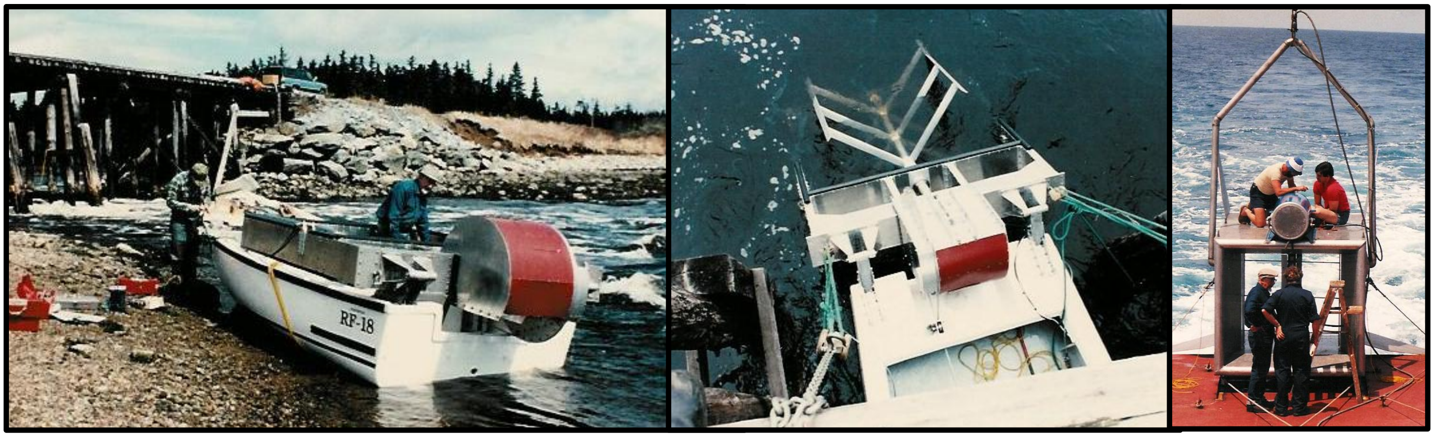

Nova Scotia Small Tidal Test Centre: Gap Analysis and Business Case

Submitted to:
Offshore Energy Research Association of Nova Scotia
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ACADIA Tidal Energy INSTITUTE

DARE TECHNOLOGY
INNOVATIVE RENEWABLE ENERGY TECHNOLOGY

LOCK

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Cover Photos:

Top Panel - Dr. David Swan (1985) - Testing of the VEGA turbine (Nova Scotia designed and built) turbine at entrance to Porters Lake prior to use in Gulf Stream near Florida

Bottom Panel (clockwise from top left)

Image 1 and 2 – Fundy Tidal Inc. (FTI) and New Energy Corporation (NEC) (2010) -Testing of NEC 5 kW turbine at Grand Passage

Image 3 – Big Moon Power (2016) - Testing of the Kinetic Keel at Minas Passage

Image 4 – Fundy Ocean Research Centre for Energy (FORCE) and Huntley's Sub-Aqua Construction (HSAC) (2017) – Deployment of Fundy Advanced Sensor Technology 3 (FAST-3) instrument platform at Minas Passage

Image 5 and 6 – Local fishermen (Freeport, NS), FTI, Dynamic Systems Analysis Ltd., Dalhousie Ocean Acoustics Laboratory, Acadia Tidal Energy Institute, University of New Brunswick, HSAC (2016) – Testing of the ecoSpray tidal platform in Grand Passage

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Abbreviations

ACOA	Atlantic Canada Opportunities Agency
ADCP	Acoustic doppler current profiler
AMREP	Area of marine renewable energy priority
ATEI	Acadia Tidal Energy Institute
AUV	Autonomous underwater vehicle
BIO	Bedford Institute for Oceanography
BMCS	Bamfield Marine Sciences Centre
BoFEP	Bay of Fundy Ecosystem Partnership
BTTS	Bourne Tidal Test Site
Capex	Capital expenditure
CFD	Computational fluid dynamics
CHS	Canadian Hydrographic Service
CHTTC	Canadian Hydrokinetic Turbine Test Centre
COMFIT	Community Feed-in Tariff
COVE	Centre for Ocean Ventures and Entrepreneurship
DFO	Department of Fisheries and Oceans (Canada)
DMEC	Dutch Marine Energy Centre
DOE	Department of Energy (Nova Scotia)
DOT	Nova Scotia Department of Transportation and Infrastructure Renewal
EMEC	European Marine Energy Centre
FCDA	Freeport Community Development Association
FERN	Fundy Energy Research Network
FIT	Feed-in tariff
FORCE	Fundy Ocean Research Centre for Energy
FORSEA	Funding Ocean Renewable Energy through Strategic European Action
FSRS	Fishermen Scientists Research Society
FVCOM	Finite Volume Community Ocean Model, the numerical model used by Acadia University
GPS	Global positioning system
IORE	Institute for Ocean Research Enterprise
IP	Intellectual property
KDC	Key decision criteria
LiR NOTF	LiR National Ocean Facility (Ireland)
MaREI	Centre for Marine and Renewable Energy
MARINet2	Marine Renewable Infrastructure Network – 2nd funding program
MERIC	Marine Energy Research and Innovation Centre
MOA	Memorandum of agreement
MOU	Memorandum of understanding
MRC	Marine Renewables Canada
MRE	Marine renewable energy
MREA	Marine renewable electricity area
MRECo	Marine Renewable Energy Collaborative
NEMEDS	New England Marine Energy Development System
NNMREC	Northwest National Marine Renewable Energy Centre
NRCan	Natural Resources Canada
NSCC	Nova Scotia Community College
O&M	Operations and maintenance
OERA	Ocean Energy Research Association
Opex	Operating expense
OTCNS	Ocean Technology Council of Nova Scotia

OTN	Ocean Tracking Network
PRIMaRE	Partnership for Research in Marine Renewable Energy
PTEC	Perpetuus Tidal Energy Centre
QML	Queens University Marine Laboratory
R&D	Research and development
RD&D	Research, development and demonstration
REIDS	Renewable Energy Integration Demonstrator - Singapore
ROV	Remotely operated vehicle
SEENEOH	Site Expérimental Estuarien National pour l'Essai et l'Optimisation d'Hydroliennes
SNMREC	Southeast National Marine Renewable Energy Centre
TC 114	International Electrotechnical Commission's technical committee for marine energy conversion systems
TRL	Technology Readiness Level
TTC-GD	Tidal Test Centre-Grevelingendam
WaTERS	International Wave and Tidal Energy Research Sites

Executive Summary

Background

Tidal energy conversion is still in the development stage of the industry life cycle. The need to realize economies of scale has driven development of large-scale devices and utility-scale arrays for power generation but the challenges have been daunting. An alternative route -- the testing of small- and community-scale devices as well as scale models of devices intended for commercial applications -- can help meet the challenges through a step-wise approach. This can facilitate technological and operational improvements, reduce costs and uncertainty, facilitate private-sector financing, and lower the cost of capital, helping to move the industry forward.

Testing and developing small tidal energy technologies also opens up the opportunity to export systems to communities where tidal energy can be a viable alternative to fossil fuel for electricity generation. Such installations would also create demand for specialized monitoring technologies, site assessments, and other expertise. However, more research, development and demonstration is needed to further reduce uncertainty - to prove the technologies, improve their reliability and energy yield, improve understanding of the effects of turbines on marine life and the natural environment, and reduce costs - before the market will open up to small-scale tidal energy solutions.

Objectives

This report was produced on behalf of the Offshore Energy Research Association (OERA) to determine whether there is an unserved market need that can be met by a small tidal test centre in Nova Scotia. "Small tidal," which encompasses "small-scale tidal" and "community-scale tidal," is distinct from the commercial, utility-scale developments planned at the Fundy Ocean Research Centre for Energy (FORCE) and other areas in the Bay of Fundy. Community-scale projects are usually off-grid or connected to the distribution electrical system, with the total power output scaled appropriately to provide sustainable energy to local, rural, coastal communities. A well-designed small tidal test centre is the next step from tank-testing facilities, necessary to advance Technology Readiness Levels (TRLs) through exposing devices to real-world conditions and evaluating how the devices operate. It is a place to address challenges and inform potential commercial applications for both community- and utility-scale projects at more challenging or remote sites.

The objectives of this study are to:

1) Scan the global tidal energy industry for test centres and their offerings, the needs of technology developers and researchers, and identify gaps or unserved niches for small-scale tidal testing.
2) Assess whether these gaps could be filled in Nova Scotia and what advantages a Nova Scotia test centre would have.
3) Identify small tidal test center models, combining Nova Scotia's unique natural and human resources, that fill an unserved or under-served market need. The model strived for should be feasible, be economically beneficial, support regional and international research and development activities, provide local research and business opportunities, and have a competitive advantage that will be sustainable as the industry develops in Nova Scotia and abroad.
4) Describe the economic and other benefits that would accrue to Nova Scotian people, researchers, and organizations if a small tidal test centre were to be built.

Analysis and alternatives

Gap analysis

A gap analysis was conducted in late 2017. The analysis contained two parts: a) a scan of the test centre facilities and services available for tidal technology testing around the world, and b) a compilation of the needs of researchers and technology developers for small-scale tidal energy technology testing. Juxtaposing the results of the industry scan and needs helped identify unserved and under-served needs.

Test centre scan

The global scan of tidal energy test centres showed a concentration in Europe, some of which are well-suited to small tidal testing. In North America, there are only four relevant test centres, two are river current, one is in the Cape Cod Canal, and the other in the Florida Strait, in a deep ocean current, twelve nautical miles offshore. In Canada, there are no open-ocean, small-scale tidal test centres. In Eastern Canada, there are no open-water, small-scale test centres, river, open-ocean, or otherwise. The scan included interviews with people at the test centres to learn what services are offered and best practices.

Needs

Interviews were conducted with individuals from the tidal industry, ocean technology industry, academia, manufacturing and marine operations supply chain, and regulators to identify the need for a small tidal test centre in Nova Scotia and specific site and test centre requirements. There was considerable agreement in the responses: an ocean research and technology development centre in Nova Scotia that specializes in smaller- and community-scale tidal energy projects is needed. There was also interest in a test centre that is accessible for a broader range of oceanographic and energy-related research and development. The following list is a summary of the needed features and characteristics:

1. *Accessibility*, in many forms, including:
    a. Ability to obtain all required permissions/permits/consents, through the test centre, with regulators, community, fishers, First Nations, etc. This would accelerate R&D and reduce the costs for developers to use the site;
    b. Physical access, including test locations close to shore; launch ramp, harbour, and wharf that are accessible through the tidal cycle; and hoists, etc. for loading and unloading equipment;
    c. Availability of high quality professionals at the test centre, as needed, to assist with developing and implementing test procedures, establishing collaborative relationships with academics and local supply-chain companies, performing marine operations, and safely handling power to shore, etc.;
    d. Ability to obtain existing high-quality site information, including flows, water levels, depths, seabed conditions, wind, waves, and marine life (access to information noted in 4);
    e. Ability for groups from local communities and First Nations to access the site and non-proprietary data for research, technology development, and training;
2. Nearby infrastructure and personnel to enable cost-effective research and development;
3. Diverse deployment locations (spatial variability in flow speeds, depth, seabed conditions, etc.);
4. A well-characterised site with high-quality data and modelling;

5. Operating turbines to investigate engineering and scientific uncertainties, including use of a site/centre with the ability to accommodate a small array with a variety of tidal turbines;
6. Ability to conduct effective environmental monitoring (visibility is key, including water clarity and proximity to shore);
7. Meaningful and purposeful involvement of local community members, fishers, and First Nations;
8. Flexibility and a client-focussed approach;
9. A pathway to commercialization that allows development from low-TRL to TRL 9.

Gap

There are gaps in the offerings of small tidal test centres around the world. The needs, noted above, allude to some. The scan of test centres shows a concentration of test centres in Europe, some of which are well suited to small-scale testing. There are no open-ocean small tidal test centres in North America. In Eastern Canada, there are no open-water small-scale test centres, river, open-ocean, or otherwise.

Upon analysis, a gap is apparent in the mid-range of tidal test centre offerings. Globally, there are few open-ocean test centres with the combined flow speed, depth, and accessibility of the Nova Scotia sites. Also, there is a gap related to a test centre that specializes in small- and community-scale tidal energy technology that could also fill a need for a broader range of oceanographic and energy-related research and development.

Figure 1 shows the ocean test centres identified in the industry scan in terms of water depths and flow speeds. It also shows the needed range of depths and flow speeds noted by developers and a range of speeds and depths generally suitable for small-scale tidal testing. As can be seen in Figure 1, there are no test centres with intermediate flow speeds (2 to 4 m/s) and intermediate depths (10 to 30 m). This is a gap a Nova Scotia test centre could fill.

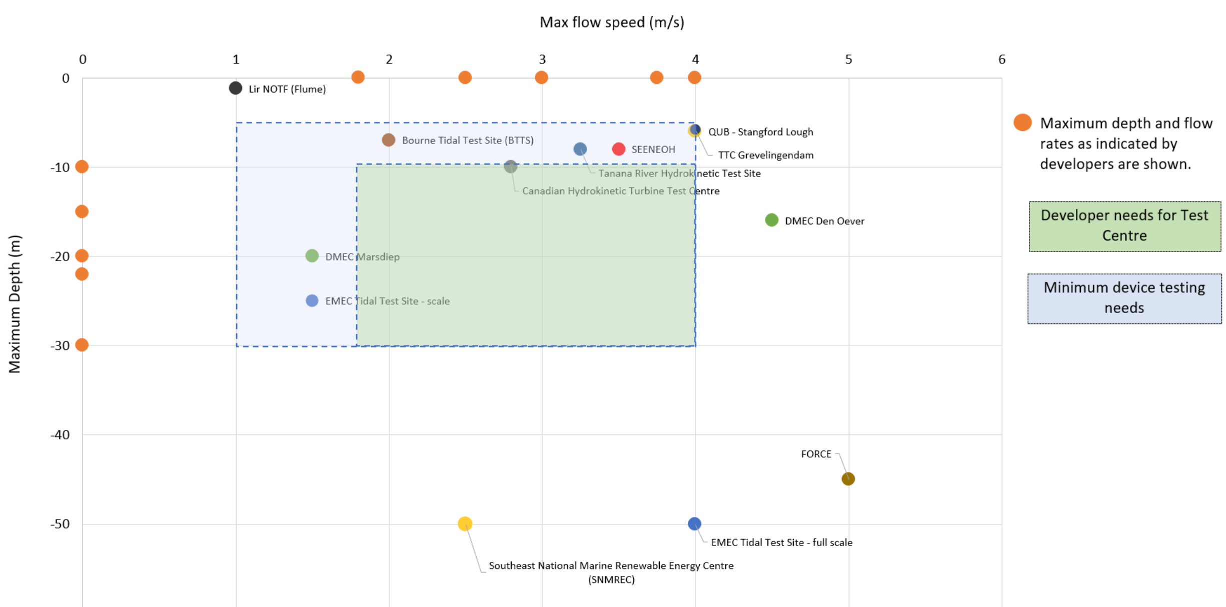

Figure 1: Test site characterization (depth and flow speed), with developers & researchers' needs (dashed-line frame).

Strategy

For a test centre to achieve its objectives and provide a sustainable benefit to Nova Scotians and the tidal energy industry, it would need to have a sustainable competitive advantage in the global marketplace. The gap analysis and a competitive industry analysis helped identify a competitive opportunity for a Nova Scotia small tidal test centre. The analysis of resources and capabilities resident in Nova Scotia helped identify a sustainable competitive advantage. A strategy, made up of goals, product- or service-market focus, core activities, and value proposition is summarized in Table 1.

Table 1: Test centre strategy

Goals	What the organization intends to achieve, in measurable terms, absolutely and relative to the competition. Hard goals: financial, marketplace and timeframe targets. Soft goals: targets for social conduct. Overarching goal: To help provide a pathway for tidal energy technology and ocean technology development and facilitate tidal stream and ocean research more broadly.
Product/Service-Market focus	What the organization intends to offer and the market it intends to compete in. What? To Whom? To Where? Product/Service offering: Test Centre: *Accessible* mid-range tidal stream for tidal and ocean technology testing and tidal stream and ocean research (refer to Section 2.2 for needs). To Whom: SMEs and large companies testing: a) Community-scale tidal energy conversion devices at mid- to high-TRL; b) Utility-scale tidal energy devices - scale models or pre-commercial full scale; c) Other tidal energy-related and ocean technology and energy storage; d) Deployment, maintenance and retrieval procedures. Researchers of: e) Tidal energy, ocean, energy storage technologies; f) Tidal streams, marine life, additional ocean industries, and oceans more generally. To Where: For tidal energy and related technology R&D - globally but with emphasis on the eastern seaboard (Labrador to Massachusetts) and Canada. For other ocean technology R&D and ocean and tidal stream research – Atlantic Canada, with emphasis on Nova Scotia.
Value Proposition	Fundamental “benefit” the organization offers in the marketplace to attract clients A facility for testing tidal energy and other ocean technologies and for tidal and ocean research in a mid-range (flow speed and depth) tidal stream that provides: *accessibility* and meeting the other needs noted in Section 2.2, flexible and client-focused service, and research collaborations. Located in Canada in the Bay of Fundy.
Core Activities	The particular value-adding activities the organization will perform, and how it intends to perform them. Offerings would include: • Berth lease with basic services (resource monitoring, ADCPs, etc.) with additional services at extra cost. • Tailored solutions, comprising of a generic base service and a flexible approach to developers’ specific requirements. • Assistance finding partners to facilitate the technology development. • Marine supports (deployment and marine operations, project management, technical and engineering support). • Coordination of testing process from test tank to full scale test site, integrate testing with other services.

	• Instrumentation, data acquisition, operations and maintenance optimization, hydrodynamic numerical modelling, operations window analysis (weather and flow), power take-off system analysis. • Education and training, community engagement. Additionally (potentially): • Collaboration with other ocean organizations, such as the Center for Ocean Ventures & Entrepreneurship (COVE), FORCE, Marine Renewable Energy Collaborative (MRECo)/(BTTS), CHTTC, West Coast Wave Initiative, universities, NSCC, and supply chain companies for coordinated services and research collaboration. • Co-ordination of the design and testing process and standards from numerical modelling, through test tank, to small-scale ocean, to mid-TRL ocean, to full-scale tests or deployments. Technology certification and standardization. • Grant-writing assistance and collaboration. • Facilitation of TC 114 standards development research.

Risks

In terms of the business case for the test centre, perhaps the greatest uncertainty is around the ultimate demand for the service. Broadening the market of the test centre to serve ocean technology and general ocean research helps the business case. A way to mitigate the uncertainty of low demand is to build a realistic roster of early projects and scenarios for growth based on market research. Good upfront work could be used to layout the projects and have those projects inform the test centre design.

The activities at FORCE are potentially synergistic but could be made competitive. Cooperation and coordination of activities and messaging would likely benefit both as well as tidal energy research and development, locally and globally.

Profit model

The profit model refers to the sources of revenue, cost structure, profits, and associated investment. This includes consideration of fixed versus variable costs and breakeven points; and required timing and flexibility of investment, relative to the characteristics of the marketplace. A profit model for the test centre, with alternatives, is provided in Table 2.

Table 2: Profit model

Sources of revenue	A combination from industry and government: • User fees for access to equipment, facilities usage, time with experts, research and analysis, and marine operations, • Operating grants, • Project-based research grants. Possible other revenue streams: • Fees for technology certification (if developed); • Consulting fees; • Feed-in tariff (if grid-connected and licensed); • Funding for TC114 standards development work (if made available); • Proceeds to test centre for developers awarded free test time (e.g. MARINet2), if developed; • Licensing fees for intellectual property developed by the test centre or in collaboration with test centre users with a joint IP agreement.
Cost structure	Salaried vs. contract personnel (alternatives):

<table>
<tr><td>(fixed vs variable)</td><td>1. Full-time staff – administrative and technical,
2. Skeletal administrative and technical staff, or
3. Skeletal administrative staff only.
For 2 and 3:
• Outsource additional administrative and technical services to private sector,
• Clients bring own teams, and
• Student interns from NSCC, local and First Nations communities, universities.</td></tr>
<tr><td>Investment, timing, and flexibility</td><td>Capital investment/capital assets (alternatives):
1. Campaign-able -
• Regular, periodic deployment (e.g. 2 months each year), pre-booked. Increase deployment periods as demand requires.
• Deploy on contract-by-contract basis.
2. Build in stages at one or several locations as demand materializes.
3. Barge that can be towed to various sites on as-needed basis (could be private-sector owned).
4. Building(s) for shop space, storage, computing equipment, etc.
• Lease,
• Build/buy.</td></tr>
<tr><td>Profit</td><td>Not-for-profit, operating grants plus fees based on cost-recovery (variable + overhead allocation), plus reserve for maintenance and possibly on-going research.</td></tr>
</table>

Form

Physical – components and areas

The components of a test centre and the areas of operation are key to its initial success and long-term sustainability. Specifically, for tidal energy, there is a need to provide an easily accessible, cost-effective, safe, well characterized, and highly functional work environment to conduct a) equipment testing to increase TRLs prior to work at FORCE, and b) research that will de-risk community- and utility-scale tidal energy developments by addressing environmental, technical, and economic uncertainties.

Essential components are the infrastructure, information, and personnel that make up a test centre. They include physical accessibility, safety, multi-user infrastructure, moorings, power and data cables, a power management system (potentially with grid interconnection but not technically required), highly qualified personnel (including regular presence in the community), low-cost accommodations nearby, high quality information, marine life abundance and variety (with an appropriate level of risk, which requires consideration of the ability to monitor at-risk and other species, and migratory pathways). Testing platforms may come and go with different tests as components of fully integrated tidal power systems, and/or could be an asset of the test centre.

The areas considered for the location of a small test centre are consistent with the Areas of Marine Renewable-Energy Priority (AMREP), described as the Fundy Area and the Bras d'Or Area in the Nova Scotia Marine Renewable-energy Act (MRE Act). They include Minas Channel; Minas Passage outside of the FORCE Marine Renewable Energy Area (MREA); FORCE MREA; Grand Passage MREA; Petit Passage MREA, Digby Gut MREA; and the Bra d'Or area's Barra Strait, Seal Island, and Cary Point.

The Bras d'Or Lake locations could be useful for testing lower-flow technologies' ability to efficiently harness flows in the range of 1 to 2 m/s; however, there are locations throughout the Bay of Fundy that can address this need as well as the noted gap for testing opportunities in flow speeds between 2 to 4 m/s.

Accordingly, the Bra d'Or sites were not carried forward for further evaluation. In addition, three locations outside the AMREPs and around bridges in medium- and high-energy environments were included, for example purposes, but not carried forward for further evaluation. These bridge locations are mentioned because they can offer unique opportunities for cost-effective testing.

The remaining areas (as listed above) were evaluated using a scoring system with weighted criteria consistent with the required test centre components. Note that categories were included for fishing, adjacent communities, and First Nations, but scores were not assigned. Focused engagement would be required at preferred test sites to properly evaluate these factors. For all three, the primary objective is to coexist.

The Minas Passage and Minas Channel offer significant opportunities for commercial utility-scale projects and is the target area for many project developers. However, in the context of testing and research, there are drawbacks primarily associated with accessibility, safety, and water clarity. The first two could be improved with significant infrastructure upgrades that may occur alongside utility-scale commercial development in the Minas Passage. Linking a small tidal test centre to the commercial development could yield benefits. The commercial developments will require marine and onshore resources that could be used by the test centre. The test centre activities could be closely tied to the commercial activities, reducing costs and increasing uptake of test results. However, in this scenario, the time frame, location and scope of a test centre would be largely determined by the needs of FORCE berth holders and other developers in the Minas Passage area permitted under the MRE Act and would not address some of the needs identified in the gap analysis.

The Digby Neck passages offer a wide range of test conditions, excellent accessibility, increased safety, and good water clarity. These factors align with needs for cost-effective testing and research, including facilitating outreach activities for education and training. Similar to much of rural Nova Scotia, the Digby Neck passages are located at the end of a weak distribution grid with frequent power outages. Significant infrastructure upgrades would be required to run a transmission line to these areas, as would be required for commercial utility-scale projects. The cost of a transmission line likely precludes utility-scale developments occurring in the Digby Neck passages. The lack of a solid grid connection may foster research that advances the development of on- and off-grid coastal community power systems, including micro-grids, energy storage, and use of tidal power systems that are in balance with community needs and the marine ecosystem. This work would apply to a number of remote and rural communities across Canada. A focus on testing in Grand Passage and Petit Passage could help advance community-scale tidal energy applications; as well as testing to increase TRLs, as a "gateway to the bay," prior to deployments in more challenging locations in the Minas Passage.

Compared to the other locations, Digby Gut has limited opportunities for testing but could be utilized in conjunction with the Digby Neck Passages. An important consideration is significant vessel traffic, including local fishing vessels and Bay Ferries.

Organizational – ownership, governance, collaborations, funding

Ownership There are various ownership alternatives for a small tidal test centre in Nova Scotia, including: private (independent), public (government-owned), university-owned, FORCE-owned (a special case of private), and owned *with* FORCE, whereby an "umbrella" organization oversees both the test centre and the FORCE demonstration centre. Using input from people familiar with the industry and the related research, the advantages and disadvantages of each of the alternatives are described.

Governance Three governance alternatives are explored: a stakeholder-based board, a skills-based board, and a third, a board that oversees both the test centre and the FORCE demonstration site. The last specifically relates to the ownership alternative, "owned *with* FORCE," noted above.

Collaborations The sustainability of the test centre and other organizations in the tidal energy and ocean sectors could be enhanced through collaboration and would minimize duplication. Possible collaborators include: First Nations and host communities; the Centre for Ocean Ventures and Entrepreneurship (COVE); FORCE; Dalhousie's Aquatron Lab; other test centres, such as CHTTC, the Bourne Tidal Test Site (BTTS), and the European Marine Energy Centre (EMEC); other research organizations, such as the Bedford Institute for Oceanography (BIO), the Ocean Tracking Network (OTN), and the Institute for Ocean Research Enterprise (IORE); and educational institutions, such as the Nova Scotia Community College (NSCC) and universities in the region, particularly Dalhousie and Acadia University; and the industry groups Marine Renewables Canada (MRC) and the Ocean Technology Council of Nova Scotia (OTANS).

Funding The sources of funding would depend on decisions made on the objectives, structure, and ownership of the test centre but the funding arrangements for COVE and FORCE could serve as models for the test centre. Sources of start-up money for the test centre could include Natural Resources Canada (NRCan) and the Atlantic Canada Opportunities Agency (ACOA). There could also be industry contributions from companies whose priorities align with the purpose of the test centre. The Industrial and Regional Benefits (IRB) program, as it relates to the Canadian shipbuilding project, may be a means of acquiring industry contributions. There could also be in-kind contributions of equipment from technology companies or researchers. Once operational, the test centre would likely need ongoing federal and/or provincial support, though some of the operating costs would be covered by industry, through revenue noted in the profit model

Economic and other benefits

A small test centre would offer a variety of benefits to Nova Scotia, to host and First Nation communities, to research and education, and to the local and global tidal energy industry. A brief summary of benefits follows.

A small tidal test centre would enable the host and First Nations communities to:

- diversify industrially;
- introduce new career paths to youth;
- contribute to the evaluation of technologies and investigation of environmental concerns;
- inform decisions on community- and utility-scale projects;
- participate in employment, internship, investment, and partnership opportunities;
- work with other remote communities to reduce their reliance on fossil fuels through community-scale energy solutions.

For Nova Scotia, particularly the tidal energy industry, a small tidal test centre would:

- attract companies to Nova Scotia earlier in their development stage, allowing the industry and the supply chain to learn, build capacity, and innovate sooner;
- enable more tidal projects by reducing the capital needed to operate;
- foster the development of teams of local, national, and international partners that would develop and export turnkey, remote-community tidal energy solutions;

- position Nova Scotia as a global leader in the commercially relevant tidal flow conditions of 2 to 4 m/s;
- facilitate the development of innovative, valuable IP and new products and services that could be sold locally and around the globe;
- inform the development of the tidal energy resource in the Minas Passage.

In terms of research and education, a small tidal test centre would increase several opportunities, including:

- to conduct effective marine life monitoring in a less challenging environment;
- for hands-on academic and student involvement in tidal energy developments;
- to test engineering theories and models and develop a wide range of technologies;
- to develop technologies, tools, and methods for marine operations in high flow environments
- to provide a lower-risk location for testing and development of all aspects of tidal power systems, including pre-commercial deployment;
- to develop safety on the water programs.

Future considerations

In making the decision to establish a small tidal test centre, there are several key decision criteria (KDC) that should be considered. KDCs are the essential criteria to be met to support a decision to invest. Six have been identified:

1) Is there sufficient demand for the test centre and its services to sustain it?
2) Will the fees and government funding the test centre can generate be sufficient for it to achieve its objectives?
3) Can host community, fisher, and First Nation acceptance be achieved and maintained for the site?
4) Can the site be permitted and consented for testing of tidal energy and other ocean technologies?
5) Can there be coordination or cooperation with FORCE so tidal energy industry progress continues?

The establishment of a small tidal test centre in Nova Scotia could be of benefit to Nova Scotia, its communities, researchers and the tidal energy industry. Undertaking such an investment is not without risk, however. If a test centre investment were to be undertaken, attention should be given to the following:

- Success of a small tidal test centre would be highly dependent on government support in terms of permitting, consents, and capital and ongoing funding.

- Though potential users of the test centre were contacted for information gathering purposes, this study does not constitute a market study. Further market research would help better gauge the demand for the test centre's services and determine if sufficient demand exists now and into the future.

- Numerous stakeholders were asked to provide input to this study, however, this should not be considered a substitute for a stakeholder consultation. Should the decision to build a small tidal test centre be considered, full community, First Nations, and other stakeholder consultations would need to be undertaken.

Should the opportunity to invest in a small tidal test centre not be taken up in the near term, steps could be taken that would still advance small tidal development in the interim. These could include:

- Several moorings that could be time-shared and utilized for deployments. The moorings could be established as part of a study on technologies including environmental effects.
- Effective environmental monitoring in the presence of turbines, including support for time, expenses, and equipment needed for focused research on near-field interactions and development/validation of tools/methods for marine life detection and assessment of collision, evasion, and avoidance.
- Functional workspace and infrastructure to support assembly, storage, marine operations, and accessibility (specific needs are location dependent).

Following an incremental development process, funding directed to any or all of the above items would facilitate the advancement of a small tidal, with potential for future expansion into a test centre.

1 Introduction

1.1 Background

The tidal energy industry, still in the development stage of the industry life cycle, has achieved many milestones. It has also encountered many setbacks. The challenges are significant and the undertaking to develop large-scale devices and utility-scale arrays for power generation has been daunting. To help meet the challenges, some companies and governments are turning their attention to the development of smaller tidal energy technology (Carlson 2017, OES 2015). Much can be learned from the testing of small- and community-scale devices and scale models of devices intended for commercial applications. Such a step-wise approach can facilitate technological and operational improvements, reduce costs and uncertainty, facilitate private-sector financing, and lower the cost of capital, helping to move the industry forward.

Also, the exportable service of building small tidal energy installations has promise due to the number of communities in the world where tidal energy development can be a viable alternative to fossil fuels for electricity generation. Such installations could create demand for specialized monitoring technologies, site assessments, and other expertise. However, more research, development, and demonstration are needed to further reduce uncertainty - to prove the technologies, improve their reliability and energy yield, improve understanding of the effects of turbines on marine life and the natural environment, and reduce costs - before the market will open up to small-scale tidal energy solutions.

1.2 Why this study?

The Offshore Energy Research Association (OERA) launched this study to determine whether there is an unserved market need for a small tidal test centre in Nova Scotia, whether it would have a competitive advantage, and what the economic and other benefits would be to Nova Scotia communities, businesses, the local tidal energy industry and the broader, global tidal energy industry, if it were built. The objectives of this study, therefore, are to:

5) Scan the global tidal energy industry for test centres and their offerings, the needs of technology developers and researchers, and identify gaps or unserved niches for small-scale tidal testing.
6) Assess whether these gaps could be filled in Nova Scotia and what advantages a Nova Scotia test centre would have.
7) Identify small tidal test center models, combining Nova Scotia's unique natural and human resources, that fill an unserved or under-served market need. The model strived for should be feasible, be economically beneficial, support regional and international research and development activities, provide local research and business opportunities, and have a competitive advantage that will be sustainable as the industry develops in Nova Scotia and abroad.
8) Describe the economic and other benefits that would accrue to Nova Scotian people, researchers, and organizations if a small tidal test centre were to be built.

