Image of Simulation Result
The measurement devices on the ecoSpray quantified the environmental forcing acting on the platform and the response of the platform and mooring to the forcing. The platform was deployed twice to test two different mooring configurations. In addition to the field work, the motion of the platform and mooring line loads were modelled using DSA's ProteusDS software.	 *Numerical model of ecoSpray in ProteusDS.*
UNB conducted CFD simulations of the platform to predict the interaction of ocean waves and tidal currents with the floating structure, and the impacts of these interactions on the resulting loads in the mooring lines.	 *CFD simulation of the ecoSpray pontoons.*
An important aspect of the ecoSpray deployment was the measurement of the platform's wake. ADCP, drifter and drone measurements were used to determine the length and characteristics of the wake.	 *Wakes of the ecoSpray platform and buoys as captured from a drone.* *(click here for drone flight video)*

In constructing, deploying and monitoring the ecoSpray, the project established several key results for the tidal energy industry. It established that a surface platform could be built and deployed using local resources at relatively low cost. It also established that costs associated with the mooring of such a platform can be reduced if carefully designed to the site characteristics. These conclusions are extremely relevant to the design and optimization of tidal power systems at similar sites worldwide.

4 Conclusion and Follow-Up

4.1 Outcomes

The project resulted in a number of important outcomes, which can be discussed in two broad categories: outcomes for the tidal energy industry and improvements in technology, software and methods.

4.1.1 Outcomes for Tidal Energy Industry:

For the tidal energy industry in Nova Scotia and Canada, the major outcome of the project was the development of a process of detailed site assessment for tidal turbines. The project emphasized that site assessment is more important for in-stream tidal turbines than any other renewable energies, due to the challenges of working in the extreme marine environment. This project produced several critical outcomes for site assessment that will be used in many sites beyond the Digby Neck passages:

- Flow characteristics vary significantly across a site, on spatial scales similar to the size of turbines. The combination of a validated numerical model and field measurements is required to make accurate forecasts of turbine performance.
- Strong tidal flow is highly turbulent, the turbulence may not be locally generated and the turbulence characteristics are different at each site. Once again, the combination of a high-resolution CFD model with on-site turbulence measurements is required to fully characterize the turbulence at a given site.
- Tidal turbines and their supporting structures must be designed to the flow characteristics and the extreme conditions at the specific deployment site. This project demonstrated that a combination of numerical models, one designed for flow–structure interaction and one a full CFD model of the turbine, can be used to cost-effectively model a turbine deployment and substantially reduce the cost and risk of deployment.
- A prototypical turbine surface platform can be constructed, deployed and operated at reasonable costs, using local resources.

4.1.2 Improvements in Technology, Software and Methods:

As discussed in previous sections, the project has seen the development of innovative methods to:

- Measure tidal currents
- Measure turbulence in high-energy flow
- Numerically model tidal passages
- Complete CFD modelling of an energy extraction device in realistic environmental conditions
- Model fluid–structure interactions and loading in extreme marine conditions

4.1.3 Long-Term Outcomes:

The long-term outcomes from this project depend on the continued development of tidal energy in the Bay of Fundy and elsewhere. The project partners continue to be involved in tidal projects in the Digby Neck passages and are involved in tidal projects in Minas Passage. If turbine deployments in these passages are successful, the tidal energy industry could expand rapidly and the techniques and expertise developed in this project could be used extensively.

Beyond tidal energy, the advancements of technology and understanding of the high-energy marine environment will be applied to environmental and industrial projects in the Bay of Fundy and beyond.