1.3 Report contents

The study objectives will be addressed sequentially. The gap analysis, conducted in late 2017, is summarized in Section 2. Section 3 describes the business model. It begins with a strategic analysis and strategic positioning of the test centre, based on data collected for the gap analysis and then vetted with people familiar with the tidal energy and ocean technology industry. This constitutes what would be the "function" of a test centre. What then follows is the "form," which is presented as a series of alternatives: first, on the physical form – areas where a small test centre could be located and key components;

secondly, its organizational form, in terms of legal structure, ownership, governance, and collaborations; and thirdly, potential sources of funding, performance metrics, and risks. Section 4 presents the benefits side of the business case analysis, including potential benefits to Nova Scotians; to host, First Nation, and remote communities; to research and education; and other benefits. A summary and conclusions, including key decision criteria for the investment decision, are presented in Section 5.

1.4 Considerations for interpreting the findings

Definitions of scale - "Small-scale" tidal energy devices are not well defined in Nova Scotia or internationally. For the purpose of this study, arbitrary limits on power output or physical dimensions will not be used. In general, differences in the goals and objectives of different test centres, where the gap analysis defines the potential focus areas of a small tidal test centre, are considered. As such, throughout this report the terms "small tidal", "small-scale tidal", or "community-scale tidal" are used as a distinction from the commercial, utility-scale developments planned at Fundy Ocean Research Centre for Energy (FORCE) and other areas in the Bay of Fundy. Community-scale tidal projects are those that are off-grid or connected to the distribution electrical system, with the total power output scaled appropriately to provide sustainable energy to rural, coastal, local communities. A small tidal test centre is meant to be the next step from tank-testing facilities to advance Technology Readiness Levels (TRL) through exposing devices to real-world conditions and evaluating how the devices operate. It could be used as a place to address challenges and inform potential commercial applications for community- and utility-scale projects at similar and more challenging sites.

The state of the industry – Since the tidal energy technology industry is in an early stage of development, future trends are fairly unpredictable. The industry is highly dependent on government support and likely will be for some time. The prospects for a small tidal test centre in Nova Scotia is equally unpredictable. This analysis should be considered indicative, not definitive, of what could occur.

Alternative visions - Alternatives presented in this study, in terms of areas, test centre components, ownership, and governance, etc. are for discussion only and to highlight the advantages, disadvantages, and other considerations. It is beyond the scope of this study to recommend any one alternative over another.

2 Gap analysis summary

A gap analysis was conducted in November and December of 2017. The purpose of the gap analysis was to determine whether there exists a gap in the global test centre offerings that a Nova Scotia test centre could fill. The analysis began with a scan of the global test centre industry, for which information was collected on facilities and services available for tidal technology testing around the world. The needs of the research community and technology developers for small-scale tidal energy technology testing were then sought. Juxtaposing the results of the industry scan and needs helped identify unserved or under-served needs. This revealed a gap in the competitive landscape. The robustness of the market in that gap and the competitive advantages Nova Scotia would have in it were then assessed. A summary of the gap analysis follows. The abridged report can be found in Appendix 1, and the full report is available on the OERA website.

2.1 Industry scan

The industry scan began with a desktop study to identify test sites that focus on tidal energy device testing. This involved an initial scan of ocean energy test sites globally, both open sea and land-based facilities, followed by a characterization of these sites and their service offerings. As the focus of the business case analysis is on the potential for an open-sea tidal test site in Nova Scotia, particular attention was paid to similar sites. The refined list is given in Table 1.

Table 1: Test centres

Test Centre / Site	Location	Status
EMEC (Scale)	Shapinsay Sound, Orkney, Scotland	Operational
EMEC Full Scale	Fall of Warness, Orkney, Scotland	Operational
QML Portaferry	Strangford Lough, Northern Ireland	Operational
SEENEOH	Bordeaux, France	Operational
DMEC Marsdiep	Marsdiep, Netherlands	Operational
DMEC Den Oever	Den Oever, Netherlands	Operational
TTC-GD	Netherlands	Operational
Perpetuus Tidal Energy Centre	Isle of Wight, UK	In development
Smartbay (Wave and instrumentation)	Galway, Ireland	Operational
MaREI (LiR NOTF Flume)	Cork, Ireland	Operational
Bourne Tidal Test Site (BTTS)	Cape Cod Canal, Massachusetts, US	Operational
Canadian Hydrokinetic Turbine Test Centre (CHTTC)	Seven Sister Falls, (Winnipeg River), Manitoba Canada	Operational
Fundy Ocean Research Centre for Energy (FORCE)	Black Rock, Colchester Co., (Minas Passage), Nova Scotia, Canada	Operational
Southeast National Marine Renewable Energy Centre (SNMREC)	Florida Strait, near Ft. Lauderdale, Florida, US	Operational
Tanana River Test Site - Northwest National Marine Renewable Energy Centre (NNMREC)	Nenana, Alaska, United States	Operational
*Zhairuoshan Tidal Energy Power Demonstration Station	Zhoushan, Zhejiang Province, China	Operational
*REIDS Sentosa Tidal Test Bed (Tropical Marine Energy Centre (TMEC))	Sentosa Island, Singapore	In development
*Marine Energy Research and Innovation Centre (MERIC)	Chile	Operational

* Denotes test centres for which insufficient information was available to complete a profile.

A profile was compiled for each site deemed to be of significant interest, detailing information on location, site characteristics, available instrumentation and other facilities, structure and governance, services offered, and history of device testing (see Appendix 1). Interviews were then conducted to discuss site characteristics and operational methods and, from the existing centres' perspectives, the fundamental services that should be offered to developers, and best practices in site operation, developed from lessons learned. Nine test centre-related interviews were conducted. They highlighted what are considered fundamental requirements, from infrastructure and management perspectives, as well as other service offerings the centres provide, either as a result of developer requests or an identified market need.

The resources and facilities available at each site reflect the scale at which they operate but it is clear that most, if not all, have some key fundamental requirements and operating principles. Interview responses highlighted that the following infrastructure, facilities and services were all required in a good test centre:

Fundamental Infrastructure

- Flexible cable and berth layout
- Detailed resource characterisation, including flow speeds, wave, climate, depth, bathymetry, and weather, at a minimum (historical)
- Data monitoring and logging
- Consented site
- Dump load
- Laydown area and office/workshop/storage facilities
- A suitable supply chain
- Experienced support staff

Additional Infrastructure

- Grid connection
- Real time data acquisition system
- Access to vessels
- Hydrography & sonar
- Marine life monitoring
- Access to wider supports through network and academic expertise.

Some of the key recommendations for a test centre are focused around a similar approach: to provide somewhat generic and flexible infrastructure for developers as a base offering, with the experience, skills and capabilities on hand to further develop it to a bespoke solution that suits the developer's needs. Close attention should be paid to university output and early-stage developer activity in the region, as this will form the pipeline of technologies to be tested at the facility. The key requirements of a test centre are to fill a developer's knowledge gaps and ensure a safe environment in which to operate, particularly for low-TRL projects, whose proponents often lack experience testing at sea.

2.2 Developer and researcher needs

In order to evaluate the need for, and potential use of, a tidal test centre in Nova Scotia, over twenty interviews were held with individuals from the tidal industry, ocean technology industry, academia, manufacturing and marine operations supply chain, and regulators. The goals of the interviews were to identify whether there is a need for a small tidal test centre in Nova Scotia and what specific site and test centre characteristics technology developers and researchers need. There was considerable agreement in the responses: an ocean research and technology development centre in Nova Scotia that specializes in smaller- and community-scale tidal energy projects is needed. There was also considerable interest in it being accessible for a broader range of oceanographic and energy-related research and development. All respondents answered that a small tidal test centre would be beneficial if properly implemented. The following list is a summary of the needed features and characteristics:

1. *Accessibility*,[1] in many forms including:
    a. Ability to obtain all required permissions/permits/consents, through the test centre, with regulators, community, fishers, First Nations, etc. This would accelerate R&D and reduce the costs for developers to use the site;
    b. Physical access, including test locations close to shore; launch ramp, harbour, and wharf that are accessible through the tidal cycle; and hoists, etc. for loading and unloading equipment;
    c. Availability of high quality professionals at the test centre, as needed, to assist with developing and implementing test procedures, establishing collaborative relationships with academics and local supply-chain companies, performing marine operations, and safely handling power to shore, etc.;
    d. Ability to obtain existing high-quality site information, including flows, water levels, depths, seabed conditions, wind, waves, and marine life (access to information noted in 4);
    e. Ability for groups from local communities and First Nations to access the site and non-proprietary data for research, technology development, and training;
2. Nearby infrastructure and personnel to enable cost-effective research and development;
3. Diverse deployment locations (spatial variability in flow speeds, depth, seabed conditions, etc.);
4. A well-characterised site with high-quality data and modelling;
5. Operating turbines to investigate engineering and scientific uncertainties, including use of a site/centre with the ability to accommodate a small array with a variety of tidal turbines;
6. Ability to conduct effective environmental monitoring (visibility is key, including water clarity and proximity to shore);

[1] This will constitute the definition of accessibility for the remainder of the report.

7. Meaningful and purposeful involvement of local community members, fishers, and First Nations people;
8. Flexibility and a client-focussed approach;
9. A pathway to commercialization that allows development from low-TRL to TRL 9.

For accessibility, beyond physical site access, it is important to facilitate collaboration and access for stakeholders in the region and not allow a single developer (or small group of developers) to "lock down the test centre." In general, a test centre that is welcoming to new opportunities and does not require developers to start from scratch on gaining permits and community acceptance to conduct a test was viewed as beneficial. The test centre would need to have good visibility from shore and quick ways to enter and exit the water, including nearby harbors and boat launches that are accessible throughout (or at least the majority) of the tidal cycle. In addition to reducing the cost of marine operations, physical site accessibility would be important for marine safety by allowing vessels easy access to protected harbors, as well as the ability for vessels to respond to marine emergencies. Close proximity to a Canadian Coast Guard base was identified as a significant asset. Essentially, users would want the test centre to be an enabler so they can "truck up and do our work," with the test centre providing significant value in accessibility and marine safety, and allowing groups of highly qualified personnel to collaborate so users of the test centre (technology developers and researchers) are able to focus on their specific tasks and objectives.

With respect to coastal communities and First Nations, a need was identified to engage local stakeholders and communities in a model of information-sharing and governance that values respect, transparency, and accountability. An opportunity was identified for a Nova Scotia small tidal test centre to develop and demonstrate a globally applicable model for a community tidal project, including providing a training centre for future sites/developments in the Canadian north and beyond. To accomplish this, a test centre could prioritize the identification, utilization, and development of community assets (personnel and infrastructure). The test centre could also provide a gateway for First Nations involvement, including bilateral knowledge-sharing and collaboration. It could help researchers and practitioners in the natural, applied, and social sciences better understand First Nations' priorities and concerns and find ways forward, together. Importantly, a small tidal test centre could offer concrete opportunities for First Nations communities and people.

Potential users felt that the more infrastructure a testing centre had, the better. However, the infrastructure should be directly applicable to testing tidal turbines but not be too technology-specific. A generic option could be provided, as well as ability to do specific testing because many developers want to test and demonstrate integrated solutions. Key infrastructure needs include marine assets for site accessibility (laydown area, hoist, wharf, ramp, etc.); highly capable local vessels and operators; a secure location for an office; workshop and storage space, including common marine tools and supplies, high-speed Internet, and a file server for onsite data storage/backup; and a freshwater rinse area/basin. Lodging, fuel, and food should also be available at (or close to) the test centre.

Respondents noted that, from a technical perspective, a power cable to shore would be needed but a grid connection, though desirable, would not be required. The ability to flow power to the turbine would be beneficial if needed for a kick-start. Primarily, a power management system would be required onshore, designed to take power from a turbine in a safe way, while monitoring the performance of the turbine, and someone local, who is trained in the use of the system. However, a grid connection with a feed-in tariff

(FIT) could attract potential users to the site and/or provide revenue to the test centre that could cover costs or be used to fund research projects.

With respect to marine life, a site with high abundance and variety would support required research but it is important to evaluate locations with consideration given to the balance between risk to (including the ability to monitor and mitigate) and abundance of marine life. Reliable information is required on marine mammal behaviors around a range of turbines varying in noise levels, type, and scale. Good water clarity and visibility from shore would be needed to correlate/validate acoustic data. A benefit of working in the presence of marine life is it would likely engender the design of low-impact technologies. Technologies that embrace this challenge may be the more likely to gain acceptance. Therefore, a small-scale tidal test site should be located where: effective monitoring of marine life is achievable with existing technologies; new monitoring devices can be tested cost-effectively to determine what works, what does not, and where improvements can be had; and data can be collected for processing and analysis. The industry and regulators need to understand how marine life is interacting with tidal power systems – the turbines, moorings, power cables, etc. – and the potential consequences. Answers to such environmental questions will be needed to reduce uncertainty before larger projects can advance.

2.3 Gap identification

There are gaps in the offerings of small tidal test centres around the world. The needs, noted above, allude to some. As well, there are no open-ocean small tidal test centres in North America. There are only four relevant test centres, though two are river current (CHTTC and Tanana River). The third test centre is the new Bourne Tidal Test Site (BTTS), in the Cape Cod Canal, which is limited to 3 m diameter mounted devices and no floating devices. The fourth centre is in the Florida Strait (SNMREC), which is 12 nautical miles offshore and in deep water (>200 m). It is largely being used for research into ocean-current energy. In Canada, there are no open-ocean small-scale tidal test centres. In Eastern Canada, there are no open-water small-scale test centres, river, open-ocean, or otherwise.

The scan of test centres shows a concentration of test centres in Europe, some of which are well suited to small-scale testing. A European small-scale tidal technology developer would likely be able to find what is needed there, though not necessarily, as evidenced by interest in Nova Scotia currently being expressed by several companies. Upon analysis, a gap is apparent in the mid-range of tidal test centre offerings that Nova Scotia can fill. Globally, there are few open-ocean test centres with the combined flow speed, depth, and accessibility of the Nova Scotia sites. There appears to be a gap in the global and regional markets, one in which a tidal test centre in Nova Scotia could compete.

There is also a gap related to a test centre that specializes in small- and community-scale tidal energy technology that could also fill a need for a broader range of oceanographic and energy-related research and development. There is currently no test centre in North America focused on determining sustainable limits (and approaches) for powering coastal communities with the tides, exploring “community-scale” approaches to tidal energy development, while also providing a “stepping-stone” towards utility scale tidal energy developments, including FORCE, and infrastructure, personnel, and site characteristics to facilitate a fairly wide range of oceanographic research and technology development. A small tidal test centre could also provide for such oceanographic research and technology development.

Additionally, Figure 1 shows the ocean test centres identified in the industry scan, organized by water depths and flow speeds. It also shows the needed range of depths and flow speeds, noted by developers, which are superimposed as a shaded box. This is shown within a larger box showing a range of speeds and depths generally suitable for small-scale tidal testing.

As can be seen in Figure 1, there are no test centres in the area of intermediate flow speeds (2-4 m/s) and intermediate depths (10-30 m). The Canadian Hydrokinetic Turbine Test Centre (CHTTC), a river current test centre, lies on the boundary. This suggests, in terms of flow speed and depth, there exists a gap in test centre offerings.

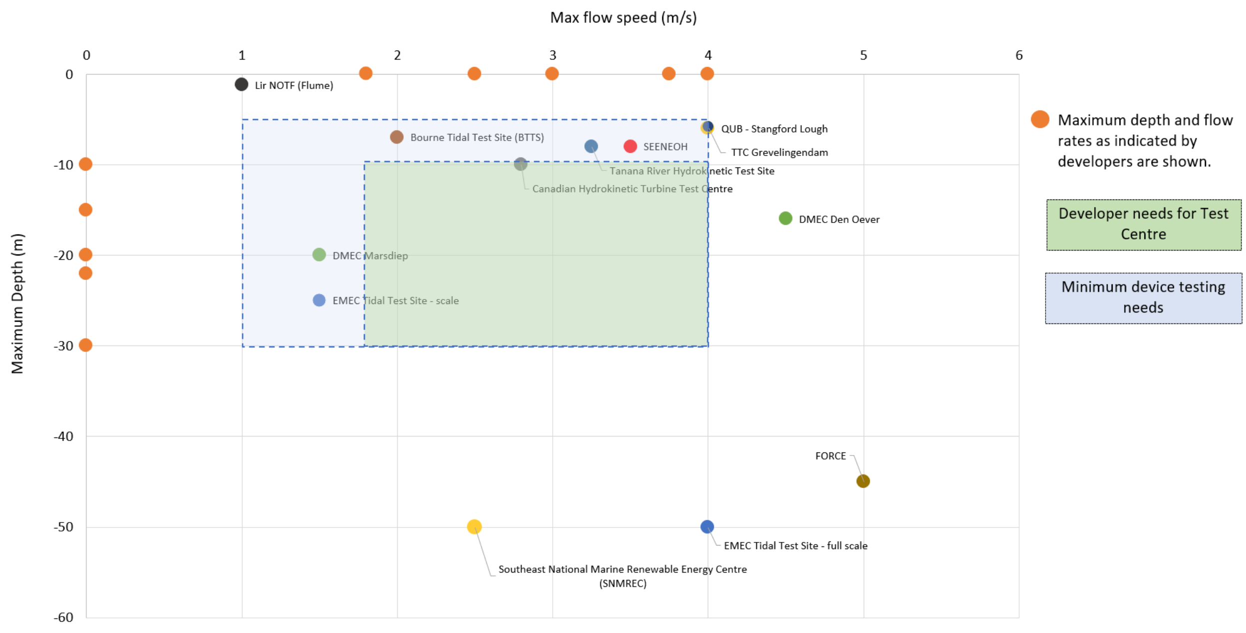

Figure 1: Test site characterization (depth and flow speed) with developers & researchers' needs

3 Business model

The business model summarizes what the organization does: its customer segment, strategy, value proposition, key activities, key resources, key partners/collaborators, associated investment, cost structure, and revenue streams.[2] This section will begin with an appropriate strategic position for a Nova Scotia small tidal test centre within the global tidal test centre industry and a strategy that builds on the region's unique competencies. With its function identified, the test centre's form (location areas, components, organization, collaborations, and funding), with alternatives, will then be presented.

3.1 Methodology

For the business case analysis, semi-structured interviews were conducted with nineteen people familiar with the industry. They included representatives from test centres, industry, research and educational organizations, funding organizations, the Ocean Supercluster, First Nations, government, and potential collaborator organizations. The interviews were conducted through January and February 2018. A profile of the group interviewed and the interview questions are provided in Appendix 2. The responses were compiled and have informed this analysis. In certain sections, paraphrased responses will be included, identified using italic font. The considered responses of all participants were greatly appreciated.

[2] The investment, cost structure and revenues streams will be described conceptually as they relate to the profit model in Section 3.3.

3.2 Strategy

For a test centre to achieve its objectives and provide a sustainable benefit to Nova Scotians and the tidal energy industry, it would need to have a sustainable competitive advantage in the global marketplace. A strategy of the test centre has been developed using elements of the Diamond-E[3] analysis, which is used for creating, evaluating, and revising competitive strategies. The Diamond-E model is also used to identify important elements of other components (resources, organization, management preferences), so they can combine to effectively implement the strategy and successfully compete in the industry.

The development of a strategy for the test centre is detailed in Appendices 3 to 5. Firstly, for a small tidal test centre to succeed, it would need to know who its clientele is, what they need, and how to survive its competition. To position itself within the industry for survival, it would also need to know the drivers of competition within the industry. A competitive industry analysis helps identify how a Nova Scotia small tidal test centre could position itself within the industry, what competitive forces would affect it, and identify key success factors. Key success factors are those that significantly influence a firm's ability to outperform rivals and survive the competition and are defined by what customers need and how they choose between rival firms' offerings. Key success factors for a test centre are identified in Appendix 3.

The industry and its key drivers inform an organization's strategy. The appropriate strategy must also align with the resources and capabilities of the organization, so it can successfully implement the strategy. Not all resources and capabilities of a test centre would be identifiable until a site is selected, the centre built, and its people employed or contracted. However, many are already resident in Nova Scotia and identifiable. Specific qualities of Nova Scotia sites and the province's reputational and intellectual assets can be combined to create a competitive advantage. Once a competitive advantage is established, its sustainability depends on the durability, transferability, and replicability of the important resources and capabilities. A relatively unique combination of Nova Scotia's resources and capabilities provides a basis for sustainability of its competitive advantage (see Appendix 3).

The gap analysis and competitive analysis helped identify a competitive opportunity for a Nova Scotia small tidal test centre. The analysis of resources and capabilities helped identify a sustainable competitive advantage. From this, a strategy can be formulated. The strategy is made up of goals, product- or service-market focus, core activities, and the value proposition (see Figure 2). These are partially developed and shown in Table 2 based on the analyses in Appendices 3 and 5.

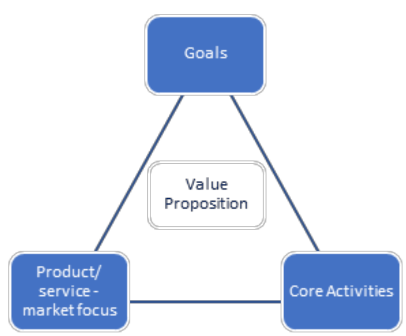

Figure 2: Strategy

[3] Crossan, M. Rouse, M., Rowe, W., Maurer, C. (2016) Strategic Analysis and Action, 9th Edition, Toronto: Pearson Canada.

Table 2: Test centre strategy

Goals	What the organization intends to achieve, in measurable terms, absolutely and relative to the competition. Hard goals: financial, marketplace and timeframe targets. Soft goals: targets for social conduct. Overarching goal: To help provide a pathway for tidal energy technology and ocean technology development and facilitate tidal stream and ocean research more broadly.
Product/Service-Market focus	What the organization intends to offer and the market it intends to compete in. What? To Whom? To Where? Product/Service offering: Test Centre: *Accessible* mid-range tidal stream for tidal and ocean technology testing and tidal stream and ocean research (refer to Section 2.2 for needs). To Whom: SMEs and large companies testing: g) Community-scale tidal energy conversion devices at mid- to high-TRL; h) Utility-scale tidal energy devices - scale models or pre-commercial full scale; i) Other tidal energy-related and ocean technology and energy storage; j) Deployment, maintenance and retrieval procedures. Researchers of: k) Tidal energy, ocean, energy storage technologies; l) Tidal streams, marine life, additional ocean industries, and oceans more generally. To Where: For tidal energy and related technology R&D - globally but with emphasis on the eastern seaboard (Labrador to Massachusetts) and Canada. For other ocean technology R&D and ocean and tidal stream research – Atlantic Canada, with emphasis on Nova Scotia.
Value Proposition	Fundamental "benefit" the organization offers in the marketplace to attract clients A facility for testing tidal energy and other ocean technologies and for tidal and ocean research in a mid-range (flow speed and depth) tidal stream that provides: *accessibility* and meeting the other needs noted in Section 2.2, flexible and client-focused service, and research collaborations. Located in Canada in the Bay of Fundy.
Core Activities	The particular value-adding activities the organization will perform, and how it intends to perform them. Offerings would include: • Berth lease with basic services (resource monitoring, ADCPs, etc.) with additional services at extra cost. • Tailored solutions, comprising of a generic base service and a flexible approach to developers' specific requirements. • Assistance finding partners to facilitate the technology development. • Marine supports (deployment and marine operations, project management, technical and engineering support). • Coordination of testing process from test tank to full scale test site, integrate testing with other services. • Instrumentation, data acquisition, operations and maintenance optimization, hydrodynamic numerical modelling, operations window analysis (weather and flow), power take-off system analysis. • Education and training, community engagement. Additionally (potentially): • Collaboration with other ocean organizations, such as the Center for Ocean Ventures & Entrepreneurship (COVE), FORCE, Marine Renewable Energy Collaborative (MRECo)/BTTS, CHTTC, West Coast Wave Initiative, universities, NSCC, and supply

	chain companies for coordinated services and research collaboration. • Co-ordination of the design and testing process and standards from numerical modelling, through test tank, to small-scale ocean, to mid-TRL ocean, to full-scale tests or deployments. Technology certification and standardization. • Grant-writing assistance and collaboration. • Facilitation of TC 114 standards development research.

Not all elements of the strategy can be fully identified at this stage; some would be developed by the test centre's leadership, particularly the strategic goals. The service-market focus and core activities can be further developed when the site locations and configurations are chosen. The goals, location, function, services offered and research programs initiated, organization, governance, alliances and collaborations, profit model and sources of funding, and infrastructure requirements could then be developed to be consistent with the opportunity available in the industry. Alternatives for some of these elements are presented and discussed in the following sections.

3.2.1 Focus

The primary focus of the test centre, whether it be primarily for research or primarily as a service to industry, has implications for ownership, governance, funding, and sources of revenue. There are examples of both in the test-centre market and there are advantages and disadvantages with each. Discussions with people familiar with the industry and research revealed views were split between the two; some respondents had difficulty prioritizing one over the other, and others cautioned against it. The alternatives are described in Table 3.

Table 3: Test centre focus - alternatives

Research as the primary focus, service to industry integral but secondary **Examples**: CHTTC, MaREI (LiR NOTF), Queen's University Marine Laboratory (QML), SNMREC **Advantages** Independent of business cycle, success/failure of companies. Research may be more rigorous and objective. Development of high-value intellectual property. Can build on academic excellence; leverage the existing research strengths in the region and build on the expertise. **Disadvantages** Dependent on government/grant funding, which can be lost, and driven by funding cycles. Timelines may not be compatible with industry needs. Can be slow to respond to the needs of the market. The research would not necessarily develop the industry. **Paraphrased, representative comments from interviewees** *As a research centre, you can leverage existing research strengths that are in the region and build on expertise that we have.* *If the service component doesn't take off, you may not actually get to the research and that might be where the higher value is.*

Service to industry as the primary focus, research integral but secondary

Examples: EMEC, BTTS, SEENEOH, PTEC (Perpetuus)

Advantages
Helping developers reach commercialization is a priority.
Activities are market/industry-led.
Creates more direct economic benefits.
Less dependent on government for funding.
Can facilitate collaborative research projects with researchers and students.

Disadvantages
May tend to focus on short-term goals.
May jeopardize public perception of the credibility of the research.
Relies on companies' priorities, which may change frequently in the early development stage
Industry involvement may be unpredictable.
May be difficult to govern.

Paraphrased, representative comments from interviewees
It's more likely the money will come from industry than it will from research. At mid-TRL and above, the industry-led projects are more engineering than fundamental research, except environmental monitoring.

There is lots of fundamental research that can be done while meeting the needs of the industry. If there isn't the potential of an industry, there won't be the need for research.

It should serve industry but not be dictated by industry. That gives the flexibility of government grants but also private institution grants. Industry money that comes in is project-specific or to hire specific personnel. It can serve industry, if industry funds research. Whatever is researched on government grants can be shared.

A lot of research questions come from the industry exposure in the facility. With the granting mechanisms in Canada being what they are right now, you really need an industry partner. As an academic, if you don't have a viable industry partner, you have no research proposal, you have no project, and then there's no primary research driving these things.

No distinction between the two – equal focus

Example: Centre for Marine and Renewable Energy (MaREI)

Advantages
Can combine the best elements of those listed above.
A balance can lead to sustained funding and government support.

Disadvantages
May lead to a lack of focus or action.
There may be potential for conflict between industry and research.
A broader focus may lead to general weakness.

Paraphrased, representative comments from interviewees
Research is a service to industry. It needs to be both. On the research side, there is still so much more to be done, especially on the environmental questions and industry needs to figure some of that out. But you need developers testing there in order to do the research.

They should be merged and be seamless. If not, it creates biases and potential problems. At certain times of the year, it will be more service and at others, more research. Industry cannot do this without research and there is no research without industry.

3.3 Profit model

The profit model refers to the sources of revenue, cost structure, profits, and associated investment. This includes consideration of fixed versus variable costs and breakeven points and required timing and flexibility of investment, relative to the characteristics of the marketplace (Crossan 2016).

Sources of revenue for the test centre would be rent and fees for service charged to the user. As a not-for-profit, rent and fees can be calculated on a cost-recovery basis. They should cover variable costs and an overhead allocation. They may include a mark-up to help cover future maintenance costs and support ongoing research. A scenario in which rent is charged may be for a mooring site. It may include a basic package of services, such as resource monitoring and ADCPs. Fees can be charged for added services, such as marine supports (deployment and marine operations, project management, technical and engineering support), instrumentation, data acquisition, operations and maintenance optimization, hydrodynamic modelling, weather window analysis, and power takeoff system analysis.

As experience at the test centre is gained and its own intellectual property (IP) developed, there may be other sources of revenue from consulting fees and licensing fees. In the case of consulting fees, care should be taken to not be in competition with private sector consulting firms with whom the expertise overlaps.

If the test centre is able to certify technology designs, a fee could be charged. There would likely be demand for this service. Also, research activities for TC114 standards development could generate grant funding.

Table 4: Profit model

Sources of revenue	A combination from industry and government: • User fees for access to equipment, facilities usage, time with experts, research and analysis, and marine operations, • Operating grants, • Project-based research grants. Possible other revenue streams: • Fees for technology certification (if developed); • Consulting fees; • Feed-in tariff (if grid-connected and licensed); • Funding for TC114 standards development work (if made available); • Proceeds to test centre for developers awarded free test time (e.g. MARINet2), if developed; • Licensing fees for intellectual property developed by the test centre or in collaboration with test centre users with a joint IP agreement.
Cost structure (fixed vs variable)	Salaried vs. contract personnel (alternatives): 4. Full-time staff – administrative and technical, 5. Skeletal administrative and technical staff, or 6. Skeletal administrative staff only. For 2 and 3: • Outsource additional administrative and technical services to private sector, • Clients bring own teams, and • Student interns from NSCC, local and First Nations communities, universities.
Investment, timing, and flexibility	Capital investment/capital assets (alternatives): 5. Campaign-able - • Regular, periodic deployment (e.g. 2 months each year), pre-booked. Increase

	deployment periods as demand requires. • Deploy on contract-by-contract basis. 6. Build in stages at one or several locations as demand materializes. 7. Barge that can be towed to various sites on as-needed basis (could be private-sector owned). 8. Building(s) for shop space, storage, computing equipment, etc. • Lease, • Build/buy.
Profit	Not-for-profit, operating grants plus fees based on cost-recovery (variable + overhead allocation), plus reserve for maintenance and possibly on-going research.

3.3.1 Sustainability

The financial sustainability of the test centre will depend on the demand for the services, its investment and cost structure (fixed vs. variable), and the offerings of other centres, like CHTTC and BTTS. The tidal energy industry is small and highly dependent on government support though, and many developers' and academics' budgets for testing are limited. Offering services to the ocean technology sector and for ocean research would broaden the market the test centre could draw from. COVE will be making ocean testing and research more accessible as well. For non-tidal ocean technology, a test centre in a tidal stream would be a niche market offering.

Demand over time is difficult to predict. The market will likely be small and demand variable, and it will depend on events in the global industry; tidal developers are often attracted to jurisdictions offering good incentives. There would be need for buy-in from the research community to use the centre, otherwise, it would need dedicated staff, capable of winning grant-based funding for the centre itself. The gap analysis indicated a need and an interest in a test centre, so there is evidence of immediate applicability. However, it would be important to determine the extent of the demand by doing dedicated market research.

The cost of operating a test centre could be high. "Right-sizing" the test centre facility and its operations would be important for financial sustainability, as illustrated by the one respondent's statement regarding a tidal technology test centre:

> *At this TRL level, it is important to be testing for a month or two or more so a berth may only be able to support 3 or 4 tests a year, assuming you don't use it in the winter. If you're talking 3-4 tests a year, there is a sustainable [sufficient] market. Whether it's enough, depends on your overhead.*

Sustainability can be further enhanced in a variety of ways, including:

- Determine the initial investment based on planned project needs. Not "build it and they will come" but "build this because we have identified a need."
- Build in stages as a way of keeping the initial capital investment and operating costs low and reducing uncertainty. A staged investment, with options to expand the scale or scope of the test centre's services, would be a practical approach.
- Keep operating leverage (fixed costs relative to total costs) low.

- Maximize the utilization of capacity by ramping operations up and down to reduce operating costs. A lot can be done by contracting work to the private sector on a per-project basis so fewer permanent staff are needed.
- Locate the tidal energy test centre close to additional assets such as active fisheries, aquaculture, and marine life, to broaden the scope of research that could be done there.
- Offer additional services, such as the following:
    - Assist with whole development cycle management – help developers get from numerical modelling and test tanks, through the test sites, to a crown lease, with permits, and a power purchase agreement. Coordinate with other centres for this purpose.
    - Certify and standardize power systems for connection with the grid.
    - Certify and/or validate oceanographic technologies, such as sensors, software, ROVs, leveraging the "Fundy Standard" brand with these certifications.
    - Coordinate with other sites, like the BTTS, CHTTC, and the FORCE to standardize and certify with the TC114 system.
    - Work with clients to help apply for government grants or private money (grant-writing).

3.4 Components and areas

The components of a test centre and the areas of operation are key to initial success and long-term sustainability. As such, this section is based on the needs of industry and researchers, identified in the gap analysis, with a focus on the ability to conduct cost-effective work in an energetic tidal environment, complementary to existing offerings at the Dalhousie Aquatron facility, COVE, and FORCE. Specifically, for tidal energy, there is a need to provide an easily accessible, cost-effective, safe, well-characterized, and highly functional work environment to conduct a) equipment testing to increase TRLs prior to work at FORCE, and b) research that will de-risk community- and utility-scale tidal energy developments by addressing environmental, technical, and economic uncertainties. Such a site could also be beneficial for obtaining and maintaining social license by helping to provide easy access to tidal energy installations, including education and training opportunities. Potential community benefits are also noted but discussed in more detail in Section 4.

Examples of a highly functional and well-utilized research centres are Bamfield Marine Sciences Centre (BMSC) and Queen's University Marine Laboratory (QML). Both provide facilities to support cost-effective research, testing, and education. The facilities include meeting rooms, laboratories, vessels, food, and accommodation. The BMCS is strategically located to provide access to a diverse marine ecosystem and is in close proximity to the community of Bamfield, British Columbia (population approx. 150 in 2011) and a Canadian Coast Guard Station. QML is located in Portaferry, Northern Ireland, on the eastern shore of the narrows at the entrance to Strangford Lough and has been home to several small- and large-scale tidal energy tests. The narrows have a striking resemblance to Grand Passage and Petit Passage, being a narrow tidal channel with towns on both sides that are easily accessible throughout the tidal cycle and connected by a ferry. An east coast marine research and test centre could have very similar components to BMSC and QML but much smaller in the initial build (with further infrastructure developed in response to need) and a focus on a) community-scale tidal energy, and b) developing transferrable knowledge and technology for utility-scale projects in the Minas Passage.

The following subsections outline the components of a small tidal test centre and potential areas of operation with a focus on addressing these needs.

3.4.1 Components

Components include infrastructure, information, and personnel that make up a test centre. In some cases, these components are existing community assets or assets of an existing institution such as FORCE, the Acadia Tidal Energy Institute, or the Dalhousie Ocean Acoustics Laboratory. In some cases, they must be developed. This is highly location-dependent.

Physical accessibility is enabled by the presence of wharfs, harbours, and boat launches, with a preference for these assets to be usable throughout the tidal cycle. In cases where accessibility is limited to operational windows around high water, the costs of research and test operation increase. For industry applications, the inconvenience of high water-only accessibility can be overcome by planning and budgeting for long days on the water, but it is especially disadvantageous for testing and research, where relatively simple tasks become significant operations, and the ability to conduct surveys at specific times in the tidal cycle becomes limited.

Safety is highly dependent on accessibility, allowing for local vessels (including any Canadian Coast Guard Base or Auxiliary) to respond to an incident on the water. In cases where existing accessibility does not permit a response, additional infrastructure is required to increase safety at sea. This can be in the form of additional vessels on the water (backup, at extra cost) or the installation of a launch/rail system to extend accessibility for small response vessels. However, such response vessels must be manned by appropriately trained emergency response personnel. A significant asset is close proximity of a Canadian Coast Guard station.

Multi-user infrastructure is a significant asset to a test centre, and should be developed with a focus on the needs of the users, also with a mind to community benefits and involvement (see Section 4). Useful facilities would include:

- Secure office and meeting space with high-speed internet
- Shop space with common oceanographic tools and supplies
- Lay down areas for larger equipment
- Vessels with highly-capable operators and crew
- Monitoring equipment (flow, waves, marine life, weather, etc.)
- Instrument mounts (autonomous and cabled, including a multi-instrument bottom pod in close proximity to a turbine test site that is easily accessible for adjustments)
- Fresh-water rise area
- Common area (could double as office space), kitchen, dry rooms, and bathrooms (with showers).

Moorings are required for testing of tidal turbines mounted to floating barges or mid-water column systems. Ideally, the moorings would be installed to allow flexibility in deployment options. Specifications and design of the moorings are dependent on the turbine systems to be tested and the local seabed conditions, and as such, should be a focal point for detailed design of a test centre. A **fixed pile for turbine testing** is a type of mooring that could be a useful asset; however, the costs of installation are high, and there is not currently sufficient demand to justify the costs to install or maintain such an asset. Furthermore, these requirements were not outlined in the industry engagement, and it is imagined that a mooring system for a barge or a floating device would cater to a wider variety of industry needs. Versatile mooring points that can take high loads, with marine vessels able to rapidly adjust for different needs, would likely be more useful.

Power and data cables are critically important for getting electricity and data to shore. Useful tests can be conducted with off-grid systems using load banks and data storage at sea (and/or wireless telemetry to shore), but longer-term operation of a test centre should focus on significant benefits of cabling to shore to enable power system research (energy storage) and high-bandwidth streaming of data from various sensors. In addition, an objective of the developer will be to develop the means to test their cable connection methodology during the development stage.

From a technical perspective, **grid interconnection** is not required for tidal turbine testing; however, a safe and reliable **power management system** would be a necessity. The system must have the ability of monitoring the performance of the turbines and transfer the power to a load, which could be in the form of a load bank (such as a heat dump), energy storage system, or a reliable interface with the grid. With respect to energy storage, there is a need to enable research, development, and demonstrations of coastal community power systems, applicable to off-grid and weak grid applications. A test centre that accommodates this focus could enable federal funding support and a world focus on Nova Scotian innovations. As noted in Section 2.2, a grid connection with a feed-in tariff (FIT) could attract users to the site and/or provide revenue to cover costs or fund research projects. However, it can be difficult to negotiate a power purchase agreement (PPA) with the utility to bring a temporary, variable-output load into the grid. There is also currently no legislative framework for doing so under the Nova Scotia Marine Renewable-energy Act (MRE Act). The establishment of a grid connection could be a longer-term goal for a test centre, while moving forward with off-grid work.

Highly qualified personnel located at the test site would be a significant asset to enable cost-effective research and testing, integration/involvement with local communities, and increased safety. EMEC is a good example of this. Personnel should be skilled in the following areas (but not limited to):

- Overall site operations, including planning and safety on land and at sea
- Marine operations
- Oceanographic R&D
- Renewable energy R&D
- Electrical and high voltage technicians
- Marine biology R&D, including active environmental monitoring
- Community and First Nations engagement, including bilateral knowledge-sharing.

Low-cost accommodations are an enabler for success and sustainability and should be readily available to users of the test centre. This is an enabler for use of the centre, collaboration, and developing relationships with the community, including sharing information on a day-to-day basis through informal community interactions. Importantly, this allows users of the facility to stay in the community for longer durations, rather than rushing in and out due to paying accommodation rates targeted at the tourist industry. Users of test facilities often work longs hours and require a quiet and secure workspace, away from the tourism industry. The ability to prepare meals is critical, as most coastal communities have limited services outside of the tourist season. It is also important to have easy access at all hours to a warm and dry space, with hot showers, as oceanographic work often results in cold and wet people.

High quality information on physical and biological site conditions, as well as existing local use, is required, and would be a significant asset to several potential test centre locations in Nova Scotia, primarily for FORCE, Grand Passage, and Petit Passage (also Digby Gut, to a lesser extent).

With a focus on developing and impelling effective monitoring technologies, **marine life abundance and variety** can be an asset to a test centre. A benefit of working in the presence of marine life is it gives rise to a requirement to design low-impact technologies, which are a core component of sustainable ocean systems.

Many developers that have expressed interest in utilizing a tidal test centre have developed integrated systems with moorings, platforms, and turbines; however, an asset of a **testing platform** could be beneficial. A mobile test platform could be useful for advancing research and testing opportunities, including use across several sites, such as COVE, locations in the outer Bay of Fundy, Minas Passage (including FORCE), and Cape Breton. However, each location would need consents/permits, community engagement, detailed site characterization, infrastructure (primarily moorings and navigational markers), and environmental monitoring. The technical and social objectives of moving the platform would also need to be evaluated with consideration of the costs and risks of mobilizing as well as the value of longer term testing at one location. One potential social benefit of mobility could be increased educational opportunities throughout Nova Scotia, although it might be more cost-effective and lower risk for people to travel to the test centre, which could also have educational components on-shore. The platform could be built to purpose, repurposed from existing infrastructure, or contributed to the test centre by an initial user. Examples for each scenario are provided in Appendix 6.

3.4.2 Areas

The following sections discuss potential areas for small tidal turbine testing. The focus areas are consistent with the Areas of Marine Renewable-Energy Priority (AMREP), described as the Fundy Area and the Bras d'Or Area, in the MRE Act. Initial location screening is conducted by evaluating information on flow speeds and depths and comparing them to the identified gap of test centres offering berths with flow speeds between 2 to 4 m/s and 10 to 30 m depth.

For the Bay of Fundy, predictions of maximum flow speeds and minimum water depths from the Acadia-Bay-of-Fundy numerical model[4] have been screened to highlight regions with flow speeds of 2 to 5 m/s and depths of 10 to 40 m. Note that the flow speeds and depth ranges have been extended a bit beyond the existing gap so to not exclude values that are useful for testing. The depth regions have been separated to show areas with minimum depth of 10 to 25 m and 25 to 40 m, where shallower waters are more suitable for floating systems and deeper waters can accommodate bottom-mounted turbines while maintaining navigational clearances. The deeper water areas are shown with a black outline around the numerical model cells. An example is shown on Figure 3.

For the Bras d'Or Lake, ADCP-measured flow speeds and depth information from the Cape Breton Resource Assessment (McMillan 2012) were used for the evaluation.

In addition, three locations outside the AMREPs that include bridges in medium- and high-energy environments are included for consideration. Two are located in Southwest Nova Scotia and included preliminary surveys as part of the Southwest Nova Scotia Tidal Resource Assessment (Trowse 2013).

[4] Dr. Richard Karsten's research group at the Acadia Tidal Energy Institute uses the Finite Volume Community Ocean Model (FVCOM) to model the tides and tidal currents in the Bay of Fundy-Gulf of Maine system. The numerical model has been refined, calibrated and validated against observations in regions of strong tidal flow. The numerical model used in this report is the same model used for the analysis of Marine Renewable Electricity Areas for the OERA.

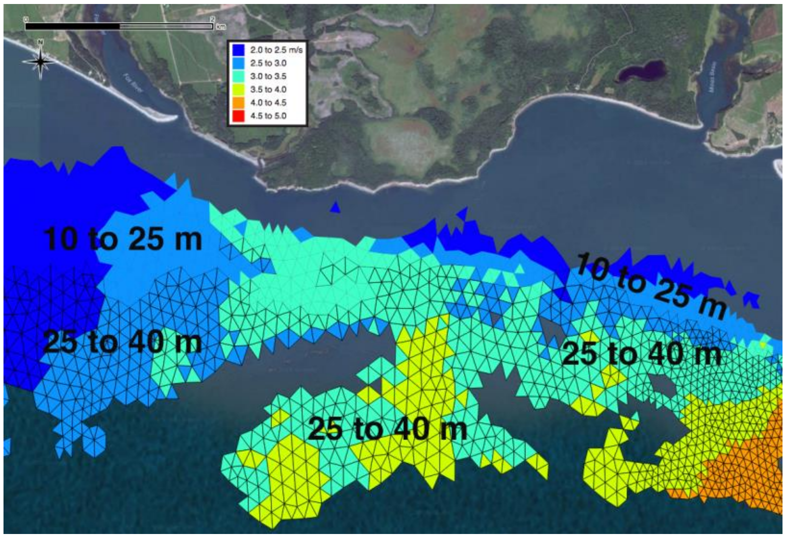

Figure 3: Example showing water velocity for shallow (10 to 25m) and deeper (25 to 40m) water areas.

The deeper areas are shown with black outline in the numerical model cells. The location shown is in Minas Passage, near Diligent River, chosen due to the variability in conditions and therefore useful as an example.

The figures provided in the following subsections are meant only to show potential regions for turbine testing, where further evaluation of promising regions should focus on minimizing impacts on existing use, and providing benefits to coastal communities. Existing assets are labeled, where W is wharf, L is boat launch, H is harbour, POI is point of grid interconnection (applies to FORCE only), BF is the Bay Ferries terminal (applies to Digby Gut), CCG is Canadian Coast Guard Station (applies to Grand Passage, which is also close to Petit Passage).

3.4.2.1 Minas Passage and Minas Channel

As shown on Figures 4 through 6, there are large areas within the Minas Passage and Minas Channel that satisfy the depth and flow speed screening, having depths that are suitable for floating and seabed mounted turbines. In this region, flow speeds cover the full range of 2 to 5 m/s. The potential test areas extend from west of Advocate Harbour to east of Parrsboro. However, many of these areas are relatively far from shore and outside of regions where detailed site characterization has been conducted (limited to FORCE region), and all require access from a dry port. Test areas near FORCE could benefit from potential shore access (93 m of waterfront at Black Rock Beach).

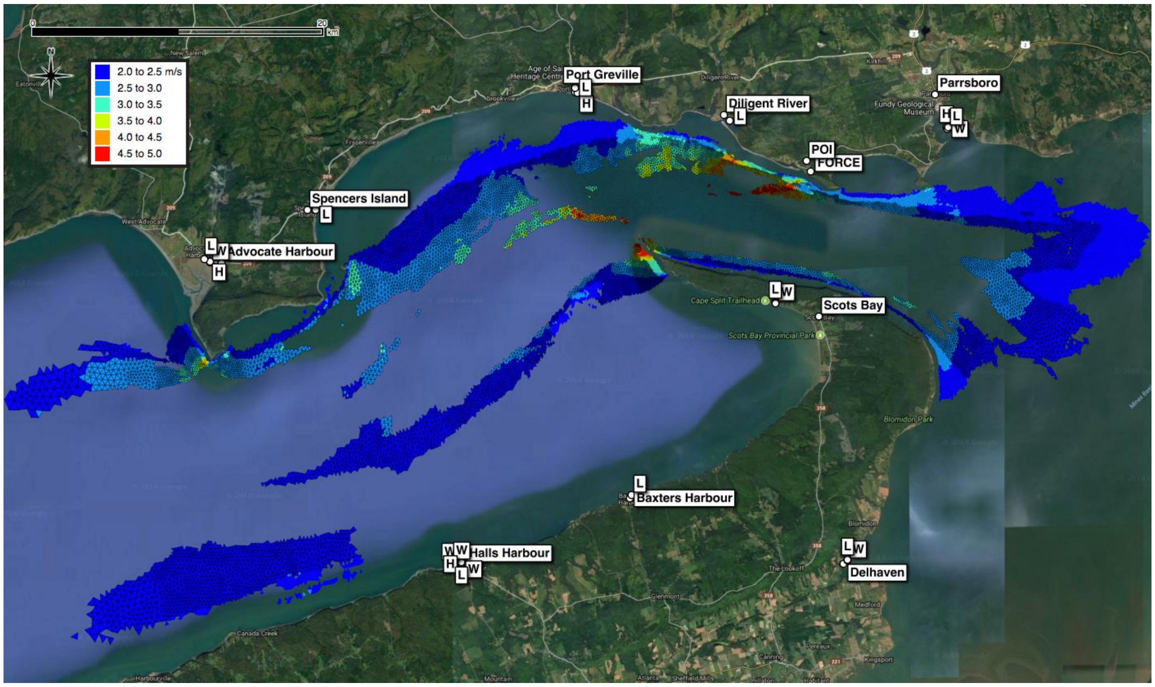

Figure 4: Minas Passage and Minas Channel

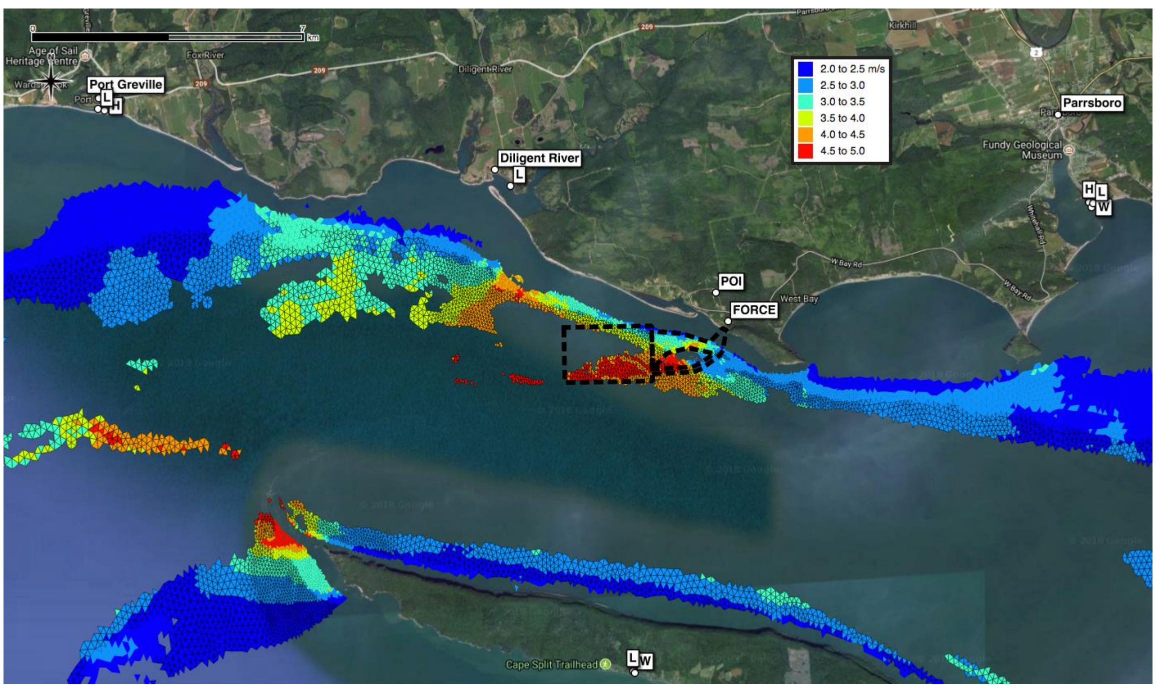

Figure 5: Minas Passage

The Marine Renewable Energy Area (MREA) is shown by dashed black lines. The MREA was formerly called the FORCE Crown Lease Area (CLA).

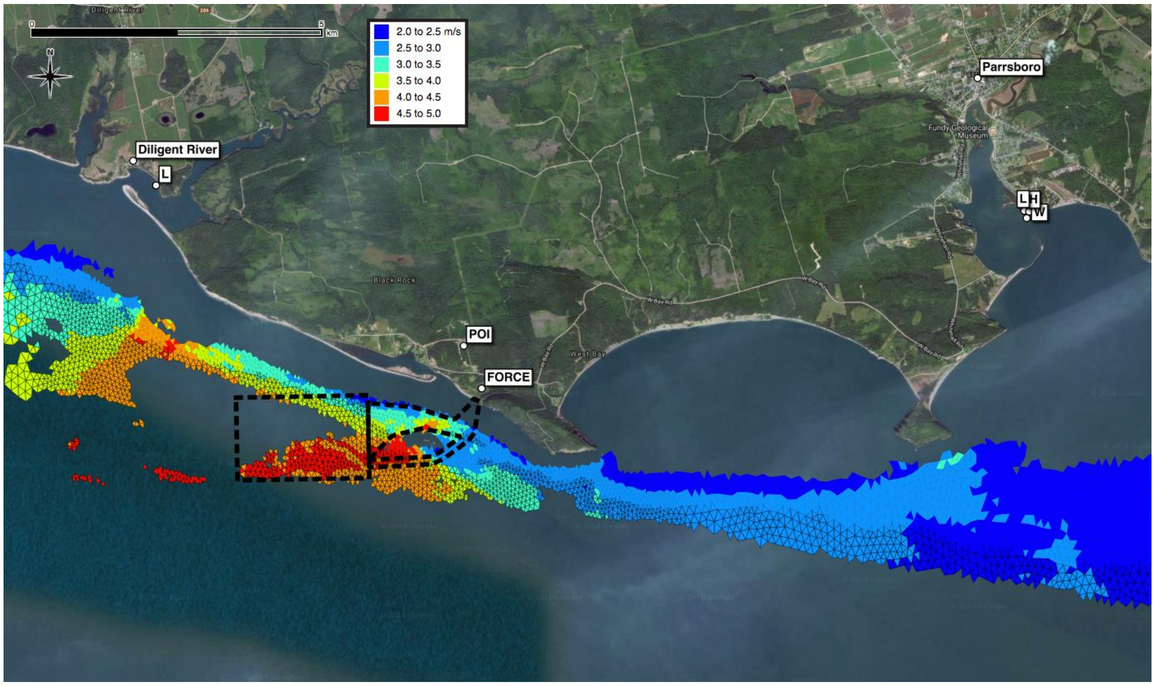

Figure 6: FORCE region (MREA shown by dashed black lines)

All locations in the Minas Passage and Minas Channel have limited accessibility from dry ports, with harbours, wharfs, and boat launches typically accessible for approximately 1 to 2 hours on either side of high water due to the extreme tidal range. Similarly, there is limited safety infrastructure and ability to respond to incidents on the water, with the most likely responders being any fishers (including Canadian Coast Guard Auxiliary), who are out when an incident occurs, or air support from Greenwood. Increasing accessibility and safety through extension of an existing or installation of a new boat launch, marine rail, and/or acquisition of a beach launch system (such as vehicle and trailers on continuous tracks) would be a useful infrastructure upgrade, provided there are qualified personnel on site for emergency response. As commercial projects advance in the Minas Passage, it is expected these constraints will be improved, with additional benefits associated with development of marine assets (such as barges and multi-cats) that could be based somewhere in the Minas Passage and/or Minas Basin region.

Locating a new test center near FORCE would create a risk to existing infrastructure for potential test locations within the MREA, including the subsea cables, as well as turbines and monitoring systems deployed by the FORCE berth holders. Subsea visibility is limited to approximately a few meters and flows are highly turbulent from the eddies resulting from Black Rock, West Bay, and Cape Sharp. Also, consideration should be given to Minas Passage being a migratory pathway for fish travelling between the outer Bay of Fundy and the Minas Basin. Testing would require effective monitoring systems that operate in low-visibility conditions using acoustic sensors.

On the other hand, FORCE, the berth holders and collaborators have completed a considerable amount of research, site development, and marine operations in the region. Installation of land-based, autonomous, and cabled observatories, ship surveys, and tagging of marine life have established a significant database of site data (physical conditions and marine life). The considerable number of marine operations that have been conducted in Minas Passage means there are a working knowledge and strategies to overcome some of the constraints noted above. Also, the potential for connection to the transmission grid, although not a specific requirement of a small tidal test centre, offers the possible benefit of revenue thorough a FIT.

3.4.2.2 Digby Neck Passages (Grand Passage and Petit Passage)

As shown in Figure 7, the Digby Neck Passages offer potential berth locations, with depths suitable for floating and seabed mounted turbines. As seen in the figure, the flow speeds cover the range of 2 to 3 m/s in Grand Passage and 2.5 to 4.5 m/s in Petit Passage.

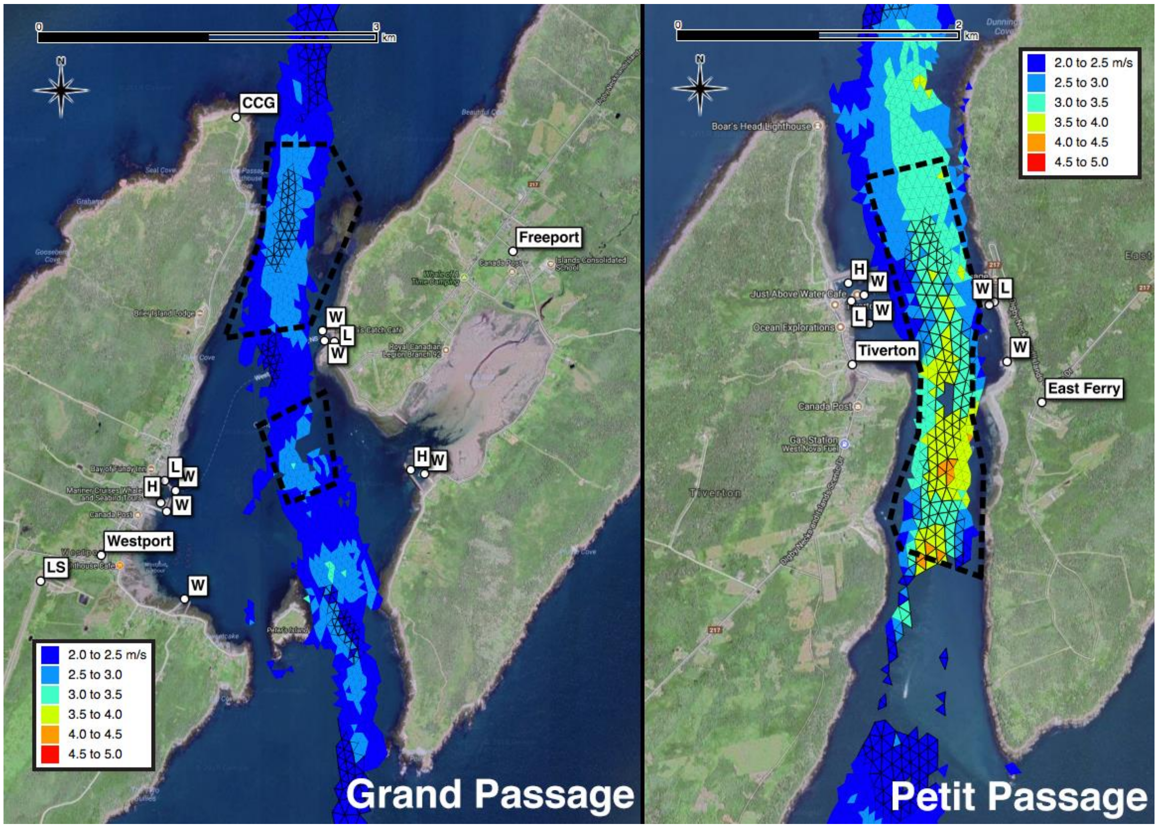

Figure 7: Digby Neck Passages (MREAs shown by dashed black lines)

Grand Passage and Petit Passage (the Digby Neck Passages) are highly accessible, with several wharfs, boat launches, and harbours located on both sides of the channels that are accessible throughout the tidal cycle. Compared to the Minas Passage, these locations are also closer to Halifax and other supply-chain ports by sea. The Canadian Coast Guard Station, in Westport, is a significant benefit for safety at sea (located at Grand Passage and approx. 10 nm from Petit Passage), as well as the ability for additional vessels to respond at any time, and for test site users to return to harbour when required. The boat launches are the vehicle ferry ramps, and as such, are concrete-steel construction, maintained by the Nova Scotia Department of Transportation and Infrastructure Renewal (DoT), with capability to support large freight- and boom-trucks. The vehicle ferries are also significant marine assets for the Digby Neck Passages. The primary ferries for Petit Passage and Grand Passage are the Petit Princess and Margaret's Justice, respectively. For data collection, they could be useful vessels of opportunity because they are easily accessible and run regular transects across the passages. Also, the Joe Casey is stationed in Westport Harbour to back-up the primary ferries. It is seldom used, and available for hire for use in marine operations. The presence of a self-propelled barge on site (in Westport, also with short mobilization to Petit Passage), available on an as-needed basis, presents opportunity for lower-cost marine operations, and an opportunity to involve the local captains and crew. The Joe Casey is 267 gross tonnage, with 34.5 m length by 12.5 m breadth, and propelled by a 544 kW twin screw diesel with a top speed of 8 knots.

Subsea visibility is excellent and suitable for use of optical systems for environmental monitoring, and there is a significant amount of marine life (species diversity and abundance). Potential test locations in the Digby Neck Passages benefit from existing site data (physical conditions and marine life).

Consideration should be given to the Digby Neck Passages being located adjacent to habitat for several species of whales, including the endangered right whale. Interactions between tidal turbines and marine mammals would occur on a regular basis, primarily seals and harbour porpoises, with white-sided dolphins to a lesser extent. Larger cetaceans are also known to use the passages, including, but not limited to: minke whale, humpback whale, fin whale, sei whale, and blue whale (rare, one known sighting in Petit Passage). Additionally, there are turtles, mola mola, basking sharks, and several other species of fish. The presence of such a wide range of marine species, including endangered species, would require a test centre to have a detailed environmental monitoring plan that would mitigate impacts on marine life.

However, along with the good subsea visibility in the region, the species abundance and diversity would be an enabler for developing and testing effective monitoring devices, needed to address uncertainties regarding marine life interactions with tidal turbines. A primary focus of testing in the Digby Neck Passages could include development, validation, and use of effective monitoring systems, including use of optical systems to validate passive and active acoustic detections with direct applicability to turbine deployments in more turbid waters (such as at FORCE).

There is more marine traffic in the Digby Neck Passages than in the Minas Passage. It includes local fishing vessels, the ferries connecting Westport and Freeport and East Ferry to Tiverton, whale tour operations, and vessels transiting through the channel. Considering local use, any testing with systems that impede navigation may be best suited for a wide portion of Grand Passage and potentially in the northern portion of Petit Passage (subject to large waves), out of the ferry route, and with the appropriate navigational markings (as would be required by Transport Canada). The presence of waves primarily at the entrances to the Digby Neck Passages can be beneficial for some research and testing but can also provide complications for marine operations, and increases mooring costs.

Similar to the FORCE area, there has been a considerable amount of research, site development, and marine operations in Grand Passage and Petit Passage. Installation of land-based, autonomous, and cabled observatories, ship surveys, dedicated marine life observation, and inclusion of local knowledge have established a significant database of site data (physical conditions and marine life). Marine operations have focused on working with local fishermen and marine contractors, resulting in capacity-building that is applicable to cost-effective research in the Digby Neck passages and has directly benefitted the utility-scale projects at FORCE.

Grand Passage is well suited for mid- to high-TRL testing for technologies developed for similar environments and mid-TRL testing for systems planned for higher energy environments, such as the Minas Passage and Petit Passage. Petit Passage is well suited for high-TRL testing for technologies developed for similar environments, including the Minas Passage. Combined, the Digby Neck passages offer diverse deployment options for a test centre.

3.4.2.3 Digby Gut

As shown in Figure 8, there are areas within Digby Gut that satisfy the depth and flow speed screening, with depths suitable for floating and seabed mounted turbines and flow speeds coving the range of 2 to 3 m/s. There are also small areas that could be technically suitable for testing floating systems; however, there is more marine traffic in Digby Gut than any other location included in this assessment, primarily being local fishing vessels and the Bay Ferries connection between Digby, NS and Saint John, NB.

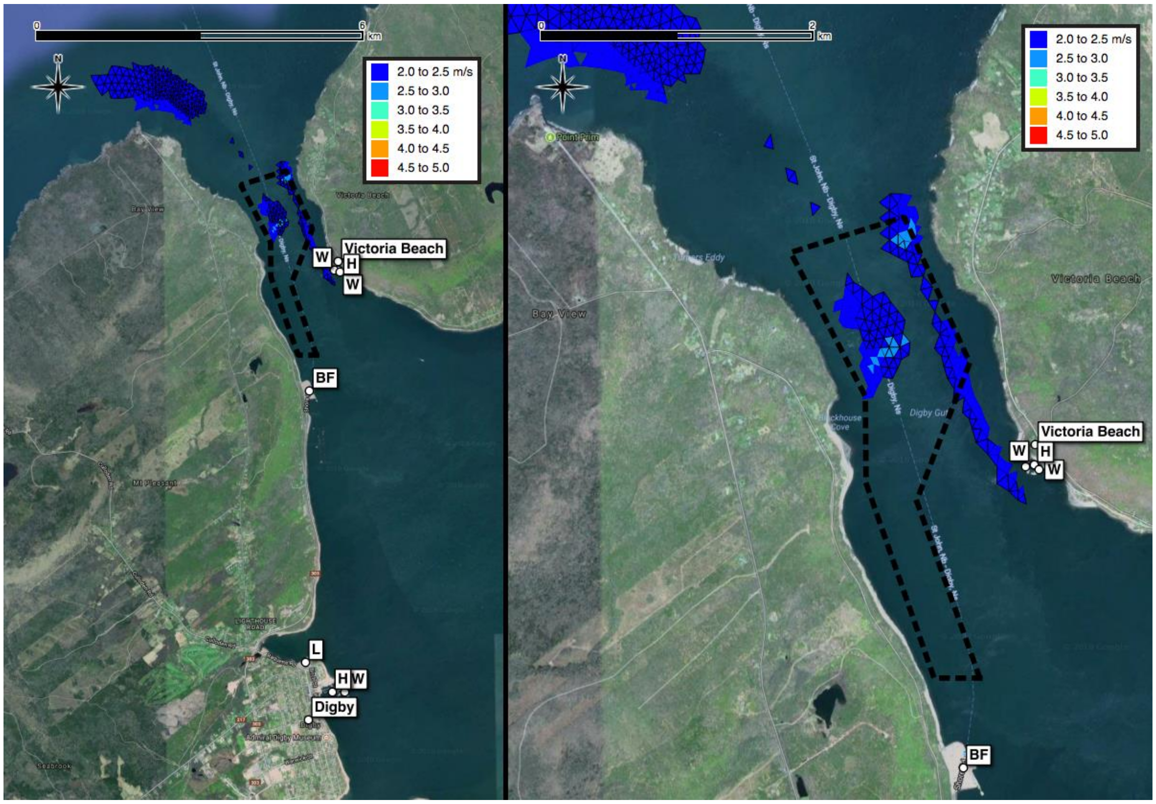

Figure 8: Digby Gut (MREA shown by dashed black lines)

Digby Gut is accessible, with harbours and wharfs in Victoria Beach and Digby that are accessible throughout the tidal cycle. There is a private boat launch in Digby that is accessible for the majority of the tidal cycle. With respect to safety, there is ability for vessels to respond at any time and for test site users to return to harbour when required. Subsea visibility is limited due to sediment from the Annapolis Basin. Potential test locations in the Digby Gut benefit from existing site data (physical conditions and marine life). Consideration should be given to Digby Gut being a migratory pathway for fish travelling between the Bay of Fundy and Annapolis Basin. Testing would require effective monitoring systems that operate in low-visibility conditions using acoustic sensors.