4.2 Next Steps

4.2.1 Next Steps for Technology Development:

1. Turbulence measurements/modelling methods will be extended to sites in Minas Passage through a project involving several project partners. The Dalhousie-led project called "Remote acoustic measurements of turbulence in high-speed flows with application to in-stream tidal turbine development: The Vectron project" is funded by an NSERC Collaborative Research and Development Grant that was awarded in March 2017.
2. The site assessment methods/technologies are being expanded for use at commercial-scale sites in Minas Passage, including interaction of marine life with turbines. To support this research, an application for $2 million in funding was submitted to the CFI Infrastructure program in October 2016. CFI will make the final decision on the funding in June 2017.
3. The application and improvement of the project's technologies and methods continue in assessment of sites and projects in Digby Neck passages, FORCE berths in Minas Passage and other sites in the Bay of Fundy.
4. Further refinements of Acadia's numerical models are being completed through application to specific resource and site assessment projects, including the following projects, which were started in 2016 and will be completed in 2017: the Marine Renewable Electricity Areas project, which analyzed the tidal resource in Minas Passage and other upper Bay of Fundy sites; a research project supported by FORCE, Open Hydro and an NSERC Engage grant; and site assessment projects in Minas Passage and Petit Passage done in partnership with Luna Oceans.

4.2.2 Next Steps for Regulatory Improvement:

1. All project partners will continue involvement with the Nova Scotia government on projects regarding regulations surrounding tidal energy.
2. The ATEI will complete the resource modelling component of the Marine Renewable Electricity Areas project for the NS Department of Energy that will be used to establish the areas for commercial-scale development of tidal energy in Minas Passage.
3. Beginning in April 2017, results of the project will be used to update the IEC standards on tidal energy resource assessment.

4.2.3 Next Steps for Market Penetration:

The commercialization of the project's results will continue in four areas:

- DSA has used the improvement in their Proteus software to work on several contracts on structural modelling related to tidal energy development. DSA is furthering its work on reading and visualizing spatially varying current data into its software, determining how turbulence and its effect on turbine loading can be numerically modelled, validating the wave-current interaction models, and validating the applications to floating tidal platforms through further post-processing of the data collected during the ecoSpray deployment. DSA has continued to work in related fields (aquaculture, wave energy, off-shore energy) and has made significant efforts to be involved in the global tidal energy industry. Further market penetration of tidal energy will depend critically on the further development of the tidal industry both in Nova Scotia and globally.

- UNB has commercialized its development of the EXN/Aero software through the spinoff company Envenio. Envenio will continue to market its innovative software and expertise in high-resolution computer modelling applied to a wide range of applications, including tidal resource development, Canadian naval platforms and Arctic exploration. Further market penetration is supported by the continuing academic–industry partnership and the support of ACENET.
- Dalhousie's development of turbulence measurements has been commercialized through partnerships with NortekUSA and Rockland Scientific. This project provided important support for the further development of these partnerships—for example, the project supported the development and testing of Rockland/Dalhousie 's Nemo Turbulence Mooring. The development of the technology has continued with projects in Minas Passage. A critical step in market penetration is continued exposure to the global market.
- Luna Ocean was established following completion of the project, with a focus on further site assessment R&D and commercial application of site assessment expertise and technologies. Luna, in partnership with Acadia, has successfully completed several site/technology assessment contracts for sites in Minas Passage and Petit Passage. Luna has also further developed its technology by combining drifters with drones (see this video of initial field experiments). Luna's initial focus is implementation at commercial tidal energy projects in Nova Scotia and throughout Atlantic Canada. However, there is significant potential for application along Canada's three coasts. Luna's objective is to provide high quality site characterization information needed for advancing in-stream tidal (and river) energy projects while helping to reduce the cost per kilowatt hour of in-stream energy production. This includes continuing to assist with the development of a streamlined standardized process for site assessment. Information requirements addressed by Luna include (a) resource predictions for use in project financing (primarily annual energy production); (b) flow, wave, water level and seabed data for engineering design; (c) marine life conditions to support environmental monitoring; and (d) existing use such as fishing, navigation and tourism to support community engagement activities and evaluate potential turbine deployment locations (while minimizing conflicts with existing use). In 2017, Luna is seeking funding to support field tests to advance equipment from prototypes to TRL 7 to 9, and further develop Luna Ocean Data Analysis Software (LODAS). Luna's continued growth is being built on strong ties to the tidal energy industry, local universities and local communities.