Digby Gut could be suitable for mid- to high-TRL testing for technologies developed for similar environments and mid-TRL testing for systems planned for higher energy environments, such as the Minas Passage and Petit Passage.

3.4.2.4 Cape Breton (Bras d'Or Area)

Figure 9 provides flow speed exceedance curves using ADCP data from the Cape Breton Resource Assessment (McMillan 2012), including Barra Strait, Seal Island Bridge, and Carey Point. The minimum depths at the Barra Strait and Seal Island ADCP locations were 21 m and 15 m, respectively, and these depths are representative of the general areas. The ADCP at Cary Point was deployed mid-water column, with the data set provided to the study by BIO, without detailed mooring plans or the pressure (depth) signal. Based on Canadian Hydrographic Service (CHS) nautical charts, the minimum depth in the highest flow section of Carey Point is approximately 10 to 15 m.

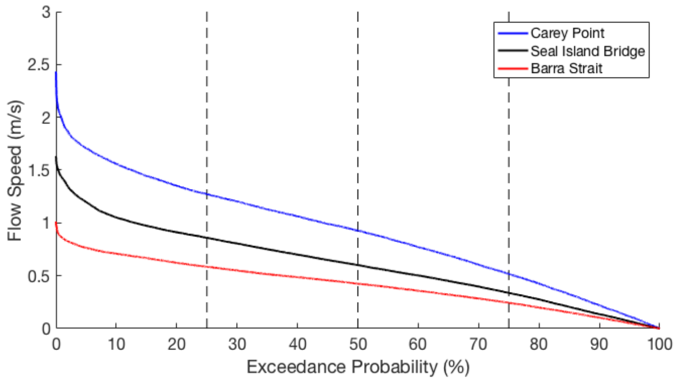

Figure 9: Cape Breton flow speed exceedance curves

The maximum flow speeds measured at Seal Island Bridge and Barra Strait were 1.6 m/s and 1.0 m/s, with 25-day and 31-day deployments, respectively. These relatively short-term deployments do not include long-term variability, and there is uncertainty with spatial variation, but they suggest that these locations would not adequately address the low-end flow speed requirement identified in the gap analysis.

The maximum flow speed measured at Cary Point was 2.4 m/s over a 229-day deployment, provided by BIO. However, as noted in McMillan (2012), the ADCP was deployed on a mid-water column SUBS mooring, which is known to induce high-frequency non-tidal variability in measured flow speeds. This is due to pitch and roll of the ADCP mount. As such, the data should be used to only evaluate general flow features, and general assessment of flow speed exceedance probability is more appropriate than focusing on a single maximum flow speed measurement. As shown on the exceedance curve (Figure 9), the flow speeds at Cary Point exceeded the 2 m/s gap threshold only 0.85% of the time.

Consistent with the findings of McMillan (2012), Cary Point likely has the most promising flow speeds in the Bras d'Or Lake region for development of a low-flow small-scale project. With respect to flow speeds, next steps would require additional analysis, following standard procedures, for tidal energy resource assessment for flow-field mapping using drifters, followed by (if costs justified it based on several factors), a bottom mounted ADCP at a potential turbine berth site. However, the accelerated flow speeds at Cary Point occur in a narrow channel (approximately 300 m wide) providing the main connection between the Bras d'Or Lake and the sea. Any potential development in this area would require focused community and First Nations engagement, including evaluating the importance of this channel for transportation and marine life.

In the context of use for a small tidal test centre, following additional flow analysis, it may be shown that Carey Point satisfies needs around the 2 m/s low-end threshold. However, the area is small and does not provide a variety of deployment options covering a range of developer needs.

More generally for the full Bras d'Or Lake region, the area could be useful if a need arises for testing lower-flow technologies, designed to efficiently harness flows in the range of 1 to 2 m/s. Again, in the context of a potential small tidal test centre, it should be noted that locations throughout the Bay of Fundy can address this need as well as the existing gap for testing opportunities in flow speeds between 2 to 4 m/s. As such, the Bras d'Or Lake region is not carried forward for further evaluation in this study.

3.4.2.5 Other

Although outside the focus for this study, there are locations outside the AMREPs that could be useful for small-scale tidal energy testing and research. For example, there is the existing Indian Sluice Bridge and former Cat Island Bridge (pillars remain) in the Argyle region, as well as the Rocky Run Bridge, in Lawrencetown, connecting Porters Lake to the sea. The two locations in Argyle were included in the Southwest Nova Scotia Tidal Energy Resource Assessment (Trowse 2013), and preliminary flow field mapping was conducted using GPS drifters deployed by kayak, with maximum values of 4.1 m/s for Indian Sluice and 3.3 m/s for Cat Island Bridge. Figure 10 shows surface flow measurements for ebb and flood tide at Indian Sluice Bridge. Dr. David Swan used the Rocky Run Bridge for a tidal energy test in 1985 (Nova Scotia designed and built “VEGA” shown on cover). Based on visual observations, the maximum flow speed is at least 2 m/s, likely closer to 3 m/s. For all three locations, the minimum depths at low water are likely in the range of 1 to 5 m, with the deepest waters located to the east of Indian Sluice Bridge. For some tests purposes, systems exposed at low water can be useful for accessibility.

These locations are mentioned because bridges can offer unique opportunities for cost-effective testing, as demonstrated at the Dutch Marine Energy Centre (see test centre profiles in Appendix 1). Tocardo Tidal Power is an example of a company that has advanced their turbine technology through different scales and versions by testing on bridge structures close to their base of operation in the Netherlands. However, further consideration would need to focus on working with local communities to evaluate testing opportunities with consideration of navigation (recreational and commercial), fishing, and marine life. They are shown here for example purposes and not carried forward for further evaluation in this study.

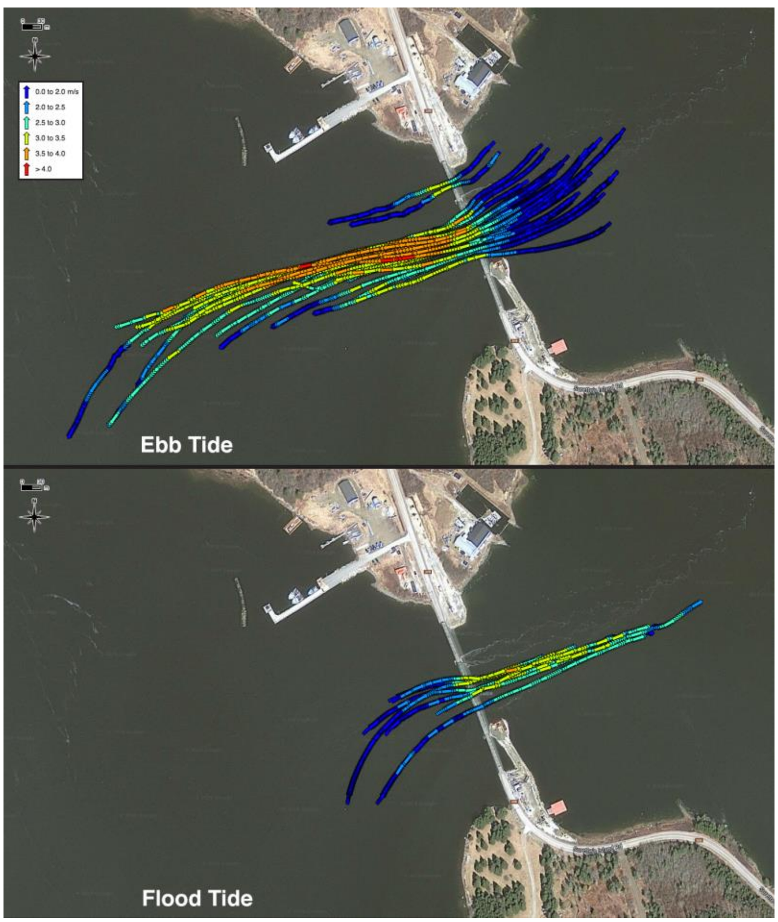

Figure 10: Indian Sluice Bridge preliminary flow field mapping

(Surface flow speeds measured by GPS. Ebb tide survey conducted with 3 kayaks, flood tide with 1.)

3.4.3 Area Comparison

Table 5 provides a comparison of the areas considered for potential use for a small tidal test centre.

Table 5: Area comparison

	Berth Variability	Physical Access	Infrastructure Useful	Infrastructure Risk to	Site Info	Permitting	Safety
Weight	**2**	**1**	**1**	**1**	**1**	**1**	**1**
Minas Channel	3	2	1	5	1	2	1
Minas Passage (outside FORCE)	4	2	1	5	2	2	1
Minas Passage (near FORCE)	4	2	2	4	3	3	1
FORCE MREA	3	2	3	2	4	4	1
Grand Passage MREA*	3	5	2	3	4	4	5
Petit Passage MREA*	3	5	2	4	4	4	4
Digby Gut MREA	2	3	2	4	2	4	3
Max	5	5	5	5	5	5	5

Highest

Medium

Lowest

	Subsea Visibility	Impact on Nav	Marine Life Abundance	Marine Life Risk	Fishing	First Nations	Adjacent Communities	Score Straight	Score Weighted
Weight	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**-**	**-**
Minas Channel	1	5	3	2				26	38
Minas Passage (outside FORCE)	1	5	3	1				27	40
Minas Passage (near FORCE)	1	5	3	1				29	42
FORCE MREA	1	4	3	1				28	39
Grand Passage MREA*	4	3	5	3				**41**	**56**
Petit Passage MREA*	4	2	4	3				39	52
Digby Gut MREA	2	1	3	1				27	35
Max	5	5	5	5				55	75

Notes:

Scoring is 1 to 5, with 5 being best. For example 5 is good access and low risk.
Categories that cannot be changed or mitigated are assigned a weighting of 2. All others have a weight of 1.
Berth variability is ability for the area to supply berth locations to address the gap of flow speeds in 2 to 4 m/s and minimum depths of 10 to 30 m.
* If evaluated collectively as the Digby Neck Passages the Berth Variability rank would increase to 5.
Physical access is ability to get equipment and personnel on and off the water (harbours, wharves, and boat launches)
Infrastructure (useful) is consistent with the test/research centre components listed previously
Infrastructure (risk to) is the risk to infrastructure that is not a component of the research/test centre
Site information is access to high quality information on physical conditions, marine life, and local use.
Permitting is ability to obtain permits, licenses, and consents, as applicable.
Safety is ability to respond to distress situations
Subsea visibility is the water clarity for use of optical systems
Impact on navigation is the size of the channel and regularity of use for commercial and recreational vessels
Marine life (abundance) is the variety and abundance of marine life, including fish, marine mammals, and birds.
Marine life (risk to) is the ability to monitoring and mitigate risk, including consideration of migratory pathways
Fishing is the ability to minimize impact on fishing grounds
First Nations is the ability to coexist with indigenous communities
Adjacent communities coexist with coastal communities located near the potential test/research centre areas

Note that categories have been included for fishing, adjacent communities, and First Nations but scores have not been assigned. For all three, the primary objective is to coexist. With respect to fishing, the focus is minimal interference. For adjacent and indigenous communities, the focus is identifying locations that can be best used to address existing concerns, achieve support for the mission of a test centre, and work together to advance our understanding of how tidal energy could contribute to a sustainable future for coastal communities. Focused engagement is required to properly evaluate these variables and should be used to inform decisions on the most appropriate locations for development of a test centre.

The Minas Passage and Minas Channel clearly offer significant opportunities for commercial utility-scale projects and is the target area for many project developers. However, in the context of testing and research, there are known drawbacks, primarily associated with accessibility, safety, and water clarity.

The first two could be improved with significant infrastructure upgrades that may occur alongside utility-scale commercial development in the Minas Passage.

Linking a small tidal test centre to the commercial development could yield benefits. The commercial developments will require marine and onshore resources that could be used by the test centre. The test centre activities could be closely tied to the commercial activities, reducing costs and increasing uptake of test results. However, in this scenario, the time frame, location and scope of a test centre would be largely determined by the needs of FORCE berth holders and other developers in the Minas Passage area permitted under the MRE Act. Although accessibility and safety can be improved, there are hard constraints associated with dry ports that cannot be fully mitigated. Wet-ports and clear water cannot be created and are enablers of cost-effective testing and research. As a result, such a test centre in the Minas Passage would not address several of the needs that were identified in the gap analysis. Furthermore, public opinion regarding expansion at FORCE to include berths for small-scale testing would need to be considered.

The Digby Neck passages offer a wide range of test conditions, excellent accessibility, increased safety, and good water clarity. These factors align with needs for cost-effective testing and research, including facilitating outreach activities for education and training. It is likely that a tidal energy installation would become part of existing whale tours and gather international attention. If properly managed, proximity to an active lobster fishery, aquaculture operations, and marine life can broaden the services offered by a test centre beyond tidal energy testing.

Similar to much of rural Nova Scotia, the Digby Neck passages are located at the end of a weak distribution grid with frequent power outages. Significant infrastructure upgrades would be required to run a transmission line to these areas, as would be required for commercial utility-scale projects. The cost of a transmission line likely precludes utility-scale developments occurring in the Digby Neck passages. The lack of a solid grid connection may foster research that advances the development of on- and off-grid coastal community power systems, including micro-grids, energy storage, and use of tidal power systems that are in balance with community needs and the marine ecosystem. This work would apply to a number of remote and rural communities across Canada. A focus on testing in Grand Passage and Petit Passage could help advance community-scale tidal energy applications; as well as testing to increase TRLs, as a "gateway to the bay," prior to deployments in more challenging locations in the Minas Passage.

Compared to the other locations, Digby Gut has limited opportunities for testing but could be utilized in conjunction with the Digby Neck passages. An important consideration is the significant vessel traffic, including local fishing vessels and Bay Ferries.

3.5 Organization

3.5.1 Ownership alternatives

There are various ownership alternatives for a small tidal test centre in Nova Scotia, including: private (independent), public (government-owned), university-owned, FORCE-owned (a special case of private), and owned *with* FORCE, whereby an "umbrella" organization oversees both the test centre and the FORCE demonstration centre. These were explored with input from people familiar with the industry and related research. The advantages and disadvantages of each of the alternatives are provided in Table 6.

At test centres investigated in the industry scan, the structure and governance tend to reflect the proportion of financial support received from industry and government, with a particular requirement for government support for lower-TRL technology companies that have not secured significant private investment.

Table 6: Ownership alternatives

Private (independent)

Definition: An incorporated entity governed by a board of directors and legally independent of government and private interests.

Examples: EMEC, SEENEOH, DMEC, BTTS (Bourne), PTEC (Perpetuus), Institute for Ocean Research Enterprise (IORE).

Advantages
- Can be nimble and responsive to client needs and changes in the marketplace.
- May be less influenced by political agendas and changes thereto.
- May have access to funds that a public entity would not, such as Natural Resources Canada funding.
- Can be driven by local entrepreneurs, with significant community involvement.

Disadvantages
- It may be difficult to find funding for startup, in terms of both sources and timing.
- It may need to continually seek government grants to support operations.
- It may become bottom-line oriented, which may compromise the research agenda, transparency, and sharing.
- As a not-for-profit, non-governmental organization, it may be hard to attract and retain high quality employees.
- There is exposure to policy risk; support can be withdrawn if government priorities change. Client projects will generally be government-funded so those can be lost also.

Further notes
- Appropriate leadership and governance would be very important for success, as would retention of quality people.
- It is important that it be independent enough so to not be overly influenced by particular individuals or stakeholder groups.

Public (government-owned)

Definition: A legal entity, governed by a board of directors, that is related (arm's-length or non-arm's-length) to a government. At least some members of the board may be appointed by government.

Example: InnovaCorp (provincial crown corporation), Bedford Institute of Oceanography.

Advantages
- Provides some access to government funds but government ownership would preclude raising grant money from other sources.
- There may be a feeling of ownership and buy-in in the community.
- Transparency and sharing may be more achievable than in the case of a private organization.
- May inhibit long-term planning, which may be done, instead, on a fiscal-to-fiscal schedule.

Disadvantages
- Exposure to policy risk - could be affected by changes in governments and government budget priorities.
- May be less than nimble and responsive if political mandates must be adhered to.
- Political timescales do not match with the tidal industry, which may need many years to reach maturity.

University-owned

Definition: A field station or research centre owned and operated by a university and overseen by university administration and board of governors.

Examples: CHTTC, SNMREC, MaREI (LiR NOTF), QML

Advantages

- Better able to access research funding than a private or public entity.
- Budget, networking, and marketing support from the university.

Disadvantages

- High overhead cost allocation.
- Focus could be on the research needs of the university, faculty and students, rather than the needs of the industry or moving the industry forward.
- There may be limited access to researchers beyond those employed at the university that owns it.
- University budget-tightening could result in a loss of support.
- Ownership model would not be aligned with a service-to-industry focus.

Paraphrased, representative comments from interviewees

- *Owning and operating a test centre is not a university's core business.*
- *It is not likely a university would take on the financial responsibility of this sort of field site.*

FORCE-owned (special case of private)

Definition: An extension of FORCE that is either co-located or located in another tidal stream and managed in a way similar to the four test locations of EMEC in Orkney, Scotland.

Example: EMEC-scale (nursery) tidal and wave sites

Advantages

- Some economies of scope and shared overhead.
- Reduced barriers to collaboration, facilitating:
    - Sharing of knowledge and experience for the benefit of both facilities, all clients, and tidal energy development in Nova Scotia generally;
    - Collaboration on research and grant applications;
    - Collaboration to help clients reach commercialization from mid-TRL;
    - Common messaging.

Disadvantages

- A small-scale test centre does not fall within the mandate of FORCE, which is focused on utility-scale tidal technology demonstration of commercial projects.
- Without an increase in human and financial resources, FORCE does not have the capacity to manage a second (or extended) test centre.
- The current board composition, with the five FORCE berth-holders, is not well-suited to overseeing a small tidal test centre with a wider technology development focus (re: Diamond-E framework's Organization-Strategy alignment);
- The organizational culture of FORCE may not be compatible with the test centre's key success factors of being flexible and responsive to the needs of small technology developers (re: Diamond-E framework's Organization-Strategy alignment).
- The organizational managerial preferences at FORCE may not be consistent with the test centre strategy developed in Section 3.2 (re: Diamond-E framework's Management Preferences-Strategy alignment).

Further notes

- Barriers to collaboration can be reduced without FORCE ownership, including arrangements such as MOUs, MOAs, partnership agreements, or other strategic alliances. However, there needs to be willingness by both parties to collaborate.
- Much of the tidal energy expertise and experience, often attributed to FORCE, is actually more widely held; it is shared with the multiple researchers, consultants, and supply chain companies who have worked with FORCE on its projects and in other locations throughout the Bay of Fundy.

- There are regional differences (logistical and social) that require consideration when comparing EMEC and FORCE as owners of multiple test sites.

Owned *with* FORCE (special case of private ownership)

Example: An independent or publicly-owned not-for-profit organization is formed to oversee both the FORCE demonstration site and the small tidal test centre. The demonstration site and the test centre(s) could either be co-located or be in different tidal streams.

Advantages

- Some economies of scope and shared overhead.
- Reduced barriers to collaboration, facilitating:
  - Sharing of knowledge and experience for the benefit of both facilities, all clients, and tidal energy development in Nova Scotia generally;
  - Collaboration on research and grant applications;
  - Collaboration to assist clients reach commercialization from mid-TRL;
  - Common messaging.

Disadvantages

- The organizational culture and managerial preferences at FORCE are not consistent with the test centre strategy developed in Section 3.2. An umbrella organization would need to oversee two different cultures and management preferences or reconcile them without hindering the success of either site.
- There may be some confusion in the marketplace regarding brand.
- The overseeing organization may be spread too thinly to provide sufficient leadership for both organizations.

Further notes

- Barriers to collaboration can be reduced without FORCE ownership, including arrangements such as MOUs, MOAs, partnership agreements, or other strategic alliances. However, there needs to be willingness by both parties to collaborate.
- Much of the tidal energy expertise and experience, often attributed to FORCE, is actually more widely held; it is shared with the multiple researchers, consultants, and supply chain companies who have worked with FORCE on its projects.

3.5.2 Governance

Governance is a critical enabling tool for an organization. The board mandate and selection of board members need to be aligned with the mission and objectives of the test centre. Board members require the experience and expertise to oversee management, understand the operations, develop the strategic plan, implement it, and understand the key factors for success. Overseeing risk management is also an essential role of the board. Board members must be able to understand the various types of risk (strategic, financial, operational, compliance, etc.) and methods for mitigation. They must also be able to commit to the achievement of the organization's mission and objectives, without conflict of interest.

The board is accountable to the organization's stakeholders. There must be careful consideration of how stakeholders are able to inform decision-making in the organization. A stakeholder-based board, one that has stakeholder representatives as board members, can help gain and maintain the trust of stakeholder groups. A skills-based approach to board composition, by which the expertise and experience needed on the board is identified and people who meet the criteria are sought, is another alternative. A skills matrix can be used to lay out the experience and expertise needed on the board, identify gaps in the board's composition, identify potential board members, and assess their candidacy. Stakeholders are given a voice through other means, such as advisory or liaison committees (Rassart & Miller 2013).

The choices made on the service-vs-research focus and from the ownership alternatives, noted in the previous sections, and sources of funding, would likely influence the composition of the board. For example, in the case of a public not-for-profit organization, some (or all) board members would likely be appointed or nominated by government. In Table 7, three alternatives are evaluated, a stakeholder-based board, a skills-based board, and a third, a board that oversees both the test centre and the FORCE demonstration site. The last specifically relates to the ownership alternative, "Owned *with* FORCE," noted in the previous section.

The structure and governance of the other test centres studied in the industry scan vary, depending on their size, complexity, maturity and level of reliance on government support. As government funding is often key to the survival of a centre, governance is generally in line with national and international guidelines and best practice. Generally, this sees a board of directors established to oversee the centre's operation, with representatives from key areas, including local and national government, academia, developers, relevant government agencies, and other industry stakeholders.

Table 7: Governance alternatives

Stakeholder-based board

Eight to ten members, suggested representation from:

- Fishers;
- First Nations;
- Local community;
- Universities, academic people;
- Private industry people with a stake in the development of the industry or retired people from the industry;
- FORCE;
- COVE;
- Government - DOE, perhaps other relevant departments as well (able to inform policy);
- OERA;
- The sponsor (e.g. municipality, province, federal government);
- Lawyer or person with legal work experience;
- Not-for-profits with similar missions, environmentally-focused organizations;
- Ocean technology companies;
- DFO/BIO;
- Emera;
- Supply chain company.

Advantages

- Stakeholder concerns and priorities will directly inform the decisions of the board.
- Representatives could communicate with their constituents to explain decisions made by the board.
- There could be greater trust between stakeholder groups and the organization.

Disadvantages

- Members would have a fiduciary responsibility to the test centre, including a commitment to the objectives of the test centre. These can, at times, conflict with the priorities of the stakeholder group.
- There may have to be a trade-off between stakeholder representation and the experience and expertise needed to govern a test centre.

Paraphrased, representative comments from interviewees

- *A small tidal test centre could do well to have a model of governance and mandate devised by community participation and decision-making, not simply be driven by industry priorities.*
- *A mix of people is good. It is good to get references; you need people who are actually being supported and have connections.*
- *Government representation can be a burden.*

Business-oriented, skills-based board

A skills matrix is developed, identifying experience and expertise needed on the board, and used to identify potential board members and assess their candidacy.

Advantages

- The needed experience and expertise to run a test centre are identified and fulfilled, enabling the test

centre to meet its objectives.
- Experience/familiarity with stakeholder groups can be included in the skills matrix.
- The potential for conflicts of interest can be mitigated.

Disadvantages
- Stakeholder groups may feel their concerns are not being addressed in decision making.
- There can be less trust between stakeholder groups and the test centre.

Paraphrased, representative comments from interviewees
- *More than anything, you need people experienced in working with similar organizations, people who can work across sectors and don't bring other agendas to the table.*
- *It will require good leadership to set up the board, the initial chair of the board will be important, as well as the leader of the facility.*

Board that oversees both centres
This relates only to the "Owned *with* FORCE" ownership alternative in Section 3.5.2.

Advantages
- If the two organizations are separate, they would likely need different board members, due to possible conflicts of interest. Being a small industry and region, it may be difficult to fill two boards with qualified people.

Disadvantages
- The product/market focus, core activities, goals, value propositions, and key success factors of the two centres would be different. A board would be need to be able to support these differences to enable both succeed.

Further note:
- The current composition of the FORCE board, exclusive of the seats for berth holder representatives, may be a suitable model for an "umbrella" organization; it includes knowledgeable representatives from community, First Nations, science, and independents. The board would likely need to include a representative from each the test centre and the FORCE demonstration centre.

3.5.3 Collaborations

The sustainability of the test centre and other organizations in the sector can be enhanced through collaboration with other organizations and would minimize duplication. A number of possible collaborations are described in this section.

Collaboration with the First Nations and coastal communities would facilitate bilateral knowledge-sharing and learning. Community-scale tidal energy would be applicable to remote communities and is relevant to their community energy plans. It could help rural and remote communities by enabling them to evaluate tidal energy as a potential contributor to sustainable living, including developing innovative, clean energy. It could provide opportunities for local businesses, employment, training, and present career prospects for youth. A test centre for community-scale tidal energy devices can help community members better understand the technologies, the opportunities, and their relevance, than with large, utility-scale projects.

There is a natural fit between a small tidal test centre and the work of COVE. Using the regional inventory of available assets and resources, COVE is looking to direct ocean technology companies, through the doors at COVE, to wherever their testing needs can be met. It is part of COVE's mandate to reach all regions of Nova Scotia and they are motivated to build such relationships. They do not intend to duplicate facilities that already exist and would view the small tidal test centre as an asset in the regional ocean technology research and development ecosystem. COVE can also help connect the test centre to Ocean Supercluster projects that need testing in high-flow tidal streams or other characteristics of the local environment at the test centre.

The work of the test centre could align with the Ocean Supercluster objectives. One of the corporate partners in the Ocean Supercluster is Emera, and their ocean technology needs relate to tidal and wave energy, including environmental monitoring. The other industry partners are from the fishing, aquaculture, and off-shore petroleum industries. Common technology needs were identified by this consortium, including underwater data transmission, better sensors, environmental genomics, better environmental monitoring, better understanding of corrosion protection, and digital twins of assets. Much of the initial testing can be done in calmer waters than those of a tidal stream, but for those technologies that need to be tested in more challenging ocean conditions, the small tidal test centre could provide that service.

FORCE is a natural choice for collaboration with the test centre. Each could help the other be successful. Some technology developers looking to develop utility-scale devices need to test in waters that are accessible and at lower speeds than the crown lease area at FORCE. Presently, to do their work, they need to test pre-commercial (including scale) models elsewhere in the world, or go through the process of establishing a permitted test site in Nova Scotia waters. Having a test centre in Nova Scotia that serves this market could facilitate coordination between the sites, help the local supply chain build capacity, and enable the community to learn about the technologies and marine life interactions with them. The business each centre would generate and the experience they would gain could be shared to help both the clients and the two centres prosper.

Local expertise with numerical modelling, the Aquatron Lab at Dalhousie, the small tidal test centre, and demonstration sites at FORCE would form a series of stepping stones in the pathway toward commercialization. Going further afield, the test centres of CHTTC and the BTTS, add complimentary stepping stones, having slower speeds, fresh water, etc. A memorandum of understanding was signed between the University of Massachusetts at Dartmouth in 2012 to facilitate engineering and environment-focused tidal research collaborations between Nova Scotia academic institutions and University of Massachusetts at Dartmouth (Bedford MA, USA). MRECo is no longer a part of UMass Dartmouth but it is still a potential collaborator, with their BTTC serving as a potential feeder site to Nova Scotia test centres. Coordination amongst these organizations on standards and procedures would enable each to facilitate a developer’s progress toward commercialization.

The University of Victoria-based West Coast Wave Initiative, though currently focused on computational fluid dynamics (CFD), tank testing, and wave energy development, may eventually pursue a tidal test facility. This could be a complimentary facility. A memorandum of understanding between Nova Scotia and British Columbia, signed in 2012 to share information and best practices in regulation and permitting for marine renewable energy and to partner on research and technology development, could facilitate this.

The test centre may be of interest to the Ocean Tracking Network (OTN) in their work. Most of their facilities are in very deep water but they may have an interest in the research that can be done in an accessible tidal stream.

Marine Renewables Canada (MRC), the industry association, and perhaps the Ocean Technology Council of Nova Scotia (OTCNS), an industry council, would provide value to and derive benefit from an accessible test facility. They could also help by identifying development projects and directing developers to the Nova Scotia test facilities.

With ocean research as part of the test centre's capability, the Bedford Institute for Oceanography (BIO) would be a natural collaborator. A great deal of research still needs to be done on tidal streams and the interaction between tidal devices and marine life. A test centre in a moderate and clear tidal stream, with turbines and other technologies in the water, could facilitate such research.

Collaboration with other established test centres, most notably EMEC, can be made to draw on the past experiences, and to share in the lessons learned at other test sites for small tidal. Sharing results of scientific research, environmental monitoring, operational procedures, and industry trends would accelerate the test centre's development to best of class, and provide a broader view of the emerging industry on a wider geographical scale. As well, an international network of test centres, called the International Wave and Tidal Energy Research Sites (WaTERS), has been established to connect test centres in order to support the development of multidisciplinary knowledge in the ocean energy sector. It meets several times per year, during industry conferences, so people from various test sites can share lessons learned.

Collaboration with province's universities, Dalhousie and Acadia University in particular, and the Nova Scotia Community College, would be very important to the work at the test centre and the educational institutions. The engagement of researchers, and projects and education programs that incorporate the use of the test centre would contribute to the development of a generation of workers and researchers focused on the issues around tidal energy and tidal stream research. It could also create a pipeline of research projects and technologies for testing at the centre.

Coordination with other organizations, such as the Acadia Tidal Energy Institute (ATEI), The Institute for Ocean Research Enterprise (IORE), OTCNS, Fishermen Scientists Research Society (FSRS), the Fundy Energy Research Network (FERN), and the Bay of Fundy Ecosystem Partnership (BoFEP) can be of mutual benefit. A regional association, consortium or partnership similar to the PRIMaRE in the UK, or NEMEDS in New England, could be formed that would include the small tidal test centre, the FORCE demonstration site, ATEI, COVE, NSCC, the Mi'kmaq Conservation Group, FERN, OERA, MRC, and host-community groups, like the Freeport Community Development Association (FCDA). Such a 'Fundy passages partnership,' connecting researchers, industry and community, could be a conduit for dialogue, a shared vision, and coordination of activities for a collaborative and sustainable development of tidal energy in Nova Scotia.

3.5.4 Funding

The sources of funding would depend on the focus of the small tidal test centre and its ownership, however the funding arrangements for COVE and FORCE could serve as models for funding the test centre. For those, government (federal, provincial, and/or municipal) funded the construction or lease-hold improvements of those facilities, and as well as supporting infrastructure, being public goods. Sources of start-up money for the test centre could include Natural Resources Canada (NRCan), the Atlantic Canada Opportunities Agency (ACOA), and various provincial funding sources. Information on government funding and financial supports in Canada and examples from abroad can be found in MacDougall (2016) and at https://bvgassociates.com/who-we-are/innovation-funding.

There could be industry contributions as well, from those companies whose priorities align with the purpose of the test centre. If the test centre is for tidal energy and ocean technology, and ocean research generally, there may be interest by ocean technology companies, Emera, and offshore oil and gas companies, and perhaps angel investors. The Industrial and Regional Benefits (IRB) program, as it relates to the Canadian shipbuilding project, may be a means of acquiring industry contributions. Customer preorders might also assist with start-up cash flow. There could also be in-kind contributions of such items as cables, buoys, and monitoring devices from technology companies or researchers.

Once operational, the test centre would likely need some ongoing federal and/or provincial support, though a portion of the operational costs would be covered by industry, through the sources of revenue noted in the profit model. While the test centre serves provincial objectives and benefits the social, economic, and environmental "greater good," care should be taken to provide some level of ongoing financial support for its operations, lest it become overly bottom-line focused for survival. A five- or ten-year commitment of government support, direct or indirect (e.g. through a program like MARINet2), might be warranted. The test centre would, in turn, be able to help with the achievement of those governments' renewable energy, carbon emission reduction, and economic development goals and ocean research priorities.

The development of many of the existing test centres studied in the industry scan has been driven by political will and government support, in recognition of the potential of marine renewable energy to address issues around sustainable energy and economic development. As such, almost all of the centres are dependent on government support in some way, whether directly, in the form of funding for their infrastructure and operations or indirectly, through developers accessing centres by grant and innovation funding for testing. An exception is EMEC, which, after being developed and supported for the first five years by government support, no longer receives direct public funding and operates as an independent, not-for-profit organization.

3.6 Performance metrics

Assessing the performance of the test centre would ultimately depend on its selected goals and core activities. Based on those provided in Section 3.2, performance metrics might include the number per year of the following: technologies tested, origin, companies participating, projects in waiting, student engagements (visits, projects, interns), community engagements, research projects conducted and publications therefrom, citations in the academic literature and conference papers, academic institutions participating, standards developed, certifications awarded, hours of turbine testing, visits to the centre by the general public and school groups, fees earned, or research grants received. Building on the notion that collaborations are important for success of not only the test centre but of other organizations in the ecosystem as well, the number and nature of partnerships and alliances would also be relevant performance metrics.

3.7 Risks

Many of the uncertainties surrounding the test centre are similar to those of tidal energy development generally. They fall into the categories of technology, supply chain, construction, operator, political/regulatory, social, market, and environmental. They are covered in numerous other reports, including in MacDougall (2013), in the Community and Business Toolkit for Tidal Energy Development, so will not will not be repeated here.

In terms of the business case for the test centre, perhaps the greatest uncertainty is around the ultimate demand for the service. The tidal energy industry is small globally, and very small regionally. If the test centre were built to fill the gap, it is uncertain how many developers, often cash-strapped, would undertake the expense to test in Nova Scotia. It is also difficult to determine whether local designs would emerge and be tested.

Broadening the market of the test centre to serve ocean technology and general ocean research helps the business case. The facilities at COVE will overlap somewhat with the services offered by an in-stream test centre, but the Ocean Supercluster will likely create new demand for the services of both, though how it will be distributed is uncertain.

A way to help mitigate the uncertainty of low demand is to build a realistic roster of early projects and scenarios for growth based on market research. Good upfront work could be used to layout the projects and have those projects inform the test centre design. To get enthusiasm in the marketplace, there could be a few experiments undertaken to draw attention to the site, build the market and social licence, and perhaps attract incremental financing. Depending on the location, attention could also be drawn to past successful experiments, showcasing the experience, knowledge gained, and community involvement that could be leveraged to the benefit of the small tidal test centre.

The activities at FORCE are potentially synergistic but could be made competitive. Although competition can drive innovation, the tidal energy industry is small, and dividing it between two test centres would make it difficult for either to thrive. On the other hand, cooperation and coordination of activities and messaging would likely benefit both as well as tidal energy research and development, locally and globally.

4 Economic and other benefits

Many of the economic and other benefits of a test centre established in a mid-range tidal stream in Nova Scotia have been noted throughout this report. In this section, further potential benefits will be described.

4.1 Benefits to Nova Scotia

Innovation has the effect of increasing economic growth and quality of life for society. The Value Proposition for Tidal Energy Development in Nova Scotia, Atlantic Canada and Canada (Gardner et al 2015) estimated an average annual increase in gross domestic product of $68 million and an average annual addition of 877 jobs could be generated in Nova Scotia with the commercial development of 300 MW of tidal energy. While impressive economic activity has already been generated by the activities at FORCE and with Cape Sharp Tidal, the much larger amount has been delayed as Nova Scotia awaits the construction and deployment of other devices at FORCE. The delays have been for a variety of reasons; it is a very challenging undertaking.

For the large-scale tidal devices being developed for use at FORCE, without small and mid-range testing facilities here, companies have had to do years of scale development and testing outside Nova Scotia. Only once their technologies are ready for a 5 m/s tidal stream, can they deploy at FORCE. A small tidal test centre could attract companies to Nova Scotia sooner, allowing the industry and the supply chain to learn, build capacity, and innovate sooner, as well. The test centre would enable projects that require less capital to operate, which may result in more of them. Also, community-scale projects have direct applicability to many coastal communities throughout Canada. With a focus on integrating tidal energy with sustainable communities, the small tidal test centre would have the potential to bring global focus to Nova Scotia, including development of world-class expertise and technologies. The test centre could also present more opportunities for local companies to work with researchers (MaREI serves as an example) or to partner with international companies, taking advantage of synergies, and for European companies to set up operations locally. The spin-off benefits of these earlier stages would be captured locally.

4.2 Benefits to host, First Nation, and remote communities

A small tidal test centre in an easily accessible environment could provide a platform for hands-on work experience that could bring together talented business people, academics, and students working in ocean-related fields – engineering, environmental science, and other areas. While direct, full-time employment at a small tidal test centre would be limited, there would be bursts of activity when testing is underway, generating a ripple effect of indirect and induced employment through the host community and surrounding area.

A small tidal test centre would not only help advance the development of community-scale technologies, but help foster understanding and greater involvement of members from the local community in the development of tidal energy. It could help rural, coastal communities diversify industrially, and introduce new career paths to the communities' youth.

As noted in test centre components (Section 3.4.1), low-cost accommodations would enable use of the centre, collaboration, and development of relationships with the community, including sharing information on a day-to-day basis, through informal community interactions. The solutions to providing low-cost accommodations would likely be unique to each community, and test centre developers should work with the local community. Potential local benefits include creation of jobs to manage the accommodations, including bookings, cleaning, and meal preparation. They would also provide living space to seasonal workers such as lobster banders, who require the same facilities for the first months of lobster season, which would typically correspond with a low period for oceanographic work.

With the work done at the small tidal test centre, community-scale energy solutions could become accessible to several remote coastal communities, enabling them to lessen their reliance on fossil fuels. This could be of particular interest to remote indigenous communities interested in evaluating hydrokinetic energy (tide or river) in their community energy plans. Access to a small tidal test centre could present opportunities for indigenous communities to evaluate technologies and investigate environmental concerns, such as device interactions with marine life. Working together could help inform decisions on community- and utility-scale projects and present employment, internship, investment, and partnership opportunities.

One of the challenges for the development of tidal energy in remote communities is the proponents do not have partners who can help make the whole system, such as a microgrid. There are companies and researchers in Nova Scotia and throughout Canada who focus on the onshore electrical components of remote, off-grid power systems, and communities located on weak distribution grids. The ability to demonstrate an entire system that would work in a remote community could contribute to the effort to power remote communities with in-stream tidal energy. Some of this work has been done at CHTTC but it has not been done in a tidal environment, at least in Canada. CHTTC has expressed interest in collaborating on next steps for this work in Nova Scotia, including assisting with the development of a small tidal test centre. The inclusion of energy storage and controls could bring broader local benefits by involving companies that do not have the expertise or objective to work on the wet side of a tidal site. Rather than a tidal turbine developer looking for international partners, there could be a team developed at the small tidal test centre; partners that could, in turn, export a turnkey remote-community solution.

4.3 Benefits to research and education

For research and education in Nova Scotia, there is good infrastructure for utility-scale tidal demonstration (cable and grid connection, a well-characterized and permitted site, political support) but this is not so for lower TRLs and small scale tidal. An accessible, small tidal test centre, developed to meet the needs identified in the study, could provide the opportunity for more academic and student involvement in tidal energy developments. Students from a range of academic programs could gain experience, do research, and contribute to the development of the tidal energy industry and community- and utility-scale projects. It would increase opportunities for the research community and start-up companies to test a variety of technologies. A smaller, more accessible test site can also feed information into the K-12 school system, so they can include it in their renewable energy curriculum.

An accessible tidal test centre in a clear, moderate tidal stream would provide new opportunities for research and development, including:

- Monitoring marine life (fish, marine mammals, plankton, and birds) interactions, which is needed to reduce uncertainty. This includes development and use of effective acoustic and optical systems, where data gathered could be analyzed for an extended period and expertise and understanding of marine life interactions could be developed.
- Testing and demonstration of community-scale tidal power systems (turbines, moorings, cables, monitoring systems, energy storage, etc.) with community involvement.
- Testing and/or wet commissioning of turbines at a 'nursery' site in the Bay of Fundy, before a significant deployment at FORCE or elsewhere in the region.
- Development of assets and methods for marine operations in high flow.
- Engineering research - testing theories and models regarding:
    - Effects of turbulence on turbine performance;
    - Corrosion and bio-fouling;
    - Device-water interactions, such as blade deflection, fatigue;
    - Engineering model validation.
- Testing and development of technology, relating to:
    - Ocean acoustics, acoustic releases, recovery equipment, mooring and deployment, wave break designs systems;
    - Incremental improvements to tidal power systems deployed for commercial projects elsewhere in Nova Scotia;
    - Testing new aspects of turbine technology specifically designed for high currents and tidal range;
    - Mooring and foundation assessment and validation.

4.4 Other benefits

Included in the location alternatives presented in this study are the areas where the Nova Scotia Community Feed-in Tariffs (COMFIT) were awarded in 2012. These areas have been extensively studied, the communities consulted and involved, and successful research and development has been conducted, including: advancement of tools and methods for physical site assessment and marine life monitoring; development of high-flow marine operations capabilities; and testing most components of small-scale tidal power systems. Much of this work has been transferrable to successes in the Minas Passage, and services to other regions in Atlantic Canada. However, due to delays with investment and subsequent turbine installations, the opportunity for Nova Scotia, the host and First Nations communities, and supply chain companies to learn, develop capacity, and innovate in the tidal energy sector has been diminished. The location of the test centre in any one or several of these areas would renew the prospects once offered by the COMFIT program and build on the work done there to date.

Once berth-holders have deployed devices in the FORCE demonstration area, there may be less tolerance for risk in that MREA (crown lease area), in which case, research and development activities may be more safely done in other locations. A test centre in more moderate flows could serve this purpose and provide opportunity for testing of the technologies and how to deploy, operate, and recover them.

Canadians have been involved with the development of industry standards. The TC 114 Canadian subcommittee's work feeds into that of the international standards committee. To be able to test and develop standards in Nova Scotia would help ensure the technologies, approaches, and tools being developed here have international applicability. This, in turn, would help local business development.

Tidal energy research and technology development is underway in several parts of the world. Much of the world's commercial development will be in tidal flows in the 2 to 4 m/s range so a test site with these conditions could help the sector in Nova Scotia meet a global need and help the global industry move forward on its research and development tasks.

The Minas Passage is a fairly unique tidal resource. If, and when, the tidal energy conversion technology becomes commercially viable, the tidal energy development opportunity in the Minas Passage may be highly coveted. Should Nova Scotia wish to develop that resource, it would make sense for Nova Scotia companies and workers to develop the capacity, knowledge, skills, and technologies here, rather than buy these later. An accessible testing environment for earlier stages and smaller sizes would facilitate the development of innovative, valuable ideas, and new products and services that could be sold locally and around the globe.

5 Summary and conclusions

The objectives of this study, as set out at the beginning, were to:

1) Scan the global tidal energy industry for test centres and their offerings, the needs of technology developers and researchers, and identify gaps or unserved niches for small-scale tidal testing.
2) Assess whether these gaps could be filled in Nova Scotia and what advantages Nova Scotia would have.
3) Identify small tidal test center models, combining Nova Scotia's unique natural and human resources, that fill an unserved or under-served market gap. The model strived for should be feasible, be economically beneficial, support regional and international research and development activities, provide local research and business opportunities, and have a competitive advantage that will be sustainable as the industry develops in Nova Scotia and abroad.
4) Describe the economic and other benefits that would accrue to Nova Scotian people, researchers, and organizations if a small tidal test centre were to be built.

An industry scan of test centres revealed a number of test sites around the world, ranging from shallow and slow tidal speeds, in ocean water and river currents, to very fast and deep tidal streams. A series of interviews with tidal energy technology developers and researchers revealed a need for a test centre in an *accessible* tidal stream in the range of 2 to 4 m/s and 10 to 30 m depth with permits and consents for testing. In this category, there appear to be no tidal test centres in existence today. In Canada and along the eastern seaboard, there are presently no test centres in natural tidal streams.

Looking at Nova Scotia's tidal and human resources, it is evident there would be an ability to serve this market with sufficient uniqueness to have a sustainable competitive advantage if an investment in a small test centre were made. The tidal industry is young and unpredictable, so providing services for other ocean technology testing and ocean research would help broaden the test centre's market and help sustain it. This study provides alternatives regarding areas in the province where a test centre could be located; components and infrastructure that could be part of the test centre; forms of organization, ownership, governance, and collaborations; risks and performance metrics; and funding sources. A framework for considering these components, called the Diamond-E framework, has been provided and can serve as a guide for choosing among the alternatives.

The potential benefits to Nova Scotia include economic development, including for host, First Nation, and remote communities; opportunities for earlier-stage development of tidal technology in the region; increased opportunities for leading-edge research and education and for development of the local tidal energy industry. The potential for a net benefit to Nova Scotia exists.

5.1 Key decision criteria

In making the decision to establish a small tidal test centre, there are several key decision criteria (KDC) that should be considered. KDCs are the essential criteria to be met to support a decision to invest. Six have been identified:

1) Is there sufficient demand for the test centre and its services to sustain it?
2) Will the fees and government funding the test centre can generate be sufficient for it to achieve its objectives?
3) Can host community, fisher, and First Nation acceptance be achieved and maintained for the site?
4) Can the site be permitted and consented for testing of tidal energy and other ocean technologies?
5) Can there be coordination or cooperation with FORCE so tidal energy industry progress continues?

5.2 Further considerations

The establishment of a small tidal test centre in Nova Scotia could be of benefit to Nova Scotia, its communities, researchers and the tidal energy industry. However, undertaking such an investment is not without risk. This study should not be considered definitive. If a test centre investment were to be undertaken, attention should be given to the following:

- Success of a small tidal test centre would be highly dependent on government support in terms of permitting, consents, capital and ongoing funding.
- Though potential users of the test centre were contacted for information gathering purposes, this study does not constitute a market study. Further market research could help better gauge the demand for the test centre's services and determine if sufficient demand exists now and into the future.
- Numerous stakeholders were asked to provide input to this study, however, this should not be considered a substitute for a stakeholder consultation. Should the decision to build a small tidal test centre be considered, full community, First Nations, and other stakeholder consultations would need to be undertaken.

This study revealed a gap in the global test centre market that presents an opportunity to Nova Scotia. It also identified the resources and capabilities resident in the province that could form a sustainable competitive advantage. Potential benefits, costs and risks of establishing a small tidal energy test centre have been summarized, and alternative forms – physical and organizational - have been provided for consideration.

Should the opportunity to invest in a small tidal test centre not be taken up in the near term, steps could be taken that would still advance small tidal development in the interim. These could include:

- Several moorings that could be time-shared and utilized for deployments. The moorings could be established as part of a study on technologies including environmental effects.
- Effective environmental monitoring in the presence of turbines, including support for time, expenses, and equipment needed for focused research on near-field interactions and development/validation of tools/methods for marine life detection and assessment of collision, evasion, and avoidance.
- Functional workspace and infrastructure to support assembly, storage, marine operations, and accessibility (specific needs are location dependent).

Funding directed to any or all of the above items would facilitate the advancement of a small tidal, with potential for future expansion into a test centre.

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Appendix 1: Gap analysis (abridged)[5]

1 Introduction

To determine whether a business case analysis of a Nova Scotian small tidal test centre should be undertaken, a global gap analysis was conducted. In a scan of the industry, information was collected on facilities and services available for small tidal testing around the world. The needs of the research community and technology developers for small tidal energy technology testing were then sought. Juxtaposing the results of the industry scan and needs helped identify unserved or under-served needs. This revealed an unfilled gap in the competitive landscape. The robustness of the gap and the competitive advantages Nova Scotia would have in this gap were then assessed.

2 Global test centre scan

A desktop study was undertaken to identify test sites that focus on tidal energy device testing. This involved an initial scan of ocean energy test sites globally, both open-sea and land-based facilities, followed by a characterization of these sites in accordance with their service offering (see Table A1-2, at the end of the appendix). As the focus of this study is on the potential for an open sea small tidal test site in Nova Scotia, particular attention was paid to similar sites. This refined list is given as Table A1-1, below.

Table A1-1: Tidal test centres identified in the initial scan

	Test Centre / Site	Location	Operational Status
1A	EMEC (scale)	Shapinsay Sound, Orkney, Scotland	Operational
1B	EMEC Full-scale	Fall of Warness, Orkney, Scotland	Operational
2	QUB Portaferry	Strangford Lough, Northern Ireland	Operational
3	SEENEOH	Bordeaux, France	Operational
4A	DMEC Marsdiep	Marsdiep , Netherlands	Operational
4B	DMEC Den Oever	Den Oever, Netherlands	Operational
5	TTC-GD	Netherlands	Operational
6	Perpetuus Tidal Energy Centre	Isle of Wight, UK	In development
7	Smartbay (Wave and instrumentation)	Galway, Ireland	Operational
8	MaREI (LiR NOTF Flume)	Cork, Ireland	Operational
9	Bourne Tidal Test Site (BTTS)	Cape Cod Canal, Massachusetts, US	Operational
10	Canadian Hydrokinetic Turbine Test Centre (CHTTC)	Seven Sister Falls, Manitoba (Winnipeg River), Canada	Operational
11	Fundy Ocean Research Centre for Energy (FORCE)	Black Rock, Colchester Co., Nova Scotia (Minas Passage), Canada	Operational
12	Southeast National Marine Renewable Energy Centre (SNMREC)	Florida Strait, near Ft. Lauderdale, Florida, US	Operational
13	Tanana River Test Site, Northwest National Marine Renewable Energy Center (NNMREC)	Nenana, Alaska, United States	Operational
14	*Zhairuoshan Tidal Energy Power Demonstration Station	Zhoushan, Zhejiang Province, China	Operational
15	*REIDS Sentosa Tidal Test Bed (Tropical Marine Energy Centre (TMEC))	Sentosa Island, Singapore	In development
16	*Marine Energy Research and Innovation Centre (MERIC)	Chile	Operational

* Denotes test centres where insufficient information was available to complete a profile.

[5] The full gap analysis report can be found on the OERA website at www.oera.ca.

A profile was then compiled for each site that was deemed to be of significant interest, detailing information on location, site characteristics, available instrumentation and other facilities, structure and governance, services offered, and history of device testing (see Figure A1-2, at the end of the appendix). Knowledge gaps for each site of interest were identified prior to interviews being carried out, where possible, to gain a deeper insight into the operational capacity of the site. The interview process sought to fill these knowledge gaps while assessing, from an existing centre's perspective, the fundamental services that should be offered to developers and best practice in site operation, developed from lessons learned.

A geographical representation of the sites locations is shown in Figure A1-1, below.

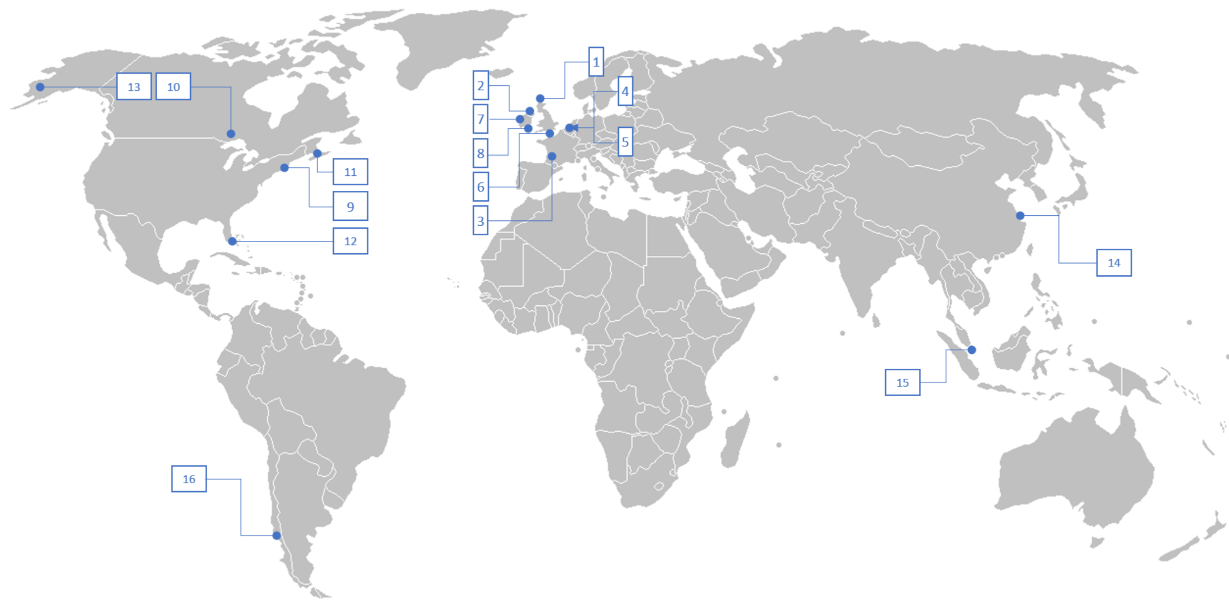

Figure A1-1: Geographical locations of open-water test sites of interest

2.1 Knowledge gaps

With a view to further developing knowledge of these centres, contact was initiated in order to arrange an interview to discuss site characteristics and operational methods. Of the 18 centres listed, 9 test centre-related interviews were conducted.

In arranging interviews, effort was made to get a general overview of the services offered by the various existing facilities as well as some insights from other facilities with unique perspectives. The responses highlighted what are considered fundamental requirements from an infrastructure and management perspective, as well as a number of other service offerings that the centres provide, either as a result of developer requests or an identified market need. Key characteristics, the water depth and maximum flow of each test site, where information is available, are shown in Figure A1-2.

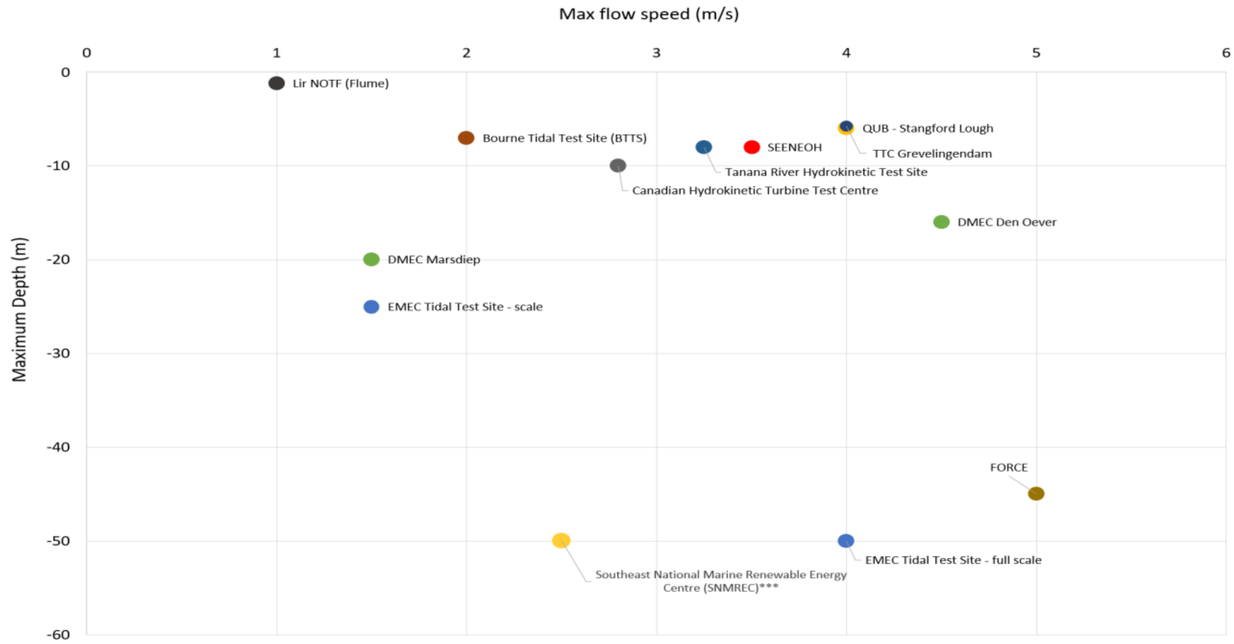

Figure A1-2 Test site characterization – maximum water depth and flow speed (maximum values correspond to a typical spring tide)

2.2 Test centre summary

The test sites can be categorized into 3 distinct groups, as follows:

A. Well-established full-scale sites (EMEC and FORCE) for TRL 9 technology;

B. Scale sites, suitable for TRL's between 4 and 9 (EMEC Sharpinsay Sound, Perpetuus, BTTS, DMEC Marsdiep, and SEENEOH);

C. Smaller scale sites that are limited to TRL 4 (flumes, LiR NOTF), river-based sites (CHTTC), and sluice gates (DMEC Den Oever).

The resources/facilities that are available at each site are reflective of the scale at which they operate but it is clear that most, if not all, have some key fundamental requirements and operating principles. Interview responses highlighted that the following infrastructure, facilities and services were all required in a good test centre:

Fundamental Infrastructure

- Flexible cable and berth layout
- Detailed resource characterization, including flow speeds, wave, climate, depth, bathymetry, and weather, at a minimum (historical)
- Data monitoring and logging
- Consented site
- Dump load
- Laydown area and office/workshop/storage facilities
- A suitable supply chain
- Experienced support staff

Additional Infrastructure

- Grid connection
- Real time data acquisition system
- Access to vessels
- Hydrography & sonar
- Marine life monitoring
- Access to wider supports through network and academic expertise.

Other support and services offered, along with the infrastructure outlined above, include marine operations, hydrodynamic and engineering support, safety, test procedures and processes, instrumentation, data acquisition and analysis, as well as funding application assistance.

The test centres also provide MRE developers and other clients with the facilities to carry out a varying range of tests on other subsystems, components, and processes, including but not limited to: deployment and retrieval methodology, O&M optimization, moorings and connectors, ROVs, sensors, and storage systems, along with the ability to test materials for corrosion and biofouling in the marine environment.

Accessing the test centres can be done in a number of ways. The well-established, full-scale sites typically charge annual, monthly or defined period berth fees for devices. This is often commercially sensitive information but is a basic offering with a set cost, with any additional requirements charged as extra. Small tidal test sites operate with differing fee structures, based on staff costs plus overheads and generally have shorter test durations. Access is also granted to developers through specific funded programmes, like MARINET2 and FORESEA in Europe, but these tests tend to be for short durations (approx. 2 weeks) and cater to devices at low-to-mid TRLs. The client must provide their own insurance (including asset recovery, if applicable) and the centres define safety procedures and processes and oversee marine operations.

To date, tidal energy test centres have not been viewed as commercially sustainable, particularly those focussed on small technology testing. Political will and academic focus in the area must drive their initial development but in locations where a good tidal resource exists and a strong pipeline of low-TRL technology awaits testing, centres have gradually moved towards a more commercial model. Direct government support is required, particularly in the initial period of centre operation, while indirect support (grants and other innovation supports for developers) is an essential revenue stream.

Utilization of the examined sites has been varied, with some of the more established sites having a regular pipeline of developers using the facilities. The test duration varies, depending on development stage. Generally, a small, full-scale device that is testing operation will require longer test periods (greater than 1.5 years). A scaled device (prototype) that is seen as a stepping stone to a larger, full-scale device will seek to test for between 6 months to 1 year. Other developers may just require a number of weeks or months for any given test phase. This is subjective and based on specific requirements. Key to maintaining a high utilization rate for the centres is engagement with local universities and developers to gain an understanding of the pipeline for future testing. It can be cost prohibitive for developers to travel long distances for testing, especially in the case of small or low-TRL devices. The primary driver for this, however, is the package of market supports in the region. There is also a need for the centres' services and offerings to constantly evolve, based on developer needs and best practices.

There is a general consensus amongst test site operators that a more integrated approach between the test phases would be very beneficial to the industry moving forward. Several of those interviewed have even expressed a wish to collaborate on a future test centre in Nova Scotia. Closer involvement in the transition from tank/flume to small or scale testing to full-scale testing is required to avoid repeating unnecessary mistakes by using outputs from one test stage as inputs to the next, building on lessons learned. In parallel with this approach, focus should also be placed on energy storage solutions and the facilitation of their testing at the sites, in order to enhance the technology offering as a complete off-grid solution for local communities.

Some of the key recommendations for a small test centre are focused around a similar approach: to provide somewhat generic and flexible infrastructure for developers, as a base offering, with the experience, skills and capabilities on hand to further develop this to a bespoke solution that suits the developer's needs. Close attention should be paid to university output, early-stage developer activity in the region, and market supports. The key requirements of a centre are to fill a developer's knowledge gaps and ensure a safe environment in which to operate, particularly for low-TRL projects, whose proponents often lack experience testing at sea.

3 Developer and Researcher Needs

In order to evaluate the need for, and potential use of, a small tidal test centre in Nova Scotia, over 20 interviews were held with individuals from the tidal energy industry, ocean technology industry, academia, the manufacturing and marine operations supply-chain, and regulators.

There was considerable agreement in the responses: an ocean research and technology development centre in Nova Scotia that specializes in small- (or community-) scale tidal energy projects is needed. There was also considerable interest in it being accessible for a broader range of oceanographic and energy-related research and development. All respondents answered that a small tidal test centre would be beneficial, if properly implemented.

The goals of the interviews were to identify whether there is a need for a small test centre in Nova Scotia and what specific site and test centre characteristics technology developers and researchers need. The following list is a summary of the needed features and characteristics:

1. Accessibility, in many forms (details to follow in Section 3.1);
2. Nearby infrastructure and personnel to enable cost-effective research and development;
3. Diverse deployment locations (spatial variability in flow speeds, depth, seabed conditions, etc.);
4. A well-characterised site with high-quality data and modelling;
5. Operating turbines to investigate engineering and scientific uncertainties, including use of a site/centre with the ability to accommodate a small array with a variety of tidal turbines;
6. Ability to conduct effective environmental monitoring (visibility is key, including water clarity and proximity to shore);
7. Meaningful and purposeful involvement of local community members, fishers, and First Nations people;
8. Flexibility and a client-focussed approach;
9. A pathway to commercialization that allows development from low-TRL to TRL 9.

3.1 Accessibility

There is fundamental need for the test centre to be easily accessible, in many ways, including:

- Ability to obtain, through the test centre, all required permissions/permits/consents with regulators, community, fishers, First Nations, etc. This will accelerate R&D and reduce costs for developers to use the site.
- Physical access, including test locations close to shore; launch ramp, harbour, and wharf that are accessible through the tidal cycle; and hoists, etc., for loading and unloading equipment.

- Availability of high quality professionals at the test centre, to assist, as needed, with developing and implementing test procedures, establishing collaborative relationships with academics and local supply-chain companies, performing marine operations, and safely handling power to shore, etc.
- Ability to obtain existing high-quality site information including flows, water levels, depths, seabed conditions, wind, waves, marine life, etc.
- Ability for groups from local communities and First Nations to access the site and non-proprietary data, for research, technology development, and training.

It was also noted that it would be highly beneficial if permitting and consenting processes were streamlined to help facilitate gaining access to the water (lowering the activation energy to do testing) but also that test centre staff (and regulators) would supervise activities to ensure a high level of professionalism and minimize risks to human health, safety, and the environment. The permits need to be flexible – with environmental checks and balances for a variety of technologies, and matching of regulatory requirements with project size and technology – while properly protecting the environment and maintaining public trust.

It is also important to facilitate collaboration and access for stakeholders in the region, rather than allowing a single developer (or small group of developers) to "lock down the test centre." In general, a test centre that is welcoming to new opportunities and does not require developers to start from scratch on gaining permits and community acceptance to conduct a test is viewed as beneficial. Without a test centre, technology developers feel they have to do everything, while wanting only to focus on testing their technology. This forces people to work in areas outside of their expertise, rather than focusing on their core competency. Department of Fisheries and Oceans and test centre staff could work together to answer questions and determine how to streamline permitting and consenting processes and establish best practices. This could serve to maximize proponent efficiency in getting devices in and out of the water.

The test centre needs to have good visibility from shore and quick ways to enter and exit the water, including nearby harbours and boat launches that are accessible throughout (or at least the majority of) the tidal cycle. In addition to reducing the cost of marine operations, physical site accessibility is important for marine safety by allowing vessels easy access to protected harbors, as well as the ability for vessels to respond to marine emergencies. Close proximity to a Canadian Coast Guard base was identified as a significant asset.

Essentially, users of the test centre want to be able to "truck up and do our work," with the test centre providing significant value in accessibility and marine safety, allowing groups of high quality personnel to collaborate, so users of the test centre (technology developers and researchers) are able to focus on their specific tasks and objectives.