4.2.4 Final Comments:

The tidal energy industry has faced many challenges over the past decade but is starting to see some important successes with the deployment of a turbine in Minas Passage by Cape Sharp Tidal and the first turbine deployments of the MeyGen project in Scotland. The next few years will be critical to establish that such projects can produce reliable renewable energy and be financially viable. While this project has established that the tidal marine environment is extremely challenging, it also established that this environment can be cost-effectively characterized and therefore allow for the development of a tidal energy industry on both commercial and community scales. The support of Natural Resources Canada was critical to these successes.

4.3 Project Publications

- P. Jeffcoate, F. Fiore, E. O'Farrell, D. Steinke, A. Baron, R. Starzmann, S. Bischof, "Comparison of Simulations of Taut-Moored Platform PLAT-O using ProteusDS with Experiments," Proceeding of the 3rd Asian Wave and Tidal Energy Conference (AWTEC), Singapore, Oct 24-28, 2016

- D. Steinke, A. Baron, R. Nicoll, A. Roy, "Dynamic Analysis of a Floating Tidal Energy Platform in Grand Passage," Proceedings of the 11th European Wave and Tidal Energy Conference (EWTEC), 6-11 Sept 2015, Nantes, France
- A. Roy, S. Beatty, V. Mishra, D. Steinke, R. Nicoll, Bradley J Buckham, "Efficient Time-Domain Hydrodynamic Simulation of A Rigid Body," Proceedings of the ASME 2015 34th.
- McMillan, J.M., A.E. Hay, R. Lueck, and F. Wolk, 2016. "Rates of dissipation of turbulent kinetic energy in a high Reynolds number tidal channel," J. Atmos. Ocean. Tech., 33(4), 817-837.
- McMillan, J. M., A. E. Hay, R. G. Lueck, and F. Wolk, "An assessment of the dissipation rates at a tidal energy site using a VMP and an ADCP," in Proc. of European Wave and Tidal Energy Conference 2015, p. 8 pp., Nantes, France, 2015.
- McMillan, J. M., and A. E. Hay, "Spectral and structure function estimates of turbulence dissipation rates in a high-flow tidal channel using broadband ADCPs," J. Atmos. Oceanic Technol., 34, 5–20, 2017.
- K.W. Wilcox, I.M. McLeod, A.G. Gerber, T.L. Jeans, J. Culina (2015) "Validation of High-Fidelity CFD Simulation of the Unsteady Turbulent Tidal Flow in Minas Passage," 11th European Wave and Tidal Energy Conference (EWTEC2015), September 2015.
- K.W. Wilcox, A.G. Gerber, J.T. Ahang, T.L. Jeans (2016) "Validation of LES Turbulence Modelling of a Tidal Site on an Industrial Timeframe," International Conference on Ocean Energy (ICOE) 2016, Poster, February 2016.
- F. Baratchi, T.L. Jeans, A. Gerber (2016) "A Comparison Between Blade Element Actuator Disk and Actuator Line Methods for a Tidal Turbine," 24th International Congress of Theoretical and Applied Mechanics (ICTAM 2016), August 21 -26, Montreal.
- Hay, A. E., J. M. McMillan, R. Cheel, and D. J. Schillinger, Turbulence and drag in a high Reynolds number tidal passage targetted for in-stream tidal power, in Proc. Oceans 2013, p. 10 pp., Institute of Electrical and Electronics Engineers (IEEE), San Diego, CA, 2013.

4.4 Contact Information

Dr. Richard Karsten
Acadia Tidal Energy Institute
Department of Mathematics and Statistics
Acadia University
Richard.Karsten@acadiau.ca

Dr. Alex Hay
Dalhousie Ocean Acoustics Lab
Department of Oceanography
Dalhousie University
Alex.Hay@Dal.Ca

Dr. Tiger Jeans
Department of Mechanical Engineering
University of New Brunswick
tjeans@unb.ca

Dr. Andrew Gerber

Department of Mechanical Engineering
University of New Brunswick
agerber@unb.ca

Dean Steinke
Director of Operations
Dynamic Systems Analysis Ltd.
dean@dsa-ltd.ca

Greg Trowse,
Principal Consultant
Luna Ocean Consulting Ltd
greg.trowse@lunaocean.ca