3.2 Community and First Nations

The test centre needs to have a commitment to long-term, meaningful, and purposeful involvement with local communities, fishers, and First Nations. It also needs to implement proper and effective environmental monitoring, with public access to information. The test centre has the potential to strengthen the foundations and resiliency of rural communities in numerous domains: economic, political, environmental, and social. Key to engaging local stakeholders and communities would be a model of information-sharing and governance that values respect, transparency, and accountability. To this end, a small tidal test centre would do well to have a model of governance and mandate devised with substantial community participation and decision-making, rather than simply be driven by industry priorities.

There is an opportunity for a Nova Scotian small tidal test centre to develop and demonstrate a globally applicable model for a community tidal project, including providing a training centre for future sites and developments in the Canadian north and beyond. To accomplish this, a test centre should prioritize the identification, utilization, and development of community assets (personnel and infrastructure).

The test centre could provide a gateway for First Nations involvement, including bilateral knowledge-sharing and collaboration. It could help researchers and practitioners in the natural, applied, and social sciences to better understand First Nations' priorities and concerns and find ways forward together.

There also would be a need to focus on economic benefits in the host communities, beyond short-term jobs. Long-term benefits in rural Nova Scotia would be needed to offset negative impacts, economic or otherwise. This aligns with a need for local expertise and highly qualified personnel (marine operations professionals, technicians, etc.) at, or readily accessible to, the test centre. Local people with directly related capabilities could also serve as a catalyst for collaboration and driving down costs with mechanisms in place to transfer knowledge, to the benefit of all. Opportunities for experienced students and interns to conduct research and further their training in tidal energy and ocean technology would be required. Not only could this attract young people interested in ocean technology/science to the region, it could provide a skilled labour pool to support commercialization.

3.3 Site Characteristics

In terms of site characteristics, a test centre with good spatial variation in flow speeds, depths, and seabed conditions is preferred to allow for flexibility in test conditions to accommodate a range of designs and approaches. In general, a deep, high-flow site would be too advanced for most small-technology developers and supply chain companies to do testing.

The test site needs to be well characterized and with good access to the information. Spatial variation may be achievable at one location or could include use of more than one tidal channel, as is done at EMEC. Collectively, the site(s) needs to have enough space to accommodate small arrays of turbines without being overly intrusive on other water uses.

Spatial variability in flow speeds would preferably include ability to test in flows up to approximately 8 knots (high-flow) and in less challenging environments in the rage of 4 to 6 knots (medium-flow). This would allow technologies that are targeted for high-flow environments to progress through the TRL scale and would also facilitate testing and demonstration of technologies that are targeted for medium-flow environments. Flow directionality is also very important. The flow should reverse on the flood to ebb cycle close to 180 degrees, with between 160 and 200 degrees preferred.

The minimum depth requirement is approximately 5 m, with many technologies preferring approximately 10 to 30 m, partly because shallow depths allow for shorter mooring lines. Berth sites with deeper waters (approximately 30 to 40 m) are needed for testing bottom-mounted turbines to maintain navigational clearances. The seabed slope should be less than approximately 5 degrees, with less than 3 degrees preferred. A varying range of bottom structure (e.g. mud, gravel, rock, sand) would allow testing on different types of mooring systems, such as concrete, and sea anchors, with rope, chains, and cables, etc.

There is need for locations that are dive accessible. Ballpark requirements for this are up to about 30 m depth, with good visibility, a 15-minute (minimum) dive window, and less than approximately 1 knot of flow. Similar conditions to those required for dive accessibility also facilitate testing and use of ROVs, and overall, result in the ability to conduct cost-effective marine operations that are fundamental to the sustainability of a test centre.

3.4 Infrastructure

In general, potential users felt the more infrastructure a testing centre has, the better. However, the infrastructure should be directly applicable to testing tidal turbines but not be too technology-specific. A generic option could be provided, as well as the ability to do specific testing, because many developers want to test and demonstrate integrated solutions. When considering infrastructure, it is important to consider the ability to move forward with a “bare bones” approach that facilitates testing, while leveraging existing local assets and capabilities. This approach allows for the staged and organic growth of a cost-effective test centre.

Infrastructure requirements include the marine assets noted previously for site accessibility (harbour, boat launch, vessels, etc.). Highly capable local vessels and operators are essential, including access to fast, maneuverable vessels, Cape Islander-style vessels, properly equipped for marine operations, and barges that are suitable for heavier lifting. As well, a secure location for office, workshop, and storage space, common marine tools and supplies, high-speed Internet, a file server for onsite data storage/backup, and a freshwater rinse area/basin is needed. Lodging, fuel, and food should also be available at, or close to, the test centre.

Instrumentation is required to measure forces exerted on the equipment tested and the performance of turbines. Operating turbines are required to investigate marine life avoidance and potential collisions, and instrumentation to evaluate a range environmental impacts is essential. The split of this infrastructure between the test centre and users would need to be determined, but as with most infrastructure, the more the test centre can provide, the better. A bottom-mounted, shore-cabled, instrument pod at a dive accessible site in close proximity to turbines would be useful for both environmental and physical monitoring.

A power cable to shore is needed but a grid connection is not required. However, the ability to flow power to the turbine would be beneficial if needed for a kick-start. This could be achieved by grid connection or a separate power source on shore. Primarily, a power management system is required onshore, designed to take power from the turbine in a safe way, while monitoring the performance of the turbine, and someone local who is trained in the use of the system. Power coming to shore from a tidal turbine can enable significant research in power management, including energy storage, off-grid systems, and connections to distribution systems. Battery storage could be used to help resolve grid-connection issues by providing good quality power.

A site/centre with the ability to accommodate a range of tidal turbines and with enough space to accommodate testing of a small array is preferred. Multi-use moorings would be beneficial for accommodating a range of floating tidal power systems and monitoring platforms, as well as readily available moorings in a sheltered location for temporary parking purposes.

3.5 Marine Life

It was noted by one respondent that, as a result of significant research (and funding) over the last 5 to 10 years, we now have very good understanding of the physical resource and the next step should be to take the same approach at the provincial and federal level to understand biological involvement. A site with high abundance and variety of marine life would support the required research but it is important to evaluate locations considering a balance between risk (including ability to monitor and mitigate) and abundance of marine life. Reliable information is required on marine mammal behaviors around a range of turbines that vary in noise levels, type, and scale. Good water clarity and visibility from shore are required to correlate/validate acoustic data.

A benefit of working in the presence of marine life is it engenders the design of low-impact technologies. Technologies that embrace this challenge are more likely to gain acceptance. Therefore, a small tidal test site should be located where effective monitoring of marine life is achievable with existing technologies; new monitoring devices can be tested cost-effectively to determine what works, what does not, and where improvements can be had; and where data can be collected for processing and analysis. The industry and regulators need to understand how marine life is interacting with tidal power systems - the turbines, moorings, power cables, etc. - and the potential consequences. Answers to such environmental questions are needed to reduce uncertainty before larger projects can advance.

4 Gap Identification

There are gaps in the offerings of tidal test centres around the world. Figure A1-2 is shown again in Figure A1-3, with the needed range of depths and flow speeds, noted by developers, superimposed as a shaded box. This is shown within a larger box showing a range of speeds and depths suitable for small tidal testing.

As can be seen in Figure 4, there are no test centres in the region with the intermediate to high flow speeds (2-4 m/s) and intermediate depths (10-30 m). The CHTTC river current centre lies on the boundary of the region. This indicates, in terms of flow speed and depth, there exists a gap in test centre offerings.

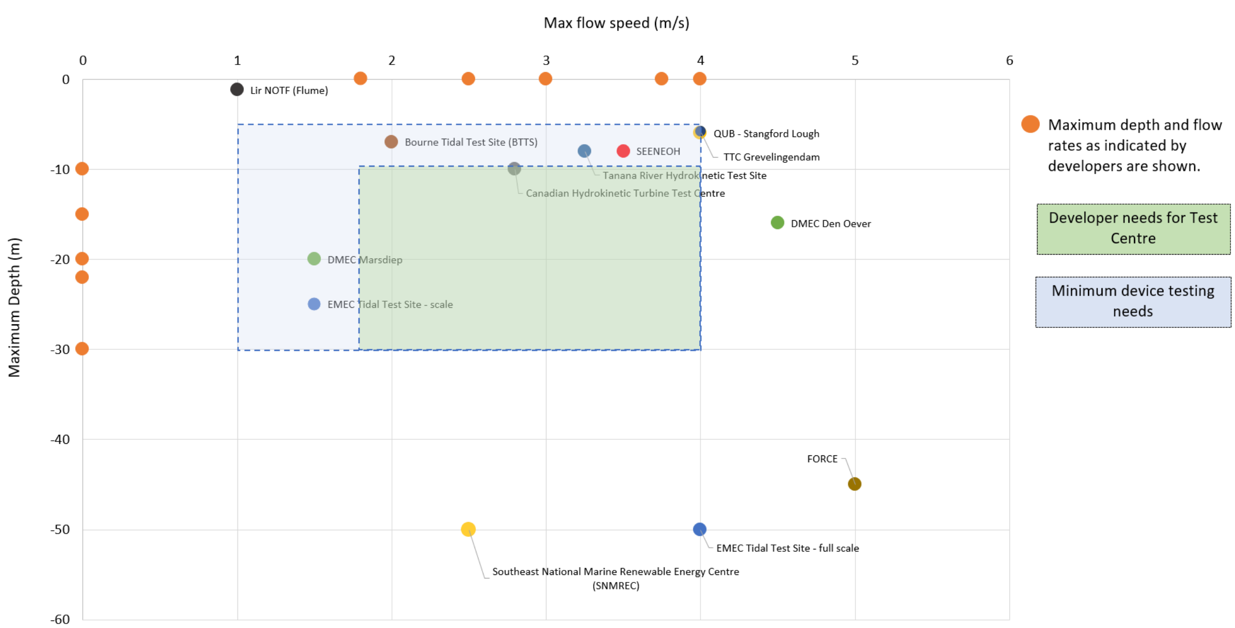

Figure A1-3: Test site characterization (depth and flow speed) with developers' and researchers' needs

In North America, there are only four relevant test centres for comparison, though two are river current (CHTTC and Tanana River). The third test centre is the new Bourne Tidal Test Site, in the Cape Cod Canal, which is limited to 3 m diameter mounted devices and no floating devices. The fourth centre is in the Florida Strait (SNMREC), which is 12 nautical miles offshore and in deep water (>200m); it is largely being used for research into ocean-current energy. In Canada, there are no open-ocean, small tidal test centres. In Eastern Canada, there are no open-water, small tidal test centres, river, open-ocean, or otherwise.

5 Gap Analysis

There does appear to be a gap in the small tidal test centre marketplace. This section provides an analysis of the gap: whether there is a market niche that can be filled by a Nova Scotia test centre, robustness of the niche, the competitive advantages a Nova Scotian test centre would have, and the likely sustainability of that advantage.

5.1 Existence of a Niche

The scan of test centres show a concentration of test centres in Europe, some of which are well suited to small tidal testing. There does not seem to be a shortage of testing facilities and more are coming on line. A European small tidal technology developer would likely be able to find what is needed there, though not necessarily, as evidenced by interest in Nova Scotia being expressed by several companies currently.

There are far fewer test centres suitable for small tidal energy in North America and they are distributed far and wide across the continent. Those suitable for small tidal are located in Massachusetts (Cape Cod Canal), Florida (Florida Strait), Alaska (Tanana River), one in Manitoba (Winnipeg River at Seven Sisters). These sites present quite different characteristics that are particularly useful for certain requirements, such as controlled flow, easy access (Cape Cod), hydrokinetic run-of-river (Manitoba, Alaska), and cold-water conditions (Alaska). Only in Florida is the test centre in the open ocean, though it is in an ocean current site rather than a tidal stream site. Each site has a less-than-comprehensive package of features to offer someone looking to test small tidal technology in open-ocean conditions. There is no open-ocean small tidal test centre in Eastern Canada.

5.2 Nova Scotia’s Competitive Advantage

Nova Scotia has many advantages that can position a test centre well in the global marketplace. Nova Scotia has a maritime economy with a well-established supply chain for the fisheries, navy, commercial shipping, ship-building, and offshore oil and gas development. It has a vibrant ocean technology sector, which is particularly leading-edge in underwater sensor technologies. The province is home to nine universities. The thirteen campuses of Nova Scotia Community College provide programmes in trades and technology, including marine engineering and navigation, nautical training, and ocean resource management.

Nova Scotia’s most promising tidal streams (Petit, Grand, Minas Passages and Digby Gut) are among the most studied in the world. All sites have had an initial resource assessment completed, including flow measurements using ADCPs and numerical modeling of the tidal currents. Most of the sites have also had extensive field campaigns of multiple ADCP deployments, detailed surface flow field mapping, turbulence measurements, multi-beam bathymetry, seabed investigations (video and acoustic), and wave measurements. Most sites have had detailed site assessments completed, including high resolution numerical models, CFD models, turbine placement studies and power extraction impact analysis completed, and some level of environmental monitoring and assessment, with acoustic detection/tracking of fish and marine mammals, marine life observation, soundscape characterization, local knowledge gathering, and benthic surveys.

There are both new and established organizations that contribute to tidal energy research, development, demonstration and commercial development or work in related areas. They include: Acadia Centre for Estuarine Research (ACER), Acadia Tidal Energy Institute (ATEI), Bedford Institute of Oceanography (BIO), Centre for Ocean Ventures and Entrepreneurship (COVE), Dalhousie Ocean Acoustics Laboratory, Marine Renewables Canada (MRC), Ocean Frontier Institute (OFI), Offshore Energy Research Association (OERA), and Verschuren Centre for Sustainability in Energy and the Environment at Cape Breton University. These organizations work both independently and collaboratively with partners in Canada and internationally.

Coastal Nova Scotian communities have been engaged in tidal energy development initiatives for nearly a decade. Residents are familiar with the prospects and risks of tidal energy development. Government-initiated consultations have included: Strategic Environmental Assessments and updates for Cape Breton and Bay of Fundy; Mi'kmaq Ecological Knowledge Studies (upper bay and outer bay); Nova Scotia renewable energy strategy consultation; and MRE legislation consultation. Additional consultations were conducted by various project proponents around the FORCE and Digby County locations.

There has been support from all three levels of government for demonstration of technologies and development of tidal energy, including technology push, market pull, and enabling supports, such as feed-in tariffs, community feed-in tariffs, renewables targets, tidal energy legislation and regulations, and funding of FORCE, FAST, and other tidal energy research initiatives. Recently, the Canadian government legislated a price on carbon, to begin in 2018.

With ample alternative test centres in Europe and typical conditions of local government funding, there may be limited demand for a Nova Scotia test centre from European technology developers and researchers. An exception will be companies interested in entering the Canadian industry and North American market, those looking for very specific characteristics that are not available in Europe, or those looking to work specifically with Nova Scotia researchers or companies.

The sites in Nova Scotia have a comprehensive bundle of the desired characteristics, unlike any of the other sites in North America, in terms of flow speed, depth, and accessibility for instream, open-sea testing and year-around operation in well-characterized waters. Several sites fit within the criteria specified by small tidal technology developers. The characteristics of the sites in Nova Scotia's Areas of Marine Renewable Energy Priority (AMREP) are as follows:

> Cape Breton (Bra D'Or Lakes) has very low to low flow speeds – peak speeds of around 1 m/s for Barra Strait, 1.5 m/s for Seal Island Bridge, and 2.0 m/s for Carey Point. The water is shallow: 10 to 20 m. The flow is complex, with high cross-channel and vertical flow components. The Seal Island Bridge and Barra Strait locations both have a bridge across the passage and limited exposure to ocean waves. Carey Point is much more exposed to open-ocean conditions. The passages have reasonable accessibility from shore at all tides, and there is a low tidal range.
>
> Digby Gut has low flow speed – peak speeds of around 2 to 3 m/s (very localized) – with shallow to medium depth sites (~15-50m). The passage has relatively low levels of turbulence, due to the low flow speeds and is exposed to less wave activity than Grand and Petit Passage. The passage is accessible from shore at all tides, and is near (approximately 3 nm) the sheltered, fully-accessible Digby wharf, though there is no public boat launch in Digby that is accessible throughout the tidal cycle.
>
> Grand Passage offers moderate flow speed – peak speeds of up to 3 m/s – with both shallow sites (~10 to 15 m) and medium-depth sites (~30m). The passage has relatively high levels of

turbulence, due to the many bathymetric features, and the channel entrances are exposed to waves during storm conditions. The water is clear and allows access to divers and subsea video systems. The passage is easily accessible from shore at all tides, with harbours and boat launches located on both sides of the channel.

Petit Passage offers high flow speed – peak speeds of up to 4 to 5 m/s – with medium depth sites (~30-50m). The passage has relatively high levels of turbulence, due to the high flow speeds. Similar to Grand Passage, the channel entrances are exposed to waves during storm conditions, the water is clear, and the passage is easily accessible from shore at all tides.

Minas Passage has extreme flow speeds – peak speeds above 6 m/s (at locations outside of the FORCE site) – with shallow-to-deep sites (~15-100m). It is considerably larger than the other passages and has a wide range of conditions. The passage has high levels of turbulence, due to the high flow speeds and bathymetric features. Minas Passage also has an extreme tidal range, approximately 12 m. It is very sheltered and only has significant waves during strong winds. Shallower waters near shore have reduced flow speeds but still see high levels of turbulence and large variations in depth, due to the tidal range. The passage is not easily accessible, with the nearby wharves only accessible at high tide (approximately a 2-hour window). The Minas Passage is the only one in Nova Scotia with fully functional onshore infrastructure for transmission grid connection.

As a test-centre location, Nova Scotia is not perfect, of course. Infrastructure, marine assets, government policies regarding financial support and future commercial development, involvement of universities and community acceptance would need to be enhanced to compare favorably with jurisdictions hosting the European test centres. All the Nova Scotia candidate sites are in somewhat remote locations, though such is often the nature of harvestable tidal resources. None is more than a four-hour drive from a city, airport, and commercial sea port.

A comprehensive site could likewise be built elsewhere in North America. British Columbia, for instance, has suitable tidal streams, some of which have much faster flow speeds than the Minas Passage. However, a Nova Scotia test centre would likely have a competitive advantage over a BC centre for quite some time, given the experience and expertise with tidal energy development that is resident in Nova Scotia at this point in the industry's development. There is likely to be, in any case, a limited geographical radius from which a test centre will draw most of its clients and researchers, so even if a BC test centre were to be built, it would not likely reduce demand for the services of a Nova Scotia centre by much.

Small tidal technology research, development and demonstration may be a more practical approach to developing tidal conversion technologies and creating a tidal energy industry than utility-scale.[6] As well, it appears probable that tidal energy can be price-competitive in off-grid Arctic and developing country communities.[7] Accordingly, it may be reasonable to expect more small technology developers to enter the market than the relatively few large-scale technology developers that exist today.

Likewise, new test centres are coming online and it is likely more will be built in the next few years since the barriers to entry are not high, at least in the case of a government-owned or government-funded not-for-profits. This is creating a fragmented industry. Competing in a fragmented industry is challenging - it would be difficult to gain a dominant position in the global small tidal test centre market. However, Nova

[6] Carlson, J.T. (2017), Go Big or Go Away? An Investigation into the Potential for Small-scale Tidal Energy Development in Canada, and Factors that May Influence its Viability, Master's Thesis, Dalhousie University.
[7] Ibid.

Scotia and the Bay of Fundy already have brand recognition in the tidal energy industry, which will help a test centre located here gain traction in the international marketplace.

Some of the industry fragmentation is due to the limited geographic reach or geographic market segment of such a facility. It may not be practical for technology developers to travel far to test their devices when there is a test centre close to home. Many of the potential test-centre clients would be small- and medium-sized enterprises (SMEs), for whom the cost of travel to a Nova Scotia test centre may be prohibitive. Furthermore, funding programmes often require research, development and testing be done in the jurisdiction providing the funding (e.g. Wave Energy Scotland, FORESEA, MaRINET2),[8] though other, more flexible funding programmes help developers travel abroad to test their devices (e.g. Europe Union's Horizon 2020). It is possible SMEs would test lower-TRL devices at nearby test centres and then travel further afield to be closer to their market for the next stage.

Other potential test-centre clients would be larger companies testing small tidal devices or scale models of large devices, or wet testing their devices prior to mobilizing to more challenging environments. They may have the means and the motivation to travel to Nova Scotia to become familiar with, and learn from, the local industry.

Despite the fragmentation in the global industry, the regional nature of a small tidal test centre's market would make it easier for a Nova Scotia test centre to dominate in the Atlantic Canadian/Maritime/Eastern Canadian/Atlantic seaboard regional small tidal test centre market. At present, the few offerings in the region would be more complimentary (fresh water, warm salt water, canal, river current) than competitive. Combined, these test centres could serve as stepping stones in the path toward commercialization.

5.3 Sustainability of the Competitive Advantage

The experience and expertise resident in Nova Scotia, as a result of tidal energy research, development, deployments, and retrievals over the past ten years, has Nova Scotia well positioned to be competitive in the small tidal test centre market. As the global industry progresses, Nova Scotia's knowledge advantage will naturally diminish. Sustainability of its competitive advantage will come from several sources. The large-scale, commercial opportunities in the Bay of Fundy, assuming Nova Scotia continues to pursue them, will keep it ahead of many jurisdictions. In a symbiotic relationship, a small tidal test centre would help the development of the utility-scale tidal energy conversion industry, through R&D, testing, supply chain learning and capacity-building, marine life monitoring, and community acceptance, while the commercial site would help create the impetus for the test centre.

Sustainability of the test centre's competitive advantage would also come from its location. Depending on whether companies are testing scale models of utility-grade devices or small devices for community-scale applications, testing in the Nova Scotia would have certain advantages over other locations:

- For small and part-scale technologies, testing in Nova Scotia will serve as a natural launch point for entry into the North American market, both for large-scale development and small, for remote community electrification.
- Testing scale models in the Bay of Fundy would provide technology companies interested in utility-scale tidal the opportunity to get acquainted with the local waters, supply chain, government regulations, and communities.

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[8] This is one way the provincial or federal government could help create and sustain demand for a Nova Scotian or Canadian test centre.

- The Bay of Fundy has some of the highest-energy tidal streams in the world, and as such, development in the Minas Passage is considered one to reach for. It will take multiple generations of technologies to cost-effectively harness the tides. For many companies, a test centre could serve long-term growth objectives.
- The Bay of Fundy waters are relatively protected from onshore wind and waves, providing uniquely favorable conditions for marine operations.
- Subject to further environmental research, community consultations, and legislative priorities, the size of the AMREP may be sufficient to gain economies of scale that would make utility-scale tidal energy price-competitive with other renewables.
- The local utility, Nova Scotia Power, Inc., is amenable to tidal energy-generated electricity and its parent company, Emera, is engaged in the undertaking.
- Though there is presently no provincial intertie or Atlantic Link, there is a large demand for clean electricity in the nearby New England states.
- The federal income tax act allows for scientific research and experimental development (SR&ED) tax incentives and flow-through shares for renewable energy development, and the provincial tax system allows for a Community Economic Development Investment Fund tax credit (CEDIF) to facilitate raising local equity capital.
- Some of the passages are ecologically-rich tidal streams, with subsea visibility that enables effective monitoring systems and meaningful research on the effects of tidal energy development on marine life.

Sustainability of the test centre could be enhanced by adding technologies and services. They could include ocean technology and scientific research related to commercial fisheries (lobster, ground fish, herring, scallops, clams, mackerel, etc.), aquaculture, marine life, and general ocean health (e.g. participation in Gulf of Maine and Bay of Fundy ecosystem monitoring programs). The opportunity to provide training for specific marine operations and general marine safety for tidal energy and other industries could also be offered.

5.4 Opportunity for Nova Scotia

Having a local small tidal energy test centre could create further research and development opportunities. For ocean and tidal technologies, an accessible test centre could greatly facilitate research. The universities, community colleges in Nova Scotia and neighbouring provinces could advance their research of tidal streams, energy development, ocean technology, and protection of marine life. A test centre could be used for educational purposes for students from grade school through to doctoral programmes, including student competitions focused on various aspects of tidal power system design and operation. In Europe, a number of universities have successfully linked masters and PhD programmes to their test centres (e.g. Queens University Belfast, University College Cork).

An open-ocean test centre could complement the facilities now in place for ocean and tidal technologies research, development, and demonstration. From computational fluid dynamic modelling, tow and flume tanks at Dalhousie University and Memorial University, a small tidal test centre, through to large-scale, fast-water demonstrations at FORCE, there would be a path to commercialization. With new emphasis on small tidal devices and other technologies for small tidal currents, there also arises an opportunity for local technologies to be designed and tested in the province. There is ample intellectual capital in the province for this to happen.

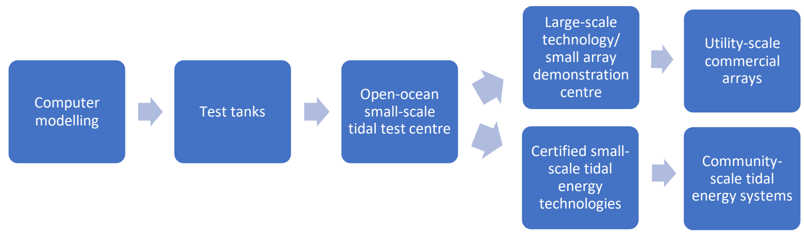


Figure A1-4: Basic pathway to commercial tidal energy conversion in Nova Scotia

A test centre could also help gain trust and acceptance of tidal energy by host communities and First Nations people. Collected data and analysis that is not proprietary to clients could be shared. Host communities and First Nations people would be able to participate in research and education, benefit from the improved knowledge of local waters and marine life and provide supply chain services to the test centre.

The Nova Scotia economy is highly dependent on the ocean. It is important that Nova Scotia continues to increase its understanding of the ocean and how to protect it through research. Beyond tidal energy development, there is much research to be done and Nova Scotia has many universities, a growing NSCC ocean technology program, COVE, and a thriving ocean technology industry engaged in that endeavor. An accessible, open-ocean small tidal technology test centre could assist with many ocean-related research questions and ocean technology development challenges.

6 Key Decision Criteria

Key decision criteria (KDC) are the essential criteria that must be met, or can be met, to support a decision to go forward with the business case analysis for a small tidal test centre. We have identified four KDCs:

1. Does Nova Scotia have a site(s) that meets technology developers' specifications?
2. Does Nova Scotia have a site(s) that provides for technology developer and researcher needs that are presently unmet by other test centres: a) in the region, and b) abroad?
3. Can the Nova Scotia site(s) offer a sufficiently unique package to draw a clientele of technology developers and researchers so the test centre is in use on a regular basis?
4. Can permits be approved and host community and First Nations acceptance achieved and maintained for the site(s)?

7 Conclusions and Recommendations

Upon analysis of the test center scan, an apparent gap exists in the small tidal test centre offerings that Nova Scotia can fill. Globally, there are few open-ocean test-centres with the combined flow speed, depth and accessibility of the Nova Scotia sites. In Canada, and arguably, in North America, there is no such test centre in existence today. Upon analysis of needs, collected by interview, Nova Scotia has tidal stream sites that meet developers' and researchers' specifications, unlike the test centres in Canada and Europe. Thus, key decision criteria #1 and #2 are met.

On key decision criteria #3, it appears Nova Scotia has tidal stream sites that offer a sufficiently unique package, such that a client-focused, well-designed test centre with knowledgeable staff could draw enough developers and researchers that the test centre would be in regular use.

Key decision criteria #4 is more difficult to predict. As for permitting, all the "candidate" test centre sites are in the two AMREPs and near the four Marine Renewable Electricity Areas (MREAs) so will benefit from the significant research and community engagement conducted over the past decade. Host community and First Nation acceptance would have to be earned. The communities adjacent to the MREAs are familiar with tidal energy testing and development so less education would be needed than would be in other locations but community input on the design, location and operation would be important for acceptance. Nova Scotia, FORCE, Fundy Tidal Inc., and various project and technology proponents have engaged with local communities and First Nations people and lessons have been learned. It is anticipated that, *if they are engaged and consulted meaningfully, their concerns addressed fairly, and the benefits shared locally*, host community and First Nations people's acceptance and participation could be earned and maintained.

There is a gap in the global and regional market - a niche in which a small tidal test centre in Nova Scotia could sustainably compete, facilitating local tidal energy and other ocean research and technology development, providing education opportunities, and stimulating rural economic development. Further research should be undertaken on the strategic positioning, function, location(s), design, ownership, governance, and economic and other benefits of a Nova Scotian small tidal test centre. A business case analysis of a small tidal energy test centre should be conducted.

Table A1-2 Initial Scan – Test Centres

Facility Name	Brief Description	Location	Country	Operator	Site Status	MaxTRL
EMEC (Scale)	2 x Non-grid connected test berths 21-25m depths Up to 75kW	Shapinsay Sound, Orkney, SCT	UK	European Marine Energy Centre	Operational	7
EMEC Full Scale	8 x grid connected test berths 12 – 50m depths 11kV sub-sea cables	Fall of Warness, Orkney, SCT	UK	European Marine Energy Centre	Operational	9
EMEC	Test Demonstration Zone		UK	European Marine Energy Centre	Operational	n/a
EMEC – Integrated Monitoring Pod	2m cube steel environmental monitoring pod	Mobile	UK	European Marine Energy Centre	Operational	n/a
QUB Portaferry	Scaled (1/10) devices	Strangford Lough, NIR	UK	Queens University Belfast	Operational	8
SEENEOH	Full and intermediate scale, >8m depth, devices up to 5m, 5t, 3 x berths, 250kW total	Bordeaux, FR	France	Energie de la Lune, Cerenis, Valorem, SEML RDL	Operational	7
SEMREV	Mainly Wave, but tidal measurement also along with other marine energy platforms Tidal range 6.2m Max tidal current (10 years) 0.7m/s	Nantes	France	Ecole Centrale Nantes,	Operational	n/a
DMEC Marsdiep	Offshore berth - 25m depth, 1-2m/s flow speeds	Netherlands	Netherlands	Dutch Marine Energy Centre	Operational	8
DMEC Den Oever	Inshore at sluice gates, Device up to 10x3m, 1.5-4.5m/s flow speed	Netherlands	Netherlands	Dutch Marine Energy Centre	Operational	7
TTC-GD	3 channels of different widths Range 3m, Flow 4-7m/s	Netherlands	Netherlands	Tidal Technology Centre Grevelingendam	Operational	7
Wavehub North Devon	Tidal stream Test & Demonstration site	UK	UK	wavehub	In Development	6
Perpetuus Tidal Energy Centre	Full Scale – Operational in 2021	Isle of Wight, UK	UK	Perpetuus Energy & Isle of Wight council	In Development	8
NZ Marine Energy Centre	Grid connected, planned	Cook Strait, NZ	New Zealand	AWATEA	Planned	-
Galway Bay Marine and Renewable Energy Test Site	Smart bay - 1/4 scale test site for wave with current measurement capability	Galway, IRL	Ireland	SEAI/Marine Institute/Smart Bay Ltd	Operational	n/a

Facility Name	Brief Description	Location	Country	Operator	Site Status	MaxTRL
National tidal energy full scale test site	three test berths, contains testing system and ocean observing system, 300 kW, 600 kW and 1 MW	Zhoushan, Zhejiang Province	China	National Tidal Current Energy Test Station (NTCETS)	In Development	8
Tidal Energy Open Sea Test Centre	5 berths of 4.5 MW grid-connected capacity, completed 2021	Undecided	South Korea	MOF	In Development	8
Tidal Energy Open Sea Test Centre	Component performance test centre Blades & Drive train	Undecided	South Korea	MOF	In Development	n/a
Sentosa tidal test bed	up to rotor diameter of 1m	Sentosa	Singapore	Sentosa Development Corporation and ERI@N	Operational	4
South West Mooring Test Facility (SWMTF)	Mooring testing Depth 27m, Tidal variation 5.4m	Falmouth Bay, Cornwall, UK	UK	University of Exeter	Operational	n/a
Bourne Tidal Test Site (BTTS)	Canal, flow rate 2 m/s, depth 7m, not grid connected, 3 berths, max 2m diameter	Cape Cod Canal, MA	USA	Marine Renewable Energy Collaborative	Near commissioning	5-6
Canadian Hydrokinetic Turbine Test Centre	River current 1.8-2.8 m/s, Depth 10 m, 30 M wide, grid connected	Seven Sister Falls, MB (Winnipeg River)	Canada	University of Manitoba	Operational	4
Fundy Ocean Research Centre for Energy (FORCE)	Large-scale instream tidal demonstration, 5 m/s, depth 45 m at low tide, 5 berths, total 1 km^2, grid connected.	Black Rock, Colchester Co., NS (Minas Passage)	Canada	Fundy Ocean Research Centre for Energy	Operational	9
Northwest National Marine Renewable Energy Centre (NNMREC)	Three test centres, primarily wave energy devices. For river current, see Tanana River Hydrokinetic Test Site.	Oregon, Washington, Alaska	USA	US DoE, Oregon State University, University of Washington, University of Alaska, Fairbanks	Operational	8
Southeast National Marine Renewable Energy Centre (SNMREC)	Onshore and offshore testing, 12 nautical miles offshore, not grid connected, permitted to 100 kw, 7 m rotor.	Florida Strait, near Ft. Lauderdale, FL	USA	Florida Atlantic University	Operational	6
Tanana River Hydrokinetic Test Site	River current, 1.5-3.5 m/s, depth 6m, 23 m wide, not grid connected, river freezes.	Fairbanks, AK	USA	University of Alaska, Alaska Centre for Energy and Power	Operational	6

Sources: Marinet2, EU Marine Research Database

Figure A1-1 Test Centres Specific to Small Tidal Energy Development

1. European Marine Energy Centre (EMEC)

Site Information (Full-scale (a) and small-scale (b) sites)		
Location	Fall of Warness, Orkney, Scotland	Shapinsay Sound, Orkney, Scotland
Max Water Depth	50 m	25 m
Max Flow Speed	4 m/s	1.5 m/s
Grid Connection	Yes	No
TRL Range	6-9	4-7
Site Characteristics	2 x 4 km site with 8 berths	0.4 x 0.9 km site with 2 berths (5 x 2m)

General Information

Instrumentation & Facilities:

- Current profiler and Test Support Buoy
- Pre-Installed anchor points and foundations (5 x 5 x 2 m gravity bases).
- Rehearsal area and deployment of new tools and techniques.
- Monitoring corrosion, biofouling and acoustic instrument packages.
- Overarching site licence which simplifies consent process within agreed envelope of activity.
- Met station
- Grid connected substation
- Marine radar
- Real time data transmission
- Wildlife observations

Test site services:

- Historical and live tidal flow and wave data.
- Certified power validation
- Device & component testing.
- Anchoring, cabling, subsea hub and wet-mate connector testing.
- Installation, O&M tests & rehearsal activities.
- Decommissioning trials.
- Health and safety procedures and training.
- Testing ROV's and vessel activities.
- Established power purchase agreement
- Independent performance validation.
- Full time emergency response cover
- Hydrographic and current surveys with live met data
- Environmental baseline studies to streamline consenting process.
- Data centre, office facilities and a mature supply chain

Associated companies/organizations:

- Carbon Trust
- Orkney Islands Council
- HIE (Highlands and Islands Enterprise) Orkney
- Scottish Government
- Department of Energy and Climate Change
- Scottish Enterprise

2. Queens University Belfast (QUB)

Site Information	
Location	Strangford Lough, Northern Ireland
Max Water Depth	10 – 50m
Max Flow Speed	2m/s in anchorages, 4 m/s main channel
Grid Connection	Yes
TRL Range	3-8
Site Characteristics	150 square km with 0.5 – 1.5km width

General Information

Instrumentation & Facilities:

- Acoustic Current Velocimeters (ADV)
- Acoustic Doppler Current Profilers
- Underwater data transmission
- Underwater video
- Specialised software available for data analysis
- Catamaran for tow tests (configurable)

Montgomery Lough – 63000m2 area – 400m length, 133m wide with 200m wide towing track. 6m depth with easy access from shore

Portaferry wave tank available for testing also

Test Site Services

- Device testing
- Environmental data
- Field office and warehouse (cable connected for data acquisition and power supply)
- Slipway
- Moorings
- 1T lift capacity on 40 ft boat, barge, tow tests
- Manufacturing/fabrication facilities
- Marine Science Lab facility at Portaferry

3. SEENEOH

Site Information	
Location	Gironde estuary, Bordeaux, France
Max Water Depth	8m
Max Flow Speed	3.5m/s
Grid Connection	Yes – 100kW per berth
TRL Range	4-7
Site Characteristics	2 x 4 km area with 3 berths – two floating, one anchored - max device size 5 x 5 x 5m

General Information

Instrumentation & Facilities:

- ADCP's: velocity, direction of current, turbidity for current
- Met Station & Hydrophones
- Multi-parameter sensors (temperature, pH, turbidity, conductivity, dissolved oxygen.
- Multibeam Sonar (Bathymetry)
- SCADA system
- Electro magnetometer
- Sedimentology sampling
- Side scan for imagery

Associated Companies / Organisations

- Energie de la Lune
- Cerenis
- EDF
- Valorem

Test site services

- Device testing (max diameter 5m, max weight 5T).
- Provision of grid connection.
- Technical facility for monitoring via SCADA.
- Real time monitoring of environmental impact, mechanical behaviour and energy performance.
- O & M support.
- Engineering, construction and installation support.

Local supply chain includes;

- Metal construction, wiring and electrical connections.
- Transportation, handling, seaport services, logistics.
- Installation at sea and maintenance.
- Subgroup of marine current power (engines, energy storage, design and materials engineering, composite materials, insulation, painting).

4. Dutch Marine Energy Centre (DMEC)

Site Information (Den Oever (a) and Marsdiep (b) sites		
Location	Den Oever, Netherlands	Marsdiep, Netherlands
Max Water Depth	4.2m	20 m
Max Flow Speed	4.5m/s (in sluice gates)	2 m/s
Grid Connection	No	Yes
TRL Range	4-7	3-8
Site Characteristics	2 berths in sluice gates – easy access	1 square km in sheltered position 800m offshore

General Information

Instrumentation & Facilities:

- Relevant instrumentation and data acquisition technology.
- Sluice gate integrated into existing infrastructure at Den Oever.

DMEC intend to develop a more integrated approach to tidal device testing in the Netherlands by providing access to all available test facilities. This includes TTC, NIOZ, MARIN and TU Delft facilities.

Test Site Services

- Device testing (intermediate and full scale)
- Environmental data
- Performance, installation, survival, O&M and demonstration tests
- Free access through FORESEA and MARINET2
- Integrate testing with other support services
- Business and commercial services (funding applications)

5. Tidal Technology Centre (TTC) Grevelingendam

Site Information	
Location	Grevelingendam, Netherlands
Max Water Depth	5.75 m
Max Flow Speed	4 m/s
Grid Connection	Yes
TRL Range	4 - 7
Site Characteristics	3 berths (3.2,6.8 and 10.4m width)

General Information

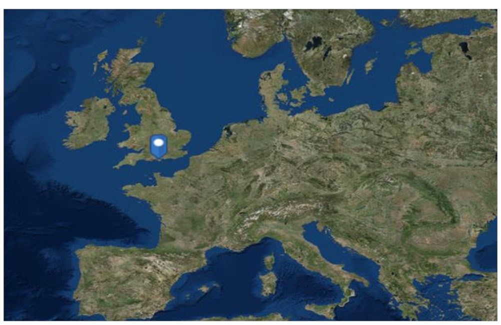
Instrumentation & Facilities:

- Monitoring and datalogging
- Demonstration setup of 4 turbines capable of producing 0.5 – 1.0 MWe of energy.
- Monitor turbine impacts on morphology, tidal flow patterns and environmental impacts.
- Low cost centre located between test tanks and large scale offshore facilities.

Test Site Services

- Device testing
- Certification and validation
- Component testing
- Turbines made available to research institutions
- Easy access from land

6. Perpetuus Tidal Energy Centre (PTEC)



Site Information	
Location	Isle of Wight, UK
Max Water Depth	-
Max Flow Speed	-
Grid Connection	Yes
TRL Range	5-8
Site Characteristics	5 square km area proposed

General Information

Proposed site – operational 2021

Site characteristics unavailable at this time

Test Site Services

- Pre-consenting by local authorities

Associated companies/organizations:

- Tocardo International,
- BV
- Schottel Hydro Gmbh
- Isle of Wight Council
- Marine Management Organisation
- Natural England

7. Smartbay

Site Information	
Location	Galway Bay, Ireland
Max Water Depth	23m
Max Flow Speed	n/a
Grid Connection	Yes
TRL Range	n/a
Site Characteristics	1.5km offshore with subsea observatory

General Information

The site is primarily used for wave and marine renewable energy subsystem components and sensor testing. A profile has been developed for this site as it has installed a state of the art subsea observatory and instrumentation facility as well as a flexible approach to layout.

Subsea cable observatory includes:
- A fibre optic data and 400v power cable.
- High speed communications via 4 pairs of optical fibres.
- A sub-sea cabled sensor platform which hosts a variety of sensors and equipment which can be tested and demonstrated in near real-time.

Sensors
- Conductivity, Temperature and Depth & Dissolved Oxygen
- Combined Turbidity and Fluorescence sensor
- Acoustic Doppler Current Profiler
- High frequency hydrophone & Acoustic fish tag detector

Test Site Services

Small /Intermediate scale device testing.
Fully licenced site with fully characterised wave climate
ICT team for data acquisition and transmission support
Proximity to ports and associated facilities

Marine Supports include:

Specialist technical and engineering support
Mobilisation and Device deployment
Health, safety and environmental management
Day-to-day marine operations
Project management
Vessel and dive services
Electrical and electronics support

8. MaREI – LiR NOTF and MaRINET2 centres

Site Information	
Location	Ringaskiddy, Co. Cork, Ireland
Max Water Depth	Varies across centres
Max Flow Speed	Varies across centres
Grid Connection	Varies across centres
TRL Range	Varies across centres
Site Characteristics	Varies across centres

General Information

MaREI acts as co-ordinator of the MaRINET2 programme. This provides access for tidal device developers to a range of facilities, some profiled here, across Europe.

As well as access to the current flume at the LiR NOTF facility, developers can also access the DMEC sites, EMEC sites and a number of other open sea and land based test facilities as well as facilities for testing ancillary components.

Testing tends to be funded for short periods - up to two weeks

Marine Supports include:

Also offer services in numerical modelling, technology development, instrumentation, data acquisition and analysis, financial modelling, O&M optimisation, hydrodynamic modelling, weather window analysis (wind and wave), PTO system analysis (power quality and grid integration).

9. Bourne Tidal Test Site

Site Information	
Location	Cape Cod Canal, Massachusetts, US
Max Water Depth	7m (low tide) 2m range
Max Flow Speed	2 m/s
Grid Connection	No
TRL Range	5-6
Site Characteristics	River site with stand to attach turbine – max turbine diameter of 3 m

General Information

Instrumentation & Facilities

- ADCP
- Seabed characterisation
- Sensors, data acquisition and transmission system.
- Solar power
- Secure building for power electronics and instrumentation

Test Site Services

- Technical support from BTTS staff and regional academic institutions
- Fully permitted site
- Remote sensor testing (oceanographic, meteorological, environmental).
- Well developed local supply chain

Associated companies/organizations:

- New England Marine Energy Development System (NEMEDS)
- USGS S.O Conte Anadromous Fish Lab
- Seaport Economic Council
- Massachusetts Clean Energy Centre
- Town of Bourne
- Falmouth Scientific Inc
- Impact Labs
- MassTank
- Pi R Shared

10. Canadian Hydrokinetic Turbine Test Centre (CHTTC)

Site Information	
Location	Seven Sisters Falls, Manitoba
Max Water Depth	10 m
Max Flow Speed	2.5 m/s
Grid Connection	Yes, one berth.
TRL Range	4
Site Characteristics	River site with 3 berths.

General Information

Instrumentation & Facilities

- Grid connected
- Bi-directional flow meter
- Aris Sonar camera
- Acoustic Doppler Velocimetry device
- ADCP's
- Hydrophone
- Load Cells
- Data Loggers

Test Site Services

- Centre has regulatory approval for turbine deployment and retrieval
- Performance and flow characterisation measurements
- Develop solutions to river and hydraulic related issues
- Design and implement mooring systems
- Underwater monitoring
- Computer modelling and CFD
- Environmental Assessment
- Cold climate testing

Associated Companies
University of Manitoba, Manitoba Hydro, DFO, Marine Renewables Canada, UVic, and UCarlton.

11. Fundy Ocean Research Centre for Energy (FORCE)

Site Information	
Location	Minas Passage, Nova Scotia, Canada
Max Water Depth	45 m
Max Flow Speed	5 m/s
Grid Connection	Yes
TRL Range	5 - 9
Site Characteristics	5 berths in 1 square km site.

General Information

Instrumentation & Facilities

- 5 grid connected berths
- Submarine cable to shore based underground cable ducts and an electrical substation
- Connected directly to the Nova Scotia electrical grid via a purpose-built 10 km transmission line.
- Fundy Advanced Sensor Technology (FAST): concurrent development of underwater monitoring platforms. The platforms use a variety of onboard sensing equipment intended to capture data from the Minas Passage, including: currents and turbulence, marine life activity, noise levels, seabed stability. Includes subsea data collection, subsea data cable installation, shore-based radar and meteorological equipment, platform fabrication, instrumentation, and deployment.

Test site services:

- Environmental monitoring and resource research – Environmental Monitoring Advisory Committee,
- Some Permits and approvals (not all, Berth holders are responsible for their own environmental monitoring, impact on transportation/navigation approvals, etc.),
- Shared services and insurance,
- Visitor centre,
- Community engagement – Community Liaison Committee.

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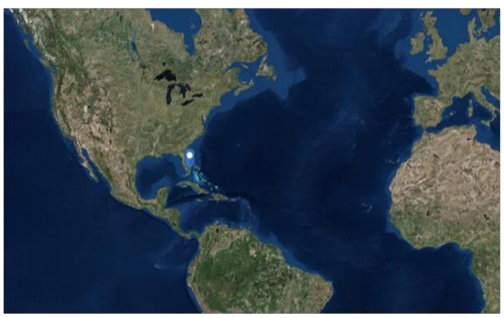
12. Southeast National Marine Renewable Energy Centre (SNMREC)



Site Information	
Location	Fort Lauderdale, Florida, US
Max Water Depth	284 m
Max Flow Speed	-
Grid Connection	No
TRL Range	4-6
Site Characteristics	Site 12 nautical miles from shore

General Information

Instrumentation & Facilities

- Onshore: 25 kW dynamometer for drive train and generator performance evaluation
- Offshore: towed or component testing with 25 kW research turbine, built by SNMREC engineers
- 20 kw 3m rotor turbine test bed
- Research and measurement platform
- Permitted for up to 100kW or 7m diameter devices

Test site services:

- Has onshore and offshore testing capabilities
- Developing grid-connected, full-scale test berths,
- Ship-board turbine management up to 25kw power
- Resource characterization
- Real-time measurement
- Florida Atlantic University (FAU) operated

.

13. Tanana River Hydrokinetic Test Site

Site Information	
Location	Fairbanks, Alaska
Max Water Depth	8 m
Max Flow Speed	3.25 m/s
Grid Connection	No
TRL Range	4-6
Site Characteristics	1 berth

General Information

Instrumentation & Facilities

- Blue View P900-2250-45 imaging sonar
- ADCP
- Simrad EK60 split beam sonar (120 kHz)
- Novatel RTK/L1 positioning system (20 cm accuracy)
- Pontoon barge

Associated companies/organizations:

- University of Alaska Fairbanks
- Alaska Centre for Energy and Power (ACEP)

Test site services:

- Fish interaction with turbine
- Debris management
- Turbine placement
- Hydrodynamic analysis
- Sediment transport and icing,
- Lab area

NOTE:The Tanana River freezes over, challenging environment

Appendix 2: Business case interviews – respondent profile and questionnaire

For the business case analysis, semi-structured interviews with nineteen people familiar with the industry were conducted through January and February 2018. Each interview lasted approximately one hour.

Firstly, the findings of the gap analysis, the competitive analysis, and the strategic position derived therefrom were described. Respondents were asked for their feedback.

Respondents were then asked questions relating to a test centre's focus, ownership, and governance alternatives; funding, revenue streams, sustainability, synergies and opportunities for collaboration with other organizations; and opportunities, risks; and economic and other benefits. A profile of the group of respondents and the questions are below.

1 Respondent profile

Twenty-two people were asked to be interviewed and nineteen agreed to participate. Among these nineteen, there was representation from the following groups (many were from more than one group):

- Test centres - 6
- Industry - 4
- Research institutes/universities/community college - 5
- FORCE board representative/experience - 3
- Funding organization - 1
- Ocean technology/ocean supercluster - 3
- First Nations - 2
- Government - 1
- Potential collaborating organizations - 7.

2 Questionnaire

The following questionnaire was used. Some questions were omitted in some interviews, depending on the respondent's expertise.

The Province of Nova Scotia has commissioned a study to evaluate the business case for establishing a small tidal test centre. The study includes evaluating the need for a test centre, identifying potential uses (and users), locations, infrastructure, governance and benefits. Benefits refer to the potential economic and other benefits to Nova Scotian communities, research, and the local (and global) tidal energy industry.

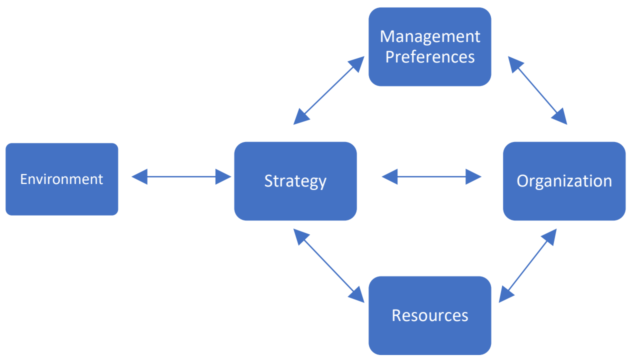
Preamble	Show gap, describe potential strategic position, customer segment, market focus.
Strategy	What are your thoughts about this? Should the primary focus be a research centre or service to industry? What do you think would help the centre be sustainable over time?
Ownership/form of organization/ governance	What are your thoughts about the legal structure, ownership, and governance of the centre? Who do you think should be on the board (whose representatives)?
Collaborations	What do you think would be the synergies with the work of other centres (e.g. FORCE, COVE, Ocean Frontier Institute, Aquatron Laboratory)? What opportunities for collaboration, alliances do you see?

	What potential conflicts do you see?
Opportunities	Do you see any opportunities on the horizon that we should consider in our analysis?
Funding, profit model	What funding sources do you see as appropriate for the centre (given research centre or service focus)? What do you think the centre's revenue streams might be?
Objectives	What do you think would be reasonable goals for the test centre?
Economic & other benefits	Do you think a small tidal test centre located in Nova Scotia would be beneficial? Who do you think would benefit? What would be the benefit(s)? Would such a test centre be of benefit to you(r organization) and your work? How? If not, why not? What risks do you foresee? How can they be mitigated?
Other	Is there anyone else you think I should speak to about this? Is there anything I have neglected to ask you that you feel I should know?

Appendix 3: Strategic positioning

The strategic positioning of the test centre will be developed using elements of the Diamond-E[9] analysis. The Diamond-E analysis is used for creating, evaluating, and revising competitive strategies (Figure A3-1). It is also used to identify important elements of other components (resources, organization, management preferences) so they can combine to effectively implement the strategy and successfully compete in the industry. The built-in feedback loop in the model helps to recognize whether the resources that can be marshalled for the test centre will be sufficient to form a strategic competitive advantage.

Applying the Diamond-E framework guides decisions regarding the strategic positioning of a test centre, its function, location, configuration, and organizational form. Not all elements will be given full attention, as some are beyond the scope of this study and would be better done by management of the test centre, should it be established. This study focuses primarily on the competitive environment, the resources, somewhat on the organization, and the strategy that would connect them.



Environment	Strategy	Resources & Capabilities	Organization	Management Preferences
Competitive Analysis (Buyer power, supplier power, substitutes, compliments, threat of entry, and competitive rivalry.)	Goals Product-market focus Core activities Value proposition	Operational Developmental (e.g. expertise, facilities, location) Human Financial Reputational Marketing (e.g. brand, channels, relationships)	Leadership Structure Management Processes Culture	What are top management's beliefs? What do they need to be?

The two-directional arrows in the model reflect the interdependence of components. The components need to be aligned. The strategy should be designed to address the opportunities and challenges presented by the industry. The strategy, in turn, indicates what resources the organization will need to compete. In the reverse direction, the ability of the organization to implement and sustain the strategy will depend on whether it has the appropriate resources.

Figure A3-1: Diamond-E Framework

Firstly, for a small tidal test centre to succeed, it needs to know who its clientele would be, what the clients need, and how to survive its competition. These will be discussed next. A competitive industry analysis will then follow. To position itself within the industry for survival, the test centre would need to know the industry, what drives competition, how intense the rivalry is, and where it can fit in strategically so it can thrive. The industry analysis will reveal where the opportunities lie.

[9] Crossan, M. Rouse, M., Rowe, W., Maurer, C. (2016) Strategic Analysis and Action, 9th Edition, Toronto: Pearson Canada.

1 Clientele and needs

Companies seeking to test technologies at a small tidal test centre would be comprised of small- to medium-sized enterprises (SMEs) and large companies that develop all aspects of tidal power systems, including (but not limited to) turbines, support structures, moorings, cables, connectors, and monitoring equipment. These potential clients may be developing technologies targeted for commercial applications similar to the test centre environment or looking to advance the TRL of prototypes of utility-scale projects at more challenging locations. Other clients of the test-centre may be developers of other ocean technologies. Company size will likely vary across the spectrum. There would also be researchers of tidal streams, oceans, and coastal regions more broadly. They would largely be associated with universities and research institutes, such as the Bedford Institute of Oceanography.

A small tidal test centre would likely have a fairly limited geographic reach, at least in terms of most potential clients. It might not be practical for technology developers to travel far to test their device when there is a suitable test centre close to home. For many of the potential international test centre clients, being SMEs, the cost of travel to a Nova Scotia test centre might be prohibitive. Furthermore, funding programmes often require research, development and testing be done in the jurisdiction providing the funding (e.g. Wave Energy Scotland, FORESEA, MaRINET2), though other, more flexible funding programmes help developers travel abroad to test their devices (e.g. Europe Union's Horizon 2020). It is conceivable that SMEs would test lower-TRL devices at nearby test centres and then travel further afield to be closer to their market for the next stage or see a small tidal test centre in Nova Scotia as a pathway to the North American market and successful testing as a globally-recognised accomplishment. Larger companies testing small tidal devices or scale models of large devices or wet testing their devices prior to mobilizing to more challenging environments may have the means and the motivation to travel to Nova Scotia to become familiar with, and learn from, the local industry. Accordingly, it is expected clients would come mostly from within Canada, potentially from the United States, with likely some from overseas, predominantly from Europe. A partial list of companies known to be developing tidal technologies as of the time of writing is shown in Appendix 4.

The needs of clients were identified in the gap analysis. They are discussed in Appendix 1 and summarized in Sections 2.2 and 2.3 of the report.

2 Competitive analysis

A competitive analysis of the industry helps to identify the drivers of competition and the intensity of the rivalry, which in turn, helps identify how a Nova Scotia test centre can position itself within the industry and what competitive forces will affect it. The five forces are: the potential entrants, buyer power, supplier power, substitutes, and competitive rivalry. The sixth force, having somewhat the opposite effect of substitutes, is compliments. A competitive analysis of the test centre industry, using the Porter Five Forces model is provided in Appendix 5. In summary, the global test centre industry is in the early growth stage. There are modest entry barriers, moderate exit barriers, limited buyer power, and varied supplier power. The competitive rivalry is not intense and the industry is somewhat regional. Substitutes exist but open-ocean testing is needed. The centres are generally government-funded, at least initially, and government permits and consents are required.

3 Fragmentation and industry segmentation

There are numerous technology test centres around the world in operation or planned. Since entry barriers are not high, it is likely more will come online as the tidal energy industry turns its attention to community-scale devices for off-grid applications and the ability to apply a step-wise approach to development, focused on learning through small-scale and then scaling up. The presence of many test centres makes for a fragmented market, which creates both competitive opportunities and challenges. Gaining a dominant position in a fragmented global small tidal test centre industry is difficult so market segmentation may be worthwhile. The market can be segmented in terms of services and geography, essentially choosing which clients to serve and what to offer them.

It makes sense to segment the market into the size of budget and region. For companies with larger budgets (large companies or foreign SMEs with sufficient and flexible funding), a Nova Scotia test centre would compete more directly with the test centres in Europe. Nova Scotia and the Bay of Fundy already have global brand recognition in the tidal energy industry, which would help a test centre located here gain traction in the international marketplace. For SMEs without flexible funding, the test centre would have a dominant position in the local region. To attract these clients, it would make sense to focus on establishing a competitive advantage within the Canadian and Eastern Seaboard tidal test centre market. This can help overcome the challenges of competing in a fragmented industry, though it is a much smaller market. At present, the few offerings in the region (fresh water, warm salt water, canal, river current) can be either considered rivals or allies that serve as stepping stones in the path toward commercialization. Collaboration with these test centres can help build demand for each and support development of the industry.

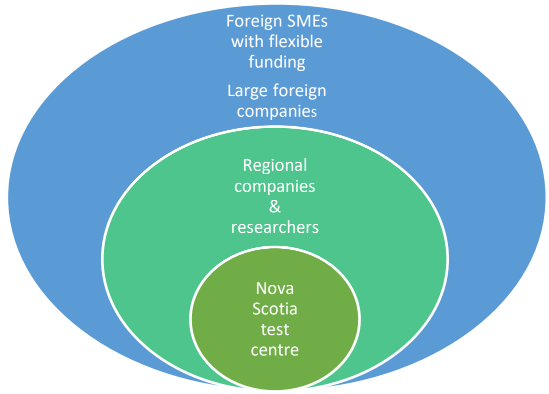


Figure A3-2 Market segmentation

4 Key Success Factors

Key success factors (KSF) are those factors that significantly influence a firm's ability to outperform rivals in supplying what customers want and surviving the competition. KSFs are defined by what customers need and how they choose between rival firms' offerings. The ability to survive competition depends on how intense the competition in the industry is and its key dimensions. Using data collected for the gap analysis, key success factors for a tidal test centre are identified as the following:

- Suitable, accessible, characterized tidal streams;
- Pre-permitted, consented sites, permits for testing;
- Ability to meet a variety of client needs and specifications;
- High quality personnel at the site or nearby;
- Regulatory & government program support;
- Engagement with local researchers and institutions;
- Supply chain capacity;
- Adequate marine assets & operators;
- Adequate infrastructure;
- Low overhead costs;
- Community and First Nations support.

The Nova Scotia tidal test centre would be alone in the regional segment, initially. When not, it can differentiate through location (resource quality, spatial variability, Fundy reputation/brand, region), and accessibility, affordability, flexibility, client-focus, experience, and expertise.

Since the tidal energy industry is relatively young, small, and unpredictable, providing access for multiple and synergistic uses, e.g. tidal energy, ocean technology, energy storage R&D, and ocean research, would broaden the market, spread costs, and reduce uncertainty.

Collaborations with other ocean organizations, universities, and complimentary-service providers would also be important for success, to take advantage synergies, provide joint or coordinated offerings, and develop a pipeline of projects.

5 Fit with resources for sustainable competitive advantage

The competitive industry analysis provides insight into where opportunities exist to strategically position a test centre. The industry and its key drivers inform an organization's strategy. However, the appropriate strategy for competing within the industry must also align with the resources and capabilities of the organization so it can successfully implement the strategy. Ultimately, there needs to be an environment-strategy-resources alignment to be successful in attracting clients and delivering the value proposition, as depicted in the Diamond-E framework (Figure A3-3).

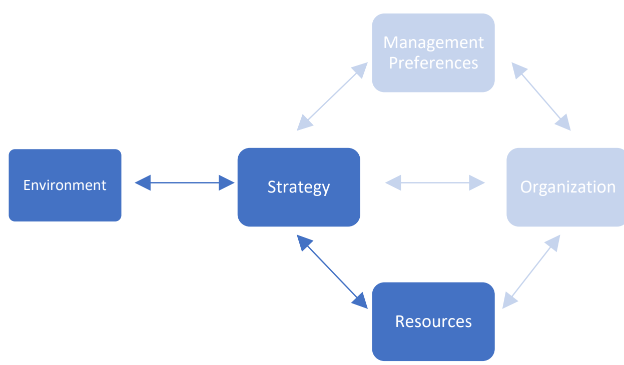


Figure A3-3 Environment-strategy-resources alignment

Since the competitive landscape will be continuously changing, the centre needs a strategy that aligns with the industry opportunities but is built on the its resources and capabilities (competencies) for a stable and constant direction. This focus on resources and capabilities as a basis for firm strategy is derived from a body of literature known as the resource-based view of the firm.[10] The resource-based view recognizes that each firm has a unique collection of resources and capabilities and formulating a strategy that exploits these can be the basis of a sustainable competitive advantage.

Comparing the relative strength to the strategic importance of an organization's resources and capabilities allows for the identification of key strengths and key weaknesses. A strategy can then be developed that exploits the strengths and minimizes the impact of significant weaknesses.

The next section identifies and evaluates the resources and capabilities already known about Nova Scotia, the Bay of Fundy, and the prospective locations. Not all resources and capabilities would be identifiable

[10] Mahoney J. and Pandian, J. (1991) Firm resources and sustained competitive advantage, Journal of Management, v.17, p. 99-120.

until a site is selected, the test centre built, and its people employed or contracted. However, with this analysis, critical gaps or weaknesses could be addressed as the test centre is designed.

6 Sustainable Competitive Advantage

A review of a test centre's capabilities before it is built and operating is limited to the resources that exist within Nova Scotia and the Bay of Fundy region generally. The specific tangible resources of the Nova Scotia test centre would depend on its location, the funding acquired, and configuration. The needs of the marketplace and the existing test centers, identified in the gap analysis, should guide the design and location selection.

What is known about a Nova Scotia test centre so far is it would have suitable tidal resources that fit within the gap, in the range of 2 to 4 m/s and depths of 10 to 30 m, and would meet various accessibility needs. With an added feature of spatial variability, a greater range of clients could be served.

Resources combine to form a competitive advantage. There are already intangible assets in the form of reputational and intellectual assets present. Reputational assets are the Fundy brand, published research, and demonstrated willingness to collaborate with researchers and developers around the world. Intellectual assets are tidal energy experience, expertise, and research that are resident in the Fundy area and Nova Scotia, generally. A Nova Scotia test centre would be able to draw and build on these, through hiring, collaborating with researchers, and contracting private-sector services. The specific qualities of Nova Scotia sites, reputational assets, and intellectual assets can thus be combined to create a competitive advantage.

In Figure A3-4, the relative strength of potential resources and capabilities of a generic Nova Scotia small tidal test centre are estimated using a scale of 1 to 10. They are then compared to the key success factors, noted earlier, to estimate their relative importance (1-10). The strength and importance are then plotted. This exercise gives a view of the key strengths and weaknesses of the test centre, vis a vis the industry. The centre's strategy should exploit the key strengths. Where the strategy can deemphasize the importance of the weaknesses, it should be designed that way. Where it cannot, the weaknesses should be strengthened (e.g. through investment in infrastructure).

Organizational Resources, Capabilities and Sustainable Competitive Advantage (Grant 2013)

Organizational resources can be grouped into tangible, intangible, and human. Tangible resources are the financial and physical assets (buildings, equipment, land) and in the case of a test centre, the tidal resource at its location. Intangible resources include intellectual property (patents, copyrights, trade secrets) and other technology resources (technical know-how), reputation (brand, relationships), and organizational culture. Human resources include skills and know-how, capacity for communication and collaboration, and motivation of the people contracted to work at/with the test centre.

Whereas resources are the productive assets of an organization, capabilities are what develops as the firm deploys the resources, in various combinations, toward a purpose. Capabilities are the outcome of complex combinations of resources and multiple capabilities interact to form competitive advantage (p. 176).

Once an organization's resources and capabilities are identified, their strategic importance must be assessed. Strategically important resources and capabilities are those that can draw clients to the test centre and generate revenue. For a resource or capability to constitute a competitive advantage, it must be scarce and it must be relevant to the key success factors (p.127). For the competitive advantage to be sustainable, it must be durable, non-transferable, and not (easily) replicated (p128).

Once a competitive advantage is established, its sustainability depends on the durability, transferability and replicability of the important resources and capabilities. The transferability and replicability of

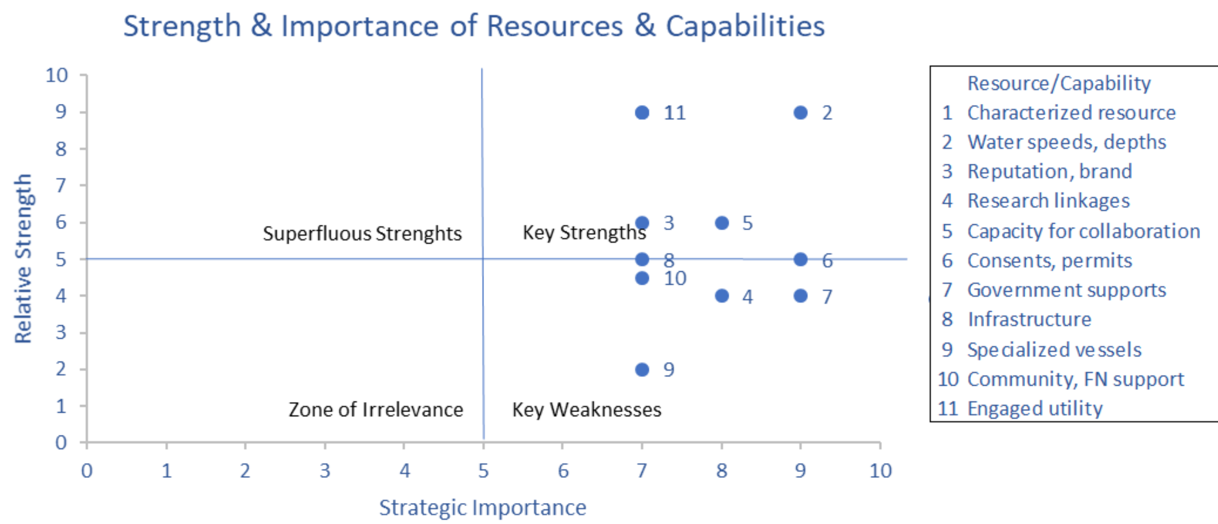


Figure A3-4 Relative Strength and Strategic Importance of Resources and Capabilities

competitive advantage are limited when there are barriers to imitation. In the case of Nova Scotia sites, the tidal resource is durable and immobile and, in combination with the area's intellectual and reputational assets, the competitive advantage in the mid-range testing segment of the industry would be difficult to transfer or replicate. There would be similar sites around the world, and intellectual and reputational assets also, though not so often in combination. A similar facility could be built, but globally, not likely many.

7 Strategy

The gap analysis and competitive analysis helped identify a competitive opportunity for a Nova Scotia test centre. The analysis of resources and capabilities helped identify a sustainable competitive advantage. From this, a strategy can be formulated. The strategy is made up of goals, product- or service-market focus, core activities and the value proposition (Figure A3-5).

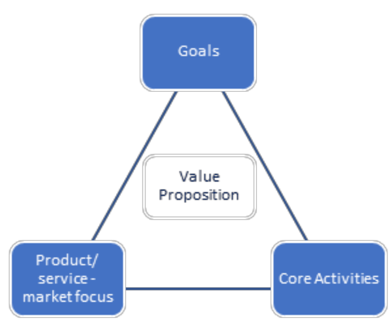


Figure A3-5 Strategy

To the extent possible, these are identified and are presented in Table A3-1, based on the above analyses and interviews. Not all elements of the strategy can be fully identified at this stage and some would be developed by the test centre's leadership, particularly the strategic goals. The service-market focus and core activities could be further developed once the site location and configuration are chosen. The goals, location, function, services offered and research programs initiated, organization, governance, alliances and collaborations, profit model and sources of funding, and infrastructure requirements could also be developed to be consistent with the opportunity available in the industry.

Table A3-1: Test centre strategy

Goals	What the organization intends to achieve, in measurable terms, absolutely and relative to the competition. Hard goals: financial, marketplace and timeframe targets. Soft goals: targets for social conduct. Overarching goal: To help provide a pathway for tidal energy technology and ocean technology development and facilitate tidal stream and ocean research more broadly.
Product/Service-Market focus	What the organization intends to offer and the market it intends to compete in. What? To Whom? To Where? Product/Service offering: Test Centre: *Accessible* mid-range tidal stream for tidal and ocean technology testing and tidal stream and ocean research (refer to Section 2.2 for needs). To Whom: SMEs and large companies testing: m) Community-scale tidal energy conversion devices at mid- to high-TRL; n) Utility-scale tidal energy devices - scale models or pre-commercial full scale; o) Other tidal energy-related and ocean technology and energy storage; p) Deployment, maintenance and retrieval procedures. Researchers of: q) Tidal energy, ocean, energy storage technologies; r) Tidal streams, marine life, additional ocean industries, and oceans more generally. To Where: For tidal energy and related technology R&D - globally but with emphasis on the eastern seaboard (Labrador to Massachusetts) and Canada. For other ocean technology R&D and ocean and tidal stream research – Atlantic Canada, with emphasis on Nova Scotia.
Value Proposition	Fundamental “benefit” the organization offers in the marketplace to attract clients A facility for testing tidal energy and other ocean technologies and for tidal and ocean research in a mid-range (flow speed and depth) tidal stream that provides: *accessibility* and meeting the other needs noted in Section 2.2, flexible and client-focused service, and research collaborations. Located in Canada in the Bay of Fundy.
Core Activities	The particular value-adding activities the organization will perform, and how it intends to perform them. Offerings would include: • Berth lease with basic services (resource monitoring, ADCPs, etc.) with additional services at extra cost. • Tailored solutions, comprising of a generic base service and a flexible approach to developers’ specific requirements. • Assistance finding partners to facilitate the technology development. • Marine supports (deployment and marine operations, project management, technical and engineering support). • Coordination of testing process from test tank to full scale test site, integrate testing with other services. • Instrumentation, data acquisition, operations and maintenance optimization, hydrodynamic numerical modelling, operations window analysis (weather and flow), power take-off system analysis. • Education and training, community engagement.

	Additionally (potentially): • Collaboration with other ocean organizations, such as the Center for Ocean Ventures & Entrepreneurship (COVE), FORCE, Marine Renewable Energy Collaborative (MRECo)/ (BTTS), CHTTC, West Coast Wave Initiative, universities, NSCC, and supply chain companies for coordinated services and research collaboration. • Co-ordination of the design and testing process and standards from numerical modelling, through test tank, to small-scale ocean, to mid-TRL ocean, to full-scale tests or deployments. Technology certification and standardization. • Grant-writing assistance and collaboration. • Facilitation of TC 114 standards development research.

Appendix 4: Turbine developers

Company	Country	Device Name	Device Type
BioPower System Pty Ltd	Australia	bioStream	Other
Cetus Energy	Australia	Cetus Turbine	Horizontal Axis Turbine
Elemental Energy Technology Ltd	Australia	SeaUrchin	Other
Mako Tidal Turbines	Australia	MAKO Tidal Turbines	Horizontal Axis Turbine
Tidal Energy Pty Ltd	Australia	Davidson Hill Venturi (DHV) Turbine	Enclosed tips (Venturi)
InCurrent Turbines Ltd	Canada	Vortex Power Drive	
Instream Energy Systems	Canada	Vertical Axis Hydrokinetic Turbines (VAHT)	Vertical Axis Turbine
Jupiter Hydro Inc	Canada		Archimedes Screw
New Energy Corporation	Canada	EnviroGen/EnviroCurrent	Vertical Axis Turbine
Water Wall Turbine Inc	Canada	Water Wall Turbine - In-Flow Water Current Technology	Horizontal Axis Turbine
EEL Energy	France	EEL Energy	Oscillating Hydrofoil
Guinard Energies SAS	France	MagaWattBlue	
Hydro-Gen	France	Hydro-Gen	Horizontal Axis Turbine
HydroQuest	France	Hydroquest Tidal	Vertical Axis Turbine
SABELLA SAS	France	D03	Horizontal Axis Turbine
Tidalys	France	ELECTRImar 1800, ELECTRImar 4200	Horizontal Axis Turbine
Atlantisstrom	Germany	Atlantisstorm	Horizontal Axis Turbine
Bosch Rexroth	Germany		Horizontal Axis Turbine
REAC Energy GmbH	Germany	StreamCube	Vertical Axis Turbine
SCHOTTEL group	Germany	STG (SCHOTTEL Tidal Generator)	Horizontal Axis Turbine
Open Ocean Energy Ltd	Ireland	Tidal Junior Flyer	
OpenHydro	Ireland	Open-Centre Turbine	Enclosed tips (Venturi)
Seapower scrl	Italy	GEM	Tidal Kite
Kawasaki Heavy Industries, Ltd	Japan		Horizontal Axis Turbine
Modec	Japan	Savonius Keel & Wind Turbine Darrieus (SKWID)	Other
Hyundai Heavy Industries	Korea		
Balkee Tide and Wave Electricity	Mauritius	Tidal and Wave Power Electrical Generator (TWPEG)	Horizontal Axis Turbine
Bluewater	Netherlands	BlueTEC	Other
Deepwater Energy BV	Netherlands	Oryon Watermill	Vertical Axis Turbine
IHC Tidal Energy	Netherlands	OceanMill	Vertical Axis Turbine
Tocardo Tidal Turbines	Netherlands	T2	Horizontal Axis Turbine
SeaCurrent	Netherlands	SeaCurrent TidalKite™	Tidal Kite
Andritz Hydro Hammerfest	Norway	HS1000	Horizontal Axis Turbine
Flumill	Norway	Flumill Power Tower	Archimedes Screw
Hydra Tidal AS	Norway	Morild II	Horizontal Axis Turbine
Norwegian Ocean Power	Norway	H300	Vertical Axis Turbine
Straum AS	Norway	Hydra Tidal	Horizontal Axis Turbine
Tidal Sails AS	Norway	Tack Reach	Other
QED Naval	Scotland	Subhub	Other
Centro Tecnologico SOERMAR	Spain	PROCODAC	
Magallanes Renovables	Spain	Magallanes Project	Horizontal Axis Turbine
Current Power AB	Sweden	Current Power	Vertical Axis Turbine
Minesto	Sweden	Deep Green	Tidal Kite

Atlantis Resources Corp	UK	AR-1000, AR-1500	Horizontal Axis Turbine
Current2Current	UK	Tidal Turbine	Vertical Axis Turbine
EC-OG	UK	Subsea Power Hub	Vertical Axis Turbine
Flex Marine Power Ltd	UK	Swimmer Turbine	
Free Flow 69	UK	Osprey	Vertical Axis Turbine
Hales Water Turbines Ltd	UK	Hales Turbine	Other
Kepler Energy	UK	Kepler Turbine	Other
Lunar Energy	UK	Rotech Tidal Turbine (LTT)	Enclosed tips (Venturi)
Marine Current Turbines	UK	SeaGen S, SeaGen U	Horizontal Axis Turbine
Nautricity Ltd	UK	CoRMaT	Horizontal Axis Turbine
Nova Innovation Ltd	UK	Nova M100	Horizontal Axis Turbine
Ocean Flow Energy	UK	Evopod	Horizontal Axis Turbine
Renewable Devices Marine Ltd	UK	Capricon 125, Capricon 5, River Otter, Sea Otter	Horizontal Axis Turbine
Repetitive Energy Company	UK	REPEN6	Vertical Axis Turbine
Scotrenewables	UK	SR2000	Horizontal Axis Turbine
SeaPower Gen	UK	SPG	
SMD Hydrovision	UK	TiDEL	Horizontal Axis Turbine
Suanders Energy Ltd	UK	Power-Frame	Horizontal Axis Turbine
Sustainable Marine Energy (SME)	UK	PLAT-O	Horizontal Axis Turbine
Tidal Energy Ltd	UK	DeltaStream	Horizontal Axis Turbine
TidalStream Limited	UK	Triton 3 (Tidal Turbine Platform System), Triton 6 (Tidal Turbine Platform System)	Horizontal Axis Turbine
Leading Edge	US		Oscillating Hydrofoil
Aquantis Ltd	USA	AQ Series	
Bourne Energy	USA	CurrentStar, OceanStar, TidalStar	Horizontal Axis Turbine
Free Flow Power Corporation	USA	SmarTurbine	Horizontal Axis Turbine
GCK Technology	USA	Gorlov Turbine	Vertical Axis Turbine
Hydro Alternative Energy	USA	OCEANUS	
Hydrovolts Inc	USA	C-12 Canal Turbine, WF-10-15 Waterfall Turbine	Horizontal Axis Turbine
Integrated Power Technology Corp.	USA	TURBOFOIL	Oscillating Hydrofoil
Lucid Energy Technologies	USA	Gorlov Helical Turbine (GHT)	Vertical Axis Turbine
Marine Energy Corporation	USA	Current Catcher	Horizontal Axis Turbine
Natural Currents	USA	Red Hawk	Other
Ocean Renewable Power Company (ORPC)	USA	OCGen, RivGen Power System TidGen Power System	Horizontal Axis Turbine
Oceana Energy Company	USA	TIDES	Horizontal Axis Turbine
Offshore Islands Ltd	USA	Current Catcher	Horizontal Axis Turbine
ResHydro	USA	Hydrofoil Cascade Resonator (HCR)	Oscillating Hydrofoil
Verdant Power	USA	Free Flow Kinetic Hydropower System (KHPS)	Horizontal Axis Turbine
Vortex Hydro Energy	USA	VIVACE (Vortex Induced Vibrations Aquatic Clean Energy)	Other
Vortex Power Drive	USA	Vortex Power Drive	

Source: http://www.emec.org.uk/, revised.

Appendix 5: Competitive industry analysis - Porter Five Forces

In this appendix, the test-centre industry is analyzed, using the industrial economics five-forces model (Porter 1990), with the addition of complements as a sixth force. This helps to identify the drivers of competition and the intensity of the rivalry, which in turn, help identify how a Nova Scotia test centre could position itself within the industry and what competitive forces would affect it.

The five forces are: the potential entrants, buyer power, supplier power, substitutes, and competitive rivalry. A sixth force, having somewhat the opposite effect of substitutes, is compliments (Grant 2010).

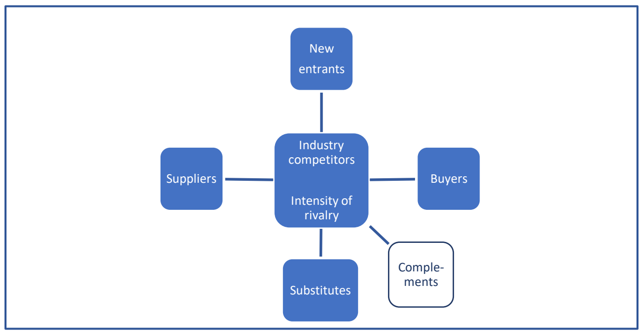


Figure A5-1 Porter Five Forces plus compliments

Threat of Entrants

The threat of entry depends on such things as economies of scale, product differentiation, capital requirements, switching costs, access to distribution channels and cost advantages that are independent of scale, and expectation of competitive retaliation.

In the test-centre industry, there are few economies of scale. A large test centre can have lower average costs but there is a limit to the size any test centre can be, based on the particular resource they are situated in. One test centre can have various sites, which can reduce average costs, but economies of scale will be quite limited.

Differentiation comes from unique product/service characteristics. Where there is differentiation, existing companies have brand recognition. EMEC has this, as does FORCE. New entrants have to pay more to develop their brand in the marketplace. In the test-centre market, the Bay of Fundy and FORCE have global brand recognition in the tidal energy industry.

The capital requirements for setting up a small test centre are not large, especially as a government-owned or -funded entity. It can also be built in stages, reducing the upfront capital expenditure and risk. A private-sector company could build a test centre but would need to get permits from the local government as well as acceptance by the community. The industry scan noted there were no profitable test centres to date so the threat of entry by a private company may be fairly small.

There would be costs to the client associated with changing from one test centre to another but there is not likely to be much in the way of repeat business from a given developer. However, if a technology company were to engage with the test centre, under contract, for a period of time, changing to another test centre would incur costs that may make the switch less than worthwhile. It should be noted, though, that if there are various test centres that provide a path to commercialization, "graduating" from one test centre to the next along the path would be advantageous. The test centres could then offer complimentary services that can benefit both centres and the tidal industry in general.

Distribution channels do not create a barrier to entry for a test centre since the service does not need to be distributed away from the site for it to succeed.

Cost advantages independent of scale can be derived from proprietary knowledge or design, favorable access to raw materials or locations, learning (experience curve), and government subsidy. There is some proprietary know-how and design knowledge in the test centre industry, which does form a barrier to entry that would effectively limit the number of entrants. The operating and design knowledge of EMEC would be difficult to duplicate at start-up without considerable time and cost. There is a fair amount of knowledge resident in Nova Scotia as a result of the work at, and with, FORCE and the COMFIT sites so this barrier may not be as high as it would be for other locations.

Favorable access to raw materials and locations: if one were to consider a tidal resource as a raw material and locations where this resource exists, these can form some barriers to entry in the global test centre market. Nova Scotia has several choice sites with good depths, speeds, and accessibility. The number of such sites around the world naturally creates a barrier to entry any potential entrants would need to overcome.

Existing centres have the advantage of learning that creates a barrier for new entrants. As noted above regarding proprietary know-how, EMEC stands out as the dominant competitor. The learning achieved in Nova Scotia from large-scale deployments, retrievals, and testing platforms would help a new test centre overcome this entry barrier.

In the tidal energy test centre market, government subsidies play a very large role. Most, if not all, of the test centres have some form of government funding. Jurisdictions recognize the economic potential of being a leader in the new marine renewable energy industry, and are investing accordingly. Unwillingness of a government to fund the start-up and operation of a test centre is a significant entry barrier, especially since test centres do not yet turn a profit. This will likely limit the proliferation of test centres within one jurisdiction and consequently, the number of entrants into the test centre industry.

The conditions for competitive retaliation include a history of retaliation; the presence of established firms with substantial resources, a large financial commitment and illiquid assets; and slow industry growth. While a new entrant could face some competitive retaliation, there still seems to be room for new entrants without established test centres being threatened, especially if they offer complimentary services. The one exception might be EMEC but its strategic position is quite dominant. A small test centre may not make large inroads into EMEC's market share for quite some time.

In summary, although barriers to entry exist, they are not insurmountable. The specific resource characteristics matter, as do resident expertise in the region, a knowledge of the resource, and experience in the supply chain. These cannot be easily duplicated globally, so there will likely be a limit to how many direct competitors will enter the market. Given the experience with tidal energy in Nova Scotia, the Bay of Fundy resource, and the Fundy brand, a new test centre would have some advantage in overcoming these barriers.

Buyer Power

The buyers' power influences how much a company can charge for its services. Buyer power comes from the buyers' price sensitivity and their bargaining power relative to the service-provider. Buyer price sensitivity depends on the cost of using the test centre relative to a buyer's total cost, differentiation between test centre offerings, intensity of the competition in the buyer's industry, and how critical the quality of the service is. Relative bargaining power comes from the size and concentration of buyers, the buyers' information or knowledge of the product/service, and the ability to do it themselves.

SMEs developing technologies do not have a lot of buyer power, though they would be sensitive to cost, due to limited budgets. They may be sensitive to price and that would depend on the total cost to them of using the test centre. The more of the cost the fee covers (e.g. permitting, data collection), the better. Clients must also cover the cost of travel and transport, etc. There is fair differentiation in offerings in terms of water speed, depth, site characteristics, accessibility, operating procedures. The buyers' industry is not yet intense and the industry is not concentrated around a few large companies, at least in the smaller-scale device market.

Most buyers will be quite knowledgeable and will understand well what the test centre does so could do testing themselves, though with cost and lead time needed for resource assessment, site characterization, community consultation, consents, and permitting. Larger companies developing small technologies or looking to test scale models will have greater buyer power, though they may be less sensitive to price because a good quality, open-ocean test will improve their prospects for certification, market acceptance, and private-sector financing.

Supplier Power

Suppliers to a test-centre would be supply chain companies, such as vessel operators, consultants, suppliers of measuring and monitoring instruments, funders/financiers, insurance companies, researchers, and government. The power of suppliers, relative to the test centre, depends on the ease with which the test centre can switch suppliers, and the relative bargaining power of the suppliers. The power of the suppliers varies by supplier. Monitoring device manufacturers would have low supplier power if there are alternative products available. Ocean vessel owners and operators would have moderate bargaining power since vessels are expensive to obtain and there is a limited quantity available. Consultants and researchers would have moderate bargaining power due to their experience and expertise. Insurers and funders have high bargaining power, as would government, with its ability to provide or restrict consents, permits and funding.

Substitutes and Compliments

The threat of substitutes depends on whether there is a close substitute for the service, the relative price and performance of a substitute, and the propensity of clients to use a substitute. For an open-ocean test centre, substitutes may be CFD modelling, flume and tow tanks, river current, river or open-ocean towing (such as in Limerick and Florida). It is probable that clients will use a substitute as a step toward certification. However, the ability to get certification, investors, and sell devices requires proof of performance and reliability in real tidal streams (for tidal devices, not necessarily river devices). CFD, flume and tow tanks may have the effect of reducing demand for an open-ocean test centre but it is likely an open-ocean test centre will help the developer progress toward a commercially-viable technology. The fee charged for using the test centre will matter, or more precisely, the total cost for the developer to use a test centre in Nova Scotia, since many will be SMEs and some of these may be quite new companies.

Somewhat opposite to substitutes, compliments are products or services that are needed with using the test centre. Consultants, researchers, monitoring technologies serve as compliments. Organizations such as COVE, the Acadia Tidal Energy Institute, Vemco, vessel operators, etc., offer complimentary services and products. Cooperation between these organizations strengthen the industry and demand for all.

Competitive Rivalry

The intensity of the competitive rivalry in an industry comes from: concentration amongst a few companies (e.g. the "big five" banks, "big three" telecoms); diversity amongst the companies, in terms of history, cost structure, strategies and objectives; product differentiation; excess capacity and exit barriers; cost conditions (scale economies, operating leverage).

To determine the competitive rivalry in the small-test centre industry, the competitors need to be identified. The most direct competitors may be the EMEC-scale (Shapinsay), SEENEOH, DMEC-Marsdiep, QUB-Strangford, TTC-Grevelingendam. In this category might also be BTTS, CHTTC, and SNMREC, though rather than being rivals, their services may be considered substitutes to an open-ocean tidal stream test centre.

The test-centre industry is not concentrated, but EMEC is the dominant competitor. There is some differentiation between the offerings of the industry rivals, based partly on the site characteristics and experience and expertise resident in the region. There are not large differences in history, cost structure, strategies and objectives among the direct competitors, at not least sufficiently large differences to increase the intensity of competitive rivalry. There are few scale economies, there is not excess capacity in the industry yet, and exit barriers are not high.

In summary, the competitive rivalry in the test-centre industry is not intense, at least yet. EMEC is dominant in Europe. Clients will go elsewhere but EMEC is the exemplar, if it fits with the technology developer's needs. It has only two berths for small tidal testing but presumably, as the demand grows, they could increase the number. However, in the interviews undertaken for the gap analysis, small-scale testing was not lucrative for test centres. Fees are charged on a cost-recovery basis, in many cases.

Summary

The global test centre industry is in the early growth stage. There are modest entry barriers, moderate exit barriers, limited buyer power, and varied supplier power. The competitive rivalry is not intense, the industry is fragmented and somewhat regional. Substitutes exist but open-ocean testing is needed. The centres are generally government-funded, at least initially, and government permits are required.

Appendix 6: Test platforms

As outlined in Section 3.4, an asset of a mobile test platform could be useful for advancing research and testing opportunities, including use across several sites. However, each location would need consenting/permits, community engagement, detailed site characterization, infrastructure (primarily moorings and navigational markers), and environmental monitoring. The technical and social objectives of moving the platform would also need to be evaluated with consideration of the costs and risks of mobilizing, as well as the value of longer term testing at one location. The platform could be built to purpose, repurposed from existing infrastructure, or contributed to the test centre by an initial user. Examples for each scenario are provided below.

Previous examples of test applications

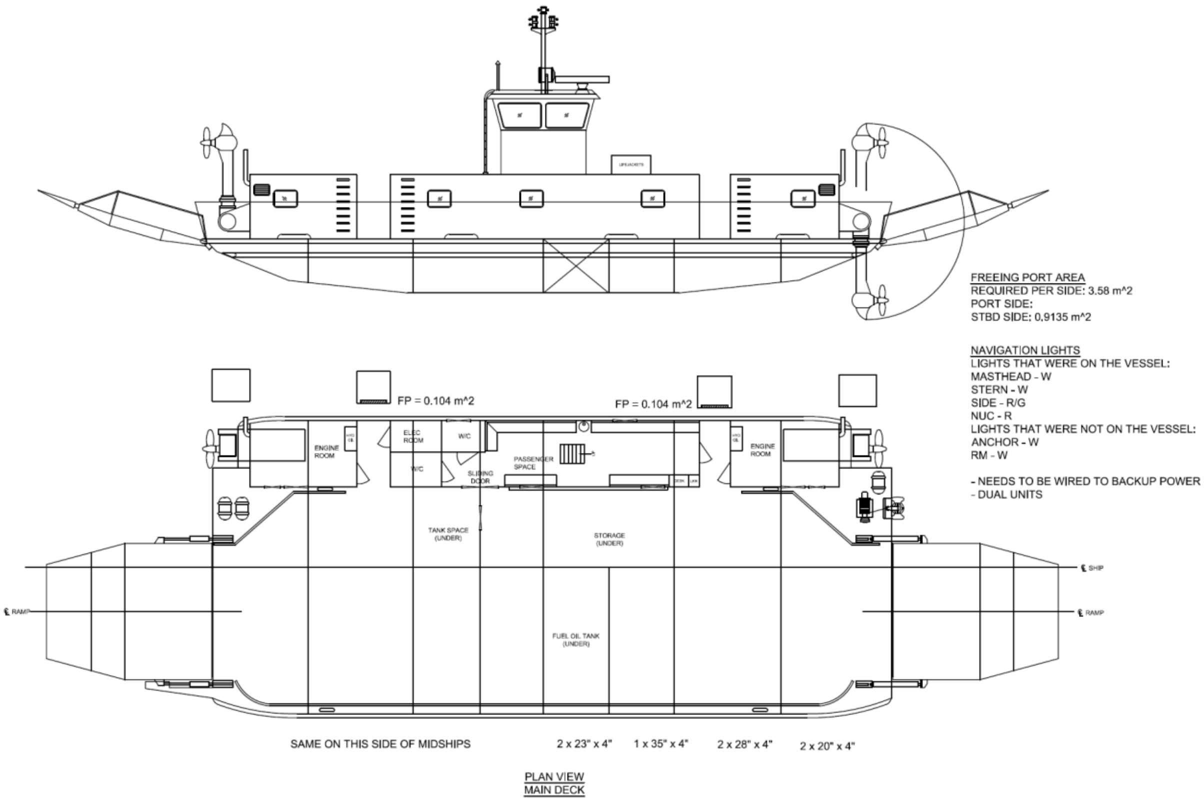
	FLOATING		*FIXED*	
APPLICATION	***BESPOKE***	***REPURPOSE***	***GRAVITY***	***DRILLED***
TEST	• ***X TIDAL*** • ***PLAT-I***** • ***SEENEOH***	• ***SPRAY II (OPTION)*** • ***CHTTC*** • ***NNMREC*** • ***SNMREC***	• ***STRANGFORD LOUGH*** • ***BOURNE*** • ***HAMMERFEST @ EMEC***	• ***OPENHYDRO @ EMEC*** • ***VOITH @ EMEC***
COMMERCIAL	• ***SCOT RENEWABLES*** • ***SCHOTTEL/ SUSTAINABE MARINE ENERGY LTD.***		• ***MEYGEN 1*** • ***SABELLA*** • ***NOVA INNOVATION*** • ***OPENHYDRO (CAPE SHARP)*** • ***MINESTO***	• ***MEYGEN 2 (PLANNED)***

****Note: Tocardo device fitted at DMEC does not fit above – use of existing infrastructure, (a bridge), for testing. not a widely available application so not considered.***

***** Uses drilled anchor sockets.***

Example for repurposing of government asset (recently sold at auction)

SPRAY II



Principle of operation

- Vessel is purchased and undergoes upgrade / modification programme.
- Vessel moored on shore when no testing or in use.
- Vessel is capable of laying own anchors.
- Once called for testing:
  - Vessel loads up device at quayside.
  - Moves to test site, (under own steam – not towed).
  - Lays 4-point mooring system and positions into test site.
  - Overboard tidal turbine and begins testing period.
  - Vessel remains on station for test / good weather period.
- Upon completion, reversal and moves back to shore.

Modifications list

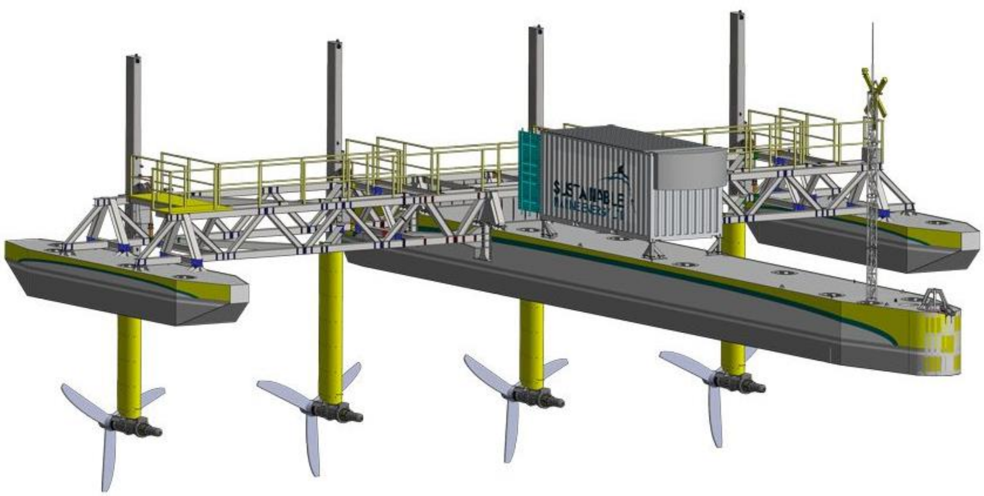
- Vessel would be modified with the following:
  - Moonpool or over boarding area dedicated for turbine testing.
  - Subsea support structure for tidal turbines.
  - On deck lifting system capable:
    - Loading
    - Over boarding of turbines.

- Mooring system
  - 4 winches to allow self-installation / removal of anchor system.
- Electrical Systems
  - Electrical generation for device testing.
  - Load bank for power dissipation.
- Environmental monitoring systems

Advantages/Disadvantages

Pros	Cons
• Self-installation • Repurpose existing asset • Opportunity for multi-purpose asset • Self-installing anchors – and can remain on site for extended duration. • Good accessibility for developers. • Could be utilized for testing electric vessel concepts	• Burden of OpEx costs to maintain and berth (depending on durations on testing) • CapEx funding for retrofit required. • Mooring in fixed heading – turbine or housing must yaw in reversing tide direction. • Will require regular supplies of fuel (could be mitigated with electric systrems and energy storage). • Standby team to remove if bad weather forecast.

Example for bespoke floating asset: X-TIDAL or SME PLAT-I (Examples only)



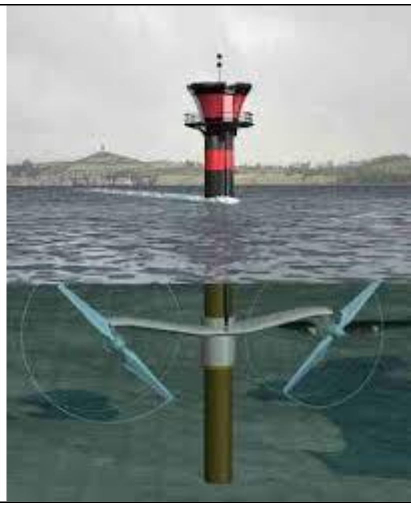
Principle of operation

- Platform fabricated, and device installed in shipyard / safe haven of port.
- Towed to site, and connected to preinstalled mooring and / or cable systems.
- Turbines lowered into flow using articulated arms once ready for testing.
- Access via small vessel for ongoing inspection – arms are articulated to surface allowing in air inspection of system.
- Device removed from site to change turbines (potential fo onsite removal, depending on several factors).

Advantages/Disadvantages

Pros	Cons
• Excellent, secure access to device for inspection and light maintenance. • Platform allows for a series of devices to be tested and removed once testing objectives complete. • Access via small, inexpensive vessel for crew. • Device can be removed from flow during strong tides (if needed, depending on test objectives). • Platform can be removed from site in poor weather. • Modular construction and easily relocated • Containerized internal electrical systems • Configurable for different turbines	• Large upfront CapEx. • Ongoing berthing costs for times not in service. • Mooring system can be complicated in areas of high tidal range and flows. (but not insurmountable). • Requires vessel for towing. • Breaking loose of moorings could become significant issue / hazard for other marine users. • Standby team to remove if bad weather forecast.

Example for fixed asset: Gravity or drilled platform



Principle of operation

- Piles are fixed to seabed using either gravity or through drilling.
- Platform is incorporated into the pile or fixed to the top of it.
- Device is lowered or raised into the water using a lifting system on the platform.
- Platform allows access to the device for inspection of maintenance when it is lifted.

Advantages/Disadvantages

Pros	Cons
• Excellent, secure access to device for inspection and light maintenance. • Platform allows for a series of devices to be tested and removed once testing objectives complete. • Access via small, inexpensive vessel for crew. • Devices can be removed from flow during strong tides or poor weather.	• Drilling on tidal site extremely challenging in most sites. • Large upfront CapEx. • Ongoing annual OpEx for structural and fabric integrity. • Large & expensive assets required for installation. • Limited access due to wave height restriction for access. • Installation / removal of device can be costly depending on marine asset required.